

**ATAL ENGINEERING LIMITED**

**Contract No. EP/SP/75/14**

**Low Level Radioactive Waste Storage Facility  
Follow-On Contract**

**Environmental Monitoring and Audit Report No. 8  
(Operation Phase)**

**Version 1.0**

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Prepared and Submitted By



(Environmental Team Leader  
and 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 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 Environmental Monitoring & Audit (EM&A) Report for the new Low Level Radioactive Waste Storage Facility Follow-On Contract.

One water sample (Location C, surface water), all fish samples and all grass samples were measured to have  $\alpha$  and/or  $\beta$  activity exceeding their respective Investigation Level (IL). Hence those samples were either recollected or re-prepared for measurement again. Results are now all below the ILs. After reviewing the sample preparation process, it was concluded that those original samples might have been contaminated during the preparation.

The  $^{228}\text{Th}$  activity concentration of Soil A sample has exceeded the IL again. Previous investigation has confirmed that the  $^{228}\text{Th}$  content in the surface soil around that area can vary a lot (see Executive Summary of EM&A Report No. 3), hence no further action was taken.

It was noted that the total release of radon for the past 12 months was much larger than previous years. Investigation revealed that the actual flow rate of radon release before June 26, 2023 should be much lower than the quoted value by about 23%, leading to a much higher calculated total amount of release. June 26 was the date when the current new flow rate was introduced in view of the increased radon concentration in the released gas. To conclude, the total release was still below the A/L level.

The Low Level Radioactive Waste Storage Facility (Facility) has been running smoothly in the past 12 months and no contamination due to the operation of the Facility was observed in the surrounding environment.

## 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 of 275 litres net capacity. The building also contains facilities for waste reception and repackaging, 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 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 EM&A Report No. 8 (Operation Phase) for the Follow-On Contract. This report covers the monitoring period from August 19, 2022 to the date of sampling which was August 15, 2023.
- 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 reports on any non-compliance of personnel doses, dose-rates on 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; 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) (Oct 2005) for details.



**Ambient  $\gamma$  Dose Rates**

2.5 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  $\gamma$  dose rates. It is noted that the overall average value has remained similar during the monitoring period.

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

| Location | ILs  | Net $\gamma$ Dose Rate ( $\mu\text{Sv h}^{-1}$ ) |      |      |      |      |      |
|----------|------|--|------|------|------|------|------|
|          |      | Baseline (2005)                                  | 2018 | 2019 | 2020 | 2021 | 2022 |
| A        | 0.17 | 0.14   | 0.13 | 0.15 | 0.16 | 0.13 | 0.14 |
| B        | 0.19 | 0.15   | 0.18 | 0.13 | 0.16 | 0.17 | 0.16 |
| D        | 0.21 | 0.16   | 0.19 | 0.17 | 0.20 | 0.20 | 0.16 |
| E        | 0.23 | 0.18   | 0.14 | 0.23 | 0.12 | 0.17 | 0.14 |
| F        | 0.22 | 0.17   | 0.14 | 0.18 | 0.19 | 0.18 | 0.16 |
| G        | 0.21 | 0.16   | 0.19 | 0.16 | 0.16 | 0.18 | 0.17 |
| H        | 0.25 | 0.20   | 0.19 | 0.15 | 0.14 | 0.11 | 0.19 |
| I        | 0.26 | --   | 0.18 | 0.18 | 0.17 | 0.21 | 0.20 |
| J        | 0.18 | 0.14   | 0.14 | 0.12 | 0.19 | 0.13 | 0.17 |
| K        | 0.26 | 0.21   | 0.22 | 0.13 | 0.18 | 0.14 | 0.20 |
| L        | 0.24 | 0.19   | 0.18 | 0.22 | 0.19 | 0.13 | 0.23 |
| M        | 0.25 | 0.20   | 0.20 | 0.17 | 0.19 | 0.16 | 0.22 |
| N        | 0.23 | 0.18   | 0.16 | 0.17 | 0.17 | 0.14 | 0.19 |
| O        | 0.18 | --   | 0.13 | 0.18 | 0.21 | 0.19 | 0.14 |
| P        | 0.23 | --   | 0.20 | 0.18 | 0.21 | 0.21 | 0.21 |

