Nordisk kernesikkerhedsforskning
Norrænar kjarnöryggisrannsóknir
Pohjoismainen ydinturvallisuustutkimus
Nordisk kjernesikkerhetsforskning
Nordisk kärnsäkerhetsforskning
Nordic nuclear safety research

NKS-19
ISBN 87-7893-069-3

NKS 1999 intercomparison of measurements of radioactivity

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December 2000

Abstract

34 laboratories have returned radioactivity measurements on six different environmental samples. The samples were analysed for their content of gamma emitters, Sr-90, transuranics and Tc-99. The samples materials are described and the results presented. Some scatter was observed in measurements of Cs-137 in low-level samples such as dry milk, meat and hay. The scatter was less pronounced for sediments and seaweed material that had higher levels of radioactivity. In general, the most of the results were consistent with a few laboratories reporting outlying values. An exception was seawater where no clear agreement could be found for the activity of Cs-137.

Keywords

Cesium 137; environmental materials; gamma radiation; gramineae; interlaboratory comparisons; meat; milk; radioactivity; seawater; seaweeds; sediments; strontium 90; technetium 99; transuranium elements

NKS-19
ISBN 87-7893-069-3

Afd. for Informationsservice, Risø, 2000

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NKS 1999 intercomparison of measurements of radioactivity

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Report from the NKS/BOK-1.1 project,
Laboratory Measurements and Quality Assurance.

Contents

Summary

The present work on intercomparison of radioactivity measurements on environmental samples was carried out as part of the NKS/BOK-1.1 project, "Laboratory Measurements and Quality Assurance", under the Nordic Nuclear Safety Research Programme 1998-2001. For the intercomparison exercise, environmental samples of milk powder, meat, sediment, hay, sea weed and sea water were packed, homogenised, and distributed to a total of thirty-five laboratories in the Nordic and Baltic countries.

The selected materials and analysis that was planned for was based on a questionnaire that was sent to potential participants in the summer of 1998. Based on the response the work was planned to include all types of radioactivity measurements: Gamma (Cs-137, K-40, Co-60 and others), Sr-90, transuranics and Tc-99m. However, it was disappointing that very few laboratories reported values for Tc-99 as this had been specially requested before the start of the exercise. Luckily, most laboratories responded with gamma results (response ratio = 95%) and partly with Sr-90 results (response ratio ~ 60 %). Overall, the level of participation has been high and sufficient to meaningfully evaluate the reported values.

Participating laboratories were allowed to re-submit values if they felt that they had improved detector calibrations, background determination, etc. This was done in order to encourage people to improve their general laboratory practise. About one third of the participants made large or small changes to their reported values. Two laboratories had reported values per kilo of ash weight rather than dry weight, some re-calibrated their Ge-detectors and some changed their background values.

For the gamma analysis the results have been mixed. For activity levels above 10 Bq kg^{-1} between 70 and 90 % of the results could be included in a balanced (reduced) mean. For lower activity levels only 50 to 70 % of the results was included in a balanced mean value. The worst result was for seawater where only 4 out of 14 results were included the balanced mean. An effort has been made to identify the main sources of variance. Ashing of samples (to improve counting efficiency) was examined, but could not be shown to improve results. Also it could not be shown that using single nuclide calibrations gives better results than using efficiency curves based on mixed calibration sources. There seemed to be a tendency that laboratories that handled many samples scored better than those handling fewer samples. The assumption is that good laboratory practise above any special corrections is the key to good results.

For Sr-90 analysis the results showed larger scatter than for the gamma analysis. Between 33 and 75 % of the results could be included in a balanced mean. However some of those results that is not included in the mean value was reported as 'below detection limit'. Sr-90 is a complicated analysis and this is clearly reflected in the large scatter.

Analysis of transuranics was done by relatively few laboratories. The results for sediments (done by most laboratories) were useless as it was realised that the sediment material was not homogeneous with respect to transuranics. Only three results were reported for seaweed, but they were all in agreement.

Tc-99 was only analysed by 3 laboratories. Good agreement was found between the reported values.

Preface

This report presents the results of the first round of two intercomparisons that will be conducted by NKS in the period 1998-2001. I have not presented the results anonymously as I felt that it would enhance discussions if you knew the reported values of your colleagues. As I have not received any complaints about this since the draft report circulated to the participants in May I have left it that way. However, the figures that presents laboratory ratings/score have been made anonymous as the purpose of this exercise is not to rate laboratories, but to help improve measuring techniques. I needed to obtain the laboratory scores in order to have a mean for rating the methods used at the different laboratories.

A number of interesting materials have been selected and tested for the second intercomparison. The proposed analysis of the materials will be more focused and the homogeneity should be better tested. I would like to thank the participants for their involvement and hope that the level of participation will be similar or higher in the next round.

Christian Lange Fogh

Risø, October 2000

1 Introduction

As part of the Nordic Nuclear Safety Research Programme 1998-2001 a subproject have been devoted to "Laboratory measurements and quality assurance". This subproject was named BOK-1.1.

Within BOK-1.1 one of the main activities is the intercomparison exercises designed to test quantitatively the analytical performance of the participating laboratories in radioactivity measurements. A first intercomparison exercise was completed in the autumn of 1999. This intercomparison included six different samples that covered a range of sample materials and radionuclides. Sample types consisted of dry milk, meat, sediments, grass, seaweed and seawater. Radionuclides determined include gamma emitters, Sr-90, Tc-99 and transuranics.

A second intercomparison on radioactivity in environmental samples will be carried out during the second half of the project period. This intercomparison will focus on some of the sample materials where the participating laboratories had problems (such as seawater).

The results of the intercomparison were discussed and evaluated at a seminar in Skagen, Denmark in August 1999 in connection with the 12th ordinary meeting of the Nordic Society for Radiation Protection.

Objectives achieved during the first project period, 1998 - 1999

Identification of the participating laboratories and their interests
Decision of the kind of samples that were to be distributed
Decision on the type of analysis to be performed for each material (gamma, beta, etc.)
Finding suitable materials containing adequate amounts of activity
Collection and preparation of the samples (drying, homogenising, testing the homogeneity, etc.)
Distribution of the samples
Collection and analysis of the results
Discussion of the results

Overview of work carried out

Due to the time involved in preparation of the first intercomparison it was important to begin the work as soon as possible. Based on positive feedback from the first meeting of the pre-project group at Risø work was begun in June 1998.

First, a questionnaire was circulated among potential participants in which they could identify the type of samples they were interested in and the kind of analysis they would be doing. Based on the response on this questionnaire a list of sample types, and the radionuclides they should contain, was produced. The second questionnaire was circulated at the end of the summer, together with additional letters to those who had not responded to the first letter.

Collection and preparation of suitable environmental materials started during the autumn. However, at the first regular BOK-1.1 meeting 24/11 1998 in Stockholm it was decided that the number of different sample materials should be reduced from the nine originally planned to the six mentioned above. After the meeting the homogeneity tests were begun for the six selected materials.

In March a sample order form was distributed and in April distribution of samples was begun. A few new participants were identified and the last samples were shipped in the beginning of June. Most results were received before the meeting in Skagen. A second deadline 30/9 1999 was set after the meeting. The results submitted here dealt mainly with Sr-90 and transuranics.

In total, 36 laboratories including two laboratories at Risø have received the samples. One laboratory reported back early that they did not want participant after all, and from two participants input was received after the draft report was circulated. Two participants have not sent anything.

Table 1.1 Scheme of distributed samples and the relevant isotope determinations

Sample type	γ-emitters	Sr-90	Tc-99	Transuranics
dry milk	x	x		
meat(beef)	x			
sediments	x	x		x
grass	x	x		x
seaweed	x	x	x	x
seawater	x	x	x	x

2 Description of distributed samples

The sample materials were selected so that they should cover a wide range of the materials typically analysed for radioactivity. Wet deposition was excluded from the program due to problems of obtaining suitable amounts of homogenous material. Aerosol has collected, but will be a part of the second intercomparison. In order to obtain environmental samples with a wider range of radionuclides sediment and seaweed was collected at Barsebäck.

To test the materials for homogeneity a X^2 (Chi-square) test was used. First the 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 measurement and s_i is standard deviation of the i-th measurement. Hereafter the X^2 sum is calculated as:

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

If the samples contain homogenous amounts of activity then variability between measured samples will be determined by the counting uncertainty. If this is the case the r.m.s. difference between the measured values and the weighted mean value should be equal to the standard deviation of the data points. Thus the average X^2 value for one data point should be unity and the X^2 sum should be of the same magnitude as the number of measurement points. For a series of measurements, the average X^2 value should be close to the average number of data points. If you have 10 measurements then your X^2 should lie between 5 and 20, roughly. X^2 values for single results are also discussed sometimes. These are simply defined as:

$$X_i^2 = (A_i - \overline{A})^2 / s_i^2, \text{ X}^2 \text{ for single value}$$

Dry matter refers to sample material dried to constant weight at 80 °C. Two of the sample types are collected near Barsebäck and contains long-lived fission product in addition to the common fallout products.

Each sample material was analysed on a single detector in order to eliminate detector to detector variations in the homogeneity test.

2.1 Dry milk

Dry milk was selected as one of the materials as it is included in the routine monitoring at several laboratories. It is a typical low activity sample, which requires pre-concentration by ashing and long count time on big detectors in order to achieve good results.

The material was collected from milk powder samples analysed as part of routine measurements at Risø. All the collected milk powder was homogenised in a forced mixing machine. Ten 2100 g samples were ashed and analysis at Risø. Table 2.1 summarises the result of the homogeneity test. Only K-40 and Cs-137 were found in the samples. Both nuclides passed the X^2-test and it can be concluded that the milk sample was homogenous regarding determination of K-40 and Cs137. 1.6 kg was distributed to each participant

Table 2.1 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	422	10	11	4	10.1
Cs-137	0.310	10	0.050	0.016	11.5

2.2 Meat

Meat was selected as another material that required some skill to measure. In order to have the reasonably levels of Cs-137 in the meat a cow grassing outdoors all summer was selected. The meat was chopped and mixed at the butcher. Due to problems with decay of fresh meat during transportation, the meat was then freeze dried for a week. Seven samples were produced and ashed at 450 °C for 24 h and analysed for a homogeneity test. The results are shown in Table 2.2. Again it can be seen that the material was homogenous with respect to the two radionuclides detected, K-40 and Cs-137.

Table 2.2 Result of analysis and homogeneity test for meat

Meat	Activity [Bq/kg]	No. samples [ ]	SD [Bq/kg]	SE [Bq/kg]	X^2 sum [ ]
K-40	329	7	14	5	12.8
Cs-137	0.382	7	0.020	0.008	4.2

2.3 Sediment

Sediment was collected outside Barsebäck close to the beach and was rather sandy. The material was grinned down to a fine powder and homogenised in a forced mixer. 11 samples of ~ 340 g was analysed in a 210 ml cylindrical container. Count time was typically one day. The result of the analysis and homogeneity test is summarised in Table 2.3.

Table 2.3 Result of analysis and homogeneity test for sediment

Sediment	Activity [Bq/kg]	No. samples [ ]	SD [Bq/kg]	SE [Bq/kg]	X^2 sum [ ]	In-hom. [%]
K-40	721	11	11	3	28.0	0.5
Mn-54	0.42	10*	0.17	0.05	23.6	0.5
Co-60	7.2	11	1.1	0.3	360.7	10
Cs-137	12.2	11	0.2	0.1	9.7	-
Tl-208	8.9	11	0.4	0.1	3.4	-
Ra-226	10.9	11	0.2	0.1	7.1	-
Th-232	9.0	11	0.7	0.2	10.5	-

*Mn-54 was not detected in one sample

The homogeneity test failed for Co-60. Probably the Co-60 activity is associated with relative few small particles, so that the number of particles in one sample will vary for statistical reasons even if you have a well-mixed material. The X^2 values for K-40 and Mn-54 indicated small possible in-homogeneities in the order of 0.5 %.

As some participants expressed a wish for measuring this material in a Marinelli beaker about 1700 g sediment was distributed.

2.4 Grass

The hay sample was produced from grass grown in 1991 or 1992 to have high levels of Cs-137 activity. However, the activity in the final intercomparison material was not higher than values recorded for Danish pastures in the late 90'es. The hay was chopped and mixed thoroughly on a floor. 35 samples were produced, 11 of which where analysed. The samples were ashed and measured in cylindrical boxes.

Table 2.4 Activity found in 11 hay samples.

Hay	No. samples [ ]	Activity [Bq/kg]	SD [Bq/kg]	SE [Bq/kg]	X^2 sum [ ]	In-hom. [%]
K-40	11	432	20	6	1621	5
Cs-137	11	0.225	0.036	0.011	24	~5

The homogeneity test clearly showed that the hay samples were not completely homogenised. To compensate for this 5 % was added to the expected error when the results from all laboratories were analysed.

2.5 Seaweed

Seaweed was collected at the seashore 2-km north of the Swedish nuclear power plant Barsebäck. It was crushed and homogenised by mixing of the obtained granulate in a forced blender. 10 samples were analysed in a full cylindrical container.

Table 2.5 Activity measurements on 10 sea weed samples.

Sea weed	No. samples [ ]	Activity [Bq/kg]	SD [Bq/kg]	SE [Bq/kg]	X^2 sum [ ]	In-hom. [%]
K-40	10	896	7	2	8.9	
Mn-54	10	29	0.5	0.2	14.4	
Co-58	10	6.74	0.21	0.07	4.2	
Co-60	10	43	0.7	0.2	30.0	1
Cs-137	10	21	0.3	0.1	5.4	
Ra-226	10	21	0.5	0.2	10.4	
Th-232	10	27	0.6	0.2	2.8	

All elements proved to be homogenous distributed in the material except for a small variance for Co-60. However, this was within the systematic error of the analysis and not significant.

Each participant received 300 g of dried sea weed.

2.6 Sea water

With assistance from the Danish Navy deep water from Kattegat near Hesselø was collected in the autumn of 1998. Deep water was selected in order to have relative high amounts of Tc-99. The Cs-137 activity would be less than in surface water.
Ten 50 litre samples were analysed for Cs-137 using the AMP procedure.

Table 2.6 Activity measurements on 10 sea water samples. Second entry gives the result of additional measurements after 8 month storage of the water.

Sea water	Activity [Bq/kg]	No. samples [ ]	SD [Bq/kg]	SE [Bq/kg]	X^2 sum [ ]
Cs-137	12.2	10	0.3	0.1	5.9
Cs-137	13.4	4	1.1	0.5	-

As can be seen from Table 7 the activity found in each sample was very similar and the X^2-test was passed without problems. However, as large variations were reported during the intercomparison from the various participants, a second set of measurements was made in September 1999 to test if the level had change during storage. The second test was made on different detectors and additional variation was to be expected. The average activity was 10 % higher after 8 month storage disproving any theory about variability in results due to changes in time.

3 Results for gamma analysis

The number of results returned for each nuclide detected during the exercise is summarised in Table 3.1. It can be seen that most analysis results were reported for gamma emitting nuclides.

Table 3.1 Number of results reported for each sample type and detected nuclide. Those combinations that have been analysed with a X^2-test have been bolded. 'NA' (No Analysis) indicate that the sample material was not analysed with regard to that radionuclide.

	Drymilk	Meat	sediment	Hay	Sea weed	Sea water
Be-7					5	
K-40	**18**	**17**	**26**	**18**	**25**	**8**
Mn-54			**9**		**18**	
Co-58					**11**	
Co-60			**28**	1	**28**	3
Ag-110m						1
Cs-134			4		2	
Cs-137	**18**	**19**	**30**	**18**	**28**	**14**
Eu-155					**2**	
Hg-203			1			
Tl-208			1			
Pb-210	1	1	2		**1**	
Pb-212			1			
Ra-226	2	2	**12**	6	**9**	1
Th-228			2		**1**	
Th-232	2	2	**12**	7	**10**	1
Th-234			**1**		**1**	
U-235	3		**2**			
Sr-90	**8**	**NA**	**6**	**7**	**8**	4
Pu-238	NA	NA	1	NA	2	
Pu-239/240	NA	NA	5	NA	3	
Am-241	NA	NA	2	NA		
Tc-99	NA	NA	NA	NA	3	**2**

3.1 Statistical treatment:

For each nuclide and sample type where more than 6 results have been received an X^2-test has been made. The test was identical to that used for the homogeneity test and described above.

As the uncertainties reported by the participants where different, some uniform method must be applied. Some laboratories reported the counting uncertainty some reported the total uncertainty (including calibration uncertainty, etc.), and some both. Having received most reports on the counting uncertainty the following algorithm was used to calculate an expanded uncertainty, 'E.U.':

$$E.U. = \max('total', \sqrt{s.d.^2 + s.e.^2})$$

where 'total' is the total uncertainty supplied by the participant, 's.d.' is the counting uncertainty supplied by the participants and 's.e.' (systematic error) is a systematic error es-

estimated to be a certainty percentage of the reported result. In most cases 's.e.' was 5 % of the reported value. For Co-60 in Sediment and for the hay samples 10 % was used as the homogeneity test had shown that these sample materials was not sufficiently homogeneous.

In essence, uncertainties of less than 5 % was not accepted and was changed according to the above expression. This was done to ensure that single values reported with very low uncertainties did not get to big an influence on the mean.

3.2 Results and comments

The following pages contains a number of figures based the Excel work sheets used to calculate the weighted mean values for the different isotopes detected in the different materials. The institute abbreviations used are listed in the back of the report on page 52.

Each sheet contains 8 columns:

'Institution'	:	name institution submitting the results See the appendix for full details on the name and adresses
2nd column	:	reported activity
's.d.'	:	reported counting uncertainty - one standard deviation
'total'	:	reported total uncertainty
'E.U.'	:	uncertainty estimated for statistical analysis see explanation in previous section
'1/s2'	:	one divided by $(E.U.)^2$
'X'	:	(reported value - weighted average)/E.U.
'X^2'	:	$(X)^2$ - for a single value. This sum of this column gives the actual X^2 result

Below the data columns there are a number parameters listed:

'Sum 1/Sigma2'	:	sum of the 1/s2 column *
'Mean'	:	arithmetic mean
's.d.'	:	standard deviation on the arithmetic mean
'Weighted mean'	:	the weighted mean
'X2 ='	:	sum of the X^2 column
'St. systematic error'	:	systematic error used to estimate the E.U.
'St. stochastic error'	:	estimated counting uncertainty

*- used for calculation of the weighted mean

Milk

K-40 is one of the nicer results. A sum X^2 = 32 for 17 results is reasonable (expected value is 17, the number of results). 13 out of 17 have single X^2 values below 2.

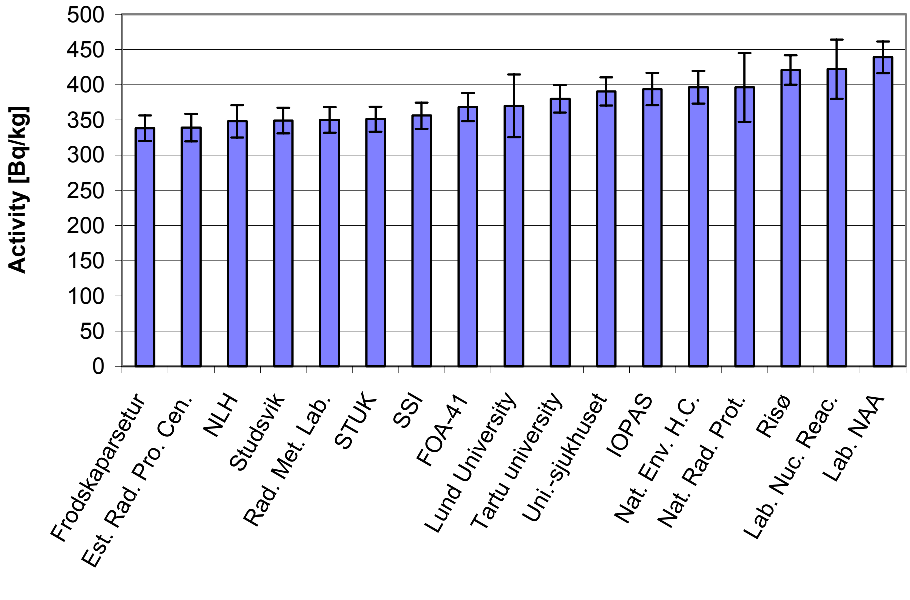
Cs-137 is much worse. Sum X^2 = 190. Some have ashed the samples and some have counted them as received in 1.0 litre Marinelli beakers. This, however, is not reflected in the results. The two methods are evenly distributed among the 'successful/unsuccessful' results.

