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For the attention of Mr Ray Leung

28 December 2016

Dear Mr Leung

Low Level Radioactive Waste Storage Facility at Siu A Chau
Independent Environmental Checker Services
Environmental Monitoring and Audit Report No. 1 (Operation Phase)

We refer to your ET's submission email dated 7 December 2016 for draft submission and 24 December 2016 for final submission, regarding the captioned report.

We have checked the report and do not have further comments and hereby enclosed the captioned report for your onward submission.

If you require any further information, please do not hesitate to contact the undersigned or our Martin Yu at 2268 3206.

Yours sincerely

Sam Tsoi
Director

Encl.

ATAL ENGINEERING LIMITED

Contract No. EP/SP/75/14

Low Level Radioactive Waste Storage Facility Follow-On Contract

Environmental Monitoring and Audit Report No. 1 (Operation Phase)

Version 1.0

September 2016

Certified By _____
(Environmental Team Leader)

REMARKS:
The information supplied and contained within this report is, to the best of our knowledge, correct at the time of printing.
The Environmental Team Leader accepts no responsibility for changes made to this report by third parties.

Dr. John K.C. Leung

E-mail: jkcleung@hku.hk

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EXECUTIVE SUMMARY

This is the first Environment Monitoring & Audit (EM&A) Report for the new Low Level Radioactive Waste Storage Facility Follow-On Contract.

The samples were collected on September 20, 2016. Starting from this year, the measurement laboratory will be changed to the Safety Office, The University of Hong Kong. The Th-228 contents in Soil Sample A & C have exceeded the Investigation Level. Investigation is being carried out.

Investigation Levels (ILs) are now shown alongside the measurement data for easy reference.

Starting from this year, a new γ dose-rate meter, Berthold LB134 will be used to measure ambient γ dose-rates. This meter has a background dose-rate much higher than the original one (LB1236): 0.15 $\mu Sv\ h^{-1}$ vs 0.06 $\mu Sv\ h^{-1}$ as measured on a boat far away from the shore. Hence all measured γ dose-rates are now much higher than previous readings and they easily exceed the ILs. In order to compare updated and old data more directly, the net (detector background and cosmic contribution subtracted) γ dose-rates are now reported instead of the measured rates. The ILs are also revised correspondingly for net γ dose-rates. Please refer to Appendix 2 for details.

It is noted that the upgrading Works have disturbed the soil surface at some γ dose-rate measurement points, notably locations H, I, J and O. Since the landscape and surface soil contents of these locations have been changed, their measurement results can no longer be compared with past results. Hence the ambient γ dose rates at these 4 locations were not measured this year. They will be measured again next year to establish new baseline values at these 4 locations.

Also starting from this year, a new calibration standard for γ spectroscopy will be used to determine the activity concentrations of γ emitters in the environmental samples. To achieve consistency between the new and old calibration standards, a factor of 1.7 is applied to all γ emitters reported including the baseline measurement in all the past EM&A Reports. As this factor is also applicable to the Investigation Levels, it implies that such changes would not affect the conclusion that the radioactivity environment in the vicinity of the LLRWSF has remained stable throughout the past 10 years of operation. Please refer to Appendix 2 for details.

The activities of air particulates collected by the cloth were reported in count per minute (cpm) in previous EM&A Reports. The result will be different if a detector of different size or sensitivity is used. For the sake of easy comparison with previous data, the results of cloth activities will now be reported in Bq per 1000 cm^2, instead of count per minute (cpm) because results in cpm will be different due to different size and sensitivity of the monitors. The conversion factor (Bq/1000 cm^2 per cpm) depends on the calibration result of alpha/beta contamination monitor.

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 were stored in disused air raid tunnels close to Queen's Road East in Wan Chai. Other arisings were 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 Low Level Radioactive Waste Storage Facility at Siu A Chau (LLRWSF) for 10 years. Thereafter, the ABJV will transfer the waste management skills for this Facility to Hong Kong.

1.4 The LLRWSF was designed to have a storage vault that can initially store 260 drums of waste, each drum of 275 litres net capacity. The building also contains facilities for waste reception and repackaging waste, and administering the process. A jetty was 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.

1.7 In 2015, ATAL was awarded the contract (Low Level Radioactive Waste Storage Facility Follow-On Contract) to operate the LLRWSF for another 10 years starting from January 19, 2016.

Purpose of the Report

1.8 This is the first EM&A Report (Operation Phase) for the Follow-On Contract. This report covers the monitoring period from April 15, 2015 to the date of sampling which was September 20, 2016.

1.9 The requirements of the operation phase monitoring and audit; monitoring scheme and monitoring equipment and procedures have been fully described in the EM&A Manual (Part 2). Please refer to that manual for reference.

1.10 This report also covers the monitoring of personnel doses, the non-active areas of the Facility and the liquid and gaseous effluents.

2. MONITORING RESULTS

2.1 The sampling scheme remained unchanged. 15 in-situ ambient γ dose rates were measured. 3 soil samples; 3 sand samples; 3 grass samples; 8 seawater samples from 4 locations at two depths; sea snails; a few fish and 3 airborne particulate samples were collected and analysed as in previous monitoring. **Figure 2.1** shows the locations for taking various samples.

