Report on Intercomparison A-12
of the Determination of Radionuclides
in Animal Bone

by

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1. Introduction

It is widely recognized that radionuclides contained in food are responsible for the major part of the radiation dose which the human population has received through the development of atomic energy for military purposes. Some of them, as strontium-89 and -90 or naturally occurring radium-226 and -228, follow calcium into bone and are retained there for long periods. Their expanded radiation may affect the bone and bone-marrow cells. Leukaemia and bone cancer are sometimes considered as a consequence of ingestion of fission products.

Many medical and biological laboratories are obliged to determine radionuclides in bone and have to check the accuracy of their results. To meet their needs, the IAEA's Analytical Quality Control Service organized already in 1973 and 1975 intercomparisons of the determination of fission products and natural radionuclides in calcinated animal bone\(^{(1,2)}\). The intercomparison reported had the additional aim of establishing the radionuclides concentration in a large batch of animal bone material for certification purposes.

2. Scope of the intercomparison

The participants were requested to determine the contents of \(^{137}\text{Cs}\), \(^{239}\text{Pu}\), \(^{226}\text{Ra}\) and \(^{90}\text{Sr}\) in the material which they received. In total, 32 laboratories from 19 countries submitted their results.

The evaluation was based on 240 individual determinations (88 laboratory means) of 4 radionuclides. The number of laboratory means per element varied from 16 to 29, however, most of the results for \(^{137}\text{Cs}\) and \(^{239}\text{Pu}\) were reported as "less than" and could not be used for statistical evaluation.
3. Description of the material

A batch of approximately 50 kg of a commercial beef marrow bone powder, which is defatted beef bone dried, sterilized and crushed (grain size below 125 μm) was additionally homogenized at the Agency's Laboratory by mixing in a rotating plastic drum for 70 hours. Finally, portions of about 80 g of this material were distributed into plastic bottles.

In order to assure a long-term conservation of the material, it was resterilized in the sealed bottles by gamma-ray irradiation (³⁰Co). The dose was approximately 2.5 Megarads.

The homogeneity was checked by determining the total concentration of strontium by flame atomic absorption analysis in several sub-samples taken from one bottle and comparing the results with those for sub-samples taken from various bottles chosen at random.

By applying F and t tests it was found that the results did not differ significantly and that this material could be considered homogeneous (at least for the sample weight ≥ 0.2 g).

The water content of the air-dried material as determined by drying at 105°C to a constant weight was found to be 1.95%. As, however, the moisture content may vary with changes in the ambient humidity and temperature, it was recommended that the water content of this material be always determined in a separate sub-sample (not taken for analysis) by drying for 20 - 24 hours at 105°C.

All results were to be reported in a dry-weight basis.
4. Results

4.1 Preparation of data

The participants were requested to make at least three, preferably
six separate determinations of each radionuclide and to report the
results of all determinations as net values, i.e. after correcting
for the blanks. Some laboratories, however, sent in the results of
only one or two determinations.

If for one or more radionuclides a laboratory submitted results
obtained by two or more different analytical procedures, the results
were entered as two or more separate sets, each bearing the same la-
boratory code no. with addition of different capital letters, e.g.
7A, 7B, etc.

The computer programme in its present form accepts a maximum of
6 individual results for a given radionuclide from one laboratory. If
the number of reported results obtained by the same analytical procedure
was larger, only the six results chosen at random were included, the
others were ignored.

The results supplied in the form "less than" were tabulated only
as additional information values but not used for statistical evaluation.

Results described as doubtful by the laboratory itself were not
included.

All data were edited, punched on cards, and processed by a special
computer programme. The results were printed in the form of tables and
plotted in the diagrams.

The activity of the radionuclides was expressed as pCi/kg for $^{137}\text{Cs}$
and $^{239}\text{Pu}$, and as pCi/g for $^{226}\text{Ra}$ and $^{90}\text{Sr}$. 
4.2 Statistical evaluation procedure

A new statistical procedure was used for the evaluation of the data in this intercomparison run. It was shown in the report on the last two intercomparisons\(^{(3,4)}\) that the results followed a non-parametric distribution rather than a normal one and that the median and its confidence interval were closer to the input values (true values) than were the arithmetic mean and its confidence interval calculated on the basis of a normal distribution.

