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Intercomparison of Radionuclides in Environmental Samples 2000-2001

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Abstract

An intercomparison exercise on radionuclides in environmental samples was carried out during 2000-2001 as part of a Nordic NKS project. The exercise included six sample types (aerosols, dry milk, soil, seawater, seaweed and lake water) and a range of man-made and naturally occurring radionuclides, mainly gamma-emitters but also beta- and alpha-emitters. A total of 25 Nordic and Baltic laboratories participated. The analytical quality across participants was generally good with about two thirds of the results in close agreement with estimated mean values. The exercise has demonstrated improved agreement between the results and more realistic analytical uncertainties submitted by the participants compared with a previous exercise carried out during 1998-1999 in the same NKS project.

Key words

Cesium 137; Environmental Materials; Gamma Radiation; Interlaboratory Comparisons; Milk; Radioactivity; Seawater; Seaweeds; Soil; Strontium 90; Technetium 99; Transuranium Elements

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Report from the NKS/BOK-1.1 Project
Laboratory Measurements and Quality Assurance

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Contents

Summary

In the second NKS intercomparison exercise in the BOK-1.1 project three types of sample materials were repeated from the first round (dried milk, seaweed and seawater) and three new materials were introduced (aerosols, soil and lake water). Weighted average radionuclide concentrations were calculated for each sample material excluding outlying results.

The results for dry milk were similar to those from the first round with 15 out of 19 results included in the weighted average for K-40 and Cs-137. The results indicated improvement for Cs-137, which could be attributed to more realistic (higher) uncertainties and better background subtraction (fewer results being too high). The results for seawater improved significantly. In the first round the results showed considerable scatter, which was reduced in the second round, but still there is room for improvement with only 4 out of 8 results included in the weighted mean. Three laboratories analysed the seawater for Tc-99 with good agreement. For seaweed the results were not better after the second intercomparison. The activity levels of the seaweed samples were quite similar for the two rounds, but the scatter in the results increased for the second round.

The soil samples included were from Gävle, Sweden, and contained relatively high levels of Cs-137, easy to analyse and with good counting statistics. However, the scatter in the results was relatively large compared to the counting statistics. One reason could be variable moisture content due to incomplete drying. The soil samples were also analysed for Pu and very good agreement was found for 6 of the 7 submitted results. The aerosol material was relatively difficult to analyse and only 60 % of the results were included in the weighted mean. The lake water was also from Gävle, Sweden, and did not represent a low-level sample for Cs-137 (approx. 170 Bq m^{-3}). Eight out of 11 results were included in the weighted mean.

Overall, 70 - 90% of the gamma spectrometric results were included in the weighted means for the traditional sample types. For the difficult samples (especially seawater and aerosols) these numbers dropped to 50 - 70%. There were no significant differences between the first and the second intercomparison. Five sample types were analysed for Sr-90 by up to 10 laboratories. Generally the agreement was poorer than for the gamma analysis, but the variability of the results was reduced significantly from the first to the second round. This may partly be explained by the fact that a number of participants with low performance for the Sr-90 analyses in the first exercise did not participate in the second exercise.

In summary, both intercomparisons have demonstrated that there is room for considerable improvement of the quality for analysis of radioactivity in environmental samples. The fact that complex analyses for Pu-239/240 show better results than relatively simple gamma spectrometric analyses indicates that there is a strong 'operator dependence'. Training and improved quality control are essential in order to improve the analytical quality.

1 Introduction

The work described in this report is part of a sub-project BOK-1.1 of the Nordic Nuclear Safety Research Programme (NKS) 1998-2001 devoted to "Laboratory measurements and quality assurance". Important activities within BOK-1.1 are intercomparison exercises designed to test the quality of laboratory analyses of radioactivity in environmental samples. Two intercomparison exercises have been carried out. The first was completed in the autumn of 1999 (Fogh, 2000) and included six types of sample material and a range of radionuclides. This report presents the results from the second intercomparison exercise, which had participants from 25 laboratories some of which submitted results from more than one group.

The present exercise was based on information collected in a questionnaire circulated among the participants prior to the exercise. Six environmental materials: dry milk, aerosol, soil, seaweed, seawater and lake water, were used (Table 1). Homogeneity tests are described, and the results from the participants are given and discussed according to sample material followed by an overall discussion.

Table ***Fejl! Ingen tekst med den anførte typografi i dokumentet.****. Sample types and relevant isotope determinations for the present exercise.*

Sample type	γ-emitters	Sr-90	Tc-99	Transuranics
Dry milk	X	X		
Aerosol	X	X		
Soil	X	X		X
Seaweed	X	X	X	
Seawater	X	X	X	
Lake water	X	X		

1.1 Statistical methods applied

The homogeneity of the sample materials was tested from repeated analyses carried out and applying a X^2 (Chi-square) test to the results. First a weighted average was calculated:

$$\overline{A} = \frac{\sum_{i=1}^{n} A_i \frac{1}{s_i^2}}{\sum_{i=1}^{n} \frac{1}{s_i^2}},$$

where $\overline{A}$ is the average activity, A_i is the activity of the i-th analysis and s_i is the standard deviation of the i-th analysis. The X^2 sum is then calculated as:

$$X^2 = \sum_{i=1}^{n} X_i^2 = \sum_{i=1}^{n} (A_i - \overline{A})^2 / s_i^2$$

If radionuclides are homogeneously distributed within a sample, the variability between sub-samples should be explained by the statistical counting uncertainties. The X^2 sum would then be approximately Chi-square distributed with a value of expectation equal to the number of measurements.

Participants were asked to provide total uncertainties of the analytical results corresponding to one standard deviation. If the reported uncertainties were below 5% these were changed to 5% in order to ensure that single values reported with very low uncertainties did not influence the weighted mean too much.

An AVM value (Accepted Value Mean) was calculated by excluding all results with X^2 values larger than 3 in an iterative process. First the result with the largest X_i^2 value was excluded and then the X^2 was recalculated and a new largest value deleted until all X_i^2 values were below 3.

2 Soil

Soil was collected July 2001 from Gävle in Sweden, the area that experienced the highest fallout of Cs-137 in Western Europe after the Chernobyl accident. Sampling was done in the forest behind the Scandic Hotel in the western outskirts of town. This soil was selected as the most appropriate matrix to use for comparing Pu-238, Pu-239/240 and Am-241 analyses.

The soil was dried at room temperature, homogenised in a grinding mill and finally dried at 80 ^{o}C. Each participant received a 200-g soil sample.

2.1 Homogeneity analyses

Ten soil sub-samples were packed in 200 ml cylindrical containers and gamma counted. The values obtained and the corresponding X^2 values are shown in Table 2.1, and these show that the soil is homogenous within the counting uncertainties except for Cs-137. The observed variability for Cs-137 is accounted for in the Chi-square test by 1% in addition to the counting statistics and this small deviation from homogeneity is considered acceptable for the purpose of the intercomparison.

Table 2.1 Review of the results of the X^2 test on 10 sub-samples of 200-ml soil

Soil	Activity [Bq/kg]	No. samples	SD [Bq/kg]	SE [Bq/kg]	X2	In-homogeneity [%]
K-40	553	10	7.81	2.47	10.6	
Cs-134	12.8	10	0.25	0.08	1.7	
Cs-137	1906	10	23	7	394.2	1
Tl-208	20.1	10	0.9	0.3	8.5	
Ra-226	22.0	10	1.0	0.3	13.8	
Th-232	20.2	10	0.9	0.3	9.5	

The homogeneity of the soil with respect to Pu-239+240 was tested prior to distribution. The results for Pu-239+240 (Figure 2.1) show a standard deviation of 7% across the 8 analyses indicating the soil is homogenous within the analytical uncertainty.

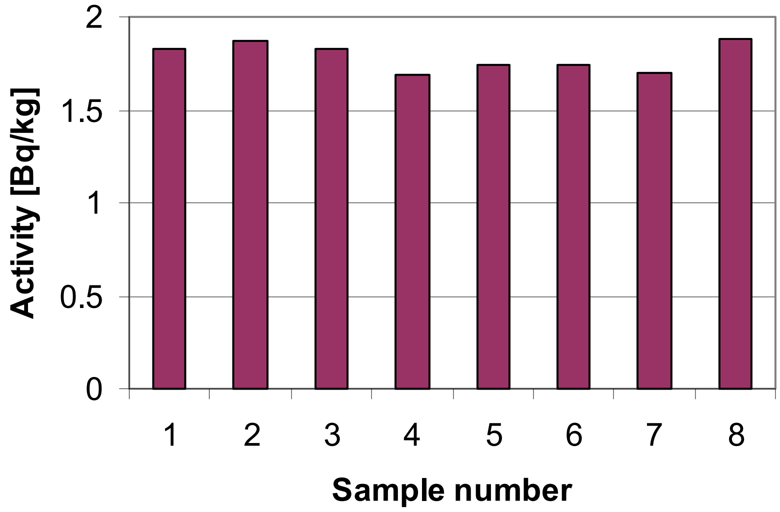

Figure 2.1 Homogeneity test for the soil material with regard to Pu-239+240 activity concentration.

