

# ATAL-BELGOPROCESS JOINT VENTURE

**Contract No. EP/SP/40/02**

## **Low Level Radioactive Waste Storage Facility at Siu A Chau**

**Eighteenth Environmental Monitoring and Audit Report  
(Operation Phase)**

**Version 1.1**

September 2014

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.

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## EXECUTIVE SUMMARY

This is the eighth yearly report after the Facility has been operated for 9 years and it presents the results of the radiological monitoring work performed between August 27, 2013 and the date of sampling, which is August 27, 2014.

The Facility was operating smoothly over the years and there is no indication that the operation of the Facility has risen or will raise the environmental radiation level around the Facility.

There are 3 cases of exceedance of Investigation Level.

1. An exceedance of Investigation Level in  $\gamma$ -dose-rate at Location J:- The exceedance is only 4% and such exceedance occurred occasionally in the past. There are many reasons for the larger fluctuations such as disturbance of the ground due to human or non-human activities; slight variation in measurement height due to unevenness of the ground; slight temperature dependent of the dose-rate reading; slight off calibration of the detector itself, etc. But as a whole, the average dose-rate at each location remains steady throughout the past years.
2. An exceedance of Investigation Level in  $\alpha$ -activity of a water sample at Location C:- Though this is the highest alpha activity recorded in water over the past years, about 13% above the investigation level, however all the other water samples are very normal, an evidence that this sample is an independent issue which is not related to the overall radioactivity in the water.
3. An exceedance of Investigation Level in  $\beta$ -activity of one fish sample:- Fish has been concluded in previous reports to be an inaccurate indicator of contamination because they can come from anywhere. There have been a number of reported exceedances in the past, evidence that the investigation level is not reliable.

Based on the storage record of wastes, there are no wastes that could have caused contamination of the environment under normal storage condition except those radon producing wastes. However, the amount of radon released into the atmosphere from such wastes is under continuous monitoring and the monthly release rate is in the order of  $10^8$  Bq per month (please refer to Section 4 of EM&A reports). This amount is significantly lower than the radon naturally emanated from soil, rocks and concrete around the facility. Given that there was no effluent discharge in the past year and the radon release rate is normal, we can conclude that the slight exceedance levels were not attributable to the operation of the facility but rather due to natural fluctuation.