2.2 Ambient γ dose rates were taken at exactly the same locations and would give a true picture of the variation of the radiation environment if there were any.

2.3 Soil and grass samples were collected at more or less the same place as for the baseline. Since we need fresh surface soils that would have stored information of fallout since the commencement of the operation, the sampling sites shifted a little bit every time.

2.4 The uncertainties of the measurement results are given as standard deviation (SD) or standard uncertainty (SU). SD is given for individual sample and is calculated according to the number of counts recorded and assuming a normal distribution for the counts. SU is reported for each group of samples and it takes into account of the variance between samples. Please refer to the First EM&A Report (Operation Phase) (Oct 2005) for details.

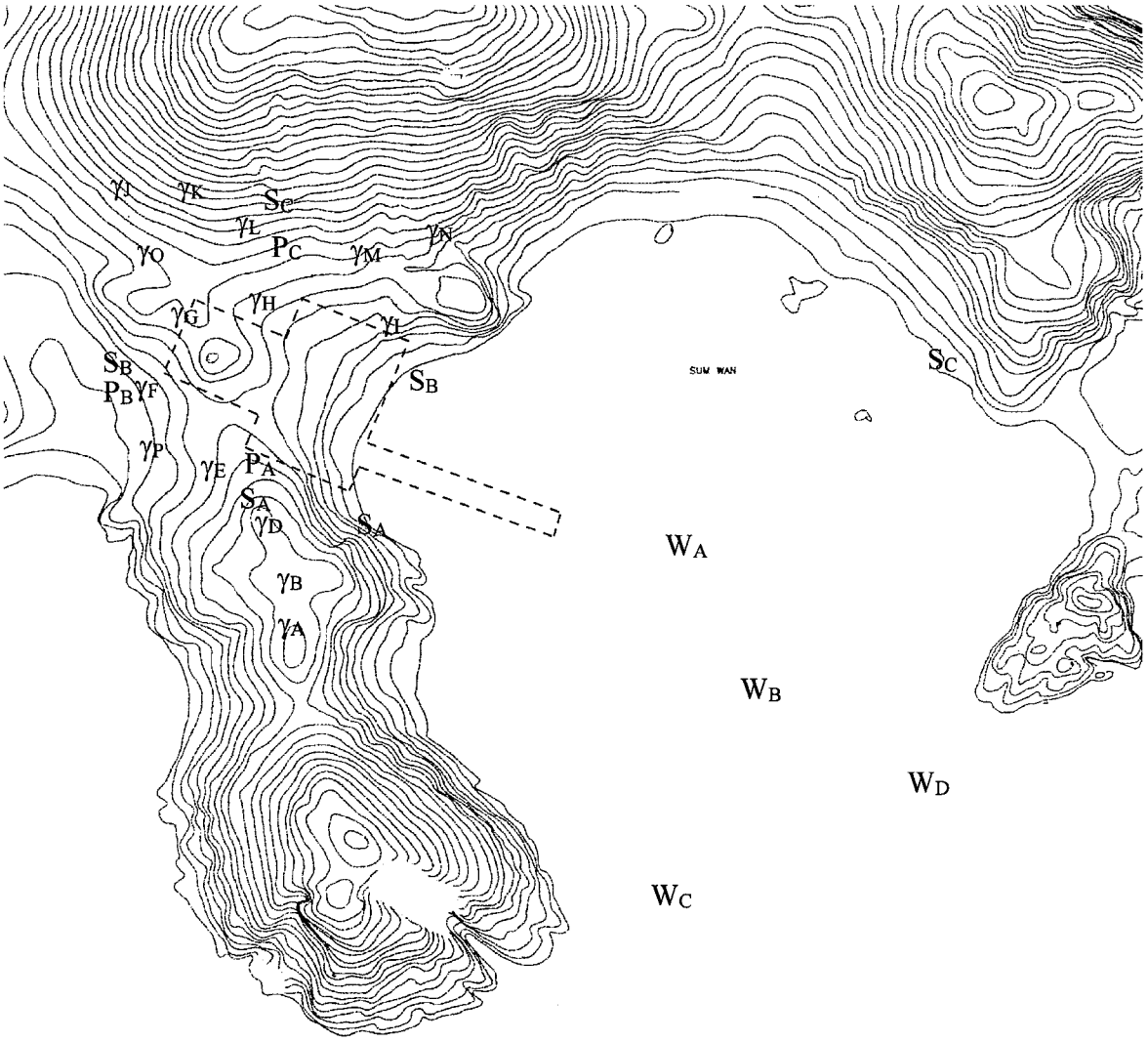


Fig. 2.1 Locations of the Sampling Sites

(γ: Ambient gamma dose rate; S: Soil or Sand; W: Water; P: Air particulates)
(Grass sampling sites are the same as soil sampling sites)

Ambient γ Dose Rates

2.5 From now on, the net ambient γ dose-rates will be reported. The measurement results are given in the last column in **Table 2.1(a)**. The last five years of results are given for comparison. **Table 2.1(b)** shows the mean γ dose rates of all the past results. It is noted that the overall average value has not changed during the monitoring period.

