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Environmental Radioactivity Intercomparison Exercise, 1998 (Overseas Report)

D.K.Modna, N.E.Bowles, W.E.Brosnan, M.Carter, M.Ciocanel, J.C.J.Dean, P.A.G.de Lavison,
S.M.Jerome, J.D.Keightley M.J.Woods and S.A.Woods
Centre for Ionising Radiation Metrology
National Physical Laboratory
Teddington
Middlesex
TW11 0LW
United Kingdom

ABSTRACT

The results of NPL's seventh Environmental Radioactivity Intercomparison Exercise are reported. The level of metrological performance was similar to that observed in the previous exercise. The inclusion of a β/γ -emitting sample at the 1-5 Bq kg⁻¹ level revealed problems with the identification and measurement of ⁸⁵Sr. An increasing number of laboratories are making corrections for cascade summing.

Although there was some evidence to suggest underestimation of Type B uncertainties, nearly all quoted overall uncertainties exceeded the corresponding NPL values.

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National Physical Laboratory
Teddington, Middlesex, TW11 0LW, UK

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Approved on behalf of Managing Director, NPL,
by Dr J B Hunt, Head of Centre, Centre for Ionising Radiation Metrology

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1. INTRODUCTION

This environmental radioactivity intercomparison was the seventh such exercise¹⁻⁶ to have been conducted by NPL. Three samples were available for analysis:

- i) A mixture of α -emitting and pure β -emitting radionuclides (~ 1 -100 Bq kg⁻¹, in dilute nitric acid)
- ii) A higher-level mixture of γ -emitting radionuclides (~ 10 -50 Bq kg⁻¹, in dilute hydrochloric acid)
- iii) A lower-level mixture of γ -emitting radionuclides (~ 1 -5 Bq kg⁻¹, in dilute hydrochloric acid)

In previous exercises, the mixing of individual radionuclides in the participants' samples had been performed at the last possible stage in the preparation regime. This allowed radiometric validation to be performed at every dilution stage and hence, traceability could be maintained. The consequence of this was that the activity ratio varied from sample to sample. Although this might be regarded as the optimum approach for an intercomparison (maintenance of traceability and elimination of any possibilities of informal comparison before submission of results), there was considerable pressure from the participants to provide identical samples to each. To that end, the source preparation regime was somewhat different to that used previously. Individual radionuclide standard solutions were mixed and then diluted before dispensing to individual participant bottles.

Because of the delays introduced, for geographical and transport regions, in the return of overseas results, the results for UK participants alone were published in an earlier report⁷: this report combines all the results, UK and overseas.

2. ORGANISATION

2.1 PARTICIPANTS

A total of 33 participants took part in this exercise. Of these, 32 took the high-level γ -emitting radionuclide mixture, 23 took the low-level γ -emitting radionuclide mixture and 18 took the α/β emitting radionuclide mixture.

The participants came from a wide cross-section of the UK measurement community; a small number of overseas organisations also took samples. A full list is given in Appendix 1.

2.2 SAMPLES

The samples were given the following identifiers:

- i) α -emitting and pure β -emitting radionuclide mixture - ABxxx/97
- ii) High-level γ -emitting radionuclide mixture- BGHxxx/97
- iii) Low-level γ -emitting radionuclide mixture - BGLxxx/97

Tables 1-6 show the principal radionuclides and their impurities for the three sample mixtures.

All the radionuclides used in this exercise are released by the nuclear industry in the course of normal operations. The following criteria were looked for when choosing the radionuclides:

- (i) that the half-lives were > 50 days;
- (ii) that no obscure species were selected (i.e. all could reasonably be found in the environment or in effluent);
- (iii) that the α/β -emitter samples contained no radionuclides conventionally used as chemical yield tracers;
- (iv) that all the radionuclides were measurable by well-established techniques.

A list of radionuclides present in the α/β -emitting mixture was provided to reduce the amount of analytical effort required. A composition list was not provided for the γ -emitting mixtures since the analytical techniques, normally used, allow for the straightforward identification of the radionuclides present.

However the following list of possible γ -emitters was provided for the participants:

^7Be , ^{22}Na , ^{46}Sc , ^{54}Mn , ^{56}Co , ^{57}Co , ^{58}Co , ^{60}Co , ^{65}Zn , ^{85}Sr , ^{88}Y , ^{95}Zr , ^{95}Nb , $^{106}\text{Ru}/^{106}\text{Rh}$, ^{109}Cd , $^{110\text{m}}\text{Ag}$, ^{113}Sn , ^{124}Sb , ^{125}Sb , $^{125\text{m}}\text{Te}$, ^{133}Ba , ^{134}Cs , ^{137}Cs , ^{139}Ce , ^{144}Ce , ^{153}Gd , ^{154}Eu , ^{155}Eu , ^{160}Tb , ^{170}Tm , ^{203}Hg and ^{207}Bi .

3. CALIBRATION

3.1 ABSOLUTE CALIBRATION

An absolute standard of radioactivity is one that has been measured directly without reference to any other standard of activity; the activity has been determined from count-rate data alone, without reference to any supplementary data determined from previous experiments. A primary standard is the highest level standard in any hierarchical measurement system. In most cases, primary standards are also absolute standards.

In the case of radioactivity standards, absolute standards are generally derived using the 4π -proportional counter- γ -coincidence counting technique for α/γ and β/γ emitting radionuclides.⁸ Those radionuclides decaying by pure α - or pure β -emission are determined by a variation of this technique.

3.2 SECONDARY STANDARDISATION

Absolute calibrations are labour intensive and require a high-level of operator expertise; this makes them very expensive. Also a limit is placed on the lowest amount of activity that can be measured without the associated uncertainties becoming unacceptably high.

A more robust and routine method of calibration is therefore needed. This is achieved by using an absolutely calibrated solution to calibrate a secondary standard instrument. In the case of α/γ or β/γ emitters and some high energy pure β -emitters, this is usually a well-type ionisation chamber that responds only to the γ -rays emitted (in the case of pure β -emitters, the ionisation chamber measures the Bremsstrahlung radiation). Other γ -ray detectors (NaI(Tl) or hyperpure Germanium detectors) can be used but they do not have the long term stability that is associated with ionisation chambers. For pure α -emitters and pure β -emitters, there are no suitable secondary standard instruments that have sufficient long term stability;

however, liquid scintillation counters can be used, albeit with counting efficiency which is dependant on such factors as particle energy, spectral shape, chemical format, etc.

4. SOURCE PREPARATION

4.1 PROCUREMENT

The individual radionuclides were procured from various suppliers and were calibrated in different laboratories. Table 7 shows the suppliers, the laboratories responsible for the calibrations and the traceability of the measurements.

4.2 PURITY

Each nuclide was checked for impurities either by γ -spectroscopy or by reference to the original calibration certificate; the impurity levels are shown in Tables 2, 4 and 6. The radionuclide ^{239}Pu contains ^{240}Pu as an impurity; however the two radionuclides cannot be distinguished from one another unless mass spectroscopy is used; therefore, the activity concentration quoted is the sum of the activity concentrations of ^{239}Pu and ^{240}Pu .

4.3 ACTIVITY CONFIRMATION

The activity concentrations of the original individual radionuclide solutions were determined either from the calibration certificates or from measurement in an NPL secondary standard instrument as described above.

4.4 PREPARATION

For both the γ -emitting and the α/β -emitting mixtures, the stock solutions of the individual radionuclides were prepared by the gravimetric dilution of the standardised solutions. By counting sources made at each dilution stage and comparing count-rates, the overall (gravimetrically determined) dilution factor was confirmed.

For the γ -emitting radionuclides the validation measurements were made using a NaI(Tl) crystal. For the α -emitters and pure β -emitters, the radionuclides were measured by liquid scintillation counting.

4.4.1 The α -emitters and pure β -emitters

The stock solutions of each nuclide (approx. 1 litre each) were combined and diluted to make 100 litres. The diluent used was 1 M nitric acid containing Strontium and Yttrium carriers, at concentrations of approximately 50 $\mu\text{g/g}$ each. The aqueous matrix acts as a carrier for tritium; there are no suitable carriers for Americium, Plutonium or Uranium.

From this solution approximately 200 x 500ml samples were made. The gravimetric dilution factor was confirmed by counting ^{241}Am in the original stock solution and from the final diluted solution, using a hyperpure Germanium γ -ray spectrometer.

4.4.2 The γ -emitting mixtures

The stock solutions of the individual radionuclides (approximately 30 ml each) were combined and diluted to make approximately 3 litres. The diluent initially used was 2.5 M hydrochloric acid containing Barium, Cobalt, Caesium, Europium, Antimony, Strontium, Tellurium and Zinc carriers at concentrations of 50 µg/g. Approximately 1 litre of this solution was then diluted again to 110 litres, from which were generated 200 x 500 ml samples. The remaining 10 litres was further diluted to 100 litres. This latter solution was used to generate a further 200 x 500 ml samples. The gravimetric dilution factors were checked by counting sources at each dilution stage, using a γ-ray spectrometer.

To further validate the activity concentrations derived from the ionisation chambers, selected samples were assayed by γ-ray spectrometry using existing calibrations.

5 TREATMENT OF DATA

5.1 NUMERICAL DATA

Data reporting forms were prepared and distributed with the samples. The data returned was used in conjunction with NPL data to calculate two main parameters. Firstly, the deviation from the NPL value was calculated as a percentage:

$$\text{Deviation (\%)} = \left(\frac{\text{Analyst's result} - \text{NPL value}}{\text{NPL value}} \right) \times 100$$

The value of the u-statistic⁹ was also calculated:

$$\text{u-statistic} = \frac{(\text{Analyst's result} - \text{NPL result})}{\sqrt{(\text{Analyst's uncertainty}^2 + \text{NPL uncertainty}^2)}}$$

This statistic is compared with values in the t-statistic tables¹⁰ and assessed in accordance with the criteria in Table 8.

5.2 NUCLEAR DECAY DATA

The data used by the participants are discussed later; the data¹¹⁻¹⁵ used by NPL for this work are given in Table 9. In each case, the γ-ray emission probabilities, P_γ , are only given if they exceed 1%; the uncertainties on these values are quoted at the 1σ level, as are all other uncertainties quoted within this report.

5.3 PRESENTATION

The results of u-tests are summarised in Tables 10 to 13.

The participants' results for the radionuclides included in the samples by NPL are tabulated in Tables 14 to 37 and are plotted in Figures 1 to 50. Other radionuclides reported by the participants are given in Table 38.

5.4 CONFIDENTIALITY

As is usual in these exercises, the relationship between the participants and the results remains confidential to NPL.

6 RESULTS FOR α -EMITTERS AND PURE β -EMITTERS

6.1 ^3H

All the participants used a form of distillation to isolate the ^3H in the sample. The majority used distillation based on boiling and condensing whilst two laboratories used low temperature distillation. There appears to be no significant difference in the results between these two methods. One laboratory carried out distillation using a modified Dean and Stark apparatus, which gave a discrepant result. Only three laboratories made corrections for isotopic fractionation during distillation. Most standards used were traceable to national standards and one laboratory used ^3H -labelled sucrose which gave a discrepant result.

It should be noted that the starting material was a standard obtained from Amersham International and the uncertainty quoted by NPL is a combination of uncertainties quoted on the standard together with additional uncertainties arising from source preparation. Of the three most discrepant results as defined by the u-test, two were quoting the smallest uncertainties whilst the third result uses a method that doesn't appear to be used by other participants. It is interesting to note that the proportion of participants returning unequivocally acceptable data has risen since the last exercise.

6.2 ^{89}Sr

Both laboratories used extraction chromatography for the separation of ^{90}Y followed by Cerenkov counting. One laboratory used a ^{85}Sr tracer which was traceable to national standards.

The number of results returned was disappointing (only two out of sixteen); however, it is encouraging that these two results showed good agreement with the expected value. Both results are about 10% higher than the expected value but, in the absence of other results, it is unfair to suggest that this is anything other than statistical.

6.3 ^{90}Sr

The participants used ion exchange and extraction chromatography to separate ^{90}Y from the sample, with one participant using solvent extraction. The majority of participants assayed the separated ^{90}Y by Cerenkov counting, with two laboratories using proportional counting techniques. Some laboratories used ^{85}Sr as a yield tracer. This approach effectively eliminates any interference from ^{89}Sr in a sample.

Only one result was clearly discrepant but there is no obvious reason for this, at this present time. Overall there continues to be a steady improvement in terms of the percentage of participants falling within the band of results with u-values less than two; whether or not this represents a general improvement, or a withdrawal by those participants who had performed less well in the past, is not known.

6.4 ^{238}U

The majority of laboratories used either ion exchange or extraction chromatography, with just one laboratory using solvent extraction: in all but one case, the ^{238}U was electrodeposited onto a stainless steel disc and counted by α -spectrometry. One laboratory used ICP-MS. Most laboratories used ^{232}U as a chemical yield tracer, this being from either NPL, AEA Technology or LMRI.

