INTERCOMPARISON OF RADIONUCLIDE MEASUREMENTS

IN MARINE COCKLE FLESH SAMPLE IAEA-134

by

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CONTENTS

ABSTRACT

The results of an intercomparison exercise on a cockle flesh sample from Irish Sea, IAEA-134, designed for the determination of artificial and natural radionuclide levels, are reported. The data from 134 laboratories representing 49 countries have been evaluated.

The following are the recommended values, with confidence intervals, for ^{40}K, ^{60}Co, ^{137}Cs and $^{239+240}Pu$ (Reference date: 1 January 1992). Information values for ^{90}Sr, ^{106}Ru, ^{125}Sb, ^{134}Cs, ^{154}Eu, ^{155}Eu, ^{210}Pb, ^{210}Po, ^{226}Ra, ^{228}Ra, ^{228}Th, ^{230}Th, ^{232}Th, ^{234}U, ^{235}U, ^{238}U, ^{238}Pu and ^{241}Am are also reported. All the following values are expressed in Bq kg^{-1} (dry weight).

Artificial radionuclides

	Recommended value	Confidence interval ($\alpha = 0.05$)
^{60}Co	4.5	4.3-4.7
^{137}Cs	49.8	48-50.6
$^{239+240}Pu$	15	13.8-16.2
	Information value	**Range**
^{90}Sr	4.8	4.1-6
^{106}Ru	11.7	10.2-14.1
^{125}Sb	2.8	2.5-3.8
^{134}Cs	1	0.16-5.9
^{154}Eu	1.25	1.1-1.4
^{155}Eu	1.6	1.0-1.8
^{238}Pu	3.1	3-3.4
^{241}Am	38.15	35.0-39.4

Natural radionuclides

	Recommended value	Confidence interval ($\alpha = 0.05$)
^{40}K	212	196-240
	Information value	**Range**
^{210}Pb	5.4	3.3 -7.0
^{210}Po	7.5	4.6 -14.4
^{226}Ra	2.6	2.0 -3.2
^{228}Ra	3.8	2.6 -4.7

	Information value	Range
^{228}Th	3	2.6 -3.4
^{230}Th	4	2 -5.6
^{232}Th	1.7	0.8 -3.0
^{234}U	3.7	2.5 -5.1
^{235}U	0.49	0.16-4.9
^{238}U	4	3.3-9

Note: * The information value for ^{241}Am may become a reference value if additional ^{241}Pu concentration results are submitted in the future.

1. Introduction

Measurements of activity levels of various radionuclides in marine biological samples are an important component of environmental programmes surveying and monitoring radioactive materials in the sea Studies on the behaviour of radioactive elements are often a co-operative international effort in which many laboratories from all over the world are involved It is important that the data be reliable and trustworthy To address these objectives, the International Atomic Energy Agency has issued a number of intercalibration and reference marine samples

In 1991, the Marine Environment Laboratory (MEL) in Monaco prepared and distributed a marine cockle flesh sample for intercomparison and certification of artificial and natural radionuclides Herein are the results for this biological sample collected in March 1991 in the Irish Sea and coded IAEA-134 It was anticipated that the concentration of artificial radionuclides in this sample be higher than what could be expected from global fallout (because of the potential influence of Sellafield discharge)

All participants were informed that the expected concentration range for the artificial radionuclides in the IAEA-134 sample was 1-100 Bq kg^{-1} and 10-100 Bq kg^{-1} for the gamma emitters and the transuranic elements, respectively, and the concentration range for the beta emitter radionuclides was 1-200 Bq kg^{-1}

2. Scope of the study

This intercomparison exercise was organized with the aim of providing the participating laboratories a possibility of testing the performance of their analytical methods and for establishing reference values for a number of radionuclides

This intercomparison material is designed for measurements of artificial and natural radionuclides Participating laboratories were requested to determine as many radionuclides as possible by gamma spectrometry and any possible transuranics and other radionuclides requiring radiochemical separation and alpha or beta counting

3. Description of the material

The original material of cockle (*Cardium edule*) was obtained in a frozen state from a commercial supplier through the Fisheries Laboratory of the Ministry of Agriculture, Fisheries and Food (Lowestoft, U K) The cockles were collected in March 1991 at Flookburgh Sands, a location on the north coast of Morecambe Bay, Cumbria, England, some 25 miles south east of the Sellafield discharge After collection, the cockles were left standing in fresh water for 24 hours to help void their gut contents and remove entrained sediment particles, then cooked and shelled The frozen cockle flesh was thawed, dried at 100 ± 5 °C and roughly homogenized

The material was subsequently ground in a ball mill and homogenized in a stainless steel rotating drum for about 5 days. The total dry weight of material was about 21.4 kg. More than 90% of the final material was in the size range 63 µm-500 µm. Of the remaining material about 8% was greater than 500 µm and a small fraction (<2%) less than 63 µm. The main fraction, 42.1%, was in the size range 125 µm-250 µm.

The bottles were filled with 75 g of cockle flesh and labelled with the code number IAEA-134.

The moisture content of the sample, determined at the time of packaging by drying several aliquots at 80°C to constant weight, was found to be about 3.3% . Eighty-two laboratories reported moisture content. Most of the values reported were between 1% and 5%, while in a few cases the values reported were as high as 7.2% and 14.7%.

Participants were requested to report results on a dry-weight basis. The reference date for reporting the radionuclide concentrations was 1 January 1992.

Prior to release any intercomparison sample from MEL, it is a requirement to assure that the radionuclides are homogeneously distributed in the samples. The homogeneity was assessed by measuring the activity of ^{40}K, ^{60}Co, ^{137}Cs, ^{210}Pb, $^{239+240}Pu$ and ^{241}Am in several samples from bottles taken at random. ^{40}K, ^{60}Co, ^{137}Cs and ^{210}Pb were determined by gamma spectrometry on 50 g samples, $^{239+240}Pu$ and ^{241}Am were determined by alpha spectrometry on 0.5 to 20 g samples. ^{241}Am was also determined by gamma spectrometry. Results for these analyses expressed in terms of relative activity are shown in Table 1. Homogeneity was determined using one-way analysis of variance and, taking into account the respective levels of the different elements, it was concluded that the material satisfied the homogeneity criteria for the radionuclides measured at the weights used.

4. Sample dispatch and data return

The samples were distributed to 173 laboratories. The deadline for reporting the data was set for 31 December 1992. Many of the participants met this deadline. Other laboratories expressed their intention to report later.

A reminder was sent to late participants in order to obtain more data. Inquiries asking general information about chemical procedures, counting systems and standards, concentration units used to laboratories which had reported meaningless values were also sent to many participants who did not provide enough information.

As of 1 May 1993, 134 sets of results (including MEL) were received from 49 countries.

Concentrations of 32 artificial and 21 natural radionuclides were reported. These 53 radionuclides are shown in Table 2 with the number of laboratories submitting results for each radionuclide. The number of reported "less than" values are shown in parentheses. The results for the most frequently measured radionuclides are shown in

Tables 3 to 12 while the less frequently measured artificial radionuclides are presented in Table 14 A summary of data with recommended values and information values is presented in Table 15 All tables are found in Annex I

The list of contributing laboratories is shown in Annex II

5. Evaluation of the results

5 1 Data treatment

The results submitted by the participants are shown under their laboratory code numbers in Tables 3 to 14 Laboratory averages were calculated when necessary from individual results and are given either as arithmetical means with corresponding standard deviation, when more than two results were reported, or as weighted means with weighted errors in the case of only two reported results All values have been rounded off to the most significant figure keeping in mind the necessity of maintaining the uniformity of presentation and the wishes of the participants

5 2 Evaluation procedure

The principles and applications of the statistical programme used for evaluation of the data have been described in previous reports Briefly, the data treatment consists of identifying and eliminating the outlying values, calculating the median and setting the confidence intervals Calculations are based on the assumption of non-parametric distribution of data to which distribution-free statistics are applicable

The "less than" values are segregated from the results and the remaining values are checked for the presence of outliers using a box and whisker plot test [1] Outliers are identified with an asterisk in Tables 3 to 13 Median values are calculated from all results passing the test These values are considered to be the most reliable estimates of the unknown true values

Confidence intervals were taken from a non-parametric sample population [2,3] They represent a two-sided interval at a significance level of 0 05

5 3 Explanation of the tables

5 3 1 Laboratory code Each laboratory was assigned an individual code number known only by the participant, as a result of an enquiry on confidentiality of the results made previously A majority of participants expressed the wish to remain anonymous

5 3 2 Method code The analytical techniques employed by the participants are

Alpha spectrometry

Code	Method
A	not specified or not enough information
A1	normal leaching, spontaneous deposition on either Ag, Au, Ni or Cu disc
A2	treatment (ashing, leaching, precipitation), ion exchange, electrodeposition
A3	treatment (ashing, leaching, precipitation), ion exchange, precipitation
A4	treatment (ashing, leaching, precipitation), liquid-liquid extraction (amines, TOA, TBP, HDEHP), electrodeposition
A5	treatment (ashing, leaching, precipitation), ion exchange, liquid-liquid extraction, electrodeposition
A6	plutonium isotopes separation, ingrowth period of ^{241}Am, washing of plutonium alpha disc and separation of ^{241}Am
A7	treatment (ashing, leaching, precipitation), LaF_3 precipitation
A8	Extraction chromatography, ion exchange, electrodeposition and precipitation

N.B. n for normal acid leaching techniques
t for total dissolution techniques

Beta counting

Code	Method
B	not specified or not enough information.
B1	precipitation (oxalate), fuming nitric acid separation, $PbCr_2O_4$ ppt
B2	spontaneous deposition of ^{210}Bi
B3	ion exchange separation, Cs_2PtCl_6 ppt
B4	successive precipitations of SO_4^{2-}, CO_3^{2-} and/or SO_4^{2-}/Cl^-, beta counting of Ba-Ra sulfate
B5	plutonium isotopes separation and liquid scintillation counting of ^{241}Pu
B6	Y-90 extraction (TBP, HDEHP), ^{90}Y oxalate ppt, beta counting of Y_2O_3.
B7	precipitation (oxalate, carbonate), separation with conc or fuming nitric acid, scavenging of Ra and Fe, 2 weeks ingrowth period, precipitation (hydroxide, oxalate, carbonate), beta counting of ^{90}Y (as Y_2O_3) or liquid scintillation
B8	ion-exchange separation, liquid scintillation and/or beta counting.
B9	precipitation (oxalate, hydroxide), scavenging, beta counting of Y oxalate
B10	ion exchange, CrO_4^{2-} ppt, oxalate ppt, ^{90}Y oxalate
B11	PO_4^{2-} ppt, liquid scintillation
B12	PO_4^{2-} ppt, ion exchange adsorption in NH_4OH, elution with HNO_3
B13	$SrCO_3$ ppt, 2 weeks ingrowth period, Y extraction with HDEHP, Y oxalate ppt.
B14	fuming HNO_3 separation followed by $SrCO_3$ ppt
B15	reflux with H_2SO_4, leaching with HNO_3, oxydation with $K_2S_2O_8$, extraction with TIOA, back extraction with NaOH, electrodeposition.