The new evaluation procedure including the test for elimination of outlying data is based on the non-parametric distribution.

It is commonly known that the median is insensitive to the presence of outliers in a set of data, however, when the number of data is relatively small and all outliers are on one side, the confidence interval of the median may be significantly deformed and expanded in the direction of outlying results. Therefore, every set of data must be tested and outliers rejected.

The main stages of the applied statistical procedure were as follows:

1. Laboratory means are calculated on the basis of the reported individual determinations.

2. All laboratory means for one radionuclide were treated as a set of data points and arranged by their ascending values (see tables 6 to 9).

3. The set of data was tested for outlying results using the procedure proposed by Veglia\(^{(5)}\) which is valid for every continuously distributed set of data:

   - the data points most distant from the mean of the set were tested sequentially one after the other;
- for every tested point an h-value was calculated:

\[ h = \left| x_j - x_{n-1} \right| (S_{n-1})^{-1} \left( \frac{n}{n-1} \right)^{1/2} \]

where: 
- \( x_j \) - value of the point to be tested
- \( x_{n-1} \) - arithmetic mean of the set without \( x_j \)
- \( S_{n-1} \) - standard deviation of the set without \( x_j \)
- \( n \) - total number of the data points in the set

- if the h-value was found to be larger than 3.162, then \( x_j \)
  was rejected as an outlier at the significance level of 0.05

4. The overall median was calculated in the usual way and then its
   confidence limits were found in the table given by Remington
   and Schork (6).

5. For comparison, the arithmetic mean and its confidence limits
   (assuming a normal distribution of data) and the mode (see
   sec. 4.4) were also calculated.

6. The distribution of the results for each radionuclide was plotted
   as a function of local density of the data (see sec. 4.4).

4.3 Description of tables

The results of the reported intercomparison after computer processing
are presented in three groups of tables:

- Tables 1 to 5 provide general information of the intercomparison;
- Tables 6 to 9 give information on reported data of radionuclides
  to be determined;
- Tables 10 to 12 provide a summary of the results of the evaluation.
The meaning of the terms used in the tables is as follows:

**Tables 1 to 5**

**Method Code No.** The main features of the analytical methods used by individual laboratories are shown in the form of code numbers. The code numbers appearing before the point refer to sample pretreatment methods such as dissolution, separation and/or preconcentration, the key to which is given in Table 1. The use of two digits before the point means that a combination of two different pretreatment methods was applied, e.g., acid digestion and solvent extraction.

The code number appearing after the point refers to the method used for the quantitative determination of an element/radionuclide. The first digit after the point characterizes the type of method, e.g. neutron activation analysis, atomic absorption spectroscopy, or spectrometry of the daughter radionuclide. The second digit gives more exact information about the analytical procedure used, e.g. neutron activation with radiochemical separation, flameless atomic absorption, or β-spectrometry of the daughter radionuclide with a scintillation detector.

If in the method code only one digit after the point is used, e.g.: 1, this code no. refers to all analytical procedures indicated by the two digits code no. in which the first digit is the same, e.g.: 10, 11, 12, etc.

**Method Abbreviation** The combination of capital letters corresponding to the first letters of the name of the analytical method. Each method abbreviation refers to the first digits after the point in the method code.

**Frequency of the Application of Pretreatment Methods** The relative number of results, which were obtained by a single procedure using the pretreatment method indicated by "Method Code No." (figures before the point), calculated as percent of all results reported for a given element including "<"-results. Because sometimes the combination of more than one pretreatment method was used, the sum of the frequencies for one element/radionuclide may exceed 100%. 
Frequency of the Application of Analytical Methods: The relative number of results, which were obtained by the analytical method indicated by "Method Code No." (figure after the point), calculated as percent of all results reported for a given element including "<"-results.