2.2 Gamma results

The results from the gamma analyses are shown in Table 2.2 and Figs. 2.2-2.7. The results are generally in good agreement with the majority of results included in the accepted value mean (AVM).

Table 2.2 Review of mean concentrations of radionuclides in the the soil material.

	Number of results	Number in AVM	AVM value [Bq/kg]	AVM min [Bq/kg]	AVM max [Bq/kg]
K-40	22	14	509	448	553
Sr-90	7	5	24.1	22.6	27
Cs-134	22	16	13.7	12.8	15.3
Cs-137	24	20	2061	1890	2285
Pb-210	4	4	140	88	158
Ra-226	12	7	23.2	21.5	29.7
Th-228	6	6	19.8	18.2	23.7
Th-232	12	9	19.8	17.3	30.5

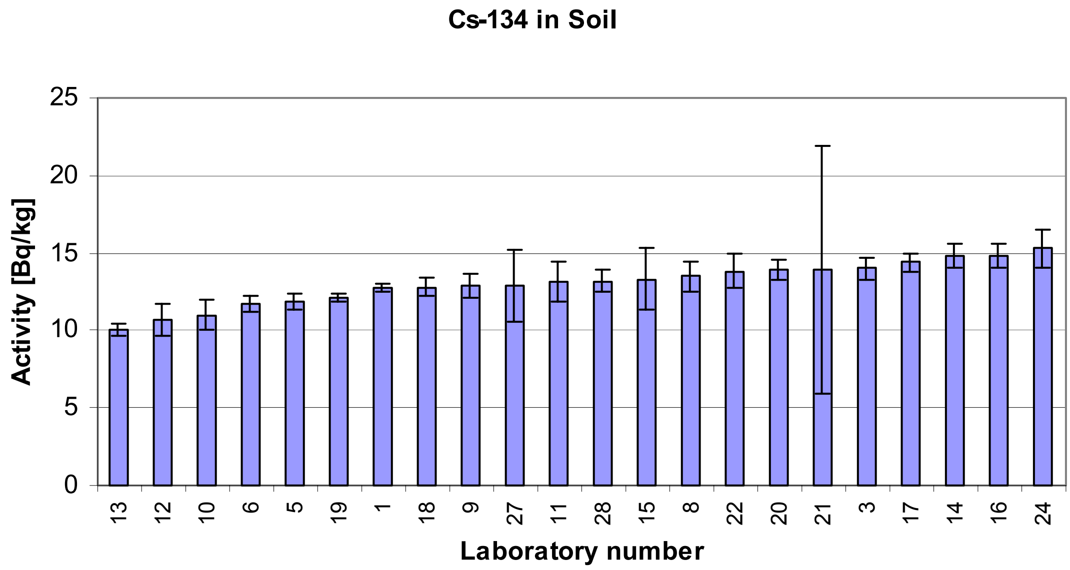

Figure 2.2 Review of the results for Cs-134 in soil.

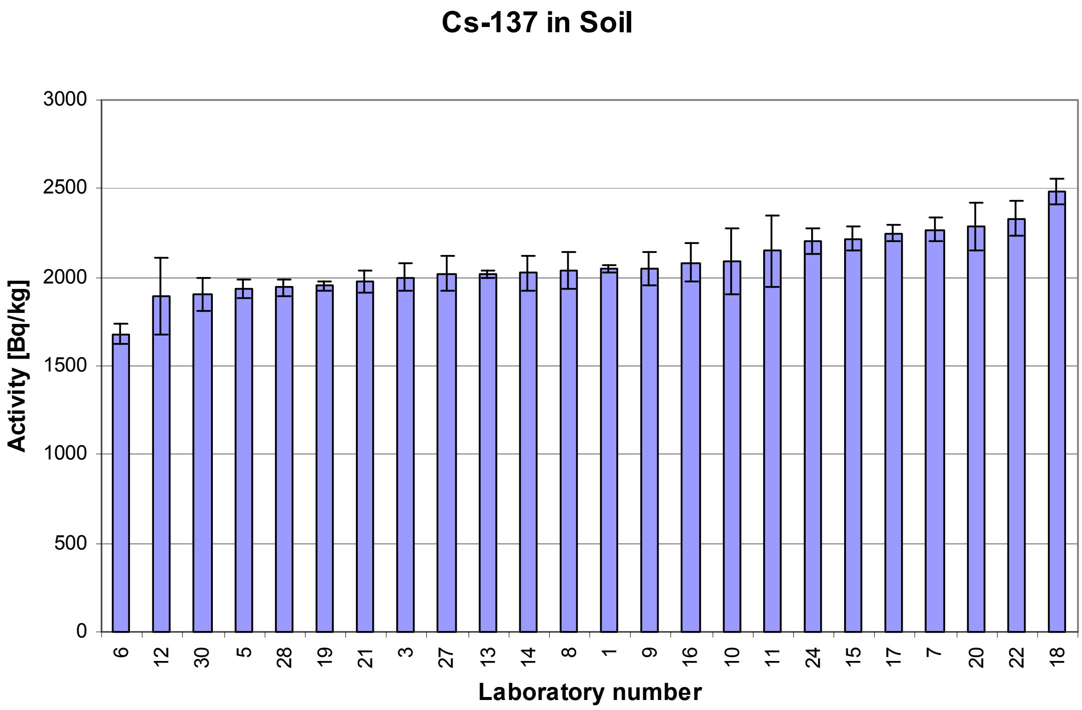

Figure 2.3 Review of the results for Cs-137 in soil.

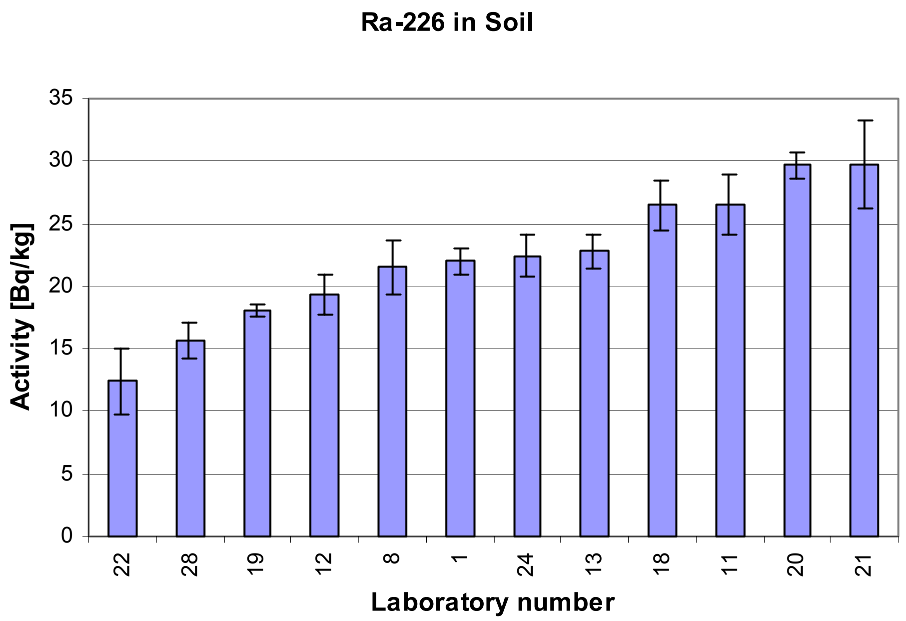

Figure 2.4 Review of the results for Ra-226 in soil.

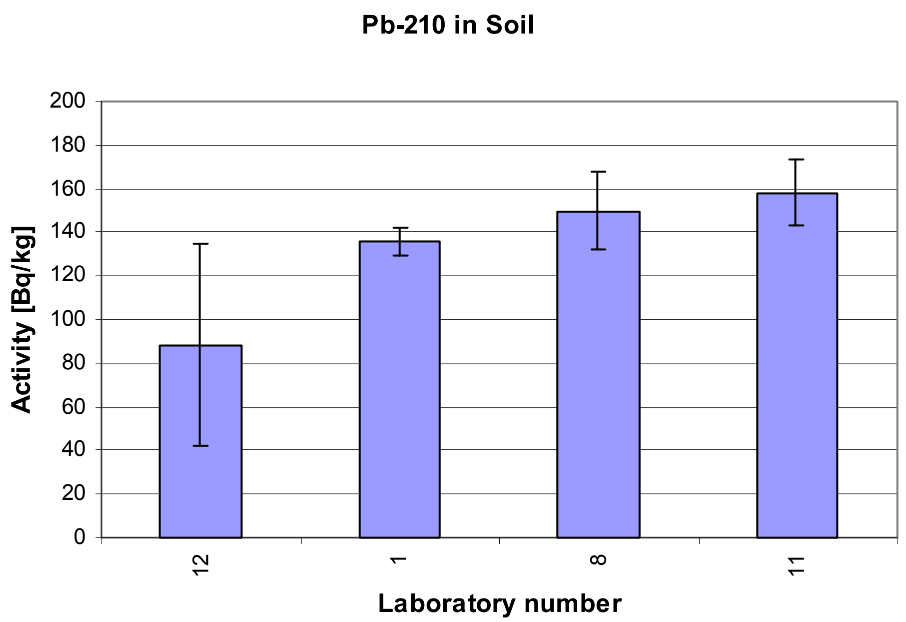

Figure 2.5 Review of the results for Pb-210 in soil.