N.B. n for normal acid leaching techniques
t for total dissolution techniques

Gamma spectrometry

Code	Method
G	not specified or not enough information.
G1	high resolution (Ge detectors), direct
G2	high resolution (Ge detectors), indirect (daughters in equilibrium).
G3	low resolution (NaI or CsI), direct.

Other methods

AAS	atomic absorption spectrometry.
C	colorimetry (spectrophotometry).
DNA	delayed neutron activation.
Em	radon emanation.
F	fluorometry.
ICPMS	Inductively Coupled Plasma Mass Spectrometry.
N	no information.
NAA	neutron activation analysis.

When a laboratory has used more than one analytical method for the determination of the same isotope, each result is regarded as a separate entry and the method is distinguished by the addition of a small letter to the laboratory code.

5.3.3. Number of results: The number of determinations corresponds to the number of individual results from which the laboratory mean was calculated. When no mention was made in a participant's report as to the number of measurements made, it has been taken as only one.

5.3.4. Activity: Corresponds to the arithmetical or weighted mean computed from all the individual results obtained from the participants with the corresponding standard deviation or weighted error.

Wherever the data were expressed in mass units, they were recalculated to activity units using conversion factors.

5.4. Criteria for certification and recommended values

For data sets comprising 5 or more accepted laboratory means, median values and confidence intervals were calculated as estimations of true activity concentrations.

Please note that the following criteria are specially designed for this report.

The median values of the overall data, excluding outliers, were considered as the recommended values when:

a. More than 10 laboratory means were available
b. The percentage of outliers was not greater than 20%

c. The relative uncertainty of the overall median did not exceed ± 10% for activity concentrations equal or higher than 100 Bq kg^{-1} and ± 20% for activity lower than 100 Bq kg^{-1}.

An activity concentration value is classified as an information value when it is based on at least 3 laboratory means that are within the same order of magnitude.

6. Results and discussion: Artificial radionuclides

Results for ^{60}Co, ^{90}Sr, ^{106}Ru, ^{125}Sb, ^{134}Cs, ^{137}Cs, ^{154}Eu, ^{155}Eu, ^{238}Pu, $^{239+240}Pu$ and ^{241}Am are presented in Tables 3 to 7. The values obtained after the application of the statistical treatment to all data sets received appear at the end of each table; they are not necessarily showing the recommended concentration values given in the summary (Table 15) (see the discussion for ^{241}Am for example).

Strontium-90

Twenty-nine results were reported that included 4 "less than" values (Table 3). Five outlying values were found in the data set and the range of accepted laboratory means spreads over 3-7.3 Bq kg^{-1}. All outlying values, spreading from 8.9 to 26 Bq kg^{-1}, are located on the high values side compared to the median. The values of the average and the median are very close, 4.9 and 4.8 Bq kg^{-1}, respectively. The median of these values is 4.8 Bq kg^{-1} with a confidence interval of 4.1-6 Bq kg^{-1}.

About 50% of the laboratories have used conventional techniques coded B7. Five laboratories, about 17%, have used a method based on direct extraction of ^{90}Y, e.g. so called rapid method, coded B6, avoiding to wait for the 2 weeks ingrowth period for ^{90}Y and two among the 5 results reported (Nos. 45 and 127) are within the confidence interval.

Quantities of material used by the participants varied between 0.9 and 71 g.

No correlation could be found between the quality of the result and the use of ^{85}Sr and/or stable strontium as yield monitor.

Cobalt-60

Eighty-eight results were reported that included 1 "less than" value (Table 4). The result reported by Lab. No. 106 was not used for average calculations at the request of the participant. Eight of the reported results were determined to be outliers, 5 results being on the lower side of the data and 3 on the higher side. The range of the accepted values is 3.3-6.3. The median of the accepted values is 4.5 Bq kg^{-1} with a confidence interval of 4.3-4.7 Bq kg^{-1}. The values of the average and the median are very close. All

results but one were obtained by using direct gamma spectrometry. Laboratory No. 149 which has used neutron activation analysis has reported a value equal to the median.

Caesium isotopes

Caesium-134

Twenty-seven results were reported including 16 "less than" values (Table 4). All results have been obtained by using gamma spectrometry techniques. None of the results were considered as outliers even though the scatter of the values is quite large, 0.158 to 9 Bq kg^{-1}. The median of the accepted values is 1 Bq kg^{-1} with a confidence interval of 0.16-5.9 Bq kg^{-1}. The calculated average value, 2.3 Bq kg^{-1}, is rather different.

Caesium-137

Hundred-twenty results were reported that included 1 "less than" value (Table 4). The result reported by Lab. No. 106 was not used for average calculations at the request of the participant. Sixteen values were rejected as outliers and they are equally shared on both low and high sides of the median of the data population. The range of the accepted laboratory means is 39.6-60 Bq $kg^{-1}$and the median is 49.8 Bq kg^{-1} with a confidence interval of 48-50.6 Bq kg^{-1}. As for ^{90}Sr and ^{60}Co, the values of the average and the median are very close.

Values of ^{134}Cs and ^{137}Cs found in cockles collected in Morecambe Bay in 1990 were 0.2 and 15 Bq kg^{-1} wet weight, respectively, with an activity ratio of 0.013 [4]. On the basis of this activity ratio, we can expect to have an activity level of ^{134}Cs close to 0.65 Bq kg^{-1}. The median value found for ^{134}Cs, 1 Bq kg^{-1}, is close to this level.

All laboratories have used gamma spectrometry techniques. Laboratory No. 83 used both beta and gamma counting: After digestion of the sample with acid mixture, adsorption of Cs on AMP (Ammonium molybdo-phosphate), purification by ion-exchange BIOREX-40 and precipitation as Cs_2PtCl_6 followed by beta counting, gamma spectrometry was also used to differentiate ^{134}Cs and ^{137}Cs.

The laboratories coded Nos. 73, 129 and 137 have used NaI detectors: Laboratories coded Nos. 73 and 129 have used rather low amounts of material, 4.4 and 11-16 g, respectively, and the results reported were not satisfactory. Laboratory No. 137 used 75 g of material and the results reported were acceptable.

Several laboratories (Nos. 9, 69, 118, 124, 127 and 131) have used rather low amounts of material with high purity Ge detectors: The results reported do not show any systematic deviation with respect to the value of the median and this shows that at such levels of activity, one of the most important parameters is the calibration of the equipment.

Ruthenium-106

Twenty-two results were reported that included 4 "less than" values (Table 5). All results were obtained by gamma spectrometry. Values reported by laboratories Nos. 23 and 61, 29 and 20.4 Bq kg^{-1}, respectively, were found to be outliers. The range of accepted laboratories means is 5.2-15 Bq kg^{-1}. The median is 11.7 Bq kg^{-1} with a confidence interval of 10.2-14.1 Bq kg^{-1}.

Antimony-125

Twenty results were reported that included one "less than" value (Table 5). All results were obtained by gamma spectrometry. No value was found to be outlier even if we notice that the distribution of the data reported is quite large. The range of accepted laboratory means is 0.9-5.3 Bq kg^{-1}. The median is 2.8 Bq kg^{-1} with a confidence interval of 2.5-3.8 Bq kg^{-1}.

Europium isotopes

Fourteen and 5 results were reported for ^{154}Eu and ^{155}Eu, respectively (Table 6). Each group of data included one "less than" value. Among the 13 results reported for ^{154}Eu, 5 were found to be outliers. The range of the accepted values is the same as the confidence interval 1.1-1.4 Bq kg^{-1} while the median is 1.25 Bq kg^{-1}.

The 4 results reported for ^{155}Eu range from 1.0 to 1.8 Bq kg^{-1} and the median value is 1.6 Bq kg^{-1}.

All results were obtained using gamma spectrometry. The difficulty of the measurements comes both from the low specific activity and from the low gamma energies emitted by both isotopes. The isotopes whose gamma energies are located between 80 and 150 keV are found to be difficult to measure due to the problem of efficiency calibration in this region.

Transuranium elements

Plutonium-238 and plutonium-239+240 were reported by 40 and 44 laboratories, respectively (Table 7). After excluding 10 outliers for ^{238}Pu, the median of the remaining 30 values is 3.1 Bq kg^{-1} with a confidence interval of 3-3.4 Bq kg^{-1}. The range of the accepted means is 2.3-3.7 Bq kg^{-1}.

Five values were determined as outliers for $^{239+240}Pu$. The median is 15 Bq kg^{-1} with a confidence interval of 13.8-16.2 Bq kg^{-1}. The ratio of the median values ^{238}Pu to $^{239+240}Pu$ is 0.21, significantly different than the ratio associated with plutonium originating from global fallout. Values of ^{238}Pu and $^{239+240}Pu$ found in cockles collected in Morecambe Bay in 1990 [4], 0.77 and 3.4 Bq kg^{-1} wet weight, respectively, show an activity ratio of 0.226.

The results reported both for ^{238}Pu and $^{239+240}Pu$ by the laboratories 45, 111 and 148 were all found to be outliers. The comparison of the values reported with the medians obtained show that these laboratories have a problem of calibration of tracer. Even if no ^{238}Pu value was reported by Lab. 39, the value for $^{239+240}Pu$, 52.8 Bq kg^{-1}, shows that this participant experienced the same problem.

Although the laboratories Nos. 65, 69, 74, 80 and 125 have reported acceptable values for $^{239+240}Pu$, their results for ^{238}Pu concentration are outliers. The information received show that these laboratories, except No.125, have used ^{242}Pu as tracer. While in the case of Labs. 69, 74, 80 and 125 which reported values, 5.1, 1.8, 1.45 and 4.6, respectively, we can suspect some problems in the background in the 4.5 MeV region, the value reported by Lab. 65, 30 Bq kg^{-1}, is abnormally high. The ratio $^{238}Pu/^{239+240}Pu$ is 1.76 which indicates some problem met by the participant.

73% of the participants have used a rather conventional method based on sample treatment, ion-exchange separation followed by electrodeposition. The chemical procedures used by the participants for plutonium are based on the following: Dry ashing followed by leaching with either conc. HNO_3 or 8N HNO_3 or Aqua regia or a mixture of $HNO_3/HF/HClO_4$; precipitation with iron hydroxide or calcium oxalate; separation and purification of plutonium with either anion-exchange using HCl or HNO_3 or with liquid-liquid extraction (Aliquat, TIOA, TTA); finally plutonium is electrodeposited on a small disc or adsorbed by a lanthanum fluoride precipitate and counted using solid state alpha detectors. Only 9% have combined ion-exchange separation with liquid-liquid extraction.

Seventeen and nineteen laboratories have applied total and normal dissolution techniques for the treatment of the samples, respectively. The average concentrations obtained using the two different techniques are 13.7±1.3 Bq kg^{-1} for total dissolution and 15.4±1.2 Bq kg^{-1} for normal dissolution.