Institution	**K-40** [Bq/kg]	s.d. [Bq/kg]	total [Bq/kg]	E.U. [Bq/kg]	1/s2	X	X2
Frodskaparsetur	338	6.4		18	0.0031	-1.79	3.20
Est. Rad. Pro. Cen.	339	10.0		20	0.0026	-1.59	2.54
NLH	348	15.0	15.0	23	0.0019	-0.97	0.95
Studsvik	349	5.0		18	0.0030	-1.18	1.38
Rad. Met. Lab.	350	4.6	17.9	18	0.0031	-1.13	1.27
STUK	351	2.8	13.0	18	0.0032	-1.09	1.19
SSI	356	5.0		18	0.0029	-0.78	0.60
FOA-41	368	7.5	16.7	20	0.0025	-0.12	0.01
Lund University	370	37.0	44.4	44	0.0005	-0.01	0.00
Tartu university	380	5.0		20	0.0026	0.49	0.24
Uni.-sjukhuset	390	4.1	16.1	20	0.0025	1.00	1.01
IOPAS	394	11.8	15.0	23	0.0019	1.03	1.06
Nat. Env. H.C.	396	11.9	13.0	23	0.0019	1.11	1.23
Nat. Rad. Prot.	396	11.9	49.0	49	0.0004	0.52	0.27
Risø	421	1.5	20.0	21	0.0022	2.40	5.76
Lab. Nuc. Reac.	422	12.7	42.0	42	0.0006	1.23	1.51
Lab. NAA	439	4.4	10.5	22	0.0020	3.07	9.40

BOLD uncertainties are estimated values

Sum 1/Sigma2	0.04
Mean	376.9
s.d.	31.2
Weighted mean	370.4
X2 =	32
St. systematic err.	5
St. stochastic err.	3

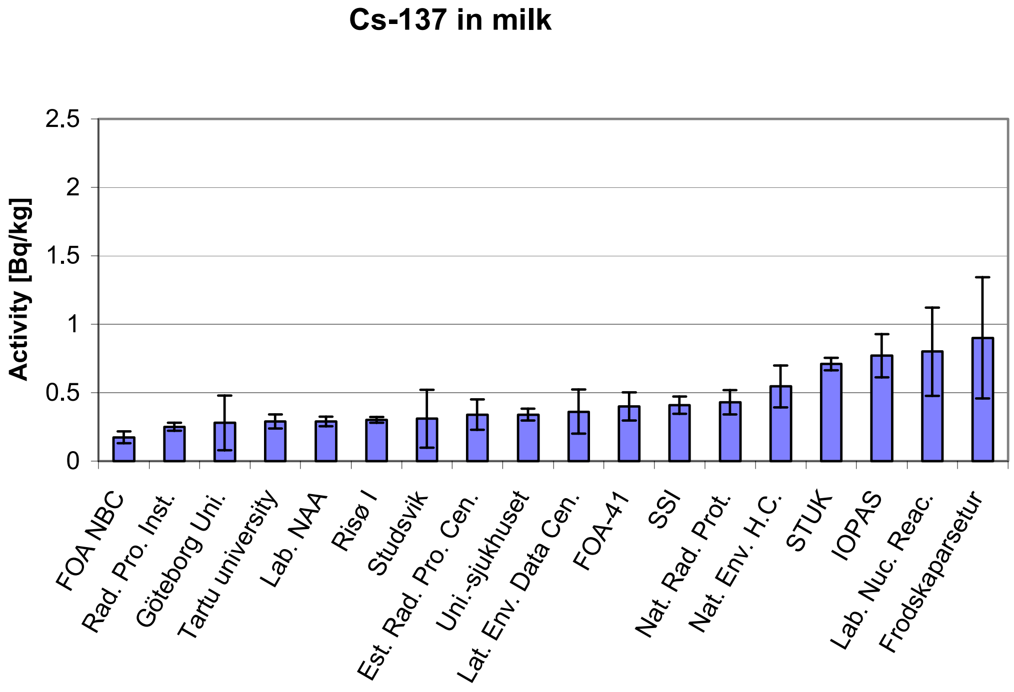
K-40 in milk



Institution	**Cs-137** [Bq/kg]	s.d. [Bq/kg]	total [Bq/kg]	E.U. [Bq/kg]	1/s2	X	X2
FOA NBC	0.174	0.043	0.043	0.044	520	-3	12
Rad. Pro. Inst.	0.25	0.026	0.026	0.028	1240	-3	7
Göteborg Uni.	0.28	0.200		0.200	25	0	0
Tartu university	0.29	0.050	0.050	0.052	369	-1	0
Lab. NAA	0.29	0.032		0.035	814	-1	1.1
Risø I	0.302	0.016		0.022	2107	-1	1.2
Studsvik	0.31	0.210	0.210	0.211	23	0	0.0
Est. Rad. Pro. Cen.	0.34	0.110	0.110	0.111	81	0	0.0
Uni.-sjukhuset	0.34	0.040		0.043	529	0	0.1
Lat. Env. Data Cen.	0.362	0.161		0.162	38	0	0.0
FOA-41	0.40	0.100		0.102	96	1	0.5
SSI	0.41	0.060	0.060	0.063	249	1	1.8
Nat. Rad. Prot.	0.43	**0.086**		0.089	127	1	1.4
Nat. Env. H.C.	0.545	0.150	0.150	0.152	43	1	2.1
STUK	0.71	0.029		0.046	476	8	70.1
IOPAS	0.77	**0.154**		0.159	40	3	7.8
Lab. Nuc. Reac.	0.8	0.320		0.322	10	1	2.2
Frodskaparsetur	0.9	0.440	0.440	0.442	5	1	1.7

BOLD uncertainties are estimated values

Sum 1/Sigma2	6791
Mean	0.439
s.d.	0.21
Weighted mean	0.326
X2 =	110
St. systematic err.	5
St. stochastic err.	20



Meat

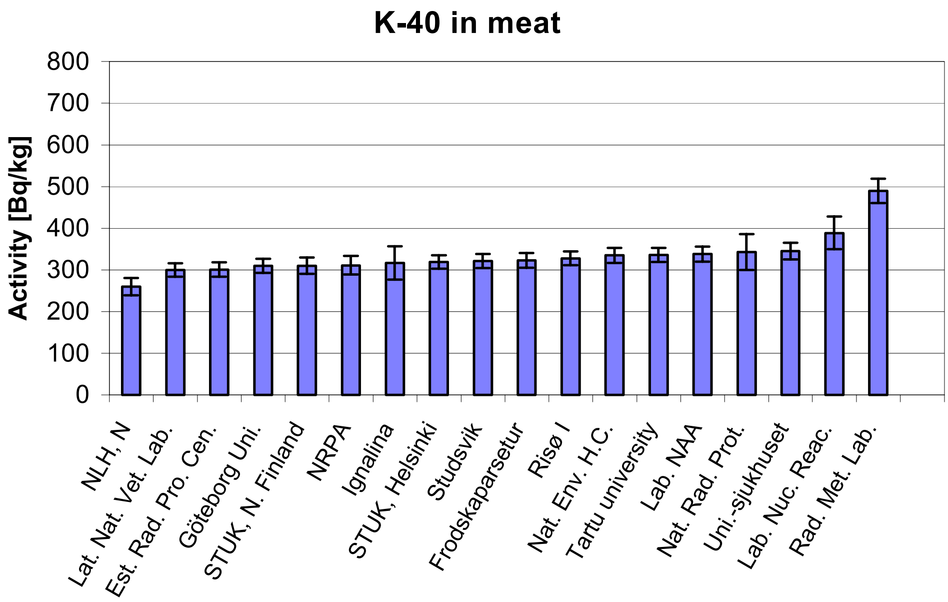
Results similar, but worse than for milk. K-40 results were in balance except for a few outlying values. Again it was tested if ashing of the sample was associated with better scores, but this was not the case. When results was compared between laboratories that had ashed the samples and laboratories that had analysed bulk samples in Marinelli beaker then there were no significant difference.

Institution	**K-40** [Bq/kg]	s.d. [Bq/kg]	total [Bq/kg]	Est. unc. [Bq/kg]	1/s2	X	X2
NLH, N	**260**	16	16	21	0.0024	-3.1	9
Lat. Nat. Vet. Lab.	**300**	6	8	16	0.0038	-1.4	2
Est. Rad. Pro. Cen.	**301**	9	9	18	0.0033	-1.3	2
Göteborg Uni.	**310**	6	0	17	0.0036	-0.8	1
STUK, N. Finland	**310**	12	12	20	0.0025	-0.7	0.4
NRPA	**311**	16	16	22	0.0020	-0.6	0.3
Ignalina	**317**	6	40	40	0.0006	-0.2	0.0
STUK, Helsinki	**319**	1	11	16	0.0039	-0.3	0.1
Studsvik	**321**	5	6	17	0.0035	-0.1	0.0
Frodskaparsetur	**323**	7	7	18	0.0032	0.0	0.0
Risø I	**328**	1	15	16	0.0037	0.3	0.1
Nat. Env. H.C.	**335**	7	12	18	0.0031	0.6	0.4
Tartu university	**336**	3	3	17	0.0034	0.7	0.6
Lab. NAA	**338**	7	10	18	0.0030	0.8	0.7
Nat. Rad. Prot.	**343**	0	43	43	0.0005	0.5	0.2
Uni.-sjukhuset	**346**	9	17	20	0.0026	1.1	1.3
Lab. Nuc. Reac.	**389**	12	39	39	0.0007	1.7	2.9
Rad. Met. Lab.	**490**	16	27	29	0.0012	5.7	32.3

BOLD uncertainties are estimated values

* Excluded from analysis

Sum 1/Sigma2	0.047
Mean	332
s.d.	5.1
Weighted mean	323
X2 =	53
St. systematic err.	5
St. stochastic err.	3

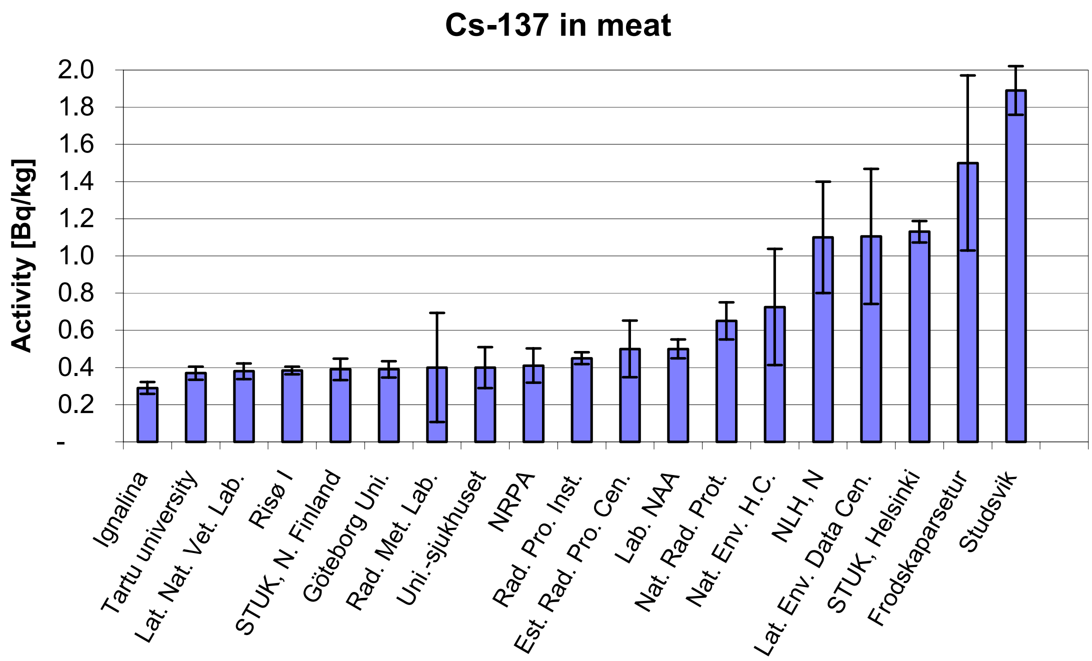


Institution	Ashing	Cs-137 [Bq/kg]	s.d. [Bq/kg]	total [Bq/kg]	E.U. [Bq/kg]	1/s2	X	X2
Ignalina		**0.29**	**0.03**	0.01	0.03	951	-4.5	20
Tartu university		**0.37**	0.03	0.00	0.04	805	-1.8	3
Lat. Nat. Vet. Lab.		**0.38**	**0.04**	0.03	0.04	554	-1.3	2
Risø I	y	**0.38**	0.01	0.020	0.0207	2337	-2.4	6.0
STUK, N. Finland		**0.39**	0.06	0.00	0.06	294	-0.8	1
Göteborg Uni.		**0.39**	**0.04**	0.00	0.04	526	-1.0	1.0
Rad. Met. Lab.		**0.40**	0.10	0.29	0.29	12	-0.1	0.0
Uni.-sjukhuset		**0.40**	0.10	0.11	0.11	83	-0.3	0.1
NRPA		**0.41**	0.09	0.09	0.09	117	-0.3	0.1
Rad. Pro. Inst.		**0.45**	0.02	0.00	0.03	1008	0.5	0.2
Est. Rad. Pro. Cen.		**0.50**	0.15	0.00	0.15	43	0.4	0.2
Lab. NAA		**0.50**	0.05	0.05	0.05	377	1.3	1.6
Nat. Rad. Prot.		**0.65**	**0.07**	0.10	0.10	100	2.2	4.6
Nat. Env. H.C.		**0.73**	0.31	0.00	0.31	10	0.9	0.9
NLH, N		**1.10**	**0.11**	0.30	0.30	11	2.2	4.9
Lat. Env. Data Cen.	y	**1.11**	0.35	0.36	0.36	8	1.8	3.4
STUK, Helsinki	y	**1.13**	0.01	0.05	0.06	301	12.1	145.7
Frodskaparsetur		**1.50**	0.47	0.00	0.47	5	2.3	5.1
Studsvik	y	**1.89**	0.09	0.09	0.13	59	11.2	124.4

BOLD uncertainties are estimated values

* Excluded from analysis

Sum 1/Sigma2	7600
Mean	0.111
s.d.	0.13
Weighted mean	0.434
X2 =	324
St. systematic err.	5
St. stochastic err.	10



Sediment

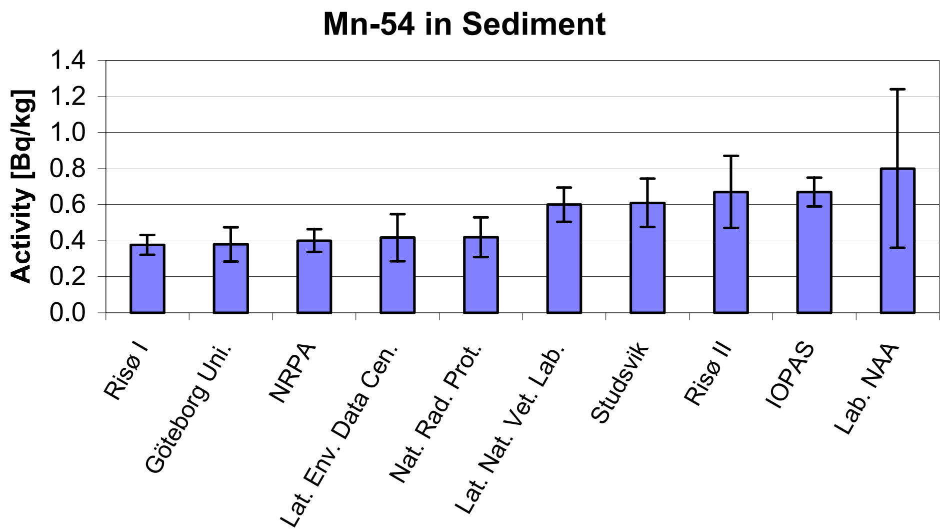
The sediment contained a number of different nuclides. However a number of laboratories reported that they had calibrations for a limited number of the most common radionuclides such as K-40, Co-60 and Cs-137. Concerning Cs-137 the activity here was more than one magnitude higher than for the hay and milk samples. But still the sum X^2 was above 120 for 30 samples.

Determination of natural activity was done by less than half the participants. The results was reasonable, e.g. a sum X^2 of 20 for 12 measurements for Th-232.

Institution	**Mn-54** [Bq/kg]	s.d. [Bq/kg]	total [Bq/kg]	Exp. U. [Bq/kg]	1/s2	X	X2
Risø I	0.38	0.05	0.05	0.06	327	-2	2.6
Göteborg Uni.	0.38	0.09	0.10	0.10	111	-1	0.8
NRPA	0.40	**0.06**	0.06	0.06	250	-1	1.1
Lat. Env. Data Cen.	0.42	0.12	0.13	0.13	58	0	0.1
Nat. Rad. Prot.	0.42	**0.06**	0.11	0.11	83	0	0.2
Lat. Nat. Vet. Lab.	0.60	**0.09**	0.04	0.09	111	1	2.0
Studsvik	0.61	0.13		0.13	56	1	1.2
Risø II	0.67	0.04	0.20	0.20	25	1	1.0
IOPAS	0.67		0.08	0.08	156	3	6.5
Lab. NAA	0.80	0.04	0.44	0.44	5	1	0.6

BOLD uncertainties are estimated values

		Sum 1/Sigma2	1182
		Mean	0.53
		s.d.	0.15
St. systematic err.	5	Weighted mean	0.47
St. stochastic err.	15	X2 =	16

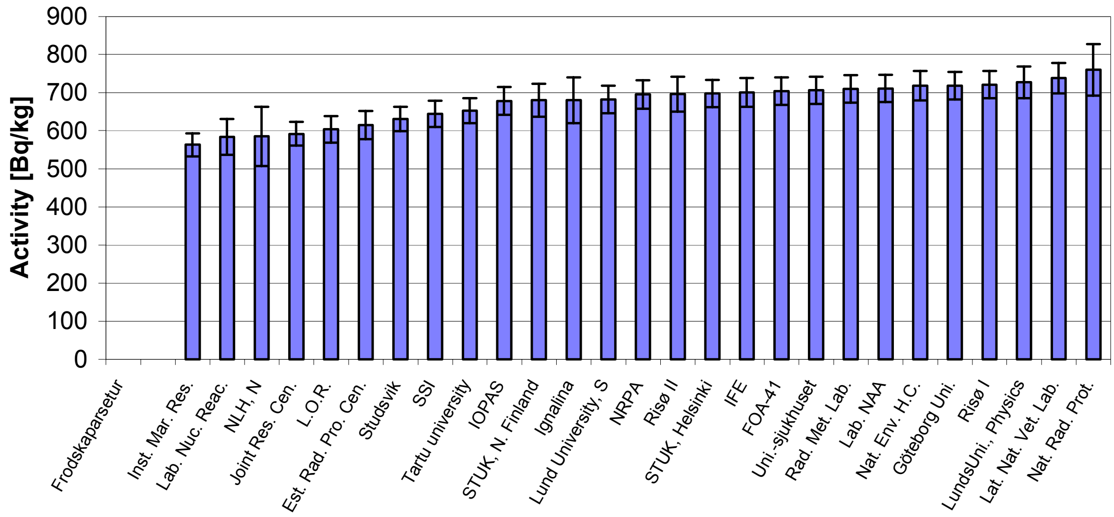


Institution	**K-40** [Bq/kg]	s.d. [Bq/kg]	total [Bq/kg]	Exp. U. [Bq/kg]	1/s2	X	X2
Frodskaparsetur	252*	3					
Inst. Mar. Res.	563	**11**	18	30	0.0011	-3.5	12.5
Lab. Nuc. Reac.	584	9	47	47	0.0005	-1.8	3.3
NLH, N	585	**12**	78	78	0.0002	-1.1	1.2
Joint Res. Cen.	592	10	26	31	0.0010	-2.5	6.2
L.O.R.	604	17	35	35	0.0008	-1.9	3.6
Est. Rad. Pro. Cen.	615	20		37	0.0007	-1.5	2.2
Studsvik	631	7		32	0.0010	-1.2	1.5
SSI	644	**13**	18	35	0.0008	-0.7	0.6
Tartu university	653	4		33	0.0009	-0.5	0.3
IOPAS	678	**14**	20	37	0.0008	0.2	0.0
STUK, N. Finland	680	27		43	0.0005	0.2	0.1
Ignalina	680	**14**	60	60	0.0003	0.2	0.0
Lund University, S	682	13	23	36	0.0008	0.3	0.1
NRPA	695	**14**	35	37	0.0007	0.7	0.4
Risø II	696	29	34	45	0.0005	0.6	0.3
STUK, Helsinki	698	7	35	36	0.0008	0.8	0.6
IFE	701	**14**	15	38	0.0007	0.8	0.7
FOA-41	704	7	25	36	0.0008	0.9	0.9
Uni.-sjukhuset	706	4	29	35	0.0008	1.0	1.0
Rad. Met. Lab.	710	6	30	36	0.0008	1.1	1.2
Lab. NAA	711	4	16	36	0.0008	1.1	1.3
Nat. Env. H.C.	718	**14**	18	39	0.0007	1.2	1.5
Göteborg Uni.	718	**3**		36	0.0008	1.3	1.8
Risø I	721	3	11	36	0.0008	1.4	2.0
LundsUni., Physics	727	20		41	0.0006	1.4	1.9
Lat. Nat. Vet. Lab.	738	**15**	18	40	0.0006	1.7	2.9
Nat. Rad. Prot.	760	**15**	68	68	0.0002	1.3	1.8

