ATAL-BELGOPROCESS JOINT VENTURE

Contract No. EP/SP/40/02

Low Level Radioactive Waste Storage Facility at Siu A Chau

First Environmental Monitoring and Audit Report (Operation Phase)

Version 1.1

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Certified By _____
(Environmental Team Responsible Person)

REMARKS:

The information supplied and contained within this report is, to the best of our knowledge, correct at the time of printing.

The Responsible Person accepts no responsibility for changes made to this report by third parties.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

EXECUTIVE SUMMARY

This is the first operation phase Environmental Monitoring & Audit report prepared for the Low Level Radioactive Waste Storage Facility (LRWF or Facility) at Siu A Chau. This report presents the baseline radiological monitoring works performed between April 2005 and July 2005, just before the commencement of the operation of the LRWF on August 2005.

The baseline environmental radioactivity in the vicinity of the LRWF has been established. It is evident from the measurement results that the activity concentrations do vary significantly among samples. This may be due to actual difference in radionuclide contents in samples, such as different types of soil or different fishes; or due to large uncertainties because of their low radioactivities.

The activity concentrations of ^{226}Ra, ^{228}Th and ^{40}K in soil and sand are similar to average values of those nuclides in soils and sand in Hong Kong. And as expected, radionuclide contents in sand are much smaller than in soils. Soils in the reformed land adjacent to the LRWF will need some time to settle and radionuclide content may change due to leaching. But they are close to the facility and are significant receptors of effluents from the facility. Moreover, no grass samples could be taken from the newly reformed land before the operation.

γ spectra for sea-water and grass are almost identical to the background meaning that their radionuclide contents are very small. However, they will still serve as a reference for future comparison, in case some extraordinary photopeaks are detected.

While Action Levels and Limit Levels for non-compliance of environmental performance have been established based on radiation dose consideration that govern the effluent releases, Investigation Levels based on results of this report have also been established to enable efficient monitoring of changes in the radiation environment during the future operation of the Facility.

1. INTRODUCTION

Background

1.1 Various industrial, educational and medical facilities in Hong Kong have, for a number of years, used radioactive materials and generated radioactive waste. Most of the existing waste arisings are stored in disused air raid tunnels close to Queen's Road East in Wan Chai. Other arisings are stored temporarily (although in some cases for several years) at the point of use in educational institutions or hospitals.

1.2 A consultancy study in 1995 concluded that Siu A Chau was a suitable location for a purpose-built storage facility to which all waste will be transported, placed in stainless steel drums and stored.

1.3 In July 2003 ATAL-Belgoprocess Joint Venture Limited (ABJV) was awarded a contract to design, construct, and operate the LRWF at Siu A Chau. Thereafter, the ABJV will transfer the waste management skills for this Facility to Hong Kong.

1.4 The LRWF was designed to have a storage vault that can initially store 260 drums of waste, each drum of 275 litres net capacity. The building will also contain facilities for waste reception and repackaging waste, and administering the process. A jetty will be built to provide marine access to the Facility.

1.5 The Facility is equipped with various radiation monitors inside the building specially installed for detecting all possible leakage of effluents from the building.

1.6 However, it is possible that minute activities may escape from detection and enter the biosphere, or an unexpected incidence would have resulted in a significant release of radionuclide from the Facility. It is one of the objectives of this environmental monitoring scheme to monitor whether in the long-term, the operation of the Facility will cause deterioration to the environment.

Purpose of the Report

1.7 The purpose of this First EM&A Report (Operation Phase) is to set out baseline levels for the radionuclides in accordance with the EM&A Manual (version 2.0). Under the requirement of the EM&A Manual, an environmental monitoring program has to be established to monitor the area local to the LRWF prior to the commencement of the operation of the LRWF at end of July 2005. These baseline levels will be used as the basis for the compliance monitoring during operation phase of the LRWF. This report presents the monitoring locations, equipment, period, methodology, results and observations for the radiological measurements during the baseline period.

Responsible Person

1.8 A Responsible Person (RP) has been nominated to be responsible for implementing

environmental monitoring and audit, ensuring access at all times to monitoring equipment, maintenance of the equipment and its accurate and continued operation. This person is also responsible for processing, storage, retrieval and reporting of environmental monitoring data and for reporting of instances of non-compliance of the Environmental Performance Requirements. The approved Responsible Person, who is also the environmental team leader (operation phase) is Dr. John K.C. Leung of the Department of Physics, The University of Hong Kong. His contacts are Tel: 2859 2858, Fax: 2471 8888 and e-mail: jkcleung@hku.hk.

2. RADIOLOGICAL MONITORING REQUIREMENTS

Monitoring Requirements and Parameters

2.1 In accordance to the EM&A Manual, an environmental radiation baseline has to be established prior to commencement of the operation. The following samplings have been done.

a. In-situ ambient gamma dose rates at 1 m above ground in 14 locations.

b. 8 samples of seawater at two depths, and 15 surface soil samples; 10 grass samples; 3 sand samples; fish and sea snail samples; and 3 airborne particulate samples.

2.2 Environmental samples are mainly analyzed by γ-spectrometry for γ-emitting radionuclides and gross α/β counting for non γ-emitting radionuclides. γ-spectrometry by high-resolution HPGe detector has the ability to identify and quantify the activity concentrations of the radionuclides. However it has a rather low counting efficiency, and therefore usually requires a large volume of sample and long counting time. According to the waste inventory, the major γ-emitters in the wastes are ^{137}Cs, ^{60}Co, ^{226}Ra and ^{232}Th. Therefore the identification of nuclides in the γ-spectroscopy study would be focused on these few radionuclides. On the other hand, the low-level α/β counter is a much more sensitive equipment, but it can only give gross counts of α and β emissions without knowing the type of emitting radionuclides. Since α and β particles will suffer from self-absorption, particularly for α particles, the samples have to be prepared in the form of thin films. Hence only biological samples can be measured for gross α/β activity.

2.3 The collection of environmental samples commenced in April 2005 and lasted until end of July 2005, just before the commencement of the operation of the LRWF. Some samples such as soil and grass near to the LRWF could not be taken until the site reformation has been completed. Similarly airborne particulates were taken when site reformation was near completion and the area became less dusty.

2.4 The terrestrial sampling covers the area within a radial distance of about 50 m from the LRWF. This distance is sufficient for detecting the fallout particulates released, if any, from the low-rise facility and the low emission point of the gaseous effluent. Sand, water and marine organisms were taken in the sea or near the shore.

2.5 As reported in the EISA Report issued on June 1995, the seabed in Sum Wan is quite rocky. It was also found in this survey that no seabed sediment could be collected by using a simple dredger. Hence sand samples along the shore instead of sediment sample were collected. However, due to the rocky nature of the coastal area, sand samples are found only along the north-eastern shoreline.

Monitoring Equipment

Low Background HPGe γ-Spectrometer

2.6 The γ-spectrometer is an extended range coaxial HPGe detector housed inside an 11 cm thick of low-background lead shield. The signals are processed by a 16k-channel multi-channel analyzer connected to a computer for data logging. The HPGe detector has an energy resolution of about 2 keV at the ^{60}Co lines and measures γ energies up to about 3 MeV. Energy calibration is done regularly by standard γ point sources. Since counting efficiency depends on form and density of the sample, special home-made standard sources have to be prepared for different types of samples. A standard γ source for soil and sand was prepared by mixing 2 kg of normal soil sample inside a 2-L Marinelli beaker thoroughly with known activity (9.18 kBq on October 8, 2003) of ^{152}Eu, which is a multi-gamma emitter. No standard sources are prepared for other types of samples. The γ-spectrometer with a 2-L Marinelli beaker is shown in **Figure 2.1**.