## **1. INTRODUCTION**

### **Background**

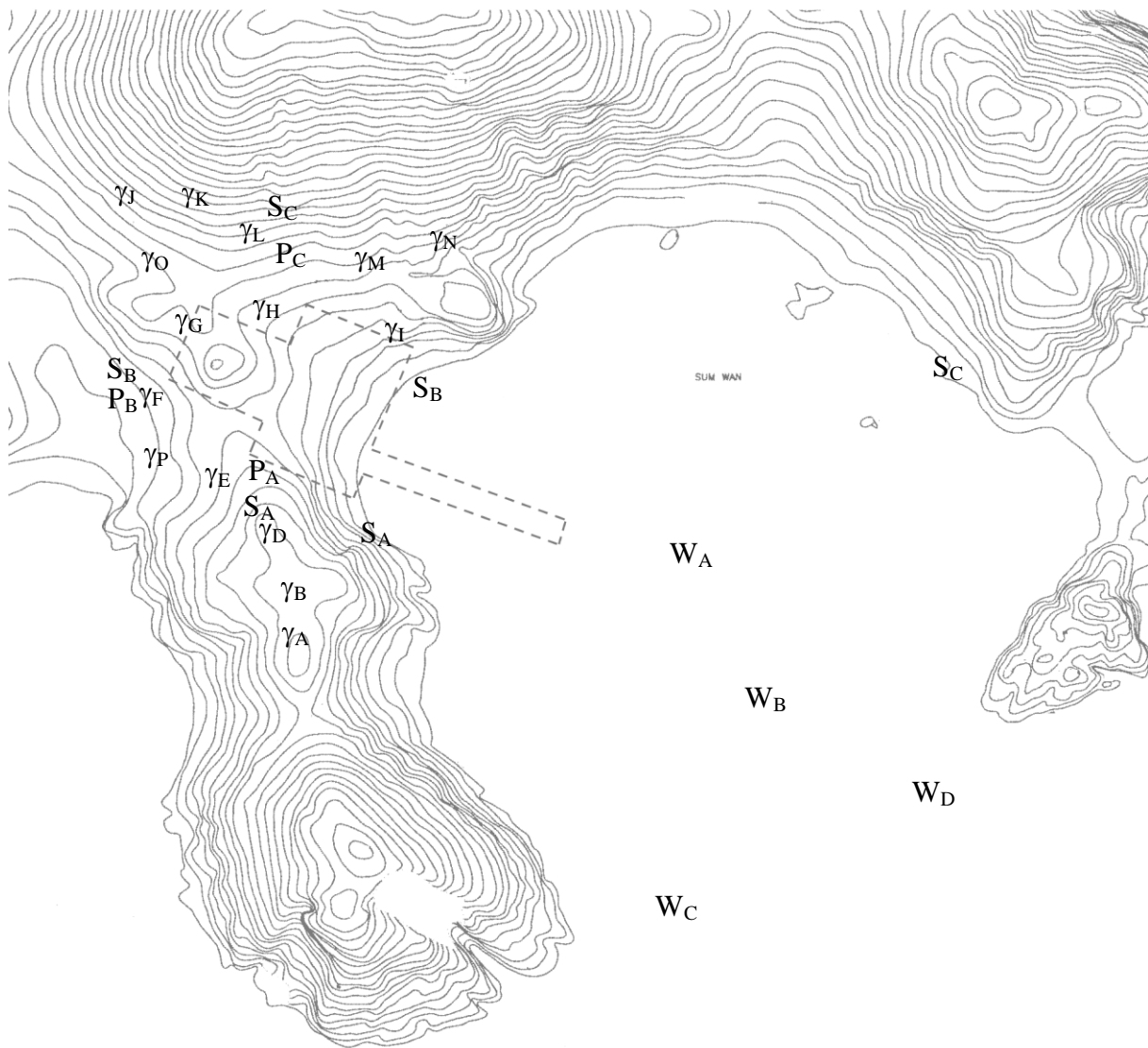
- 1.1 Various industrial, educational and medical facilities in Hong Kong have, for a number of years, used radioactive materials and generated radioactive waste. Most of the existing waste arisings were stored in disused air raid tunnels close to Queen's Road East in Wan Chai. Other arisings were stored 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 LRWF at Siu A Chau for 10 years. 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 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.

### **Purpose of the Report**

- 1.7 This is the eighteenth EM&A (Operation Phase) report, which is also the eighth annual report on measurement results of environmental samples taken after the commencement of operation of the LRWF on July 28, 2005. This report covers the monitoring period from August 27, 2013 to the date of sampling which was August 27, 2014.
- 1.8 The requirements of the operation phase monitoring and audit; monitoring scheme and monitoring equipment and procedures have been fully described in the First EM&A (Operation Phase) Report. Please refer to that report for reference.
- 1.9 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  $\gamma$  dose rates were measured. 3 soil samples; 3 sand samples; 3 grass samples; 8 seawater samples from 4 locations at two depths; 1 kg of 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  $\gamma$  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) 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  $\gamma$  Dose Rates**

**2.5** The measurement results are given in the last column in **Table 2.1(a)**. The 1<sup>st</sup> year results are average of all previous results measured within the 1<sup>st</sup> year. **Table 2.1(b)** also shows the results of the previous measurements for comparison. It is noted that the overall average value has not changed during the monitoring period.

