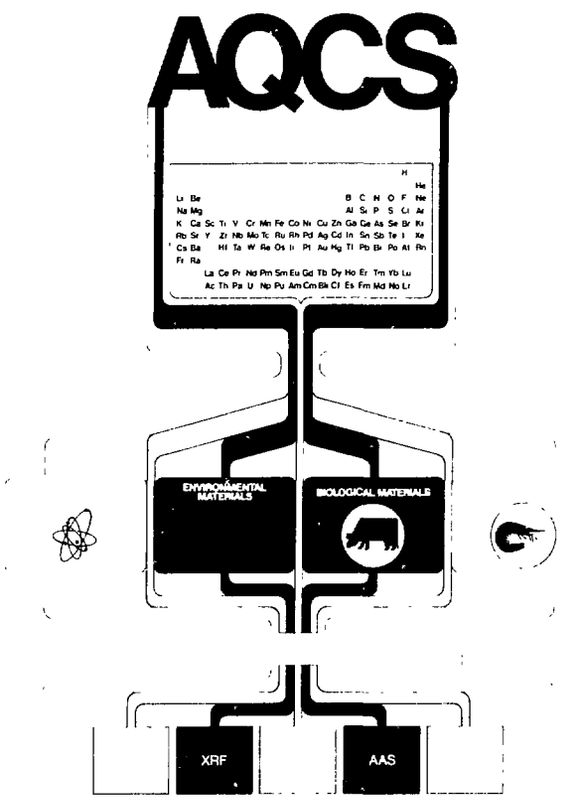
IAEA/AL/032

# REPORT ON THE INTERCOMPARISON RUN

# IAEA-352

## RADIONUCLIDES IN TUNA FISH FLESH

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FINAL REPORT

# INTERCOMPARISON OF RADIONUCLIDE MEASUREMENTS IN MEDITERRANEAN TUNA FISH SAMPLE IAEA-352

by

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## ABSTRACT

The results of an intercomparison exercise on a sample of tuna fish flesh from the Mediterranean Sea, IAEA-352, designed for the determination of artificial and natural radionuclide levels, are reported. The data from 63 laboratories from 31 countries have been evaluated.

The following are the recommended values, with confidence intervals, for the most frequently measured radionuclides (Reference date : 1 January 1989). An information value for $^{90}Sr$ is also suggested.

Artificial radionuclides

| | Recommended value* (Bq kg$^{-1}$) | Confidence interval** (Bq kg$^{-1}$) |
|---|---|---|
| $^{137}Cs$ | 2.7 | 2.5-2.8 |
| **Information value** | | |
| $^{90}Sr$ | 0.2 | 0.17-0.5 |

Natural series radionuclides

| | Recommended value* (Bq kg$^{-1}$) | Confidence interval** (Bq kg$^{-1}$) |
|---|---|---|
| $^{40}K$ | 391 | 379-405 |
| $^{210}Pb$ | 0.6 | 0.36-1.0 |
| $^{210}Po$ | 2.2 | 1.7-2.7 |

* Activities are expressed on dry-weight basis
** At the significance level of $\alpha$=0.05

## 1. Introduction

In 1989, the International Laboratory of Marine Radioactivity in Monaco prepared and distributed a tuna fish sample for intercomparison and certification.

## 2. Scope of the study

Participants were requested to determine natural and artificial radionuclides but mainly $^{40}K$, $^{137}Cs$ and $^{210}Po$. Any additional measurements were welcome. The analysts were requested to make, whenever possible, three determinations for each radionuclide reported.

All participants were informed that the expected levels of the artificial radionuclides concentrations were very low.

## 3. Description of the material

About 200 kg of tuna fish were collected in the Western Mediterranean Sea (Sète, France) in April 1988. The flesh was separated from approximately half the fish and prepared as an intercomparison sample for trace metals and organo-chlorine compounds. A second sample, consisting of 80% fish flesh and 20% bones, was prepared for the analyses of radionuclides. The latter sample (61.5 kg) was freeze-dried and then ground in a laboratory cutting mill. The resulting powder was passed through a 1mm sieve and was further homogenized. The moisture content was determined to be 4.1 % at the time of sample preparation.