Ninety-one results were reported for ^{241}Am that did not include any "less than" value. Among the laboratories which reported both plutonium and americium results a majority analysed plutonium by alpha spectrometry and americium by gamma spectrometry. The laboratories 14, 37, 80, 127 and 132 reported ^{241}Am results obtained by both alpha and gamma spectrometry. Labs. 14 and 132 have reported very close concentrations while in the case of Labs. 37, 80 and 127, the values reported are similar within 1σ (Lab. 127) and 2 σ (Labs. 37 and 80). Statistical tests applied to the two sets of ^{241}Am data show that they are different: The medians and averages are 38.9 Bq kg^{-1}, 37.9 ± 2.3 Bq kg^{-1} and 43.7 Bq kg^{-1}, 42.5 ±2.7 Bq kg^{-1} for the alpha data set and the gamma data set, respectively. The value reported by Lab. No. 106 was not used for average calculations at the request of the participant.

Twenty-one of the reported results were determined by alpha spectrometry following radiochemical separation and 69 by direct gamma spectrometry.

The application of a t-test to the two groups of data of ^{241}Am obtained either directly by gamma spectrometry or by alpha spectrometry shows that, after rejection of the outlying values of each group, the mean values (and median values) obtained for the two populations are rather different: 37.8 Bq kg^{-1} (38.15 Bq kg^{-1} as median) for the alpha data set and 42.2 Bq kg^{-1} (43 Bq kg^{-1} as median) for the gamma data set. It is

unlikely that the two data sets come from the same population of results (t = 3.60, significance level = 5.7 10^{-4}). It is not, therefore, justified to pool all ^{241}Am results.

Experiences from recent exercises had shown that at a level of 2 Bq kg^{-1} (IAEA-306 Baltic Sea sediment, 1989), we could not find any correlation between the values of ^{241}Am obtained by alpha or gamma spectrometry while later at levels of 1.3 and 26 Bq kg^{-1} (IAEA-368 and IAEA-367 Pacific Ocean sediments, 1991) the correlation was found satisfactory. It is apparent here that both techniques, direct gamma spectrometry or radiochemical separation followed by alpha spectrometry, do not give similar quality results at a concentration level of about 40 Bq kg^{-1}, the results obtained by gamma spectrometry being biased of about 10% on the higher side of the average. It is worthwhile to note that the number of ^{241}Am data obtained by gamma spectrometry has increased from 26 for IAEA-367 in 1991 to 69 for IAEA-134 in 1993 and the input of new participants may have brought some bias.

Considering all possible errors and uncertainties attached to the ^{241}Am measurement by using gamma spectrometry, and also the presence, among the participants who reported ^{241}Am results by using alpha spectrometry, of high quality experienced laboratories, we would recommend the median value of the data set obtained by alpha spectrometry, 38.15 Bq kg^{-1} (confidence interval 35.0-39.4 Bq kg^{-1}), as the most probable concentration.

The value for ^{241}Am is given on the reference date of 1 January 1992 only. The activity of ^{241}Am will change with time as the ^{241}Pu present in the sample decays. Unfortunately, only 4 values, spreading from 201 to 250 Bq kg^{-1} were reported for ^{241}Pu (Table 14). On the basis of an average value of 226±20 Bq kg^{-1} and taking into account the decay of ^{241}Am, we can estimate that the activity of ^{241}Am will change to about 39.4 Bq kg^{-1} in 5 years and 40.4 Bq kg^{-1} in 10 years. These values are either within or very close to the statistical uncertainty of the median; however, we hesitate to recommend a reference value since only 4 measurements of the parent radionuclide were reported.

Other isotopes

Several laboratories submitted results on ^{46}Sc, ^{54}Mn, ^{57}Co, ^{65}Zn, ^{89}Sr, ^{95}Zr, ^{95}Nb, ^{99}Tc, ^{109}Cd, ^{110m}Ag, ^{133}Ba, ^{141}Ce, ^{144}Ce, ^{160}Tb, ^{181}Hf, ^{182m}Ta, ^{229}Th, ^{237}Np, ^{241}Pu, ^{242}Cm and $^{243+244}$Cm. Those results are presented in Table 14. Most of the concentrations are reported as "less than" values.

Recommended values

Application of statistical treatment and test for outliers to the different data populations allow us to generate recommended concentration values for some of these isotopes. On the basis of the criteria described in the paragraph 5.4, we give reference values for ^{60}Co, ^{137}Cs and $^{239+240}$Pu only.

7. Results and discussion: Natural radionuclides

The results are presented in Tables 8 to 13.

The laboratory coded No.106 suggested that the results reported for ^{40}K and ^{235}U "should not be included in any average activity calculation" and therefore, the data reported were not used.

Potassium-40

Of the 111 results reported, they were no "less than" values. Lab. No. 140 determined ^{40}K by measuring stable potassium by atomic absorption spectrometry and made the appropriate calculations for converting to ^{40}K.

The other results were obtained by gamma spectrometry: One of them reported by Lab. No. 137 was obtained by gamma counting with a NaI detector The results cover nearly two orders of magnitude from 13 to 700 Bq kg^{-1}. After the rejection of 22 outliers, the remaining results give a median value of 212 Bq kg^{-1} with a confidence interval of 196-240 Bq kg^{-1}. Both laboratories mentioned above, Labs No. 137 and 140, have reported results which fall within the confidence interval. Quantities of material used by the participants for gamma spectrometry varied between 2.7 and 77 g.

Uranium isotopes

The results of the uranium isotopes are presented in Table 9.

The data set of ^{234}U was composed of 9 results that included one "less than" value. After the rejection of 2 outliers, the median concentration is 3.7 Bq kg^{-1} with a confidence interval of 2.5-5.1 Bq kg^{-1}.

Fourteen results of ^{235}U were reported including 2 "less than" values. There was no rejection of outliers and the median obtained is 0.49 Bq kg^{-1} with a confidence interval of 0.16-4.9 Bq kg^{-1}.

Nineteen results of ^{238}U were reported including 2 "less than" values. Five laboratories determined ^{238}U by gamma spectrometry of daughter products, 9 have chemically separated uranium isotopes and used alpha spectrometry, one participant used ICPMS technique while 2 participants used NAA and DNA techniques.

The application of statistical tests to the whole group of ^{238}U data and to the one obtained with results based on alpha spectrometry measurements gives for the median 4 Bq kg^{-1} (confidence interval 3.3-9 Bq kg^{-1}) and 3 Bq kg^{-1} (confidence interval 2.2-4.0 Bq kg^{-1}), respectively. As the median obtained for ^{234}U is 3.7 Bq kg^{-1}, rather close to the median of ^{238}U, 4 Bq kg^{-1} obtained from the whole data set which passed the tests, and considering the ratio $^{234}U/^{238}U$ being about 1.0, we have taken the value of 4 Bq kg^{-1} (confidence interval of 3.3-9 Bq kg^{-1}) as the information value for the ^{238}U activity concentration.

Four laboratories reported ^{234}Th results that included one "less than" value (Table 14), all obtained by gamma spectrometry measurements. Considering the dispersion of the data it was impossible to correlate ^{234}Th with the ^{238}U .

The laboratory No. 80 reported also uranium as natural uranium by using fluorometry (Table 14).

Thorium isotopes

The results of the thorium isotopes are presented in Table 10.

Twenty-two results were reported for ^{228}Th including 3 "less than" values. Three results were obtained by alpha spectrometry while the remaining were obtained by gamma spectrometry using the gamma rays of ^{208}Tl (583 keV) and ^{212}Pb (239 keV). Laboratory No. 14 reported a ^{228}Th value at the reference date of 1992-09-29. On the basis of a ^{228}Ra activity concentration of 3.9 Bq kg-1 on 1992-01-01, (see paragraph on Radium and Actinium isotopes), we obtain a value of ^{228}Th of 2.6 Bq kg^{-1} on 1992-01-01. This value is not very different than the median value obtained after statistical treatment. After rejection of 4 outliers, the median for ^{228}Th is 3 Bq kg^{-1} with a confidence interval of 2.6-3.4 Bq kg^{-1}.

Th-230 concentrations were reported by 8 laboratories including one "less than" value. No value was rejected as an outlier and we obtain a median value of 4 Bq kg^{-1} with a confidence interval of 2-5.6 Bq kg^{-1}.

Twenty-five results were submitted for ^{232}Th including 5 "less than" values. The median value is 3.25 Bq kg^{-1} with a confidence interval of 2.1-8 Bq kg^{-1}. Considering the data sets obtained by alpha and gamma spectrometry, respectively, statistical tests show no correlation between these two data populations: The median values obtained for the alpha and the gamma groups are 1.7 Bq kg^{-1} (confidence interval 0.8-3.0 Bq kg^{-1}) and 7.5 Bq kg^{-1} (confidence interval 3.5-12.0 Bq kg^{-1}). Based on these considerations, we would propose an information value for ^{232}Th of 1.7 Bq kg^{-1} with a range of 0.8-3.0 Bq kg^{-1}.

Radium and Actinium isotopes

Thirty-two results were reported for ^{226}Ra that included 9 "less than" values (Table 11). Most of the participants determined ^{226}Ra by gamma spectrometry. One result reported by Lab. 89 was obtained by beta counting of "Ba(Ra) sulfate" and one result was obtained by radon emanation technique (Lab. 93). The 20 results obtained by gamma spectrometry were divided into three groups:

1st) One result obtained by measuring the 186 keV gamma ray of ^{226}Ra (Method code G1);

2nd) 7 results by using the gamma rays of the daughter products $^{214}Pb/^{214}Bi$ and expressed as ^{226}Ra concentration (Method code G2);

3rd) 12 results reported as obtained by gamma spectrometry but without any clear information (Method code G).

After rejection of one outlier, the data set of results obtained by method code G2 gave an average of 2.8±0.5 Bq kg^{-1} (median value = 2.8 Bq kg^{-1}) while in the case of data set obtained by method code G, we had to reject 4 outliers and we obtained an average of 4.8±2.6 Bq kg^{-1}(median = 4.2 Bq kg^{-1}).

We have also considered the results of measurements of ^{214}Bi and ^{214}Pb (Table 13) which normally correspond to ^{226}Ra when the equilibrium is reached. There are 8 results that include 2 "less than" values and 13 results that include 1 "less than" value reported for ^{214}Bi and ^{214}Pb, respectively. After rejection of outlying values, we obtain the following averages and median values: 4.5±3.2 Bq kg^{-1} and 3.5 Bq kg^{-1} for ^{214}Bi, 3.5±2.0 Bq kg^{-1} and 2.7 Bq kg^{-1} for ^{214}Pb, respectively.

Statistical tests allow to pool the 2 data sets of ^{226}Ra(Method code G2) and of $^{214}Pb/^{214}Bi$ in order to obtain for ^{226}Ra a median of 2.6 Bq kg^{-1} with a confidence interval of 2.0-3.2 Bq kg^{-1}.

After rejection of one outlier, the data sets of results of ^{228}Ra and ^{228}Ac (Table 11), give an average of 3.6±0.8 Bq kg^{-1} (median value = 3.7 Bq kg^{-1}) and 9.2±6.3 Bq kg^{-1} (median = 7.6 Bq kg^{-1}), respectively. The comparison of different medians obtained after statistical test allows to pool the two data sets and to obtain for ^{228}Ra a median value of 3.8 Bq kg^{-1} with a confidence interval of 2.6-4.7 Bq kg^{-1}.