**Table 2.1(a) Ambient  $\gamma$  Dose Rates at 1 m above Ground**

Location	$\gamma$ Dose Rate $\pm$ 1 SD ( $\mu\text{Sv h}^{-1}$ )									
	Baseline (2005)	2006	2007	2008	2009	2010	2011	2012	2013	2014
Boat	0.07	0.06	0.06	0.07	0.06	0.07	0.07	0.06	0.06	0.06 $\pm$ 0.004
A	0.21	0.22	0.21	0.20	0.19	0.21	0.23	0.20	0.21	0.23 $\pm$ 0.02
B	0.22	0.24	0.25	0.24	0.23	0.25	0.24	0.24	0.23	0.25 $\pm$ 0.02
D	0.23	0.26	0.26	0.25	0.25	0.26	0.27	0.25	0.24	0.27 $\pm$ 0.02
E	0.25	0.23	0.22	0.20	0.20	0.22	0.22	0.20	0.22	0.22 $\pm$ 0.01
F	0.24	0.27	0.29	0.26	0.25	0.23	0.26	0.25	0.27	0.27 $\pm$ 0.02
G	0.23	0.26	0.26	0.25	0.25	0.27	0.25	0.27	0.25	0.26 $\pm$ 0.02
H	0.27	0.29	0.30	0.29	0.30	0.25	0.32	0.29	0.28	0.31 $\pm$ 0.02
I	--	0.29	0.29	0.27	0.27	0.26	0.24	0.26	0.28	0.26 $\pm$ 0.02
J	0.21	0.23	0.24	0.22	0.24	0.25	0.25	0.24	0.23	0.25 $\pm$ 0.02
K	0.28	0.27	0.27	0.26	0.27	0.25	0.28	0.26	0.25	0.28 $\pm$ 0.02
L	0.22	0.26	0.27	0.25	0.26	0.25	0.28	0.25	0.24	0.26 $\pm$ 0.02
M	0.27	0.28	0.27	0.30	0.26	0.31	0.25	0.31	0.28	0.30 $\pm$ 0.02
N	0.25	0.25	0.27	0.25	0.24	0.28	0.23	0.25	0.27	0.23 $\pm$ 0.02
O	--	0.22	0.24	0.20	0.22	0.22	0.24	0.22	0.23	0.21 $\pm$ 0.01
P	--	0.25	0.27	0.27	0.25	0.29	0.28	0.27	0.24	0.28 $\pm$ 0.02

-- Not measured

**2.6** A slight exceedance of Investigation Level was observed in Location J (0.25  $\mu\text{Sv h}^{-1}$  against 0.24  $\mu\text{Sv h}^{-1}$ ).



**Table 2.1(b) Comparison of Ambient  $\gamma$  Dose Rates with Previous Results**

<b>EM&amp;A Report No.</b>	<b>Mean <math>\gamma</math> Dose Rate (<math>\mu\text{Sv h}^{-1}</math>)</b>	<b>SU</b>
1 (Baseline)	0.24	0.026
2	0.26	0.028
3	0.25	0.022
4	0.25	0.029
5	0.26	0.027
6	0.25	0.024
7	0.26	0.022
8	0.25	0.031
9	0.24	0.031
10	0.25	0.029
11 (2007)	0.26	0.025
12 (2008)	0.25	0.031
13 (2009)	0.25	0.028
14 (2010)	0.25	0.027
15 (2011)	0.26	0.026
16 (2012)	0.25	0.030
17 (2013)	0.25	0.023
18 (2014)	0.26	0.028

2.7 The overall mean ambient  $\gamma$  dose-rate for this year is the same as those in previous years.

**Soil**

- 2.8 Soil samples were collected at 3 locations only, 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)**.

**Table 2.2(a) Activity Concentration of Some Major Radionuclides in Soil Samples**

Location	Collection Date	Activity Concentration (Bq kg <sup>-1</sup> )							
		<sup>226</sup> Ra	SD	<sup>228</sup> Th	SD	<sup>40</sup> K	SD	<sup>137</sup> Cs	SD
A	27 Aug 14	55.7	0.5	73.8	0.4	251	3.9	0.45	0.1
B	27 Aug 14	49.5	0.4	67.8	0.4	678	3.9	0.48	0.1
C	27 Aug 14	75.2	0.6	51.5	0.5	715	6.3	0.27	0.1

