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**Marshall Islands Program  
Quality Assurance Report**

**Performance Evaluation of Whole  
Body Counting Facilities in the  
Marshall Islands (2002-2005)**

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**February 2007**

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# **Performance Evaluation of Whole Body Count Measurements Performed by Participants under the Marshall Islands Radiological Surveillance Program (2002-2005)**

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## **Introduction**

The United States Department of Energy (U.S. DOE) has recently implemented a series of strategic initiatives to address long-term radiological surveillance needs at former U.S. nuclear test sites in the Marshall Islands (<https://eed.llnl.gov/mi/>). Local atoll governments have been actively engaged in developing shared responsibilities for protecting the health and safety of resettled and resettling population at risk from exposure to elevated levels of residual fallout contamination in the environment. Under the program, whole body counting facilities have been established at three locations in the Marshall Islands. These facilities are operated and maintained by Marshallese technicians with scientists from the Lawrence Livermore National Laboratory (LLNL) providing technical support services including data quality assurance and performance testing. We have also established a *mirror* whole body counting facility at the Lawrence Livermore National Laboratory as a technician training center. The LLNL facility also allows program managers to develop quality assurance and operational procedures, and test equipment and corrective actions prior to deployment at remote stations in the Marshall Islands.

This document summarizes the results of external performance evaluation exercises conducted at each of the facilities (2002-2005) under the umbrella of the Oak Ridge National Laboratory Intercomparison Studies Program (ISP). The ISP was specifically designed to meet intercomparison requirements of the United States (U.S.) Department of Energy Laboratory Accreditation Program (DOELAP). In this way, the Marshall Islands Radiological Surveillance Program has attempted to establish quality assurance measures in whole body counting that are consistent with standard requirements used to monitor DOE workers in the United States. Based on ANSI N13.30, the acceptable performance criteria for relative measurement bias and

precision for radiobioassay service laboratory quality control, performance evaluation, and accreditation is -25% to +50% and less than or equal to 40%, respectively.

## Results and Discussion

LLNL receives performance evaluation samples from the Oak Ridge National Laboratory on a bi-annual basis. The performance evaluation samples are prepared in a mock-up geometry (i.e., a 5-bottle phantom) that simulates the upper and lower torso of the human body. The samples usually contain a mix of barium-133 ( $^{133}\text{Ba}$ ), cobalt-60 ( $^{60}\text{Co}$ ), cesium-137 ( $^{137}\text{Cs}$ ) and yttrium-88 ( $^{88}\text{Y}$ ) isotopes at nominal concentrations of  $\leq 500$  nCi (18.5 kBq) per sample. The ISP at Oak Ridge use stock isotope solutions indirectly traceable to the National Institute of Standards and Technology (NIST). Details concerning the NIST stock solutions and ISP spikes used in the preparation of the 5-bottle whole body count performance evaluation samples can be found elsewhere (ISP Report, 2005 and related publications). The primary pathway for exposure to residual fallout contamination in the Marshall Islands is ingestion, especially in relation to the uptake of  $^{137}\text{Cs}$  and, to a lesser extent, strontium-90 ( $^{90}\text{Sr}$ ) from consumption of locally grown food crop products such as coconuts. Consequently, we have limited the focus of our performance evaluation exercises under the Marshall Islands Program to whole body count measurements of  $^{137}\text{Cs}$ .

The individual results of performance evaluation exercises conducted between 2002 and 2005 (N=7) are shown in the charts presented in Appendix 1 and summarized in Table 1a-d. The relative performance of whole body counting facilities has also been represented graphically in a Multivar quality control chart (Figure 1).

For testing purposes, the relative bias (% ,  $B_{ri}$ ) for the  $i^{\text{th}}$  measurement conducted in a facility shows how close the measured activity ( $A_i$ ) is to the actual spike value ( $A_{ai}$ ), and is defined as;

$$B_{ri} = \frac{(A_i - A_{ai})}{A_{ai}} \times 100$$

The relative bias (% ,  $B_r$ ) for any whole body count facility is calculated as the average of the individual relative biases  $B_{ri}$ , and is defined as;

$$B_r = \sum_{i=1}^n \frac{B_{ri}}{N}$$

where N is the number of test measurements performed within each facility. The acceptance criteria for the relative measurement bias statistic based on the ANSI 13.30 standard for radiobioassay service laboratory quality control, performance testing, and accreditation is -25% to +50%.