Participants were requested to report results on a dry weight basis. The reference date for reporting the radionuclide concentrations was set for 1 January 1989.

Laboratory tests were made to check the homogeneity of the sample. Aliquots of 100 g were packaged in polyethylene bottles and labelled with the code number IAEA-352.

Homogeneity of the material was checked by measuring the concentration of several radionuclides in a series of 10 bottles taken at random from the stock of samples. The amount of $^{40}K$ and $^{137}Cs$ present in the individual samples was determined instrumentally by gamma spectrometry and $^{210}Po$ was chemically separated and measured by alpha spectrometry. Separations of $^{210}Po$ were made simultaneously from all samples.

Results for these radionuclides, expressed as relative activities, allow us to state that the homogeneity of the sample was satisfactory for the radionuclides measured (Table 1).

## 4. Sample dispatch and data return

The tuna fish sample was dispatched to 75 laboratories. Included were those laboratories participating in the ILMR Coordinated Research Programme ("Sources of Radioactivity in the Marine Environment and their Relative Contributions to Overall Dose Assessment from Marine Radioactivity"). By 15 February 1990, 54 laboratories reported their data. An interim report was issued and participants were asked to look over their results and inform us of any errors. Several replies were received and the data were corrected accordingly. We assumed that afterwards no further correction would be submitted and that the original data were correct and could be used for this report. As of 1 of July 1990, 63 sets of results were received from 31 countries.

Concentrations of 9 artificial and 13 natural radionuclides were reported. These 22 radionuclides are shown in Table A with the number of laboratories submitting results. The results for the most frequently measured radionuclides are shown in Tables 2 to 5. The less frequently measured radionuclides are presented in Table 6. The list of contributing laboratories can be found in the Annex.

## 5. Evaluation of the results

### 5.1. Data treatment

The results submitted by the participants are shown under their laboratory code numbers in Tables 2 to 6. 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 when it was judged to be necessary.

### 5.2. Evaluation procedure

The "less than" values were segregated from the results and the remaining values were checked for the presence of outliers using a box and whisker plot test (1). Outliers are identified with an asterisk in Tables 2 to 5. Median values were calculated from all results passing the test. These values are the most reliable estimates of the unknown true values.

Confidence intervals were taken from a non-parametric sample population (2). They represent a two-sided interval at a significance level of 0.05.

### 5.3. Explanation of tables

5.3.1. Laboratory code number : each laboratory was assigned a code number. The numbers do not correspond to the sequence in the list of the participants given in the Annex in order to ensure the anonymity.

5.3.2. Method code : the analytical techniques employed by the participants are :

| Method code | Method |
|---|---|
| A($^{210}$Po) | Alpha spectrometry of $^{210}$Po ingrown from $^{210}$Pb |
| A2 | Alpha spectrometry after radiochemical separation |
| B | Beta measurements after chemical separation |
| G | Gamma spectrometry : not specified |
| G1 | Gamma spectrometry : direct Ge(Li) |
| G2 | Chemical treatment followed by gamma spectrometry |
| V | Volumetric determination of total K. |

5.3.3. 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.

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 :

1. More than 10 laboratory means were available
2. The percentage of outliers was not greater than 20 % and
3. The relative uncertainty of the overall median did not exceed ± 10 % for activity concentrations equal to or higher than 100 Bq kg$^{-1}$ and ± 30 % for activity concentrations 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 of $^{90}$Sr, $^{134}$Cs, $^{137}$Cs and transuranium elements are presented in Tables 2, 3 and 4.

Strontium-90

Eight results were reported that included two "less than" values (Table 2). Two values reported by Labs. 7 and 45 were determined to be outliers. The median of the accepted values is 0.19 Bq kg$^{-1}$. Because there were few statistically accepted values for $^{90}$Sr, it was only possible to classify the median as an information value.