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

EM&A Report No.	Mean Activity Concentration (Bq kg <sup>-1</sup> )							
	<sup>226</sup> Ra	SU	<sup>228</sup> Th	SU	<sup>40</sup> K	SU	<sup>137</sup> Cs	SU
1 (Baseline)	50.0	13.9	80.2	16.1	606	297	0.25	0.37
2	41.7	17.0	63.7	20.5	387	219	*	*
3	41.8	15.4	75.6	20.1	423	237	*	*
4	45.3	7.1	104.5	11.4	574	319	0.25	0.43
5	57.8	17.7	95.8	4.2	535	294	0.41	0.42
6	59.9	19.0	103.9	14.3	479	277	0.25	0.23
7	60.8	22.4	102.9	16.2	464	258	0.36	0.33
8	51.9	17.6	95.0	14.8	449	263	0.19	0.17
9	52.5	18.6	98.4	16.3	523	307	0.07	0.12
10	50.7	16.1	97.7	9.5	498	282	0.18	0.17
11 (2007)	52.8	15.7	106.8	16.9	483	253	0.27	0.01
12 (2008)	64.3	34.5	99.1	25.3	506	218	0.18	0.04
13 (2009)	59.3	12.0	116.0	12.0	474	199	*	*
14 (2010)	58.7	9.7	105	23.2	626	290	*	*
15 (2011)	48.9	31.5	52.5	27.1	504	249	0.1	0.03
16 (2012)	44.9	33.2	63.6	36.9	460	308	*	*
17 (2013)	52.9	5.2	67.9	8.8	671	52.6	0.07	0.13
18 (2014)	60.1	13.4	64.4	11.5	548	258	0.4	0.1

\* Not detected

- 2.9 No exceedance of Investigation Level is observed.

**Sand**

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

**Table 2.3(a) Activity Concentration of Some Major Radionuclides in Sand Samples**

Location	Collection Date	Activity Concentration (Bq kg <sup>-1</sup> )					
		<sup>226</sup> Ra	SD	<sup>228</sup> Th	SD	<sup>40</sup> K	SD
A	27 Aug 14	15.9	0.3	9.0	0.3	373	4.5
B	27 Aug 14	13.4	0.3	8.2	0.2	326	4.2
C	27 Aug 14	15.3	0.3	8.7	0.2	249	3.5

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

EM&A Report No.	Mean Activity Concentration (Bq kg <sup>-1</sup> )					
	<sup>226</sup> Ra	SU	<sup>228</sup> Th	SU	<sup>40</sup> K	SU
1 (Baseline)	18.8	4.4	21.6	5.5	576	106
2	11.1	3.8	12.8	5.0	357	100
3	11.4	3.2	13.2	4.4	382	141
4	28.3	22.8	24.5	17.4	360	165
5	23.3	12.7	25.6	17.9	323	117
6	20.8	8.0	25.8	18.0	329	95.7
7	30.2	24.8	24.3	17.0	320	173
8	15.4	4.6	15.4	4.1	246	30.5
9	14.5	1.2	17.3	5.8	380	99.1
10	18.4	1.7	18.5	2.4	377	124
11 (2007)	17.0	2.4	18.6	4.4	397	71.3
12 (2008)	18.0	4.7	16.5	1.7	382	20.6
13 (2009)	19.1	2.2	17.3	3.4	313	115
14 (2010)	14.3	2.2	12.5	0.3	301	71.5
15 (2011)	16.9	1.8	10.9	1.4	331	80
16 (2012)	19.2	2.5	13.9	3.0	273	49
17 (2013)	20.9	1.1	14.0	0.5	295	51.2
18 (2014)	14.9	1.3	8.6	0.4	316	62.6

2.11 No exceedance of Investigation Level is observed.

**Grass**

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

**Table 2.4(a) Activity Concentration of Gross  $\alpha$  and  $\beta$  Emitters in Grass Samples**

Location	Collection Date	$\alpha$ Activity* (Bq g <sup>-1</sup> )	SD (Bq g <sup>-1</sup> )	$\beta$ Activity* (Bq g <sup>-1</sup> )	SD (Bq g <sup>-1</sup> )
A	27 Aug 14	0.019	0.003	0.174	0.006
B	27 Aug 14	0.052	0.004	0.256	0.006
C	27 Aug 14	0.036	0.004	0.256	0.006