All whole body counting facilities operating under the Marshall Islands Radiological Surveillance Program passed the bias performance test criteria for all exercises conducted during this performance evaluation period (Table 1a-d). The mean relative bias statistic for the LLNL, Rongelap, Enewetak and Utrök (Majuro) facilities over performance evaluation period was 25%, 15.4%, 19.6% and -5.4%, respectively.

The relative precision (% ,  $S_B$ ) of the measurements performed across each whole body count facility is the relative dispersion of the values of  $B_{ri}$  from their mean  $B_r$ , and is defined as;

$$S_B = \sqrt{\frac{\sum_{i=1}^N (B_{ri} - B_r)^2}{(N - 1)}}$$

The acceptance criteria for the relative measurement precision statistic ( $S_B$ ) based on the ANSI 13.30 standard for radiobioassay service laboratory quality control, performance testing, and accreditation is less than or equal to 40%.

All whole body counting facilities operating under the Marshall Islands Radiological Surveillance Program passed the relative precision performance test criteria for all exercises conducted during this performance evaluation period (Table 1a-d). The mean relative precision statistic for the LLNL, Rongelap, Enewetak and Utrök (Majuro) facilities over this performance evaluation period was 8.9%, 1.6%, 9.5% and 16.7%, respectively.

The combined relative bias and relative precision statistic for all measurements was 12.6% and 20.5%, respectively.

## **Summary**

During this performance evaluation period (2002-2005), the Marshall Islands whole body counting program passed all applicable ANSI N13.30 performance criteria for relative measurement bias and precision for measurements of  $^{137}\text{Cs}$  in performance evaluations samples prepared and distributed by the Oak Ridge National Laboratory.

## **References**

ISP (2005), Annual Performance Evaluation 2005 Whole Body Count, Intercomparison Studies Program (ISP), Oak Ridge National Laboratory, Oak Ridge, Tennessee.

HPS N13.30-1996 (1996), Performance Criteria for Radioassay, Health Physics Society, McLean, VA, 112 pp.

DOELAP (1995), Department of Energy Laboratory Accreditation Program for Personnel Dosimetry Systems, DOE-STD-1095-95, U.S. Department of Energy, Washington, D.C.

## **Acknowledgments**

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**Table 1a.** Performance evaluation summary statistics for whole body count measurements of  $^{137}\text{Cs}$  performed at the LLNL facility (2002–2005).

| Facility/Date  | Reference Value, nCi ( $\pm 1\sigma$ ) | Reported Value, nCi ( $\pm 1\sigma$ ) | Measurement Bias (%) | ANSI N13.30 Performance Evaluation Criteria (Pass or Fail) |
|--|--|---------------------------------------|----------------------|--|
| <b><u>LLNL</u></b>   |  |                                       |                      |  |
| 4th Quarter 2002   | 291 $\pm$ 8                            | 396 $\pm$ 25                          | 36.2%                | Pass   |
| 2nd Quarter 2003   | 123 $\pm$ 3                            | 158 $\pm$ 12                          | 28.2%                | Pass   |
| 4th Quarter 2003   | 332 $\pm$ 9                            | 440 $\pm$ 27                          | 32.6%                | Pass   |
| 2nd Quarter 2004   | 401 $\pm$ 3                            | 517 $\pm$ 24                          | 29.0%                | Pass   |
| 4th Quarter 2004   | 253 $\pm$ 7                            | 325 $\pm$ 15                          | 28.5%                | Pass   |
| 1st Quarter 2005   | 250 $\pm$ 7                            | 300 $\pm$ 58                          | 20.6%                | Pass   |
| 4th Quarter 2005   | 75 $\pm$ 2                             | 83 $\pm$ 5                            | 11.0%                | Pass   |
| <b>Mean Measurement Bias Statistic (all values) =</b>      |  |                                       | <b>25.0%</b>         | <b>Pass</b>  |
| <b>Mean Measurement Precision Statistic (all values) =</b> |  |                                       | <b>8.9%</b>          | <b>Pass</b>  |

**Table 1b.** Performance evaluation summary statistics for whole body count measurements of <sup>137</sup>Cs performed at the Enewetak facility (2002–2005).