Caesium isotopes

Eleven results were submitted for $^{134}Cs$ that included eight "less than" and one "N.D." values (Table 3).

Fifty-eight results of $^{137}Cs$ were submitted that included 4 "less than" and one "background level" values (Table 3). All but two participants determined the concentration of $^{137}Cs$ in the sample directly by gamma spectrometry. Labs. 7 and 10 separated caesium by dissolution of the sample, adsorption on AMP followed by gamma spectrometry (Lab. 7) and by ion-exchange purification and beta counting (Lab. 10). Nine values were determined as outliers. The median of the 44 accepted values is 2.7 Bq $kg^{-1}$ with a confidence interval of 2.5-2.8 Bq $kg^{-1}$.

Transuranium elements

$^{239,240}Pu$ and $^{241}Am$ were reported by 7 laboratories. All results were generated by alpha spectrometry except for Lab. 55 which measured $^{241}Am$ by gamma spectrometry. Most of the results were given as "less than" values.

Other isotopes

Several laboratories submitted results on $^{106}Ru$, $^{110m}Ag$, $^{125}Sb$, and $^{238}Pu$. These results which are all reported as "less than" values are presented in Table 6.

## 7. Results and discussion : Natural radionuclides

Potassium-40

All but one of the 56 reported concentrations for $^{40}K$ were determined by gamma spectrometry. Lab. 35 used a volumetric method which consisted of wet ashing of the sample followed by precipitation of the $(C_6H_5)_4$ borate and titration with silver nitrate to determine total K. $^{40}K$ was then assessed from its natural abundance. Results are presented in Table 3.

Seven results were identified as outliers, six of them being higher than the maximum of the accepted range. The median of the 49 accepted values is 391 Bq $kg^{-1}$ with a confidence interval of 379-405 Bq $kg^{-1}$.

Polonium-210

Eleven $^{210}Pb$ results and 25 $^{210}Po$ results were submitted by the participants (Table 5). The $^{210}Pb$ results were generated by direct measurement of the 46 keV gamma photopeak (3 results); beta counting of the $^{210}Bi$ daughter product following radiochemistry (4 results); and from the alpha activity of the $^{210}Po$ daughter product (4 results). Two results were reported as "less than" values. The 9 remaining results cover a wide range from 0.36 to 16.5 Bq $kg^{-1}$. Four values

from this data set were assessed to be outliers. The median of the 5 accepted values is 0.6 Bq $kg^{-1}$ with a confidence interval of 0.36-1.0 Bq $kg^{-1}$.

The 25 results reported for $^{210}Po$ can be divided into 2 sets of data. One group of participants used the reference date of 1 January 1989 assuming equilibrium and provided 6 results. The other 19 participants reported concentrations on specific separation dates between 25 April 1989 and 20 June 1990.

The values from the first set of data, based on the reference date of 1 January 1989, cover a range from 0.88 to 12.5 Bq $kg^{-1}$. The values from the second set of results cover a range from 0.025 to 3.7 Bq $kg^{-1}$.

The equation describing the amount of $^{210}Po$ initially present in a sample and as a result of growth from $^{210}Pb$ decay is :

$$A(^{210}Po)_t = A(^{210}Pb)_o \times 1.017 \, (e^{-\gamma_{Pb}t} - e^{-\gamma_{Po}t}) + A(^{210}Po)_o \times e^{-\gamma_{Po}t}$$

where: $A(^{210}Po)_t$= activity of $^{210}Po$ at time of separation

$A(^{210}Pb)_o$ and $A(^{210}Po)_o$= activity of $^{210}Pb$ and $^{210}Po$ at reference date

t is the time in days between the reference date of 1 Jan.1989 and the date of separation of $^{210}Po$ from $^{210}Pb$

$\gamma_{Pb}$ and $\gamma_{Po}$ are the decay constants of Pb and Po, respectively (expressed in $days^{-1}$)

This equation has been applied to the data set based on separation date to compute $(^{210}Pb)_o$ and $(^{210}Po)_o$ because it did not appear from the results that $^{210}Po$ was in equilibrium with $^{210}Pb$.