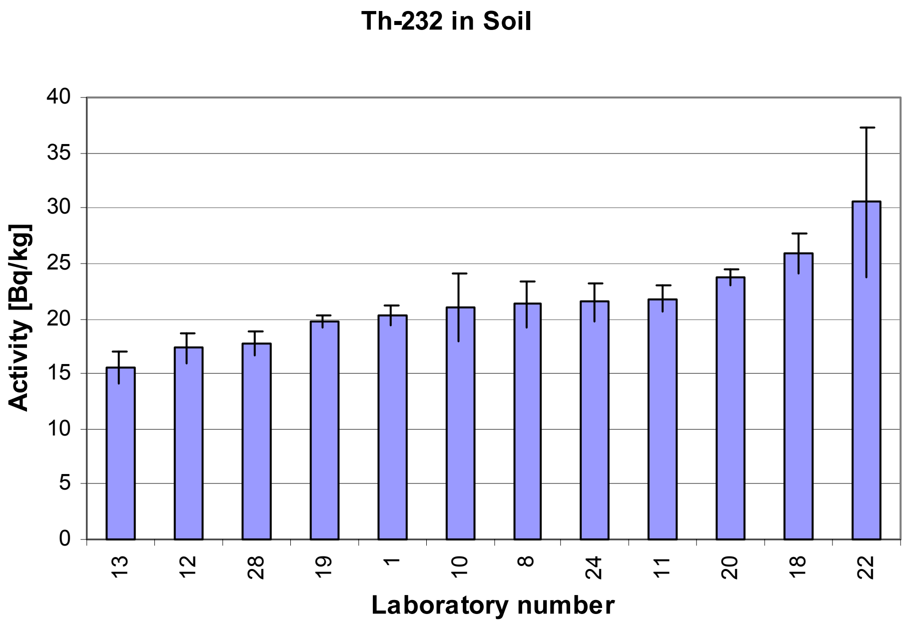

Figure 2.6 Review of the results for Th-228 in soil.

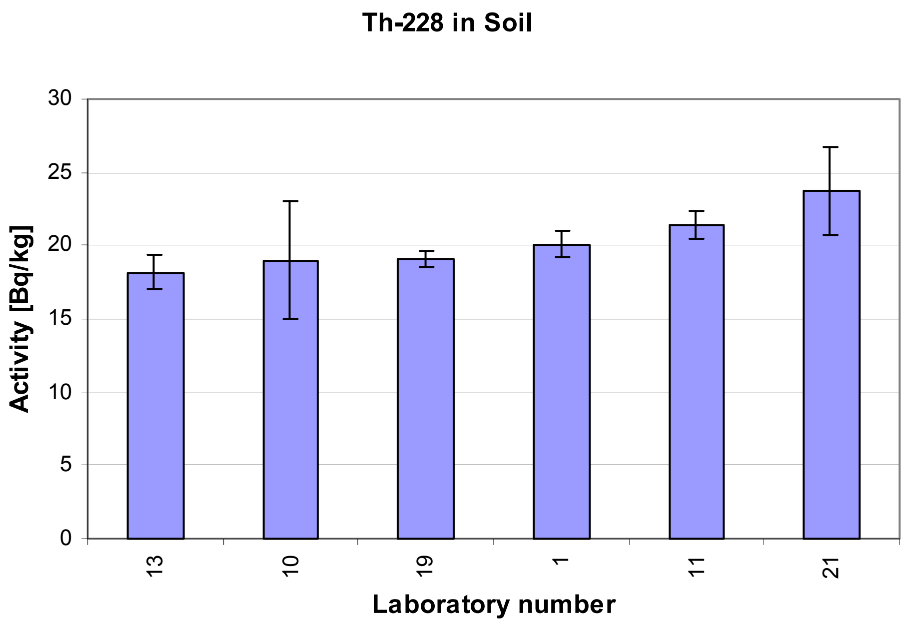

Figure 2.7 Review of the results for Th-232 in soil.

2.3 Sr-90 results

The results of analyses of Sr-90 in the soil samples are shown in Figure 2.8. The agreement is very good for 6 out of 8 results. The AVM value is 24.1 Bq/kg, with a minimum value of 22.6 Bq/kg and a maximum value of 27 Bq/kg.

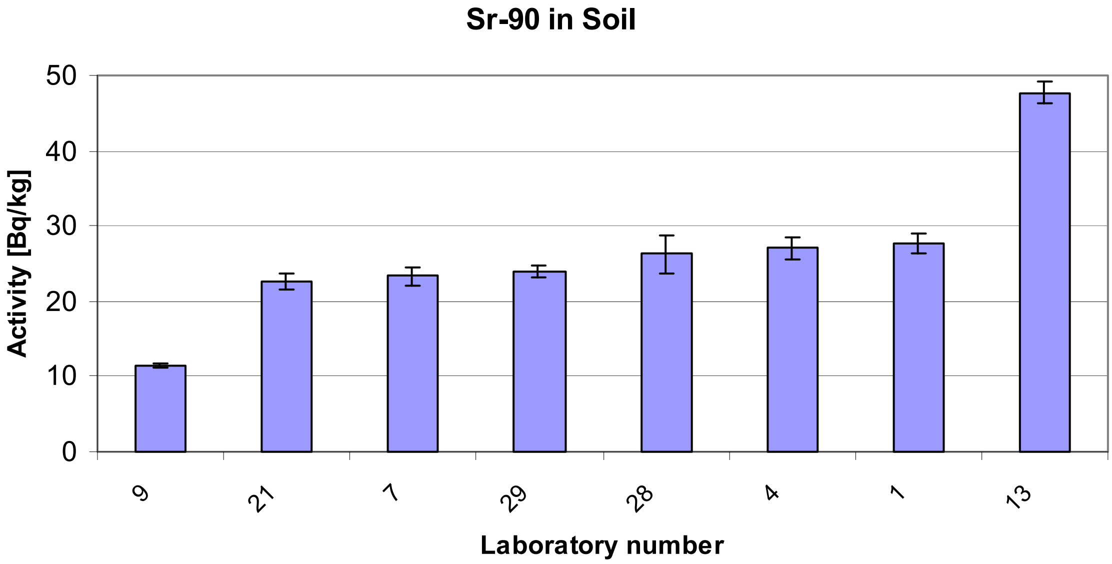

Figure 2.8 Review of the results for Sr-90 in soil.

2.4 Transuranic element results

The results for the transuranic radionuclides are shown in Table 2.3. The Pu analyses were carried out by relatively few laboratories but the majority of the results could be included in the AVM (>71%). The submitted Am-241 results are also good, covering a narrow range of values.

Table 2.3 Review of estimated mean concentrations of transuranic nuclides in the soil.

	Number of results	Number in AVM	AVM value [Bq/kg]	AVM min [Bq/kg]	AVM max [Bq/kg]
Pu-238	6	5	0.066	0.056	0.095
Pu-239+240	7	5	1.72	1.62	1.78
Am-241	3	3	0.75	0.73	0.93

3 Dry milk

The dry milk material was obtained from Danish dairies. About 80 kg was collected over a four-month period. The milk powder was homogenised in a forced mixing machine. Each participant received a 2-kg dry milk sample.

3.1 Homogeneity test

In order to test the homogeneity, ten 2-kg samples were ashed and analysed. Table 3.1 summarises the result of the test. Only K-40 and Cs-137 were detected in the samples. Both nuclides passed the X^2-test and it can be concluded that the milk sample was homogenous. Further, it can be noted the X^2 values are lower than those obtained for the milk powder sample material used in the first intercomparison and so it appears to have been better mixed.

Table 3.1 Result of analysis and homogeneity test for milk

Milk	Activity [Bq/kg]	No.samples	SD [Bq/kg]	SE [Bq/kg]	X^2 sum
K-40	387	10	7	2	9.5
Cs-137	0.355	10	0.023	0.007	4.9

3.2 Gamma results

Twenty laboratories submitted results for gamma emitters in dry milk, two more than in the first intercomparison. 15 results were included in the AVM value for both nuclides, the same number as in the first intercomparison.

For K-40, all of the results are within 20% of the AVM, as can be seen in Figure 3.1. However, the low reported uncertainties on the individual measurements (typically at 5%) limited the number included in the AVM.