BOLD uncertainties are estimated values
* Excluded from analysis

		Sum 1/Sigma2	0.02
		Mean	674
		s.d.	53
St. systematic err.	5	Weighted mean	670
St. stochastic err.	2	X2 =	50

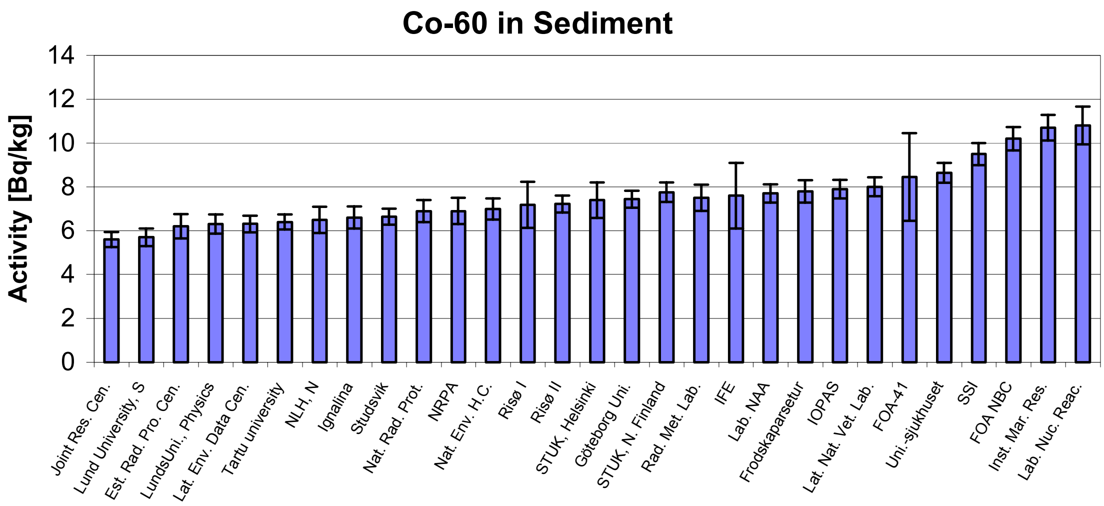
K-40 in Sediment



Institution	**Co-60** [Bq/kg]	s.d. [Bq/kg]	total [Bq/kg]	Exp. U. [Bq/kg]	1/s2	X	X2
Joint Res. Cen.	5.6	0.20	0.30	0.34	8.4	-4.8	22.8
Lund University, S	5.7	0.13	0.40	0.40	6.3	-3.9	14.9
Est. Rad. Pro. Cen.	6.2	0.45		0.55	3.3	-1.9	3.6
LundsUni., Physics	6.3	0.30		0.44	5.3	-2.2	4.7
Lat. Env. Data Cen.	6.3	0.21	0.22	0.38	7.0	-2.5	6.2
Tartu university	6.4	0.10		0.34	8.9	-2.5	6.3
NLH, N	6.5	0.50	0.50	0.60	2.8	-1.2	1.6
Ignalina	6.6	**0.13**	0.50	0.50	4.0	-1.3	1.7
Studsvik	6.6	0.16		0.37	7.4	-1.6	2.7
Nat. Rad. Prot.	6.9	**0.14**	0.50	0.50	4.0	-0.7	0.5
NRPA	6.9	**0.14**	0.60	0.60	2.8	-0.6	0.3
Nat. Env. H.C.	7.0	**0.14**	0.48	0.48	4.3	-0.5	0.3
Risø I	7.2	0.32	1.05	1.05	0.9	-0.1	0.0
Risø II	7.2	0.13	0.35	0.38	6.8	-0.1	0.0
STUK, Helsinki	7.4	0.37	0.81	0.81	1.5	0.2	0.0
Göteborg Uni.	7.4	0.13	0.21	0.39	6.4	0.5	0.2
STUK, N. Finland	7.8	0.22		0.45	5.0	1.2	1.3
Rad. Met. Lab.	7.5	0.47	0.59	0.60	2.8	0.4	0.2
IFE	7.6	0.15	1.50	1.50	0.4	0.2	0.1
Lab. NAA	7.7	0.15	0.23	0.41	5.8	1.1	1.2
Frodskaparsetur	7.8	0.33		0.51	3.9	1.1	1.2
IOPAS	7.9	**0.16**	0.40	0.43	5.5	1.5	2.4
Lat. Nat. Vet. Lab.	8.0	**0.16**	0.20	0.43	5.4	1.8	3.1
FOA-41	8.5	0.70	2.00	2.00	0.3	0.6	0.4
Uni.-sjukhuset	8.7	0.15	0.30	0.46	4.8	3.1	9.4
SSI	9.5	**0.19**	0.40	0.51	3.8	4.4	19.5
FOA NBC	10.2	0.15		0.53	3.5	5.6	31.0
Inst. Mar. Res.	10.7	**0.21**	0.50	0.58	3.0	6.0	36.0
Lab. Nuc. Reac.	10.8	0.43	0.86	0.86	1.3	4.0	16.0

BOLD uncertainties are estimated values

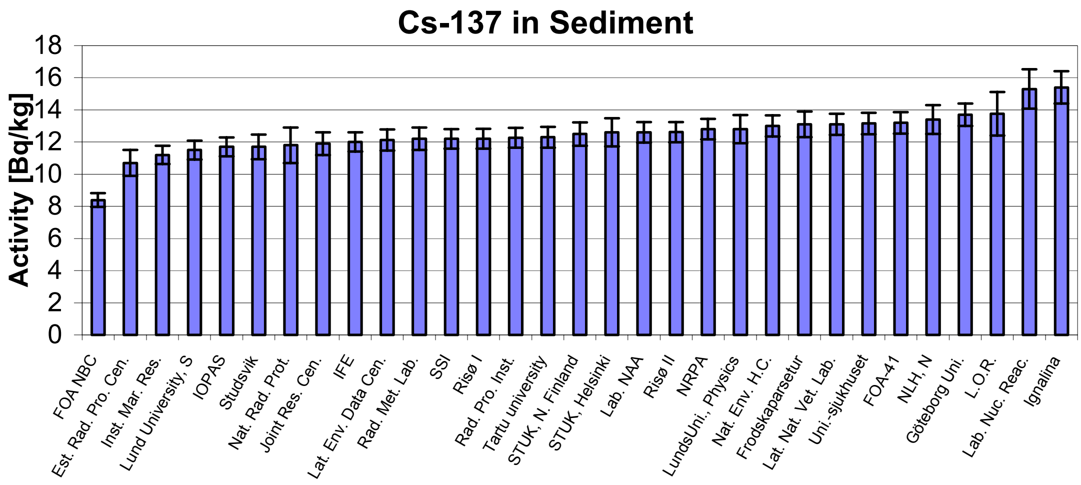
		Sum 1/Sigma2	125.8
		Mean	7.5
		s.d.	1.4
St. systematic err.	5.0	Weighted mean	7.2431
St. stochastic err.	2.0	X2 =	187.54



Institution	Cs-137 [Bq/kg]	s.d. [Bq/kg]	total [Bq/kg]	Exp. U. [Bq/kg]	1/s2	X	X2
FOA NBC	8.4	0.10		0.43	5.4	-8.6	74.3
Est. Rad. Pro. Cen.	10.7	0.60		0.80	1.5	-1.8	3.1
Inst. Mar. Res.	11.2	**0.11**	0.20	0.57	3.1	-1.6	2.6
Lund University, S	11.5	0.10	0.43	0.58	2.9	-1.1	1.1
IOPAS	11.7	**0.00**	0.40	0.59	2.9	-0.7	0.5
Studsvik	11.7	0.50		0.77	1.7	-0.5	0.3
Nat. Rad. Prot.	11.8	**0.00**	1.10	1.10	0.8	-0.3	0.1
Joint Res. Cen.	11.9	0.30	0.70	0.70	2.0	-0.3	0.1
IFE	12.0	**0.00**	0.30	0.60	2.8	-0.2	0.0
Lat. Env. Data Cen.	12.1	0.26	0.28	0.66	2.3	0.0	0.0
Rad. Met. Lab.	12.2	0.33	0.68	0.69	2.1	0.1	0.0
SSI	12.2	**0.00**	0.50	0.61	2.7	0.1	0.0
Risø I	12.2	0.07	0.24	0.61	2.6	0.2	0.0
Rad. Pro. Inst.	12.3	0.05		0.61	2.6	0.2	0.1
Tartu university	12.3	0.20		0.65	2.4	0.3	0.1
STUK, N. Finland	12.5	0.38		0.73	1.9	0.5	0.3
STUK, Helsinki	12.6	0.38	0.88	0.88	1.3	0.5	0.3
Lab. NAA	12.6	0.13	0.30	0.64	2.4	0.8	0.6
Risø II	12.6	0.00	0.35	0.63	2.5	0.8	0.6
NRPA	12.8	**0.00**	0.63	0.64	2.4	1.1	1.1
LundsUni., Physics	12.8	0.60		0.88	1.3	0.8	0.6
Nat. Env. H.C.	13.0	**0.00**	0.35	0.65	2.4	1.4	1.9
Frodskaparsetur	13.1	0.47		0.80	1.5	1.2	1.5
Lat. Nat. Vet. Lab.	13.1	**0.00**	0.34	0.66	2.3	1.5	2.3
Uni.-sjukhuset	13.2	0.11	0.42	0.67	2.2	1.6	2.5
FOA-41	13.2	0.10	0.43	0.67	2.2	1.6	2.6
NLH, N	13.4	0.60	0.60	0.90	1.2	1.4	2.0
Göteborg Uni.	13.7	0.14	0.33	0.70	2.0	2.3	5.1
L.O.R.	13.8	0.95	1.36	1.36	0.5	1.2	1.5
Lab. Nuc. Reac.	15.3	0.31	1.22	1.22	0.7	2.6	6.8
Ignalina	15.4	**0.00**	1.00	1.00	1.0	3.3	10.8

BOLD uncertainties are estimated values

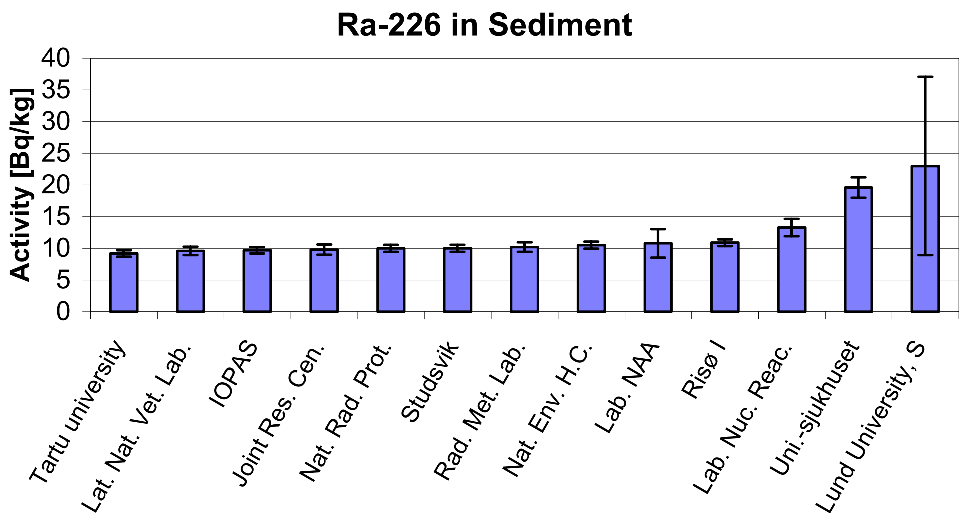
Sum 1/Sigma2	66	Weighted mean	12.1
Mean	12.5	X2 =	123
s.d.	1.3	St. systematic err	5
		St. stochastic err.	1



Institution	**Ra-226** [Bq/kg]	s.d. [Bq/kg]	total [Bq/kg]	Exp. U. [Bq/kg]	1/s2	X	X2
Tartu university	**9.2**	0.20		0.50	4	-1.9	3.7
Lat. Nat. Vet. Lab.	**9.6**	**0.19**	0.67	0.67	2.2	-0.8	0.7
IOPAS	**9.7**		0.30	0.49	4.3	-1.0	0.9
Joint Res. Cen.	**9.8**	0.30	0.80	0.80	1.6	-0.5	0.2
Nat. Rad. Prot.	**10.0**	**0.20**		0.54	3.4	-0.3	0.1
Studsvik	**10.0**	**0.20**		0.54	3.4	-0.3	0.1
Rad. Met. Lab.	**10.2**	0.58	0.69	0.77	1.7	0.0	0.0
Nat. Env. H.C.	**10.5**	**0.21**	0.38	0.57	3.1	0.6	0.3
Lab. NAA	**10.8**	0.22	2.25	2.25	0.2	0.3	0.1
Risø I	**10.9**	0.07	0.23	0.55	3.3	1.3	1.7
Lab. Nuc. Reac.	**13.3**	1.20		1.37	0.5	2.3	5.2
Uni.-sjukhuset	**19.6**	1.30	1.50	1.63	0.4	5.8	33.5
Lund University, S	**23.0**	14.03	14.03	14.08	0.0	0.9	0.8

BOLD uncertainties are estimated values

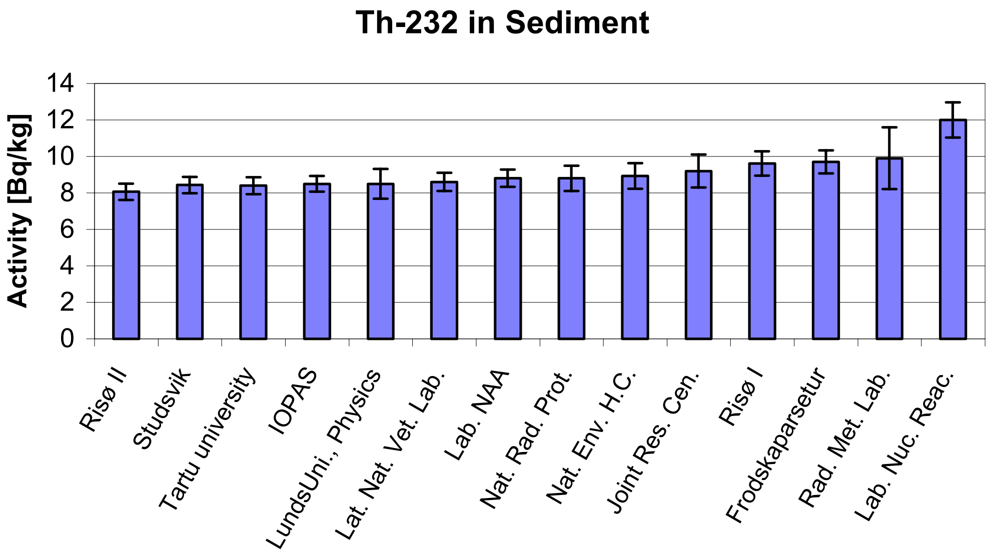
Sum 1/Sigma2	28
Mean	12.0
s.d.	4.3
Weighted mean	10.2
X2 =	48
St. systematic err	5
St. stochastic err.	2



Institution	Th-232 [Bq/kg]	s.d. [Bq/kg]	total [Bq/kg]	Exp. U. [Bq/kg]	1/s2	X	X2
Risø II	**8.1**	0.19	0.42	0.45	5	-1.6	2.4
Studsvik	**8.4**	0.13		0.44	5.1	-0.7	0.6
Tartu university	**8.4**	0.20		0.47	4.6	-0.8	0.6
IOPAS	**8.5**		0.30	0.43	5.5	-0.6	0.4
LundsUni., Physics	**8.5**	0.70		0.82	1.5	-0.3	0.1
Lat. Nat. Vet. Lab.	**8.6**	**0.26**	0.22	0.50	4.0	-0.3	0.1
Lab. NAA	**8.8**	0.18	0.26	0.47	4.5	0.1	0.0
Nat. Rad. Prot.	**8.8**	**0.26**	0.70	0.70	2.0	0.1	0.0
Nat. Env. H.C.	**8.9**	**0.27**	0.70	0.70	2.0	0.2	0.1
Joint Res. Cen.	**9.2**	0.30	0.90	0.90	1.2	0.5	0.2
Risø I	**9.6**	0.20	0.67	0.67	2.2	1.3	1.7
Frodskaparsetur	**9.7**	0.41		0.63	2.5	1.5	2.2
Rad. Met. Lab.	**9.9**	0.54	1.69	1.69	0.3	0.7	0.5
Lab. Nuc. Reac.	**12.0**	0.36	0.96	0.96	1.1	3.4	11.4

BOLD uncertainties are estimated values

Sum 1/Sigma2	42
Mean	9.1
s.d.	1.0
Weighted mean	8.8
X2 =	20
St. systematic err	5
St. stochastic err.	3

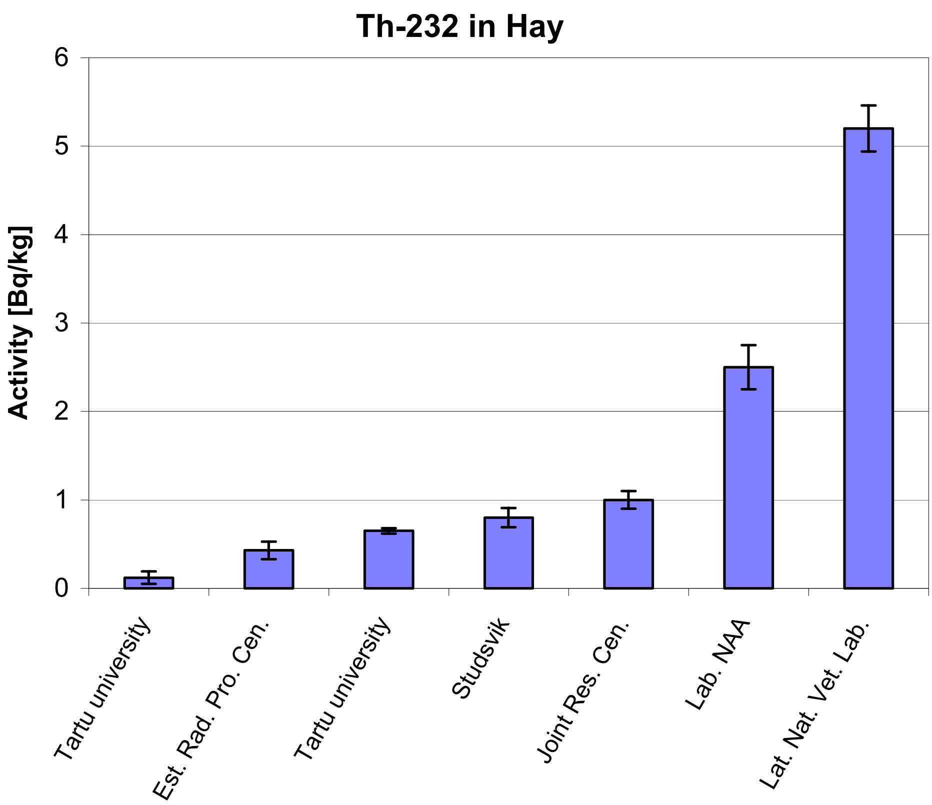


Hay

Hay was similar to milk and meat as a typical low activity environmental material. Again the results for K-40 were reasonable except for two strange values. For Cs-137 there was an even more pronounced spread with a number of very high values reported.