Two different types of frequencies are listed in Table 4: frequencies of exactly specified methods (two digits code no.) and frequencies of the group of methods (one digit code no.). The frequencies of the second type were calculated as the sum of the frequencies of all methods of the group concerned.

Laboratory Mean: The arithmetic mean computed from all individual results supplied by a given laboratory. An asterisk next to a laboratory mean denotes that this mean was classified as an outlier and was not taken into account when computing the overall mean.

Outlier: Laboratory mean classified as an outlying value in the set of all laboratory means obtained for the element/radioisotope concerned (see sec. 4.2).

"<"-Result: Result reported by a laboratory as "less than". If a laboratory supplied some different "<"-results for the element/radioisotope then only one, viz. the highest, was accepted.

Total Number of Laboratory Means: The total number of all laboratory means and "<"-results obtained for all elements/radioisotopes which were to be determined in the intercomparison run.

Total Number of Outliers: The sum of outliers obtained in the intercomparison run for all elements/radioisotopes which were to be determined. Its relative number was calculated as percent of the "Total Number of Laboratory Means".

Total Number of "<"-Results: The sum of all "<"-results reported in this intercomparison. Its relative value is calculated as the percentage of total number of laboratory means.
Number of Laboratory Means, Outliers, and "<"-Results by the Method:
Numbers corresponding to above defined "total numbers" but concern the
results obtained by one analytical method indicated in the table by
code no. and abbreviation. Their relative values were calculated as
percentage of "Number of Laboratory Means by the Method".

Tables 6 to 9

Method Code No.: )
Laboratory Mean: ) See description of Tables 1 - 5
"<"-Result : )

Input Value: Known concentration of an element/radionuclide put in and
homogeneously distributed in the bulk of material to be analysed. (Not
applicable in the reported intercomparison).

Units: Units in which the concentration of an element/radionuclide to
be determined is expressed.

Laboratory Code No.: Each laboratory is represented by a code number,
which remains unchanged throughout the tables. These numbers, however,
do not correspond to the sequence of laboratories in the list of partici-
pants given at the end of this report, so that anonymity is secured.
When a laboratory used more than one analytical procedure for deter-
mination of the same element/radionuclide, then the results were distin-
guished as different set of data by different capital letters added to
the code (see sec. 4.1).

Number of Determinations: The number of individual determinations per-
fomed by the laboratory using the same analytical procedure ("<"-results
excluded).

Laboratory Standard Deviation: The absolute and relative laboratory
standard deviations were calculated in the usual way only if at least
three results were reported by a laboratory.
Estimated Laboratory Error: The participants' own estimate of relative standard deviation expressed in percent. The figure before the point refers to the error due to counting statistics (only for radiometric methods), and that after the point to the error due to a complete analytical procedure.

Deviation from Input Value: Not applicable in the reported intercomparison.

F-Value: Not applicable in the reported intercomparison.

Tables 10 to 12

Method Code No.: )
Method Abbreviation: ) See description of Tables 1 to 5.
Laboratory Mean: )
Outliers: )

Unit: ) See description of Tables 6 to 9.
Input Value: )

Number of Reported Results: Laboratory Means: Number of laboratory means (excluding "<"-results) reported for an element/radioisotope.

Number of Reported Results: Individual Determinations: Number of individual determinations (excluding "<"-results) reported by all laboratories for an element/radioisotope.

Number of Accepted Results: Laboratory Means: Number of laboratory means (excluding "<"-results and outliers) reported for an element/radioisotope.

Number of Accepted Results: Individual Determinations: Number of individual determinations (excluding "<"-results and outliers) reported by all laboratories for an element/radioisotope.
Total Range of Laboratory Means: The range between the lowest and the highest of the "Reported Results".

Range of Accepted Laboratory Means: The range between the lowest and the highest of the "Accepted Results".

Percentage of Outlying Laboratories: Relative number of laboratories which have supplied outlying results given in percent of the total number of laboratories which have reported results.

Percentage of Outliers: Percentage of "Outlying Laboratories"

Percentage of Laboratories with the R-Value > 1: Not applicable in the reported intercomparison.