-- Not measured

| Location | ILs  | Net $\gamma$ Dose Rate $\pm 1$ SD ( $\mu\text{Sv h}^{-1}$ ) |
|----------|------|---|
|          |      | 2023  |
| A        | 0.17 | 0.15 $\pm$ 0.02   |
| B        | 0.19 | 0.18 $\pm$ 0.03   |
| D        | 0.21 | 0.13 $\pm$ 0.03   |
| E        | 0.23 | 0.13 $\pm$ 0.03   |
| F        | 0.22 | 0.15 $\pm$ 0.03   |
| G        | 0.21 | 0.20 $\pm$ 0.03   |
| H        | 0.20 | 0.20 $\pm$ 0.03   |
| I        | 0.34 | 0.19 $\pm$ 0.03   |
| J        | 0.20 | 0.18 $\pm$ 0.03   |
| K        | 0.26 | 0.18 $\pm$ 0.03   |
| L        | 0.24 | 0.20 $\pm$ 0.03   |
| M        | 0.25 | 0.16 $\pm$ 0.03   |
| N        | 0.23 | 0.18 $\pm$ 0.03   |
| O        | 0.21 | 0.14 $\pm$ 0.02   |
| P        | 0.23 | 0.14 $\pm$ 0.02   |



**Table 2.1(b) Comparison of Ambient  $\gamma$  Dose Rates for the past years**

| <b>EM&amp;A Report No.</b> | <b>Mean Net <math>\gamma</math> Dose Rate<br/>(<math>\mu\text{Sv h}^{-1}</math>)</b> | <b>SU</b> |
|----------------------------|--|-----------|
| Baseline (2005)            | 0.18   | 0.026     |
| 1 (2016)                   | 0.18   | 0.022     |
| 2 (2017)                   | 0.16   | 0.021     |
| 3 (2018)                   | 0.17   | 0.028     |
| 4 (2019)                   | 0.17   | 0.031     |
| 5 (2020)                   | 0.18   | 0.025     |
| 6 (2021)                   | 0.16   | 0.032     |
| 7 (2022)                   | 0.18   | 0.032     |
| 8 (2023)                   | 0.17   | 0.026     |

2.6 No exceedance of IL was observed.

**Soil**

2.7 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)**.

**Table 2.2(a) Activity Concentration of Some Major Radionuclides in Soil Samples (ILs for <sup>226</sup>Ra, <sup>228</sup>Th, <sup>40</sup>K and <sup>137</sup>Cs are respectively 155, 218, 2544 & 2.31 Bq kg<sup>-1</sup>)**

| 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        | 15/8/2023       | 82.1  | 1.3 | 250               | 1.7 | 1009            | 6.1 | 0.0*              | 0.3 |
| B        | 15/8/2023       | 114   | 1.4 | 166               | 1.6 | 1052            | 6.4 | 0.0*              | 0.3 |
| C        | 15/8/2023       | 56.4  | 1.2 | 167               | 1.5 | 385             | 4.2 | 0.0*              | 0.2 |

\* Below minimum detectable activity of 1.86 Bq kg<sup>-1</sup>

**Table 2.2(b) Comparison of Activities in Soil Samples for past years**

| EM&A Report No. | Mean Activity Concentration (Bq kg <sup>-1</sup> ) |                   |                 |
|-----------------|--|-------------------|-----------------|
|                 | <sup>226</sup> Ra                                  | <sup>228</sup> Th | <sup>40</sup> K |
| Baseline (2005) | 85   | 136               | 1030            |
| 1 (2016)        | 101  | 213               | 704             |
| 2 (2017)        | 91.8   | 165               | 878             |
| 3 (2018)        | 82.8   | 179               | 774             |
| 4 (2019)        | 92.2   | 184               | 825             |
| 5 (2020)        | 81.8   | 170               | 795             |
| 6 (2021)        | 74.9   | 169               | 801             |
| 7 (2022)        | 80.3   | 189               | 776             |
| 8 (2023)        | 84.1   | 194               | 816             |