2.6 Starting from this year, a new γ dose-rate meter, Berthold LB134 (Fig. 2.2) will be used to measure ambient γ dose-rates. This meter has a background dose-rate much higher than the original one (LB1236): 0.15 μSv h-1 vs 0.06 μSv h-1 as measured on a boat far away from the shore. Hence all measured γ dose-rates are now much higher than previous readings and they easily exceed the ILs. In order to compare updated and old data more directly, the net (detector background and cosmic contribution subtracted) γ dose-rates are now reported instead of the measured rates. The ILs are also revised correspondingly for net γ dose-rates. Please refer to Appendix 2 for details.

Fig. 2.2 LB134 compared with LB1236

2.7 It is noted that the upgrading Works have disturbed the soil surface at some γ dose-rate measurement points, notably locations H, I, J and O (marked by a red circle) as shown in Fig. 2.3 to Fig. 2.6. Since the landscape and surface soil contents of these locations have been changed, their measurement results can no longer be compared with past results. Hence the ambient γ dose rates at these 4 locations were not measured this year. They will be measured again next year to establish new baseline values at these 4 locations.

Fig. 2.3 Location H

Fig. 2.4 Location I

Fig. 2.5 Location J

Fig. 2.6 Location O

Table 2.1(a) Ambient γ Dose Rates at 1 m above Ground

Location	ILs*	Net γ Dose Rate (μSv h^{-1})					
		Baseline (2005)	2011	2012	2013	2014	2015
A	0.17	0.14	0.16	0.14	0.15	0.17	0.16
B	0.19	0.15	0.17	0.18	0.17	0.19	0.17
D	0.21	0.16	0.20	0.19	0.18	0.21	0.20
E	0.23	0.18	0.15	0.14	0.16	0.16	0.16
F	0.22	0.17	0.19	0.19	0.21	0.21	0.19
G	0.21	0.16	0.18	0.21	0.19	0.20	0.19
H	0.25	0.20	0.25	0.23	0.22	0.25	0.21
I	0.26	--	0.17	0.20	0.22	0.20	0.24
J	0.18	0.14	0.18	0.18	0.17	0.19	0.18
K	0.26	0.21	0.21	0.20	0.19	0.22	0.22
L	0.24	0.19	0.21	0.19	0.18	0.20	0.22
M	0.25	0.20	0.18	0.25	0.22	0.24	0.20
N	0.23	0.18	0.16	0.19	0.21	0.17	0.19
O	0.18	--	0.17	0.16	0.17	0.15	0.15
P	0.23	--	0.21	0.21	0.18	0.22	0.23

Location	ILs*	Net γ Dose Rate ± 1 SD (μSv h^{-1})
		2016
A	0.17	0.14±0.02
B	0.19	0.16±0.02
D	0.21	0.18±0.02
E	0.23	0.15±0.02
F	0.22	0.18±0.02
G	0.21	0.18±0.02
H	0.25	--
I	0.26	--
J	0.18	--
K	0.26	0.18±0.02
L	0.24	0.21±0.02
M	0.25	0.21±0.02
N	0.23	0.19±0.02
O	0.18	--
P	0.23	0.18±0.02

-- Not measured

* Updated ILs for Net γ Dose Rates, see Executive Summary at page 1

2.8 Locations H, I, J and O have been disturbed by the works done on-site, hence they were not measured.

2.9 The new data has higher uncertainties because the new probe is less sensitive, hence giving larger statistical errors.

Table 2.1(b) Comparison of Ambient γ Dose Rates with Previous Results

EM&A Report No.	Mean Net γ Dose Rate (μSv h^{-1})	SU
1 (Baseline) (2005)	0.18	0.026
10 (2006)	0.19	0.029
11 (2007)	0.20	0.025
12 (2008)	0.18	0.031
13 (2009)	0.19	0.028
14 (2010)	0.18	0.027
15 (2011)	0.19	0.026
16 (2012)	0.19	0.030
17 (2013)	0.19	0.023
18 (2014)	0.20	0.028
19 (2015)	0.19	0.027
1 (2016)	0.18	0.022

2.10 The overall mean ambient γ dose-rate for this year is the same as those in previous years.

Soil

2.11 Soil samples were collected at 3 locations, all from the undisturbed areas. These locations correspond to the passive air sampler locations which aim to detect dispersion of effluent leakages, if any, in the prevailing wind directions. The measurement results are given in **Table 2.2(a) & (b)**.

2.12 Starting from this year, a new calibration standard for γ spectroscopy will be used to determine the activity concentrations of γ emitters in the environmental samples. To achieve consistency between the new and old calibration standards, a factor of 1.7 is applied to all γ emitters reported including the baseline measurement in all the past EM&A Reports. As this factor is also applicable to the Investigation Levels, it implies that such changes would not affect the conclusion that the radioactivity environment in the vicinity of the LLRWSF has remained stable throughout the past 10 years of operation. Please refer to Appendix 2 for details.