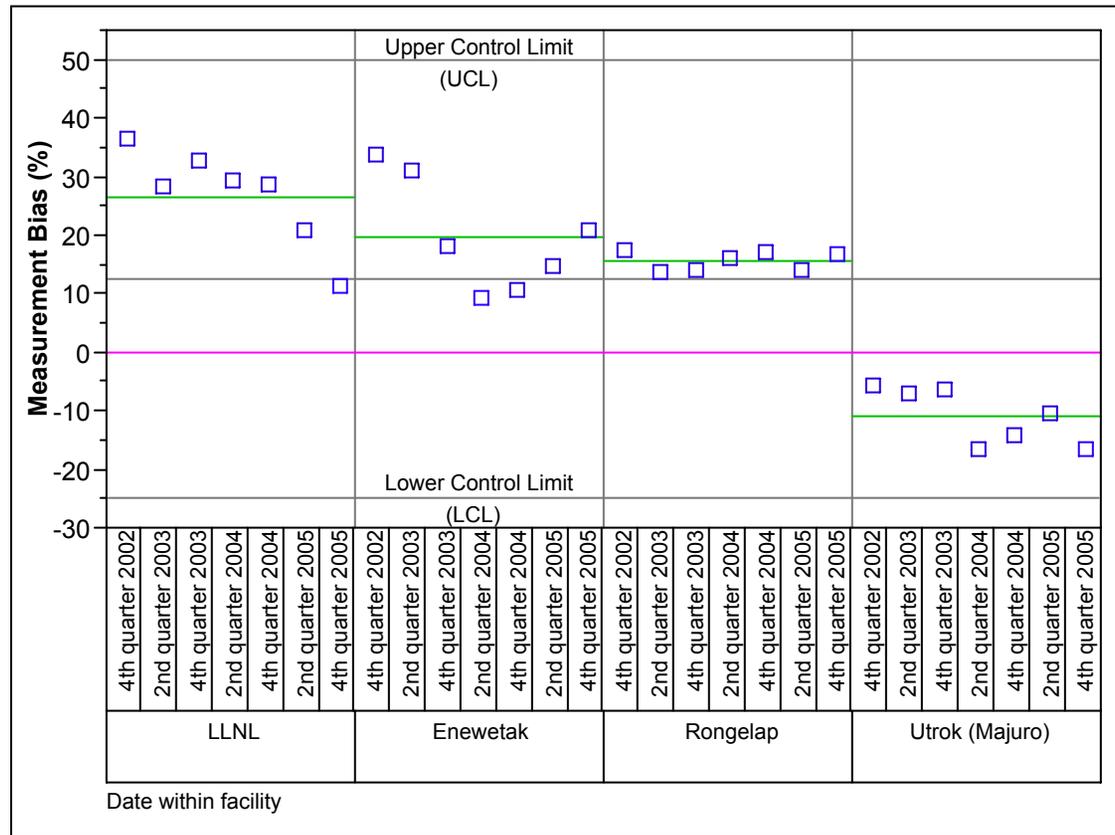
| Facility/Date  | Reference Value, nCi ( $\pm 1\sigma$ ) | Reported Value, nCi ( $\pm 1\sigma$ ) | Measurement Bias (%) | ANSI N13.30 Performance Evaluation Criteria (Pass or Fail) |
|--|--|---------------------------------------|----------------------|--|
| <b><u>Enewetak</u></b>                                     |  |                                       |                      |  |
| 4th Quarter 2002   | 291 $\pm$ 8                            | 389 $\pm$ 11                          | 33.6%                | Pass   |
| 2nd Quarter 2003   | 123 $\pm$ 3                            | 161 $\pm$ 5                           | 31.0%                | Pass   |
| 4th Quarter 2003   | 332 $\pm$ 9                            | 391 $\pm$ 11                          | 17.9%                | Pass   |
| 2nd Quarter 2004   | 401 $\pm$ 3                            | 438 $\pm$ 12                          | 9.2%                 | Pass   |
| 4th Quarter 2004   | 253 $\pm$ 7                            | 280 $\pm$ 8                           | 10.6%                | Pass   |
| 1st Quarter 2005   | 250 $\pm$ 7                            | 286 $\pm$ 9                           | 14.5%                | Pass   |
| 4th Quarter 2005   | 75 $\pm$ 2                             | 90 $\pm$ 4                            | 20.7%                | Pass   |
| <b>Mean Measurement Bias Statistic (all values) =</b>      |  |                                       | <b>19.0%</b>         | <b>Pass</b>  |
| <b>Mean Measurement Precision Statistic (all values) =</b> |  |                                       | <b>9.5%</b>          | <b>Pass</b>  |