Percentage of Laboratories with no R-Value: Not applicable in the reported intercomparison.

Overall Mean: Non-weighted mean of all accepted "Laboratory Means", after elimination of outliers.

Confidence Limits of the Overall Mean: Is calculated from the relation:

\[ \bar{X} - t_{0.05} (S.E.) \leq \mu \leq \bar{X} + t_{0.05} (S.E.) \]

where:
- \( \mu \) - consensus value ("true value")
- \( \bar{X} \) - overall mean
- \( t_{0.05} \) - Student's factor for the significance level of 0.05
- \( S.E. \) - standard error \( S.E. = (S.D.)n^{-\frac{1}{2}} \)
- \( S.D. \) - standard deviation of laboratory means

If for an element/radionuclide the calculated lower confidence limit was found to be negative, then it was taken to be equal to zero.

Relative Uncertainty of the Mean: The differences between the overall mean and its confidence limits expressed as percent of this overall mean.
Overall Median: The median value of all "accepted" laboratory means (after elimination of outliers). It was found in the following way: the laboratory means were arranged in order of increasing values and when their number \( n \) was odd, \( n = 2k-1 \), the \( k \)-th result was accepted as the median; when \( n \) was even, \( n = 2k \), the median was calculated as the arithmetic mean of the \( k \)-th and the \((k+1)\)-th results.

Confidence Limits of the Overall Median: Values of the data points (Overall means) which were found in the table given by Remington and Schork\(^6\) for the significance level of 0.05.

Relative Uncertainty of the Overall Median: The differences between the overall median and its confidence limits expressed as percent of the value of this median. Notice that the confidence interval can be distributed asymmetrically around the median.

Overall Mode: The concentration value corresponding to the maximum local density of laboratory means (see sec. 4.4)

Relative Deviation from the Input Value: Not applicable in the reported intercomparison.

Mean Value by the Method: The arithmetic mean of results (laboratory means) obtained by the method appointed by the code no.

Median Value by the Method: The median of results (laboratory means) obtained by the method appointed by the code no.
4.4 Description of diagrams

A graphical presentation of the results of this intercomparison is made in Figures 1 - 4. The figures present the distribution of results as plots of their local density against their values. The local density of data was calculated as shown below.

All accepted results (laboratory means) \( X_i \) were treated as a set of data points and arranged by ascending values. The distances between every point \( X_i \) and its two neighbouring points \( X_{i-1} \) and \( X_{i+1} \), expressed in units of concentration, are dependent on the local density of points in the surroundings of \( X_i \) and may be used as a measure of this density. However, \( X_i \) is a random variable which, for a limited number of data, may form accidental small clusters of points with a very high local density which do not result from the distribution of the total set. These anomalies were eliminated by a correction of the original data. The corrected value \( \bar{X}_i \) of every original experimental point \( X_i \) was calculated as an arithmetic mean of its value and the values of two neighbouring points:

\[
\bar{X}_i = \frac{X_{i-1} + X_i + X_{i+1}}{3}
\]

but the value of the first point and that of the last were not changed:

\[
\bar{X}_1 = X_1 \quad \text{and} \quad \bar{X}_n = X_n
\]

The operation was repeated once and then the corrected values \( X_i \) were found.

The above procedure eliminates local accidental small agglomerations containing two or three points without deforming the distribution in a larger interval. The mean distance \( a_k \) from a corrected data point \( X_i \) to two neighbouring points \( X_{i-1} \) and \( X_{i+1} \) was calculated from the formula:

\[
a_k = \frac{X_{i+1} - X_{i-1}}{2}
\]

\( k = 2 \ldots (n-1) \)
From the extreme points \(X_1\) and \(X_n\) only the one-side distance may be calculated because the position of points, which could appear as more distant from the centre of the set if the number of data was increased, is not known. So, the mean distance for these points is arbitrarily approximated by:

\[ a_1 = X_2 - X_1 \quad \text{and} \quad a_n = X_n - X_{n-2} \]