Five results were rejected as outliers from the $^{210}Po$ data set and the remaining 14 results generated $^{210}Po$ and $^{210}Pb$ concentrations on the reference date, 1 January 1989 :

$(^{210}Po)_o$ = 2.2 Bq $kg^{-1}$ and $(^{210}Pb)_o$ = 0.6 Bq $kg^{-1}$

The correlation coefficient of the least squares regression is 0.77 while the errors for the $(^{210}Po)_o$ and $(^{210}Pb)_o$ values are 23 % in both cases. The value of $^{210}Pb$ obtained both by the statistical treatment of the $^{210}Pb$ reported results and by the least squares regression analysis applied to the $^{210}Po$ values are identical.

Other isotopes

Several laboratories submitted results on $^{208}Tl$, $^{212}Pb$, $^{226}Ra$, $^{228}Ra$, $^{229}Th$, $^{230}Th$, $^{232}Th$, $^{234}U$, $^{238}U$ and natural uranium. These results are presented in Table 5 but were insufficient to permit a statistical evaluation of median values.

## 8. Summary

A summary of the results for the concentrations of the radioisotopes determined in the tuna fish flesh sample IAEA-352 is shown in Table 7. The median concentrations, computed after rejection of outliers are the most reliable estimators of the true values.

This table provides the list of the recommended values and confidence intervals for the most frequently reported radionuclides in this intercomparison sample.

## 9. References

(1). J.W. Tukey. Exploratory data analysis. Addison-Wesley Publishing Company, Reading, Mass., 1977.

(2). Geigy Scientific Tables, 1(1982) in "Statistical Methods for Environmental Pollution Monitoring", pages 173 and 266, by R.O. Gilbert, Van Nostrand Reinhold Company, New York, 1987.

## 10. Acknowledgments

80 % of the participants receiving the tuna fish sample provided results. The participants who contributed their time and laboratory's facilities to the present work are hereby acknowledged.

Your laboratory code number is : ___

TABLE A. Mediterranean tuna fish sample IAEA-352

| Radionuclide | Number of reported results | Number of total reported as "less than" values |
|---|---|---|
| $^{40}K$ | 56 | - |
| $^{137}Cs$ | 57 | 5 |
| $^{210}Po$ | 25 | - |
| $^{134}Cs$ | 11 | 9 |
| $^{90}Sr$ | 8 | 2 |
| $^{210}Pb$ | 11 | 2 |
| $^{239}Pu$ | 7 | 5 |
| $^{241}Am$ | 7 | 5 |
| $^{226}Ra$ | 6 | 2 |
| $^{238}U$ | 4 | - |
| $^{228}Ra$ | 3 | 2 |
| $^{110m}Ag$ | 2 | 2 |
| $^{228}Th$ | 2 | - |
| $^{106}Ru$ | 1 | 1 |
| $^{125}Sb$ | 1 | 1 |
| $^{208}Tl$ | 1 | - |
| $^{212}Pb$ | 1 | - |
| $^{230}Th$ | 1 | 1 |
| $^{232}Th$ | 1 | 1 |
| $^{234}U$ | 1 | - |
| $^{238}Pu$ | 1 | 1 |
| natural U | 1 | 1 |

TABLE 1. Homogeneity tests for IAEA-352 tuna fish sample.