Some laboratories also reported natural radioactivity for hay. Results are very variable especially for Th-232.

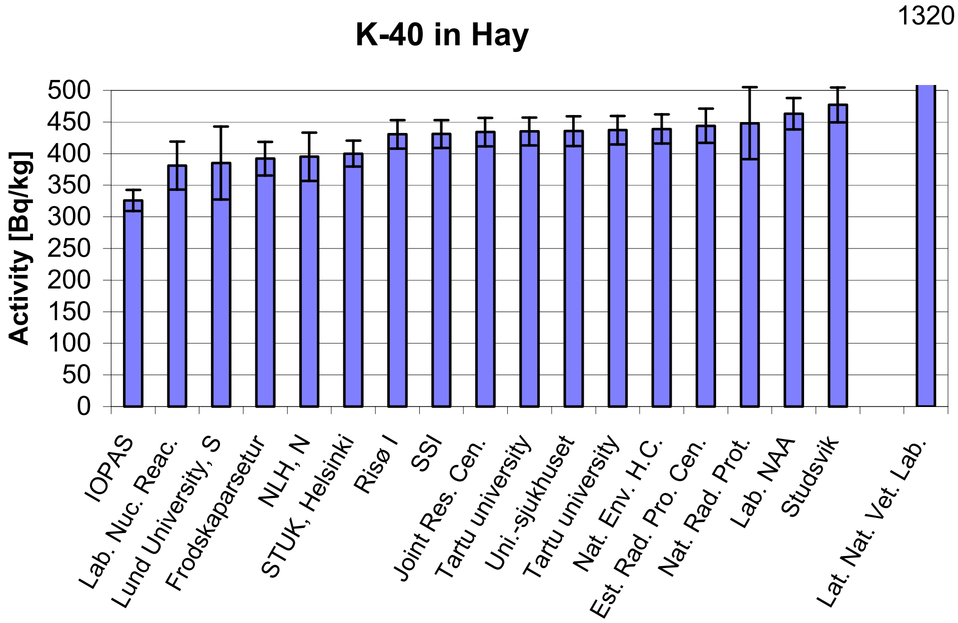
Institution	Th-232 [Bq/kg]	s.d. [Bq/kg]	total [Bq/kg]
Tartu university	0.12	0.07	
Est. Rad. Pro. Cen.	0.43	0.1	
Tartu university	0.65	0.03	
Studsvik	0.8	0.11	
Joint Res. Cen.	1	0.1	0.300
Lab. NAA	2.5	0.25	0.258
Lat. Nat. Vet. Lab.	5.2	0.26	0.260



Institution	K-40 [Bq/kg]	s.d. [Bq/kg]	total [Bq/kg]	Exp. U. [Bq/kg]	1/s2	X	X2
IOPAS	326	**3**		16.6	0.0036	-5.4	29.6
Lab. Nuc. Reac.	381	11	38	38.1	0.0007	-0.9	0.9
Lund University, S	385	42	58	57.8	0.0003	-0.5	0.3
Frodskaparsetur	392	18		26.4	0.0014	-0.9	0.9
NLH, N	395	**4**	38	38.0	0.0007	-0.6	0.3
STUK, Helsinki	400	4	20	20.4	0.0024	-0.8	0.7
Risø I	430	6	20	22.4	0.0020	0.6	0.4
SSI	431	**4**	13	22.0	0.0021	0.7	0.4
Joint Res. Cen.	434	6	15	22.5	0.0020	0.8	0.6
Tartu university	435	2		21.8	0.0021	0.8	0.7
Uni.-sjukhuset	436	8	19	23.3	0.0018	0.8	0.7
Tartu university	437	5		22.4	0.0020	0.9	0.8
Nat. Env. H.C.	439	**4**	23	23.0	0.0019	1.0	1.0
Est. Rad. Pro. Cen.	444	16		27.1	0.0014	1.0	1.0
Nat. Rad. Prot.	448	**4**	57	57.0	0.0003	0.6	0.3
Lab. NAA	463	9	14	24.9	0.0016	1.9	3.5
Studsvik	477	14	0	28	0.0013	2.2	4.8
Lat. Nat. Vet. Lab.	1320	0	33	66	0.0002	13.7	187.4

BOLD uncertainties are estimated values

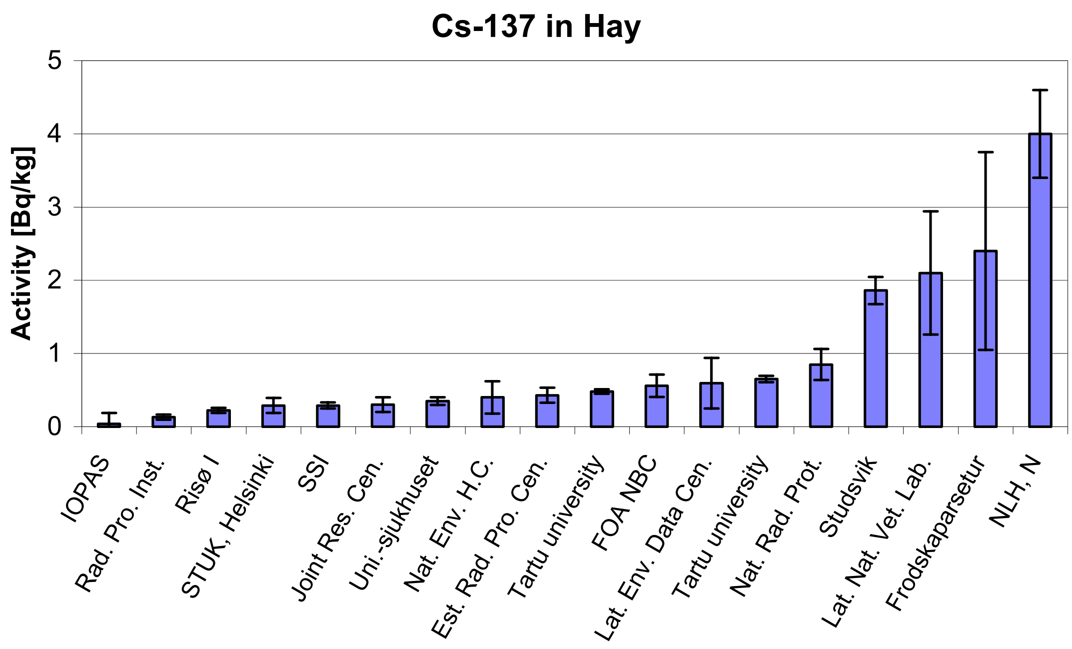
Sum 1/Sigma2	0.028
Mean	421
s.d.	37
Weighted mean	416
X2 =	47
St. systematic err	5
St. stochastic err.	1



Institution	Cs-137 [Bq/kg]	s.d. [Bq/kg]	total [Bq/kg]	Exp. U. [Bq/kg]	1/s2	X	X2
IOPAS	0.04	**0.00**	0.15	0.15	44	-2.1	4.5
Rad. Pro. Inst.	0.13	0.04		0.04	784.8	-6.4	41.4
Risø I	0.22	0.01	0.04	0.04	763.1	-3.8	14.2
STUK, Helsinki	0.29	0.04	0.10	0.10	97.1	-0.7	0.5
SSI	0.29	**0.03**	0.04	0.04	625.0	-1.7	3.0
Joint Res. Cen.	0.30	0.10	0.10	0.10	97.8	-0.6	0.3
Uni.-sjukhuset	0.35	0.05	0.05	0.05	356.3	-0.2	0.0
Nat. Env. H.C.	0.40	**0.04**	0.22	0.22	20.7	0.2	0.0
Est. Rad. Pro. Cen.	0.43	0.10		0.10	95.6	0.7	0.5
Tartu university	0.48	0.02	0.02	0.03	1024.6	3.8	14.8
FOA NBC	0.56	0.15		0.15	42.9	1.3	1.7
Lat. Env. Data Cen.	0.59	0.32	0.35	0.35	8.4	0.7	0.5
Tartu university	0.65	0.03		0.04	511.2	6.6	43.1
Nat. Rad. Prot.	0.85	**0.09**	0.21	0.21	22.7	2.3	5.4
Studsvik	1.86	0.16		0.19	29.2	8.1	65.7
Lat. Nat. Vet. Lab.	2.10	**0.21**	0.84	0.84	1.4	2.1	4.3
Frodskaparsetur	2.40	1.35		1.35	0.5	1.5	2.3
NLH, N	4.00	**0.40**	0.60	0.60	2.8	6.1	36.8

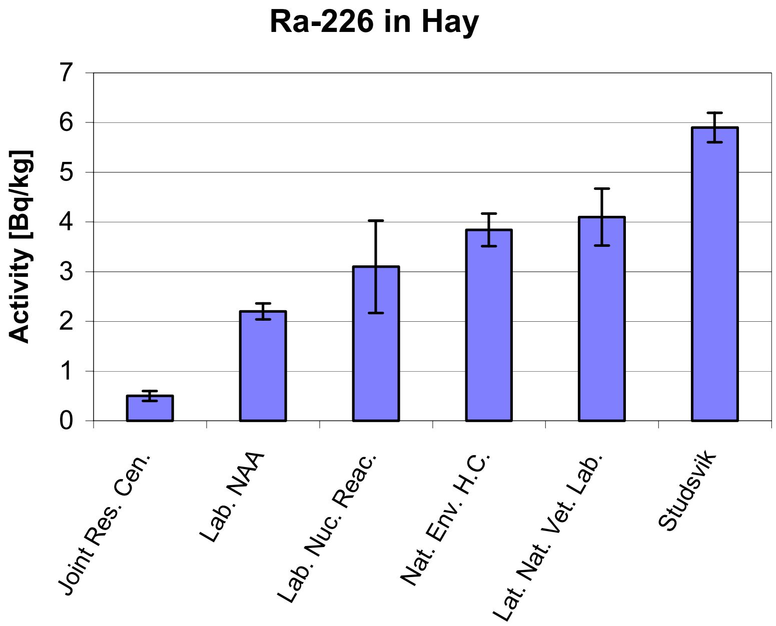
BOLD uncertainties are estimated values

Sum 1/Sigma2	4528
Mean	0.9
s.d.	1.0
Weighted mean	0.4
X2 =	239
St. systematic err	5
St. stochastic err.	10



Institution	Ra-226 [Bq/kg]	s.d. [Bq/kg]	total [Bq/kg]
Joint Res. Cen.	0.5	0.1	0.100
Lab. NAA	2.2	0.154	0.163
Lab. Nuc. Reac.	3.1	0.837	0.930
Nat. Env. H.C.	3.84	0	0.330
Lat. Nat. Vet. Lab.	4.1	0	0.574
Studsvik	5.9	0	**0.30**

BOLD uncertainties are estimated values



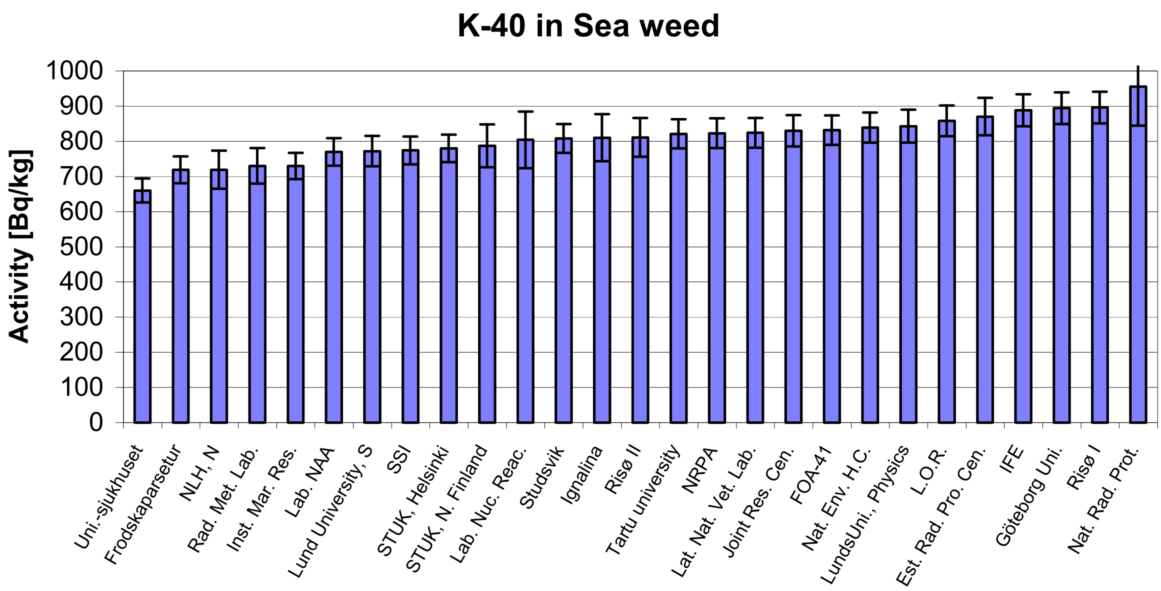
Sea weed

The sea weed sample contained the highest number of different nuclides. Many of the nuclides were present at easily detctable levels. However, none of the data sets are in statistical balance. The best result is for K-40 with sum X^2 = 50 for 25 results.

Institution	K-40 [Bq/kg]	s.d. [Bq/kg]	total [Bq/kg]	Exp. U. [Bq/kg]	1/s2	X	X2
Uni.-sjukhuset	660	9	28	34	0.0009	-4.0	16.4
Frodskaparsetur	719	13		38	0.0007	-2.1	4.3
NLH, N	719	**7**	54	54	0.0003	-1.5	2.2
Rad. Met. Lab.	730	**7**	50	50	0.0004	-1.4	1.8
Inst. Mar. Res.	730	**7**	24	37	0.0007	-1.8	3.4
Lab. NAA	770	8	18	39	0.0006	-0.7	0.5
Lund University, S	772	19	28	43	0.0005	-0.6	0.4
SSI	774	**8**	30	39	0.0006	-0.6	0.4
STUK, Helsinki	780	4	35	39	0.0007	-0.5	0.2
STUK, N. Finland	787	47		61	0.0003	-0.2	0.0
Lab. Nuc. Reac.	804	24	80	80	0.0002	0.1	0.0
Studsvik	808	9	9	41	0.0006	0.2	0.1
Ignalina	810	**8**	67	67	0.0002	0.2	0.0
Risø II	811	37	50	55	0.0003	0.2	0.1
Tartu university	821	7		42	0.0006	0.5	0.3
NRPA	823	**8**	42	42	0.0006	0.6	0.3
Lat. Nat. Vet. Lab.	824	**8**	21	42	0.0006	0.6	0.4
Joint Res. Cen.	830	17	44	45	0.0005	0.7	0.5
FOA-41	832	4	24	42	0.0006	0.8	0.6
Nat. Env. H.C.	839	**8**	22	43	0.0005	0.9	0.9
LundsUni., Physics	843	20		47	0.0005	1.0	0.9
L.O.R.	858	**9**	26	44	0.0005	1.4	1.9
Est. Rad. Pro. Cen.	870	31		53	0.0004	1.3	1.8
IFE	888	**9**	19	45	0.0005	2.0	3.9
Göteborg Uni.	894	6		45	0.0005	2.1	4.5
Risø I	896	2	7	45	0.0005	2.2	4.7
Nat. Rad. Prot.	955	**10**	111	111	0.0001	1.4	2.0

BOLD uncertainties are estimated values

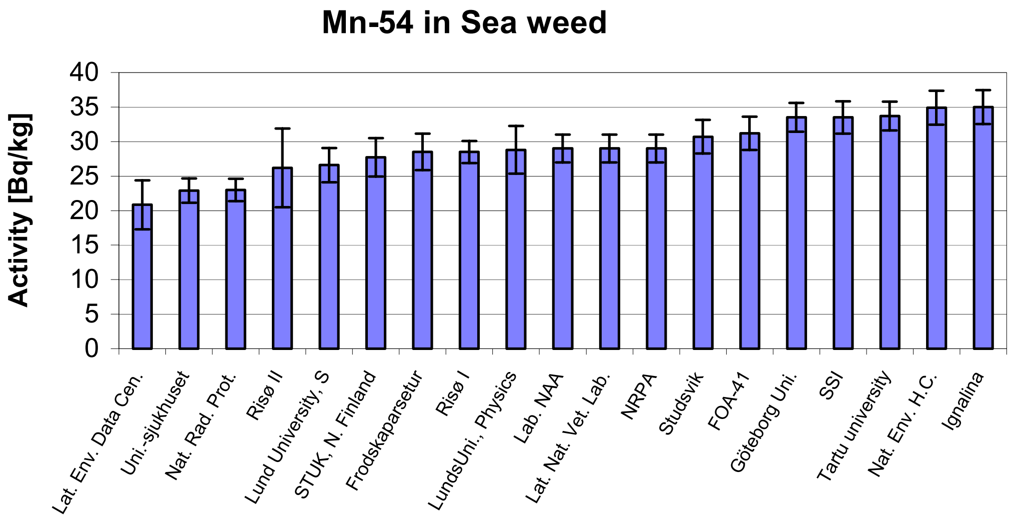
		Sum 1/Sigma2	0.013
		Mean	809
		s.d.	65
St. systematic err.	5	Weighted mean	798.5
St. stochastic err.	1	X2 =	53



Institution	Mn-54 [Bq/kg]	s.d. [Bq/kg]	total [Bq/kg]	Exp. U. [Bq/kg]	1/s2	X	X2
Lat. Env. Data Cen.	20.8	3.4	3.6	3.6	0.1	-2.3	5.2
Uni.-sjukhuset	22.9	0.6	0.9	1.7	0.3	-3.5	11.9
Nat. Rad. Prot.	23.0	**0.5**	3.0	1.6	0.4	-3.7	13.5
Risø II	26.2	4.4	6.6	5.7	0.0	-0.5	0.2
Lund University, S	26.6	1.2	1.2	2.5	0.2	-0.9	0.9
STUK, N. Finland	27.7	1.4		2.8	0.1	-0.4	0.2
Frodskaparsetur	28.5	1.2		2.7	0.1	-0.2	0.0
Risø I	28.5	0.2	0.5	1.6	0.4	-0.3	0.1
LundsUni., Physics	28.8	2.0		3.4	0.1	0.0	0.0
Lab. NAA	29.0	0.6	0.9	2.0	0.2	0.0	0.0
Lat. Nat. Vet. Lab.	29.0	**0.6**	1.7	2.0	0.2	0.0	0.0
NRPA	29.0	**0.6**	1.5	2.0	0.2	0.0	0.0
Studsvik	30.7	0.9	0.9	2.4	0.2	0.7	0.5
FOA-41	31.2	0.9	1.6	2.4	0.2	0.9	0.9
Göteborg Uni.	33.5	0.4	0.8	2.1	0.2	2.2	4.9
SSI	33.5	**0.7**	2.0	2.3	0.2	2.0	3.8
Tartu university	33.7	0.4		2.1	0.2	2.3	5.2
Nat. Env. H.C.	34.9	**0.7**	2.3	2.4	0.2	2.4	6.0
Ignalina	35.0	**0.7**	2.0	2.5	0.2	2.5	6.2