2.8 The <sup>228</sup>Th activity concentration in Soil A has exceeded the IL.

**Sand**

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

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

| 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        | 15/8/2023       | 29.4  | 0.8 | 32.0              | 0.9 | 444             | 3.9 |
| B        | 15/8/2023       | 32.0  | 0.7 | 34.9              | 0.8 | 416             | 3.6 |
| C        | 15/8/2023       | 16.8  | 0.7 | 20.8              | 0.8 | 478             | 3.9 |

**Table 2.3(b) Comparison of Activities in Sand Samples for past years**

| EM&A Report No. | Mean Activity Concentration (Bq kg <sup>-1</sup> ) |                   |                 |
|-----------------|--|-------------------|-----------------|
|                 | <sup>226</sup> Ra                                  | <sup>228</sup> Th | <sup>40</sup> K |
| Baseline (2005) | 31.9   | 36.7              | 979             |
| 1 (2016)        | 26.5   | 25.3              | 433             |
| 2 (2017)        | 27.9   | 29.5              | 473             |
| 3 (2018)        | 30.9   | 32.6              | 526             |
| 4 (2019)        | 28.6   | 28.3              | 518             |
| 5 (2020)        | 37.9   | 32.9              | 422             |
| 6 (2021)        | 25.2   | 26.6              | 365             |
| 7 (2022)        | 26.4   | 25.2              | 350             |
| 8 (2023)        | 26.1   | 29.3              | 446             |

2.10 No exceedance of IL was observed.

**Grass**

2.11 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 (ILs for  $\alpha$  and  $\beta$  activities are respectively 0.22 & 0.43 Bq g<sup>-1</sup>)**

| 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        | 15/8/2023       | 0.012                                    | 0.007                    | 0.247                                   | 0.027                    |
| B        | 15/8/2023       | 0.013                                    | 0.007                    | 0.284                                   | 0.027                    |
| C        | 15/8/2023       | 0.015                                    | 0.008                    | 0.402                                   | 0.028                    |

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

**Table 2.4(b) Comparison of  $\alpha/\beta$  Activities in Grass for past years**

| 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> ) |
|-----------------|--|--------------------------|---|--------------------------|
| Baseline (2005) | 0.083  | 0.044                    | 0.33  | 0.03                     |
| 1 (2016)        | 0.008  | 0.006                    | 0.24  | 0.03                     |
| 2 (2017)        | 0.006  | 0.004                    | 0.16  | 0.04                     |
| 3 (2018)        | 0.013  | 0.003                    | 0.21  | 0.06                     |
| 4 (2019)        | 0.014  | 0.013                    | 0.17  | 0.09                     |
| 5 (2020)        | 0.027  | 0.012                    | 0.34  | 0.09                     |
| 6 (2021)        | 0.025  | 0.006                    | 0.10  | 0.02                     |
| 7 (2022)        | 0.017  | 0.013                    | 0.32  | 0.09                     |
| 8 (2023)        | 0.013  | 0.002                    | 0.31  | 0.08                     |

2.12 No exceedance of Investigation Level was observed.

**Sea Water**

- 2.13 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)**.
- 2.14 Similar to grass samples, the  $\gamma$  spectra are not reported. There is no sign of presence of  $\gamma$  emitters.
- 2.15 No exceedance of Investigation Level is observed.