The values of \(a_i\) are inversely proportional to the data density and it is more convenient to use their reciprocals:

\[ \tilde{\phi} (X_i) = \frac{1}{a_i} \]

The function \(\tilde{\phi} (X_i)\) expresses the dependence of the local density of data on their values \(X_i\), i.e. the number of points per one concentration unit in the immediate vicinity of a given point. The accidental small maxima of this function were removed or minimized by a smoothing procedure, same as that used for the correction of data points. The new values \(\tilde{\phi}_k\) were calculated for every point as follows:

\[ \tilde{\phi}_i = \frac{\tilde{\phi}_{i-1} + \tilde{\phi}_i + \tilde{\phi}_{i+1}}{3} \]

but

\[ \tilde{\phi}_1 = \tilde{\phi}_1 \quad \text{and} \quad \tilde{\phi}_n = \tilde{\phi}_n \]

The absolute values of \(\tilde{\phi} (X_i)\) depend not only on the dispersion of results but also on their number and they can be compared only with other values calculated for the same set of data. The normalization of \(\tilde{\phi} (X_i)\) assigning to its maximum a value 100 gives the new function \(\phi (X_i)\), identical in the shape with the previous one, which allows a comparison of the distribution of different sets independent of the number of data contained in them.

The relative local density functions \(\phi (X_i)\) of all data determined in the intercomparison plotted against the corrected values of results are shown in Figures 1–4 as the continuous lines with small circles. The values of original results (laboratory means) are indicated directly above the abscissa. The values of the overall means and medians accompanied
by their confidence limits and values of the modes are indicated in
the plots by vertical arrows. The values of outliers are listed on
both sides of the plots by horizontal arrows indicating the direction
of their position (Fig's 3 and 4).

For a multimodal distribution (Fig. 4) the function \( \phi (x_i) \)
should be processed further by calculation for every point \( x_i \) its
average value for this point and for four, six, eight, etc. neigh-
bouring points. This operation can be repeated until a unimodal distri-
bution function will be achieved. In this intercomparison the procedure
was stopped at the stage of six points (Fig. 4 - the line without circles)
and therefore the second maximum is still visible.

5. Discussion

In the determination of radionuclides in the reported intercom-
parison a very large variety of pretreatment and determination pro-
cedures was used (Tables 3 and 4). In general, it may be stated that
\(^{137}\text{Cs} \) was determined predominantly by direct \( \gamma \)-spectrometry and \(^{239}\text{Pu} \)
by \( \alpha \)-spectrometry after separation and electrodeposition. Radium was
determined either by direct measurement with or without separation or
by determination of radon. \(^{90}\text{Sr} \) was determined most frequently by
measurement of its daughter \(^{90}\text{Y} \).

Tables 6 and 7 show that the activities of \(^{137}\text{Cs} \) (level of pCi/kg)
and of \(^{239}\text{Pu} \) (level of 0.1 pCi/kg) were lower than the detection limits
of the methods used by most of the participating laboratories and their
results were frequently reported as "<"-results ("less than"). The
results of laboratories which were able to determine these radionuclides
are widely dispersed and therefore cannot be used to estimate "consensus
values" (Table 10 and Fig's 1 and 2).

\(^{226}\text{Ra} \) and \(^{90}\text{Sr} \) were present in the samples at the level of pCi/g.
The results for these nuclides (Tables 8 and 9) are of essentially
better quality and could be evaluated according to the criteria used in
previous intercomparisons (3,4). These criteria, after necessary
modification for the determination of radionuclides and for the use of
median as the basic estimator of "consensus value" (see sec. 4.2), are
as follows:

1. The sum of the relative uncertainties (negative and positive
values) of the overall median is not higher than 50% for
an activity level from 1 to 100 pCi/g and not higher than
100% for an activity below 1 pCi/g.

2. Data from at least two different analytical methods are available
for the calculation of the overall median.

3. More than half of all medians obtained by a method and calcu-
lated on the basis of more than one result is enclosed inside
the confidence limits found for the overall median.