BOLD uncertainties are estimated values

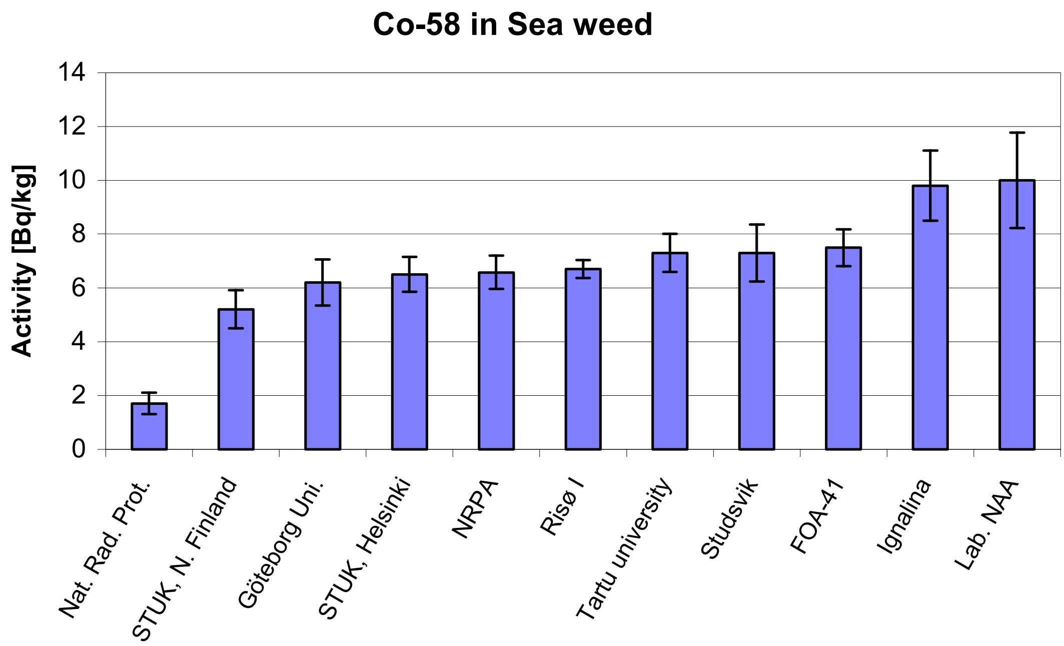
Sum 1/Sigma2	4
Mean	29.1
s.d.	4.1
Weighted mean	28.9
X2 =	59
St. systematic err	5
St. stochastic err.	2



Institution	**Co-58** [Bq/kg]	s.d. [Bq/kg]	total [Bq/kg]	Exp. U. [Bq/kg]	1/s2	X	X2
Nat. Rad. Prot.	1.7	0.034	0.4	0.4	6.3	-10.0	99.4
STUK, N. Finland	5.2	0.660		0.7	2.0	-0.7	0.5
Göteborg Uni.	6.2	0.800	0.8	0.9	1.4	0.6	0.4
STUK, Helsinki	6.5	0.260	0.7	0.7	2.4	1.2	1.6
NRPA	6.6	**0.132**	0.6	0.6	2.6	1.4	2.0
Risø I	6.7	0.065	0.2	0.3	8.6	3.0	8.8
Tartu university	7.3	0.600		0.7	2.0	2.3	5.3
Studsvik	7.3	1.000	1.0	1.1	0.9	1.5	2.3
FOA-41	7.5	0.500	0.7	0.7	2.1	2.6	6.9
Ignalina	9.8	**0.196**	1.3	1.3	0.6	3.2	10.0
Lab. NAA	10.0	1.700	1.7	1.8	0.3	2.4	5.9

BOLD uncertainties are estimated values

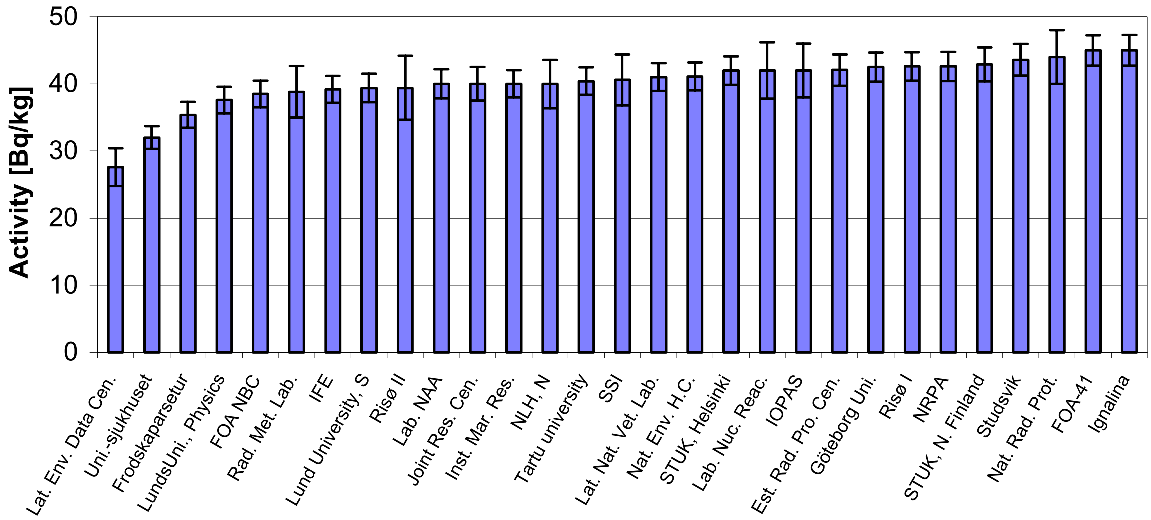
Sum 1/Sigma2	29
Mean	6.8
s.d.	2.2
Weighted mean	5.7
X2 =	143
St. systematic err	5
St. stochastic err.	2



Institution	Co-60 [Bq/kg]	s.d. [Bq/kg]	total [Bq/kg]	Exp. U. [Bq/kg]	1/s2	X	X2
Lat. Env. Data Cen.	27.6	2.4	2.6	2.8	0.13	-4.4	19.3
Uni.-sjukhuset	32.0	0.5	1.0	1.7	0.36	-4.7	22.2
Frodskaparsetur	35.4	0.8	0.8	1.9	0.27	-2.3	5.5
LundsUni., Physics	37.6	0.6		2.0	0.26	-1.2	1.4
FOA NBC	38.5	0.5	0.5	2.0	0.25	-0.7	0.5
Rad. Met. Lab.	38.8	**0.39**	3.8	3.8	0.07	-0.3	0.1
IFE	39.2	**0.39**	1.6	2.0	0.25	-0.4	0.1
Lund University, S	39.4	0.8	1.3	2.1	0.22	-0.2	0.1
Risø II	39.4	3.2	4.8	4.8	0.04	-0.1	0.0
Lab. NAA	40.0	0.8	1.2	2.2	0.22	0.0	0.0
Joint Res. Cen.	40.0	1.0	2.5	2.5	0.16	0.0	0.0
Inst. Mar. Res.	40.0	**0.40**	1.0	2.0	0.24	0.0	0.0
NLH, N	40.0	3.0	3.0	3.6	0.08	0.0	0.0
Tartu university	40.4	0.3	0.3	2.0	0.24	0.2	0.1
SSI	40.6	**0.41**	3.8	3.8	0.07	0.2	0.0
Lat. Nat. Vet. Lab.	41.0	**0.41**	1.0	2.1	0.23	0.5	0.3
Nat. Env. H.C.	41.1	**0.41**	2.0	2.1	0.23	0.6	0.3
STUK, Helsinki	42.0	0.3	2.0	2.1	0.22	1.0	1.0
Lab. Nuc. Reac.	42.0	1.3	4.2	4.2	0.06	0.5	0.2
IOPAS	42.0	**0.42**	4.0	4.0	0.06	0.5	0.3
Est. Rad. Pro. Cen.	42.1	1.0	1.0	2.3	0.18	0.9	0.9
Göteborg Uni.	42.5	0.4	1.0	2.2	0.21	1.2	1.4
Risø I	42.6	0.2	0.7	2.1	0.22	1.3	1.6
NRPA	42.6	**0.43**	2.1	2.2	0.21	1.2	1.5
STUK, N. Finland	42.9	1.3	0.0	2.5	0.16	1.2	1.4
Studsvik	43.6	0.9	0.9	2.4	0.18	1.6	2.5
Nat. Rad. Prot.	44.0	**0.44**	4.0	4.0	0.06	1.0	1.0
FOA-41	45.0	0.4	1.5	2.3	0.19	2.2	5.0
Ignalina	45.0	**0.45**	2.0	2.3	0.19	2.2	4.9

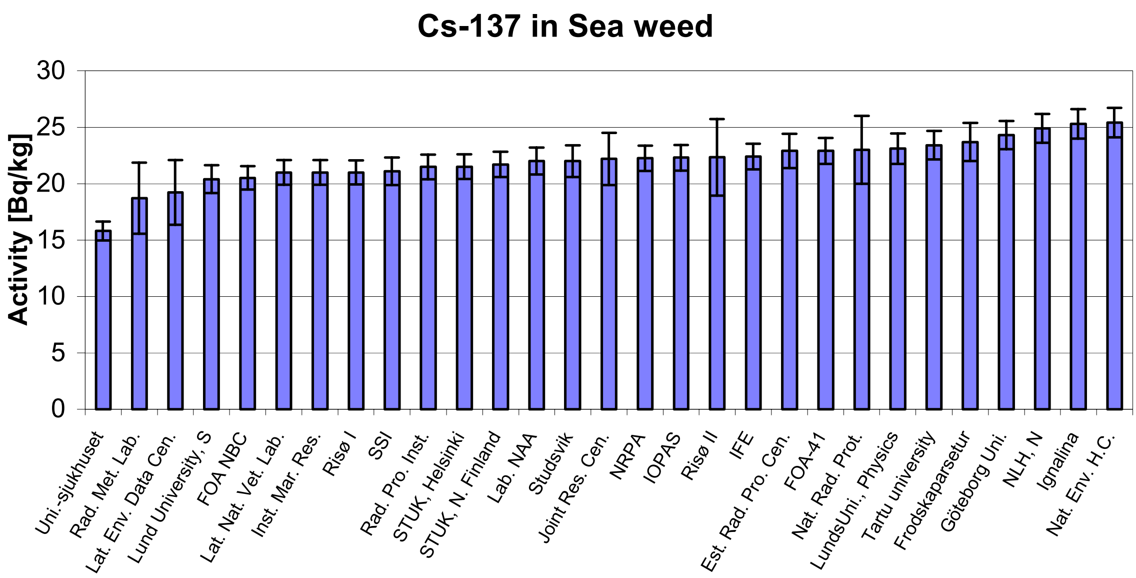
		Sum 1/Sigma2	5.3
		Mean	40.3
		s.d.	3.7
St. systematic err.	5	Weighted mean	39.9
St. stochastic err.	1	X2 =	72

Co-60 in Sea weed



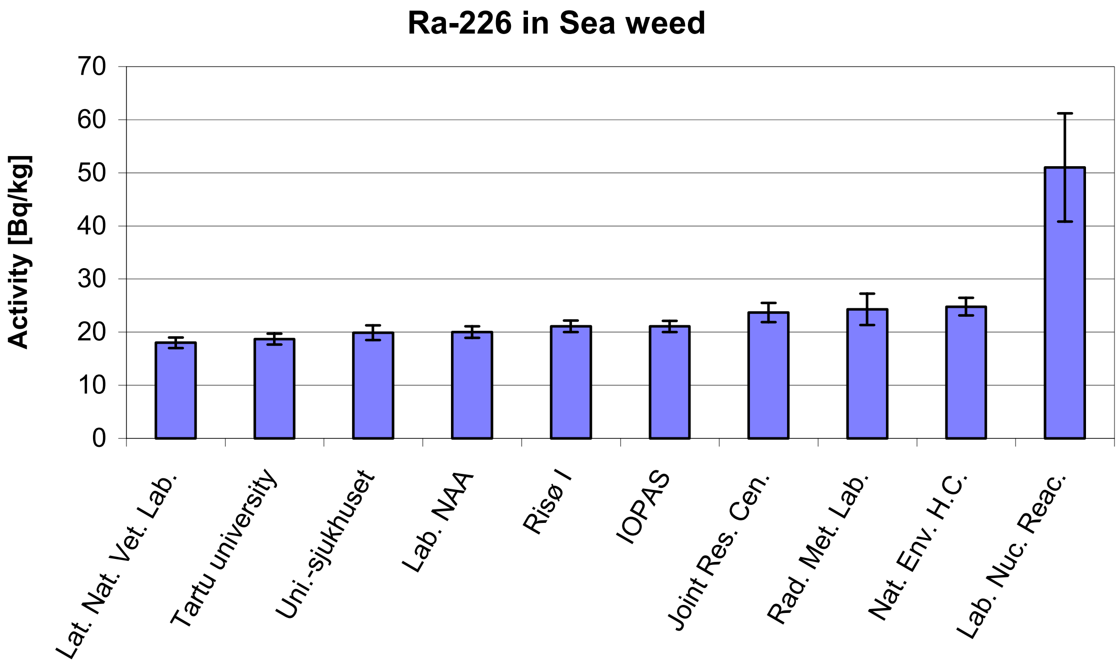
Institution	Cs-137 [Bq/kg]	s.d. [Bq/kg]	total [Bq/kg]	Exp. U. [Bq/kg]	1/s2	X	X2
Uni.-sjukhuset	15.8	0.3	0.5	0.8	1.40	-7.0	49.3
Rad. Met. Lab.	18.7	**0.19**	3.2	3.2	0.10	-1.0	0.9
Lat. Env. Data Cen.	19.2	2.7	2.9	2.9	0.12	-0.9	0.8
Lund University, S	20.4	0.7	1.2	1.2	0.65	-1.1	1.2
FOA NBC	20.5	**0.21**	0.4	1.0	0.92	-1.2	1.4
Lat. Nat. Vet. Lab.	21.0	**0.21**	0.5	1.1	0.87	-0.7	0.5
Inst. Mar. Res.	21.0	**0.21**	0.7	1.1	0.87	-0.7	0.5
Risø I	21.0	0.1	0.3	1.1	0.90	-0.7	0.5
SSI	21.1	**0.21**	1.2	1.2	0.69	-0.5	0.3
Rad. Pro. Inst.	21.5	0.2	0.0	1.1	0.84	-0.2	0.1
STUK, Helsinki	21.5	0.2	0.8	1.1	0.84	-0.2	0.0
STUK, N. Finland	21.7	**0.22**	1.1	1.1	0.82	0.0	0.0
Lab. NAA	22.0	0.4	0.7	1.2	0.71	0.2	0.1
Studsvik	22.0	0.9	0.9	1.4	0.50	0.2	0.0
Joint Res. Cen.	22.2	0.9	2.3	2.3	0.19	0.2	0.0
NRPA	22.3	**0.22**	1.1	1.1	0.78	0.5	0.2
IOPAS	22.3	**0.22**	0.9	1.1	0.77	0.5	0.2
Risø II	22.3	3.2	3.2	3.4	0.09	0.2	0.0
IFE	22.4	**0.22**	0.3	1.1	0.77	0.6	0.3
Est. Rad. Pro. Cen.	22.9	1.0		1.5	0.43	0.8	0.6
FOA-41	22.9	0.2	0.8	1.2	0.74	1.0	1.0
Nat. Rad. Prot.	23.0	**0.23**	3.0	3.0	0.11	0.4	0.2
LundsUni., Physics	23.1	0.70		1.4	0.55	1.0	1.0
Tartu university	23.4	0.5		1.3	0.62	1.3	1.7
Frodskaparsetur	23.7	1.2		1.7	0.35	1.2	1.4
Göteborg Uni.	24.3	0.3	0.6	1.2	0.65	2.1	4.3
NLH, N	24.9	**0.25**	0.7	1.3	0.62	2.5	6.2
Ignalina	25.3	**0.25**	1.2	1.3	0.60	2.8	7.6
Nat. Env. H.C.	25.4	**0.25**	0.9	1.3	0.60	2.8	8.0

	Sum 1/Sigma2	18.1
	Mean	22.0
	s.d.	2.0
St. systematic err. 5	Weighted mean	21.7
St. stochastic err. 1	X2 =	88



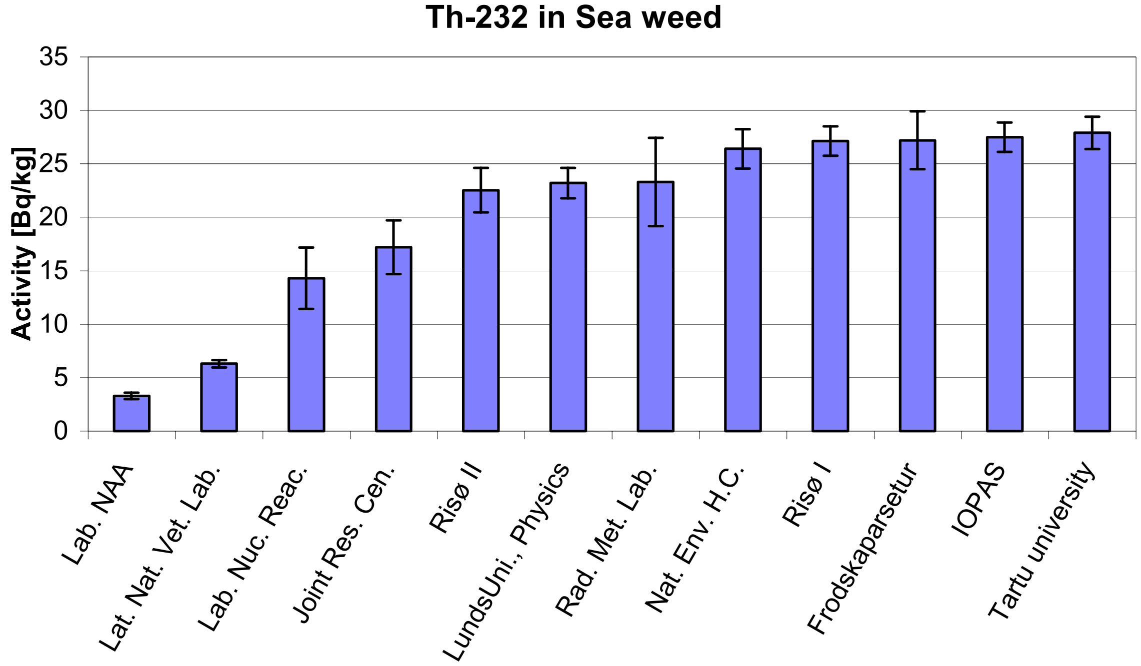
Institution	Ra-226 [Bq/kg]	s.d. [Bq/kg]	total [Bq/kg]	Exp. U. [Bq/kg]	1/s2	X	X2
Lat. Nat. Vet. Lab.	18.0	**0.36**	0.7	1.0	1.1	-2.4	6.0
Tartu university	18.7	0.4		1.0	1.0	-1.6	2.7
Uni.-sjukhuset	19.9	1.0	1.3	1.4	0.5	-0.3	0.1
Lab. NAA	20.0	0.4	0.6	1.1	0.9	-0.3	0.1
Risø I	21.1	0.2	0.5	1.1	0.9	0.7	0.5
IOPAS	21.1		0.5	1.1	0.9	0.7	0.5
Joint Res. Cen.	23.7	0.7	1.8	1.8	0.3	1.8	3.4
Rad. Met. Lab.	24.3	**0.49**	3.0	3.0	0.1	1.3	1.8
Nat. Env. H.C.	24.8	**0.50**	1.7	1.7	0.4	2.7	7.2
Lab. Nuc. Reac.	51.0	5.1	10.2	10.2	0.0	3.0	9.0

Sum 1/Sigma2	6
Mean	24.3
s.d.	9.7
Weighted mean	20.4
X2 =	31
St. systematic err	5
St. stochastic err.	2