**Table 2-5(a) Activity Concentration of Gross  $\alpha/\beta$  Emitters in Sea Water Samples (ILs for  $\alpha$  and  $\beta$  activities are respectively 1.52 & 9.3 Bq L<sup>-1</sup>)**

| 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        | 15/8/2023       | 1               | 1.22 <sup>#</sup>                       | 1.3                      | 4.1 <sup>#</sup>                       | 3.1                      |
|          |                 | 3.5             | 0 <sup>#</sup>                          | 1.2                      | 2.8 <sup>#</sup>                       | 3.1                      |
| B        | 15/8/2023       | 1               | 0.7 <sup>#</sup>                        | 1.3                      | 2.7 <sup>#</sup>                       | 3.1                      |
|          |                 | 6.5             | 0 <sup>#</sup>                          | 1.2                      | 3.1 <sup>#</sup>                       | 3.1                      |
| C        | 15/8/2023       | 1*              | 0 <sup>#</sup>                          | 1.3                      | 4.2 <sup>#</sup>                       | 3.1                      |
|          |                 | 7.5             | 0.18 <sup>#</sup>                       | 1.2                      | 4.1 <sup>#</sup>                       | 3.1                      |
| D        | 15/8/2023       | 1               | 0 <sup>#</sup>                          | 1.2                      | 2.8 <sup>#</sup>                       | 3.1                      |
|          |                 | 5               | 0.7 <sup>#</sup>                        | 1.3                      | 3.8 <sup>#</sup>                       | 3.1                      |

<sup>#</sup> Below minimum detectable activity of 2.59 Bq L<sup>-1</sup> for  $\alpha$  and 4.54 Bq L<sup>-1</sup> for  $\beta$

\*Surface water at Location C was re-collected for measurement on 4/9/2023

**Table 2.5(b) Comparison of  $\alpha/\beta$  Activities in Sea Water for past years**

| 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> ) |
|-----------------|--|--------------------------|---|--------------------------|
| Baseline (2005) | 0.77   | 0.25                     | 7.20  | 0.70                     |
| 1 (2016)        | 0.00   | 0.00                     | 2.66  | 2.63                     |
| 2 (2017)        | 0.00   | 0.00                     | 1.97  | 2.32                     |
| 3 (2018)        | 0.00   | 0.00                     | 1.01  | 0.98                     |
| 4 (2019)        | 0.00   | 0.01                     | 2.47  | 1.65                     |
| 5 (2020)        | 0.06   | 0.09                     | 5.29  | 0.61                     |
| 6 (2021)        | 0.20   | 0.26                     | 6.56  | 1.50                     |
| 7 (2022)        | 0.42   | 0.44                     | 6.14  | 1.46                     |
| 8 (2023)        | 0.35   | 0.47                     | 3.44  | 0.67                     |

**Marine Organisms**

- 2.16 Fishes were caught along the jetty and sea snails were collected randomly along the shores.
- 2.17 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**  
(ILs for  $\alpha$  and  $\beta$  activities are respectively 0.021 & 0.076 Bq g<sup>-1</sup>)

| 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      | 4/9/2023        | 0.002 <sup>#</sup>                       | 0.004                    | 0.047                                   | 0.019                    |
| 2      | 4/9/2023        | 0.000 <sup>#</sup>                       | 0.004                    | 0.059                                   | 0.019                    |
| 3      | 4/9/2023        | 0.000 <sup>#</sup>                       | 0.005                    | 0.076                                   | 0.020                    |

\* 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 for past years**

| 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> ) |
|-----------------|--|--------------------------|---|--------------------------|
| Baseline (2005) | 0.0093                                       | 0.004                    | 0.068                                       | 0.003                    |
| 1 (2016)        | 0.0077                                       | 0.008                    | 0.014                                       | 0.005                    |
| 2 (2017)        | 0.0000                                       | 0.000                    | 0.055                                       | 0.012                    |
| 3 (2018)        | 0.0000                                       | 0.000                    | 0.032                                       | 0.032                    |
| 4 (2019)        | 0.0000                                       | 0.000                    | 0.029                                       | 0.010                    |
| 5 (2020)        | 0.0020                                       | 0.000                    | 0.046                                       | 0.010                    |
| 6 (2021)        | 0.0034                                       | 0.003                    | 0.049                                       | 0.007                    |
| 7 (2022)        | 0.0000                                       | 0.000                    | 0.062                                       | 0.010                    |
| 8 (2023)        | 0.0007                                       | 0.001                    | 0.061                                       | 0.015                    |

- 2.18 There is no exceedance of IL.