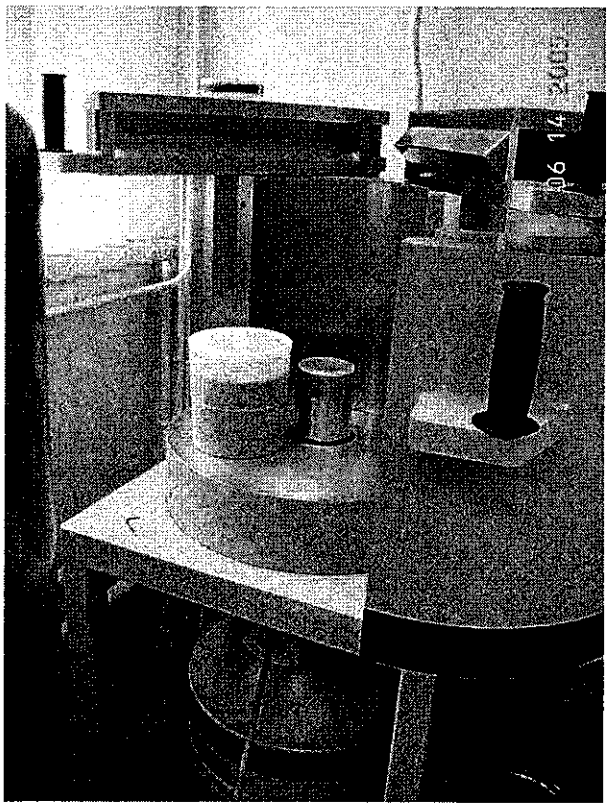

Figure 2.1 Low-background HPGe γ-spectrometer and a 2-L Marinelli Beaker

2.7 The minimum detectable activity (MDA) is defined as the activity that will give 3 times the standard deviation of the background activity. It is dependent on the measurement time and the background activity. For un-naturally occurring radionuclides, since they are not normally found in the background, any detection of their photopeaks in the γ spectrum signifies their presence.

Low-Level α/β Counter

2.8 The counter consists of a flow-through type multi-wire proportional counter enclosed inside a low-background lead shield. Calibration is done regularly by counting a standard planar ^{241}Am source (1.17 kBq on May 16, 1995) for the α-channel and a planar ^{90}Sr source (1.03 kBq on May 16, 1995) for the β-channel. A photograph of the counter is given in **Figure 2.2.**

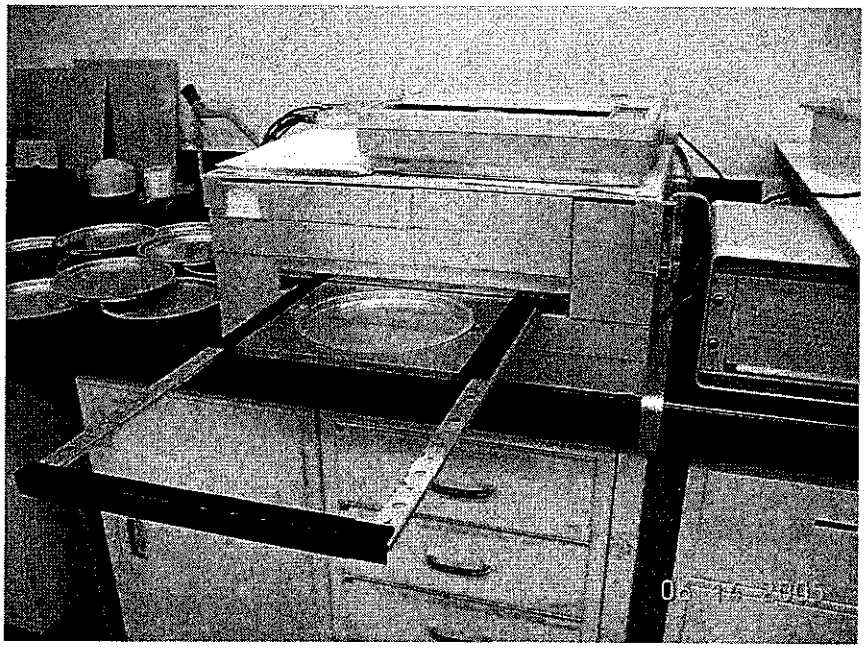

Figure 2.2 Low-level α/β Counter

2.9 α and β particles emitted from a sample will experience self-absorption loss, particularly for α particles. The self-absorption correction factors were determined by drying different volumes of sea-water taken from the same sample on 20-cm planchets, which were subsequently counted in the α/β counter. The decrease in count-rate due to self-absorption was compared with the expected count-rate to determine the correction factor at different sample volumes. Self-absorption correction factors for grass, fish and sea snail samples were assumed to be the same as for sea-water.

2.10 MDA is again defined as the activity that will give 3 times the standard deviation of the background activity. It depends on the measurement time, physical form of the sample,

self absorption coefficient and the background activity.

2.11 The measurement results are expressed in α count-rate and β count-rate, which have no information about the activity of the radionuclide contents. However, the α/β counter is calibrated against the ^{241}Am and ^{90}Sr source, hence the α and β activity of the grass, sea water, fish and sea snail samples are expressed in ^{241}Am-equivalent activity and ^{90}Sr-equivalent activity respectively. Airborne particulate samples are reported in α and β counts per minute (cpm) only because no self-absorption correction will be done on the cloth. MDA for the different samples are given in **Table 2.1**.

Table 2.1 MDA for Different Samples.

Sample	α MDA	β MDA
Grass	6.9×10^{-3} Bq g^{-1} dry weight	4.6×10^{-3} Bq g^{-1} dry weight
Sea water	0.57 Bq L^{-1}	0.38 Bq L^{-1}
Fish or sea snails	4.8×10^{-3} Bq g^{-1} wet weight	3.0×10^{-3} Bq g^{-1} wet weight
Airborne particulate	0.37 cpm	0.80 cpm

Microwave Oven

2.12 This is a computer-controlled microwave oven such that the temperature rise-time, duration and fall-time, etc can be programmed. Microwave is generated to heat up the oven walls, thus heating the samples inside. A photograph is shown in **Figure 2.3.** Biological samples are usually ashed at 400 °C for over 10 hours.