\* Bq g<sup>-1</sup> refers to dry mass of grass

**Table 2.4(b) Comparison of  $\alpha/\beta$  Activities in Grass with Previous Results**

EM&A Report No.	Mean $\alpha$ Activity (Bq g <sup>-1</sup> )	SU (Bq g <sup>-1</sup> )	Mean $\beta$ Activity (Bq g <sup>-1</sup> )	SU (Bq g <sup>-1</sup> )
1 (Baseline)	0.083	0.044	0.33	0.03
2	0.037	0.012	0.25	0.01
3	0.081	0.017	0.30	0.10
4	0.093	0.009	0.26	0.03
5	0.084	0.020	0.23	0.04
6	0.081	0.056	0.22	0.09
7	0.077	0.046	0.25	0.08
8	0.068	0.047	0.28	0.05
9	0.050	0.023	0.29	0.02
10	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

2.13 No exceedance of Investigation Level is observed.

**Sea Water**

- 2.14 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)**.
- 2.15 Similar to grass samples, the  $\gamma$  spectra are not reported. There is no sign of presence of  $\gamma$  emitters.
- 2.16 There is a slight exceedance in Investigation Level for surface water at Location C. But the activity is only just above the minimum detectable activity and is therefore too small to be of concern.

**Table 2-5(a) Activity Concentration of Gross  $\alpha/\beta$  Emitters in Sea Water Samples**

Location	Collection Date	Water Depth (m)	$\alpha$ Activity (Bq L <sup>-1</sup> )	SD (Bq L <sup>-1</sup> )	$\beta$ Activity (Bq L <sup>-1</sup> )	SD (Bq L <sup>-1</sup> )
A	27 Aug 14	1	1.32 <sup>#</sup>	0.35	2.34	0.56
		3.5	0.10 <sup>#</sup>	0.10	5.70	0.54
B	27 Aug 14	1	1.52	0.35	3.90	0.57
		6.5	0.36 <sup>#</sup>	0.32	5.82	0.58
C	27 Aug 14	1	1.72	0.34	3.60	0.53
		7.5	1.16 <sup>#</sup>	0.34	6.30	0.58
D	27 Aug 14	1	0.72 <sup>#</sup>	0.33	5.78	0.54
		5	1.20 <sup>#</sup>	0.34	5.84	0.54

<sup>#</sup> Below minimum detectable activity of 1.5 Bq L<sup>-1</sup> for  $\alpha$  and 1.0 Bq L<sup>-1</sup> for  $\beta$ .

**Table 2.5(b) Comparison of  $\alpha/\beta$  Activities in Sea Water with Previous Results**

EM&A Report No.	Mean $\alpha$ Activity (Bq L <sup>-1</sup> )	SU (Bq L <sup>-1</sup> )	Mean $\beta$ Activity (Bq L <sup>-1</sup> )	SU (Bq L <sup>-1</sup> )
1 (Baseline)	0.77	0.25	7.20	0.70
2	0.49	0.47	6.10	0.46
3	0.57	0.21	7.43	0.80
4	0.71	0.50	7.00	0.81
5	0.92	0.44	6.15	0.64
6	0.63	0.28	6.99	0.37
7	0.25	0.28	6.30	0.45
8	0.19	0.23	5.84	1.34
9	0.32	0.29	5.21	0.38
10	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

**Marine Organisms**

- 2.17 Fishes were caught along the jetty and sea snails were collected randomly along the shores.
- 2.18 The measurement results are given in **Table 2.6(a) & (b)** and **Table 2.7(a) & (b)** for the gross  $\alpha/\beta$  activities in fish and sea snails respectively.

**Table 2.6(a) Activity Concentration of Gross  $\alpha/\beta$  Emitters in Fish Samples**

Sample	Collection Date	$\alpha$ Activity* (Bq g <sup>-1</sup> )	SD (Bq g <sup>-1</sup> )	$\beta$ Activity* (Bq g <sup>-1</sup> )	SD (Bq g <sup>-1</sup> )
1	27 Aug 14	0.004 <sup>#</sup>	0.002	0.07	0.004
2	27 Aug 14	0.004 <sup>#</sup>	0.002	0.07	0.004
3	27 Aug 14	0.017	0.002	0.08	0.004

\* Bq g<sup>-1</sup> refers to wet mass of fish flesh.