**Table 1c.** Performance evaluation summary statistics for whole body count measurements of <sup>137</sup>Cs performed at the Rongelap facility (2002–2005).

| Facility/Date  | Reference Value, nCi ( $\pm 1\sigma$ ) | Reported Value, nCi ( $\pm 1\sigma$ ) | Measurement Bias (%) | ANSI N13.30 Performance Evaluation Criteria (Pass or Fail) |
|--|--|---------------------------------------|----------------------|--|
| <b><u>LLNL</u></b>   |  |                                       |                      |  |
| 4th Quarter 2002   | 291 $\pm$ 8                            | 396 $\pm$ 25                          | 36.2%                | <b>Pass</b>  |
| 2nd Quarter 2003   | 123 $\pm$ 3                            | 158 $\pm$ 12                          | 28.2%                | <b>Pass</b>  |
| 4th Quarter 2003   | 332 $\pm$ 9                            | 440 $\pm$ 27                          | 32.6%                | <b>Pass</b>  |
| 2nd Quarter 2004   | 401 $\pm$ 3                            | 517 $\pm$ 24                          | 29.0%                | <b>Pass</b>  |
| 4th Quarter 2004   | 253 $\pm$ 7                            | 325 $\pm$ 15                          | 28.5%                | <b>Pass</b>  |
| 1st Quarter 2005   | 250 $\pm$ 7                            | 300 $\pm$ 58                          | 20.6%                | <b>Pass</b>  |
| 4th Quarter 2005   | 75 $\pm$ 2                             | 83 $\pm$ 5                            | 11.0%                | <b>Pass</b>  |
| <b>Mean Measurement Bias Statistic (all values) =</b>      |  |                                       | <b>25.0%</b>         | <b>Pass</b>  |
| <b>Mean Measurement Precision Statistic (all values) =</b> |  |                                       | <b>8.9%</b>          | <b>Pass</b>  |

**Table 1d.** Performance evaluation summary statistics for whole body count measurements of <sup>137</sup>Cs performed at the Utrök (Majuro) facility (2002–2005).

| Facility/Date  | Reference Value, nCi ( $\pm 1\sigma$ ) | Reported Value, nCi ( $\pm 1\sigma$ ) | Measurement Bias (%) | ANSI N13.30 Performance Evaluation Criteria (Pass or Fail) |
|--|--|---------------------------------------|----------------------|--|
| <u>Utrök (Majuro)</u>                                      |  |                                       |                      |  |
| 4th Quarter 2002   | 291 $\pm$ 8                            | 274 $\pm$ 10                          | -6.0%                | Pass   |
| 2nd Quarter 2003   | 123 $\pm$ 3                            | 114 $\pm$ 5                           | -7.1%                | Pass   |
| 4th Quarter 2003   | 332 $\pm$ 9                            | 311 $\pm$ 11                          | -6.4%                | Pass   |
| 2nd Quarter 2004   | 401 $\pm$ 3                            | 333 $\pm$ 12                          | -16.9%               | Pass   |
| 4th Quarter 2004   | 253 $\pm$ 7                            | 217 $\pm$ 8                           | -14.3%               | Pass   |
| 1st Quarter 2005   | 250 $\pm$ 7                            | 223 $\pm$ 9                           | -10.6%               | Pass   |
| 4th Quarter 2005   | 75 $\pm$ 2                             | 62 $\pm$ 4                            | -16.6%               | Pass   |
| <b>Mean Measurement Bias Statistic (all values) =</b>      |  |                                       | <b>-5.4%</b>         | <b>Pass</b>  |
| <b>Mean Measurement Precision Statistic (all values) =</b> |  |                                       | <b>16.7%</b>         | <b>Pass</b>  |



[Statistical reference lines include the null value (---); UCL (Upper Control Limit) = 50% (---); UCL (Lower Control Limit) = -25% (---); individual facility mean (—); and the overall or combined facility mean (—)]

**Figure 1.** Multivar chart expressed as the relative bias statistic for whole body count measurements of  $^{137}\text{Cs}$  in performance evaluation samples supplied by the Oak Ridge National Laboratory (2002–2005).