This is the second time in which ^{238}U has been included in the intercomparison sample. The results this time compare well with those in the previous exercise. Three points are worth noting. First, one laboratory is clearly discrepant and clearly that laboratory will wish to examine its techniques more closely. Second, the only other result which has a u-value greater than 1.64 also has an uncertainty which is almost half that quoted by NPL: even a small change (upwards) in this estimate of uncertainty would reduce the u-value sufficiently. Third, it is pleasing to note that one laboratory used ICP-MS although the uncertainty quoted is at least twice the largest uncertainty quoted for other methods: there is very good agreement with the expected value.

6.5 ^{238}Pu and $^{239+240}\text{Pu}$

Concerns had been raised in previous exercises about the values of the activity concentrations quoted for the samples supplied by NPL and, in turn, this raised questions about the certified activities quoted by the supplier of the standardised starting materials. Measurements on the starting materials this year have indicated that the actual activity concentrations are lower than those quoted on the suppliers certificates. Further unconfirmed evidence from a third party lends weight to the view that the certificates of the starting materials should be investigated further. Until these problems are resolved, it is unreasonable to draw conclusions from the apparent bias observable in this, and previous, exercises.

6.6 ^{241}Am

A total of 11 sets of results were returned. Two techniques were used to measure ^{241}Am ; γ -spectrometry and α -spectrometry. Two laboratories used both techniques, with one laboratory using both techniques for the same sample. For this laboratory both sets of results were in good agreement with the expected value and each other. Where a tracer was used it was mainly obtained from either NPL or AEA Technology Harwell.

The ^{241}Am results have been identified within the tables and graphs according to the analytical technique, be it α - or γ -spectrometry. This radionuclide has not caused any significant problems in previous exercises. In the past, the difference in performance between the two methods has not been consistent. In some cases, α -spectrometry has produced significantly better results than γ -spectrometry, whilst in other years the reverse has been true. The spread of the results in general is much the same with four notable exceptions; the remainder of the results would appear non discrepant.

7 RESULTS FOR γ -EMITTERS

7.1 $^{57}\text{Co}/^{155}\text{Eu}$

It is interesting to compare the results from these two radionuclides. It is assumed that ^{57}Co assays will be derived from the counts in the 122 keV photopeak whilst for the ^{155}Eu it would be in the 105 keV photopeak. In essence, therefore, one might

assume that the results would be somewhat similar. It has to be kept in mind that the emission probability of the ^{155}Eu photopeak is only a quarter of that for the ^{57}Co photopeak. Inspection of the ^{57}Co results showed remarkably similar distributions for high and low activity level samples. Indeed they both appear remarkably identical with the distribution seen in previous exercises; the principal difference to be noted is that the fraction of apparently discrepant results is significantly lower for the low activity samples (of the order of 10 %) compared with a figure of about 30 % or more for the high-level samples. The reason for this is apparent when the general level of uncertainty estimates is examined. For the low-level samples, the counting uncertainties are relatively large and are greater than the systematic uncertainties. For the high activity level samples, the counting uncertainties are correspondingly low, such that the systematic uncertainties make a larger contribution to the overall uncertainty. The variation in the fraction of apparently discrepant results between two levels suggest that perhaps the systematic uncertainties have been somewhat underestimated.

In the case of ^{155}Eu , the same arguments in respect of uncertainty levels may be reasonably applied and examination of the tables and graphical results supports this. However, it is noticeable that the distributions of results about the expected values are very different between the two activity levels. The high-level results are very consistent with the previous exercises: the low-level results show a marked tendency to overestimate the activity. A cursory examination of detector type does not give any clue to this variation. The assumption must be that it is associated with the low energy and low abundance of the photopeak, which will consequently be more sensitive to variations in the quality of the fitting procedures and calibration techniques. Examination of the other radionuclides would lead one to expect that the distribution of results for the low-level samples might be worse than for the high-level samples; that this is not the case may be fortuitous.

7.2 $^{137}\text{Cs}/^{85}\text{Sr}$

At a first glance, these two radionuclides appear to be broadly similar in that they are both single γ -emitting radionuclides in the medium energy range i.e. 200-1000 keV. In addition, both are used in the mixed γ -ray emitting radionuclide standards offered by UK-based suppliers. However, there appears to be significant differences in the quoted results for these two radionuclides. This may be attributable to the proximity between the positron annihilation γ -ray at 511 keV and the 514 keV photopeak arising from the ^{85}Sr decay. Even with well shielded systems, the 511 keV γ -ray is usually seen and, in this case, a positron emitting radionuclide (^{65}Zn) is also present, thus complicating the measurement of ^{85}Sr . For the high-level solutions, a majority of results can be accepted as being non-discrepant although the distribution of results is fairly widely spread. For the low-level solution, the situation is much worse with most of the results deviating widely from the expected value. In both cases, there was some difficulty in even identifying this radionuclide. From further discussion with participants, it would appear that some supplied software is incapable of identifying ^{85}Sr although its presence is clear from a visual inspection of the spectrum. It is suspected that this is due to the inability of the software to differentiate between the two peaks at 511 keV and 514 keV.

The radionuclide ^{137}Cs has been included in all but one of the previous intercomparisons and it appears that performance in this intercomparison is comparable with previous exercises in that about 60 % of results are unequivocally acceptable. This is somewhat worrying considering that this is a calibration radionuclide and one would hope for a higher success rate. The wider spread of

low-level results is no doubt a function of the lower activity levels and may be attributable to poorer counting statistics (resulting in a larger contribution of the Type A uncertainty to the overall uncertainty); additionally the estimates of the Type B uncertainties may be optimistic. In both cases, the results are biased slightly high, which is surprising, but no explanation is immediately obvious in that there is no particular correlation between detector type, sample volume, or calibration standard.

7.3 $^{125}\text{Sb} / ^{134}\text{Cs}$

These two radionuclides emit a similar range of medium energy γ -rays. Both of these radionuclides require summing corrections (depending on detector and geometry), although this effect is larger for ^{134}Cs ¹⁶. For the high-level solution, the results are comparable for both radionuclides with reasonable distributions of results; ^{125}Sb results are biased slightly high and ^{134}Cs slightly low. For lower activity solutions, the distributions of results are much wider, and are markedly so for ^{125}Sb . However, it is noticeable that the ^{125}Sb results have improved on those reported last year.

The level of acceptable results for ^{134}Cs remains the same at around 70 % (which it has been for recent exercises) and this represents a dramatic improvement from the first exercise. Increasingly, laboratories are either making corrections or at least noting that these radionuclides exhibit cascade summing. Here too, the low-level results appear worse than the higher-level results for the reasons stated above.

7.4 $^{65}\text{Zn} / ^{60}\text{Co}$

These two radionuclides emit γ -rays above 1 MeV. Cobalt-60 is used in the mixed radionuclide solution for detector calibration: accordingly, one might expect to see a similar distribution of results to ^{137}Cs and this is, indeed, the case. In this region of the spectrum, the background tends to be lower due to the lower incidence of Compton scattering effects and so the peak area uncertainty tends to dominate the uncertainty budget; this is demonstrated by the results for the higher-level sample, which shows a narrower distribution of results. Once more this is not so for the low-level results and the reasons for this have been explained earlier. On a long term basis, the proportion of acceptable results has remained consistently above 70%.

For ^{65}Zn , the results are similar in terms of the proportion, and distribution, of acceptable results. This radionuclide is a positron emitter and therefore gives rise to photons at 511 keV as a result of positron annihilation. This has not caused any problems with the measurement of this radionuclide although it may have compromised the measurement of ^{85}Sr . Once again, the low-level results show a larger spread of data and the number of discrepant results is higher. This radionuclide has only been included in one previous exercise and it is difficult to draw conclusions from the results of two exercises.

7.5 ^{154}Eu

Europium-154 emits γ -rays across all energy regions of the γ spectrum. It is possible to confuse ^{154}Eu with a number of other radionuclides, such as ^{152}Eu , ^{56}Co , ^{124}Sb , ^{108}Ag , ^{95}Zr , and ^{22}Na . It is also a radionuclide that exhibits cascade summing effects of the same order of magnitude as for ^{134}Cs and this is evident from the spread of results. Although these results are centred on the expected value, the distribution is somewhat wider than those for ^{134}Cs and ^{60}Co . The pattern of data distributions

between the higher and lower level results is again repeated, presumably for similar reasons. It is worrying that a number of participants misinterpreted the peak data for different radionuclides (e.g. ^{56}Co , ^{95}Zr , ^{22}Na): in particular, one participant found that the analysis software did not accept the absence of ^{22}Na . Although γ -lines at 511 keV and 1274 keV are emitted by ^{22}Na , it should be clear from the examination of the other γ -rays present that those are accounted for by ^{65}Zn , ^{85}Sr and ^{154}Eu . However, considering the challenges in measuring this radionuclide, the results are comparable with other less problematic radionuclides.

8 DISCUSSION

8.1 α -EMITTERS

The levels of performance for measurements of ^{238}U and ^{241}Am were comparable to those of the previous exercise, albeit with reductions in the proportions of unambiguously correct data. Problems still persist with the plutonium radionuclides, in that ambiguities in the calibration of the starting material have been identified by both NPL and one other centre. This warrants action to be undertaken by the various national standards laboratories under the auspices of BIPM.

It is encouraging that a greater proportion of laboratories quoted uncertainties exceeding the corresponding NPL values.

8.2 β -EMITTERS

This is the first time that ^{89}Sr has been included in the α/β -mixture. The shortage of data for this radionuclide makes it difficult to draw conclusions on measurement capabilities. Overall performance for both ^3H and ^{90}Sr seems to have improved in terms of the proportions of results yielding $u < 2$, although the numbers of results obtained were rather small for meaningful year-on-year trends to be identified.

8.3 γ -EMITTERS

This is the first exercise to include β/γ -mixtures at both the 10-50 Bq/kg and 1-5 Bq/kg levels. The results demonstrate several points:

- (i) the data for some radionuclides suggest that systematic uncertainties may be underestimated, although quoted uncertainties exceeded the corresponding NPL values. It is clear that the user community may benefit from a general workshop in the estimation of uncertainties. In any case, the UKAS publications¹⁷⁻¹⁹ dealing with uncertainties should be perused;
- (ii) most radionuclides exhibit a higher spread for the lower-level sample. The bias may be larger although not significantly so once obvious outliers are excluded.
- (iii) measurements of ^{85}Sr at the lower-level are problematic, possibly because of the proximity of the annihilation peak at 511 keV. The deconvolution of the two peaks is difficult for existing software packages to perform due to the broadened nature of the annihilation peak; this is particularly true when measurement conditions cause the annihilation peak to be enhanced relative to the 514 keV peak;
- (iv) the number of laboratories making cascade summing corrections continues to increase;

- (v) overall performance is comparable with that of the 1996 exercise - for the higher-level sample, 0 - 37% of results yielded $u > 2.58$ (compared with 13-31% in 1996); for the lower-level sample, the range was 5-43%;
- (vi) the calibration radionuclides (^{57}Co , ^{60}Co , ^{85}Sr and ^{137}Cs) are still causing significant problems in that the proportions of unambiguously correct results (higher-level samples) are 60%, 73%, 43% and 57% respectively, similar to the last exercise.

8.4 GENERAL COMMENTS

8.4.1 Nuclear Decay Data

The participants used a variety of data sources to obtain their nuclear data. The majority of participants used data from internationally recognised nuclear data sources. A number of participants used data supplied with detector systems which they had modified with the recommended values from IAEA or NPL: this practice is to be encouraged. A small number of participants are placing full trust in manufacturers data: although such data may be of good quality, the user should check the provenance of such data and adjust where necessary.

It is still of concern, however, that some participants are using data which is no longer recommended and some participants do not seem to be aware of where their data came from. It must be emphasised that participants should where possible use data arising from recently recommended data sets; if there is any doubt as to the reliability of the data, an expert body such as NPL would be able to advise.

8.4.2 Standards

Almost all of the participants now use γ -emitting standards of the mixed radionuclide type. For the α/β -emitting radionuclides, the standards and chemical yield tracers are, in the majority, obtained from NPL or AEA Technology, although some other calibration sources were used. In most cases, however, the tracers/standards are traceable to national standards.

9 CONCLUSIONS

The results of this exercise seem to indicate that the overall level of metrological performance has not changed markedly since the last exercise in 1996. The results for the plutonium radionuclides are clearly biased low and this again raises concerns over the certified values of the starting materials.

The inclusion of a lower-level β/γ -mixture has pointed to possible problems with Type B uncertainty evaluations and the identification/measurement of ^{85}Sr ; also, quoted activity concentrations seem to have a greater spread at lower levels. The proportions of unequivocally correct data for calibration radionuclides remain somewhat low.