Institution	**Th-232** [Bq/kg]	s.d. [Bq/kg]	total [Bq/kg]	Exp. U. [Bq/kg]	1/s2	X	X2
Lab. NAA	3.3	0.2	0.3	0.3	11.3	-13.4	178.9
Lat. Nat. Vet. Lab.	6.3	**0.13**	0.3	0.3	8.7	-2.9	8.2
Lab. Nuc. Reac.	14.3	2.1	2.9	2.9	0.1	2.5	6.0
Joint Res. Cen.	17.2	1.0	2.5	2.5	0.2	4.0	15.8
Risø II	22.5	1.8	1.8	2.1	0.2	7.3	53.6
LundsUni., Physics	23.2	0.8		1.4	0.5	11.3	127.8
Rad. Met. Lab.	23.3	**0.47**	4.1	4.1	0.1	3.9	15.1
Nat. Env. H.C.	26.4	**0.53**	1.9	1.9	0.3	10.3	106.9
Risø I	27.1	0.2	0.6	1.4	0.5	14.5	210.3
Frodskaparsetur	27.2	2.3		2.7	0.1	7.4	54.4
IOPAS	27.5	0.0	0.9	1.4	0.5	14.7	216.4
Tartu university	27.9	0.6		1.5	0.4	13.6	184.5

Sum 1/Sigma2	23
Mean	20.5
s.d.	8.5
Weighted mean	7.3
X2 =	1178
St. systematic err	5



Sea water

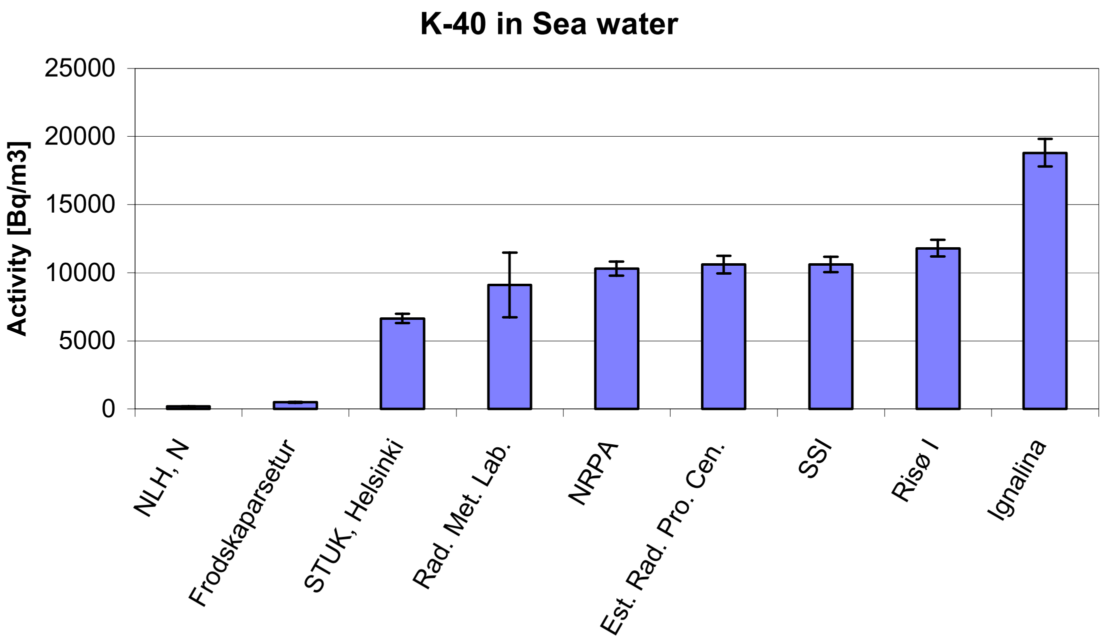
Sea water seems to have been the most difficult material to handle, the result being very variable.

For K-40 some agreement exists. A value of 11000 Bq m-3 seems likely. However, two laboratories that used the AMP method (precipitation of Cs-137 using Ammonium-Molybdo-Phosphate) reported K-40 results anyway?

For Cs-137 the scatter is very bad. The result of 400 Bq m^{-3} is probably due to a missing conversion between volume of water and dry weight of sea salt. The results have been illustrated in Figure 3.1 below. The precipitation method seems to have a plateau between 12 and 18 Bq m^{-3}, whereas people using the evaporation technique achieve higher values. Unfortunately information on method applied is still missing from some participants.

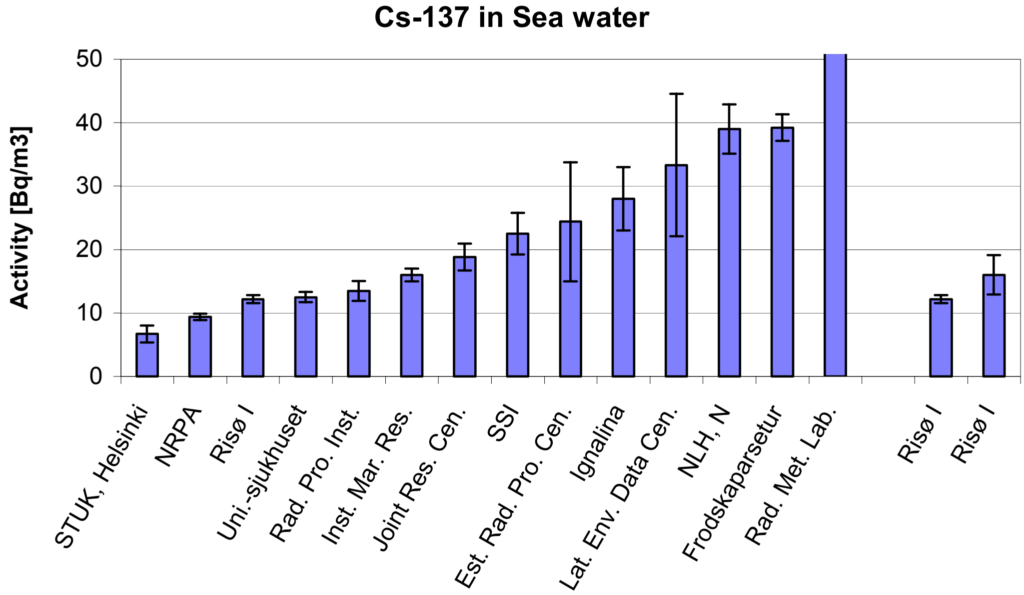
Institution	K-40 [Bq/m3]	s.d. [Bq/m3]	**total** [Bq/m3]	Exp. U. [Bq/m3]	1/s2	X	X2
NLH, N	174	**3**		9	0.011389	-5	30
Frodskaparsetur	493	10		27	0.001409	10	101
STUK, Helsinki	6640	46	312	335	0.000009	19	366
Rad. Met. Lab.	9100	355	2366	2366	0.000000	4	14
NRPA	10300	2		515	0.000004	20	383
Est. Rad. Pro. Cen.	10600	382		653	0.000002	16	252
SSI	10600	212		571	0.000003	18	330
Risø I	11800	120		602	0.000003	19	370
Ignalina	18800	376		1012	0.000001	18	337

Sum 1/Sigma2	0
Mean	8723.0
s.d.	5764.6
Weighted mean	225.0
X2 =	2183
St. systematic err.	5
St. stochastic err.	2



Institution	Cs-137 [Bq/m3]	s.d. [Bq/m3]	**total** [Bq/m3]	Exp. U. [Bq/m3]	1/s2	X	X2
STUK, Helsinki	6.7	0.6	1.3	1.3	0.557	-4.2	18.0
NRPA	9.4	**0.2**		0.5	3.903	-5.9	34.7
Risø I	12.2	0.1		0.6	2.615	-0.3	0.1
Uni.-sjukhuset	12.5	0.5	0.6	0.8	1.562	0.1	0.0
Rad. Pro. Inst.	13.5	1.4		1.6	0.414	0.7	0.5
Inst. Mar. Res.	16.0	**0.3**	1.0	1.0	1.000	3.6	13.1
Joint Res. Cen.	18.8	0.8	2.1	2.1	0.227	3.1	9.3
SSI	22.5	**0.5**	3.3	3.3	0.092	3.1	9.4
Est. Rad. Pro. Cen.	24.4	9.3		9.4	0.011	1.3	1.6
Ignalina	28.0	**0.6**	5.0	5.0	0.040	3.1	9.8
Lat. Env. Data Cen.	33.3	10.2	11.2	11.2	0.008	1.9	3.5
NLH, N	39.0	**0.8**	3.9	3.9	0.066	6.8	46.6
Frodskaparsetur	39.2	0.8		2.1	0.225	12.7	161.8
Rad. Met. Lab.	400.0	32.4	191.6	191.6	0.000	2.0	4.1

Risø I	12.2	0.11		1	Sum 1/Sigma2	11
Risø I	16.0	3		3	Mean	48.2
					s.d.	101.8
					Weighted mean	12.4
					X2 =	313
					St. systematic err	5
					St. stochastic err.	2



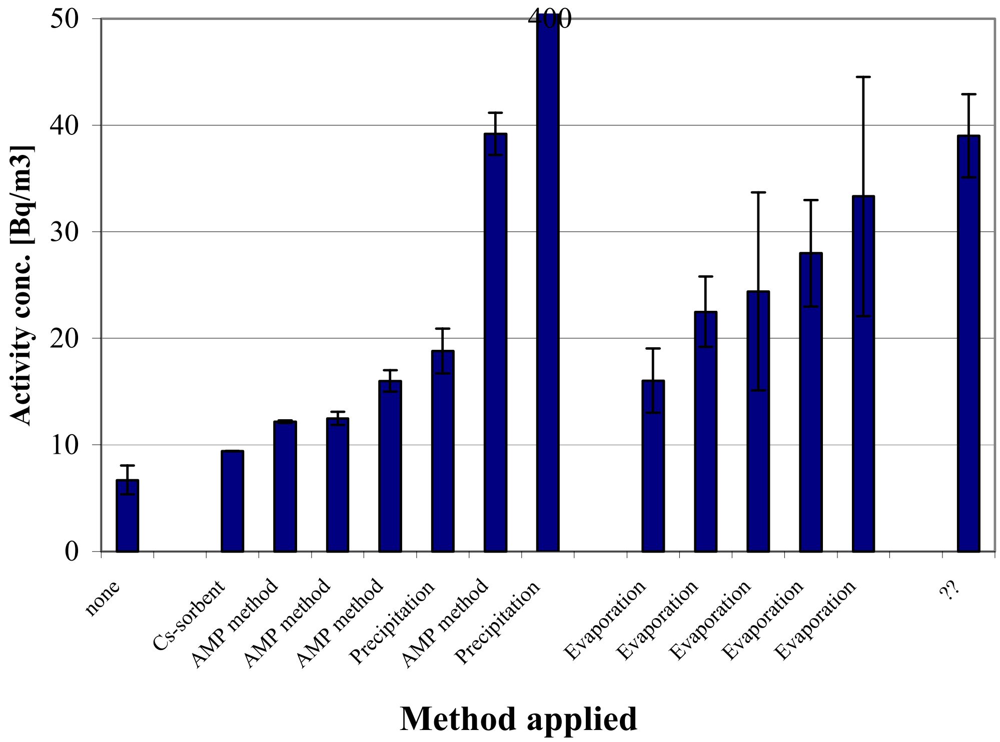


Figure 3.1 Cs-137 activity measurements for seawater sorted by analysis method. 'none' refers to a measurement made directly on the water in a 1 litre Marinelli. Cs-sorbing and precipitation methods are assumed to be similar or equivalent to the AMP procedure. Two participants have given no information on the method used.

3.3 Weighted mean results for the gamma analysis

After the first analysis and evaluation it was found that the obtained weighted mean values sometimes were significantly influenced by outlying values with low reported uncertainties. For purpose of estimating actual activity content of the samples and subsequent evaluation of the methods used by the individual participants a 'reduced mean value' was constructed by deleting all entries with a X^2 larger than 3 from the mean. This was done as an iterative process where the entry with the highest X^2 value deleted first. Based on the reduced data set a new mean and new X^2 values where calculated and again the entry with the highest X^2 was deleted. Often results with initial X^2 values larger than 3 would have there X^2 values reduced below three when the mean value shifted and would then be included in the final mean. This fact was the reason for using this iterative procedure.

Table 3.2 lists the calculated reduced mean values. Based on these reduced mean values new X^2 scores was recalculated for all samples. A mean and median score was then calculated for each participating laboratory. The mean and median was calculated on a data set consisting of all reported results from the respective laboratories for which a reduced mean have been calculated. This was done in order to have a mean for comparison of the different methods used by different laboratories and how they rated.

*Table **Fejl! Ingen tekst med den anførte typografi i dokumentet.**. Reduced mean values or best estimate on activity content for the 6 sample types.*

Sample material	Isotope	Number of replies	Weighted mean	N. in RM	Reduced mean		X2 sum
Dry milk	K-40	17	370	15	**363**	[Bq/kg]	15
Dry milk	Cs-137	18	0.33	14	**0.32**	[Bq/kg]	12
Meat	K-40	18	323	16	**322**	[Bq/kg]	11
Meat	Cs-137	19	0.43	11	**0.40**	[Bq/kg]	6
Sediment	K-40	28	670	21	**697**	[Bq/kg]	11
Sediment	Mn-54	10	0.47	8	**0.41**	[Bq/kg]	5
Sediment	Co-60	29	7.2	17	**6.8***	[Bq/kg]	13
Sediment	Cs-137	31	12.1	25	**12.4**	[Bq/kg]	15
Sediment	Ra-226	13	10.2	11	**10.0**	[Bq/kg]	8
Sediment	Th-232	14	8.8	13	**8.7**	[Bq/kg]	8
Hay	K-40	18	416	16	**430**	[Bq/kg]	13
Hay	Cs-137	18	0.36	10	**0.28**	[Bq/kg]	13
Sea weed	K-40	27	798	22	**825**	[Bq/kg]	17
Sea weed	Mn-54	19	29	11	**29**	[Bq/kg]	2.8
Sea weed	Co-58	11	5.7	7	**6.8**	[Bq/kg]	2.7
Sea weed	Co-60	29	40	25	**41****	[Bq/kg]	14
Sea weed	Cs-137	29	22	24	**22**	[Bq/kg]	13
Sea weed	Ra-226	10	20	6	**20**	[Bq/kg]	6
Sea weed	Th-232	12	7.3	6	**27**	[Bq/kg]	1.3
Sea water	K-40	9	225	5	**10758**	[Bq/m3]	4
Sea water	Cs-137	14	12.4	4	**12.4**	[Bq/m3]	2

*Sample is inhomogeneious with respect to Co-60 at 10 % level
**Sample is inhomogeneious with respect to Co-60 at 1 % level

The mean and median score for each are presented in Figure 3.2 sorted according to the mean score. Further the median score and the number of reported results have been illustrated. The median score was included as the mean score will be heavily influenced by one or a few bad results that can have very high X^2 scores assigned. For example, the laboratory with the second worst mean score (27) has a median X^2 of 0.43, which is the 7th best median score.

Only 11 out of 31 laboratories had a mean X^2 score that is better than 2 (ideal score is between 0 and 2). When looking at median scores this improves to 25 laboratories. This still leaves 6 laboratories with a median score that is worse than 2. Four of these have median scores higher than 5. This corresponds too more than half of the reported results deviated from the estimated mean value by more than two standard deviations.

In all scores the single X^2 values have been derived using the uncertainties supplied the participants. However, when results are ranked as in Figure 3.2 this can be misleading as laboratories reporting high uncertainties will come out with lower scores than laboratories reporting lower uncertainties (higher quality of results?). Instead uncertainties from one participant could be used for all results to do an unbiased ranking of precision. This has not been done here, but is contemplated for the next round.

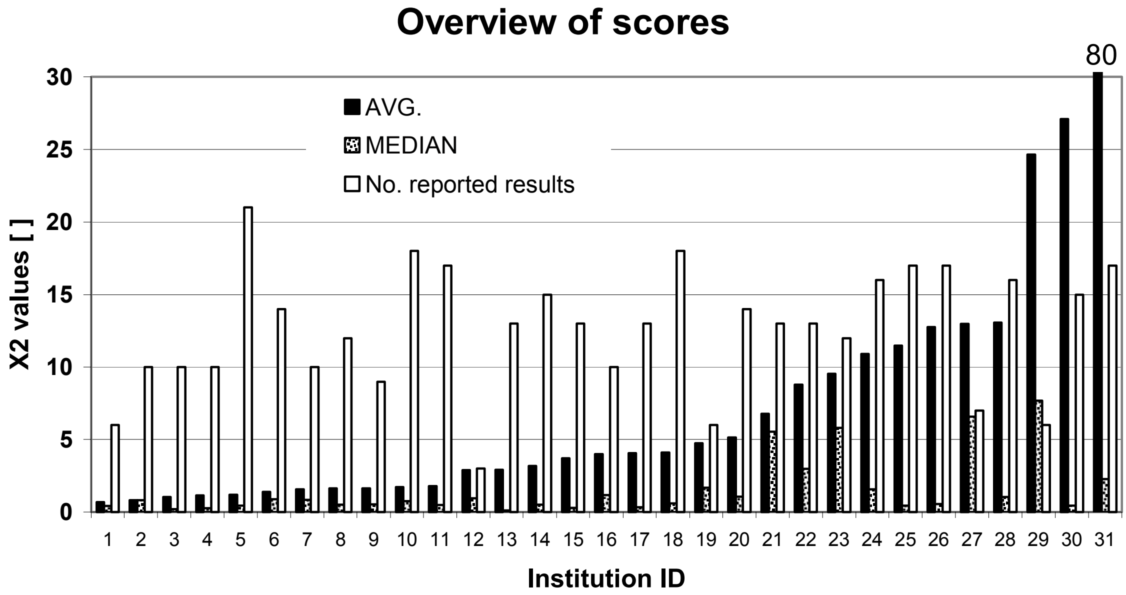


Figure 3.2 Average and median score for each participant printed together with the number of reported results. The numbers have been sorted according to increased average score.

3.4 Discussion

In the discussions in the BOK 1.1 planning group prior to the inter-calibration exercise it was discussed that emphasis should be put at identifying not deviations between laboratories, but also an attempt should be made to detect the reasons for the discrepancies.

As mentioned above results have been compared analysis ashed samples in opposition to bulk analysis. This did not show any influence of the analysis method on the reported results.

A correlation study has been made to see if any relationships could be found between various parameters such as: size of detector used, amount analysed, count time and obtained score. No significant relationships were found. The best correlation found (r=0.64, n=19) was between detector size used and average X^2 score. This implies that using larger detectors will actually reduced the quality of work! However, the most obvious reason for this relationship is that you report lower uncertainties with larger detectors and thereby obtain higher X^2 for each result. Table 3.3 shows an example of an example of the correlation between different results for seaweed and the measurement conditions.

Table3.3 Correlation between different analysis parameters and reported activity levels for the seaweed. Nothing special can be found.

	Amount analysed	Gamma detector size	Sample geo-metry	Count time	K-40	Mn-54	Co-58	Co-60	Cs-137	Ra-226	Th-232	Sr-90
Amount analyzed	1											
Gamma det.	0.20	1.00										
Sample geo	0.49	0.06	1.00									
Count time	-0.53	0.16	-0.32	1.00								
K-40	0.12	-0.42	-0.15	-0.06	1.00							
Mn-54	0.28	0.31	0.01	0.22	0.15	1.00						
Co-58	0.33	0.19	0.12	0.07	-0.68	0.71	1.00					
Co-60	0.27	-0.06	-0.26	-0.10	0.61	0.60	-0.21	1.00				
Cs-137	0.24	-0.25	-0.18	0.00	0.45	0.70	0.19	0.55	1.00			
Ra-226	0.34	-0.51	-0.44	-0.26	0.02	0.40	-0.12	0.25	0.20	1.00		
Th-232	-0.33	-0.04	-0.62	0.35	0.18	0.28	-0.98	-0.15	0.29	-0.10	1.00	
Sr-90	0.14	-0.29	0.66	0.25	-0.06	0.61	1.00	0.36	-0.22	-1.00	1.00	1.00

Another issue that was discussed before the beginning of the intercomparison was the effect of using mixed radionuclide standards rather than single nuclide calibrations. The mixed nuclide standards from Amersham contain Co-60 and Y-88 for the high-energy peaks. Both these nuclides have several lines and the measured spectrum will have reduced count rates for these lines due to true coincidence. This error is highly dependent on sample geometry, but for typical geometries it might be in the order of 1 to 3 %. When you subsequently measure single gamma emitters such as K-40 the calculated activity will be little higher as the efficiency of the crystal is underestimated. This have been investigated by looking at the results for K-40 for seaweed and sediment; the two sample types with the most reported results. Figure 3.3 shows the result for seaweed. No difference can be seen for the two types of calibration. Group A-C (single nuclide calibration) had a mean value of 809 ± 70 Bq kg^{-1} whereas group B (mixed gamma standard calibration) had a mean activity of 822 ±56 Bq kg^{-1}. The results for sediments showed no significant difference between the two groups either. It must be concluded that such differences in calibration methods are too insignificant to show up in the results of an intercomparison.