Table 2.2(a) Activity Concentration of Some Major Radionuclides in Soil Samples (ILs for ^{226}Ra, ^{228}Th & ^{40}K are respectively 155, 218 & 2544 Bq kg^{-1})

Location	Collection Date	Activity Concentration (Bq kg^{-1})					
		^{226}Ra	SD	^{228}Th	SD	^{40}K	SD
A	20 Sep 16	98.2	1.6	237	1.9	972	6.2
B	20 Sep 16	124	1.6	168	1.7	875	6.2
C	20 Sep 16	91.8	1.6	235	2.0	266	4.2

Table 2.2(b) Comparison of Activities in Soil Samples with Updated Previous Results*

EM&A Report No.	Mean Activity Concentration (Bq kg^{-1})					
	Previous ^{226}Ra	Updated ^{226}Ra#	Previous ^{228}Th	Updated ^{228}Th#	Previous ^{40}K	Updated ^{40}K#
1 (Baseline)	50.0	85	80.2	136	606	1030
10 (2006)	50.7	86.2	97.7	166	498	846
11 (2007)	52.8	89.8	107	181	483	821
12 (2008)	64.3	109	99.1	168	506	860
13 (2009)	59.3	100	116	197	474	805
14 (2010)	58.7	99.8	105	178	626	1064
15 (2011)	48.9	83.1	52.5	89.3	504	857
16 (2012)	44.9	76.3	63.6	108	460	782
17 (2013)	52.9	89.9	67.9	115	671	1140
18 (2014)	60.1	102	64.4	109	548	931
19 (2015)	63.0	107	74.2	126	597	1015
1 (2016)	--	101	--	213	--	704

* Only updated results will be reported in future EM&A Reports
# See Executive Summary at Page 1

2.13 Th-228 in sample A and C have exceeded the IL.

Sand

2.14 The measurement results are shown in **Table 2.3(a) & (b)**.

2.15 Starting from this year, a new calibration standard for γ spectroscopy will be used to determine the activity concentrations of γ emitters in the environmental samples. To achieve consistency between the new and old calibration standards, a factor of 1.7 is applied to all γ emitters reported including the baseline measurement in all the past EM&A Reports. As this factor is also applicable to the Investigation Levels, it implies that such changes would not affect the conclusion that the radioactivity environment in the vicinity of the LLRWSF has remained stable throughout the past 10 years of operation. Please refer to Appendix 2 for details.

Table 2.3(a) Activity Concentration of Some Major Radionuclides in Sand Samples (ILs for ^{226}Ra, ^{228}Th & ^{40}K are respectively 54, 65 & 1520 Bq kg^{-1})

Location	Collection Date	Activity Concentration (Bq kg^{-1})					
		^{226}Ra	SD	^{228}Th	SD	^{40}K	SD
A	20 Sep 16	26.4	0.8	25.0	0.8	465	4.1
B	20 Sep 16	30.6	0.8	24.3	0.8	306	3.4
C	20 Sep 16	22.4	0.8	26.7	0.9	527	4.4

Table 2.3(b) Comparison of Activities in Sand Samples with Updated Previous Results*

EM&A Report No.	Mean Activity Concentration (Bq kg^{-1})					
	Previous ^{226}Ra	Updated ^{226}Ra#	Previous ^{228}Th	Updated ^{228}Th#	Previous ^{40}K	Updated ^{40}K#
1 (Baseline)	18.8	31.9	21.6	36.7	576	979
10 (2006)	18.4	31.2	18.5	31.4	377	640
11 (2007)	17.0	28.9	18.6	31.6	397	674
12 (2008)	18.0	30.6	16.5	28.0	382	649
13 (2009)	19.1	32.4	17.3	29.4	313	532
14 (2010)	14.3	24.3	12.5	21.2	301	511
15 (2011)	16.9	28.7	10.9	18.5	331	562
16 (2012)	19.2	32.6	13.9	23.6	273	464
17 (2013)	20.9	35.5	14.0	23.8	295	501
18 (2014)	14.9	25.3	8.6	14.6	316	537
19 (2015)	17.0	28.9	15.9	27.0	261	443
1 (2016)	--	26.5	--	25.3	--	433

* Only updated results will be reported in future EM&A Reports
# See Executive Summary at Page 1

2.16 No exceedance of Investigation Level is observed.

Grass

2.17 Grass samples were collected in locations near to the soil samples. The measurement results are given in **Table 2.4(a) & (b)**. The γ-spectra are identical to the background of the γ spectrometer and do not reveal the presence of any significant γ-emitting radionuclides, hence they are not reported here.

Table 2.4(a) Activity Concentration of Gross α and β Emitters in Grass Samples (ILs for α and β activities are respectively 0.22 & 0.43 Bq g^{-1})

Location	Collection Date	α Activity* (Bq g^{-1})	SD (Bq g^{-1})	β Activity* (Bq g^{-1})	SD (Bq g^{-1})
A	20 Sep 16	0.009	0.001	0.227	0.002
B	20 Sep 16	0.002	0.001	0.269	0.003
C	20 Sep 16	0.013	0.001	0.223	0.003

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

Table 2.4(b) Comparison of α/β Activities in Grass with Previous Results

EM&A Report No.	Mean α Activity (Bq g^{-1})	SU (Bq g^{-1})	Mean β Activity (Bq g^{-1})	SU (Bq g^{-1})
1 (Baseline)	0.083	0.044	0.33	0.03
10 (2006)	0.051	0.008	0.40	0.07
11 (2007)	0.030	0.022	0.27	0.06
12 (2008)	0.012	0.020	0.17	0.04
13 (2009)	0.014	0.016	0.10	0.03
14 (2010)	0.038	0.027	0.21	0.04
15 (2011)	0.021	0.019	0.15	0.03
16 (2012)	0.022	0.022	0.10	0.03
17 (2013)	0.026	0.015	0.27	0.06
18 (2014)	0.036	0.017	0.23	0.05
19 (2015)	0.019	0.002	0.27	0.03
1 (2016)	0.008	0.006	0.24	0.03

2.18 No exceedance of Investigation Level is observed.

Sea Water

2.19 Approximately the same 4 locations were chosen to collect the water samples at 2 depths. The measurement results are given in **Table 2.5(a) & (b)**.