In conclusion, one can say that:

- (i) there still remains scope for improvement in metrological performance, even for aqueous matrices; better performance is expected for the calibration radionuclides;
- (ii) specific areas for improvement again include uncertainty budgets (although there has been progress here), and also low-level β/γ -emitter measurements for radionuclides with γ -emissions close to the 511 keV annihilation peak;
- (iii) the certified values for the plutonium radionuclides need to be further investigated;
- (iv) measurement capabilities in non-aqueous matrices must be further addressed in due course.

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Table 1- ABxxx/97 - principal radionuclides.

Radionuclide	Emission	Activity concentration @ 1200 GMT 1/11/97 (Bq kg ⁻¹)	Overall uncertainty (1 σ) (Bq kg ⁻¹)
³ H	β	99.39	4.25
⁸⁹ Sr	β	48.57	0.49
⁹⁰ Sr	β	24.16	0.18
²³⁸ U	α	6.50	0.16
²³⁸ Pu	α	3.36	0.02
²³⁹⁺²⁴⁰ Pu	α	11.65	0.08
²⁴¹ Am	α/γ	4.82	0.11

Table 2 - ABxxx/97 - impurities.

Radionuclide	Emission	Activity concentration @ 1200 GMT 1 / 11 / 97 (Bq kg ⁻¹)	Overall uncertainty (1σ) (Bq kg ⁻¹)
⁸⁵ Sr	β/γ	< 0.07	-
⁸⁸ Y	β/γ	< 0.3	-
²⁴¹ Pu	β	< 1.5	-
²⁴² Pu	α	< 0.01	-

Table 3 - Principal radionuclides - BGHxxx/97

Radionuclide	Emission	Activity concentration @ 1200 GMT 1 / 11 / 97 (Bq kg ⁻¹)	Overall uncertainty (1σ) (Bq kg ⁻¹)
⁵⁷ Co	e.c.* / γ	26.15	0.22
⁶⁰ Co	β / γ	25.88	0.13
⁶⁵ Zn	β ⁺ / γ	20.13	0.17
⁸⁵ Sr	β / γ	23.88	0.20
¹²⁵ Sb	β / γ	20.44	0.15
¹³⁴ Cs	β / γ	15.99	0.14
¹³⁷ Cs	β, β / γ	26.92	0.22
¹⁵⁴ Eu	β / γ	24.27	0.21
¹⁵⁵ Eu	β / γ	21.18	0.23

Table 4 - BGHxxx/97 impurities

Radionuclide	Emission	Activity concentration @1200 GMT 1/11/97 (Bq kg ⁻¹)	Overall uncertainty (1σ) (Bq kg ⁻¹)
⁵⁶ Co	β/γ	< 0.01	-
^{125m} Te ⁺	β/γ	5.2	0.4
¹⁵² Eu	β/γ	0.31	0.02

* e.c. denotes electron capture

⁺ daughter of ¹²⁵Sb

Table 5- Principal radionuclides - BGLxxx/97

Radionuclide	Emission	Activity concentration @ 1200 GMT 1/11/97 (Bq kg ⁻¹)	Overall uncertainty (1σ) (Bq kg ⁻¹)
⁵⁷ Co	e.c.* / γ	2.81	0.03
⁶⁰ Co	β/γ	2.79	0.02
⁶⁵ Zn	β ⁺ / γ	2.17	0.02
⁸⁵ Sr	β/γ	2.57	0.03
¹²⁵ Sb	β/γ	2.20	0.02
¹³⁴ Cs	β/γ	1.72	0.02
¹³⁷ Cs	β,β/γ	2.90	0.03
¹⁵⁴ Eu	β/γ	2.61	0.03
¹⁵⁵ Eu	β/γ	2.28	0.03

Table 6 - BGLxxx / 97 - impurities

Radionuclide	Emission	Activity concentration @1200 GMT 1 / 11 / 97 (Bq kg ⁻¹)	Overall uncertainty (1σ) (Bq kg ⁻¹)
⁵⁶ Co	β/γ	<0.001	-
^{125m} Te ⁺	β/γ	0.56	0.04
¹⁵² Eu	β/γ	0.033	0.003

⁺ daughter of ¹²⁵Sb

Table 7 - Radionuclide provenance

Radionuclide	Origin	Calibrating Laboratory	Traceability
²³⁸ U	ORNL, USA	NPL	French Primary Standard / LPRI
²³⁸ Pu	CEA, France	CEA / NPL	French Primary Standard / LPRI
²³⁹⁺²⁴⁰ Pu	CEA, France	CEA / NPL	French Primary Standard / LPRI
²⁴¹ Am	NA, UK	NPL	UK Primary Standard / NPL
³ H	NA, UK	NA	US Primary Standard / NIST
⁸⁵ Sr	NA, UK	NPL	UK Primary Standard / NPL
⁸⁹ Sr	NA, UK	NPL	UK Primary Standard / NPL
⁹⁰ Sr	NA, UK	NPL	UK Primary Standard / NPL
⁵⁷ Co	NA, UK	NPL	UK Primary Standard / NPL
⁶⁰ Co	NA, UK	NPL	UK Primary Standard / NPL
⁶⁵ Zn	NA, UK	NPL	UK Primary Standard / NPL
¹²⁵ Sb	NA, UK	NPL	UK Primary Standard / NPL

¹³⁴ Cs	NA, UK	NPL	UK Primary Standard / NPL
¹³⁷ Cs	NA, UK	NPL	UK Primary Standard / NPL
¹⁵⁴ Eu	NPL, UK	NPL	UK Primary Standard / NPL
¹⁵⁵ Eu	IIR, Czech Republic	NPL	UK Primary Standard / NPL

NA: Nycomed-Amersham, UK
 CEA: Commissariat à l'Énergie Atomique, France
 IIR: Inspektorát pro Ionizující Zářeni, Czech Republic
 LPRI: Laboratoire Primaire des Rayonnements Ionisants, France
 NIST: National Institute of Standards and Technology, USA
 ORNL: Oak Ridge National Laboratory, USA

Table 8- Criteria for u-tests

Value	Conclusion
$u < 1.64$	The values do not differ significantly
$1.64 < u < 1.96$	The values probably do not differ significantly but more data are required to confirm this
$1.96 < u < 2.58$	One cannot say whether there is a significant difference without further data
$2.58 < u < 3.29$	The values probably differ significantly but more data are required to confirm this
$3.29 < u$	The values differ significantly

Table 9 - Nuclear decay data

Nuclide	Half life (days)	E γ (keV)	P γ (%)	Reference
³ H	4504 $\pm$ 22			[14]
⁵⁷ Co	271.79 $\pm$ 0.09	14.4	9.16 $\pm$ 0.15	[12]
		122.1	85.60 $\pm$ 0.17	[12]
		136.5	10.68 $\pm$ 0.08	[12]
⁶⁰ Co	1925.5 $\pm$ 0.5	1173.2	99.857 $\pm$ 0.022	[12]
		1332.5	99.983 $\pm$ 0.006	[12]
⁶⁵ Zn	244.26 $\pm$ 0.26	1115.5	50.6 $\pm$ 0.24	[12]
⁸⁵ Sr	64.849 $\pm$ 0.004	514	98.4 $\pm$ 0.4	[12]
⁸⁹ Sr	50.52 $\pm$ 0.08	-	-	[13]
⁹⁰ Sr	10460 $\pm$ 60	-	-	[13]
^{125m} Te	57.40 $\pm$ 0.15	35.5	6.67 $\pm$ 0.20	[14]
¹²⁵ Sb	1007.7 $\pm$ 0.6	176.3	6.85 $\pm$ 0.07	[12]
		380.5	1.518 $\pm$ 0.016	[12]
		427.9	29.7 $\pm$ 0.3	[12]
		463.4	10.48 $\pm$ 0.11	[12]
		600.6	17.73 $\pm$ 0.18	[12]
		606.7	5.00 $\pm$ 0.05	[12]
		636.0	11.21 $\pm$ 0.12	[12]
¹³⁴ Cs	754.28 $\pm$ 0.22	475.4	1.49 $\pm$ 0.02	[12]
		563.2	8.36 $\pm$ 0.03	[12]
		569.3	15.39 $\pm$ 0.06	[12]
		604.7	97.63 $\pm$ 0.06	[12]
		795.9	85.4 $\pm$ 0.3	[12]
		801.9	8.69 $\pm$ 0.03	[12]
		1168.0	1.792 $\pm$ 0.007	[12]
		1365.2	3.016 $\pm$ 0.011	[12]

Table 9 - Nuclear decay data (continued)

Nuclide	Half life (days)	E_γ (keV)	P_γ (%)	Reference
¹³⁷ Cs	11020 ± 60	661.7	85.1 ± 0.2	[12]
¹⁵⁴ Eu	3136.8 ± 2.9	123.1	41.2 ± 0.5	[12]
		247.9	6.95 ± 0.09	[12]
		591.8	4.99 ± 0.06	[12]
		692.4	1.80 ± 0.03	[12]
		723.3	20.2 ± 0.2	[12]
		756.8	4.58 ± 0.06	[12]
		873.2	12.24 ± 0.15	[12]
		996.3	10.48 ± 0.13	[12]
		1004.7	18.2 ± 0.2	[12]
		1274.4	35.0 ± 0.4	[12]
¹⁵⁵ Eu	1770 ± 50	60.0	1.13 ± 0.05	[12]/[14]
		86.5	30.7 ± 0.7	[14]
		105.3	21.2 ± 0.5`	[14]
²³⁸ U	(1.6319 ± 0.0011) x 10 ¹²			[14]
²³⁸ Pu	(3.203 ± 0.011) x 10 ⁴			[15]
²³⁹ Pu	(8.806 ± 0.011) x 10 ⁶			[15]
²⁴⁰ Pu	(2.3971 ± 0.0026) x 10 ⁶			[15]
²⁴¹ Am	(1.5785 ± 0.0024) x 10 ⁵	59.5	36.0 ± 0.4	[12]

Table 10 - results of u-tests for α -emitters

NUCLIDE	LIMITS	NUMBER OF RESULTS
²³⁸ U	< 1.64	8
	1.64 - 1.96	1
	1.96 - 2.58	
	2.58 - 3.29	
	> 3.29	1
²³⁸ Pu	< 1.64	7
	1.64 - 1.96	
	1.96 - 2.58	1
	2.58 - 3.29	1
	> 3.29	2
²³⁹ Pu + ²⁴⁰ Pu	< 1.64	7
	1.64 - 1.96	
	1.96 - 2.58	1
	2.58 - 3.29	1
	> 3.29	2
²⁴¹ Am	< 1.64	6
	1.64 - 1.96	2
	1.96 - 2.58	2
	2.58 - 3.29	1
	> 3.29	1

Table 11 - Results of u-tests for β -emitters

NUCLIDE	LIMITS	NUMBER OF RESULTS
³ H	< 1.64	11
	1.64 - 1.96	1
	1.96 - 2.58	1
	2.58 - 3.29	1
	> 3.29	1
⁸⁹ Sr	< 1.64	2
	1.64 - 1.96	
	1.96 - 2.58	
	2.58 - 3.29	
	> 3.29	
⁹⁰ Sr	< 1.64	6
	1.64 - 1.96	
	1.96 - 2.58	
	2.58 - 3.29	
	> 3.29	1

Table 12 - Results of u-tests for γ -emitters

* Number of results quoted as maximum values.