Lead-210 and Polonium-210

Twenty-two results including 8 "less than" values were reported for ^{210}Pb. Two laboratories did not give sufficient information regarding the procedure used to determine ^{210}Pb (Nos. 85 and 114). Three participants have used radiochemical separation followed by beta counting of ^{210}Bi (Labs. 39, 45 and 92) while six have used alpha spectrometry measurement of ^{210}Po ingrown. All remaining ten results were obtained by measuring the 46 keV photopeak of ^{210}Pb by gamma spectrometry. Among this data set, 7 results were expressed as "less than" values: The limits of detection were rather high, from 14 to 170 Bq kg^{-1} which shows the limits and difficulties of the gamma spectrometry at such low energy (46 keV) and level of activity.

Considering the small number and the quality of the results reported in each group of data, it is difficult to give any reference value for ^{210}Pb. By pooling altogether the results obtained by alpha, beta, gamma techniques and the value with no information, we have obtained an average value of 5.3±1.4 Bq kg^{-1} with a median value equal to 5 Bq kg^{-1}. The confidence interval is 3.3-7 Bq kg^{-1}.

Twenty results of ^{210}Po were submitted. Most of the participants assumed there was equilibrium between ^{210}Pb and ^{210}Po and reported the concentrations of ^{210}Po at the reference date of 1 January 1992. Four laboratories (Labs. Nos. 14, 83, 131 and 150) reported the concentration of ^{210}Po at the separation dates of ^{210}Pb and ^{210}Po which, in most cases, were close to the end of 1992 or early 1993, e.g. more than three ^{210}Po half-

lives after the collection date. Taking into account the time elapsed between the collection and the distribution of the samples and/or the analyses, it seems reasonable to assume that ^{210}Pb and ^{210}Po are in equilibrium. The statistical treatment of the ^{210}Po data reported at the 1 January 1992 reference date gives a median of 7.5 Bq kg^{-1} (confidence interval 4.6-14.4 Bq kg^{-1}). The difference between the values of ^{210}Pb and ^{210}Po might be due to the low levels of both isotopes and to the errors attached to the measurements. The results reported by the 4 laboratories mentioned above better reflect the equilibrium between ^{210}Pb and ^{210}Po.

Other isotopes

Ten laboratories reported results of ^{212}Pb (Table 13). The data set gives a median of 2.2 Bq kg^{-1} with a confidence interval of 1-6.9 Bq kg^{-1}.

Several laboratories submitted results on ^{208}Tl, ^{224}Ra, ^{210}Tl, ^{212}Bi,. Those results are presented in Table 14. Most of the concentrations are reported as "less than" values.

Recommended values

Application of statistical treatment and test for outliers to the different data populations allow us to generate recommended concentration values for some of these isotopes. On the basis of the criteria described in the paragraph 5.4, we may give reference value for ^{40}K only.

8. Conclusion

Many laboratories have reported results of concentration such as 1239.333±0.004 Bq kg^{-1}, 3.89±0.68 Bq kg^{-1}, 34.833 ± 0.001 Bq kg^{-1}, etc. For example, Lab. 121 reported ^{241}Am concentration obtained by gamma spectrometry as 12.95662 ± 0.845 Bq kg^{-1}, Lab. 56 reported ^{40}K concentration as 176.73 ±11.04 Bq kg^{-1}. It seems that for many participants the concept of significant figures and the error attached to a result have been disregarded. This is particularly true in the case of results obtained by gamma spectrometry where probably in many cases the results are reported as they are produced by the software. All participants are encouraged to pay more attention to this problem in the future.

Some laboratories reported measurement of gamma emitters such as ^{106}Ru, ^{137}Cs, ^{228}Ac obtained by using different counting systems but without producing a final result. In some cases the results reported for each isotope were very different. While we have to acknowledge the effort rendered we would like to recommend these laboratories to make a final choice in order to report a final result.

Unsubstantiated assumptions regarding radioactive equilibria in samples often lead to erratic results for some natural radionuclides. For example, ^{238}U was determined

in some cases from the concentration of the gamma emitting ^{226}Ra decay products assuming radioactive equilibrium between ^{238}U and ^{226}Ra

The median concentrations for the sets of individual data -after rejection of outliers- were chosen as the most reliable estimates of the true values A summary of the recommended values and information values with confidence intervals for the most frequently reported radionuclides is given in Table 15 for the IAEA-134 cockle flesh sample.

9. References

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10. Acknowledgments

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More than 77% of the participants responded to this intercomparison exercise and the laboratories which contributed their time and facilities to the present work are hereby acknowledged. We also acknowledge the effort made by the laboratory No. 14 which, in addition to supplying results for ^{60}Co, ^{90}Sr, ^{210}Pb, ^{210}Po, thorium and uranium isotopes, ^{226}Ra, ^{238}Pu, $^{239+240}Pu$ and ^{241}Am results also, reported values for ^{237}Np, ^{241}Pu, ^{242}Cm and $^{243+244}Cm$.

Note: The results presented in this report are subject to further revision and re-evaluation with the admission of additional data. Data of ^{241}Pu will be especially welcome for the certification of ^{241}Am. The users of the reference material IAEA-134 are therefore encouraged to report all meaningful data and they will be notified of any changes in the certification status of the sample.

Your Laboratory Code Number is: ___

ANNEX I

Tables for IAEA-134 Report

TABLE 1 Homogeneity tests for IAEA-134 cockle flesh sample

Relative activity of randomly selected samples*

Sample	Radionuclide					
No	^{40}K**	^{60}Co**	^{137}Cs**	^{210}Pb**	$^{239+240}Pu$+	^{241}Am**
1	0 97	0 78	0 96	0 99	0 72	0 89
2	0 99	1 17	1 00	1 06	0 76	0 95
3	1 09	1 17	0 96	1 01	0 77	0 95
4	0 99	0 89	1 04	1 35	0 80	1 00
5	1 01	1 00	1 00	1 00	0 92	1 05
6	1 03	0 61	0 96	0 98	0 89	0 95
7	1 01	1 11	0 96	1 07	0 94	0 95
8	1 09	1 00	1 00	0 91	0 96	0 95
9	0 96	1 00	1 04	0 89	1 01	0 97
10	0 86	0 94	0 96	0 97	1 07	0 92
11	1 00	0 78	1 00	0 94	1 13	0 95
12	1 03	1 00	1 00	0 95	1 09	1 16
13	0 99	0 72	0 96	0 89	1 14	1 03
14	0 89	1 33	1 04	1 02	1 06	1 05
15	0 97	0 78	0 96	0 93	1 06	0 92
16	0 99	1 00	1 00	1 03	1 20	1 00
17	1 04	1 28	0 96	0 92	1 37	1 13
18	1 03	1 28	1 00	1 10	1 16	1 00

	^{40}K	^{60}Co	^{137}Cs	^{210}Pb	$^{239+240}Pu$	^{241}Am	All
Minimum	0 86	0 61	0 96	0 89	0 72	0 89	0 61
Maximum	1 09	1 33	1 04	1 35	1 37	1 16	1 37
Mean	1 00	0 99	0 99	1 00	1 00	0 99	0 995
Median	1 00	1 00	1 00	0 99	1 04	0 95	1 00
Standard dev	0 06	0 21	0 03	0 11	0 17	0 07	0 12
Coef var (%)	6	21	3	11	17	7	12

* $=x/\bar{X}$ (individual/mean values) mutually expressed in this manner to assure confidentiality of results

** determined by gamma spectrometry

\+ determined by alpha counting

TABLE 2 Radionuclides reported in Irish Sea cockle flesh sample IAEA-134

Radionuclide	Number of reported results	Radionuclide	Number of reported results
^{137}Cs	120 (1)	^{109}Cd	1
^{40}K	111	^{110m}Ag	1 (1)
^{241}Am	91	^{133}Ba	1
^{60}Co	88 (1)	^{160}Tb	1
$^{239+240}Pu$	44	^{181}Hf	1
^{238}Pu	40	^{182m}Ta	1
^{226}Ra	32 (9)	^{210}Tl	1 (1)
^{90}Sr	29 (4)	^{212}Bi	1 (1)
^{134}Cs	27 (16)	^{229}Th	1
^{232}Th	25 (5)	^{242}Cm	1
^{228}Th	22 (3)	U-natural	1
^{106}Ru	22 (4)		
^{210}Pb	21 (8)		
^{125}Sb	20 (1)		
^{238}U	19 (2)		
^{210}Po	19		
^{235}U	14 (2)		
^{154}Eu	14 (1)		
^{214}Pb	13 (1)		
^{212}Pb	10 (1)		
^{234}U	9 (1)		
^{228}Ra	9 (2)		
^{214}Bi	8 (2)		
^{228}Ac	8 (1)		
^{230}Th	8 (1)		
^{155}Eu	5 (1)		
^{208}Tl	5 (2)		
^{234}Th	4 (1)		
^{241}Pu	4		
^{57}Co	3		
^{65}Zn	3 (1)		
^{144}Ce	3 (3)		
^{237}Np	3		
^{95}Zr	2 (2)		
^{99}Tc	2		
^{141}Ce	2		
^{224}Ra	2		
$^{243+244}Cm$	2		
^{46}Sc	1		
^{54}Mn	1		
^{89}Sr	1 (1)		
^{95}Nb	1 (1)		

"Less than" values are shown in parenthesis

TABLE 3 Results for Sr-90 in IAEA-134 cockle flesh sample
(Reference date 1992-01-01, unit: Bq kg^{-1})

Lab code	Method code	No. of results	Weight (g)	Sr-90
7	B7,n	3	10	4.3 ± 1.2
14	B7	2	10	4.05± 0.68
16	B	1	5	6.0 ± 2.0
24	B7,i	4	5	6 ± 2
28	B9	3	25	6.8 ± 0.4
33	B7	4	10	<1
34	B8	2	25	3.2 ± 0.5
35	B	-	-	3.0 ± 0.3
38	B4,n	1	71	4.2 ± 0.8
39	B6,n	1	10	8.9 ± 1.2*
40	B7,n	5	10	<10
43	B7	3	20	4.9 ± 0.4
45	B6	2	5	4.7 ± 2.0
48	B7	2	35	5.3 ± 0.2
56	B11	2	5	11.8± 2.5*
65	B	-	-	<LLD
71	B13	4	12	3.4 ± 1.6
72	B7	2	15	7.3 ± 1.5
80	B14	5	0.9	<20
84	B7	3	15	5 ± 2
85	N	3	5	17.7± 2.1*
102	B6	3	-	11.3± 1.0*
109	B7	1	10	4.4 ± 0.7
110	B7	2	10-50	3.4 ± 0.5
122	B7	3	30	4.9 ± 0.3
123	B10	2	10	4.1 ± 0.5
127	B6,n	3	20	6.1 ± 0.3
132	B7	4	20	6.5 ± 1.5
145	B6,n	5	5	26 ± 2*

* Result rejected by the test for outliers

Number of reported lab means	25
Number of accepted lab. means	20
Range of accepted lab. means	3 - 7.3
Median	4.8
Confidence interval (α= 0.05)	4.1 - 6

TABLE 4. Results for Co-60, Cs-134 and Cs-137 in IAEA-134 cockle flesh sample
(Reference date: 1992-01-01, unit: Bq kg^{-1})