The AVM is strongly influenced by results with low measurement uncertainties. Within the Cs-137 results there are 2 clusters of results with low uncertainties; 4 below 0.4 Bq kg^{-1} and 2 around 0.47 Bq kg^{-1} and these affect the AVM value. The AVM was calculated at a value of 0.36 Bq kg^{-1} by excluding the result with the highest X^2 value first, as described in the introduction.

Table 3.2 Review of radionuclides detected in dry milk.

Milk powder	Number of results	Number in AVM	AVM value [Bq/kg]	AVM min [Bq/kg]	AVM max [Bq/kg]
K-40	19	15	384	360	425
Sr-90	10	6	0.30	0.26	0.54
Cs-137	20	15	0.36	0.20	0.50

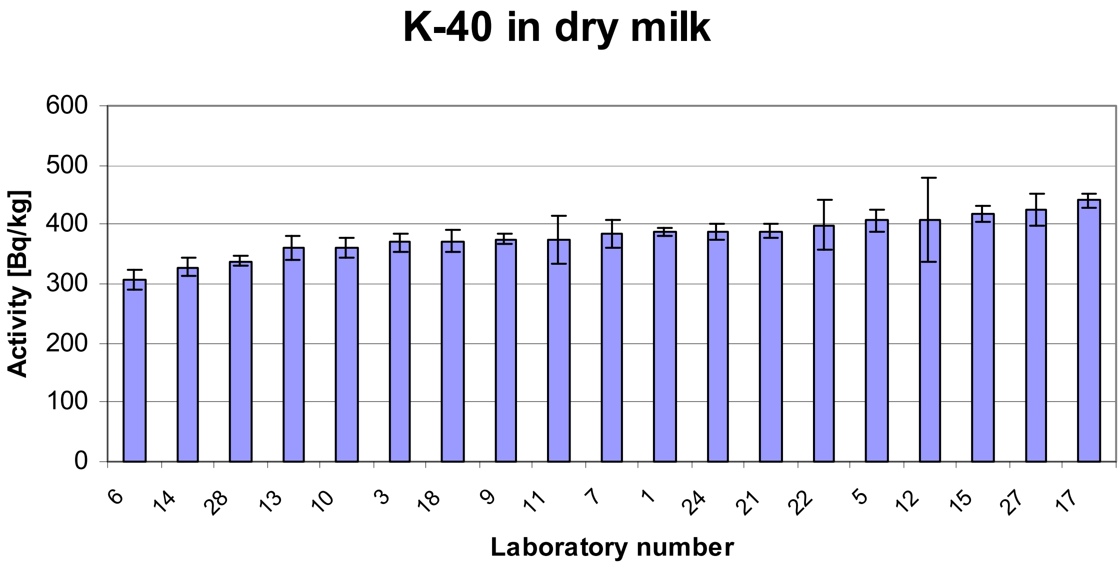

Figure 3.1 Review of the results for K-40 in dry milk. The three lowest and the highest value were excluded from the AVM value.

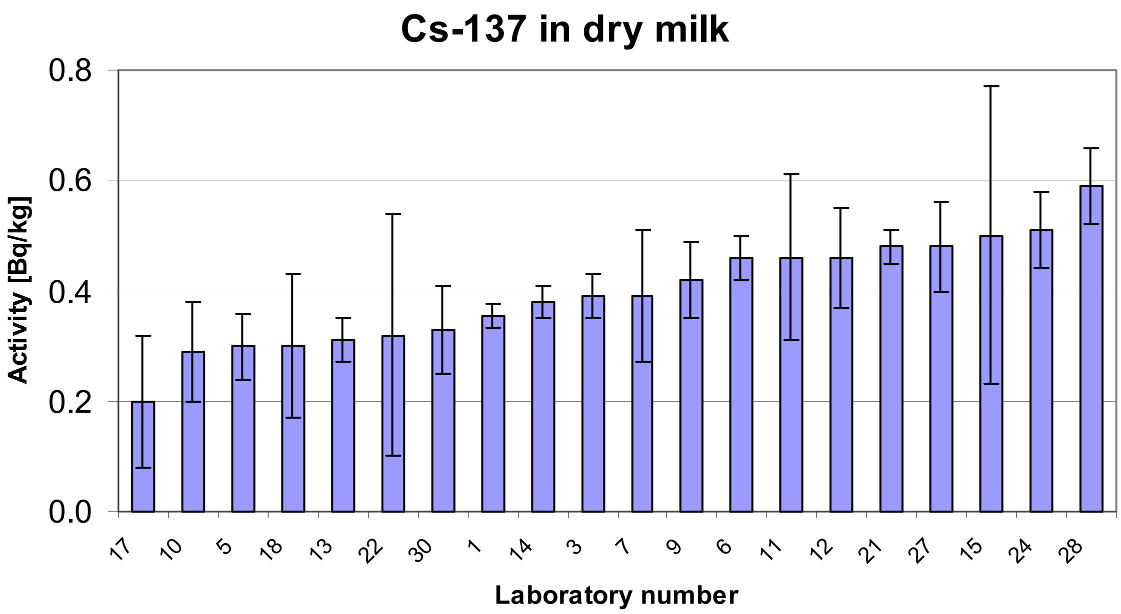

Figure 3.2 Review of the results for Cs-137 in dry milk.

3.3 Sr-90 results

Sr-90 results were submitted by 10 laboratories, 2 more than in the first intercomparison. 6 results were included in the AVM value. A seventh value could have been included as it was reported with more than 90 % uncertainty, but was excluded as it was considered to have to little informative value. For Sr-90 this was a significant improvement compared to the first intercomparison where only 3 out of 8 results were included in the AVM.

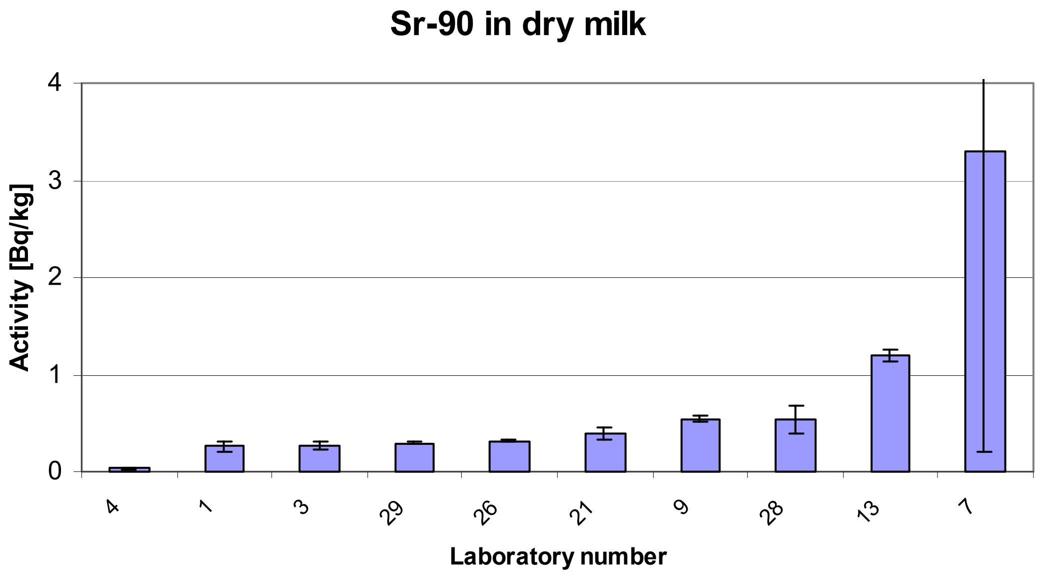

Figure 3.3 Review of the results for Sr-90 in milk powder. Results from laboratories 4,9, 13 and 7 were not included in the AVM value.

4 Aerosols

The aerosol sample material was intended for use in the first intercomparison exercise and therefore collected in 1998 and 1999. When it was decided to reduce the programme for the first round, the aerosol material was saved for the second exercise.

A high-volume air sampler was used to collect aerosols for 36 weeks. Aerosols from a total of 13 million m^3 of air were collected. The long delay from collection to distribution of this sample material meant that the Be-7 concentrations were significantly lower than in a normal air sample. The air filters were ashed at 450 °C thus evaporating the polypropylene filter material. The aerosols were homogenised and a 5-g sample was sent to each participant.

4.1 Homogeneity test

Ten sub-samples of the homogenised aerosols were tested for homogeneity. The results of the homogeneity test are summarised in Table 4.1. Since Pb-210 has high activity and low counting uncertainty, any significant in-homogeneity would be clearest from the Pb-210 data. However, the observed X^2 value indicates an in-homogeneity of less than 1 %.

Table 4.1 Review of homogeneity test of the aerosol samples.