NUCLIDE	LIMITS	NUMBER OF RESULTS HIGH LEVEL	NUMBER OF RESULTS LOW LEVEL
⁵⁷ Co	< 1.64 1.64 - 1.96 1.96 - 2.58 2.58 - 3.29 > 3.29 * maximum	21 1 3 3 8	20 1 1 2 1
⁶⁰ Co	< 1.64 1.64 - 1.96 1.96 - 2.58 2.58 - 3.29 > 3.29 * maximum	27 3 2 1 4	15 1 3 5 1
⁶⁵ Zn	< 1.64 1.64 - 1.96 1.96 - 2.58 2.58 - 3.29 > 3.29 * maximum	27 2 2 6	18 2 2 3
⁸⁵ Sr	< 1.64 1.64 - 1.96 1.96 - 2.58 2.58 - 3.29 > 3.29 * maximum	12 5 6 2 4	3 3 6 2 3 1
¹²⁵ Sb	< 1.64 1.64 - 1.96 1.96 - 2.58 2.58 - 3.29 > 3.29 * maximum	35 2	18 1 2 2 1
¹³⁴ Cs	< 1.64 1.64 - 1.96 1.96 - 2.58 2.58 - 3.29 > 3.29 * maximum	25 3 1 2 6	14 1 4 5 1
¹³⁷ Cs	< 1.64 1.64 - 1.96 1.96 - 2.58 2.58 - 3.29 > 3.29 * maximum	21 5 3 3 5	15 1 2 7
¹⁵⁴ Eu	< 1.64 1.64 - 1.96 1.96 - 2.58 2.58 - 3.29 > 3.29 * maximum	21 3 1 4 8	17 1 5 2
¹⁵⁵ Eu	< 1.64 1.64 - 1.96 1.96 - 2.58 2.58 - 3.29 > 3.29 * maximum	22 3 3 1 6	17 3 2 2

Table 13 - Results for ^3H

Sample	NPL Data		Analyst Data		Deviation (%)	u-test statistic
	^3H Bq kg^{-1}	$\pm$ Bq kg^{-1}	^3H Bq kg^{-1}	$\pm$ Bq kg^{-1}		
AB001/97	99.39	4.25	89.7	11.0	-9.75	0.82
AB002/97	99.39	4.25	109	8	9.67	1.06
AB003/97	99.39	4.25	111.89	3.45	12.58	2.28
AB005/97	99.39	4.25	92	4	-7.44	1.27
AB006/97	99.39	4.25	98.9	4.4	-0.49	0.08
AB008/97	99.39	4.25	102	7.6	2.63	0.30
AB009/97	99.39	4.25	102	7	2.62	0.32
AB012/97	99.39	4.25	97.42	6.86	-1.98	0.24
AB013/97	99.39	4.25	67.0	3.9	-32.59	5.62
AB014/97	99.39	4.25	105	7	5.64	0.68
AB015/97	99.39	4.25	201.64	35.34	102.88	2.87
AB017/97	99.39	4.25	110.32	4.68	11.00	1.73
AB018/97	99.39	4.25	98	5	-1.40	0.2
AB019/97	99.39	4.25	110.60	5.98	11.28	1.53
AB021/97	99.39	4.25	106.0	8.04	6.65	0.72

Table 14 - Results for ^{89}Sr

Sample	NPL Data		Analyst Data		Deviation (%)	u-test statistic
	^{89}Sr Bq kg^{-1}	$\pm$ Bq kg^{-1}	^{89}Sr Bq kg^{-1}	$\pm$ Bq kg^{-1}		
AB001/97	48.57	0.49	53.3	5.8	9.74	0.81
AB006/97	48.57	0.49	54.6	6.3	12.42	0.95

Table 15 - Results for ^{90}Sr

Sample	NPL Data		Analyst Data		Deviation (%)	u-test statistic
	^{90}Sr Bq kg^{-1}	$\pm$ Bq kg^{-1}	^{90}Sr Bq kg^{-1}	$\pm$ Bq kg^{-1}		
AB001/97	24.16	0.18	24.8	1.0	2.65	0.63
AB001/97/1	24.16	0.18	23.0	0.7	-4.80	1.60
AB003/97	24.16	0.18	12.78	2.13	-47.10	5.32
AB006/97	24.16	0.18	24.9	1.3	3.06	0.56
AB007/97	24.16	0.18	21.9	4.2	-9.35	0.54
AB010/97	24.16	0.18	23.0	0.7	-4.80	1.60
AB019/97	24.16	0.18	25.41	2.71	5.17	0.46

Table 16 - Results for ^{238}U

Sample	NPL Data		Analyst Data		Deviation (%)	u-test statistic
	^{238}U Bq kg^{-1}	$\pm$ Bq kg^{-1}	^{238}U Bq kg^{-1}	$\pm$ Bq kg^{-1}		
AB001/97	6.50	0.16	6.35	0.22	-2.31	0.55
AB002/97	6.50	0.16	6.55	0.27	0.77	0.16
AB003/97	6.50	0.16	2.39	0.06	-63.23	24.05
AB004/97	6.50	0.16	6.34	0.32	-2.46	0.45
AB005/97	6.50	0.16	6.15	0.10	-5.38	1.85
AB006/97	6.50	0.16	6.55	0.66	0.77	0.07
AB009/97	6.50	0.16	6.06	0.24	-6.77	1.53
AB015/97	6.50	0.16	6.16	0.33	-5.23	0.93
AB019/97	6.50	0.16	6.72	0.61	3.38	0.35
AB020/97	6.50	0.16	6.69	0.2	2.92	0.74

Table 17 - Results for ^{238}Pu

Sample	NPL Data		Analyst Data		Deviation (%)	u-test statistic
	^{238}Pu Bq kg ⁻¹	$\pm$ Bq kg ⁻¹	^{238}Pu Bq kg ⁻¹	$\pm$ Bq kg ⁻¹		
AB002/97	3.36	0.02	2.90	0.09	-13.69	4.99
AB003/97	3.36	0.02	2.75	0.23	-18.15	2.64
AB005/97	3.36	0.02	3.23	0.08	-3.87	1.58
AB006/97	3.36	0.02	3.28	0.06	-2.38	1.26
AB007/97	3.36	0.02	3.07	0.19	-8.63	1.52
AB009/97	3.36	0.02	2.9	0.2	-13.69	2.29
AB010/97	3.36	0.02	3.02	0.08	-10.12	4.12
AB015/97	3.36	0.02	3.35	0.2	-0.30	0.05
AB018/97	3.36	0.02	3.31	0.07	-1.49	0.69
AB019/97	3.36	0.02	3.37	0.36	0.30	0.03
AB021/97	3.36	0.02	3.28	0.18	-2.38	0.44

Table 18 - Results for $^{239+240}\text{Pu}$

Sample	NPL Data		Analyst Data		Deviation (%)	u-test statistic
	$^{239+240}\text{Pu}$ Bq kg ⁻¹	$\pm$ Bq kg ⁻¹	$^{239+240}\text{Pu}$ Bq kg ⁻¹	$\pm$ Bq kg ⁻¹		
AB002/97	11.65	0.08	9.90	0.23	-15.02	7.19
AB003/97	11.65	0.08	10.16	0.64	-12.79	2.31
AB005/97	11.65	0.08	10.3	0.15	-11.59	7.94
AB006/97	11.65	0.08	11.4	0.2	-2.15	1.16
AB007/97	11.65	0.08	11.16	0.57	-4.21	0.85
AB009/97	11.65	0.08	10.9	0.5	-6.43	1.48
AB010/97	11.65	0.08	10.94	0.25	-6.09	2.70
AB015/97	11.65	0.08	11.19	0.64	-3.95	0.71
AB018/97	11.65	0.08	11.4	0.2	-2.15	1.16
AB019/97	11.65	0.08	11.29	0.96	-3.09	0.37
AB021/97	11.65	0.08	11.3	0.55	-3.00	0.63

Table 19 - Results for ^{241}Am

Sample	NPL Data		Analyst Data		Deviation (%)	u-test statistic
	^{241}Am Bq kg^{-1}	$\pm$ Bq kg^{-1}	^{241}Am Bq kg^{-1}	$\pm$ Bq kg^{-1}		
AB001/97(γ)	4.82	0.07	4.67	0.37	-3.11	0.40
AB002/97(α)	4.82	0.07	4.47	0.30	-7.26	1.14
AB003/97(α)	4.82	0.07	2.87	0.12	-40.46	14.04
AB005/97(α)	4.82	0.07	4.64	0.12	-3.73	1.30
AB006/97(α)	4.82	0.07	4.31	0.47	-10.58	1.07
AB006/97(γ)	4.82	0.07	4.49	0.08	-6.85	3.10
AB007/97(α)	4.82	0.07	4.90	0.2	1.66	0.38
AB009/97(γ)	4.82	0.07	5.5	0.8	14.11	0.85
AB010/97(α)	4.82	0.07	4.54	0.12	-5.81	2.02
AB013/97(γ)	4.82	0.07	8.4	1.8	74.27	1.99
AB015/97(γ)	4.82	0.07	4.55	0.12	-5.60	1.94
AB019/97(α)	4.82	0.07	3.96	0.45	-17.84	1.89

Table 20 - Results for ^{57}Co (higher level)

Sample	NPL Data		Analyst Data		Deviation (%)	u-test statistic
	^{57}Co Bq kg^{-1}	$\pm$ Bq kg^{-1}	^{57}Co Bq kg^{-1}	$\pm$ Bq kg^{-1}		
BGH001/97	26.15	0.22	24.4	0.4	-6.69	3.83
BGH002/97	26.15	0.22	26.0	0.6	-0.57	0.23
BGH003/97	26.15	0.22	26.6	0.4	1.72	0.99
BGH004/97	26.15	0.22	26.85	0.48	2.68	1.33
BGH005/97	26.15	0.22	24.8	0.4	-5.16	2.96
BGH006/97	26.15	0.22	26.2	0.6	0.19	0.08
BGH007/97	26.15	0.22	27.1	2.6	3.63	0.36
BGH008/97	26.15	0.22	26.3	1.4	0.57	0.11
BGH011/97	26.15	0.22	30.23	4.24	15.60	0.96
BGH013/97	26.15	0.22	28.86	1.01	10.36	2.62
BGH014/97	26.15	0.22	25	5	-4.40	0.23
BGH015/97	26.15	0.22	19.33	1.28	-26.08	5.25
BGH016/97	26.15	0.22	26.1	2.1	-0.19	0.03
BGH017/97	26.15	0.22	27.5	2.3	5.16	0.58
BGH018/97	26.15	0.22	15.3	1.5	-41.49	7.16
BGH019/97	26.15	0.22	26.66	1.49	1.95	0.34
BGH021/97	26.15	0.22	25.802	0.66	-1.33	0.5
BGH022/97/1*	26.15	0.22	26.215	1.29	0.25	0.05
BGH022/97/2*	26.15	0.22	27.348	0.85	4.58	2.48
BGH023/97	26.15	0.22	10.9	1.1	58.32	13.59
BGH024/97	26.15	0.22	26.5	4.0	1.34	0.09
BGH025/97	26.15	0.22	27.196	0.30	3.84	2.81
BGH026/97	26.15	0.22	26.0	0.9	-0.57	0.16
BGH027/97	26.15	0.22	25.21	0.76	-3.59	1.19
BGH028/97/1*	26.15	0.22	25.81	0.69	-1.30	0.47
BGH028/97/2*	26.15	0.22	24.79	0.77	-5.20	1.70
BGH028/97/3*	26.15	0.22	22.36	0.94	-14.49	3.96
BGH028/97/4*	26.15	0.22	21.63	2.04	-17.28	2.20
BGH029/97	26.15	0.22	21.6	1.8	-17.40	2.51
BGH031/97	26.15	0.22	25.1	0.8	-4.02	1.27
BGH032/97	26.15	0.22	29.1	0.22	11.28	9.48
BGH033/97	26.15	0.22	27.47	1.25	5.05	1.04
BGH034/97	26.15	0.22	44.8	2.05	71.32	9.04

Sample	NPL Data		Analyst Data		Deviation (%)	u-test statistic
	^{57}Co Bq kg ⁻¹	$\pm$ Bq kg ⁻¹	^{57}Co Bq kg ⁻¹	$\pm$ Bq kg ⁻¹		
BGH035/97	26.15	0.22	10	1	-61.76	15.77
BGH036/97	26.15	0.22	25.94	0.8	-0.80	0.25
BGH038/97	26.15	0.22	26.0	2.4	-0.57	0.06

* Laboratories 22 and 28 submitted two and four sets of results respectively.