2.20 Similar to grass samples, the γ spectra are not reported. There is no sign of presence of γ emitters.

2.21 No exceedance of Investigation Level is observed.

Table 2-5(a) Activity Concentration of Gross α/β Emitters in Sea Water Samples (ILs for α and β activities are respectively 1.52 & 9.3 Bq L^{-1})

Location	Collection Date	Water Depth (m)	α Activity (Bq L^{-1})	SD (Bq L^{-1})	β Activity (Bq L^{-1})	SD (Bq L^{-1})
A	20 Sep 16	1	0.00#	0.14	2.58	0.42
		3.5	0.00#	0.14	7.95	0.43
B	20 Sep 16	1	0.00#	0.14	1.29	0.42
		6.5	0.00#	0.15	2.06	0.43
C	20 Sep 16	1	0.00#	0.14	0.00#	0.42
		7.5	0.00#	0.13	2.71	0.42
D	20 Sep 16	1	0.00#	0.14	0.00#	0.42
		5	0.00#	0.15	4.65	0.43

Below minimum detectable activity of 0.028 Bq for α and 0.118 Bq for β.

Table 2.5(b) Comparison of α/β Activities in Sea Water with Previous Results

EM&A Report No.	Mean α Activity (Bq L^{-1})	SU (Bq L^{-1})	Mean β Activity (Bq L^{-1})	SU (Bq L^{-1})
1 (Baseline)	0.77	0.25	7.20	0.70
10 (2006)	0.70	0.35	8.35	2.19
11 (2007)	0.00	0.00	2.35	0.21
12 (2008)	0.00	0.00	4.08	0.42
13 (2009)	0.32	0.29	5.44	1.27
14 (2010)	0.00	0.00	4.80	0.41
15 (2011)	0.14	0.21	2.88	1.39
16 (2012)	0.03	0.07	3.74	0.96
17 (2013)	0.00	0.00	2.76	1.14
18 (2014)	1.01	0.57	4.91	1.43
19 (2015)	0.00	0.00	6.34	2.08
1 (2016)	0.00	0.00	2.66	2.63

Marine Organisms

2.22 Fishes were caught along the jetty and sea snails were collected randomly along the shores.

2.23 The measurement results are given in **Table 2.6(a) & (b)** and **Table 2.7(a) & (b)** for the gross α/β activities in fish and sea snails respectively.

Table 2.6(a) Activity Concentration of Gross α/β Emitters in Fish Samples (ILs for α and β activities are respectively 0.021 & 0.076 Bq g^{-1})

Sample	Collection Date	α Activity* (Bq g^{-1})	SD (Bq g^{-1})	β Activity* (Bq g^{-1})	SD (Bq g^{-1})
1	20 Sep 16	0.000#	0.000	0.008	0.002
2	20 Sep 16	0.017	0.003	0.017	0.007
3	20 Sep 16	0.006	0.000	0.016	0.002

* Bq g^{-1} refers to wet mass of fish flesh.
# Below minimum detectable α activity of 0.028 Bq.

Table 2.6(b) Comparison of α/β Activities in Fish Samples with Previous Results

EM&A Report No.	Mean α Activity (Bq g^{-1})	SU (Bq g^{-1})	Mean β Activity (Bq g^{-1})	SU (Bq g^{-1})
1 (Baseline) (2005)	0.0093	0.004	0.068	0.003
10 (2006)	0.0060	0.005	0.078	0.007
11 (2007)	0.0003	0.001	0.055	0.012
12 (2008)	0.0000	0.000	0.067	0.003
13 (2009)	0.0075	0.002	0.079	0.000
14 (2010)	0.0030	0.003	0.111	0.023
15 (2011)	0.0032	0.001	0.040	0.001
16 (2012)	0.0000	0.000	0.027	0.004
17 (2013)	0.0000	0.000	0.040	0.000
18 (2014)	0.0083	0.007	0.072	0.011
19 (2015)	0.0100	0.006	0.035	0.015
1 (2016)	0.0077	0.008	0.014	0.005

2.24 No exceedance in Investigation Level is observed.

Table 2.7(a) Activity Concentration of Gross α/β Emitters in Sea Snail Samples (ILs for α and β activities are respectively 0.048 & 0.076 Bq g^{-1})

Sample	Collection Date	α Activity* (Bq g^{-1})	SD (Bq g^{-1})	β Activity* (Bq g^{-1})	SD (Bq g^{-1})
1	20 Sep 16	0.000#	0.000	0.034	0.002
2	20 Sep 16	0.002	0.002	0.007	0.007
3	20 Sep 16	0.000#	0.000	0.035	0.002

* Bq g^{-1} refers to wet mass of sea snail flesh.
# Below minimum detectable activity of 0.028 Bq for α and 0.118 Bq for β.