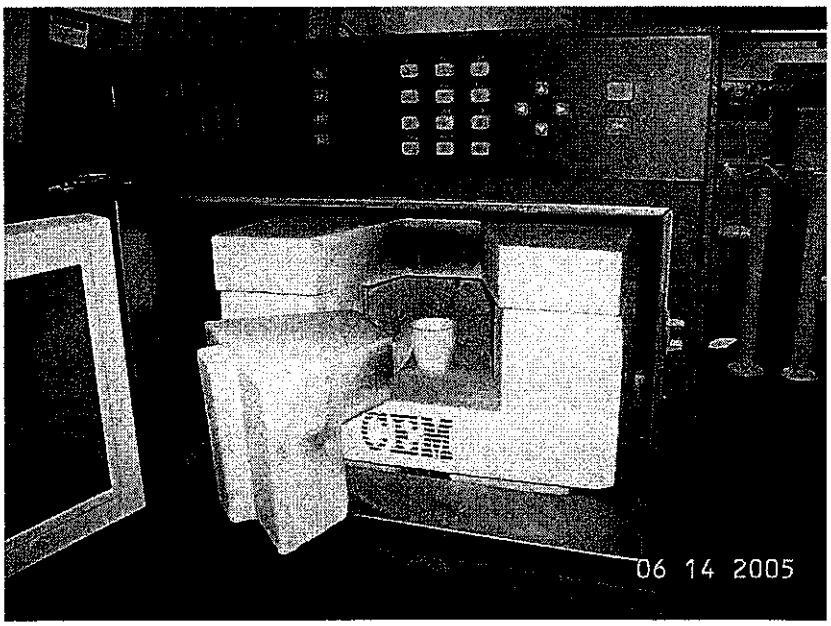

Figure 2.3 The CEM Microwave Oven

Monitoring Procedures

2.13 Since the LRWF is not expected to release radioactivity in significant quantity except possibly a higher level of radon or other radioactive gas from the waste; or leakage of contaminated water from the delay tank of the facility, so that majority of the samples should contain radioactivities close to or below the detection limits of general laboratory equipment. Furthermore, according to the inventory of wastes, all the strontium sources are sealed and tritium wastes aren't in vast quantities, so there is no need to carry out complex radiochemical analysis of these two elements. In view of the above, the principal detection method used here for all samples is the high-resolution germanium gamma-spectrometry (HPGe) for identification of gamma emitters. Water and biological samples are further assayed for alpha and beta emissions by a proportional counter after volume reduction by evaporation and ashing respectively.

2.14 The monitoring scheme was designed based on the following criteria.

a. γ dose rates, soil and vegetation samples are taken from accessible and near-flat surfaces to prevent running-off of nuclides on slopes.

b. The LRWF is located at the bottom of the basin landscape; hence terrestrial sampling will be restricted to areas within the basin.

c. The number of terrestrial sampling points for the baseline monitoring is arbitrarily chosen according to point (a) and (b) above.

d. The ambient γ dose-rate will be measured at exactly the same locations in future monitoring, so that any change in the environment can be tracked.

e. Soil and vegetation samples will be collected from new sampling locations adjacent to previous sites. This will make sure that the samples will have recorded depositions since the commencement of operation of the LRWF. The number of sampling points will be reduced to 3 in subsequent monitoring, and their locations are nearby to the 3 airborne particulate sampler locations.

f. These 3 locations are selected according to the prevalent wind directions throughout the year as reported by the Hong Kong Observatory.

g. Passive cloth samplers are selected as the airborne particulate samplers instead of active samplers. It has the advantages of simple operation, maintenance free and large collection area.

h. Water samples will be collected at 2 depths corresponding to surface water and bottom water. There are 4 sampling locations corresponding to the point near the liquid effluent port of the Facility and also near the opening of the bay area.

i. Sand samples and sea snails are collected randomly along the north-eastern shore from 3 locations. The exact locations are not specified as long as the sand is immersed in sea water at all time.

j. Fish samples are just for spot checking purpose since the fishes do not stay in the bay area all the time and therefore the activity concentrations in their bodies do not really reflect the performance of the LRWF. They are caught by hanging a trapping-net from the jetty about 2 days before the sampling date. Since fish is not an important bio-indicator of contamination in this monitoring, its species and number are not specified.

Ambient Gamma Dose Rate

2.15 The γ dose rate was measured by a portable γ dose ratemeter (Berthold LB123 with LB1236 probe) placed at 1m above the ground. The counting period was 5 min for each location. Unlike other sampling collection, γ dose rates are measured at the same locations repeatedly and therefore provide a reliable indication of any change in the surface radioactivity on the ground. Hence they are measured in the largest number and cover the largest area. The dose rate due to cosmic ray at the LRWF was determined by measuring the γ dose rate on a boat at a distance away from the shore. The γ dose ratemeter is shown in **Figure 2.4.**

Figure 2.4 γ Dose Ratemeter

Soil

2.16 Surface soil samples were collected in places free of vegetation. About 2.5 kg of surface soil down to 5 cm deep was collected at each site. After returning to the laboratory, the soil samples were cleaned by removing remaining vegetations, rocks and pebbles etc. The samples were dried inside an oven and then crushed into small grains of less than 2 mm. Exactly 2 kg of dried soil was put into a Marinelli beaker which was then sealed for no less than 3 weeks to allow for radioactive equilibrium before measurement. After about 3 weeks, the soil samples were measured by the low-level HPGe γ spectrometer.

2.17 Soil contains large quantities of naturally occurring ^{226}Ra, ^{228}Th, ^{40}K and their decay products. Because of the high background levels and the large deviations of these radionuclides, it would not be possible to tell whether any of these radionuclides detected in the soil are originated from the Facility. Nevertheless, it is possible to identify and quantify any un-naturally occurring γ-emitters in the soil samples and relate them to possible release from the Facility. Hence in the baseline measurement, a large number of soil samples were collected aiming to establish a standard error of the activities of naturally occurring radionuclides in the soil and to confirm the presence or absence in the soil of any un-naturally occurring radionuclides that are also found in the Facility. In future monthly and yearly monitoring, soil samples will be reduced to 3 locations, corresponding to the 3 prevailing wind directions. (Please refer to section in Airborne Particulates for details).

Sand

2.18 About 2.5 kg of partially immersed coastal sand samples were collected from each location. In the laboratory, large rocks and marine organisms were removed before the sand samples were dried in an oven. The dried sand was then sealed inside Marinelli beakers and then radioassayed by the HPGe γ spectrometer after 3 weeks just like for the soil samples.

2.19 The original aim was to collect seabed sediment which may contain radionuclides deposited on the seabed or dissolved radionuclides that have adsorbed on sediments. But as mentioned before, seabed sediment is scarce and not easy to be taken, hence coastal sand samples were collected instead. This is of course less desirable as the deposited nuclides may not be detected.

Grass

2.20 Grass samples were collected near to the soil sampling sites so that there results between soil and grass could be correlated. No grass sample was collected from the newly reformed land.

2.21 About 1.5 kg of grass was collected at each site by cutting the grass at 3 cm above the

ground. Care was taken to avoid contamination with soil and slopes on which abnormal runoff may occur were avoided. The grass was washed and dried in an oven until weight became constant. Exactly 1 kg of dried grass was put inside a Marinelli beaker and then assayed by the HPGe γ-spectrometer. No waiting for equilibrium was required because the main purpose of doing γ-spectroscopy for grass samples is to detect trace amount of radionuclides that may be accumulated in the grass. The detection efficiency for grass samples is approximated by using point γ sources. Though the detection efficiency is not accurately determined, the γ spectrum will still serve as a baseline for future reference.

2.22 Another 7 g of dried grass was dry-ashed inside the microwave oven for 10 hours. The ash was mixed in de-ionized water on a 20-cm planchet, which was subsequently dried on a heating plate, then measured in the low-level α/β counter. The activity concentration was determined after correcting for self-absorption as described in Section 2.6.