Table 21 - Results for ^{60}Co (higher level)

Sample	NPL Data		Analyst Data		Deviation (%)	u-test statistic
	^{60}Co Bq kg ⁻¹	$\pm$ Bq kg ⁻¹	^{60}Co Bq kg ⁻¹	$\pm$ Bq kg ⁻¹		
BGH001/97	25.88	0.13	25.5	0.4	-1.47	0.90
BGH002/97	25.88	0.13	26.9	0.5	3.94	1.97
BGH003/97	25.88	0.13	26.2	0.5	1.24	0.62
BGH004/97	25.88	0.13	27.19	0.73	5.06	1.77
BGH005/97	25.88	0.13	23.8	0.5	-8.04	4.03
BGH006/97	25.88	0.13	25.6	0.6	-1.08	0.46
BGH007/97	25.88	0.13	26.3	0.6	1.62	0.68
BGH008/97	25.88	0.13	26.1	1.0	0.85	0.22
BGH011/97	25.88	0.13	27.29	1.01	5.45	1.38
BGH013/97	25.88	0.13	29.29	0.50	13.18	6.60
BGH014/97	25.88	0.13	28	3	8.19	0.71
BGH015/97	25.88	0.13	26.3	1.12	1.62	0.37
BGH016/97	25.88	0.13	26.7	1.4	3.17	0.59
BGH017/97	25.88	0.13	24.7	2.2	-4.56	0.54
BGH018/97	25.88	0.13	26.7	2.7	3.17	0.30
BGH019/97	25.88	0.13	29.40	3.10	13.60	1.13
BGH021/97	25.88	0.13	26.592	0.70	2.75	1.00
BGH022/97/1*	25.88	0.13	28.735	0.94	11.03	3.01
BGH022/97/2*	25.88	0.13	28.277	0.82	9.26	5.57
BGH023/97	25.88	0.13	26.9	0.95	3.94	1.06
BGH024/97	25.88	0.13	26.9	3.8	3.94	0.27
BGH025/97	25.88	0.13	27.466	0.30	6.13	4.85
BGH026/97	25.88	0.13	25.9	0.90	0.08	0.02
BGH027/97	25.88	0.13	25.15	0.66	-2.82	1.09
BGH028/97/1*	25.88	0.13	27.46	0.77	6.11	2.02
BGH028/97/2*	25.88	0.13	25.96	0.79	0.31	0.10
BGH028/97/3*	25.88	0.13	26.68	1.36	3.09	0.59
BGH028/97/4*	25.88	0.13	26.12	0.70	0.93	0.34

Sample	NPL Data		Analyst Data		Deviation (%)	u-test statistic
	^{60}Co Bq kg ⁻¹	$\pm$ Bq kg ⁻¹	^{60}Co Bq kg ⁻¹	$\pm$ Bq kg ⁻¹		
BGH029/97	25.88	0.13	27.8	2.2	7.42	0.87
BGH031/97	25.88	0.13	25.7	0.8	-0.70	0.22
BGH032/97	25.88	0.13	26.7	0.4	3.17	1.95
BGH033/97	25.88	0.13	24.30	1	-6.11	1.57
BGH034/97	25.88	0.13	25.6	0.88	-1.08	0.31
BGH035/97	25.88	0.13	23.3	1.4	-9.97	1.83
BGH036/97	25.88	0.13	25.11	0.5	-2.98	1.49
BGH038/97	25.88	0.13	26.4	1.4	2.01	0.37
BGH039/97	25.88	0.13	26.9	1.3	3.94	0.78

* Laboratories 22 and 28 submitted two and four sets of results respectively.

Table 22 - Results for ^{65}Zn (higher level)

Sample	NPL Data		Analyst Data		Deviation (%)	u-test statistic
	^{65}Zn Bq kg ⁻¹	$\pm$ Bq kg ⁻¹	^{65}Zn Bq kg ⁻¹	$\pm$ Bq kg ⁻¹		
BGH001/97	20.13	0.17	21.0	0.9	4.32	0.95
BGH002/97	20.13	0.17	22.5	1.5	11.77	1.57
BGH003/97	20.13	0.17	22.1	1.4	9.79	1.40
BGH004/97	20.13	0.17	22.10	1.25	9.79	1.56
BGH005/97	20.13	0.17	20.1	1.1	-0.15	0.03
BGH006/97	20.13	0.17	21.3	1.3	5.81	0.89
BGH007/97	20.13	0.17	17.2	0.9	-14.56	3.20
BGH008/97	20.13	0.17	21.2	1.8	5.32	0.59
BGH011/97	20.13	0.17	23.12	1.82	14.85	1.64
BGH013/97	20.13	0.17	22.38	0.8	11.18	2.75
BGH014/97	20.13	0.17	18	4	-10.58	0.53
BGH015/97	20.13	0.17	15.7	1.46	-22.01	3.01
BGH016/97	20.13	0.17	21.8	1.3	8.30	1.28
BGH017/97	20.13	0.17	20.2	1.6	0.35	0.04
BGH018/97	20.13	0.17	21.0	2.1	4.32	0.41
BGH019/97	20.13	0.17	20.08	3.81	-0.25	0.01
BGH021/97	20.13	0.17	21.035	2.04	4.5	0.45
BGH022/97/1*	20.13	0.17	22.872	4.93	13.62	0.56
BGH022/97/2*	20.13	0.17	20.97	3.10	4.17	0.54
BGH023/97	20.13	0.17	20.7	4.2	2.83	0.14
BGH024/97	20.13	0.17	20.8	3.6	3.33	0.19
BGH025/97	20.13	0.17	21.983	0.95	9.21	1.92
BGH026/97	20.13	0.17	19.5	1.0	-3.13	0.62
BGH027/97	20.13	0.17	22.63	0.93	12.42	2.64

Sample	NPL Data		Analyst Data		Deviation (%)	u-test statistic
	^{65}Zn Bq kg^{-1}	$\pm$ Bq kg^{-1}	^{65}Zn Bq kg^{-1}	$\pm$ Bq kg^{-1}		
BGH028/97/1*	20.13	0.17	24.92	2.26	23.80	2.11
BGH028/97/2*	20.13	0.17	19.29	2.26	-4.18	0.37
BGH028/97/3*	20.13	0.17	27.70	2.93	37.61	2.58
BGH028/97/4*	20.13	0.17	21.99	1.88	9.24	0.99
BGH029/97	20.13	0.17	22.2	2.6	10.28	0.79
BGH031/97	20.13	0.17	20.8	1.4	3.33	0.48
BGH032/97	20.13	0.17	23.4	1.2	16.24	2.70
BGH033/97	20.13	0.17	20.13	1	0	0
BGH034/97	20.13	0.17	20.1	1	-0.15	0.03
BGH035/97	20.13	0.17	21.7	1.5	7.80	1.04
BGH036/97	20.13	0.17	20.9	1.1	3.83	0.69
BGH038/97	20.13	0.17	23.2	1.4	15.25	2.18
BGH039/97	20.13	0.17	20.0	1.7	-0.65	0.08

* Laboratories 22 and 28 submitted two and four sets of results respectively.

Table 23 - Results for ^{85}Sr (higher level)

Sample	NPL Data		Analyst Data		Deviation (%)	u-test statistic
	^{85}Sr Bq kg^{-1}	$\pm$ Bq kg^{-1}	^{85}Sr Bq kg^{-1}	$\pm$ Bq kg^{-1}		
BGH001/97	23.88	0.20	20.0	0.7	-16.25	5.33
BGH002/97	23.88	0.20	20.7	1.3	-13.32	2.42
BGH004/97	23.88	0.20	19.98	1.60	-16.33	2.42
BGH005/97	23.88	0.20	22.3	0.9	-6.62	1.71
BGH006/97	23.88	0.20	18.8	1.7	-21.27	2.97
BGH007/97	23.88	0.20	25.0	1.1	4.69	1.00
BGH008/97	23.88	0.20	25.8	2.6	8.04	0.74
BGH011/97	23.88	0.20	26.39	3.28	10.51	0.76
BGH013/97	23.88	0.20	25.49	1.01	6.74	1.56
BGH014/97	23.88	0.20	27	5	13.07	0.62
BGH015/97	23.88	0.20	7.82	1.16	-67.25	13.64
BGH016/97	23.88	0.20	20.6	1.4	-13.74	2.32
BGH017/97	23.88	0.20	21.5	1.4	-9.97	1.68
BGH018/97	23.88	0.20	23.2	2.3	-2.85	0.29
BGH021/97	23.88	0.20	26.010	1.47	8.92	1.74
BGH024/97	23.88	0.20	19.8	4.2	-17.09	0.97
BGH026/97	23.88	0.20	27.1	1.3	13.48	2.45
BGH027/97	23.88	0.20	18.50	1.27	-22.53	4.18
BGH028/97/1*	23.88	0.20	24.04	2.40	0.67	0.07
BGH028/97/2*	23.88	0.20	22.57	2.34	-5.49	0.56

Sample	NPL Data		Analyst Data		Deviation (%)	u-test statistic
	⁸⁵ Sr Bq kg ⁻¹	± Bq kg ⁻¹	⁸⁵ Sr Bq kg ⁻¹	± Bq kg ⁻¹		
BGH028/97/3*	23.88	0.20	31.95	3.34	33.79	2.41
BGH028/97/4*	23.88	0.20	28.35	2.32	18.72	1.92
BGH031/97	23.88	0.20	25.6	1.6	7.20	1.07
BGH032/97	23.88	0.20	27.7	1.4	16.00	2.70
BGH033/97	23.88	0.20	24.07	1.45	0.80	0.13
BGH034/97	23.88	0.20	27.0	1.70	13.07	1.82
BGH036/97	23.88	0.20	26.3	2.2	10.13	1.10
BGH038/97	23.88	0.20	20.3	0.16	-14.99	13.98
BGH039/97	23.88	0.20	21.1	1.3	-11.64	2.11

* Laboratories 22 and 28 submitted two and four sets of results respectively.

Table 24 - Results for ¹²⁵Sb (higher level)

Sample	NPL Data		Analyst Data		Deviation (%)	u-test statistic
	¹²⁵ Sb Bq kg ⁻¹	± Bq kg ⁻¹	¹²⁵ Sb Bq kg ⁻¹	± Bq kg ⁻¹		
BGH001/97	20.44	0.15	20.5	1.1	0.29	0.05
BGH002/97	20.44	0.15	20.7	1.5	1.27	0.17
BGH003/97	20.44	0.15	21.4	0.85	4.70	1.11
BGH004/97	20.44	0.15	21.39	1.42	4.65	0.67
BGH005/97	20.44	0.15	18.0	1.0	-11.94	2.41
BGH006/97	20.44	0.15	23.5	1.9	14.97	1.61
BGH007/97	20.44	0.15	21.0	0.9	2.74	0.61
BGH008/97	20.44	0.15	21.3	1.7	4.21	0.50
BGH011/97	20.44	0.15	21.90	1.32	7.14	1.10
BGH013/97	20.44	0.15	20.95	1.12	2.50	0.45
BGH014/97	20.44	0.15	17	3	-16.83	1.15
BGH015/97	20.44	0.15	19.1	1.32	-6.56	1.01
BGH016/97	20.44	0.15	20.5	1.4	0.29	0.05
BGH017/97	20.44	0.15	22.5	1.7	10.08	1.21
BGH018/97	20.44	0.15	19.86	2.0	-2.84	0.29
BGH019/97	20.44	0.15	29.87	6.29	46.14	1.50

Sample	NPL Data		Analyst Data		Deviation (%)	u-test statistic
	¹²⁵ Sb Bq kg ⁻¹	± Bq kg ⁻¹	¹²⁵ Sb Bq kg ⁻¹	± Bq kg ⁻¹		
BGH021/97	20.44	0.15	22.223	1.55	8.72	1.15
BGH022/97/1*	20.44	0.15	20.590	3.18	0.73	0.05
BGH022/97/2*	20.44	0.15	21.720	2.19	6.26	1.15
BGH023/97	20.44	0.15	25.9	2.5	26.71	2.18
BGH024/97	20.44	0.15	21.7	3.5	6.16	0.36
BGH025/97	20.44	0.15	22.646	0.88	10.79	0.47
BGH026/97	20.44	0.15	21.7	1.2	6.16	1.04
BGH027/97	20.44	0.15	19.65	0.62	-3.86	1.24
BGH028/97/1*	20.44	0.15	20.35	1.60	-0.44	0.06
BGH028/97/2*	20.44	0.15	21.57	1.87	5.53	0.60
BGH028/97/3*	20.44	0.15	19.95	2.02	-2.40	0.24
BGH028/97/4*	20.44	0.15	19.29	0.99	-5.63	1.15
BGH029/97	20.44	0.15	20.2	2.1	-1.17	0.11
BGH031/97	20.44	0.15	20.9	1.1	2.25	0.41
BGH032/97	20.44	0.15	20.9	2.2	2.25	0.21
BGH033/97	20.44	0.15	20.21	1	-1.13	0.23
BGH034/97	20.44	0.15	21.1	1.20	3.23	0.55
BGH035/97	20.44	0.15	20.1	1.4	-1.66	0.24
BGH036/97	20.44	0.15	19.82	0.4	-3.03	1.45
BGH038/97	20.44	0.15	20.3	1.5	-0.68	0.09
BGH039/97	20.44	0.15	21.1	1.3	3.23	0.50

* Laboratories 22 and 28 submitted two and four sets of results respectively.