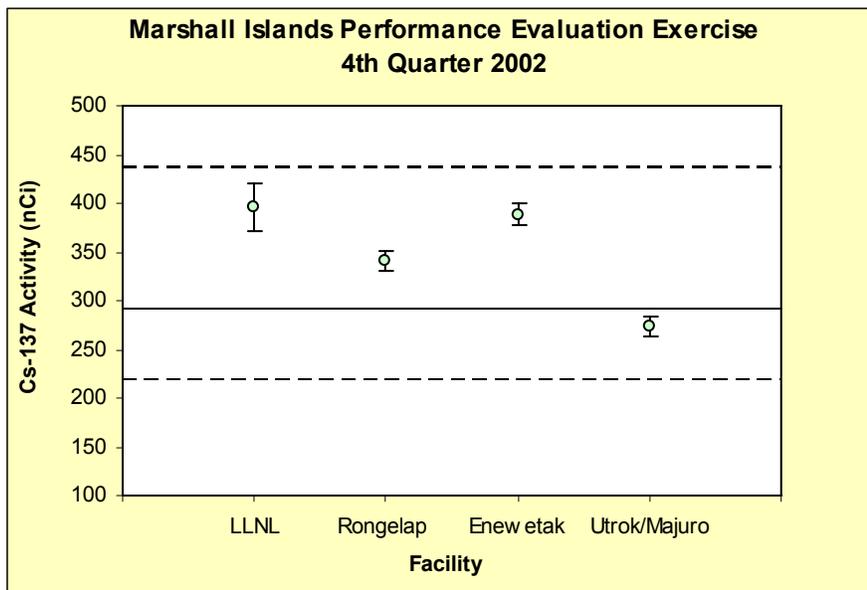


# Appendix A

Summary performance evaluation statistical data and charts for whole body count measurements performed at the LLNL, Enewetak, Rongelap and Utrōk (Majuro) Atoll whole body counting facilities used in support of the Marshall Islands Radiological Surveillance Program (2002–2005)

# Performance Evaluation Data (4<sup>th</sup> Quarter 2002)

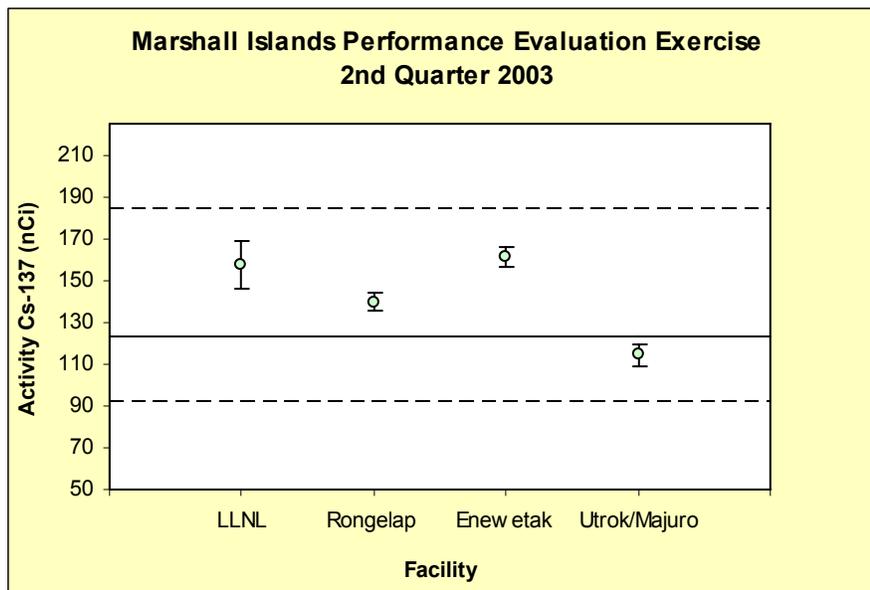
## Whole Body Count Measurements of <sup>137</sup>Cs



|                                  |             |
|----------------------------------|-------------|
| Number of participating facility | 4           |
| Number of reported results       | 4           |
| Reference value                  | 291 nCi     |
| Facility Mean                    | 350 nCi     |
| Standard Deviation               | 56 nCi      |
| Standard Error Mean              | 28 nCi      |
| 95% Confidence Interval          | 260-439 nCi |