**Table 2.7(a) Activity Concentration of Gross  $\alpha/\beta$  Emitters in Sea Snail Samples**  
 (ILs for  $\alpha$  and  $\beta$  activities are respectively 0.048 & 0.076 Bq g<sup>-1</sup>)

| 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      | 15/8/2023       | 0.001 <sup>#</sup>                       | 0.005                    | 0.070                                   | 0.019                    |
| 2      | 15/8/2023       | 0.001 <sup>#</sup>                       | 0.005                    | 0.070                                   | 0.019                    |
| 3      | 15/8/2023       | 0.000 <sup>#</sup>                       | 0.004                    | 0.049                                   | 0.019                    |

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

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

**Table 2.7(b) Comparison of  $\alpha/\beta$  Activities in Sea Snails for past years**

| 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> ) |
|-----------------|--|--------------------------|---|--------------------------|
| Baseline (2005) | 0.029  | 0.006                    | 0.064                                       | 0.004                    |
| 1 (2016)        | 0.001  | 0.001                    | 0.025                                       | 0.016                    |
| 2 (2017)        | 0.003  | 0.001                    | 0.017                                       | 0.002                    |
| 3 (2018)        | 0.002  | 0.002                    | 0.048                                       | 0.012                    |
| 4 (2019)        | 0.005  | 0.005                    | 0.041                                       | 0.002                    |
| 5 (2020)        | 0.004  | 0.002                    | 0.040                                       | 0.009                    |
| 6 (2021)        | 0.005  | 0.002                    | 0.039                                       | 0.016                    |
| 7 (2022)        | 0.000  | 0.000                    | 0.052                                       | 0.012                    |
| 8 (2023)        | 0.007  | 0.001                    | 0.063                                       | 0.012                    |

2.19 No exceedance in Investigation Level is observed.

**Airborne Particulates**

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

**Table 2.8(a) Net Gross  $\alpha/\beta$  Activities in Airborne Particulate Samples (ILs are not defined)**

| Location | Collection Date | $\alpha$ Activity (Bq per 1000 cm <sup>2</sup> ) | SD   | $\beta$ Activity (Bq per 1000 cm <sup>2</sup> ) | SD   |
|----------|-----------------|--|------|---|------|
| Blank    |                 | 0.09   | 0.02 | 9.33  | 0.01 |
| A1       | 15/8/2023       | 0.82   | 0.20 | 3.37  | 0.56 |
| A2       | 15/8/2023       | 0.30   | 0.17 | 2.97  | 0.56 |
| B1       | 15/8/2023       | 0.18 <sup>#</sup>                                | 0.16 | 1.19  | 0.55 |
| B2       | 15/8/2023       | 0.72   | 0.20 | 1.83  | 0.56 |
| C1       | 15/8/2023       | 0.66   | 0.19 | 1.59  | 0.55 |
| C2       | 15/8/2023       | 0.16 <sup>#</sup>                                | 0.15 | 2.30  | 0.55 |

<sup>#</sup> Below minimum detectable  $\alpha$ -activity of 0.30 Bq per 1000 cm<sup>2</sup>

**Table 2.8(b) Comparison of  $\alpha/\beta$  in Airborne Particulate Samples for past years (Units in Bq per 1000 cm<sup>2</sup>)**