Table 25 - Results for ¹³⁴Cs (higher level)

Sample	NPL Data		Analyst Data		Deviation (%)	u-test statistic
	¹³⁴ Cs Bq kg ⁻¹	± Bq kg ⁻¹	¹³⁴ Cs Bq kg ⁻¹	± Bq kg ⁻¹		
BGH001/97	15.99	0.14	14.1	0.5	-11.82	3.64
BGH002/97	15.99	0.14	16.7	1.0	4.44	0.70
BGH003/97	15.99	0.14	14.8	0.4	-7.44	2.81
BGH004/97	15.99	0.14	15.33	0.50	-4.13	1.27
BGH005/97	15.99	0.14	12.0	0.3	-24.95	12.05
BGH006/97	15.99	0.14	14.6	0.5	-8.69	2.68
BGH007/97	15.99	0.14	15.6	0.5	-2.44	0.75
BGH008/97	15.99	0.14	14.9	0.9	-6.82	1.2
BGH011/97	15.99	0.14	15.93	0.66	-0.38	0.09
BGH013/97	15.99	0.14	16.98	0.54	6.19	1.77
BGH014/97	15.99	0.14	16	2	0.06	0.005
BGH015/97	15.99	0.14	13.7	1.08	-14.32	2.10

Sample	NPL Data		Analyst Data		Deviation (%)	u-test statistic
	¹³⁴ Cs Bq kg ⁻¹	± Bq kg ⁻¹	¹³⁴ Cs Bq kg ⁻¹	± Bq kg ⁻¹		
BGH016/97	15.99	0.14	15.7	0.9	-1.81	0.32
BGH017/97	15.99	0.14	14.1	1.4	-11.82	1.34
BGH018/97	15.99	0.14	14.91	1.5	-6.75	0.72
BGH019/97	15.99	0.14	14.15	2.09	-11.51	0.88
BGH021/97	15.99	0.14	15.464	0.48	-3.29	1.06
BGH022/97/1*	15.99	0.14	14.794	0.85	-7.48	1.39
BGH022/97/2*	15.99	0.14	13.393	0.64	-16.24	7.44
BGH023/97	15.99	0.14	14.8	0.9	-7.44	1.31
BGH024/97	15.99	0.14	16.1	2.5	0.69	0.04
BGH025/97	15.99	0.14	14.752	0.27	-7.74	4.07
BGH026/97	15.99	0.14	17.1	0.7	6.94	1.55
BGH027/97	15.99	0.14	16.40	0.43	2.56	0.91
BGH028/97/1*	15.99	0.14	14.91	0.63	-6.75	1.67
BGH028/97/2*	15.99	0.14	15.17	0.76	-5.13	1.06
BGH028/97/3*	15.99	0.14	16.42	1.03	2.69	0.41
BGH028/97/4*	15.99	0.14	15.96	0.81	-0.19	0.04
BGH029/97	15.99	0.14	16.2	1.4	1.31	0.15
BGH031/97	15.99	0.14	14.2	0.5	-11.19	3.45
BGH032/97	15.99	0.14	15.9	1.6	-0.56	0.06
BGH033/97	15.99	0.14	14.82	0.65	-7.32	1.76
BGH034/97	15.99	0.14	15.30	0.62	-4.32	1.09
BGH035/97	15.99	0.14	15.7	1	-1.81	0.29
BGH036/97	15.99	0.14	14.65	0.08	-8.38	8.31
BGH038/97	15.99	0.14	15.6	2.2	-2.44	0.18
BHG039/97	15.99	0.14	16.1	0.8	0.69	0.14

* Laboratories 22 and 28 submitted two and four sets of results respectively.

Table 26 - Results for ¹³⁷Cs (higher level)

Sample	NPL Data		Analyst Data		Deviation (%)	u-test statistic
	¹³⁷ Cs Bq kg ⁻¹	± Bq kg ⁻¹	¹³⁷ Cs Bq kg ⁻¹	± Bq kg ⁻¹		
BGH001/97	26.92	0.22	26.2	0.5	-2.67	1.32
BGH002/97	26.92	0.22	29.7	0.8	10.33	3.35
BGH003/97	26.92	0.22	28.1	0.4	4.38	2.58
BGH004/97	26.92	0.22	27.81	0.50	3.31	1.63
BGH005/97	26.92	0.22	26.7	0.5	-0.82	0.40
BGH006/97	26.92	0.22	27.8	0.6	3.27	1.38
BGH007/97	26.92	0.22	25.8	0.6	-4.16	1.75
BGH008/97	26.92	0.22	27.8	1.2	3.27	0.72

Sample	NPL Data		Analyst Data		Deviation (%)	u-test statistic
	¹³⁷ Cs Bq kg ⁻¹	± Bq kg ⁻¹	¹³⁷ Cs Bq kg ⁻¹	± Bq kg ⁻¹		
BGH011/97	26.92	0.22	28.93	1.38	7.47	1.44
BGH013/97	26.92	0.22	29.50	0.81	9.58	3.07
BGH014/97	26.92	0.22	28	3	4.01	0.36
BGH015/97	26.92	0.22	27.7	1.08	2.90	0.71
BGH016/97	26.92	0.22	28.2	1.5	4.75	0.85
BGH017/97	26.92	0.22	24.5	1.9	-8.99	1.27
BGH018/97	26.92	0.22	28.12	2.8	4.46	0.43
BGH019/97	26.92	0.22	25.25	0.86	-6.20	1.88
BGH021/97	26.92	0.22	29.526	0.84	9.68	3.00
BGH022/97/1*	26.92	0.22	31.191	0.88	15.87	4.71
BGH022/97/2*	26.92	0.22	28.790	0.72	6.95	4.43
BGH023/97	26.92	0.22	29.5	1.1	9.58	2.30
BGH024/97	26.92	0.22	27.7	3.9	2.90	0.20
BGH025/97	26.92	0.22	29.826	0.39	10.79	6.49
BGH026/97	26.92	0.22	28.3	1.0	5.13	1.35
BGH027/97	26.92	0.22	27.11	0.75	0.71	0.24
BGH028/97/1*	26.92	0.22	28.85	0.90	7.17	2.08
BGH028/97/2*	26.92	0.22	29.08	0.98	8.02	2.15
BGH028/97/3*	26.92	0.22	27.57	1.14	2.41	0.56
BGH028/97/4*	26.92	0.22	28.61	0.86	6.28	1.90
BGH029/97	26.92	0.22	28.2	2.3	4.75	0.55
BGH031/97	26.92	0.22	27.4	0.9	1.78	0.52
BGH032/97	26.92	0.22	28.5	0.4	5.87	3.46
BGH033/97	26.92	0.22	27.30	1	1.41	0.38
BGH034/97	26.92	0.22	28.8	1.00	6.98	1.84
BGH035/97	26.92	0.22	30	1.7	11.44	1.80
BGH036/97	26.92	0.22	27.04	0.4	0.45	0.26
BGH038/97	26.92	0.22	28.7	1.6	6.61	1.10
BGH039/97	26.92	0.22	27.3	0.8	1.41	0.46

* Laboratories 22 and 28 submitted two and four sets of results respectively.

Table 27 - Results for ¹⁵⁴Eu (higher level)

Sample	NPL Data		Analyst Data		Deviation (%)	u-test statistic
	¹⁵⁴ Eu Bq kg ⁻¹	± Bq kg ⁻¹	¹⁵⁴ Eu Bq kg ⁻¹	± Bq kg ⁻¹		
BGH001/97	24.27	0.21	21.0	0.4	-13.47	7.24
BGH002/97	24.27	0.21	21.9	0.5	-9.77	4.37
BGH003/97	24.27	0.21	24.2	0.5	-0.29	0.13
BGH004/97	24.27	0.21	22.71	0.78	-6.43	1.93

Sample	NPL Data		Analyst Data		Deviation (%)	u-test statistic
	¹⁵⁴ Eu Bq kg ⁻¹	± Bq kg ⁻¹	¹⁵⁴ Eu Bq kg ⁻¹	± Bq kg ⁻¹		
BGH005/97	24.27	0.21	21.2	0.5	-12.65	5.66
BGH006/97	24.27	0.21	22.0	0.8	-9.35	2.74
BGH007/97	24.27	0.21	25.5	1.1	5.07	1.10
BGH008/97	24.27	0.21	24.4	1.3	0.54	0.10
BGH011/97	24.27	0.21	26.15	2.26	7.75	0.83
BGH013/97	24.27	0.21	26.96	0.85	11.08	3.07
BGH014/97	24.27	0.21	25	3	3.01	0.24
BGH015/97	24.27	0.21	25.45	2.7	4.86	0.44
BGH016/97	24.27	0.21	23.6	2.7	-2.76	0.25
BGH017/97	24.27	0.21	27.0	2.0	11.25	1.36
BGH018/97	24.27	0.21	37.56	3.8	54.76	3.49
BGH019/97	24.27	0.21	20.22	2.23	-16.69	1.81
BGH021/97	24.27	0.21	27.156	0.90	11.89	3.12
BGH022/97/1*	24.27	0.21	23.772	1.66	-2.05	0.30
BGH022/97/2*	24.27	0.21	21.847	1.12	-9.98	4.05
BGH023/97	24.27	0.21	28.7	1.3	18.25	3.36
BGH024/97	24.27	0.21	25.6	3.9	5.48	0.34
BGH025/97	24.27	0.21	21.661	0.48	-10.75	4.98
BGH026/97*	24.27	0.21	25.1	1.0	3.42	0.81
BGH027/97	24.27	0.21	23.34	0.71	-3.83	1.26
BGH028/97/1*	24.27	0.21	23.09	1.12	-4.86	1.04
BGH028/97/2*	24.27	0.21	28.40	1.70	17.02	2.41
BGH028/97/3*	24.27	0.21	25.94	1.28	6.88	1.29
BGH028/97/4*	24.27	0.21	22.17	0.71	-8.65	2.84
BGH029/97	24.27	0.21	27.4	2.3	12.90	1.36
BGH031/97	24.27	0.21	22.6	0.9	-6.88	1.81
BGH032/97	24.27	0.21	23.5	2.1	-3.17	0.36
BGH033/97	24.27	0.21	22.72	1.15	-6.39	1.33
BGH034/97	24.27	0.21	30.3	1.56	24.85	3.83
BGH035/97	24.27	0.21	25.2	0.8	3.83	1.12
BGH036/97	24.27	0.21	22.74	1.5	-6.30	1.01
BGH038/97	24.27	0.21	21.9	2.0	9.77	1.18
BGH039/97	24.27	0.21	23.9	1.6	-1.52	0.23

* Laboratories 22 and 28 submitted two and four sets of results respectively.

Table 28 - Results for ¹⁵⁵Eu (higher level)

Sample	NPL Data	Analyst Data	Deviation (%)	u-test statistic
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	¹⁵⁵ Eu Bq kg ⁻¹	± Bq kg ⁻¹	¹⁵⁵ Eu Bq kg ⁻¹	± Bq kg ⁻¹		
BGH001/97	21.18	0.23	22.0	1.0	3.87	0.80
BGH002/97	21.18	0.23	23.4	2.0	10.48	1.10
BGH003/97	21.18	0.23	20.6	0.5	-2.74	1.05
BGH004/97	21.18	0.23	16.70	0.63	-21.15	6.68
BGH005/97	21.18	0.23	17.4	0.7	-17.85	5.13
BGH006/97	21.18	0.23	21.4	0.8	1.04	0.26
BGH007/97	21.18	0.23	22.0	1.2	3.87	0.67
BGH008/97	21.18	0.23	13.3	1.1	37.2	7.01
BGH011/97	21.18	0.23	23.42	1.32	10.58	1.67
BGH013/97	21.18	0.23	25.70	1.87	21.34	2.40
BGH014/97	21.18	0.23	20	2	-5.57	0.59
BGH015/97	21.18	0.23	21.1	2.1	-0.38	0.04
BGH016/97	21.18	0.23	22.4	1.5	5.76	0.81
BGH017/97	21.18	0.23	22.4	1.4	5.76	0.86
BGH019/97	21.18	0.23	21.83	1.06	3.07	0.60
BGH021/97	21.18	0.23	21.659	0.89	2.26	0.52
BGH022/97/1*	21.18	0.23	32.393	2.47	52.94	4.52
BGH022/97/2*	21.18	0.23	21.589	1.15	1.93	0.66
BGH023/97	21.18	0.23	35.9	3.8	69.50	3.87
BGH024/97	21.18	0.23	24.8	3.8	17.09	0.95
BGH025/97	21.18	0.23	21.680	0.41	2.36	1.06
BGH026/97	21.18	0.23	21.4	1.2	1.04	0.18
BGH027/97	21.18	0.23	19.06	0.67	-10.01	2.99
BGH028/97/1*	21.18	0.23	19.74	0.67	-6.80	2.03
BGH028/97/2*	21.18	0.23	22.87	0.84	7.98	1.94
BGH028/97/3*	21.18	0.23	20.98	1.06	-0.94	0.18
BGH028/97/4*	21.18	0.23	20.39	0.68	-3.73	1.10
BGH029/97	21.18	0.23	23.6	2.1	11.43	1.15
BGH031/97	21.18	0.23	23.2	1.3	9.54	1.53
BGH032/97	21.18	0.23	23.4	1.0	10.48	2.16
BGH033/97	21.18	0.23	22.64	1.2	6.89	1.20
BGH034/97	21.18	0.23	22.6	1.14	6.70	1.22
BGH035/97	21.18	0.23	8	1	-62.23	12.84
BGH036/97	21.18	0.23	20.38	0.7	-3.78	1.09
BGH038/97	21.18	0.23	23.5	1.3	10.95	1.76

* Laboratories 22 and 28 submitted two and four sets of results respectively.