# Performance Evaluation Data (2<sup>nd</sup> Quarter 2003)

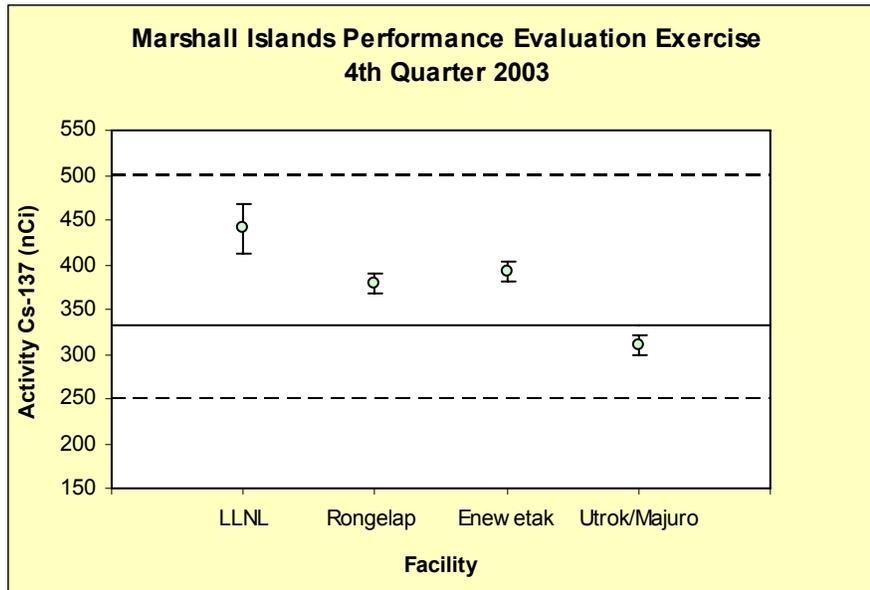
## Whole Body Count Measurements of <sup>137</sup>Cs



|                                  |             |
|----------------------------------|-------------|
| Number of participating facility | 4           |
| Number of reported results       | 4           |
| Reference value                  | 123 nCi     |
| Facility Mean                    | 143 nCi     |
| Facility Median                  | 149 nCi     |
| Standard Deviation               | 22 nCi      |
| Standard Error Mean              | 11 nCi      |
| 95% Confidence Interval          | 118-109 nCi |

# Performance Evaluation Data (4<sup>th</sup> Quarter 2003)

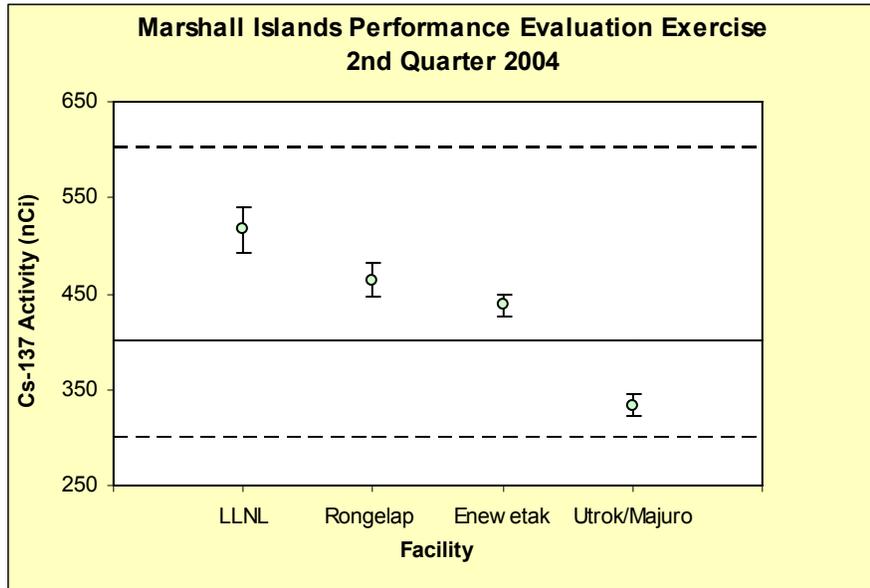
## Whole Body Count Measurements of <sup>137</sup>Cs