Relative activity* of randomly selected samples

| Sample No. | Radionuclide | | |
|---|---|---|---|
| | $^{40}K$ | $^{137}Cs$ | $^{210}Po$ |
| 1 | 0.96 | 0.86 | 0.74 |
| 2 | 0.97 | 0.86 | 0.77 |
| 3 | 0.98 | 0.97 | 0.89 |
| 4 | 0.99 | 0.97 | 0.89 |
| 5 | 1.00 | 1.02 | 0.91 |
| 6 | 1.01 | 1.02 | 1.04 |
| 7 | 1.01 | 1.08 | 1.28 |
| 8 | 1.01 | 1.08 | 1.43 |
| 9 | 1.03 | 1.08 | - |
| 10 | 1.04 | 1.08 | - |

| | Radionuclide | | |
|---|---|---|---|
| | $^{40}K$ | $^{137}Cs$ | $^{210}Po$ |
| No. of determinations | 10 | 10 | 8 |
| Minimum | 0.96 | 0.86 | 0.74 |
| Maximum | 1.04 | 1.08 | 1.43 |
| Mean | 1.00 | 1.00 | 0.99 |
| Median | 1.01 | 1.02 | 0.90 |
| Standard deviation | 0.03 | 0.08 | 0.24 |
| Coeff.of variation (%) | 0.03 | 0.08 | 0.24 |

*= x/X (individual/mean values): initially expressed in this manner to assure confidentiality of results.

TABLE 2. Results for $^{90}Sr$ in tuna fish sample IAEA-352
(Bq kg $^{-1}$ dry weight, reference date : 1 January 1989).

| Lab. code No. | Method code | $^{90}Sr$ |
|---|---|---|
| 7 | B | 2.0 ± 1.5* |
| 17 | B | <0.014 |
| 41 | B | 0.2 ± 0.4 |
| 42 | B | 0.5 ± 0.1 |
| 45 | B | 1.8 ± 0.9* |
| 53 | B | 0.03 ± 0.02 |
| 54 | B | 0.17 ± 0.08 |
| 59 | B | <1.5 |

* Result rejected by the test for outliers

| | |
|---|---|
| Number of reported lab. means | 6 |
| Number of accepted lab. means | 4 |
| Range of accepted lab. means | 0.03-0.5 |
| Median | 0.19 |

TABLE 3. Results for $^{40}K$, $^{134}Cs$ and $^{137}Cs$ in tuna fish sample IAEA-352
(Bq $kg^{-1}$ dry weight, reference date : 1 January 1989).

