IAEA Intercomparisons in the Frame of the Occupational Radiation Protection Programme

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Abstract. The IAEA safety activities to support the assessment of occupational exposure through a comprehensive set of Safety Guides, Safety Reports and other related documents will soon be completed. Several intercomparison exercises were organized by the IAEA on the determination of radionuclides in human urine samples, whole body counting and external dosimetry. These previous intercomparison exercises revealed significant differences in the approaches, methods and assumptions, and consequently in the results. This underlined the importance of this kind of intercomparison programme as a key element of the international harmonization of quantities and units. The purpose of this paper is to present the current and future IAEA activities in support of assessment of occupational exposure by organizing intercomparison runs.

1. Introduction

Radiation monitoring of workers to assess exposure due to external sources of radiation and intakes of radionuclides is an essential component of any occupational radiation protection programme [1]. Comprehensive international guidance on the use of dose related quantities for radiological protection is provided in several publications. A Safety Guide on Assessment of occupational exposure due to intakes of radionuclides [2] was developed to address the assessment of exposure in the workplace. It is supported by three Safety Reports, namely: Direct methods for measuring radionuclides in the human body [3]; Indirect methods for assessing intakes of radionuclides causing occupational exposure [4] and Assessment of radiation doses from intakes of radionuclides by workers [5]. A Safety Guide on Assessment of occupational exposure to external sources of radiation [6] was also developed to address the assessment of exposure in the workplace. A further IAEA document on Dosimetry services for individual monitoring of occupational exposure [7] is also being developed.

In view of the technical difficulties associated with occupational exposure assessment and in order to promote international harmonization, the IAEA has been assisting its Member States in their provision of appropriate occupational monitoring for protection purposes. It has been organizing international and regional intercomparison in the field of external and internal dosimetry since early 80’s. The principal aims are:

(a) to facilitate the estimation of similarities or dissimilarities in the measurements of radiation protection quantities performed;
(b) to foster exchanges of information and experience relating to the measurement of radiation protection quantities and to methods for estimating derived quantities;
(c) to provide access to resources, which might otherwise not be available to some Member States, for the calibration of radiation protection monitoring devices.

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An IAEA safety related service was launched in 1999 for the harmonization of radiological quantities and units through *Intercomparison of Radiological Measurements for Monitoring Purposes*. The objective of this service is to provide national authorities with a mechanism for the intercomparison of radiological measurements that will ensure that their responsibilities for radiation protection are properly met as far as the assessment of radiation doses to workers and the public is concerned. This paper summarizes the organizational arrangements and the main technical findings for the most recent intercomparison events.

2. **Intercomparison programmes for external dosimetry**

In the mid-80’s there was no detailed rationale for the choice of monitoring quantities. During the first international intercomparison (1988-1992) phantoms for calibrations were not yet standardized, and the appertaining conversion factors from air kerma $K_a$ to the personal dose equivalent $H_p(10)$ were lacking [8-10]. The situation was completely different for the second international intercomparison (1996-1998) [11]. Calibration phantoms and conversion coefficients had been established. A new element in this intercomparison was the examination of the performance of dosimetry systems in radiation fields, which were similar to those encountered in practical routine monitoring.

The first phase focused on the selection of a backscatter phantom for calibration and on, for example, the identification of systematic differences in the quality of dosimetry due to dosemeter type, design, interpretation. A sphere phantom was regarded as impractical for irradiation although, in ICRU Report 43 [12], some preference was given to mounting a personal dosemeter on an ICRU sphere. Instead, a cubic water phantom (dimensions $30\text{cm} \times 30\text{cm} \times 30\text{cm}$) was chosen, later called the “IAEA water phantom”.

Irradiations during phase 1 of the 1988-1992 intercomparison were performed using only photon beams normally incident on the phantom surface. At the beginning of the first phase of the intercomparison, data of the conversion coefficients $H_p(10)/K_a$ for the cube were known to a rather limited extent only. As a first step, corrected data for the ICRU sphere were used. Questions regarding conversion coefficients have meanwhile been answered for most applications. A report of a joint task group of ICRP and ICRU provides monoenergetic data for conversion coefficients; ISO standards state conversion coefficients for numerous reference radiations and describe calibration procedures.