Sea Water

2.23 About 2 L of sea water was collected into a polyethylene bottle at each sampling site. Two water samples were collected at each location, corresponding to near-surface (1 m deep) water and near-bottom (1 m above bottom) water. Similar to the grass samples, the water samples were divided into two parts in the laboratory, 1.5 L for γ spectrometry and 50 mL for gross α, β counting. The results show that the radionuclide contents in the sea water samples are very small and their γ spectra are similar to the background of the γ spectrometer. Nevertheless the spectra will be used as a baseline for future reference and for tracing of extraordinary activities. There is no standard γ source prepared for determination of the counting efficiency.

2.24 The other 50 mL of sea water was carefully dried in a 20-cm planchet above a hot plate to form a uniform layer of fine salt. The gross α and β emissions were then counted by the low-level α/β counter. The activity concentration was determined after correcting for self-absorption as described in Section 2.6.

Marine Organisms

2.25 Two types of marine organisms were collected: fish and sea snails. Fishes were caught on the boat or along the jetty while sea snails were sampled along the north-eastern shore. At least 3 fish of the species (either *Siganus canaliculatus* or *Terapon jarbua*) were obtained, and about 1 kg of sea snails of mixed species (*Thais clavigera, Thais luteostoma, Lunella coronata* and *Nerita albicilla*) were collected. In the laboratory, the fresh of the sea snails were removed from the shells and washed. 3 samples each of exactly 10 g of fresh were dry-ashed in the microwave oven. The ash was then mixed with de-ionized water and transferred to a 20-cm planchet. After dried on a hot-plate, the gross activity concentration of radionuclides in the ash was obtained by counting the sample in the

low-level α/β counter, just like for other biological samples.

2.26 The head and tail of each fish was cut and discarded. The remaining fresh, internal organs and bones were then chopped into small pieces and then 10 g of the mixture was dry-ashed in the microwave oven. The ash was then mixed with de-ionized water and then transferred to a 20-cm planchet; dried and counted. 3 fish samples were counted.

2.27 No γ spectroscopy was performed for the marine organisms.

Airborne Particulates

2.28 Particles suspended in the air were collected by passive cloth samplers installed at three corners of the LLWRF. The locations of the samplers were determined according to the prevalent wind directions throughout the year as reported by the Hong Kong Observatory. The bearing of the sampling locations from the emission point of the stack are approximately N20°E; N80°E and S45°W. The samplers are installed at 2 m above ground.

2.29 Each sampler consists of a piece of cloth wrapped around a cylindrical wire mesh of 20 cm tall and 13 cm in diameter and the cloth is protected from heavy rainfall by a rain cap. The photograph of a sampler is shown in **Figure 2.5**. The sampling was not started until early July when the site reformation was almost completed and the environment was less dusty. After sampling, the cloths were removed from the samplers and taken to the laboratory for gross α/β counting. Each piece of cloth was cut into two halves (20 cm x 20 cm) and each half was counted separately. A piece of unexposed cloth was counted for establishing the background.

Figure 2.5 The Passive Cloth Sampler for Collecting Airborne Particulates

3. RESULTS AND OBSERVATIONS

Standard Deviation and Standard Uncertainty

3.1 The sampling locations and the measurement result for each type of samples are given in the following sections. Except for ambient γ dose rates whose uncertainties are reported in percentage, all other uncertainties are given in one standard deviation (SD). SD for individual sample is calculated according to the number of counts recorded and assuming a normal distribution for the counts.

3.2 The arithmetic mean value of the measurements and its standard uncertainty (SU) are reported in separate tables following the main data tables. SU is an experimental standard uncertainty that takes in account the variance between samples. SU is calculated by

$$SU = \sqrt{\frac{\sum_{i=1}^{n}(q_i - \bar{q})}{n-1}}$$

where q_i = measured value for the i^{th} sample;

$\bar{q}$ = arithmetic mean of the q_i;

n = number of samples.

Measurement Results

Ambient γ Dose Rates

3.3 The sampling locations and measurement results are given in **Figure 3.1** and **Table 3.1** respectively.

Table 3.1(a) Ambient γ Dose Rates at 1 m above Ground

Location	γ Dose Rate (μSv h^{-1})	SD
On the boat	0.07	0.006
A	0.17	0.010
B	0.22	0.012
C	0.28	0.014
D	0.23	0.012
E	0.25	0.013
F	0.24	0.012
G	0.23	0.012
H	0.27	0.013

Location	γ Dose Rate (μSv h^{-1})	SD
I	0.28	0.013
J	0.21	0.011
K	0.28	0.013
L	0.22	0.011
M	0.27	0.013
N	0.25	0.013

Table 3.1(b)

Mean γ Dose Rate (μSv h^{-1})	SU
0.24	0.032

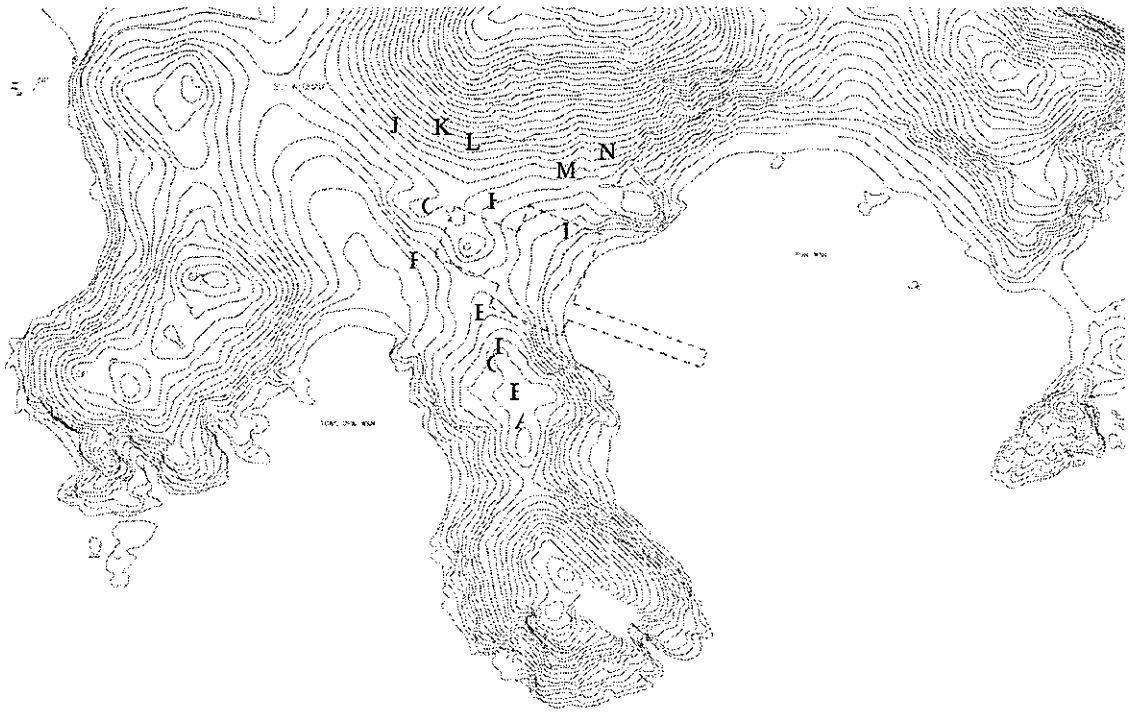

Figure 3.1 Locations for Measuring Ambient γ Dose Rate

3.4 The measured γ dose rate included cosmic radiation whose contribution was determined to be 0.07 μSv h^{-1} by measuring the γ dose rate on a marine vessel far away from the land.