Lab code	Method code	No. of results	Weight (g)	Co-60	Cs-134	Cs-137
1	Gl	2	75	-	-	29.2 ± 0.2*
3	Gl	5	20	3.8 ± 0.8	<2	45 ± 4
4	Gl	3	18	3.3 ± 0.4	-	45.9 ± 1.3
5	Gl	2	75	-	-	54 ± 20
6	Gl	3	-	4 ± 1	<2	48 ± 2
7	Gl	3	67	4.1 ± 1.0	-	51 ± 5
8	Gl	1	51	4.5 ± 0.3	1.3± 0.3	42.0 ± 0.8
9	Gl	1	14	-	-	44.9 ± 2.0
10	Gl	1	75	3.9 ± 0.4	-	43.8 ± 4.4
11	Gl	1	75	-	0.1600± 0.0002	22.9 ± 1.0*
13	Gl	4	30	4.7 ± 1.3	-	46.5 ± 1.9
14	Gl	2	20	4.8 ± 0.3	-	47.5 ± 0.5
16	Gl	5	19	4.4 ± 0.6	-	44.9 ± 2.4
18	Gl	4	75	0.85± 0.05*	-	5.8 ± 0.5*
19	Gl	2	50	-	-	36.55± 0.07*
21	Gl	3	54	5.2 ± 0.4	<2.1	44.4 ± 0.9
23	Gl	7	51	4.1 ± 0.3	-	47 ± 2
25	Gl	2	21	4.1 ± 0.5	0.4± 0.3	47 ± 2
26	Gl	2	29	4.1 ± 1.0	-	51 ± 7
27	Gl	2	52	4.6 ± 0.5	-	58 ± 6
28	Gl	5	32	4.1 ± 0.4	-	46.8 ± 3.4
29	Gl	6	35	4.3 ± 1.3	-	55.8 ± 5.6
31	Gl	6	68	5.6 ± 1.4	<0.3	56.0 ± 8.5
32	Gl	3	62	7.2 ± 1.2*	-	57 ± 4
33	Gl	4	19	-	-	50.6 ± 3.3
34	Gl	3	50	4.6 ± 1.4	-	49 ± 4
35	Gl	4	75	-	-	63.6 ± 2.1*
36	Gl	5	60	6.1 ± 0.9	-	53.7 ± 1.3
37	Gl	1	39	5.8 ± 1.9	<2.8	56.4 ± 3.5
38	Gl	4	44	4.4 ± 1.2	-	46.2 ± 2.7
39	Gl	3	76	5.3 ± 1.1	-	52.1 ± 7.9
40	Gl	4	36	-	-	43.0± 3.0
41	Gl	1	72	-	-	59 ± 6
43	Gl	3	64	4.1 ± 0.3	-	50 ± 2
44	Gl	3	50	1.0 ± 0.5*	-	6 ± 2*
45	Gl	5	75	3.7 ± 1.6	-	51 ± 8
46	Gl	4	31	4.3 ± 0.3	<0.5	47.0 ± 1.5
48	Gl	2	75	3.9 ± 0.8	-	54.0 ± 1.5
51	Gl	3	-	5.4 ± 0.5	<1.5	54.6 ± 3.7
52	Gl	1	37	4.3 ± 0.7	-	48.5 ± 0.9
53	Gl	4	43	2.7 ± 1.0*	0.4± 0.3	42.9 ± 2.0
54	Gl	2	75	5.5 ± 1.4	5.9± 1.5	67.2 ± 15.3*
55	Gl	1	36	4 ± 2	5 ± 3	60 ± 10
56	Gl	2	27	3.7 ± 0.6	-	46.1 ± 3.2
57	Gl	1	17	3.4 ± 0.8	-	45.5 ± 5.3

TABLE 4 (contd).

Lab code	Method code	No. of results	Weight (g)	Co-60	Cs-134	Cs-137
58	G1	4	17	4.2 ± 0.2	-	48 ± 1
59	G1	2	19	4.9 ± 0.4	-	48 ± 2
60	G1	2	37	4.6 ± 0.3	-	51.6 ± 2.0
61	G1	1	75	4.2 ± 0.4	-	47.8 ± 3.3
63	G1	2	25	-	-	48 ± 4
64	G1	1	50	6.8 ± 1.3*	<3	45.2 ± 3.7
65	G1	6	63	-	-	47 ± 2
66	G1	1	22	5.4 ± 1.0	-	51 ± 6
67	G1	3	36	4.9 ± 1.2	1.5± 0.8	52 ± 3
68	G1	6	23-34	4.4 ± 0.7	<1.1	48.0 ± 2.4
69	G1	6	16	-	-	49.9 ± 2.5
71	G1	3	74	-	<1	52 ± 1
72	G1	1	30	4.9 ± 2.1	-	52.6 ± 3.2
73a	G1	1	75	-	-	50 ± 25
73b	G3	1	4.4	-	-	<90
75	G1	3	30-40	-	-	59 ± 5
76	G1	10	58	-	-	61.7 ± 9.3*
78	G1	4	32	4.3 ± 0.3	-	56 ± 2
79	G1	3	2.7	5 ± 3	-	464 ± 4*
80	G1	5	25	5.6 ± 1.0	-	50 ± 3
81	G1	4	67	4.7 ± 0.3	-	50.6 ± 1.1
83	B3,n/G1	4	10	-	-	46 ± 2
84	G1	5	36	5 ± 3	-	52 ± 6
85	G1	3	67	2.93 ± 0.04*	-	42.9 ± 1.0
86	G1	6	72	4.6 ± 0.6	-	52.1 ± 2.3
87	G1	2	30	12 ± 13*	9 ± 8	55 ± 29
89	G1	1	20	-	-	52.0 ± 2.1
90	G1	4	74	2.7 ± 0.4*	<0.4	39.6 ± 2.7
94	G1	3	37	6.3 ± 2.0	-	55.1 ± 6.4
95	G1	3	33	3.7 ± 0.1	-	44.5 ± 1.1
96	G1	3	63	5.2 ± 0.3	<2	59.5 ± 1.0
97	G1	6	72	4.3 ± 0.6	-	39.7 ± 1.3
98	G1	4	39	4.5 ± 1.1	-	48.3 ± 4.0
101	G1	2	75	3.5 ± 0.5	-	40.6 ± 4.1
102	G1	2	-	-	-	53.1 ± 5.0
103	G1	1	35	6.2 ± 2.0	<1.6	50.6 ± 4.5
104	G1	3	50	-	-	34.8 ± 1.7*
105	G1	4	67	5.0 ± 0.6	-	50.0 ± 2.5
106	G1	3	74	4.5 ± 1.6^{+}	-	51.3 ± 4.3^{+}
108	G1	1	35	-	-	59.1 ± 3.0
109	G1	1	56	4.6 ± 0.6	-	47.3 ± 1.0
110	G1	6	77	3.8 ± 2.0	-	48.8 ± 3.6
111	G1	3	76	4.2 ± 0.7	-	40.8 ± 7.3
112	G1	1	77	4.1 ± 0.7	<1.1	52.0 ± 2.9
113	G1	3	40	5.1 ± 1.1	-	50.0 ± 3.0
114	G1	4	75	4 ± 1	-	182 ± 5*

TABLE 4 (contd).

Lab code	Method code	No. of results	Weight (g)	Co-60	Cs-134	Cs-137
116	G1	3	71	4.5 ± 0.9	-	48.5 ± 1.2
117	G1	2	68	3.9 ± 0.4	-	49 ± 2
118	G1	1	3.5	-	-	49.6 ± 1.0
119	G1	6	72	4.2 ± 0.8	-	55.2 ± 5.0
120	G1	6	75	5.4 ± 0.9	-	61.2 ± 6.7*
121	G1	1	75	-	0.1580± 0.0001	22.9 ± 1.6*
122	G1	1	72	4.2 ± 0.3	-	44.6 ± 3.8
123	G1	1	35	4.8 ± 1.0	-	46.1 ± 2.0
124	G1	3	7	-	-	46.3 ± 5.5
125	G1	3	75	-	-	50.6 ± 6.9
127	G1	2	5	-	-	46.2 ± 3.9
128	G1	5	40	4.5 ± 1.0	-	47.7 ± 1.4
129	G1	3	11-16	-	-	37.5 ± 0.2*
130	G1	6	75	5.1 ± 0.5	<2	49.7 ± 1.0
131	G1	8	9	4.7 ± 1.1	-	49 ± 3
132	G1	3	75	4.9 ± 0.3	0.7± 0.1	50.4 ± 2.6
134	G1	6	23	4.3 ± 0.2	-	49.5 ± 2.0
136	G1	6	74	-	-	48.0 ± 6.3
137	G1	3	75	-	-	40 ± 3
138	G1	6	73	5.0 ± 0.5	-	56 ± 2
139	G1	1	20	-	-	69.3 ± 4.0*
140	G1	3	40	-	1.0± 1.5	51.2 ± 5.1
142	G1	4	46	4.8 ± 0.5	-	50.6 ± 1.8
143	G1	10	39	4.2 ± 0.7	-	52.6 ± 2.6
144	G1	1	38	<11	-	60 ± 3
145	G1	3	74	4.1 ± 0.6	<1.5	51 ± 3
146	G1	1	17	5.4 ± 2.0	-	59 ± 6
147	G1	3	76	3.9 ± 0.8	-	50.0± 2.0
149	NAA	3	0.1	4.5 ± 1.4	-	-
151	G1	1	76	-	-	91.8 ± 10.1*

* Result rejected by the test for outliers
\+ Not considered for average calculation at the request of the participant

Number of reported lab. means	86	11	118
Number of accepted lab. means	78	11	102
Range of accepted lab. means	3.3 - 6.3	0.16 - 9	39.6 - 60
Median	4.5	1	49.8
Confidence interval (α = 0.05)	4.3 - 4.7	0.16 - 5.9	48 - 50.6

TABLE 5 Results for Ru-106 and Sb-125 in IAEA-134 cockle flesh sample
(Reference date 1992-01-01, unit Bq kg^{-1})

Lab code	Method code	No of results	Weight (g)	Ru-106	Sb-125
3	G1	5	20	<18	-
14	G1	2	20	11 0± 3 2	3 2± 0 6
16	G1	4	19	10 9± 5 4	-
23	G1	5	51	29 ± 10*	2 5± 0 4
25	G1	2	21	-	2 6± 0 7
27	G1	2	52	<20	3 8± 0 8
28	G1	5	32	10 0± 1 2	2 8± 0 4
29	G1	6	35	10 2± 3 6	-
37	G1	1	39	<33 8	<7 3
45	G1	2	75	-	2 8± 1 4
46	G1	4	31	12 2± 2 4	2 6± 2 4
48	G1	2	75	-	4 3± 1 2
53	G1	4	43	-	0 9± 0 6
60	G1	2	37	13 5± 3 0	2 1± 0 5
61	G1	1	75	20 4± 6 3*	2 1± 0 7
67	G1	3	36	-	5 3± 1 6
68	G1	6	23-34	15 ± 5	2 4± 0 7
81	G1	2	67	11 8± 2 0	-
90	G1	4	74	5 2 ± 1 2	-
96	G1	3	63	15 0± 4 0	-
103	G1	1	35	<30 1	-
112	G1	1	77	-	4 3 ±1 5
116	G1	3	71	10 5 ± 4 0	-
119	G1	5	72	11 5± 4 0	2 8± 1 0
122	G1	1	72	12 6± 3 6	2 7± 0 6
132	G1	3	75	14 1± 1 5	3 8± 0 4
134	G1	6	23	8 ±3	2 5± 0 3
138	G1	4	73	15 ± 2	3 0± 0 9