Table 29 - Results for ⁵⁷Co (lower level)

Sample	NPL Data		Analyst Data		Deviation (%)	u-test statistic
	^{57}Co Bq kg ⁻¹	$\pm$ Bq kg ⁻¹	^{57}Co Bq kg ⁻¹	$\pm$ Bq kg ⁻¹		
BGL001/97	2.81	0.03	2.87	0.10	2.14	0.57
BGL002/97	2.81	0.03	2.7	0.11	-3.91	0.96
BGL003/97	2.81	0.03	3.1	0.2	10.32	1.43
BGL004/97	2.81	0.03	2.86	0.23	1.78	0.22
BGL006/97	2.81	0.03	2.81	0.28	0	0
BGL007/97	2.81	0.03	2.6	0.3	-7.47	0.7
BGL009/97	2.81	0.03	<2	-	> -29	-
BGL011/97	2.81	0.03	2.18	0.40	-22.42	1.57
BGL012/97	2.81	0.03	2.7	0.7	-3.91	0.16
BGL013/97	2.81	0.03	3.0	0.3	6.76	0.63
BGL014/97	2.81	0.03	1.5	0.2	-46.62	6.48
BGL015/97	2.81	0.03	2.8238	0.19	0.49	0.07
BGL016/97/1*	2.81	0.03	2.4082	0.58	-14.30	0.69
BGL016/97/2*	2.81	0.03	3.1221	0.58	11.11	0.54
BGL017/97	2.81	0.03	2.8	0.5	-0.36	0.02
BGL018/97	2.81	0.03	2.613	0.24	-7.01	0.81
BGL019/97	2.81	0.03	3.0	0.2	6.76	0.94
BGL021/97	2.81	0.03	2.85	0.07	1.42	0.53
BGL022/97/1*	2.81	0.03	2.53	0.18	-9.96	1.53
BGL022/97/2*	2.81	0.03	2.41	0.12	-14.23	3.23
BGL023/97	2.81	0.03	2.4	0.3	-14.59	1.36
BGL024/97	2.81	0.03	2.8	0.1	-0.36	0.10
BGL026/97	2.81	0.03	3.00	0.70	6.76	0.27
BGL027/97	2.81	0.03	4.55	0.24	61.92	7.19
BGL028/97	2.81	0.03	2.52	0.11	-10.32	2.54

* Laboratories 16 and 22 both submitted two sets of results.

Table 30 - Results for ^{60}Co (lower level)

Sample	NPL Data		Analyst Data		Deviation (%)	u-test statistic
	^{60}Co Bq kg ⁻¹	$\pm$ Bq kg ⁻¹	^{60}Co Bq kg ⁻¹	$\pm$ Bq kg ⁻¹		
BGL001/97	2.79	0.02	3.64	0.24	30.47	3.53
BGL002/97	2.79	0.02	3.60	0.17	29.03	4.73
BGL003/97	2.79	0.02	3.0	0.3	7.53	0.70
BGL004/97	2.79	0.02	3.79	0.33	35.84	3.02
BGL006/97	2.79	0.02	2.92	0.15	4.66	0.86
BGL007/97	2.79	0.02	2.8	0.3	0.36	0.03
BGL009/97	2.79	0.02	3.0	0.5	7.53	0.42
BGL011/97	2.79	0.02	3.11	0.35	11.47	0.91
BGL012/97	2.79	0.02	2.8	0.2	0.36	0.05
BGL013/97	2.79	0.02	2.7	0.4	-3.23	0.22
BGL014/97	2.79	0.02	2.9	0.3	3.94	0.37
BGL015/97	2.79	0.02	3.1523	0.34	12.99	1.06
BGL016/97/1*	2.79	0.02	<1.15	-	> -58	-
BGL016/97/2*	2.79	0.02	6.9555	1.10	149.30	3.79
BGL017/97	2.79	0.02	2.9	0.5	3.94	0.22
BGL018/97	2.79	0.02	3.593	0.25	28.78	3.20
BGL019/97	2.79	0.02	2.5	0.1	-10.39	2.84
BGL021/97	2.79	0.02	3.66	0.12	31.18	7.15
BGL022/97/1*	2.79	0.02	3.35	0.16	20.07	3.47
BGL022/97/2*	2.79	0.02	2.97	0.17	6.45	1.05
BGL023/97	2.79	0.02	3.7	0.4	32.62	2.27
BGL024/97	2.79	0.02	2.8	0.2	0.36	0.05
BGL026/97	2.79	0.02	2.89	0.11	3.58	0.89
BGL027/97	2.79	0.02	2.66	0.16	-4.66	0.81
BGL028/97	2.79	0.02	2.67	0.09	-4.30	1.30

* Laboratories 16 and 22 both submitted two sets of results.

Table 31 - Results for ^{65}Zn (lower level)

Sample	NPL Data		Analyst Data		Deviation (%)	u-test statistic
	^{65}Zn Bq kg^{-1}	$\pm$ Bq kg^{-1}	^{65}Zn Bq kg^{-1}	$\pm$ Bq kg^{-1}		
BGL001/97	2.17	0.02	3.03	0.41	39.63	2.10
BGL002/97	2.17	0.02	3.16	0.65	45.62	1.52
BGL003/97	2.17	0.02	2.7	0.6	24.42	0.88
BGL004/97	2.17	0.02	3.09	0.98	42.40	0.94
BGL006/97	2.17	0.02	2.79	0.28	28.57	2.21
BGL007/97	2.17	0.02	2.1	0.9	-3.23	0.08
BGL009/97	2.17	0.02	< 5	-	-	-
BGL011/97	2.17	0.02	1.43	0.58	-34.10	1.28
BGL012/97	2.17	0.02	2.3	0.3	5.99	0.44
BGL013/97	2.17	0.02	2.5	0.6	15.21	0.55
BGL014/97	2.17	0.02	2.6	0.3	19.82	1.43
BGL015/97	2.17	0.02	< 1.2	-	> -45	-
BGL016/97/1*	2.17	0.02	6.368	2.83	193.46	1.48
BGL016/97/2*	2.17	0.02	<5.65	-	-	-
BGL017/97	2.17	0.02	2.4	0.9	10.60	0.26
BGL018/97	2.17	0.02	2.775	0.78	27.88	0.78
BGL019/97	2.17	0.02	2.5	0.3	15.21	0.92
BGL021/97	2.17	0.02	2.24	0.14	3.23	0.49
BGL022/97/1*	2.17	0.02	4.69	0.44	116.13	5.72
BGL022/97/2*	2.17	0.02	2.05	0.44	-5.53	0.27
BGL023/97	2.17	0.02	2.5	0.9	15.21	0.37
BGL024/97	2.17	0.02	2.4	0.3	10.6	0.76
BGL026/97	2.17	0.02	2.36	0.28	8.76	0.68
BGL027/97	2.17	0.02	1.95	0.305	-10.14	0.72
BGL028/97	2.17	0.02	1.44	0.10	-33.64	7.16

* Laboratories 16 and 22 both submitted two sets of results.

Table 32 - Results for ^{85}Sr (lower level)

Sample	NPL Data		Analyst Data		Deviation (%)	u-test statistic
	^{85}Sr Bq kg^{-1}	$\pm$ Bq kg^{-1}	^{85}Sr Bq kg^{-1}	$\pm$ Bq kg^{-1}		
BGL001/97	2.57	0.03	4.30	0.70	67.32	2.47
BGL002/97	2.57	0.03	2.90	0.70	12.84	0.47
BGL004/97	2.57	0.03	3.29	0.58	28.02	1.24
BGL006/97	2.57	0.03	3.54	0.56	37.74	1.73
BGL007/97	2.57	0.03	5.0	1.3	94.55	1.87
BGL009/97	2.57	0.03	<8	-	-	-
BGL011/97	2.57	0.03	1.20	0.64	-53.31	2.14
BGL012/97	2.57	0.03	3.8	0.4	47.86	3.07
BGL014/97	2.57	0.03	2.85	0.3	10.89	0.93
BGL015/97	2.57	0.03	4.5177	0.79	75.79	2.46
BGL019/97	2.57	0.03	3.1	0.3	20.62	1.76
BGL021/97	2.57	0.03	3.26	0.20	26.85	3.41
BGL022/97/1*	2.57	0.03	5.52	0.66	114.79	4.47
BGL022/97/2*	2.57	0.03	4.80	0.68	86.77	3.28
BGL024/97	2.57	0.03	3.6	0.5	40.08	2.06
BGL026/97	2.57	0.03	3.29	0.33	28.02	2.17
BGL027/97	2.57	0.03	4.20	0.75	63.42	2.17
BGL028/97	2.57	0.03	4.13	0.26	60.70	5.96

* Laboratories 16 and 22 both submitted two sets of results.

Table 33 - Results for ^{125}Sb (lower level)

Sample	NPL Data		Analyst Data		Deviation (%)	u-test statistic
	^{125}Sb Bq kg^{-1}	$\pm$ Bq kg^{-1}	^{125}Sb Bq kg^{-1}	$\pm$ Bq kg^{-1}		
BGL001/97	2.20	0.02	2.79	0.38	26.82	1.55
BGL002/97	2.20	0.02	2.66	0.35	20.91	1.31
BGL003/97	2.20	0.02	2.8	0.8	27.27	0.75
BGL004/97	2.20	0.02	5.56	1.11	152.73	3.03
BGL006/97	2.20	0.02	2.51	0.29	14.09	1.07
BGL007/97	2.20	0.02	3.0	0.8	36.36	1.0
BGL009/97	2.20	0.02	< 4	-	-	-
BGL012/97	2.20	0.02	2.0	0.3	-9.09	0.67
BGL013/97	2.20	0.02	2.5	0.4	13.64	0.75
BGL014/97	2.20	0.02	2.18	0.2	-0.91	0.10
BGL015/97	2.20	0.02	4.4495	1.01	102.25	2.23
BGL016/97/1*	2.20	0.02	10.943	3.37	397.41	2.59
BGL016/97/2*	2.20	0.02	4.4275	2.14	101.25	1.04
BGL017/97	2.20	0.02	2.7	0.9	22.73	0.56
BGL018/97	2.20	0.02	3.712	0.78	68.73	1.94
BGL019/97	2.20	0.02	2.5	0.3	13.64	1.0
BGL021/97	2.20	0.02	2.36	0.16	7.27	0.99
BGL022/97/1*	2.20	0.02	1.95	0.27	-11.36	0.92
BGL022/97/2*	2.20	0.02	2.09	0.24	-5	0.46
BGL023/97	2.20	0.02	3.5	0.8	59.09	1.62
BGL024/97	2.20	0.02	2.4	0.3	9.09	0.67
BGL026/97	2.20	0.02	2.00	0.45	-9.09	0.44
BGL027/97	2.20	0.02	3.22	0.43	46.36	2.37
BGL028/97	2.20	0.02	2.14	0.11	-2.73	0.54

* Laboratories 16 and 22 both submitted two sets of results.

Table 34 - Results for ^{134}Cs (lower level)

Sample	NPL Data		Analyst Data		Deviation (%)	u-test statistic
	^{134}Cs Bq kg^{-1}	$\pm$ Bq kg^{-1}	^{134}Cs Bq kg^{-1}	$\pm$ Bq kg^{-1}		
BGL001/97	1.72	0.02	1.73	0.17	0.58	0.06
BGL002/97	1.72	0.02	2.87	0.36	66.86	3.19
BGL003/97	1.72	0.02	1.4	0.3	-18.60	1.06
BGL004/97	1.72	0.02	1.97	0.24	14.53	1.04
BGL006/97	1.72	0.02	1.88	0.14	9.30	1.13
BGL007/97	1.72	0.02	1.7	0.3	1.16	0.07
BGL009/97	1.72	0.02	2.3	0.6	33.72	0.97
BGL011/97	1.72	0.02	1.21	0.24	-29.65	2.12
BGL012/97	1.72	0.02	2.0	0.1	16.28	2.75
BGL013/97	1.72	0.02	1.4	0.2	-18.60	1.59
BGL014/97	1.72	0.02	1.58	0.2	-8.14	0.70
BGL015/97	1.72	0.02	1.6447	0.19	-4.38	0.39
BGL016/97/1*	1.72	0.02	<1.21	-	> -30	-
BGL016/97/2*	1.72	0.02	2.59	0.55	50.58	1.58
BGL017/97	1.72	0.02	1.8	0.4	4.65	0.20
BGL018/97	1.72	0.02	1.195	0.18	-30.52	2.90
BGL019/97	1.72	0.02	1.7	0.1	-1.16	0.20
BGL021/97	1.72	0.02	2.02	0.09	17.44	3.25
BGL022/97/1*	1.72	0.02	2.18	0.19	26.74	2.41
BGL022/97/2*	1.72	0.02	1.40	0.15	-18.60	2.11
BGL023/97	1.72	0.02	1.2	0.2	-30.23	2.59
BGL024/97	1.72	0.02	1.6	0.1	-6.98	1.18
BGL026/97	1.72	0.02	1.37	0.15	-20.35	2.31
BGL027/97	1.72	0.02	1.74	0.13	1.16	0.15
BGL028/97	1.72	0.02	1.60	0.06	-6.98	1.90

* Laboratories 16 and 22 both submitted two sets of results.