| Lab. code | Method code | $^{40}K$ | Method code | $^{134}Cs$ | $^{137}Cs$ |
|---|---|---|---|---|---|
| 1 | G1 | 432 ± 9 | G1 | - | 3.0 ± 1.3 |
| 2 | G1 | 410 ± 4 | G1 | - | 2.4 ± 0.4 |
| 3 | G1 | 300 ± 29 | G1 | N.D | - |
| 4 | G1 | 394 ± 20 | G1 | <0.5±0.25 | 2.5 ± 0.3 |
| 6 | G1 | 376 ± 19 | G1 | - | 2.6 ± 0.2 |
| 7 | G1 | 410 ± 22 | G2 | - | 8 ± 4* |
| 8 | G1 | 371 ± 20 | G1 | - | 2.9 ± 0.6 |
| 9 | G1 | 389 ± 19 | G1 | - | 3.1 ± 0.8 |
| 10 | - | - | B | - | 2.8 ± 0.7 |
| 11 | G1 | 518 ± 93* | G1 | - | <5.2 |
| 12 | G1 | 339 ± 12 | G1 | - | 2.3 ± 0.3 |
| 13 | G1 | 425 ± 15 | G1 | - | 3.2 ± 0.5 |
| 14 | G1 | 376 ± 30 | G1 | <2.7 | 2.9 ± 1.4 |
| 15 | G1 | 310 ± 7 | G1 | - | 2.1 ± 0.2 |
| 16 | G1 | 556 ± 17* | G1 | <2.10 | 2.9 ± 0.4 |
| 17 | G1 | 360 ± 18 | G1 | - | 2.5 ± 0.2 |
| 18 | G1 | 401 ± 12 | G1 | - | 2.4 ± 0.5 |
| 19 | G1 | 271 ± 46* | G1 | - | 1.8 ± 0.6* |
| 20 | G1 | 396 ± 3 | G1 | 1.4 ± 0.2 | 2.6 ± 0.1 |
| 21 | G1 | 459 ± 32 | G1 | - | 2.8 ± 0.4 |
| 22 | G1 | 405 ± 40 | G1 | - | 2.5 ± 0.9 |
| 23 | G1 | 390 ± 25 | G1 | - | 3.0 ± 0.3 |
| 24 | G1 | 440 ± 70 | G1 | - | 4.8 ± 1.5* |
| 25 | G1 | 341 ± 25 | G1 | - | 1.9 ± 0.8 |
| 26 | G1 | 409 ± 10 | G1 | <0.15 | 2.5 ± 0.3 |
| 27 | G | 365 ± 25 | G1 | - | 3.3 ± 0.7 |
| 28 | G1 | 379 ± 16 | G1 | - | 2.5 ± 0.3 |
| 29 | G1 | 369 ± 18 | G1 | - | 3.0 ± 0.6 |
| 30 | G1 | 391 ± 27 | G1 | - | 2.0 ± 1.2 |
| 31 | G1 | 1056 ± 81* | G1 | - | 5.0 ± 3.3* |
| 32 | G1 | 300 ± 20 | G1 | - | <2 |
| 33 | G1 | 386 ± 17 | G1 | - | 2.5 ± 0.3 |
| 34 | G1 | 451 ± 20 | G1 | - | 3.5 ± 1.1 |
| 35 | V | 982 ± 85* | G1 | - | - |
| 36 | G1 | 415 ± 30 | G1 | - | 2.7 ± 0.3 |
| 37 | G1 | 388 ± 35 | G1 | - | 2.6 ± 0.3 |
| 38 | G1 | 322 ± 28 | G1 | - | 2.1 ± 0.2 |
| 39 | G1 | 423 ± 17 | G1 | - | 3.0 ± 0.2 |
| 40 | G1 | 400 ± 15 | G1 | - | 2.7 ± 0.5 |
| 42 | G1 | 468 ± 95 | G1 | - | 3.9 ± 3.0* |
| 43 | G1 | 388 ± 14 | G1 | <0.6 | 2.2 ± 0.2 |
| 44 | - | - | G1 | - | B.G. level |
| 45 | G1 | 429 ± 30 | G1 | - | 3.0 ± 0.5 |

TABLE 3 (Contd.)

| Lab. code | Method code | $^{40}K$ | Method code | $^{134}Cs$ | $^{137}Cs$ |
|---|---|---|---|---|---|
| 46 | G1 | 371 ± 35 | G1 | - | <5.9 |
| 47 | G1 | 453 ± 86 | G1 | - | <5 |
| 48 | G1 | 395 ± 24 | G1 | - | 3.3 ± 0.4 |
| 50 | G1 | 430 ± 25 | G1 | - | 2.7 ± 0.5 |
| 51 | G1 | 415 ± 7 | G1 | - | 3.5 ± 0.6 |
| 52 | G1 | 394 ± 32 | G1 | <2.2 | 2.8 ± 1.1 |
| 53 | - | - | G1 | - | 2.1 ± 0.2 |
| 54 | G1 | 347 ± 72 | G1 | - | 2.1 ± 1 |
| 55 | G1 | 443 ± 50 | G1 | <2.2 | 2.8 ± 0.8 |
| 56 | G1 | 535 ± 40* | G1 | - | 5.1 ± 1.3* |
| 57 | G1 | 470 ± 65 | G1 | - | 7.5 ± 4.0* |
| 58 | G1 | 334 ± 17 | G1 | 3.5 ± 0.6 | 4 ± 0.7* |
| 59 | G1 | 360 ± 40 | G1 | - | 2.6 ± 1.1 |
| 60 | G1 | 370 ± 10 | G1 | <2.4 | 2.8 ± 0.3 |
| 61 | G1 | 381 ± 10 | G1 | - | 2.6 ± 0.2 |
| 62 | G1 | 584 ± 19* | G1 | - | 2.5 ± 0.3 |
| 63 | - | - | G1 | - | 1.6 ± 0.7* |