Soil

3.5 The sampling locations and measurement results are given in Figure 3.2 and Table 3.2 respectively. Because the site reformation was not completed until mid of July 2005, the soil samples close to the LRWF were collected just before the commencement of the operation. It is noted that some samples contain trace amount of ^{137}Cs which are fallout of previous atmospheric nuclear detonations.

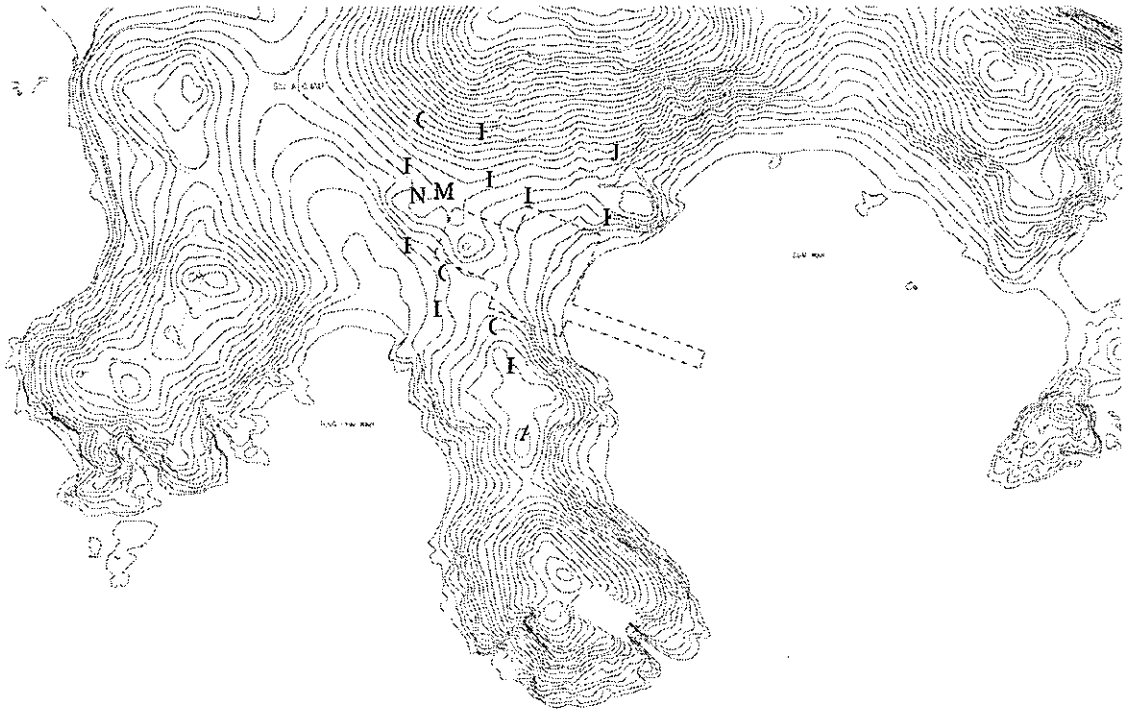

Figure 3.2 Locations for Collecting Soil Samples

Table 3.2(a) Activity Concentration of Some Major Radionuclides in Soil Samples

Location	Collection Date	Activity Concentration (Bq kg^{-1})							
		^{226}Ra	SD	^{228}Th	SD	^{40}K	SD	^{137}Cs	SD
A	17 Jun 05	43.5	0.4	63.8	0.6	781	4.5	0.53	0.07
B	8 Apr 05	66.0	0.6	107.7	1.0	1090	5.2	1.10	0.12
C	8 Apr 05	56.9	0.6	80.4	0.9	932	6.5	*	*
D	17 Jun 05	65.9	0.5	98.0	0.9	1062	5.2	0.88	.011
E	17 Jun 05	35.3	0.4	71.9	0.8	431	3.8	0.66	0.07
F	8 Apr 05	57.4	0.7	81.3	1.0	954	6.4	*	*
G	17 Jun 05	23.6	0.4	67.5	0.8	191	3.8	*	*
H	17 Jun 05	29.4	0.4	92.7	0.9	143	2.6	*	*

I	8 Apr 05	46.2	0.5	97.0	0.9	499	4.1	0.28	0.06
J	17 Jun 05	33.3	0.4	51.1	0.7	359	3.6	0.31	0.05
K	19 Jul 05	52.2	0.4	62.8	0.8	478	4.0	*	*
L	19 Jul 05	61.6	0.5	78.0	0.9	497	4.0	*	*
M	19 Jul 05	59.0	0.5	100.1	1.0	616	4.6	*	*
N	19 Jul 05	61.1	0.5	74.0	0.9	544	4.2	*	*
O	19 Jul 05	58.5	0.5	77.3	0.9	508	4.9	*	*

* Not detected

Table 3.2 (b)

Mean Activity Concentration (Bq kg^{-1})							
^{226}Ra	SU	^{228}Th	SU	^{40}K	SU	^{137}Cs	SU
50.0	13.9	80.2	16.1	606	297	0.25	0.37

Sand

3.6 The sampling locations and measurement results are given in **Figure 3.3** and **Table 3.3** respectively. As expected, the radionuclide contents in sand are much less than in soils. Though to a lesser extent than soil, sand also contains high activity of naturally occurring radionuclides, hence it will only be used for detection of un-naturally occurring γ-emitters that exists in liquid effluent. Since sandy area is restricted to a small region in the north-eastern shoreline, only samples from 3 locations were randomly collected. The sampling locations and measurement results are given in Fig. 3-3 and Table 3-3. As expected, the radionuclide contents in sand are much less than in soils. No ^{137}Cs are detected since they will not adhere to the sand.

Table 3.3 (a) Activity Concentration of Some Major Radionuclides in Sand Samples

Location	Collection Date	Activity Concentration (Bq kg^{-1})					
		^{226}Ra	SD	^{228}Th	SD	^{40}K	SD
A	29 Apr 05	15.1	0.3	17.3	0.4	497	3.5
B	29 Apr 05	23.6	0.3	27.8	0.4	697	4.3
C	29 Apr 05	17.6	0.3	19.6	0.4	535	4.0

Table 3.3 (b)

Mean Activity Concentration (Bq kg^{-1})					
^{226}Ra	SU	^{228}Th	SU	^{40}K	SU
18.8	4.4	21.6	5.5	576	106