Table 2.7(b) Comparison of α/β Activities in Sea Snails with Previous Results

EM&A Report No.	Mean α Activity (Bq g^{-1})	SU (Bq g^{-1})	Mean β Activity (Bq g^{-1})	SU (Bq g^{-1})
1 (Baseline) (2005)	0.029	0.006	0.064	0.004
10 (2006)	0.010	0.009	0.045	0.005
11 (2007)	0.000	0.001	0.043	0.002
12 (2008)	0.000	0.000	0.024	0.002
13 (2009)	0.003	0.003	0.035	0.004
14 (2010)	0.005	0.000	0.034	0.002
15 (2011)	0.002	0.001	0.048	0.001
16 (2012)	0.000	0.000	0.014	0.001
17 (2013)	0.001	0.000	0.082	0.024
18 (2014)	0.011	0.003	0.050	0.008
19 (2015)	0.006	0.005	0.045	0.023
1 (2016)	0.001	0.001	0.025	0.016

2.25 No exceedance in Investigation Level is observed.

Airborne Particulates

2.26 The measurement results are given in **Table 2.8(a) & 2.8(b).**

2.27 The activities of air particulates collected by the cloth were reported in count per minute (cpm) in previous EM&A Reports. The result will be different if a detector of different size or sensitivity is used. For the sake of easy comparison with previous data, the results of cloth activities will now be reported in Bq per 1000 cm2, instead of count per minute (cpm) because results in cpm will be different due to different size and sensitivity of the monitors. The conversion factor (Bq/1000 cm2 per cpm) depends on the calibration result of alpha/beta contamination monitor.

Table 2.8(a) Net Gross α/β Activities in Airborne Particulate Samples (ILs are not defined)

Location	Collection Date	α Activity (Bq per 1000 cm^2)	SD	β Activity (Bq per 1000 cm^2)	SD
Blank		0.32	0.01	10.4	0.05
A1	20 Sep 16	0.00#	0.02	0.73	0.07
A2	20 Sep 16	0.00#	0.02	0.19	0.07
B1	20 Sep 16	0.00#	0.02	0.47	0.07
B2	20 Sep 16	0.00#	0.01	0.20	0.06
C1	20 Sep 16	0.00#	0.02	0.13#	0.07
C2	20 Sep 16	0.00#	0.02	0.20	0.07

Below minimum detectable activity of 0.006 Bq for α and 0.025 Bq for β.

Table 2.8(b) Comparison of α/β in Airborne Particulate Samples with Previous Results (Units in Bq per 1000 cm^2)

EM&A Report No.	A		B		C	
	α	β	α	β	α	β
1 (Baseline) (2005)	0.00	0.00	0.00	0.00	0.00	0.13
10 (2006)	0.07	0.21	0.02	0.11	0.00	0.00
11 (2007)	0.08	0.11	0.02	0.00	0.00	0.19
12 (2008)	0.06	0.66	0.09	0.59	0.04	0.30
13 (2009)	0.22	0.39	0.06	0.33	0.18	0.19
14 (2010)	0.21	1.75	0.00	0.67	0.00	0.38
15 (2011)	--	--	--	--	--	--
16 (2012)	--	--	--	--	--	--
17 (2013)	0.00	0.07	0.00	0.06	0.00	0.07
18 (2014)	0.11	0.64	0.19	0.51	0.07	0.46
19 (2015)	0.00	0.44	0.00	0.10	0.09	0.56
1 (2016)	0.00	0.46	0.00	0.34	0.00	0.17

2.28 All activities are normal.

3. REPORT ON ELEVATED ENVIRONMENTAL RADIATION BACKGROUND

3.1 The Investigation Levels for environmental samples have been established and they are given in Appendix 1. The relevant action plan is given in the First EM&A Report (Operation Phase) (Oct 2005).

3.2 Th-228 in soil sample A and C have exceeded the Investigation Level. Repeated samples showed similar exceedance. Investigation is recommended.

3.3 Preliminary investigation shows the environmental conditions are normal. The exceedance may be due to sampling error. Resampling will be carried out in December 2016 to further investigate the issue.

4. REPORT ON NON-COMPLIANCE

4.1 The Action Level and Limit Level (A/L Levels) for non-compliance have been established and they are given in Appendix 1 for easy reference. The relevant Event and Action Plan have been developed. Please refer to the First EM&A Report (Operation Phase) (Oct 2005) for details.

Dose for Radiation Workers

4.2 There was no record of exceeding the A/L Levels as recorded by TLDs.

Dose Rates at Un-controlled Areas

4.3 No exceedance of the A/L Levels was observed.

Liquid Effluent Discharge

4.4 There was no liquid effluent discharged during the monitoring period.

Airborne Effluent Discharge

4.5 The average total radon released during the monitoring period was estimated to be 4 x 10^8 – 5 x 10^8 Bq/month, which is below the A/L Levels.