4. Not more than 30% of laboratory means were rejected as out-
liers.

5. The overall median was calculated on the basis of at least the
following number of laboratory means:
   a) 5 laboratory means
   b) 3 laboratory means
   c) 2 laboratory means

A result (overall median) can be classified as recommended value
with a satisfactory degree of confidence (Class A) when it fulfills the
first four criteria and criterion 5a.

A result can be classified as recommended value with an acceptable
degree of confidence (Class B) when it fulfills at least criteria 1, 2,
3 and 5b or criteria 1, 4 and 5a.

A result can be classified as uncertified information value (Class
C) when it fulfills at least criteria 4 and 5c and its confidence inter-
val is reasonable for the given concentration level.
All data necessary for a classification of results of the intercomparison according to the above mentioned criteria are listed in Table 12.

On this basis both results for radium-226 and strontium-90 can be classified as recommended values with a satisfactory degree of confidence, Class A (Table 13).

6. Conclusion

Cesium-137 and plutonium-239, which were present at a level of pCi/kg in the investigated animal bone material could not be determined with a necessary degree of confidence even for information values.

The quality of determinations of radium-226 and strontium-90 may be accepted as satisfactory, however, some laboratories, particularly those whose results were rejected as outliers, are advised to check carefully their measurement procedures.

The comparison of the overall means (Tables 10 and 11) with those obtained in the previous intercomparison A-10(2) in 1975 shows that, in the present intercomparison, the confidence intervals of the means are two times larger, however, the content of radionuclides is now lower by one order of magnitude for radium, and by two orders of magnitude for strontium. In this situation it may be assumed that the quality of the present results is significantly better.

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The authors will appreciate all remarks and comments from analysts using the reference material IAEA Animal Bone A-12 which is certified on the basis of the reported Intercomparison Run.
7. References


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<th>Method Code No.</th>
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<td>not communicated or not clearly indicated</td>
</tr>
<tr>
<td>0.</td>
<td>no pretreatment</td>
</tr>
<tr>
<td>1.</td>
<td>separation - general statement without details</td>
</tr>
<tr>
<td>2.</td>
<td>extraction</td>
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<td>3.</td>
<td>ion exchange</td>
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<tr>
<td>6.</td>
<td>complex treatment combining more than two of separation and/or purification methods, e.g., extraction, coprecipitation and ion exchange</td>
</tr>
<tr>
<td>7.</td>
<td>electrodeposition</td>
</tr>
<tr>
<td>8.</td>
<td>removing of radon gas</td>
</tr>
<tr>
<td>9.</td>
<td>adsorption</td>
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Table 2

Code No. and Abbreviations of Methods Used for Quantitative Determination of Radionuclides in Intercomparison A-12

A. General Classification (first figure after the point in Code No.)

<table>
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<th>Code No.</th>
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<th>Method</th>
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<td>.</td>
<td></td>
<td>not communicated or not clearly indicated</td>
</tr>
<tr>
<td>.1</td>
<td>S</td>
<td>(\alpha), (\beta), or (\gamma)-counting or spectrometry - general statement without details</td>
</tr>
<tr>
<td>.2</td>
<td>DS</td>
<td>direct measurement without separation</td>
</tr>
<tr>
<td>.3</td>
<td>SS</td>
<td>measurement after separation</td>
</tr>
<tr>
<td>.4</td>
<td>SD</td>
<td>counting or spectrometry of daughter radionuclide - general statement</td>
</tr>
<tr>
<td>.5</td>
<td>DSD</td>
<td>direct measurement of daughter radionuclide without separation</td>
</tr>
<tr>
<td>.6</td>
<td>SSD</td>
<td>measurement of daughter radionuclide after separation</td>
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</table>