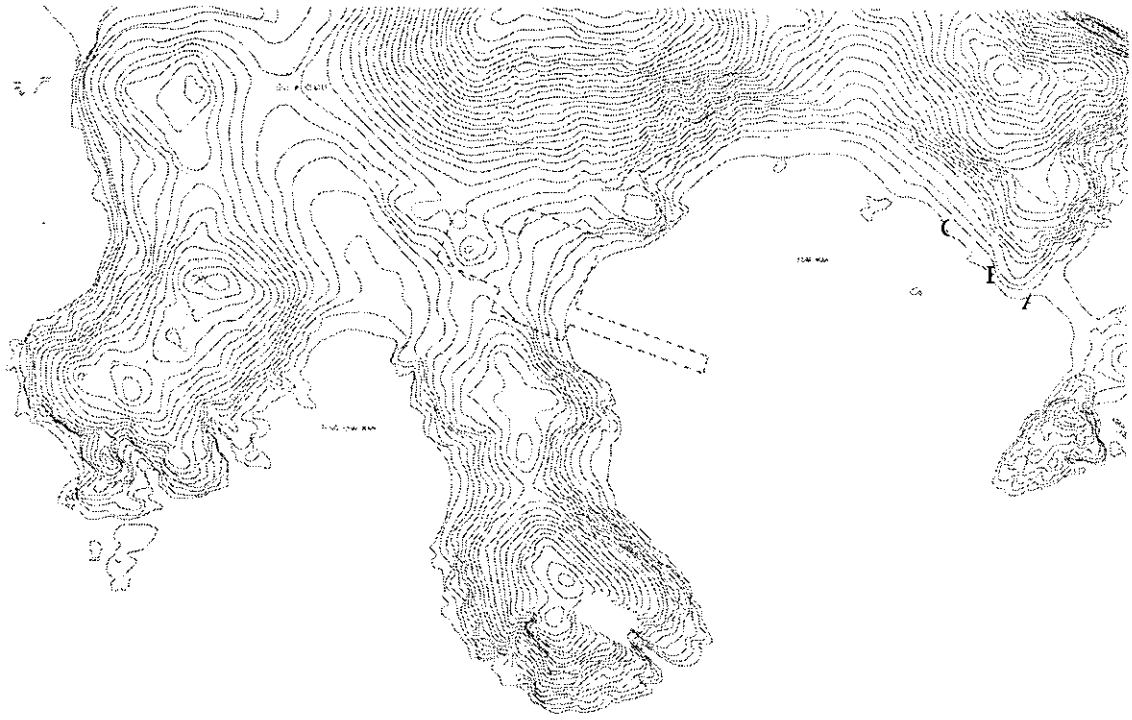

Figure 3.3 Locations for Collecting Sand Samples

Grass

3.7 The sampling locations and measurement results are given in **Figure 3.4** and **Table 3.4** respectively. The γ-spectra of grass samples were nearly identical to the background, hence they were not reported here. Similar to soil samples, any un-naturally occurring γ-emitters will be searched and identified.

Table 3.4 (a) Activity Concentration of Gross α and β Emitters in Grass Samples

Location	Collection Date	α Activity ($Bq\ g^{-1}$)	SD ($Bq\ g^{-1}$)	β Activity ($Bq\ g^{-1}$)	SD ($Bq\ g^{-1}$)
A	17 Jun 05	0.0256	0.0025	0.286	0.005
B	27 Apr 05	0.0647	0.0038	0.359	0.006
C	27 Apr 05	0.0926	0.0044	0.362	0.007
D	17 Jun 05	0.0639	0.0038	0.333	0.006
E	17 Jun 05	0.0503	0.0035	0.276	0.005
F	27 Apr 05	0.0987	0.0045	0.373	0.006
G	17 Jun 05	0.0816	0.0042	0.309	0.005
H	17 Jun 05	0.1669	0.0060	0.350	0.006
I	27 Apr 05	0.1400	0.0055	0.337	0.006
J	17 Jun 05	0.0448	0.0032	0.306	0.006

* $Bq\ g^{-1}$ refers to dry mass of grass

Table 3.4 (b)

Mean α Activity ($Bq\ g^{-1}$)	SU ($Bq\ g^{-1}$)	Mean β Activity ($Bq\ g^{-1}$)	SU ($Bq\ g^{-1}$)
0.083	0.044	0.33	0.033

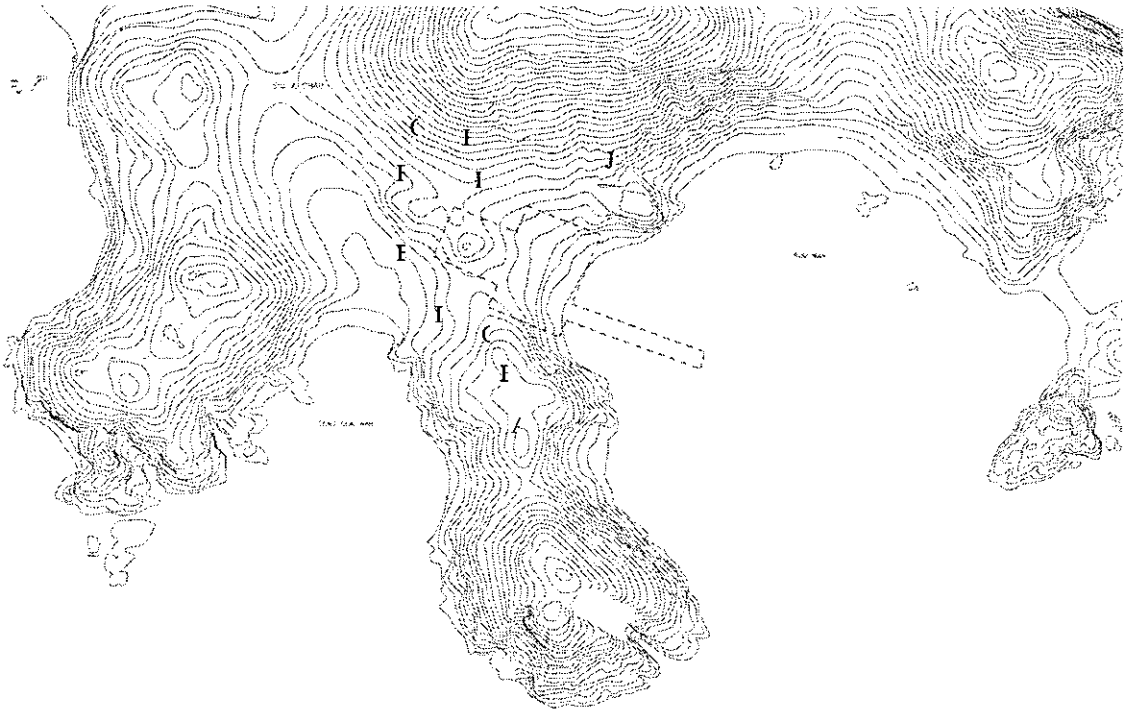

Figure 3.4 Locations for Collecting Grass Samples

Sea Water

3.8 The sampling locations and measurement results are given in **Figure 3.5** and **Table 3.5** respectively. The 4 locations represent:

a. near the liquid effluent point; and

b. near the opening of the bay area.

3.9 Similar to grass samples, the γ-spectra are not reported, but they will be searched for un-naturally occurring γ emitters.