4.6 The discharged α and β activities were also below the A/L Levels.

4.7 The total airborne effluent discharge was below the A/L Levels.

5. RECORD OF ENVIRONMENTAL COMPLAINTS

5.1 No environmental compliant was received during the period.

APPENDIX 1

Limit Level and Action Level

The Limit Levels for non-compliance with the Environmental Performance Requirements during the Operation are shown in **Table A1-1**.

Table A1.1 Limit Levels for Non-compliance and Action Levels

Environmental Performance Requirements	Limit Levels	Action Levels (3/10th 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

Investigation Level

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 A1.2**.

Table A1.2 Investigation Levels for Environmental Samples

Environmental Samples		Investigation Levels	
Net Ambient γ dose rate ($\mu Sv\ h^{-1}$)	A	0.17	3 × SD of individual baseline dose rate
	B	0.19	
	D	0.21	
	E	0.23	
	F	0.22	
	G	0.21	
	H	0.25	
	I	0.26	
	J	0.18	
	K	0.26	
	L	0.24	
	M	0.25	
	N	0.23	
	O	0.18	
	P	0.23	
Soil ($Bq\ kg^{-1}$)	^{226}Ra	155	3 × SU of baseline samples
	^{228}Th	218	
	^{40}K	2544	
	^{137}Cs	2.31	

	Other γ emitters		Occurrence in any quantities
Sand ($Bq\ kg^{-1}$)	^{226}Ra ^{228}Th ^{40}K	54.4 64.8 1520	3 × SU of baseline samples
	Other γ emitters		Occurrence in any quantities
Grass ($Bq\ g^{-1}$)	Gross α Gross β	0.22 0.43	3 × SU of baseline samples
	γ emitters not found in baseline		Occurrence in any quantities
Sea water ($Bq\ L^{-1}$)	Gross α Gross β	1.52 9.3	3 × SU of baseline samples
	γ emitters not found in baseline		Occurrence in any quantities
Fish ($Bq\ g^{-1}$)	Gross α Gross β	0.021 0.076	3 × SU of baseline samples
Sea snails ($Bq\ g^{-1}$)	Gross α Gross β	0.048 0.076	3 × SU of baseline samples
Airborne particulates (Bq per 1000 cm^2)	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.
- ILs for Net Ambient γ dose rate, soil and sand samples are updated values, please refer to Appendix 2 for details.

APPENDIX 2

Correction of γ Spectroscopy Data due to the Different Calibration Standard

Following the transfer of all radiation measurements of Siu A Chau samples to the Safety Office, The University of Hong Kong starting in this new contract, a new HPGe γ spectrometer and new γ calibration standards are used.

When the new HPGe γ spectrometer was used to measure the old calibration standard, a significant difference was observed between the measured and quoted activity of the old calibration standard.

The old calibration standard was home made by mixing 2 kg of dried soil with a calibrated liquid source of ^{152}Eu in a Marinelli beaker which has the same size as the sample holders. The quoted activity was 7.611 kBq on 8/10/2003.

^{152}Eu emits a wide range of γ whose energies are different from those emitted from naturally occurring radionuclides in the soil. The major γ energies are 121.8, 244.7, 344.3, 440.0, 778.9, 867.4, 964.1, 1085.8, 1112.1 and 1408.0 keV. In this way, the original radionuclide contents in the soil is not relevant while the soil itself provides the same absorption matrix as the samples.

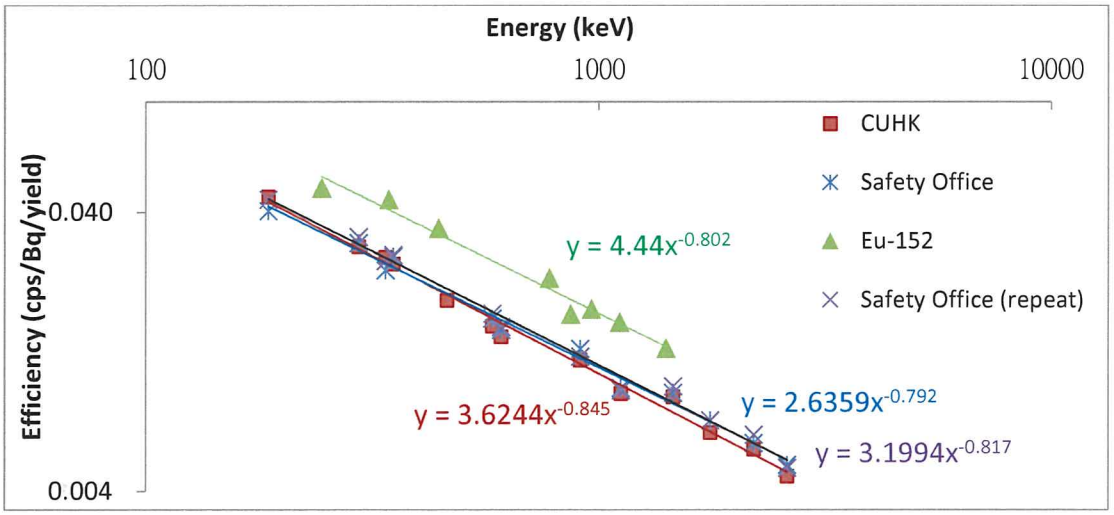
The new γ calibration standard is a mixture of 4 radionuclides: ^{238}U, ^{226}Ra, ^{232}Th and ^{40}K having activities of 1.507, 1.778, 0.560 and 1.719 kBq respectively at 15/4/2004, mixed in a powder matrix in a Marinelli beaker.