|                                  |             |
|----------------------------------|-------------|
| Number of participating facility | 4           |
| Number of reported results       | 4           |
| Reference value                  | 332 nCi     |
| Facility Mean                    | 380 nCi     |
| Facility Median                  | 385 nCi     |
| Standard Deviation               | 53 nCi      |
| Standard Error Mean              | 27 nCi      |
| 95% Confidence Interval          | 295-465 nCi |

# Performance Evaluation Data (2<sup>nd</sup> Quarter 2004)

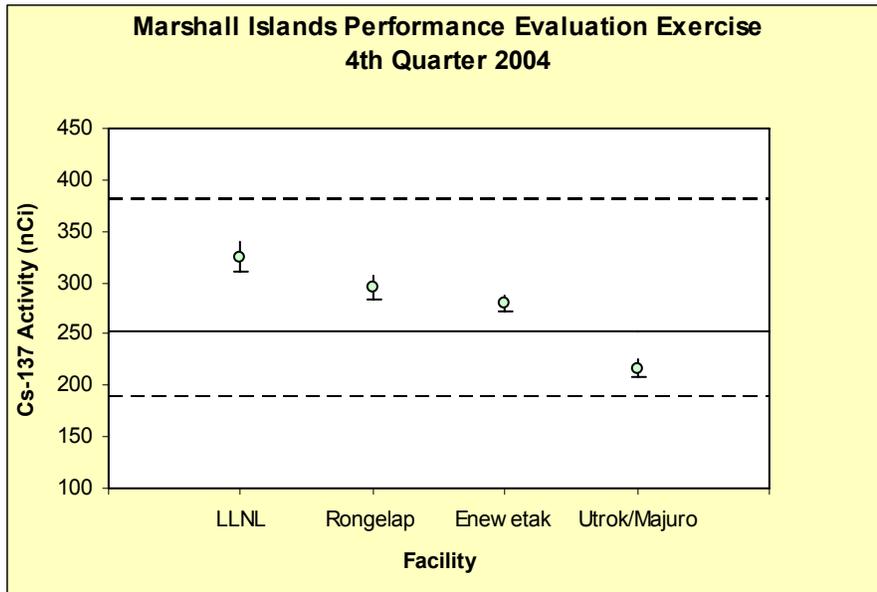
## Whole Body Count Measurements of <sup>137</sup>Cs



|                                  |             |
|----------------------------------|-------------|
| Number of participating facility | 4           |
| Number of reported results       | 4           |
| Reference value                  | 401 nCi     |
| Facility Mean                    | 438 nCi     |
| Facility Median                  | 451 nCi     |
| Standard Deviation               | 77 nCi      |
| Standard Error Mean              | 39 nCi      |
| 95% Confidence Interval          | 314-561 nCi |