Table 35 - Results for ^{137}Cs (lower level)

Sample	NPL Data		Analyst Data		Deviation (%)	u-test statistic
	^{137}Cs Bq kg^{-1}	$\pm$ Bq kg^{-1}	^{137}Cs Bq kg^{-1}	$\pm$ Bq kg^{-1}		
BGL001/97	2.90	0.03	3.79	0.22	30.69	4.01
BGL002/97	2.90	0.03	4.58	0.31	57.93	5.39
BGL003/97	2.90	0.03	3.2	0.3	10.34	1.0
BGL004/97	2.90	0.03	3.22	0.25	11.03	1.27
BGL006/97	2.90	0.03	2.82	0.11	2.76	0.70
BGL007/97	2.90	0.03	3.0	0.3	3.45	0.33
BGL009/97	2.90	0.03	2.0	0.6	-31.03	1.50
BGL011/97	2.90	0.03	3.18	0.29	9.66	0.96
BGL012/97	2.90	0.03	3.1	0.2	6.90	0.99
BGL013/97	2.90	0.03	2.6	0.3	-10.34	1.00
BGL014/97	2.90	0.03	3.02	0.3	4.14	0.40
BGL015/97	2.90	0.03	4.7546	0.32	63.95	5.77
BGL016/97/1*	2.90	0.03	4.944	0.55	70.48	3.71
BGL016/97/2*	2.90	0.03	4.40	0.43	51.72	3.48
BGL017/97	2.90	0.03	3.0	0.5	3.45	0.20
BGL018/97	2.90	0.03	3.642	0.33	25.59	2.24
BGL019/97	2.90	0.03	3.2	0.2	10.34	1.48
BGL021/97	2.90	0.03	2.89	0.10	-0.34	0.10
BGL022/97/1*	2.90	0.03	2.27	0.17	-21.72	3.65
BGL022/97/2*	2.90	0.03	3.41	0.26	17.59	1.95
BGL023/97	2.90	0.03	3.0	0.3	3.45	0.33
BGL024/97	2.90	0.03	3.3	0.2	13.79	1.98
BGL026/97	2.90	0.03	3.00	0.10	3.455	0.96
BGL027/97	2.90	0.03	3.92	0.185	35.17	5.44
BGL028/97	2.90	0.03	2.95	0.09	1.72	0.53

* Laboratories 16 and 22 both submitted two sets of results.

Table 36 - Results for ^{154}Eu (lower level)

Sample	NPL Data		Analyst Data		Deviation (%)	u-test statistic
	^{154}Eu Bq kg^{-1}	$\pm$ Bq kg^{-1}	^{154}Eu Bq kg^{-1}	$\pm$ Bq kg^{-1}		
BGL001/97	2.61	0.03	2.56	0.14	-1.92	0.35
BGL002/97	2.61	0.03	< 1.7	-	> -35	-
BGL003/97	2.61	0.03	2.6	0.3	-0.38	0.03
BGL004/97	2.61	0.03	2.19	0.34	-16.09	1.23
BGL006/97	2.61	0.03	3.22	0.37	23.37	1.64
BGL007/97	2.61	0.03	2.8	0.3	7.28	0.63
BGL009/97	2.61	0.03	< 7	-	-	-
BGL011/97	2.61	0.03	2.11	0.73	-19.16	0.68
BGL012/97	2.61	0.03	2.7	0.7	3.45	0.13
BGL013/97	2.61	0.03	3.6	0.7	37.93	1.41
BGL014/97	2.61	0.03	4.29	0.5	64.37	3.35
BGL015/97	2.61	0.03	3.4902	0.26	33.72	3.36
BGL016/97/1*	2.61	0.03	2.4962	0.78	-4.36	0.15
BGL016/97/2*	2.61	0.03	2.9456	0.73	12.86	0.46
BGL017/97	2.61	0.03	2.7	0.6	3.45	0.15
BGL018/97	2.61	0.03	2.493	0.30	-4.48	0.39
BGL019/97	2.61	0.03	2.6	0.2	-0.38	0.05
BGL021/97	2.61	0.03	2.88	0.20	10.34	1.34
BGL022/97/1*	2.61	0.03	2.53	0.25	-3.07	0.32
BGL022/97/2*	2.61	0.03	1.92	0.19	-26.44	3.59
BGL023/97	2.61	0.03	5.3	0.6	103.07	4.48
BGL024/97	2.61	0.03	2.5	0.1	-4.21	1.05
BGL026/97	2.61	0.03	2.00	0.48	-23.37	1.27
BGL027/97	2.61	0.03	4.54	0.405	73.95	4.75
BGL028/97	2.61	0.03	2.40	0.13	-8.05	1.57

* Laboratories 16 and 22 both submitted two sets of results.

Table 37 - Results for ^{155}Eu (lower level)

Sample	NPL Data		Analyst Data		Deviation (%)	u-test statistic
	^{155}Eu Bq kg^{-1}	$\pm$ Bq kg^{-1}	^{155}Eu Bq kg^{-1}	$\pm$ Bq kg^{-1}		
BGL001/97	2.28	0.03	3.22	0.42	41.23	2.23
BGL002/97	2.28	0.03	4.10	0.60	79.82	3.03
BGL003/97	2.28	0.03	2.8	0.4	22.81	1.30
BGL004/97	2.28	0.03	2.44	0.40	7.02	0.40
BGL006/97	2.28	0.03	1.95	0.25	-14.47	1.31
BGL007/97	2.28	0.03	1.7	0.6	-25.44	0.97
BGL009/97	2.28	0.03	3.3	1.0	44.7	1.02
BGL011/97	2.28	0.03	3.48	1.03	52.63	1.16
BGL012/97	2.28	0.03	3.0	0.3	31.58	2.39
BGL013/97	2.28	0.03	2.8	0.6	22.81	0.87
BGL015/97	2.28	0.03	2.4856	0.34	9.02	0.60
BGL016/97/1*	2.28	0.03	<2.67	-	-	-
BGL016/97/2*	2.28	0.03	3.9649	1.15	73.90	1.46
BGL017/97	2.28	0.03	2.7	0.6	18.42	0.70
BGL018/97	2.28	0.03	<1.47	-	> -36	-
BGL019/97	2.28	0.03	2.6	0.3	14.04	1.06
BGL021/97	2.28	0.03	2.16	0.12	-5.26	0.97
BGL022/97/1*	2.28	0.03	2.97	1.10	30.26	0.62
BGL022/97/2*	2.28	0.03	2.11	0.12	-7.46	1.37
BGL023/97	2.28	0.03	2.2	0.8	-3.51	0.10
BGL024/97	2.28	0.03	2.7	0.2	18.42	2.08
BGL026/97	2.28	0.03	2.42	0.21	6.14	0.66
BGL027/97	2.28	0.03	3.15	0.28	38.16	3.09
BGL028/97	2.28	0.03	2.31	0.08	1.32	0.35

* Laboratories 16 and 22 both submitted two sets of results.

Table 38- Other reported radionuclides

Sample identifier	Radionuclide	Reported activity concentration (Bq kg ⁻¹)	Overall uncertainty (Bq kg ⁻¹)
BGH018/97	²² Na	9.6	1.0
BGH019/97	^{110m} Ag	11.78	0.82
BGH022/97/1*	⁹⁵ Zr	48.233	15.72
BGH022/97/*2	⁹⁵ Zr	19.267	11.64
BGH023/97	¹⁰⁹ Cd	64.9	15.1
BGL014/97	⁴⁶ Sc	1.6	0.2
BGL018/97	²² Na	0.922	0.18
BGL019/97	⁵⁶ Co	1.6	0.4
BGL016/97	⁵⁸ Co	<5.12	-
BGL016/97	⁵⁸ Co	10.131	4.08
BGL016/97	⁸⁸ Y	8.5372	2.03
BGL016/97	⁸⁸ Y	<2.27	-

APPENDIX 1

List of participants (Alphabetically by company)

J Toole
AEA Technology Plc
551 Harwell
Didcot
Oxfordshire
OX11 0RA

J A Desmond
British Nuclear Fuels plc
Geoffrey Schofield Laboratories
Moor Row
Cumbria
CA24 3JZ

R Lukey
Veterinary Laboratories Agency
Woodham Lane
New Haw
Addlestone
Surrey
KT15 3NB

Mr I Warburton
Cardiff Scientific Services
Crofts Street
Roath
Cardiff, CF2 3DY

Mr Y Bourlat
CEA
Etablissement de Bruyères-le-Châtel
Réception Bât. PM1
Domaine de Garad Rué
91680 Bruyères-Le Châtel
France

Boguslaw Michalik
Central Mining Institute

Laboratory of Radiometry
Pl. Gwarkow 1
40-166 Katowice
Poland

Mr L Exmelin
COGEMA La Hague
Laboratoire D'Analyses Médicales
50444 Beaumont-Hague Cedex
France

N.Baglan
Commissariat a L'Energie Atomique de Fontenay aux Roses
Route du Panorama
92265 Fontenay aux Rose Cedex
France

Mr A Johnson
DANI
Agriculture and Food Science Centre
Food Science Division
Newforge Lane
Belfast BT9 5PX

Mr T Gingell
DERA
Radiation Protection Services
Crescent Road
Alverstoke
Hants PO12 2DL

G Shepherd
Devonport Management Limited
Devonport Royal Dockyard
Noeth Yard, Devonport
Plymouth
Devon
PL1 4SG

K McKay
Glasgow Scientific Services
64 Everard Drive
Glasgow
G21 1XG

J Carrington
GMSS
Scotscroft Building
Towers 2000 Business Park
Didsbury
Manchester
M20 2RY

P McKenna

Government Analysts Laboratory
Department of Local Government
Kingswood Grove
Douglas
Isle of Man
IM1 3LY

R McReddie
ICI Tracerco
PO Box 1
Belasis Avenue
Billingham
TS23 1LB

R Bojanowski
Institute of Oceanology
Powstancow Warszawy 55
81-712 SOPOT
Poland

A Sanchez
Institute of Terrestrial Ecology
Merlewood Research Station
Windemere Road
Grange-over-Sands
Cumbria
LA11 6JU

K Reardon
Laboratory of Government Chemist
Queens Road
Teddington
Middlesex
TW11 0LY

K Odell
BNFL Magnox Generation
Berkerley Centre
Berkerley
Gloucestershire
G13 9PB

T Godfrey
Magnox Eelectric plc
Bradwell Power Station
Bradwell-On-Sea
Southminster
Essex
CM0 7HP

P Clarke
Magnox Electric plc
Oldbury-On-Severn Power Station
Oldbury Naite
Thornbury
South Gloucestershire
BS12 1RQ

G Ham
National Radiological Protection Board
Chilton
Didcot
Oxfordshire
OX11 0RQ

M Youngman
National Radiological Protection Board
Block 'F'
Chilton
Didcot
Oxfordshire
OX11 0RQ

J Dunderdale
National Radiological Protection Board
Northern Centre
Hospital Lane
Cookridge, Leeds
LS16 6RW

S Williams
British Energy
Nuclear Electric Plc
Hartlepool Power Station
Tees Road
Hartlepool
TS25 2BZ

S Long
Radiological Protection Institute of Ireland
3 Clonskeagh Square
Clonskeagh Road
Dublin 14
Ireland

J Kemp
Reactor Chemistry Section
Scientific Services
Wood Road
Rosyth Royal Dockyard

Rosyth
FIFE, KY11 2YD

F Barr/E Howie
Scottish Nuclear Ltd
Hunterston Power Station
West Kilbride
Ayrshire
KA23 9QJ

S Day
Stanger Science and Environment
Great Guildford House
30 Great Guildford Street
London
SE1 0ES

J Hartley
Somerset Scientific Services
County Laboratory
County Hall
Taunton
Somerset TA1 4DY

Gerard Puil
SUBATECH
4 rue Alfred Kastler
BP 20722
44307 Nantes Cedex 3
France

R Sharrock
Urenco(Capenhurst)Ltd
Chemistry Services, B.C16
Capenhurst
Chester
CH1 6ER

P Jodlowski
University of Mining and Metallurgy
Faculty of Physics and Nuclear Techniques
Al.Mickiewicza 30
PI-30-059 KRAKOW
Poland

J Ennis
Dockside Laboratory
VSEL
Barrow-in-Furness
Cumbria
LA14 1AF