Aerosols	Activity [Bq/kg]	No. samples	SD [Bq/kg]	SE [Bq/kg]	X2
Be-7	444	10	31	10	4.4
K-40	1016	10	27	9	4.7
Cs-137	69.0	10	2.13	0.67	6.2
Pb-210	35050	10	484	153	17.6
Ra-226	25.7	10	1.64	0.52	2.5

4.2 Results

The results are shown in table 4.2. Due to low activity levels the results for Be-7, Na-22 and Ra-226 had high measurement uncertainties and so almost all reported results were included in the AVM value. However the variability is rather large, as can be seen from the maximum and minimum values.

The results for K-40 are shown in Figure 4.1. For K-40, the AVM value includes the four values from laboratory number 3 to laboratory number 8 in Fig 4.1. The two other values with low uncertainties (laboratory number 1 and laboratory number 24) were excluded. The very high results from laboratories 13 and 17 show difficulties in measuring samples in such a small geometry.

The results for Cs-137 are illustrated in Figure 4.2. Most values given with small uncertainties agree well. The AVM value is 69 Bq kg^{-1}.

Table 4.2 Review of the estimated true values for the aerosol material.

Aerosols	Number of Results	Number in AVM	AVM value [Bq/kg]	AVM min [Bq/kg]	AVM max [Bq/kg]
Be-7	5	5	447.6	377	710
Na-22	5	5	17.68	8.4	24
K-40	15	11	905	712	1308
Cs-137	16	9	69.3	54	81
Pb-210	8	6	35457	32400	42200
Ra-226	7	6	25.1	17.9	50

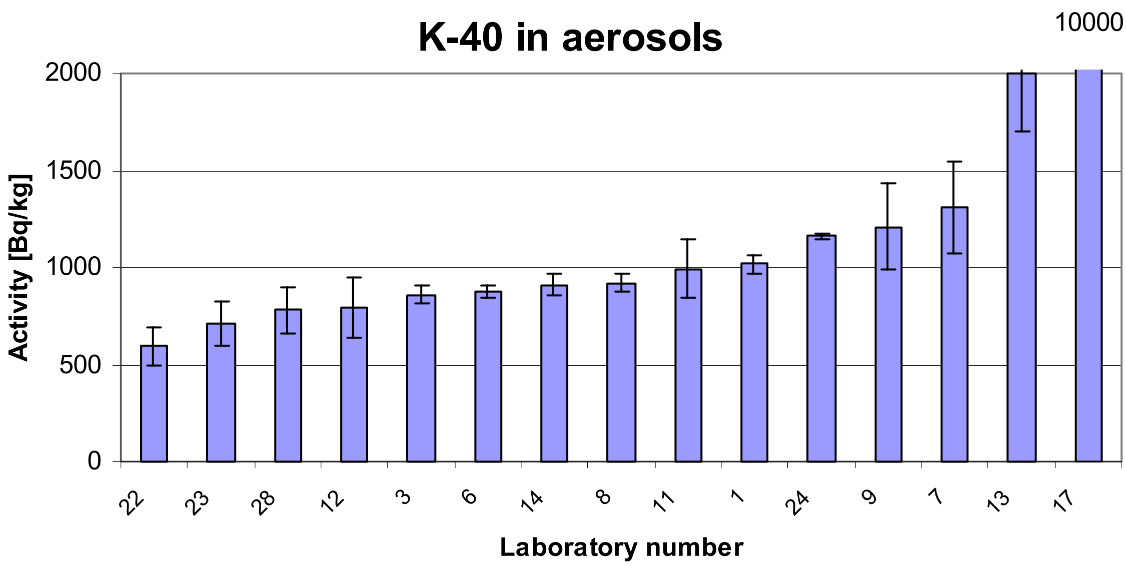

Figure 4.1 Review of the results for K-40 in aerosols.

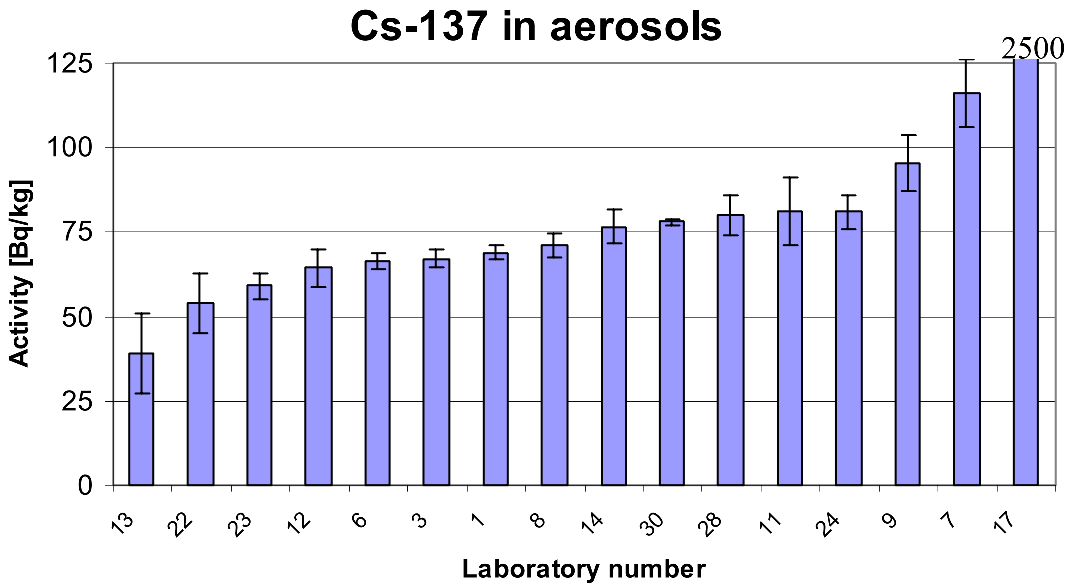

Figure 4.2 Review of the results for Cs-137 in aerosols.

The results for Pb-210 are summarised in Figure 4.3. Six out of eight results contribute to the AVM value at 35 kBq kg^{-1}.

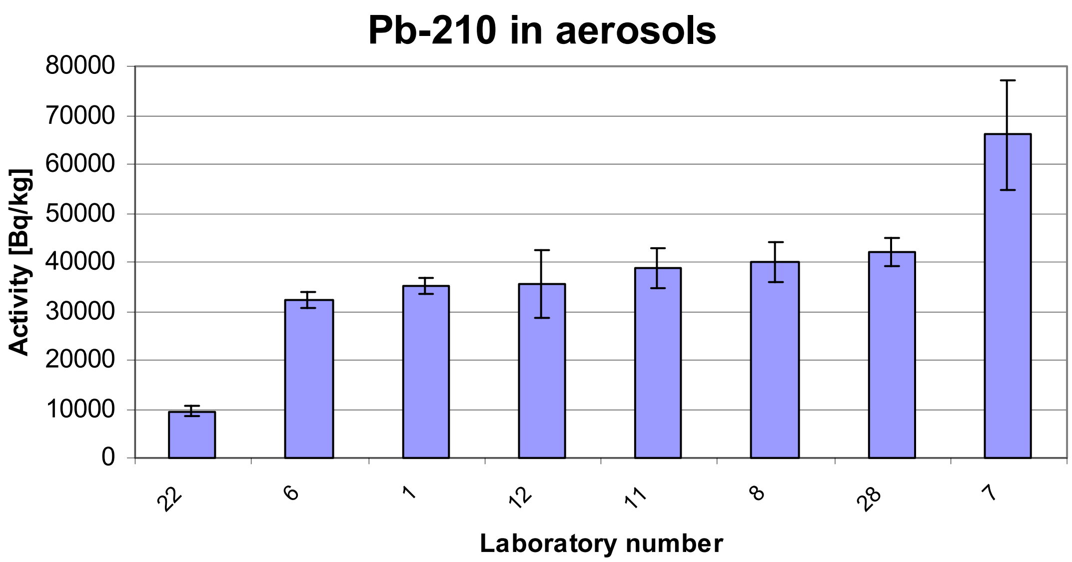

Figure 4.3 Review of the results for Pb-210 in aerosols.

5 Seaweed

The seaweed was collected in September 2000 from the seashore 2 km north of the Swedish nuclear power plant Barsebäck at the same location as used in the previous intercomparison exercise. This sample was distributed for gamma, Sr-90 and Tc-99 analysis. However, homogeneity was tested using the gamma-emitters. Each participant received a 200-g seaweed sample.

5.1 Homogeneity test

The seaweed was dried at 100°C, crushed and homogenised by mixing in a forced blender. Ten samples were analysed in a 200-ml cylindrical container.
The radionuclide concentrations corresponded to those of the samples collected in 1998. However, the scatter observed in the Co-60 results indicated a 2% in-homogeneity compared to 1% in the first intercomparison. The X^2 value was also a little high for Cs-137. Results for K-40 showed a standard deviation of 1.4 %, while below 1 % in the first intercomparison. In summary, the seaweed sample showed in-homogeneity for Co-60 and Cs-137 at the 2% level. However, the dried seaweed was sufficiently homogenous for the intended purpose.