# Performance Evaluation Data (4<sup>th</sup> Quarter 2004)

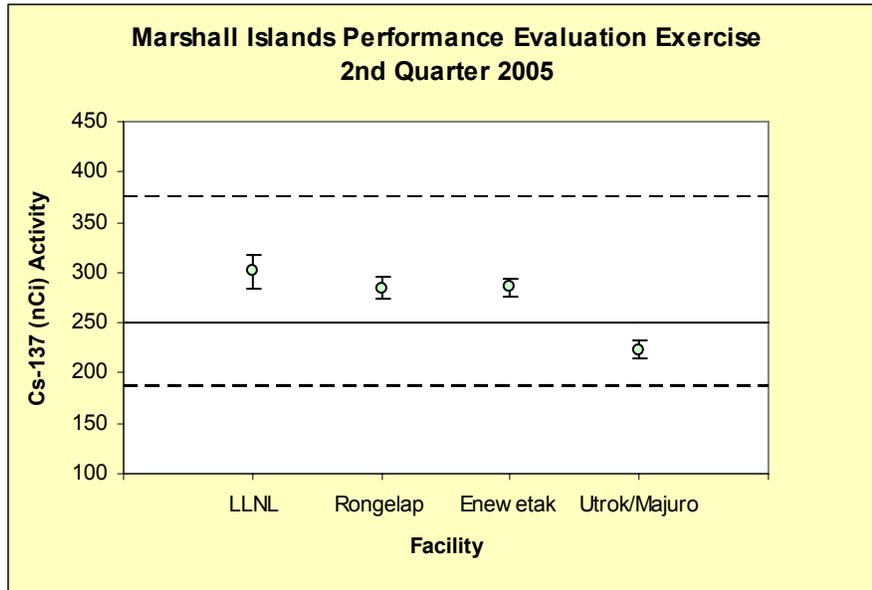
## Whole Body Count Measurements of <sup>137</sup>Cs



|                                  |             |
|----------------------------------|-------------|
| Number of participating facility | 4           |
| Number of reported results       | 4           |
| Reference value                  | 253 nCi     |
| Facility Mean                    | 279 nCi     |
| Facility Median                  | 288 nCi     |
| Standard Deviation               | 46 nCi      |
| Standard Error Mean              | 23 nCi      |
| 95% Confidence Interval          | 207-352 nCi |

# Performance Evaluation Data (2<sup>nd</sup> Quarter 2005)

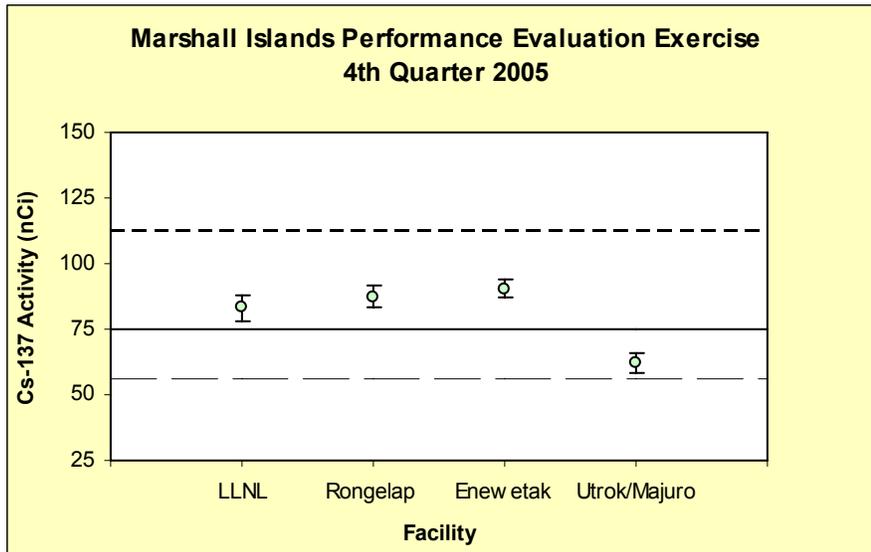
## Whole Body Count Measurements of <sup>137</sup>Cs



|                                  |             |
|----------------------------------|-------------|
| Number of participating facility | 4           |
| Number of reported results       | 4           |
| Reference value                  | 250 nCi     |
| Facility Mean                    | 274 nCi     |
| Facility Median                  | 286 nCi     |
| Standard Deviation               | 35 nCi      |
| Standard Error Mean              | 17 nCi      |
| 95% Confidence Interval          | 218-329 nCi |

# Performance Evaluation Data (4<sup>th</sup> Quarter 2005)

## Whole Body Count Measurements of <sup>137</sup>Cs



|                                  |               |
|----------------------------------|---------------|
| Number of participating facility | 4             |
| Number of reported results       | 4             |
| Reference value                  | 75.0 nCi      |
| Facility Mean                    | 80.5 nCi      |
| Facility Median                  | 85.0 nCi      |
| Standard Deviation               | 12.7 nCi      |
| Standard Error Mean              | 8.3 nCi       |
| 95% Confidence Interval          | 60.4-101 nCi. |



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