* Result rejected by the test for outliers

Number of reported lab means	18	19
Number of accepted lab means	16	19
Range of accepted lab means	5 2 - 15	0 9 - 5 3
Median	11 7	2 8
Confidence interval (α = 0 05)	10 2 - 14 1	2 5 - 3 8

TABLE 6 Results for Eu-154 and Eu-155 in IAEA-134 cockle flesh sample
(Reference date 1992-01-01, unit Bq kg^{-1})

Lab code	Method code	No of results	Weight (g)	Eu-154	Eu-155
10	G1	1	75	1 3± 0 2	-
23	G1	6	51	0 7± 0 2*	1 0± 0 5
25	G1	2	21	0 7± 0 3*	<0 6
27	G1	2	52	1 9± 0 6*	-
28	G1	3	32	1 0± 0 1*	-
36	G1	5	60	-	1 8± 0 6
56	G1	2	27	-	1 6± 1 4
58	G1	4	17	1 2± 0 2	-
68	G1	6	23-34	1 2± 0 3	1 5± 0 5
81	G1	2	67	1 4± 0 3	-
110	G1	6	77	1 9± 1 2*	-
112	G1	1	77	<0 9	-
119	G1	3	72	1 3± 0 5	-
122	G1	1	72	1 2± 0 2	-
132	G1	1	75	1 1± 0 2	-
134	G1	6	23	1 3± 0 3	-

* Result rejected by the test for outliers

Number of reported lab means	13	4
Number of accepted lab means	8	4
Range of accepted lab means	1 1 - 1 4	1 0 - 1 8
Median	1 25	1 6
Confidence interval ($\alpha = 0\ 05$)	1 1 - 1 4	-

TABLE 7 Results for Pu-238, Pu-239+240 and Am-241 in IAEA-134
(Reference date 1992-01-01, unit Bq kg^{-1})

Lab code	Method code	No of results	Weight (g)	Pu-238	Pu-239+240	Am-241
3	G1	5	20	-	-	41 ± 4
4	G1	3	18	-	-	35·8 ± 2 3
7	A2	6	5	3 5 ± 0 7	18 6 ± 3 0	52 5 ± 8 5
8	G1	1	51	-	-	38 ± 5
10	G1	1	75	-	-	34 6 ± 3 5
11	G1	1	75	-	-	13 0 ± 0 9*
14a	A2,n	2	10	3 13± 0 08	15 6 ± 0 2	39 9 ± 0 5
14b	G1	2	20	-	-	38 9 ± 0 8
16	A2	5	1	3 0 ± 0 6	15 0 ± 1 6	-
16	G1	5	19	-	-	46 4 ± 3 3
21	A2,n	3	2	3 1 ± 0 2	15 5 ± 0 5	-
21	G1	3	54	-	-	33 8 ± 6 4
23	G1	8	51	-	-	38 ± 4
24	A2,t	5	1	3 1 ± 0 2	15 2 ± 0 4	37 7 ± 0 8
25	G1	2	21	-	-	44 ± 2
26	G1	2	29	-	-	47 ± 6
27	G1	2	52	-	-	35 ± 4
28	A5,n	3	25	3 1 ± 0 2	15 6 ± 1 5	-
28	G1	5	32	-	-	48 1 ± 4 5
29	G1	6	35	-	-	46 2 ± 8 3
32	G1	3	62	-	-	44 ± 4
33	G1	2	19	-	-	44 0 ± 4 0
34	G1	3	50	-	-	47 ± 3
36	G1	5	60	-	-	7 9 ± 0 7*
37a	A2,t	1	5	2 7 ± 0 3	12 8 ± 1 5	34 5 ± 2 8
37b	G1	1	39	-	-	43 7 ± 6 4
38	A2,t	2	2	3 4 ± 0 4	14 6 ± 0 9	-
38	G1	4	44	-	-	28 0 ± 4 2*
39	A4,t	1	10	-	52 8*	-
40	A2	5	10	3 5 ± 0 1	16 2 ± 0 2	-
40	A5	5	10	-	-	38 3 ± 0 4
42	A2,t	1	1	3 4 ± 0 9	13 0 ± 1 7	44 ± 6
43	G1	3	64	-	-	43 ± 2
44	G1	3	50	-	-	6 ± 3*
45	A	2	4	5 3 ± 1 4*	32 ± 6*	-
45	G1	1	75	-	-	47 ± 4
48	A2,t	2	4	2 9 ± 0 3	13 4 ± 0 8	-
49	A4,t	4	1-3	2 9 ± 0 4	14 8 ± 1 0	-
50	A2,t	2	2	2 7 ± 0 3	12 9 ± 1 0	35 0 ± 5 0
51	A2,n	3	-	3 4 ± 0 6	16 ± 2	38 ± 5
53	G1	1	43	-	-	54 ± 13*
54	G1	2	75	-	-	158 3*
55	G1	1	36	-	-	40 ± 20
56	G1	2	27	-	-	42 1 ± 2 9
58	A2,t	1	2	4 4 ± 0 5*	13 8 ± 1 5	-
58	G1	8	17	-	-	34 ± 3

TABLE 7 (contd).

Lab code	Method code	No of results	Weight (g)	Pu-238	Pu-239+240	Am-241
59	G1	3	19	-	-	43 ± 2
60	G1	2	37	-	-	46.8 ± 2.6
61	A2	3	5	3.6 ± 0.2	18.7 ± 0.1	-
61	G1	1	75	-	-	44.3 ± 1.6
63	G1	2	25	-	-	42 ± 2
64	A2,t	4	1	2.9 ± 2.2	11.2 ± 7.6	-
64	G1	1	50	-	-	37.0 ± 2.4
65	A2,n	4	1	30 ± 14*	17 ± 3	32 ± 4
66	A2,n	2	2	2.5 ± 1.0	13.8 ± 2.0	-
68	G1	6	23-34	-	-	41.9 ± 4.3
69	A2,n	1	2	5.1 ± 1.9*	14.0 ± 3.1	-
69	G1	6	16	-	-	38.8 ± 2.9
71	A5,n	2	10	6.8 ± 1.0*	28.0± 3.0*	-
71	G1	3	74	-	-	41 ± 1
72	G1	1	30	-	-	43 ± 11
74	A2,t	2	25	1.8 ± 0.3*	12.0 ± 1.2	-
76	G1	10	58	-	-	58.5 ± 11.7*
77	A2,t	3	10	2.8 ± 0.6	14.1 ± 2.2	36.8 ± 6.3
78	G1	4	32	-	-	24 ± 1*
79	A2,n	3	3	-	17 ± 1	-
80a	A5,t	3	3	1.45± 0.15*	13.4 ± 1.3	36.6 ± 3.7
80b	G1	5	25	-	-	44 ± 4
81	G1	1	67	-	-	39.8 ± 1.3
83	A2,n	4	10	3.4 ± 0.3	15.9 ± 0.6	40 ± 2
84	A2,n	3	15	3 ± 1	16 ± 3	-
84	G1	5	36	-	-	45 ± 5
86	G1	6	72	-	-	44.7 ± 12.5
89	G1	1	20	-	-	47.5 ± 1.8
91	A3,t	3	15	-	13.1 ± 0.3	20.9 ± 0.4*
94	G1	3	37	-	-	41.2 ± 7.3
96	G1	3	63	-	-	67.7 ± 7.0*
98	A2,n	3	5.5	3.7 ± 0.9	14.2 ± 2.1	-
98	G1	4	39	-	-	43.5 ± 5.0
103	G1	1	35	-	-	45.8 ± 6.0
105	G1	4	67	-	-	46 ± 5
106	G1	3	74	-	-	44.1 ± 5.8*
109	A2,n	1	5-10	3.3 ± 0.2	16.8 ± 0.6	44.6 ± 0.4
110	G1	6	77	-	-	33.6 ± 6.6
111	A3,n	1	40	4.9 ± 0.8*	22.0 ± 3.6*	-
111	G1	3	76	-	-	49.6 ± 8.8
112	G1	1	77	-	-	47.9 ± 2.6
113	G1	3	40	-	-	49.3 ± 4.4
114	A7,t	3	11	-	13 ± 3	-
116	G1	3	71	-	-	31.8 ± 3.2
117	A2,n	2	2.5	3.1 ± 0.1	15.3 ± 0.3	33.4 ± 1.7
119	G1	6	72	-	-	40.6 ± 5.0
120	G1	6	75	-	-	43.1 ± 4.9

TABLE 7 (contd)

Lab code	Method code	No of results	Weight (g)	Pu-238	Pu-239+240	Am-241
121	G1	1	75	-	-	13 0 ± 0 8*
122	A2,n	2	1	3 1 ± 0 2	15 7 ± 1 1	33 7 ± 2 6
123	A2	2	5-10	3 16± 0 15	15 8 ± 1 7	38 3 ± 1 4
125	A	3	25	4 6 ± 0 5*	19 8 ± 1 2	-
127a	A3,t	3-4	10	3 22± 0 18	16 15± 0 53	38 9 ± 1 7
127b	G1	2	5	-	-	45 5 ± 9 3
128	G1	8	40	-	-	41 4 ± 3 8
129	A2	2	16	2 3 ± 0 2	10 5 ± 0 5	14 6 ± 2 0*
130	G1	6	30	-	-	39 4 ± 3 2
131	G1	8	9	-	-	23 ± 2*
132a	A2,n	15	1-20	35 ± 0 5	14 8 ± 1 5	39 4 ± 3 7
132b	G1	3	75	-	-	40 6 ± 2 2
134	G1	6	23	-	-	40 ± 2
135	A2,n	6	5-11	3 6 ± 0 3	16 2 ± 0 3	38 8 ± 1 7
136	G1	6	74	-	-	38 0 ± 4 3
138	G1	6	73	-	-	34 ± 15
140	G1	3	40	-	-	40 ± 11
145	A5,n	2	10	2 9 ± 0 6	12 8 ± 2 6	-
145	G1	4	74	-	-	47 ± 4
146	G1	1	17	-	-	56 ± 10*
147	G1	3	76	-	-	6 0 ± 2 0*
148	A2,n	5	2	52 7± 4 7*	301 7± 18 1*	-

* Result rejected by the test for outliers
\+ Value not used for average concentration at the request of the participant

Number of reported lab means	40	44	90
Number of accepted lab means	30	39	75
Range of accepted lab means	2 3 - 3 7	10 5 - 19 8	31 8 - 52 5
Median	3 1	15	41
Confidence interval (α= 0 05)	3 - 3 4	13 8 - 16 2	39 4 - 43 0

TABLE 8. Results for K-40 in IAEA-134 cockle flesh sample.
(Reference date: 1992-01-01, unit: Bq kg^{-1})