Table 5.1 Results of the homogeneity test.

Seaweed	Activity	No. samples	SD	SE	X^2	In-hom.
	[Bq/kg]		[Bq/kg]	[Bq/kg]		[%]
K-40	868	10	12.3	3.9	15.1	
Mn-54	3.53	10	0.22	0.07	3.2	
Co-60	33.2	10	1.27	0.40	99.2	2
Ag-110m	3.9	10	0.21	0.07	3.7	
Cs-137	25.2	10	0.73	0.23	26.8	
Ra-226	16.5	10	0.48	0.15	6.4	
Th-232	20.9	10	1.06	0.34	4.43	
Tl-208	2.4	10	NA	NA	NA	
Pb-212	2.08	10	0.40	0.13	12	

5.2 Results of gamma analyses

The results from the gamma analysis of the seaweed are shown in Table 5.2 and Figs. 5.1-5.5.

Table 5.2 Summary of gamma emitters in seaweed.

	Number of results	Number in AVM	AVM value [Bq/kg]	AVM min [Bq/kg]	AVM max [Bq/kg]
K-40	20	13	783	623	872
Mn-54	13	12	3.57	2.70	4.60
Co-60	20	12	33.2	30.3	37.23
Sr-90	8	8	4.31	3.55	5.56
Tc-99	3	3	81.7	74.3	98.6
Ag-110m	8	7	4.07	3.40	4.50
Cs-137	21	16	26.6	24.0	29.0
Ra-226	10	7	15.6	13.0	21.2
Tl-208	3	3	2.06	1.70	2.50
Th-228	5	3	4.71	4.30	5.70
Th-232	8	7	18.8	16.4	22.3

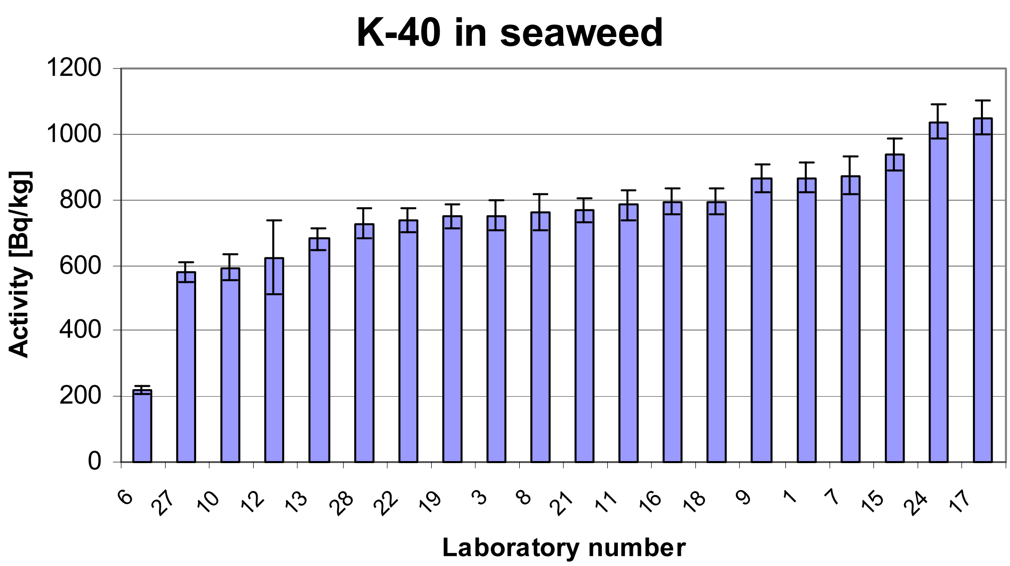

Figure 5.1 Review of the results for K-40 in seaweed.

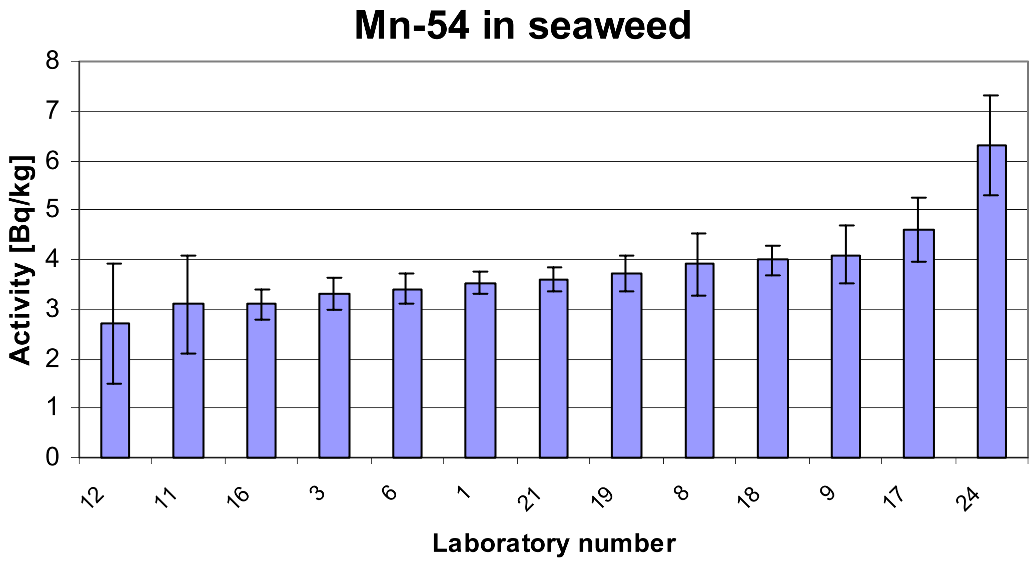

Figure 5.2 Review of the results for Mn-54 in seaweed.

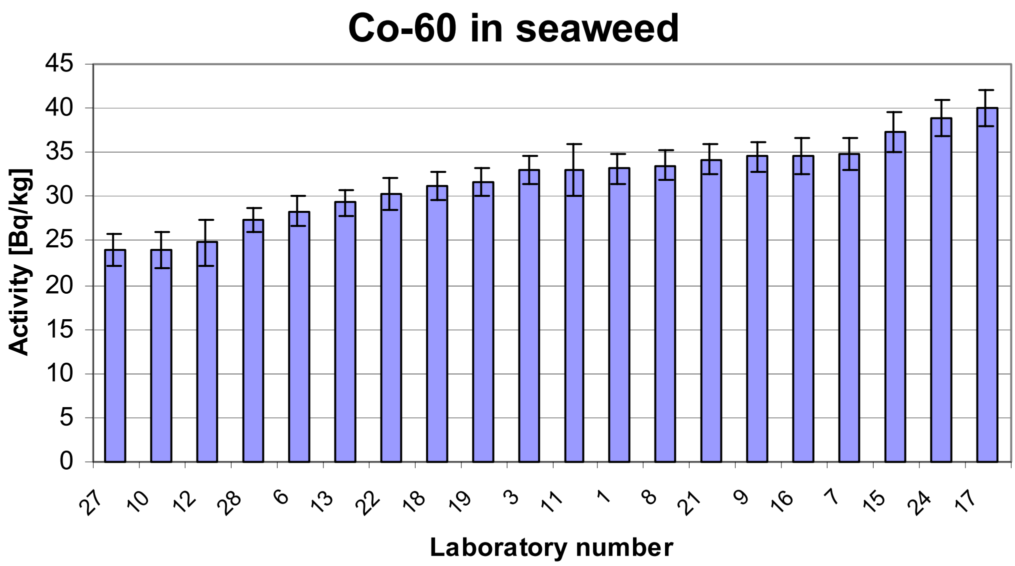

Figure 5.3 Review of the results for Co-60 in seaweed.

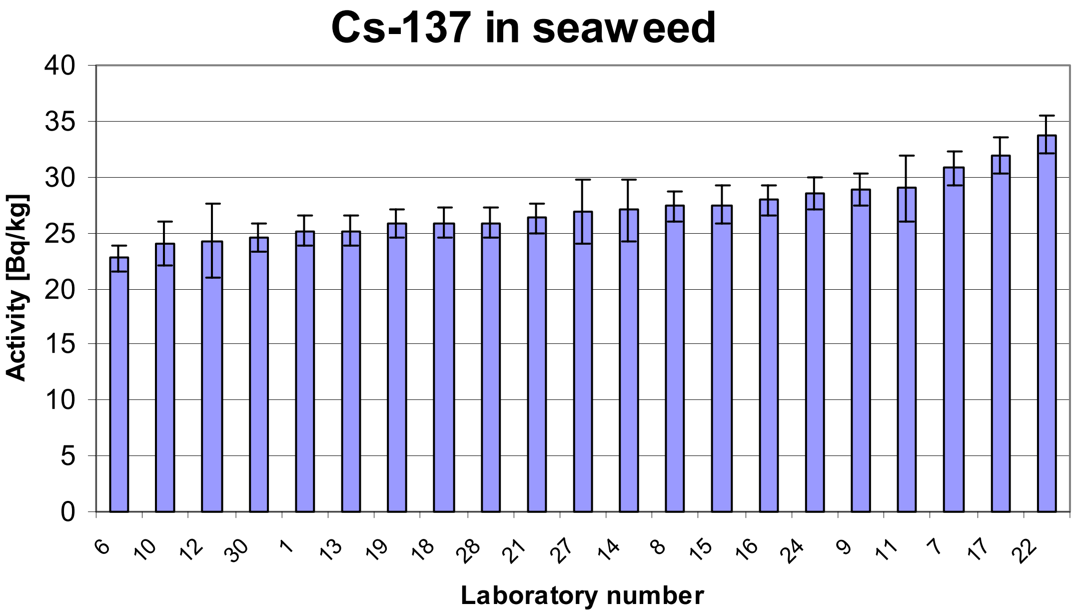

Figure 5.4 Review of the results for Cs-137 in seaweed.