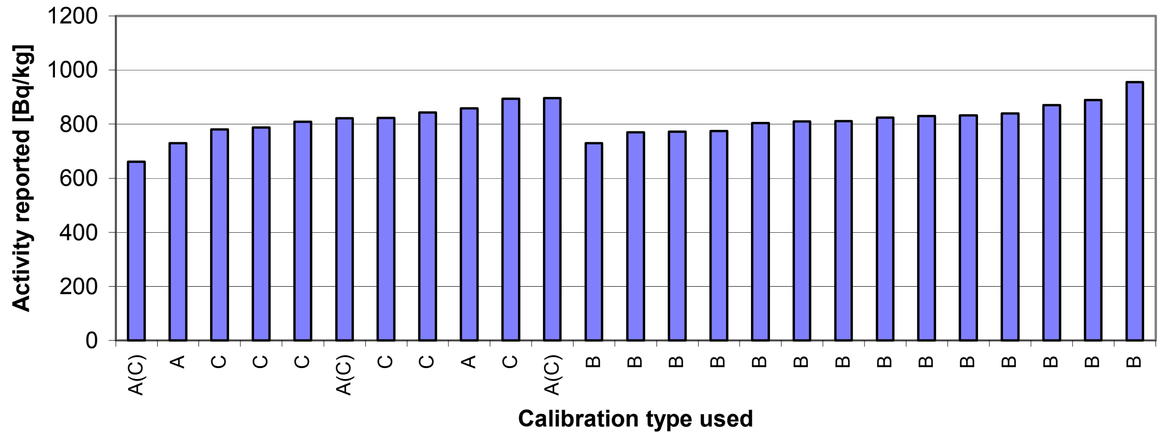


Figure 3.3 K-40 results shown in two groups sorted according calibration method of the Detector system. A, C, and A(C) is calibrations that include single nuclide standards in the detectors calibration. Type B is for detectors that are calibrated with multi-energy radionuclide mix.

A more general approach is illustrated in Figure 3.4. The mean and median score for each participant have been plotted as a function of the corrections that the laboratory applies on a routine basis. It can be seen that laboratories with excellent scores exist for all levels of sophistication in the gamma analysis. Again it seems that it can be concluded that density and coincidence corrections (usually less than 10 %) are too insignificant to show up in an intercomparison that includes a number of low-level samples. Filling corrections are often more significant (a factor of two is common between a nearly empty and a full cylindrical container), but when you don't use filling corrections you usually operate with full sample containers to eliminate the problem of variable filling. You might then need calibration for a greater number of containers with different sample volumes.

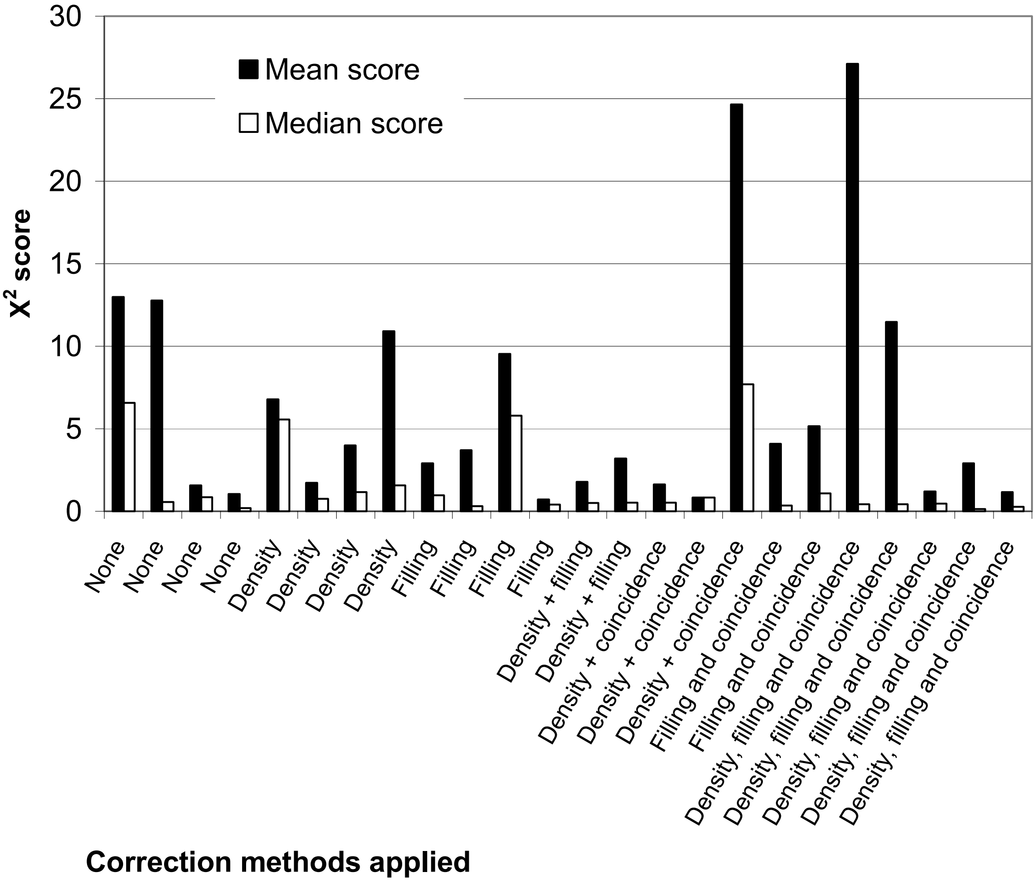


Figure 3.4 Laboratory scores showed as a function of the corrections that are used on a routine basis by the individual participants.

In Figure 3.5 the median score for each participant has been shown as a function of the number of results reported by that participant. A tendency can be seen that laboratories that report many results all have low scores while laboratories that report few results have more variable scores. That is an indication that laboratories that handle many samples (are more experienced/ambitious?) are doing better than other laboratories.

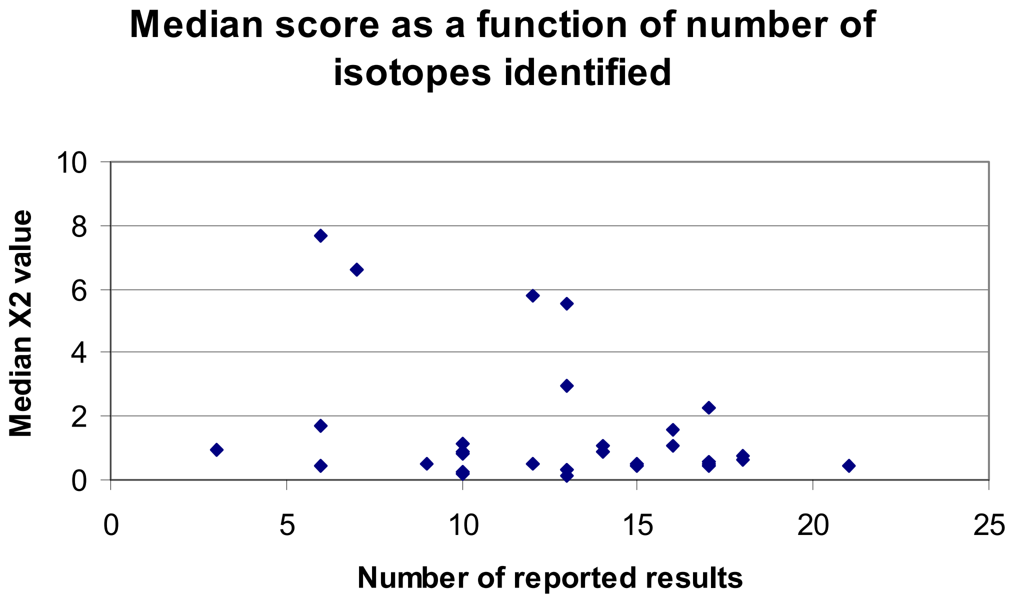


Figure3.5. Median score shown as function of the number of results.

Most laboratories handled medium activity samples (seaweed and sediment) well. The results for the low activity samples (dry milk, grass, meat and seawater) showed larger scatter and several laboratories had problems handling these samples. Especially the sea water sample gave serious problems and this was the only sample were a sensible mean value could not be constructed as the scatter was too large.

4 Strontium analysis

Five materials have been analysed for their content of Sr-90. Meat was excluded as strontium has a very low uptake in meat. Up to 10 laboratories have reported results for Sr-90. This is a high level of participation for a relatively difficult analysis. The results varied rather much. The results were treated in a similar way as the gamma results as described above. The following pages illustrate the results for the five different sample types. The denotations on the figures are the same as for gamma analysis, as explained in Chapter 3.

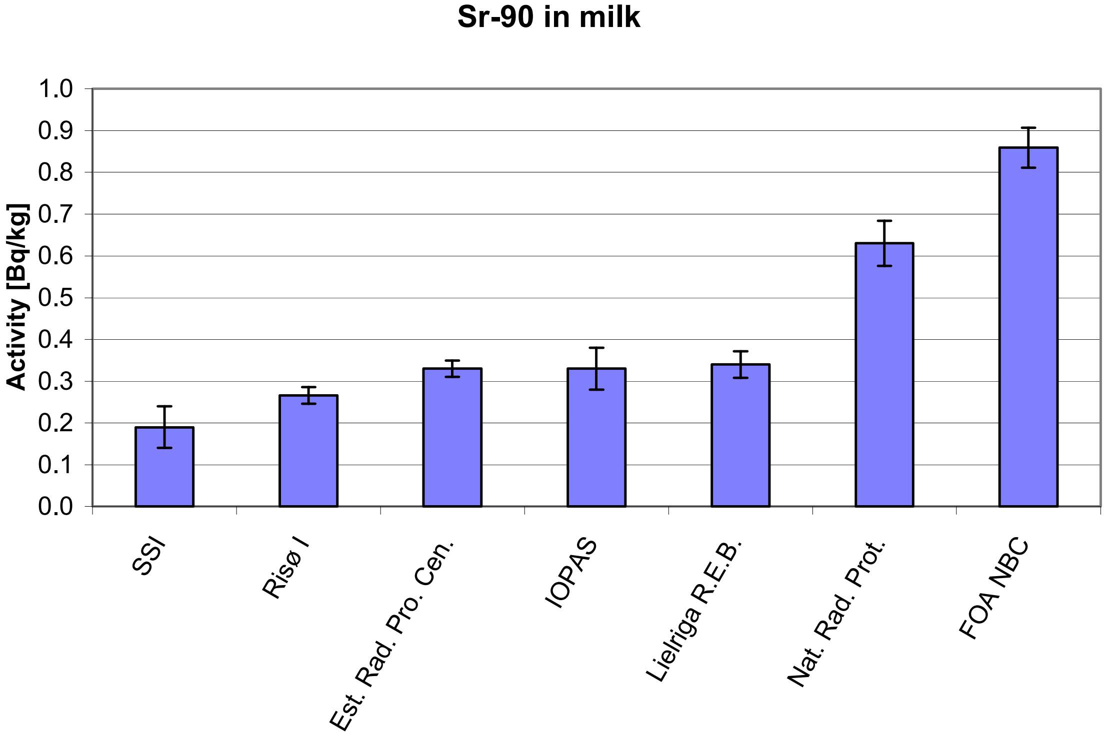
No specific homogeneity test was made with regard to Sr-90, but all analyses by Risø were carried out in duplicate and these results showed very small variability, a few percent. It is my belief that the variation seen in the results can be attributed to differences (inadequacies) in analysis procedures, both for sample preparation and sample counting.

Institution	Sr-90 [Bq/kg]	s.d. [Bq/kg]	total	E.U. [Bq/kg]	1/s2	X2	X2
SSI	0.190	**0.013**	0.050	0.050	400	-3	10
Risø I	0.266	0.007	0.020	0.020	2500	-4	16
Est. Rad. Pro. Cen.	0.330	0.010		0.019	2686	-1	0.7
IOPAS	0.330	**0.023**	0.050	0.050	400	0	0.1
Lielriga R.E.B.	0.340	0.027		0.032	972	0	0.0
Nat. Rad. Prot.	0.630	**0.044**	0.020	0.054	340	5	27
FOA NBC	0.859	0.022	0.038	0.048	429	11	113

NLH, N <5.8

BOLD uncertainties are estimated values

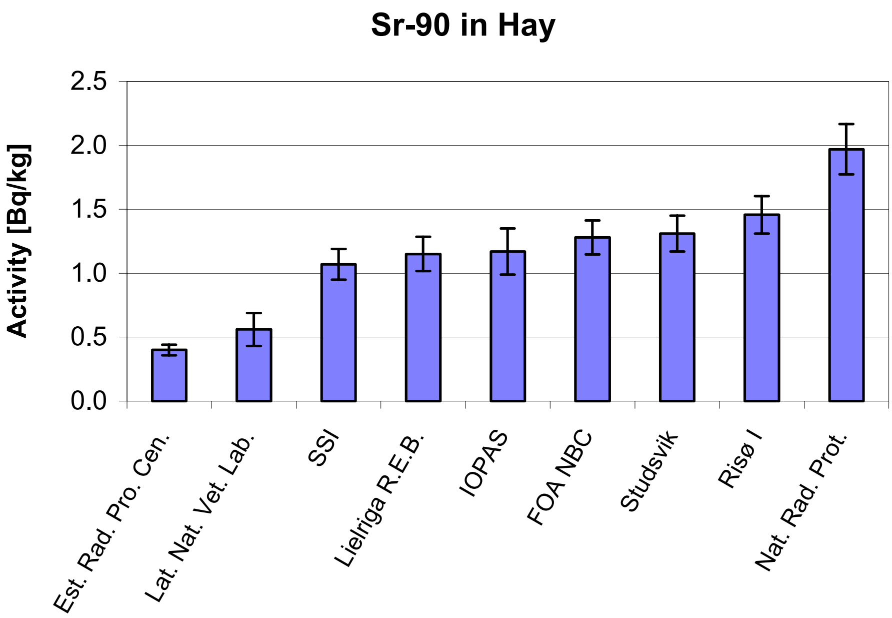
Sum 1/Sigma2	7728
Mean	0.421
s.d.	0.24
Weighted mean	0.346
s.d.	0.24
95% int	0.47
X2 =	167
St. systematic err.	5
St. stochastic err.	7



Eight laboratories reported results for milk. One result was 'below detection limit' and the seven others are shown above. It can be seen that three results in the middle are in good agreement. These three measurements form the reduced mean presented in Table 4.1. The result from Risø is a little below average. Actually an IAEA intercomparison had shown that Risø's results were a higher than expected for low level samples and our analysis procedure was changed shortly after this analysis was made. This new procedure includes a background determination by counting the sample again 3 weeks after electro deposition.

Institution	Sr-90 [Bq/kg]	s.d. [Bq/kg]	total [Bq/kg]	Exp. U. [Bq/kg]	1/s2	X	X2
Est. Rad. Pro. Cen.	0.4	0.01		0.04	588.2	-7.6	57.6
Lat. Nat. Vet. Lab.	0.56	**0.028**	0.128	0.13	61.0	-1.2	1.4
SSI	1.07	**0.054**	0.07	0.12	69.9	3.0	8.9
Lielriga R.E.B.	1.15	0.069		0.13	55.6	3.3	10.6
IOPAS	1.17	**0.059**	0.18	0.18	30.9	2.5	6.4
FOA NBC	1.28	0.033	0.06	0.13	57.2	4.3	18.4
Studsvik	1.31	0.05		0.14	50.9	4.3	18.1
Risø I	1.46	0.009		0.15	46.9	5.1	26.0
Nat. Rad. Prot.	1.97	0	0.07	0.20	25.8	6.4	40.7
NLH, N	<5.7	0	0				

Sum 1/Sigma2	986
Mean	1.15
s.d.	0.46
Weighted mean	0.71
X2 =	188
St. systematic err	10
St. stochastic err.	5



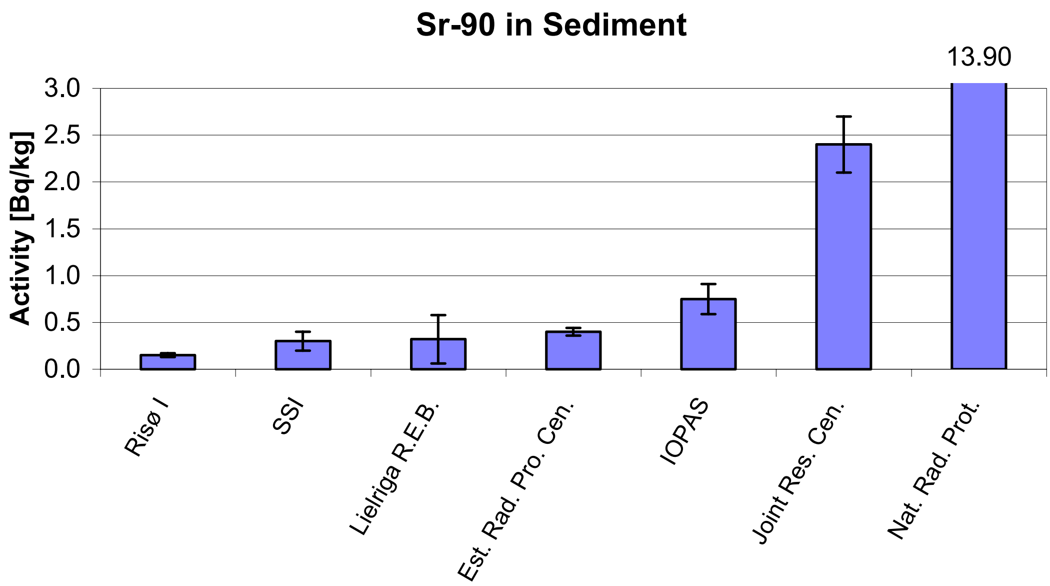
The Sr-90 result for hay illustrates some the shortcomings of the X^2 method. Six out of nine data are in reasonable agreement, but one very low entry with a low reported uncertainty drags down the weighted average and consequently all entries score a bad single X^2 value.

When a reduced average was calculated six results could be included and the X^2 sum was 5 for these six results. Measurement of hay was the most successful Sr-90 analysis. This could be due to the fact that the activity in hay was higher than in milk and sediment, but seaweed also had a high concentration.