<sup>#</sup> Below minimum detectable  $\alpha$  activity of 0.008 Bq g<sup>-1</sup>.

**Table 2.6(b) Comparison of  $\alpha/\beta$  Activities in Fish Samples with Previous Results**

EM&A Report No.	Mean $\alpha$ Activity (Bq g <sup>-1</sup> )	SU (Bq g <sup>-1</sup> )	Mean $\beta$ Activity (Bq g <sup>-1</sup> )	SU (Bq g <sup>-1</sup> )
1 (Baseline)	0.0093	0.004	0.068	0.003
2	0.0068	0.004	0.16	0.15
3	0.0116	0.005	0.026	0.006
4	0.0066	0.004	0.065	0.005
5	0.0040	0.004	0.056	0.010
6	0.0069	0.002	0.063	0.002
7	0.0120	0.021	0.047	0.035
8	0.0037	0.002	0.074	0.006
9	0.0100	0.004	0.062	0.050
10	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

- 2.19 A slight exceedance in Investigation Level is observed in the  $\beta$  activity of Sample 3 but is too small to be of concern.

**Table 2.7(a) Activity Concentration of Gross  $\alpha/\beta$  Emitters in Sea Snail Samples**

Sample	Collection Date	$\alpha$ Activity* (Bq g <sup>-1</sup> )	SD (Bq g <sup>-1</sup> )	$\beta$ Activity* (Bq g <sup>-1</sup> )	SD (Bq g <sup>-1</sup> )
1	27 Aug 14	0.011	0.002	0.041	0.002
2	27 Aug 14	0.013	0.002	0.057	0.004
3	27 Aug 14	0.008	0.002	0.053	0.004

\* Bq g<sup>-1</sup> refers to wet mass of sea snail flesh.

**Table 2.7(b) Comparison of  $\alpha/\beta$  Activities in Sea Snails with Previous Results**

EM&A Report No.	Mean $\alpha$ Activity (Bq g <sup>-1</sup> )	SU (Bq g <sup>-1</sup> )	Mean $\beta$ Activity (Bq g <sup>-1</sup> )	SU (Bq g <sup>-1</sup> )
1 (Baseline)	0.029	0.006	0.064	0.004
2	0.010	0.008	0.034	0.007
3	0.009	0.002	0.032	0.002
4	0.032	0.011	0.050	0.002
5	0.004	0.005	0.045	0.007
6	0.007	0.005	0.042	0.006
7	0.014	0.006	0.063	0.008
8	0.005	0.001	0.040	0.004
9	0.000	0.000	0.023	0.002
10	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

2.20 No exceedance of Investigation Level is observed.

**Airborne Particulates**

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

**Table 2.8(a) Net Gross  $\alpha/\beta$  Counts in Airborne Particulate Samples**

Location	$\alpha$ Count-rate (cpm)	SD	$\beta$ Count-rate (cpm)	SD
Blank	2.91	0.23	5.68	0.31
A1	0.51 <sup>#</sup>	0.29	5.92	0.96
B1	0.86	0.3	4.75	0.97
C1	0.29 <sup>#</sup>	0.28	4.27	0.94

<sup>#</sup> Below minimum detectable limit of 0.66 cpm for  $\alpha$  and 1.6 cpm for  $\beta$