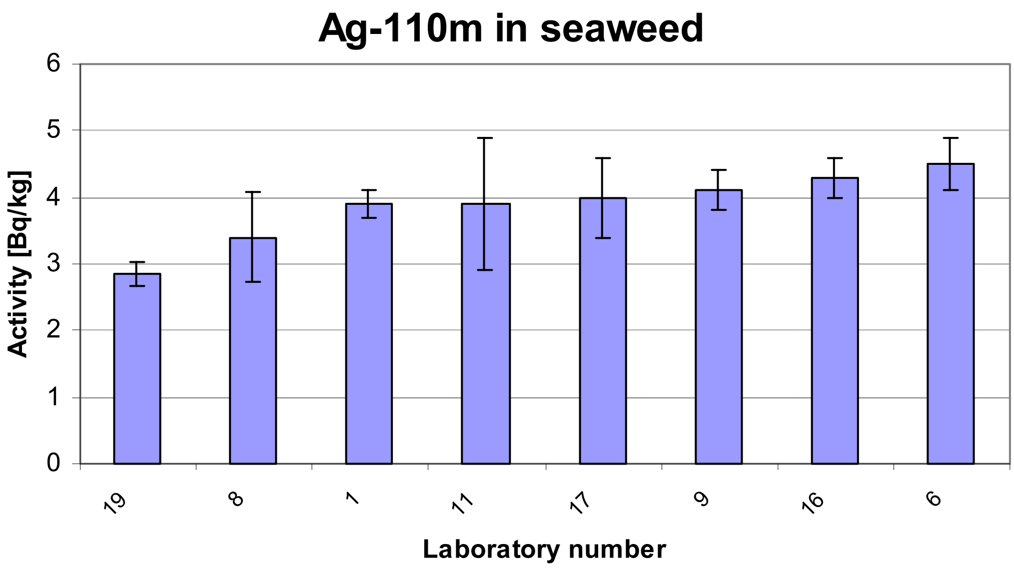

Figure 5.5 Review of the results for Ag-110m in seaweed.

5.3 Results of Sr-90 analysis

The results of the analyses of Sr-90 in seaweed are shown in figure 5.6. An AVM value of 3.8 Bq kg^{-1} was calculated from 5 of the 8 results submitted.

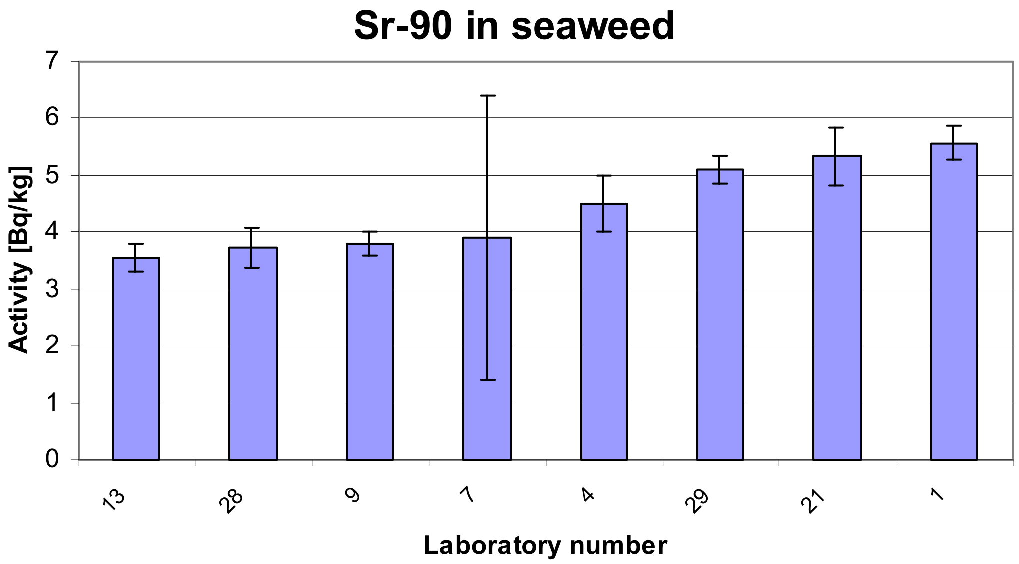

Figure 5.6 Review of the results for Sr-90 in seaweed.

5.4 Tc-99 analysis of seaweed

The results for the analyses of Tc-99 in seaweed are shown in table 5.3. Only 3 laboratories provided results and with reasonable agreement. The AVM value was 75.2 Bq kg^{-1} based on two results.

Table 5.1. Results for Tc-99 analysis of seaweed

Laboratory number	Tc-99 [Bq/kg]	Error [Bq/kg]
1	74.3	4
16	77	5
28	98.6	5

6 Seawater

Near-bottom water was collected from Kattegat close to Hesselø in June 2001 with assistance from the Danish Navy. Near-bottom water was selected as it contains higher concentrations of Tc-99, although the Cs-137 concentrations are higher in the surface water. Each participant received a 50-litre sample.

6.1 Homogeneity test

Ten 50-litre samples of seawater were analysed for Cs-137 using an AMP procedure involving Ammonium Molybdophosphate (AMP) in a strongly acidic solution (based on Dutton, 1970) to test for homogeneity. This was considered a sufficient check of overall homogeneity. The observed variability of the results corresponded to the counting uncertainties demonstrated by the X^2-test as shown in Table 6.1.

Table 6.1 Results of the homogeneity test for Cs-137 in seawater

Seawater	Activity [Bq/m^3]	No. samples	SD [Bq/m^3]	SE [Bq/m^3]	X2
Cs-137	5.1	10	0.3	0.1	6.9

6.2 Results

The results from the participating laboratories for Cs-137 in seawater are shown in Fig. 6.1 and Table 6.2. The reported results vary considerably, but 5 results could be included in AVM.

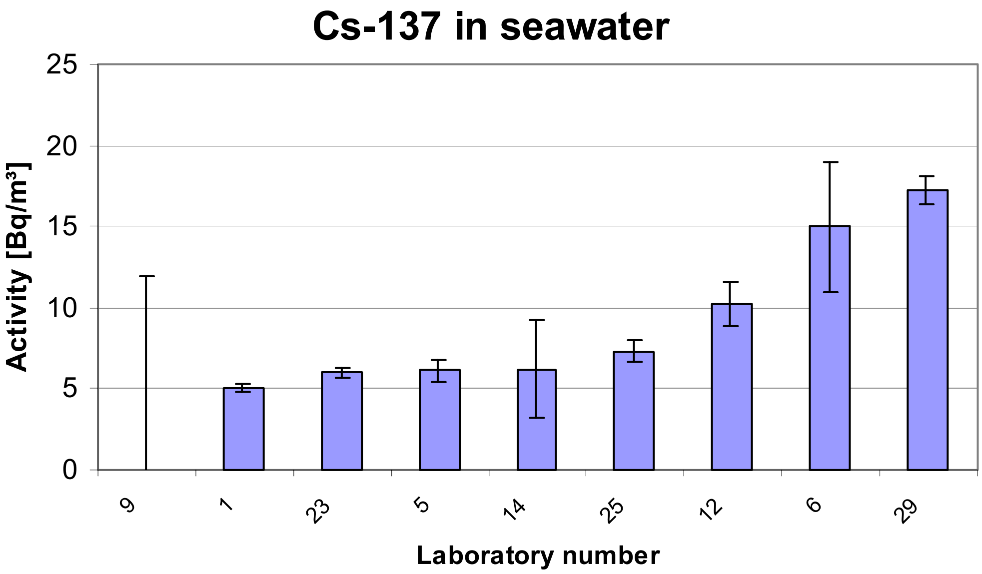

Figure 6.1 Results for Cs-137 in seawater.