Lab code	Method code	No. of results	Weight (g)	K-40
1	GI	2	75	37.1 ± 0.6*
3	GI	5	20	213 ± 16
4	GI	3	18	80 ± 12*
5	GI	2	75	143 ± 15*
6	GI	3	-	210 ± 16
7	GI	3	67	204 ± 28
8	GI	1	51	210 ± 5
9	GI	1	14	197 ± 14
10	GI	1	75	188 ± 21
11	GI	1	75	139.1± 8.4*
13	GI	4	30	229 ± 29
14	GI	2	20	226.0± 5.9
16	GI	5	19	230 ± 16
18	GI	4	75	166 ± 9
19	GI	2	50	160.5± 29.0
21	GI	3	54	215 ± 9
23	GI	8	51	196 ± 10
25	GI	2	21	186 ± 10
26	GI	2	29	211 ± 36
27	GI	2	52	250 ± 20
28	GI	5	32	199 ± 20
29	GI	6	35	217 ± 33
31	GI	6	68	245.9± 34.2
32	GI	3	62	269 ± 29
33	GI	2	19	198 ± 12
34	GI	3	50	220 ± 25
35	GI	4	75	291 ± 16*
36	GI	5	60	250.1± 20.8
37	GI	1	39	350 ± 60*
38	GI	4	44	260 ± 110
39	GI	3	76	282 ± 48*
40	GI	4	36	252 ± 15
41	GI	1	72	390 ± 160*
43	GI	3	64	230 ± 20
44	GI	3	50	13 ± 5*
45	GI	4	75	210 ± 30
46	GI	4	31	211 ± 8
48	GI	2	75	220 ± 22
51	GI	3	-	223.0± 4.1
52	GI	1	37	205 ± 10
53	GI	2	43	202 ± 50
54	GI	2	75	324.3± 59.5*
55	GI	1	36	200 ± 30
56	GI	2	27	206.6± 27.2
57	GI	1	17	182 ± 32

TABLE 8 (contd)

Lab code	Method code	No. of results	Weight (g)	K-40
58	GI	4	17	200 ± 20
59	GI	2	19	200 ± 10
60	GI	2	37	220 ± 14
61	GI	1	75	233 ± 20
63	GI	2	25	236 ± 14
64	GI	1	50	380 ± 38*
67	GI	3	36	224 ± 16
68	GI	6	23-34	199 ± 21
69	GI	6	16	176 ± 55
71	GI	3	74	227 ± 11
72	GI	1	30	220 ± 62
73	GI	1	75	122 ± 61*
75	GI	3	30-40	240 ± 26
78	GI	4	32	225 ± 10
79	GI	3	2.7	168 ± 13
80	GI	5	25	230 ± 10
81	GI	4	67	211 ± 9
84	GI	5	36	200 ± 63
85	GI	3	67	207 ± 5
86	GI	6	72	234.9± 16.4
87	GI	2	30	474 ± 165*
89	GI	1	20	232.2± 41.2
90	GI	4	74	176.7± 11.0
94	GI	3	37	260 ± 39
95	GI	3	33	262.4± 1.4
96	GI	3	63	250 ± 15
97	GI	6	72	129.0± 17.5*
98	GI	4	39	226 ± 34
101	GI	2	75	154 ± 15*
102	GI	1	-	241.0± 55.4
103	GI	1	35	241.7± 61.9
104	GI	3	50	322.8± 14.5*
105	GI	4	67	290 ± 14*
106	GI	3	74	290 ± 52+
108	GI	1	35	197 ± 23
109	GI	1	56	214 ± 9
110	GI	6	77	221.1± 34.9
111	GI	3	76	177.8± 35.4
112	GI	1	77	200 ± 19
113	GI	3	40	223 ± 25
114	GI	4	75	213 ± 20
116	GI	3	71	211 ± 14
117	GI	2	68	199 ± 10
118	GI	1	3.5	506.9± 24.3*
119	GI	6	72	209 ± 15
120	GI	6	75	218 ± 18

TABLE 8 (contd)

Lab code	Method code	No of results	Weight (g)	K-40
121	GI	1	75	139 1± 8 4*
122	GI	2	72	192 ± 14
123	GI	1	35	222 ± 22
127	GI	2	5	240 ± 110
128	GI	8	40	189 ± 9
130	GI	6	75	200 ± 10
131	GI	8	9	208 ± 42
132	GI	3	75	205 ± 11
134	GI	6	23	203 ± 8
136	GI	6	74	373 5± 114 1*
137	GI	3	75	209 ± 21
139	GI	1	20	194 ± 12
140	AAS	3	0 3	208 ± 10
140	GI	3	40	243 ± 80
142	GI	4	46	218 8± 11 7
143	GI	10	39	213 ± 25
144	GI	1	38	700 ± 10*
145	GI	4	74	198 ± 12
147	GI	3	76	220 ± 15
151	GI	1	76	550 3± 40 4*

* Result rejected by the test for outliers
\+ Value not used in average concentration at the request of the participant

Number of reported lab means	110
Number of accepted lab means	88
Range of accepted lab means	160 5 - 269
Median	212
Confidence interval (α = 0 05)	196 - 240

TABLE 9 Results for U-234, U-235 and U-238 in IAEA-134 cockle flesh sample
(Reference date 1992-01-01, unit Bq kg^{-1})

Lab code	Method code	No of results	Weight (g)	U-234	U-235	U-238
14	A2,a	2	4	3 44± 0 09	0 12± 0 01	3 11± 0 09
21	G2	4	51	-	-	9. ±3
25	G2	2	21	-	-	6 ±2
34	G1	3	50	-	3 0 ± 1 2	-
36	G2	5	60	-	-	3 9 ± 1 2
42	A2,t	1	1	2 5 ± 1 2	-	3 2 ± 1 3
45	A	2	2	15 ±3*	0 26± 0 07	8 7 ± 2 4
52	G	1	37	-	5	-
64	G1	1	50	-	1 3 ± 2 5	-
71	A5,a	1	10	2 7 ± 0 5	0 2 ± 0 1	2 4 ± 0 5
77	A	3	10	23 5± 6 6*	0 72± 0 38	20 5 ± 5 8*
78	G	4	32	-	-	<20
80	G	5	25	-	<5	<20
104	NAA	3	0 2	-	-	5 5 ± 1 7
105	G1	4	67	-	4 9 ± 0 6	-
106	G	3	74	-	<1 5	-
107	DNA	4	5	-	-	30 7 ± 1 3*
109	A5,a	1	10	5 1 ± 0 3	0 14± 0 03	4 0 ± 0 2
111	G1	3	76	<11 1	-	-
114	A7,t	3	11	-	-	4 0 ± 0 3
117	A2,a	3	6	4 0 ± 0 3	0 16± 0 02	3 3 ± 0 3
123	A4	2	5	4 00± 0 35	0 19± 0 08	3 50 ± 0 33
131	G1	8	9	-	5 2 ± 0 8	-
132	ICPMS,t	3	0 2	-	-	9 3 ± 1 5
147	G	3	76	-	-	15 0 ± 8 0
151	G2	1	76	-	-	10 3 ± 1 2

* Result rejected by the test for outliers

Number of reported lab means	8	12	17
Number of accepted lab means	6	12	15
Range of accepted lab means	2 5 - 5 1	0 12 - 5 2	2 4 - 15
Median	3 7	0 49	4
Confidence interval (α= 0 05)	2 5 - 5 1	0 16 - 4 9	3 3 - 9

TABLE 10 Results for Th-228, Th-230 and Th-232 in IAEA-134 cockle flesh sample (Reference date 1992-01-01, unit Bq kg^{-1})

Lab code	Method code	No of results	Weight (g)	Th-228	Th-230	Th-232
14	A2,n	2	8	2 20 ± 0 05#	2 50± 0 06	1 37± 0 04
16	G	4	19	3 0 ± 0 6	-	-
23	G2	7	51	2 7 ± 0 4	-	-
25	G2	2	21	2 6 ± 0 7	-	-
27	G	2	52	-	-	3 5 ± 0 7
32	G2	3	62	3 6 ± 1 8	-	-
36	G2	5	60	-	-	<8 8
38	G	4	44	<9	-	-
41	G	1	72	-	-	3 ± 14
42	A2,t	1	1	4 1 ± 1 9	5 6 ± 2 1	3 0 ± 1 4
44	G1	3	50	150 ± 137*	-	-
45	G	3	75	3 2 ± 1 3	-	-
45	A	2	4	-	5 5 ± 1 2	2 7 ± 0 8
46	G	4	31	3 1 ± 0 6	-	-
52	G	1	37	11*	-	12 ± 5
56	G2	2	27	-		15 7± 2 9
64	A2,t	4	1	4 3 ± 3 7	5 6 ± 1 9	1 3 ± 1 1
69	G	4	16	-	-	12 ± 7
78	G	4	32	-	-	<3
79	A2,n	6	5 5	3 4 ± 0 2	2 6 ± 0 2	-
80	Em	3	1	<13	-	-
80	A	3	1	-	<50	<30
101	G2	2	75	-	-	<1 2
104	NAA	3	0 2	-	-	2 0 ± 0 3
107	NAA	4	0 1	-	-	2 3 ± 0 4
108	G	1	35	36 3 ± 4 0*	-	-
111	G	3	76	<41 8	-	-
116	G2	3	71	-	-	3 9 ± 1 3
117	A	2	5	1 5 ± 0 1	2 0 ± 0 1	0 8 ± 0 1
119	G	6	72	-	-	<5
120	G	6	75	-	-	4 3 ± 0 5
130	G2	6	75	-	-	7 0 ± 1 3
132a	G2	3	75	3 0 ± 0 6	-	-
132b	A2,t	4	1-2	2 9 ± 0 5	4 0 ± 0 4	2 1 ± 0 4
132	ICPMS,t	3	0 2	-	-	6 9 ± 0 2
138	G2	6	73	2 9 ± 0 8	-	-
140	G	3	40	1 7 ± 1 4	-	-
144	G2	1	38	-	-	40 ± 2*
147	G	3	76	5 0 ± 2 0*	-	8 0 ± 3 0
151	G2	1	76	-	-	8 0 ± 1 7

* Result rejected by the test for outliers # Activity concentration on 1992-09-29

Number of reported lab means	19	7	20
Number of accepted lab means	15	7	19
Range of accepted lab means	1 5 - 4 3	2 - 5 6	0 8 - 15 7
Median	3	4	3 25
Confidence interval (α= 0 05	2 6 - 3 4	2 - 5 6	2 1 - 8

TABLE 11. Results for Ra-226, Ra-228 and Ac-228 in IAEA-134 cockle flesh sample.
(Reference date. 1992-01-01, unit: Bq kg^{-1})