A third γ calibration standard was borrowed from the Chinese University of Hong Kong (CUHK) to carry out an inter-comparison test.

The CUHK standard is a set of 3 separate sources (^{238}U, ^{232}Th and ^{40}K having activities of 0.269, 0.179 and 0.654 kBq respectively at 1/1/1987) inside small containers.

The 3 calibration standards (old, new and CUHK) were separately measured by the same HPGe γ spectrometer to determine their efficiency curves. The results are shown in the following figure.

Fig. A2.1 Comparison of Efficiencies of 3 Separate Calibration Sources



The Safety Office and CUHK results match each other well while the ^{152}Eu gives a higher efficiency implying that its quoted activity was underestimated by 42%. Hence all the radionuclide contents measured in the past have to be multiplied by a factor of 1.7.

As the baseline values were underestimated and hence the derived Investigation Levels, all Investigation Levels associated with γ spectroscopic measurement data have to be multiplied by a factor of 1.7.

The old γ calibration standard has been verified by comparing with Belgoprocess at the onset of the last contract some 11 years ago. There was nothing wrong with the calibration standard at that time. The reason for this error to occur is not known.

Updated ILs are given in the following Table A2.1.

Table A2.1 Updated Investigation Levels for Soil and Sand Samples

Environmental Samples		Updated Investigation Levels	
Soil ($Bq\ kg^{-1}$)	^{226}Ra ^{228}Th ^{40}K ^{137}Cs	155 (91.7)* 218 (128.5)* 2544 (1497)* 2.31 (1.36)*	3 × SU of baseline samples
	Other γ emitters		Occurrence in any quantities
Sand ($Bq\ kg^{-1}$)	^{226}Ra ^{228}Th ^{40}K	54.4 (32.0)* 64.8 (38.1)* 1520 (894)*	3 × SU of baseline samples
	Other γ emitters		Occurrence in any quantities

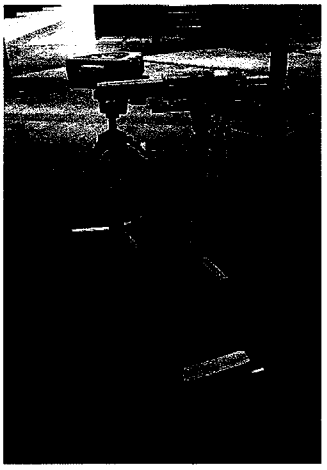
* Previous IL

Change in Reporting of Ambient γ Dose Rates due to the Use of a New Meter

A new γ dose-rate meter, Berthold LB134 was used to measure ambient γ dose-rates. This meter has a background (detector noise + cosmic ray contribution) dose-rate much higher than the original one (LB1236)

An intercomparison was done between the LB134 and LB1236 by placing them close together to measure ambient γ dose-rates at various locations as shown in the following figure. Results are shown in the Table A2.2 below.

Table A2.2 Comparison between New & Old γ dose ratemeters



Location	LB134 (μSv h^{-1})	LB1236 (μSv h^{-1})
Indoor 1	0.25±0.02	0.22±0.01
Indoor 2	0.29±0.02	0.23±0.01
Outdoor 1	0.30±0.02	0.23±0.01
Outdoor 2	0.33±0.02	0.25±0.01
Outdoor 3	0.34±0.02	0.26±0.01
On a boat	0.15±0.02 (Average of 6 measurements)	0.06±0.01

The cosmic contribution to the background will be smaller in indoor environment because cosmic rays can be absorbed as they go through buildings. The measurements taken on the boat when travelling to Siu A Chau is a true representation of the detector background for ambient γ dose-rates in Siu A Chau.

Because of the higher detector background of LB134, all measured γ dose-rates are now much higher than previous readings and they easily exceed the ILs.

In order to compare updated and old data more directly, the net (detector background subtracted) γ dose-rates will be reported instead of the measured rates.

The ILs are also revised correspondingly by subtracting the dose-rate measured on the boat by the old detector (0.06 μSv h^{-1}). Updated ILs are given in Table A2.3.

Table A2.3 Updated Investigation Levels for Ambient γ dose rates

Environmental Samples		Updated Investigation Levels	
Net Ambient γ dose rate (μSv h^{-1})	A	0.17 (0.23)*	3 × SD of individual baseline dose rate
	B	0.19 (0.25)*	
	D	0.21 (0.27)*	
	E	0.23 (0.29)*	
	F	0.22 (0.28)*	
	G	0.21 (0.27)*	
	H	0.25 (0.31)*	
	I	0.26 (0.32)*	
	J	0.18 (0.24)*	
	K	0.26 (0.32)*	
	L	0.24 (0.30)*	
	M	0.25 (0.31)*	
	N	0.23 (0.29)*	
	O	0.18 (0.24)*	
	P	0.23 (0.29)*	

* Previous IL