| EM&A Report No. | A        |         | B        |         | C        |         |
|-----------------|----------|---------|----------|---------|----------|---------|
|                 | $\alpha$ | $\beta$ | $\alpha$ | $\beta$ | $\alpha$ | $\beta$ |
| Baseline (2005) | 0.00     | 0.00    | 0.00     | 0.00    | 0.00     | 0.13    |
| 1 (2016)        | 0.00     | 0.46    | 0.00     | 0.34    | 0.00     | 0.17    |
| 2 (2017)        | 0.03     | 0.37    | 0.01     | 0.26    | 0.04     | 0.27    |
| 3 (2018)        | 0.11     | 1.33    | 0.13     | 0.59    | 0.13     | 1.25    |
| 4 (2019)        | 0.04     | 0.36    | 0.05     | 0.57    | 0.04     | 0.18    |
| 5 (2020)        | 0.07     | 0.79    | 0.15     | 0.56    | 0.01     | 0.09    |
| 6 (2021)        | 0.07     | 1.03    | 0.05     | 0.52    | 0.10     | 0.64    |
| 7 (2022)        | 0.63     | 1.76    | 0.14     | 0.42    | 0.14     | 0.18    |
| 8 (2023)        | 0.56     | 3.17    | 0.45     | 1.51    | 0.41     | 1.95    |

2.21 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 There is no evidence that the environmental radiation background has been elevated.

**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  $8.6 \times 10^8$  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. RECORD OF ENVIRONMENTAL COMPLAINTS**

5.1 No environmental complaint 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 (3/10 <sup>th</sup> of Limit Levels) |
|--|---------------------|--|
| Dose for radiation workers             | 1.67 mSv per month  | 0.5 mSv per month                                  |
| Dose rate at un-controlled areas       | 1 $\mu$ Sv per hour | 0.3 $\mu$ Sv 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 $\gamma$ dose rate ( $\mu$ Sv h <sup>-1</sup> ) | A                 | 0.17                 | 3 $\times$ SD of individual baseline dose rate |
|   | B                 | 0.19                 |  |
|   | D                 | 0.21                 |  |
|   | E                 | 0.23                 |  |
|   | F                 | 0.22                 |  |
|   | G                 | 0.21                 |  |
|   | H                 | 0.21                 |  |
|   | I                 | 0.34                 |  |
|   | J                 | 0.20                 |  |
|   | K                 | 0.26                 |  |
|   | L                 | 0.24                 |  |
|   | M                 | 0.25                 |  |
|   | N                 | 0.23                 |  |
| O   | 0.21              |                      |  |
| P   | 0.23              |                      |  |
| Soil (Bq kg <sup>-1</sup> )                                 | <sup>226</sup> Ra | 155                  | 3 $\times$ SU of baseline samples              |
|   | <sup>228</sup> Th | 218                  |  |
|   | <sup>40</sup> K   | 2544                 |  |
|   | <sup>137</sup> Cs | 2.31                 |  |

|   |   |                      |                              |
|---|---|----------------------|------------------------------|
|   | Other $\gamma$ emitters                                   |                      | Occurrence in any quantities |
| Sand<br>(Bq kg <sup>-1</sup> )                          | <sup>226</sup> Ra<br><sup>228</sup> Th<br><sup>40</sup> K | 54.4<br>64.8<br>1520 | 3 × SU of baseline samples   |
|   | Other $\gamma$ emitters                                   |                      | Occurrence in any quantities |
| Grass<br>(Bq g <sup>-1</sup> )                          | Gross $\alpha$<br>Gross $\beta$                           | 0.22<br>0.43         | 3 × SU of baseline samples   |
|   | $\gamma$ emitters not found in baseline                   |                      | Occurrence in any quantities |
| Sea water<br>(Bq L <sup>-1</sup> )                      | Gross $\alpha$<br>Gross $\beta$                           | 1.52<br>9.3          | 3 × SU of baseline samples   |
|   | $\gamma$ emitters not found in baseline                   |                      | Occurrence in any quantities |
| Fish<br>(Bq g <sup>-1</sup> )                           | Gross $\alpha$<br>Gross $\beta$                           | 0.021<br>0.076       | 3 × SU of baseline samples   |
| Sea snails<br>(Bq g <sup>-1</sup> )                     | Gross $\alpha$<br>Gross $\beta$                           | 0.048<br>0.076       | 3 × SU of baseline samples   |
| Airborne particulates<br>(Bq per 1000 cm <sup>2</sup> ) | Gross $\alpha$<br>Gross $\beta$                           |                      | Occurrence in any quantities |

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