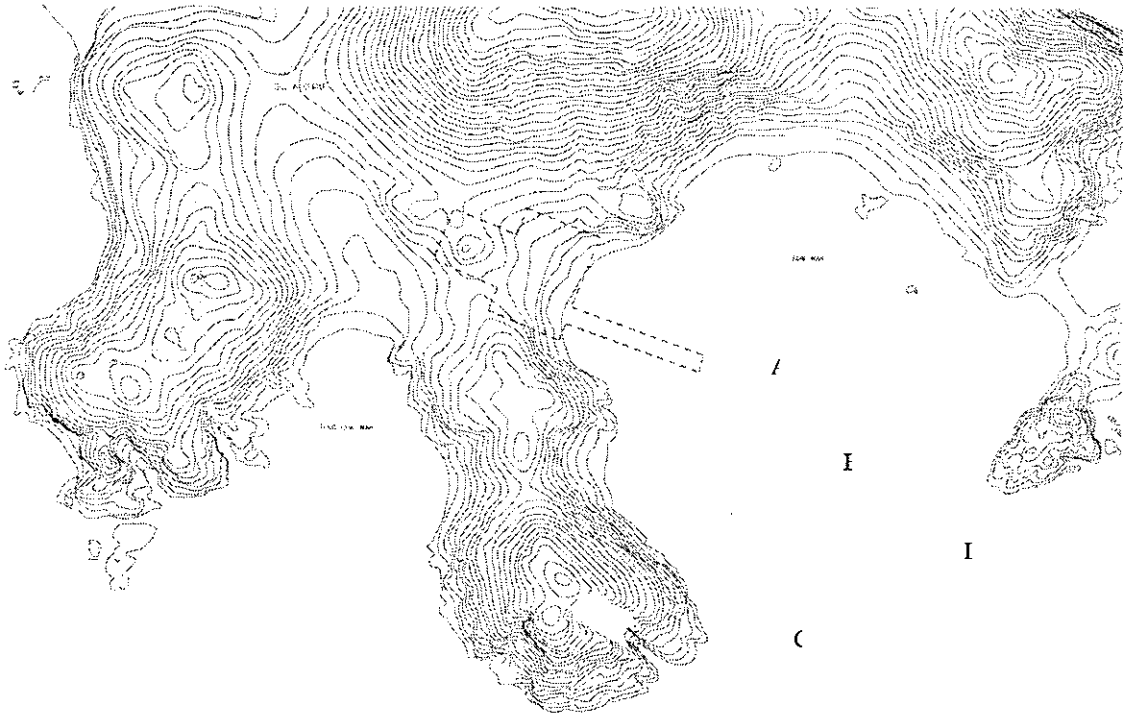

Figure 3.5 Locations for Collecting Water Samples

Table 3-5 (a) Activity Concentration of Gross α and Gross β Emitters in Sea Water Samples

Location	Total Depth (m)	Collection Date	Water Level	α Activity (Bq L^{-1})	SD (Bq L^{-1})	β Activity (Bq L^{-1})	SD (Bq L^{-1})
A	6.6	29 Apr 05	Surface	1.21	0.22	7.28	0.23
			Bottom	0.55	0.19	8.18	0.25
B	7.7	29 Apr 05	Surface	0.95	0.21	6.39	0.22
			Bottom	0.66	0.19	6.71	0.23
C	8.9	29 Apr 05	Surface	0.95	0.21	7.43	0.23
			Bottom	0.47	0.18	7.63	0.24
D	11.5	29 Apr 05	Surface	0.66	0.19	6.21	0.22
			Bottom	0.72	0.19	7.80	0.23

Table 3.5 (b)

Mean α Activity (Bq L^{-1})	SU (Bq L^{-1})	Mean β Activity (Bq L^{-1})	SU (Bq L^{-1})
0.77	0.25	7.20	0.70

Marine Organisms

3.10 Three fish were caught in the jetty area. Sea snails were collected randomly in the north-eastern shore. The meat of the snails were taken out and randomly divided into 3 groups for measurement. The measurement results are given in **Tables 3.6 and 3.7** for fish and sea snails respectively.

Table 3.6 (a) Activity Concentration of Gross α and Gross β Emitters in Fish Samples

Sample	Collection Date	α Activity* (Bq g^{-1})	SD (Bq g^{-1})	β Activity* (Bq g^{-1})	SD (Bq g^{-1})
1	17 Jun 05	0.013	0.002	0.066	0.002
2	17 Jun 05	0.005	0.001	0.068	0.002
3	17 Jun 05	0.010	0.002	0.071	0.002

* Bq g^{-1} refers to wet mass of fish fresh.

Table 3.6 (b)

Mean α Activity* (Bq g^{-1})	SU (Bq g^{-1})	Mean β Activity* (Bq g^{-1})	SU (Bq g^{-1})
0.0093	0.004	0.068	0.0025

* Bq g^{-1} refers to wet mass of fish fresh.

Table 3.7 (a) Activity Concentration of Gross α and Gross β Emitters in Sea Snail Samples

Sample	Collection Date	α Activity* (Bq g^{-1})	SD (Bq g^{-1})	β Activity* (Bq g^{-1})	SD (Bq g^{-1})
1	30 May 05	0.022	0.002	0.063	0.002
2	30 May 05	0.031	0.002	0.069	0.002
3	30 May 05	0.034	0.003	0.061	0.002

* Bq g^{-1} refers to wet mass of sea snail fresh.

Table 3.7 (b)

Mean α Activity* (Bq g^{-1})	SU (Bq g^{-1})	Mean β Activity* (Bq g^{-1})	SU (Bq g^{-1})
0.029	0.0062	0.064	0.004

* Bq g^{-1} refers to wet mass of sea snail fresh.

Airborne Particulates

3.11 Locations of the air samplers and the measurement results are given in **Figure 3.6** and **Table 3.8** respectively. Mean count-rates and SUs are not given because almost all data are zero.

Table 3-8 Gross α and Gross β Counts in Airborne Particulate Samples

Sampling start date: July 20, 2005
Sampling end date: August 12, 2005.

Location	α Count-rate (cpm)	SD	β Count-rate (cpm)	SD
Blank	0.93	0.13	4.30	0.27
A1	0.00	0.0	0.00	0.0
A2	0.00	0.0	0.00	0.0
B1	0.00	0.0	0.00	0.0
B2	0.00	0.0	0.00	0.0
C1	0.00	0.0	2.33	0.4
C2	0.00	0.0	0.00	0.0

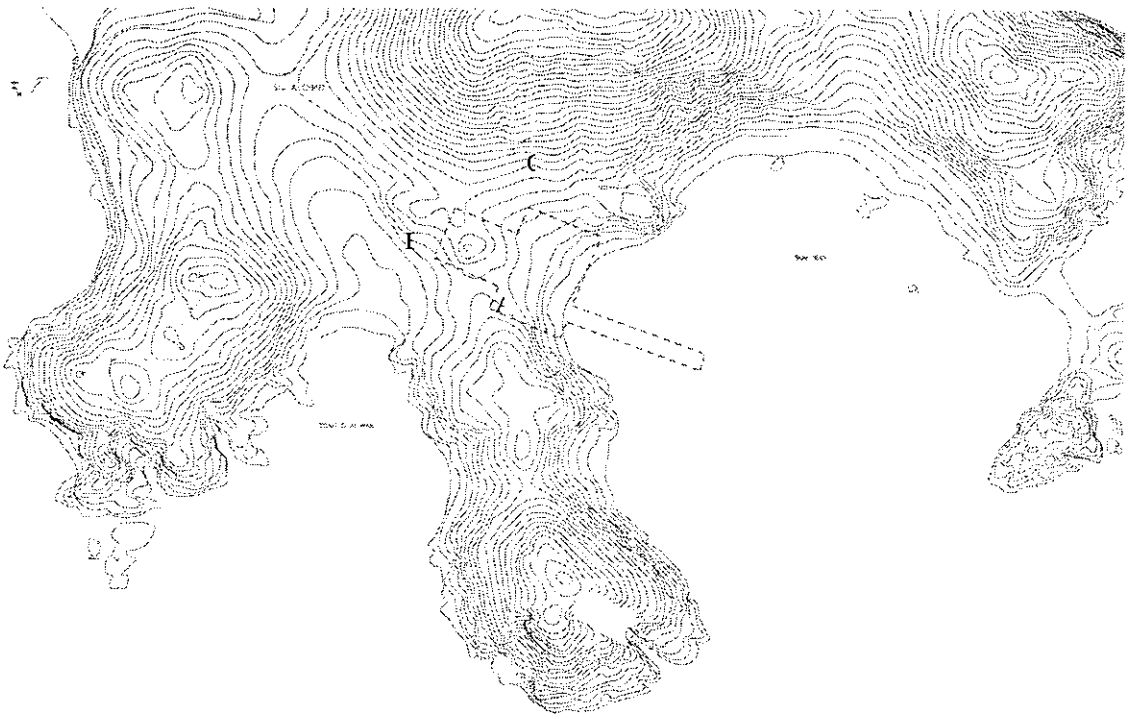

Figure 3.6 Locations of the Passive Airborne Particulate Samplers

4. RADIOLOGICAL NON-COMPLIANCE LEVELS, ACTION LEVELS & INVESTIGATION LEVELS

Limit Level and Action Level

4.1 The Limit Levels for non-compliance with the Environmental Performance Requirements during the Operation are shown in **Table 4-1**.