B. Detailed Classification (second figure after the point in Code No.)

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</tr>
<tr>
<td>.01</td>
<td>(\gamma)-spectrometry or counting without additional information</td>
</tr>
<tr>
<td>.02</td>
<td>(\gamma)-spectrometry - semiconductor detectors</td>
</tr>
<tr>
<td>.03</td>
<td>(\gamma)-spectrometry - other types of detectors</td>
</tr>
<tr>
<td>.04</td>
<td>(\beta)-counting - without additional information</td>
</tr>
<tr>
<td>.05</td>
<td>(\beta)-spectrometry - solid or liquid scintillation detectors</td>
</tr>
<tr>
<td>.06</td>
<td>(\beta)-counting - other types of detectors</td>
</tr>
<tr>
<td>.07</td>
<td>(\alpha)-counting - without additional information</td>
</tr>
<tr>
<td>.08</td>
<td>(\alpha)-counting - semiconductor detectors</td>
</tr>
<tr>
<td>.09</td>
<td>(\alpha)-counting - scintillation and pulse ionization chambers</td>
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TABLE No. 3

FREQUENCY OF THE APPLICATION OF PRETREATMENT
METHODS USED IN INTERCOMPARISON FOR A-12, 1981

(Not including radiocellulical separation after
neutron activation).

% OF USE IN THE RUN FOR ELEMENT

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<th>RA-226</th>
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*METHOD CODE NUMBERS AS IN TABLE 2*
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<tr>
<td>Percentage of Outliers by the Method</td>
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<td>12.2</td>
</tr>
<tr>
<td>Number of Results Given as &quot;&lt;&quot; by the Method</td>
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<td>4</td>
</tr>
<tr>
<td>Percentage of Results Given as &quot;&lt;&quot; by the Method</td>
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<td>50.0</td>
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(METHOD CODE NUMBERS AS IN TABLE 2)
## TABLE NO. 6

**RESULTS OF INTERCOMPARISON FOR CS-137 IN A-12, 1981**

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<th>LAB. CODE</th>
<th>METH. CODE</th>
<th>NO. OF FIRM.</th>
<th>LAB. PLAN</th>
<th>LAB. ANS</th>
<th>REL %</th>
<th>ESTIM. LAB.</th>
<th>DEVIATION FROM INPUT VALUE</th>
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<td>0.00</td>
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<td>19.333</td>
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<td>7.01</td>
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</tr>
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<td>15</td>
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<td>2</td>
<td>20.117</td>
<td>4.163</td>
<td>20.145</td>
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*Note:*
TABLE NO. 7

RESULTS OF INTERCOMPARISON FOR Pu-239 IN A-12, 1981

<table>
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<th>UNITS</th>
<th>PCI/kg</th>
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<th>MEAN</th>
<th>STD. DEVIATION</th>
<th>REL. FCL</th>
<th>ESTIM. DEVIATION</th>
<th>R FROM INPUT VALUE</th>
<th>ERR. %</th>
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<td>2</td>
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<th>LAB. MEAN</th>
<th>LAB. STANDARD DEVI.</th>
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TABLE NO. 9

RESULTS OF INTERCOMPARIISON FOR SR-90 IN A-12, 10F1
### TABLE NO. 10

**SUMMARY OF THE RESULTS OF THE INTERCOMPARISON A-12, 1981**

<table>
<thead>
<tr>
<th>ELEMENTS DETERMINED</th>
<th>CS-137</th>
<th>DU-239</th>
<th>RA-226</th>
<th>SB-90</th>
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<tr>
<td>UNIT</td>
<td>PCI/KG</td>
<td>PCI/KG</td>
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<td>•</td>
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</tr>
</tbody>
</table>

| NUMBER OF LABORATORY MEANS | 9      | 6      | 18     | 29    |
| RESULTS INDIVIDUAL DETERMINATIONS | 22 | 24 | 54 | 113 |

| NUMBER OF ACCEPTED MEANS | 9      | 6      | 14     | 20    |
| RESULTS INDIVIDUAL DETERMINATIONS | 22 | 24 | 41 | 107 |