* Result rejected by the test for outliers

| | $^{40}K$ | $^{137}Cs$ |
|---|---|---|
| No. of reported lab. means | 56 | 53 |
| No. of accepted lab. means | 49 | 44 |
| Range of accept.lab. means | 300-470 | 1.9-3.5 |
| Median | 391 | 2.7 |
| Confidence interval ($\alpha$=0.05) | 379-405 | 2.5-2.8 |

TABLE 4. Results for the transuranic elements, $^{238}Pu$, $^{239+240}Pu$ and $^{241}Am$ in tuna fish sample IAEA-352 (Bq $kg^{-1}$ dry weight, reference date : 1 January 1989).

| Lab. code | Method code | $^{239+240}Pu$ | $^{241}Am$ |
|---|---|---|---|
| 5 | A2 | <0.0013 | <0.004 |
| 10 | A2 | <0.01 | - |
| 17 | A2 | <0.005 | <0.005 |
| 19 | A2 | - | <0.05 |
| 36 | A2 | <0.001 | <0.002 |
| 45 | A2 | 0.078±0.018 | 0.028±0.007 |
| 53 | A2 | $(0.0\pm0.5)10^{-3}$ | - |
| 55 | G1 | - | <2.2 |
| 61 | A2 | ≤0.041 | ≤0.031 |

Table 5. Results for $^{210}Pb$ and $^{210}Po$ in tuna fish sample IAEA-352 (Bq $kg^{-1}$ dry weight).

| | $^{210}Pb$ | | | $^{210}Po$ | | |
|---|---|---|---|---|---|---|
| Lab. code | Method code | Reference date | Concentration | Method code | Reference date | Concentration |
| 1 | - | - | - | A2 | 3 Aug 89 | 1.08 ± 0.10 |
| 8 | - | - | - | A2 | 16 Oct 89 | 0.95 ± 0.05 |
| 9 | - | - | - | A2 | 23 Sep 89 | 0.28 ± 0.01* |
| 10 | B | 1 Jan 89 | 0.6 ± 0.3 | A2 | 11 Oct 89 | 1.1 ± 0.2 |
| 11 | - | - | - | A2 | 1 Jan 89 | 11.7 ± 4.83 |
| 12 | - | - | - | A2 | 4 Sep 89 | 1.30 ± 0.15 |
| 13 | - | - | - | A2 | 21 Dec 89 | 0.83 ± 0.13 |
| 15 | A($^{210}Po$) | 1 Jan 89 | 0.52 | A2 | 20 Jun 90 | 0.47* |
| 17 | - | - | - | A2 | 15 Jan 90 | 0.95 |
| 19 | B | 1 Jan 89 | 1.0 ± 0.5 | A2 | 1 Jan 89 | 3.9 ± 2.0 |
| 21 | - | - | - | A2 | 1 Jan 89 | 0.88 ± 0.20 |
| 23 | - | - | - | A2 | 15 Oct 89 | 0.67 ± 0.21 |
| 26 | G1 | 1 Jan 89 | 0.9 ± 0.7 | - | - | - |
| 28 | - | - | - | A2 | 12 Sep 89 | 1.07 ± 0.07 |
| 32 | - | - | - | A2 | 12 Oct 89 | 0.99 ± 0.08 |
| 33 | A($^{210}Po$) | 1 Jan 89 | 2.2 ± 1.0* | A2 | 4 Oct 89 | 1.23 ± 0.06 |
| 34 | B | 1 Jan 89 | 16.5 ± 4.6* | A2 | 1 Jan 89 | 5.8 ± 1.1 |
| 35 | B | 1 Jan 89 | <0.05 | A2 | 30 Dec 89 | 0.025 ± 0.004* |
| 36 | A($^{210}Po$) | 1 Jan 89 | 0.36 ± 0.13 | A2 | 25 Apr 89 | 1.4 ± 0.2 |
| 37 | G1 | 1 Jan 89 | <4.8 | - | - | - |
| 38 | - | - | - | A2 | 1-25 Dec 89 | 1.7 ± 0.2* |
| 40 | - | - | - | A2 | 5 Jan 90 | 0.76 ± 0.05 |
| 44 | A($^{210}Po$) | 1 Jan 89 | 12.2 ± 1.4* | A2 | 1 Jan 89 | 12.5± 1.1 |
| 45 | - | - | - | A2 | 1 Dec 89 | 0.84 ± 0.25 |
| 49 | - | - | - | A2 | 14 Nov 89 | 3.7 ± 0.4* |
| 50 | G1 | 1 Jan 89 | 12.6 ± 3.8* | - | - | - |
| 53 | - | - | - | A2 | 27 Oct 89 | 0.7 ± 0.2 |
| 56 | - | - | - | A2 | 1 Jan 89 | 1.9 ± 0.5 |