**Table 2.8(b) Comparison of  $\alpha/\beta$  in Airborne Particulate Samples with Previous Results**

EM&A Report No.	A		B		C	
	$\alpha$ (cpm)	$\beta$ (cpm)	$\alpha$ (cpm)	$\beta$ (cpm)	$\alpha$ (cpm)	$\beta$ (cpm)
1 (Baseline)	0.00	0.00	0.00	0.00	0.00	1.17
2	0.09	1.38	0.00	0.39	0.00	0.00
3	0.04	0.45	0.00	1.18	0.13	0.86
4	0.12	1.75	0.65	2.18	0.00	0.28
5	0.35	0.94	0.24	0.66	0.07	0.83
6	0.18	0.33	0.00	0.02	0.00	0.00
7	0.16	0.75	0.16	0.09	0.20	0.00
8	0.84	4.87	0.24	1.64	0.09	1.84
9	0.91	3.03	0.29	1.36	0.09	0.42
10	0.32	1.97	0.11	1.05	0.00	0.03
11 (2007)	0.35	1.00	0.11	0.04	0.02	1.75
12 (2008)	0.26	6.18	0.42	5.51	0.19	2.83
13 (2009)	0.97	3.62	0.25	3.09	0.79	1.78
14 (2010)	0.93	16.3	0.00	6.27	0.00	3.55
15 (2011)	--	--	--	--	--	--
16 (2012)	--	--	--	--	--	--
17 (2013)	0.00	12.0	0.00	9.83	1.93	25.1
18 (2014)	0.51	5.92	0.86	4.75	0.29	4.27

2.22 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).
- 3.2 There is a slight exceedance of Investigation Level in  $\gamma$ -dose-rate at Location J; in  $\alpha$ -activity of a water sample taken in shallow water at Location C and in  $\beta$ -activity of one fish sample. However all the exceedances are very small to be of concern.
- 3.3 All other samples are normal.
- 3.4 Based on the storage record of wastes, there are no wastes that could have caused contamination of the environment under normal storage condition except those radon producing wastes.
- 3.5 Amount of radon released into the atmosphere from such wastes is under continuous monitoring and the monthly release rate is in the order of  $10^8$  Bq per month (please refer to Section 4 of EM&A reports). This amount is significantly lower than the radon naturally emanated from soil, rocks and concrete around the facility.
- 3.6 Given that there was no effluent discharge in the past year and the radon release rate is normal, we can conclude that the slight exceedance levels were not attributable to the operation of the facility but rather due to natural fluctuation.

#### **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) 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  $3.2 \times 10^8$  Bq/month, which is below the A/L Levels.

4.6 The discharged  $\alpha$  and  $\beta$  activities were also below the A/L Levels.

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

**5. RESULT OF ENVIRONMENTAL COMPLIANCE AUDITS**

5.1 No 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**

<b>Environmental Performance Requirements</b>	<b>Limit Levels</b>	<b>Action Levels (3/10<sup>th</sup> of Limit Levels)</b>
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**

<b>Environmental Samples</b>		<b>Investigation Levels</b>	
Ambient $\gamma$ dose rate ( $\mu\text{Sv h}^{-1}$ )	A	0.23	3 × SD of individual baseline dose rate
	B	0.25	
	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	0.30	
	M	0.31	
	N	0.29	
O	0.24		
P	0.29		
Soil ( $\text{Bq kg}^{-1}$ )	<sup>226</sup> Ra	91.7	3 × SU of baseline samples
	<sup>228</sup> Th	128.5	
	<sup>40</sup> K	1497	

	<sup>137</sup> Cs	1.36	
	Other $\gamma$ emitters		Occurrence in any quantities
Sand (Bq kg <sup>-1</sup> )	<sup>226</sup> Ra	32.0	3 × SU of baseline samples
	<sup>228</sup> Th	38.1	
	<sup>40</sup> K	894	
	Other $\gamma$ emitters		Occurrence in any quantities
Grass (Bq g <sup>-1</sup> )	Gross $\alpha$	0.22	3 × SU of baseline samples
	Gross $\beta$	0.43	
	$\gamma$ emitters not found in baseline		Occurrence in any quantities
Sea water (Bq L <sup>-1</sup> )	Gross $\alpha$	1.52	3 × SU of baseline samples
	Gross $\beta$	9.3	
	$\gamma$ emitters not found in baseline		Occurrence in any quantities
Fish (Bq g <sup>-1</sup> )	Gross $\alpha$	0.021	3 × SU of baseline samples
	Gross $\beta$	0.076	
Sea snails (Bq g <sup>-1</sup> )	Gross $\alpha$	0.048	3 × SU of baseline samples
	Gross $\beta$	0.076	
Airborne particulates (cpm)	Gross $\alpha$ Gross $\beta$		Occurrence in any quantities

- SD is the standard deviation of a single sample.

- SU is standard uncertainty of the sample group.