**TOTAL RANGE OF LABORATORY MEANS**

- CS-137: 0.017 - 1.967
- DU-239: 0.005 - 17.333
- RA-226: 0.017 - 0.250
- SB-90: 0.467 - 9.545

**RANGE OF ACCEPTED LABORATORY MEANS**

- CS-137: 0.010 - 226.000
- DU-239: 0.005 - 17.333
- RA-226: 0.017 - 0.250
- SB-90: 0.467 - 2.533

**PERCENTAGE OF CUTTING LABORATORIES**

- CS-137: 0%
- DU-239: 0%
- RA-226: 22%
- SB-90: 3%

**PERCENTAGE OF LABORATORIES WITH THE T VALUE > 1**

- CS-137: •
- DU-239: •
- RA-226: •
- SB-90: •

**OVERALL MEAN OF ACCEPTED LABORATORY MEANS**

- CS-137: 84.272
- DU-239: 5.714
- RA-226: 0.137
- SB-90: 1.473

**CONFIDENCE LIMITS OF THE OVERALL MEAN AT 0.05 SIGN. LEVEL**

- CS-137: 5.824 - 164.920
- DU-239: 0.090 - 14.825
- RA-226: 0.105 - 0.169
- SB-90: 1.305 - 1.641

**OVERALL MEDIAN OF ACCEPTED LABORATORY MEANS**

- CS-137: 31.000
- DU-239: 0.169
- RA-226: 0.137
- SB-90: 1.473

**CONFIDENCE LIMITS OF THE OVERALL MEDIAN AT 0.05 SIGN. LEVEL**

- CS-137: 0.310 - 236.000
- DU-239: 0.005 - 17.333
- RA-226: 0.120 - 0.182
- SB-90: 1.247 - 1.600

**OVERALL MEDIAN OF ACCEPTED LABORATORY MEANS**

- CS-137: 12.027
- DU-239: 0.077
- RA-226: 0.135
- SB-90: 1.541

**RELATIVE DEVIATION % FROM THE MEAN**

- CS-137: •
- DU-239: •
- RA-226: •
- SB-90: •

**INPUT VALUE**

- CS-137: •
- DU-239: •
- RA-226: •
- SB-90: •
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<tr>
<th>ELEMENT OF TAE OF UNIT</th>
<th>OVERALL CONFIDENCE LIMITS (0.05)</th>
<th>MEAN RELATIVE UNCERTAINTY (%)</th>
<th>ANALYTICAL METHODS USED</th>
<th>MEAN VALUE</th>
<th>NUMBER OF ACCEPTED RESULTS</th>
<th>NUMBER OF OUTLIERS</th>
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<tr>
<td>CS-127</td>
<td>8.51 - 164.92 ± 95</td>
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<td>55.15</td>
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<td>DU-215</td>
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<td>6.56</td>
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<tr>
<td>RA-226</td>
<td>0.14 - 0.17 ± 23</td>
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<td>0.02</td>
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<td>*2 DS</td>
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<td>*3 SS</td>
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<td>SF-50</td>
<td>1.47 - 1.64 ± 11</td>
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## Table 12

**Comparison of the Overall Medians with the Median Values Obtained by Various Analytical Methods in Intercomparison A-12, 1981**

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<th>CONFIDENCE LIMITS (0.05)</th>
<th>RELATIVE UNCERTAINTY (%)</th>
<th>ANALYTICAL METHODS USED</th>
<th>CODE NO.</th>
<th>MEDIAN VALUE</th>
<th>NUMBER OF ACCEPTED RESULTS</th>
<th>NUMBER OF OUTLIERS</th>
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<td>31.00</td>
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### Notes:
- The table compares overall median values with median values obtained by various analytical methods.
- Methods are identified by their codes and abbreviations.
- Results are given with confidence limits and relative uncertainties.
- The number of accepted results and outliers is provided for each method.
Table 13

Certified Content of Radionuclides in IAEA Animal Bone A-12

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<th>Confidence limits (0.05) pCi/g</th>
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<td>$^{226}\text{Ra}$</td>
<td>0.14</td>
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<tr>
<td>$^{90}\text{Sr}$</td>
<td>1.48</td>
<td>1.25 &amp; 1.60</td>
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FIG. 2
FIG 3