Table 4-1 Limit Levels for Non-compliance and Action Levels

Environmental Performance Requirements	Limit Levels	Action Levels ($3/10^{th}$ of Limit Levels)
Dose for radiation workers	1.67 mSv per month	0.5 mSv per month
Dose rate at un-controlled areas	1 μSv per hour	0.3 μSv per hour
Liquid effluent discharge	10 ALI per month	3 ALI per month
Airborne effluent discharge	10 ALI per month	3 ALI per month

4.2 These levels will be monitored by installed radiation monitors inside LRWF. Radiation dose for the workers will be monitored and recorded by TLDs on a monthly basis during operation. Dose rates at uncontrolled areas are monitored regularly by portable γ dose ratemeter. All waste water generated in the controlled areas is stored in a delay tank. Activity of the water will be measured to make sure that its activity concentration is below the statutory limit before discharge. Activity in discharged air is continuously monitored by a stack monitor which also records the cumulative discharge.

4.3 **Table 4-2** lists the actions that should be taken when the action levels or trigger levels for non-compliance are reached.

Investigation Level

4.4 With the help of all the internal monitoring, it is unlikely that the effluents will cause any observable increase in the radiation levels in the vicinity of the Facility under normal operation. It is also not anticipated that any significant quantity of the radioactive wastes would be released to the environment under even the most severe natural disasters. Nevertheless when the environmental samples are found to have radioactivities higher than the normal fluctuation of the established baseline levels, some investigation has to be initiated. The levels that trigger the investigation are called investigation levels and they are given in **Table 4-3**.

Table 4.2 Event and Action Plan for Exceedance of Action Levels & Limit Levels

EVENT	ACTION				
	ET	IEC	ER	CONTRACTOR	DoH
Action level being exceeded	1. Repeat in-situ measurement to confirm findings; 2. Identify source(s) of impact; 3. Inform IEC, Contractor, ER and EPD; 4. Check monitoring data, all plant, equipment and Contractor's working methods; 5. Discuss mitigation measures with IEC, ER and Contractor; 6. Ensure mitigation measures are implemented; 7. Increase the monitoring frequency to daily until no exceedance.	1. Discuss with ET and Contractor on possible mitigation measures; 2. Review the proposed mitigation measures submitted by Contractor and advise the ER accordingly; 3. Assess the effectiveness of the implemented mitigation measures.	1. Discuss with IEC, ET and Contractor on the proposed mitigation measures; 2. Request Contractor to critically review the working methods; 3. Make agreement on the mitigation measures to be implemented; 4. Assess the effectiveness of the implemented mitigation measures.	1. Inform the ER and confirm notification of the non-compliance in writing; 2. Rectify unacceptable practice; 3. Check all plant and equipment 4. Consider changes of working methods; 5. Discuss with ET, IEC, DoH and ER and propose mitigation measures to IEC and ER within 3 working days; 6. Implement the agreed mitigation measures.	1. Discuss with all parties on the proposed mitigation measures; 2. Make agreement on the mitigation measures to be implemented; 3. Assess the effectiveness of the implemented mitigation measures.
Limit level being exceeded	In addition to all the above actions, to: 1. Provide a full report of the cause, the damage and mitigations done; 2. Conduct a follow up investigation to confirm effectiveness of mitigation measures.	Same actions as above.	Same actions as above.	Same actions as above.	Same actions as above.

Remarks:

ET = Environmental Team

IEC = Independent Environmental Checker

ER = Employer's Representative

DoH = Department of Health

Table 4-3 Investigation Levels for Environmental Samples

Environmental Samples		Investigation Levels	
Ambient γ dose rate ($\mu Sv\ h^{-1}$)	A	0.20	3 × SD of individual baseline dose rate
	B	0.25	
	C	0.32	
	D	0.27	
	E	0.29	
	F	0.28	
	G	0.27	
	H	0.31	
	I	0.32	
	J	0.24	
	K	0.32	
	L	0.25	
	M	0.31	
	N	0.29	
Soil ($Bq\ kg^{-1}$)	^{226}Ra	91.7	3 × SU of baseline samples
	^{228}Th	128.5	
	^{40}K	1497	
	^{137}Cs	1.36	
	Other γ emitters		Occurrence in any quantities
Sand ($Bq\ kg^{-1}$)	^{226}Ra	32.0	3 × SU of baseline samples
	^{228}Th	38.1	
	^{40}K	894	
	Other γ emitters		Occurrence in any quantities
Grass ($Bq\ g^{-1}$)	Gross α	0.22	3 × SU of baseline samples
	Gross β	0.43	
	γ emitters not found in baseline		Occurrence in any quantities
Sea water ($Bq\ L^{-1}$)	Gross α	1.52	3 × SU of baseline samples
	Gross β	9.3	
	γ emitters not found in baseline		Occurrence in any quantities
Fish ($Bq\ g^{-1}$)	Gross α	0.021	3 × SU of baseline samples
	Gross β	0.076	

Sea snails ($Bq\ g^{-1}$)	Gross α Gross β	0.048 0.076	3 × SU of baseline samples
Airborne particulates (cpm)	Gross α Gross β		Occurrence in any quantities

- SD is the standard deviation of a single sample.
- SU is standard uncertainty of the sample group.

4.5 Since γ dose rates are measured at the same locations every time and there will not be any sample variations, 3 standard deviations of the baseline level at each individual location are used as the investigation levels. On the other hand, soil, sand, water and marine organism samples will be collected at slightly different locations, and will inevitably exhibit variation among the samples, hence the 3 times standard uncertainty is used as the investigation level. If γ-emitters other than those recorded in the baseline monitoring are detected in future samples, actions will be taken to investigate their presence.

4.6 It is unlikely that the investigation levels for environmental samples will be exceeded without triggering the action levels governing the discharges in the first place. As such, the investigation levels do not serve as alarms that need immediate action.

Exceedance of Investigation Level

4.7 When investigation level is exceeded, RP shall advise the next step to be taken to investigate the reason for exceeding the limit and to re-conduct sampling if necessary. ET shall report investigation result to Operation Manager of the Facility, IEC and EPD

REFERENCES

- Official methods of analysis of the Association of Official Analytical Chemists, 1990.
- Measurement of Radionuclides in Food and the Environment – A Guidebook. International Atomic Energy Agency, Vienna, 1989.