Lab code	Method code	No. of results	Weight (g)	Ra-226	Ra-228	Ac-228
11	G1	1	75	-	-	4.7 ± 1.5
23	G2	6	51	3.3 ± 1.0	2.6 ± 0.7	-
25	G	2	21	7 ± 3*	3.1 ± 1.1	-
26	G1	2	29	-	-	3.9 ± 2.7
27	G	2	52	2.6 ± 0.6	-	-
29	G1	6	35	-	3.5 ± 2.0	-
32	G2	3	62	2.9 ± 1.4	-	-
33	G	2	19	6.4 ± 1.4*	-	-
34	G1	3	50	21 ± 17*	-	-
38	G	4	44	<17	28 ± 10*	-
41	G	1	72	32 ± 10*	-	-
44	G1	3	50	-	-	12 ± 12
46	G	4	31	1.9 ± 0.2	3.8 ± 1.0	-
52	G	1	37	<10	-	-
53	G1	4	43	-	-	<10
54	G	2	75	1055 ± 279*	-	7.6 ± 3.9
60	G	2	37	9.3 ± 4.4*	-	2.4 ± 1.2
71	G	3	74	<2	-	-
73	G	1	75	<LLD	-	-
78	G	4	32	<3	-	-
80	G	5	25	<5	-	-
85	N	3	5	2.6 ± 0.4	-	-
89	B4,n	4	1	1.94 ±0.01	-	-
90	G	4	74	4.7 ± 0.2*	-	-
93	Em	6	1	4.0 ± 0.6	-	-
101	G2	2	75	<1.3	-	-
104	G	3	50	11.2 ± 1.4*	-	-
108	G	1	35	-	<3	-
113	G	3	76	<14.8	-	-
116	G2	3	71	2.7 ± 1.1	-	-
118	G2	1	4	3.2 ± 2.8	-	-
118	G1	1	4	-	-	13.7 ± 3.2
119	G	6	72	<5	-	-
122	G1	1	72	-	3.9 ± 0.7	-
130	G2	6	75	2.5 ± 0.5	-	-
131	G1	8	9	-	-	20 ± 4
132	G2	3	75	2.1 ± 0.3	4.9 ± 0.7	-
138	G2	6	73	6.0 ± 2.3*	-	-
140	G	3	40	3.8 ± 2.7	<10	-
146	G	1	17	14 ± 4*	-	-
147	G	3	76	2.6 ± 1.3	-	-

* Result rejected by the test for outliers

Number of reported lab. means	23	7	7
Number of accepted lab. means	13	6	7
Range of accepted lab. means	1.9 - 4	2.6 - 4.9	2.4 - 20
Median	2.6	3.75	7.6
Confidence interval (α = 0.05)	2.1 - 3.3	2.6 - 4.9	2.4 - 20

TABLE 12 Results for Pb-210 and Po-210 in IAEA-134 (Reference date 1992-01-01, unit Bq kg^{-1})

Lab code	Method code	No of results	Weight (g)	Pb-210	Po-210	Reference date
6	A1	2	-	6 ± 2	6 ± 2	
7	A1	3	1	-	4 6 ± 1 0	
14	A1	3	4	3 3 ± 0 2	4 2 ± 0 2	1992-10-28
21	A1	3	2	-	13 8± 0 6	
22	A1	3	2	48 7 ± 2 7*	-	
24	A1	6	1	-	24 ± 1	
25	G1	2	21	7 ± 2	-	
38	G1	4	44	<170	-	
39	B1,n	1	10	6 7 ± 1 3	-	
39	A1	1	10	-	4 5 ± 0 5	
42	A2,t	1	1 3	-	6 5 ± 3 3	
45	B1	2	4	5 7 ± 0 6	-	
45	A1	2	1	-	2 5 ± 1 3	
58	G1	3	17	<20	-	
60	G1	2	37	7 6 ± 4 8	-	
61	A1	4	1 5	-	5 0 ± 0 4	
63	A1	3	5	3 3 ± 0 3	12 2± 1 3	
68	G1	6	23-34	<14	-	
80	A1	3	3 3	-	4 1 ± 0 4	
83	A1	4	10	-	5 1 ± 0 4	1992-11-09
85	N	3	2-5	4 8 ± 0 4	8 5 ± 2 0	
91	A1	3	2	-	18 5± 0 8	
92	B2,n	4	3	4 6 ± 3 9	-	
92	A1	4	3	-	14 4± 3 8	
111	G1	3	76	<19 8	-	
114	N	3	11	50 ± 31*	-	
117	A1	3	6	-	5 0 ± 0 7	
118	A	1	1 4	5 0 ± 0 6	-	
118	G1	1	3 5	<LLD	-	
120	G1	6	75	<24	-	
122	G1	1	2	<26	-	
122	A1	1	2	-	27 ± 4	
131	A1	8-10	-	4 6 ±2 5	4 4 ±0 5	1993-01-01
132	G1	3	75	14 8 ± 5 6*	-	
132	A1	3	1	-	12 5 ± 1 3	
140	G1	3	40	<95	-	
150	A1,t	2	1	-	4 4 ± 1 1	1993-03-05

* Result rejected by the test for outliers

Number of reported lab means	14	20
Number of accepted lab means	11	see explanations
Range of accepted lab means	3 3 - 7 6	in the text
Median	5	7 5
Confidence interval (α = 0 05)	3 3 - 7	4 6 -14 4

TABLE 13 Results for Pb-214, Bi-214 and Pb-212 in IAEA-134 cockle flesh sample (Reference date 1992-01-01, unit Bq kg^{-1})

Lab code	Method code	No of results	Weight (g)	Pb-214	Bi-214	Pb-212
11	G1	1	75	1 3 ± 0 3	-	1 0 ± 0 2
14	G1	2	20	-	-	2 2 ± 0 6
25	G1	2	21	2 1 ± 0 7	-	-
26	G1	2	29	-	-	1 7 ± 1 3
34	G1	3	50	7 0 ± 2 4	3 5 ± 2 0	6 9 ± 1 8
44	G1	3	50	2 ± 2	2 ± 2	4 ± 2
53	G1	4	43	<10	-	-
54	G	2	75	56 5± 11 0*	5 6 ± 2 6	64 8± 11 0*
60	G1	2	37	4 9 ± 1 2	9 6 ± 1 8	2 2 ± 0 3
73	G	1	75	-	<LLD	<LLD
97	G1	6	72	2 1 ± 0 9	-	1 4 ± 0 4
111	G1	3	76	2 7 ± 1 1	<2 6	3 4 ± 1 3
118	G1	1	3 5	3 7 ± 2 4	1 9 ± 1 8	-
121	G1	1	75	22 7± 0 3*	-	-
131	G1	8	9	5 9 ± 1 5	-	-
144	G1	1	38	32 ± 5*	38 ± 5*	-

* Result rejected by the test for outliers

Number of reported lab means	12	6	9
Number of accepted lab means	9	5	8
Range of accepted lab means	1 3 - 7	1 9 - 9 6	1 - 6 9
Median	2 7	3 5	2 2
Confidence interval (α= 0 05)	2 - 5 9	1 9 - 9 6	1 - 6 9

TABLE 14 Results for the less frequently reported radionuclides in IAEA-134 cockle flesh sample (Reference date 1992-01-01 unit Bq kg^{-1})

Isotope	Lab code	Method code	No of results	Weight (g)	Activity concentration
U-nat	80	F	5	0 0002	3 9 ± 1 0
Sc-46	149	NAA	3	0 1	9416 0± 2 7
Mn-54	67	G1	3	36	1 0 ± 0 5
Co-57	60	G1	2	37	0 9 ± 0 2
	61	G1	1	75	0 9 ± 0 3
	138	G1	2	73	1 8 ± 0 4
Zn-65	3	G1	5	20	<6
	5	G1	2	75	3 7 ± 2 4
	149	NAA	3	0 1	2930 ± 1
Sr-89	80	B14	5	0 9	<20
Nb-95	3	G1	5	20	<72
Zr-95	3	G1	5	20	<16
	37	G1	1	39	<105
Tc-99	42	B12,t	1	4	40 ± 8
	122	B15	2	10	17 8 ± 1 6
Cd-109	142	G1	4	46	32 4 ± 10 1
Ag-110m	37	G1	1	39	<6 7
Ba-133	90	G1	4	74	2 4 ± 2 3
Ce-141	132	G1	3	75	9 8 ± 3 4
	149	NAA	3	0 1	4550 0 ± 2 4
Ce-144	3	G1	5	20	<10
	37	G1	1	39	<22 3
	103	G1	1	35	<13 2
Tb-160	149	NAA	3	0 1	3630 0± 1 2
Hf-181	149	NAA	3	0 1	4000 0± 1 6
Ta-182m	149	NAA	3	0 1	1070 0± 0 5

TABLE 14 (contd)

Isotope	Lab code	Method code	No of results	Weight (g)	Activity concentration
Tl-208	11	G1	1	75	0 40 ± 0 06
	34	G1	3	50	3 3 ± 1 1
	44	G1	3	50	14. ± 7
	60	G1	2	37	<0 5
	111	G1	3	76	<1 1
Tl-210	111	G1	3	76	<0 8
Bi-212	111	G1	3	76	<14 6
Ra-224	60	G1	2	37	<7 5
	111	G	3	76	<20 2
Th-229	149	NAA	3	0 1	37 4 ± 12 7
Th-234	37	G1	1	39	<31 6
	105	G1	4	67	73 ± 17
	118	G1	1	3 5	6 3 ± 3 9
	131	G1	8	9	63 ± 30
Np-237	14	A2,n	2	10	1 55 ± 0 03
	81	G1	2	67	1 6 ± 0 1
	129	A2	1	16	0 74 ± 0 05
Pu-241	14	B5,n	2	10	224 ± 8
	45	B5	2	4	250 ± 70
	109	B5	1	5	228 ± 8
	132	A6,n	3	20	201 ± 10
Cm-242	14	A2,n	2	10	0 041 ± 0 022
Cm-243+244	14	A2,n	2	10	0 124 ± 0 020
	132	A2,n	3	5	0 044 ± 0 022

TABLE 15 Summary of data for radionuclide concentrations in cockle flesh sample IAEA-134 (Reference date 1992-01-01, unit Bq kg^{-1} dry weight)

Radionuclide	Range of accepted values	Median of accepted values	Confidence interval (α= 0 05)
Recommended values			
Potassium-40	160 5-269	212	196-240
Cobalt-60	3 3-6 3	4 5	4 3-4 7
Caesium-137	39 6-60	49 8	48-50 6
Plutonium-239+240	10 5-19 8	15	13 8-16 2
Information values			
Strontium-90	3-7 3	4 8	4 1-6
Ruthenium-106	5 2-15	11 7	10 2-14 1
Antimony-125	0 9-5 3	2 8	2 5-3 8
Caesium-134	0 16-9	1	0 16-5 9
Europium-154	1 1-1 4	1 25	1 1-1 4
Europium-155	1 0-1 8	1 6	1 0-1 8
Lead-210*	3 2-7 6	5 4	3 3-7
Radium-226	1 9-4	2 6	2 0-3 2
Radium-228	2 4-4 9	3 8	2 6-4 7
Thorium-228	1 5-4 3	3	2 6-3 4
Thorium-230	2-5 6	4	2-5 6
Thorium-232	0 8-3 0	1 7	0 8-3 0
Uranium-234	2 5-5 1	3 7	2 5-5 1
Uranium-235	0 12-5 2	0 49	0 16-4 9
Uranium-238	2 4-15	4	3 3-9
Plutonium-238	2 3-3 7	3 1	3-3 4
Americium-241	32-44 6	38 15	35 0-39 4

* Pb-210 and Po-210 are considered to be at equilibrium

Remark The confidence interval is the confidence limit at 95% significance level

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