Institution	Sr-90 [Bq/kg]	s.d. [Bq/kg]	total [Bq/kg]	Exp. U. [Bq/kg]	1/s2	X	X2
Risø I	0.15	0.01	0.02	0.02	2500	-3.3	11.1
SSI	0.30	**0.03**	0.10	0.10	100	0.8	0.7
Lielriga R.E.B.	0.32	0.26		0.26	15	0.4	0.2
Est. Rad. Pro. Cen.	0.40	0.01		0.04	588	4.4	19.8
IOPAS	0.75	**0.08**	0.16	0.16	39	3.3	11.1
Joint Res. Cen.	2.40	0.10	0.30	0.30	11	7.3	53.0
Nat. Rad. Prot.	13.90	**1.39**	0.40	1.97	0	7.0	48.5
NLH, N	<6.3						

BOLD uncertainties are estimated values

Sum 1/Sigma2	3254
Mean	2.6
s.d.	5.0
Weighted mean	0.2
X2 =	144
St. systematic err.	10
St. stochastic err.	10

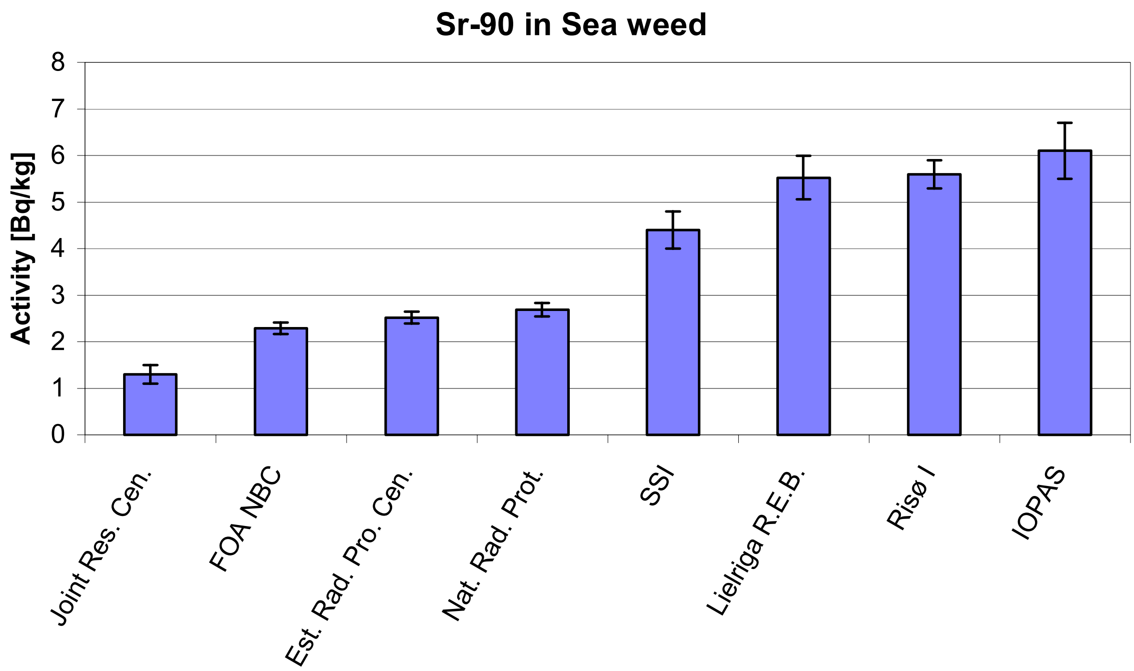


The sediment sample had a relatively low Sr-90 activity concentration. Double determinations did not indicate any inhomogeneity, though it should be noted that the sediment material was inhomogeneous with regard to a number of other radionuclides. Only three results were included in the reduced mean and it must be concluded that the reduced mean for sediments has a high uncertainty and there is reason too believe that the material was inhomogeneous with respect to Sr-90 even though the double determination did not indicate this.

Institution	Sr-90 [Bq/kg]	s.d. [Bq/kg]	total [Bq/kg]	Exp. U. [Bq/kg]	1/s2	X	X2
Joint Res. Cen.	1.30	0.10	0.20	0.20	25.0	-6.8	46.5
FOA NBC	2.29	0.05	0.09	0.12	64.5	-3.0	9.0
Est. Rad. Pro. Cen.	2.52	0.01		0.13	62.6	-1.1	1.3
Nat. Rad. Prot.	2.69	**0.05**	0.06	0.14	47.7	0.2	0.0
SSI	4.40	**0.09**	0.40	0.40	6.3	4.3	18.8
Lielriga R.E.B.	5.53	0.38		0.47	4.5	6.1	37.1
Risø I	5.60	0.10	0.30	0.30	11.1	9.8	95.8
IOPAS	6.10	**0.12**	0.60	0.60	2.8	5.7	32.8

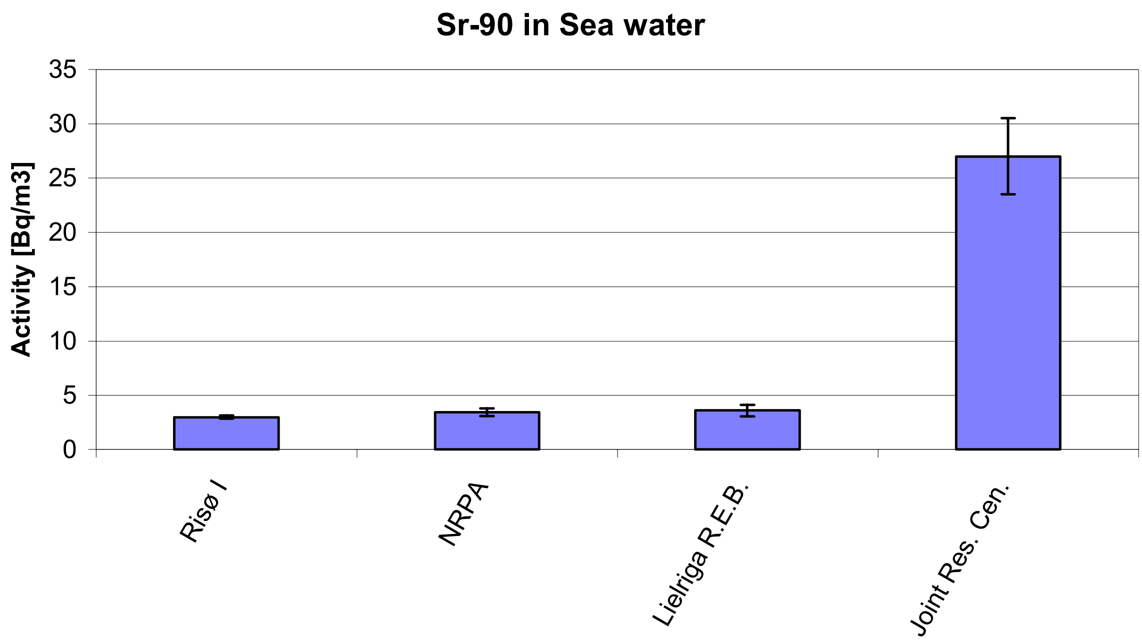
NLH, N	<6.3

Sum 1/Sigma2	224
Mean	3.8
s.d.	1.8
Weighted mean	2.7
X2 =	241
St. systematic err	5
St. stochastic err.	2



For seaweed two different reduced means could be constructed each containing three results. The three laboratories that reported the highest value (average 5.7 Bq kg^{-1}) had the best results for the other materials and this might lead to increased confidence in this value. The occurrence of the lower values might indicate that the Sr-90 has been incompletely extracted from the matrix by some laboratories.

	Sr-90 [Bq/m3]	s.d. [Bq/m3]	total [Bq/m3]	Exp. U. [Bq/m3]
Risø I	2.9835	0.03	0.15	0.2
NRPA	3.44		0.34	0.3
Lielriga R.E.B.	3.6	0.504		0.5
Joint Res. Cen.	27	1.3	3.5	3.5
St. systematic err.		5		
St. stochastic err.		2		



For seawater three out of four results agreed on an activity of 3.1 Bq m^{-3}, giving this value some confidence.

Table 4.1 Review of calculated mean values and reduced mean values. The reduced mean value was calculated by excluding all results with a X^2 value larger than 3 from the calculations.

Sr-90	Number of replies	Weighted mean	Number of replies included in RM	RM		X^2 sum
Dry milk	8	0.35	3	**0.33**	[Bq/kg]	0.07
Sediment	8	0.22	3	**0.16**	[Bq/kg]	2.57
Hay	10	0.71	6	**1.23**	[Bq/kg]	5.15
Sea weed	9	2.66	3	**2.5****	[Bq/kg]	4.53
Sea water	4	3.09*	3	**3.1**	[Bq/m3]	2.46

*One result was a factor 10 off and was excluded from the mean calculation.
** Two different sets of three measurements where in balance. Alternate value is 5.7 Bq kg^{-1}.

As for the gamma-emitters, an attempt to assign a score to each laboratory has been made. The procedure is the same. For each participating laboratory the single X^2 for each reported result have been summarised and the mean and median values have been found. This is summarised in Figure 4.1. It can be seen that only three laboratories have an ideal score for both mean and median. Another 2 laboratories have a reasonably good median score. Six laboratories have generally bad scores when it comes to Sr-90 measurements!

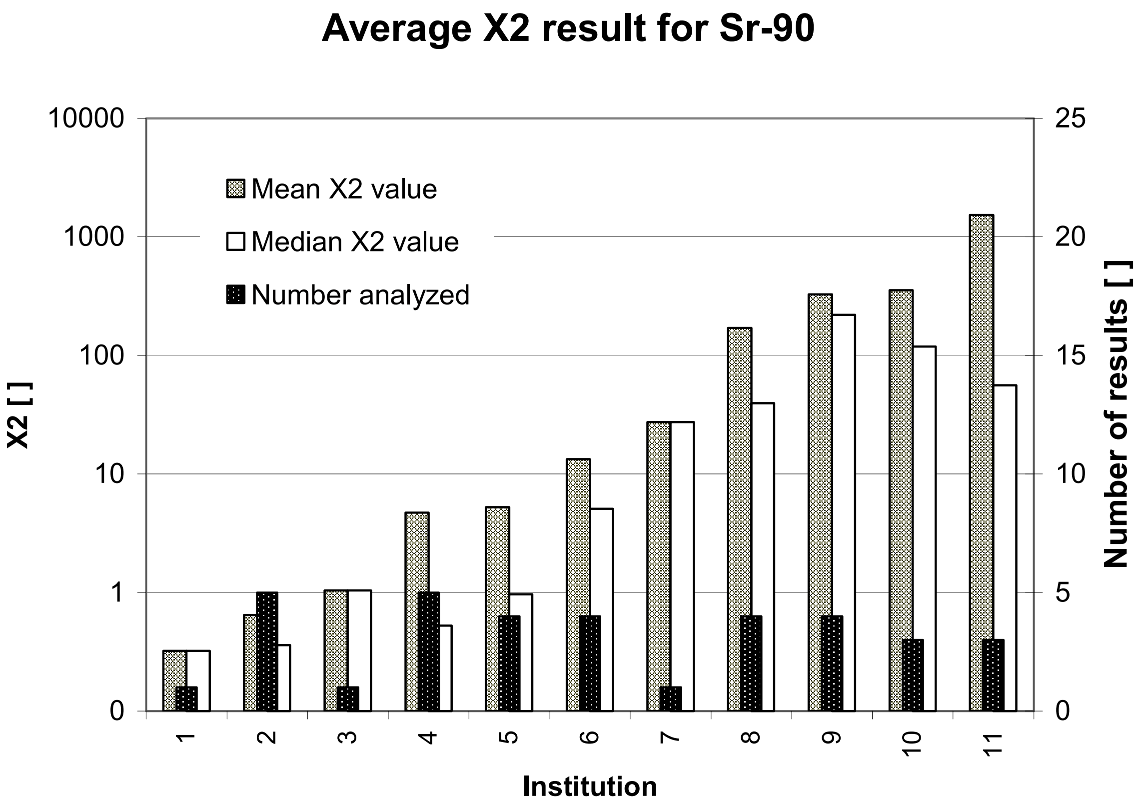


Figure 4.1 Summary of mean and median score and number of samples analysed.

5 Tc-99 analysis

Seven laboratories expressed interest in analysing samples for Tc-99 content. However, only four laboratories have submitted results. The submitted results were in good agreement. The most notable difference was between the radiochemistry and the ICP-MS measurement for seawater at Risø. The Norwegian measurement was in between these two values and thus did not support either. It is still being investigated if one of the two methods used have systematic errors.

Table 5.1 Summary of results for Tc-99.

Sea weed				result	counting	Total
Institution	Country	Method		[Bq/kg]	[Bq/kg]	[Bq/kg]
Risø	Den	β-counting		38.4	0.7	2.6
STUK, Helsinki	Fin	β-counting		42.1	0.8	3.4
NRPA	Nor	β-counting		46.9	?	?
Rad. Pro. Inst.	Ice	β-counting		42.2	0.4	2.4
			Average	42.4	s.d.	4.3

Sea water				result	counting	Total	Salinity
Institution	Country	Method		[Bq/m3]	[Bq/m3]	[Bq/m3]	0/00
Risø	Den	β-counting		2.89	0.03	0.2	32.86
Risø	Den	ICP-MS		3.8	0.1	0.3	32.86
NRPA	Nor	β-counting		3.54		0.35	31.9
			Average	3.4	s.d.	0.5	

6 Analysis for transuranics

No special effort had been made to test for homogeneity of the sediment and seaweed samples with regard to transuranics. Risø did four separate analyses for the sediment sample and there was considerable variation. However, these analyses were not made until after the sample material had been distributed and it was too late to cancel the effort.

The response ratio was low for the transuranics. Less than half of the participants that had expressed interest in analysing for these radionuclides submitted results.

The results submitted for the sediment sample is shown in Table 7.1. 6 laboratories submitted results. The results are included here for the sake of completeness, but have no real value due to the large scatter. The large scatter observed can unfortunately be attributed to in-homogeneity in the sample material. The four alpha measurements made by Risø gave from 0.02 to 0.17 Bq kg^{-1}. The value of 0.014 Bq kg-1 seems high, as the Pu-238 activity usually is much lower than the Pu-239/240 activity. Similar the value of 0.17 Bq kg^{-1} seems very high for Am-241.

For seaweed there is much less scatter and the three submitted results are in good agreement for Pu-239/240. The result reported for Pu-238 again seems high compared to the Pu-239/240 values, but the reported value has an uncertainty of more than 100 %, so any ratio to Pu-238/240 is not significant.

Table 6.1 Review of results for transuranics for the sediment sample.

Institution	Pu-238 [Bq/kg]	total [Bq/kg]	Pu-239/240 [Bq/kg]	total [Bq/kg]	Am-241 [Bq/kg]	total [Bq/kg]
Nat. Rad. Prot.	0.014	0.007	0.045	0.031		
L.O.R.			0.018	0.007		
IOPAS					0.17	0.14
Risø I, Alpha			0.072	0.064	0.009	0.003
Risø I, ICP-MS			0.0446	0.0352		
STUK, N. Finland	<0.01		0.016	0.003		

Table 6.2 Review of results for transuranics for the sea weed sample.

Institution	Pu-238 [Bq/kg]	total s.d. [Bq/kg]	Pu-239/240 [Bq/kg]	total [Bq/kg]
Nat. Rad. Prot.	0.009	0.011	0.043	0.016
IOPAS			0.036	0.004
STUK, N. Finland	<0.01		0.042	0.0076

In summary, the sediment sample was unsuitable for intercomparison purposes. The results reported for the seaweed sample was in good agreement, but a only few laboratories analysed this sample. For the next intercomparison only one sample type will be selected for transuranics analysis and the homogeneity will be tested before the material is distributed.

7 Conclusions

For the gamma analysis the results have been mixed. For activity levels above 10 Bq kg^{-1} between 70 and 90 % of the results could be included in a 'reduced' or 'balanced' mean activity value. For the lower activity levels, e.g. Cs-137 in dry milk or hay, only 50 to 70 % of the results was included in a balanced mean value. The worst result was for seawater where only 4 out of 14 results were included the balanced mean. An effort has been made to identify the main sources of variance. Ashing of samples (to improve counting efficiency) was examined, but could not be shown to improve results. Also it could not be shown that using single nuclide calibrations gives better results than using efficiency curves based on mixed calibration sources. There seemed to be a tendency that laboratories that handled many samples scored better than those handling fewer samples. The assumption is that good laboratory practise above any special corrections is the key to good results.

For Sr-90 analysis the results showed larger scatter than for the gamma analysis. Between 33 and 75 % of the results could be included in a balanced mean. However some of those results that is not included in the mean value was reported as 'below detection limit'. Sr-90 is a complicated analysis and this is clearly reflected in the large scatter.

Analysis of transuranics was done by relatively few laboratories. The results for sediments (done by most laboratories) were useless as it was realised that the sediment material was not homogeneous with respect to transuranics. Only three results were reported for seaweed, but they were all in agreement.

Tc-99 was only analysed by 3 laboratories. Good agreement was found between the reported values.

During the project I have had an opportunity to discuss the results with almost all participants either at meetings, seminars or by e-mail. Based on these somewhat subjective impressions my estimate of the most acute problems are as follows:

1) Lack of training.

The most common 'excuse' was: "Ouh, I was away/busy and I asked XX to do it although I know he/she is not as qualified as could be wished for." or " Our regular technician is on leave so the replacement handled the samples.." I believe that 'experience' was the most crucial factor for obtaining a good result. However, this is difficult to quantify. During the next round it is planned to ask about the experience level of the person handling the individual samples.

2) Lack of quality assurance systems.

Several participants ashed the samples and then reported the values as activity per mass of ashes. One participant used an efficiency correction is his software that belonged to a detector that had been replaced. Such mistakes should be recognised be double checking calculation before submitting results and use of calibration sources for continuous evaluation of detector performance.

3) Background subtraction

The technical problem that caused the biggest deviations for the low level samples was probably missing or insufficient background subtraction. Again this is somewhat subjective assumption based on my discussion with the participants.

8 Abbreviations for participants

Abbreviation	Institution	Country	Contact person
Est. Rad. Pro. Cen.	Estonian Radiation Protection Centre	Estonia	Eia Jakobsen
Tartu university	Tartu university	Estonia	Enn Realo
STUK, Helsinki	STUK, Helsinki	Finland	Seppo Klemola
Rad. Pro. Inst.	Radiation Protection Institute	Iceland	Sigurdur E. Palsson
Frodskaparsetur	Frodskaparsetur Føroya	Faeroes	Hans Pauli Joenson
Lielriga R.E.B.	Lielriga Regional Environmental Board	Latvia	Anita Skujina
Lab. Nuc. Reac.	Laboratory of Nuclear Reactions	Latvia	J. Berzins
Lab. NAA	Laboratory of Neutron Activation Analysis	Latvia	Daina Rukstina
Lat. Env. Data Cen.	Latvian Environmental Data Centre	Latvia	Vija Bute
Nat. Env. H.C.	National Environmental Health Centre	Latvia	Victor Kuzmenko
Lat. Nat. Vet. Lab.	Latvian National Veterinary Laboratory	Latvia	Vilnis Sarkanis
Nat. Rad. Prot.	Department of Radiological Protection.	Latvia	Gendrutis Morkunas
Joint Res. Cen.	Joint Research Centre	Lit.	Rimantas Petrosius
Rad. Met. Lab.	Radiation Metrology Laboratory	Latvia	A. Lapenas
Inst. Mar. Res.	Institute of Marine Research	Norway	Ingrid Sværen
L.O.R.	Central Laboratory for Radiological Protection	Poland	Maria Suplinska
IOPAS	Institute of Meteorology and Water Management	Poland	Ryszard Bojanowski
Göteborg Uni.	Göteborg University	Sweden	Mats Isaksson
Uni.-sjukhuset	Universitetssjukhuset	Sweden	Håkon Pettersson
Studsvik	Studsvik	Sweden	Yvonne Sandell
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SSI	Swedish Radiation Protection Institute	Sweden	Lena Wallberg
FOA-41	FOA-41	Sweden	Rune Arntsing
FOA NBC	FOA NBC-skydd	Sweden	Ulrika Nygren
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Risø I	Risø National Laboratory	Denmark	Jytte Clausen
Risø II	Risø National Laboratory	Denmark	Henrik Prip
Ignalina	Ignalina Nuclear Power Plant	Lithuania	Edmundas Vaitkus
NRPA	Norwegian Radiation Protection Agency	Norway	Anne Lene Brungot
IFE	Institutt for Energiteknikk	Norway	Per Varskog
NLH, N	Laboratory for Anal. Chem., Agricultural University	Norway	Lindis Skipperud
STUK, N. Finland	STUK, Northern Finland	Finland	Kristina Rissanen

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ISBN	87-7893-069-3
Date	December, 2000
Project	NKS/BOK-1.1
No. of pages	53
No. of tables	14
No. of illustrations	34
No. of references	0
Abstract	34 laboratories have returned radioactivity measurements on six different environmental samples. The samples were analysed for their content of gamma emitters, Sr-90, transuranics and Tc-99. The samples materials are described and the results presented. Some scatter was observed in measurements of Cs-137 in low-level samples such as dry milk, meat and hay. The scatter was less pronounced for sediments and seaweed material that had higher levels of radioactivity. In general, the most of the results were consistent with a few laboratories reporting outlying values. An exception was seawater where no clear agreement could be found for the activity of Cs-137.
Key words	Cesium 137; environmental materials; gamma radiation; gramineae; interlaboratory comparisons; meat; milk; radioactivity; seawater; seaweeds; sediments; strontium 90; technetium 99; transuranium elements

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