* Result rejected by the test for outliers

| | $^{210}Pb$ | $^{210}Po$ |
|---|---|---|
| No. of reported lab. means | 9 | 25 |
| No. of accepted lab. means | 5 | 14 |
| Range of accepted lab. means | 0.36-1.0 | see text |
| Median | 0.6 | - |
| Confidence interval ($\alpha$=0.05) | 0.36-1.0 | - |

TABLE 6. Results for the remainder of the less frequently reported radionuclides in tuna fish sample IAEA-352 (Bq $kg^{-1}$ dry weight, reference date : 1 January 1989).

| Isotope | Lab. code No. | Activity concentration |
|---|---|---|
| $^{106}Ru$ | 43 | <8 |
| $^{110m}Ag$ | 43 | <3 |
| | 55 | <4.7 |
| $^{125}Sb$ | 43 | <1 |
| $^{208}Tl$ | 3 | 5.3 ± 1.0 |
| $^{212}Pb$ | 3 | 3.1 ± 0.7 |
| $^{226}Ra$ | 3 | 4 ± 2 |
| | 26 | 0.7 ± 0.3 |
| | 28 | 0.10± 0.02 |
| | 38 | <6 |
| | 43 | <1 |
| | 44 | 1.8 ± 0.4 |
| $^{228}Ra$ | 26 | 1.0 ± 0.5 |
| | 38 | <2 |
| | 43 | <2 |
| $^{228}Th$ | 26 | 0.5 ± 0.3 |
| | 28 | 0.13± 0.07 |
| $^{230}Th$ | 28 | <0.03 |
| $^{232}Th$ | 28 | <0.02 |
| $^{234}U$ | 28 | 0.09± 0.03 |
| $^{238}U$ | 25 | 4.8 ± 8.5 |
| | 26 | 2.5 ± 0.8 |
| | 28 | 0.04± 0.02 |
| | 44 | 1.59± 0.03 |
| $^{238}Pu$ | 17 | <0.055 |
| natural U | 27 | <5.7 |

Table 7. Summary of data for radionuclide concentrations in intercomparison tuna fish sample IAEA-352
(Bq $kg^{-1}$, reference date : 1 January 1989)

| Radionuclide | Range of accepted values | Median or accepted value | Confidence interval ($\alpha$=0.05) |
|---|---|---|---|
| Potassium-40 | 300-470 | 391 | 379-405 |
| Caesium-137 | 1.9-3.5 | 2.7 | 2.5-2.8 |
| Lead-210 | 0.36- 1.0 | 0.6 | 0.36- 1.0 |
| Polonium-210 | - | 2.2 | 1.7-2.7 |
| (Strontium-90) | - | 0.2* | 0.17-0.5 |

Activities are expressed on dry weight basis (constant weight at 80°C).

* This value is given as information value only.

ANNEX

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