Table 6.2 Review of the estimated true values for the seawater

	Number of results	Number in AVM	AVM value [Bq/m^3]	AVM min [Bq/m^3]	AVM max [Bq/m^3]
Cs-137*	8	4	5.51	5.06	6.20
Sr-90	2	2	1.82	1.76	1.90
Tc-99	3	3	1.42	1.21	1.65
K-40	3	2	12137	11100	12800

* two results were reported below detection limit

Only few laboratories analysed the seawater for Sr-90, Tc-99 or K-40. However, the results received were in good agreement. The Sr-90 results were within measurement uncertainty of each other. The Tc-99 results showed a 17% standard deviation, which was little higher than the quoted uncertainties (5 – 9%) but still reasonable. Finally, the variability between the K-40 results was only a little higher than accounted for by the reported uncertainties.

7 Lake water

Lake water was collected in July 2001 from lake Hillesjön in Gävle, Sweden. The water shows relatively high concentrations of Cs-137 due to significant fallout over the Gävle area from the Chernobyl accident in 1986. Each participant received a 50-litre sample.

7.1 Homogeneity test

The lake water was tested for homogeneity with respect to Cs-137 using the AMP method. The sample was homogenous as shown in Table 7.1.

Table 7.1 Results from the homogeneity test of the lake water

Fresh water	Activity [Bq/m^3]	No. samples	SD [Bq/m^3]	SE [Bq/m^3]	X^2
Cs-137	171.6	10	3.8	1.2	10

7.2 Results

The results submitted for the lake water sample are shown in Table 7.2 and Figures 7.1 and 7.2. The variability of the results reported for Sr-90 is rather large compared with the reported analytical uncertainties. Therefore only half of the results are included in the AVM. The three results that are included agree quite well especially considering the narrow error margins used in calculating the AVM. The Cs-137 results are rather better, with only 3 out of 11 results excluded.

Table 7.2 Estimated true values for the lake water sample.

	Number of results	Number in AVM	AVM value [Bq/m^3]	AVM min [Bq/m^3]	AVM max [Bq/m^3]
Sr-90	6	3	16.3	15.4	17.6
Cs-137	11	8	166	147	191
K-40	3	3	87.1	64.3	110

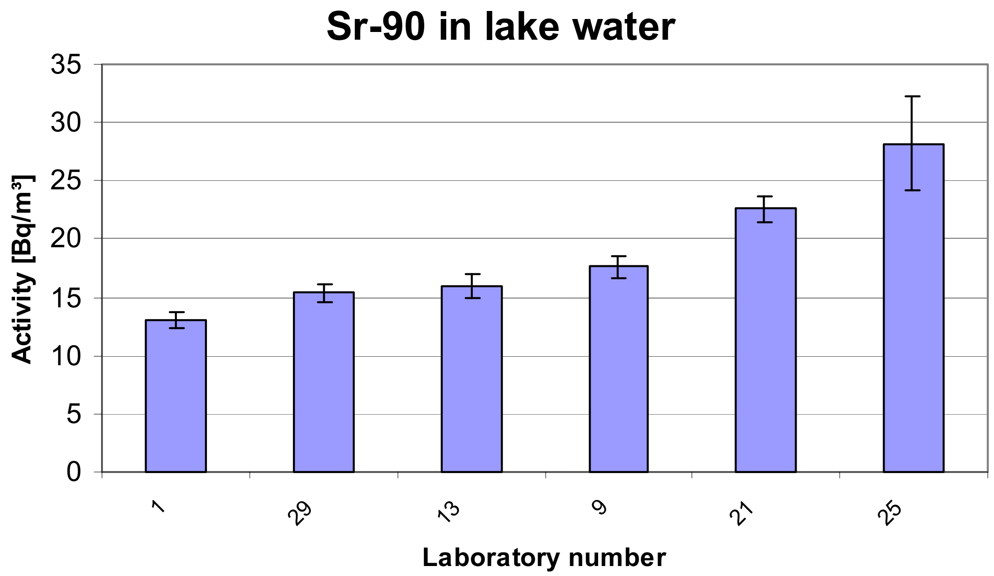

Figure 7.1 Results of Sr-90 in lake water.

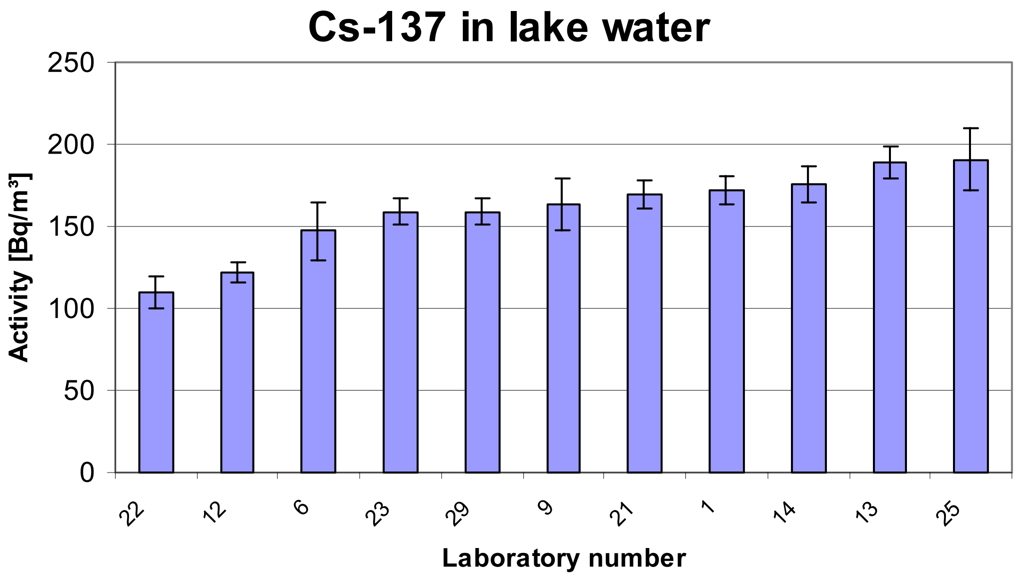

Figure 7.2 Review of the results for Cs-137 in lake water.

8 Conclusions

This intercomparison exercise has had participants from 25 laboratories in the Nordic and Baltic countries. The exercise has covered six environmental sample types: aerosols, dry milk, soil, seaweed, seawater and lake water and a range of man-made and naturally occurring radionuclides. The response from the participants was highest for soil and seaweed for which more than 100 results were received. About 50 results were received for milk and aerosols and a few tens of results were received for the seawater and lake-water samples. Most of the results related to gamma-emitting radionuclides, particularly Cs-137 and K-40, while there were fewer results for beta (Sr-90 and Tc-99) and alpha emitters (Pu-239+240 and Am-241).

The evaluation of the results was based on comparison with an "accepted value mean, AVM", which is derived from the results after removal of outlying data. Typically two thirds of the results were within 10 to 20% of the AVM. For the aerosol samples, however, only about half of the results were within 10 to 20% of the AVM. For the radiologically important radionuclide Cs-137 the overall comparison has shown that two thirds of the results were within 10% of the AVM.

There were eight more laboratories participating in the first NKS intercomparison exercise compared with the second. The change in participation from the first to the second exercise was distributed equally between Nordic and Baltic laboratories. There were about 30% more results in the first exercise mainly on gamma-emitting radionuclides, but the number of results for beta- and alpha-emitting radionuclides did not change between the two exercises.

The overall analytical quality across participants showed differences between the two exercises. There was improvement for the determination of Cs-137 in seawater from the first to the second exercise, but still with considerable room for improvement. There was also better agreement between results in the second exercise for Sr-90 in soil compared with Sr-90 in sediments in the first exercise. Furthermore, the participants supplied more realistic uncertainties to the analytical results in the second exercise than in the first. This development was probably motivated by the use of these uncertainties in the evaluation procedure.

In summary, both intercomparisons have demonstrated that there is room for considerable improvement of the quality for analysis of radioactivity in environmental samples. The fact that complex analyses for Pu-239+240 show better results than relatively simple gamma spectrometric analyses indicates that there is a strong 'operator dependence'. Training and improved quality control are essential in order to improve the analytical quality.

The intercomparison exercises organised in NKS projects are important activities for the participating laboratories to ensure and maintain a good quality of the analytical results from determination of radionuclides in environmental samples.

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Abstract	An intercomparison exercise on radionuclides in environmental samples was carried out during 2000-2001 as part of a Nordic NKS project. The exercise included six sample types (aerosols, dry milk, soil, seawater, seaweed and lake water) and a range of man-made and naturally occurring radionuclides, mainly gamma-emitters but also beta- and alpha-emitters. A total of 25 Nordic and Baltic laboratories participated. The analytical quality across participants was generally good with about two thirds of the results in close agreement with estimated mean values. The exercise has demonstrated improved agreement between the results and more realistic analytical uncertainties submitted by the participants compared with a previous exercise carried out during 1998-1999 in the same NKS project.
Key words	Cesium 137; Environmental Materials; Gamma Radiation; Interlaboratory Comparisons; Milk; Radioactivity; Seawater; Seaweeds; Soil; Strontium 90; Technetium 99; Transuranium Elements

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