A co-ordinated research project (CRP) was started in 1997 on *Intercomparison for Individual Monitoring of External Exposure to Photon Radiation*, involving more than twenty laboratories from Eastern Europe and the Republics of the former Soviet Union, and focusing on personnel dosimetry services for nuclear power plants. This CRP was part of the activities of the IAEA *Occupational Protection Programme* [11]. The preparatory phase included, in May 1997, a workshop aimed at familiarizing the participants with the new operational quantities. The workshop, attended by all the participants, covered the philosophy underlying the development and adoption of the operational quantities; calibration procedures; the energy of the photon workplace fields and angle distributions; and dosimeter characteristics. The participants were actively involved in the discussions and gave details of their services and dosimeters.
The intercomparison had 23 participating dosimetry services. The purpose of the intercomparison was to examine the performance of the dosimetry systems in radiation fields which were similar to those encountered in practical routine monitoring. These fields included, for a range of doses, mixed normally incident and wide-angle fields of simulated direct source and room scatter radiation for some typical energy distributions and high-energy photons (6-7 MeV) with and without secondary electron equilibrium. Before the irradiations, participants received a questionnaire to be filled in to provide information on their dosimetry system. Sixteen participants used only thermoluminescence (TL) detectors, four participants used only film, and three participants used a film-TL detector combination. The TL materials are LiF:Mg,Ti - LiF-N:Mg,Ti - Li₂B₄O₇, Si - LiF₇, LiF₆ - CaF₂ - Al₂O₃. The films are from different manufacturers.

For every irradiation, the participant was informed of the irradiation date, but no information was provided about the radiation quality or the angle of incidence. As the dosimeters of every participant had to be divided into groups to enable dosimeter irradiation to be carried out at three different institutes, three dosimeters from each group were kept unirradiated for background corrections.

Each group was composed of 4 dosimeters, for irradiations at different radiation qualities and/or different dose levels. In total, 12 results had to be reported by each participant. Participants were requested to report their results on a prepared data-sheet, according to the following instructions:

- all results corrected for background
- dose values given in term of \( H_p(10) \)
- mean energy and angle of incidence to be completed (if the dosimetry system enabled such data to be provided).

Seven participants provided mean energy and angle of incidence, one participant provided mean energy only, and 15 participants did not provide any additional information besides the dose values.

The radiation qualities S-Ir-192, S-Co+W-80 and R-F can be measured quite well by all the participants. But for W-80, R-F+W-300, R-F at low level and R-F without electronic equilibrium, there are, respectively, 3, 2, 5 and 6 outliers. Another question is how many dosimetry systems in this intercomparison fulfil the ICRP requirement, i.e., results for which at most one quotient lies within the trumpet curves. This is answered in Table 1. Almost all of the services satisfied the evaluation criteria on overall accuracy for all fields.

Table I. Relative number of dosimetry systems for which at most one quotient lies between 1/1.5 and 1.5.

<table>
<thead>
<tr>
<th>Dosimetry system</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>TLD</td>
<td>62.5 %</td>
</tr>
<tr>
<td>Film</td>
<td>75 %</td>
</tr>
<tr>
<td>Others</td>
<td>100 %</td>
</tr>
</tbody>
</table>

This co-ordinated research project had the aim to further both these objectives. In particular, this CRP gave participating dosimetry services from IAEA Member States in Eastern Europe the opportunity to assess the recommendation of the IAEA to use the operational quantity personal dose equivalent, \( H_p(10) \), and to evaluate the performance of their dosimetry systems. The intercomparison of systems
was limited to whole body photon dosimeters in this instance, and examined the performance in simulated workplace fields. The use of such fields was to allow the assessment of the dosimetry systems under actual working conditions, at least in part.

A new project was launched by the IAEA in 1999, an Intercomparison for Individual Monitoring of Radiological Measurements for Monitoring Purposes [13]. All participating laboratories were asked to return a filled in questionnaire concerning their dosimetry system. Information about type of detector, measuring quantities and measuring dose and energy range was requested. Only 3 laboratories out of 35 did not reply. Eight participating laboratories used films and 27 participants used thermoluminescence (TL) detectors. The bulk of participating laboratories (23) used personal dose equivalent \( H_p(10) \) as measuring quantity for the routine services. Seven laboratories measured, in addition, personal dose equivalent \( H_p(0.07) \). For the submission of the results, all participating laboratories were asked to report their results in terms of \( H_p(10) \).

Nine dosimeters of each participant’s dosimetry system were irradiated in three different radiation qualities W-80; W-80 + W-200 (mixed quality) and W-300. Only the information about the irradiation date was provided to the participating laboratories. No information about the radiation quality or the angle of incidence was given. The participating laboratories were requested to report their results in term of personal dose equivalent \( H_p(10) \) on a prepared data-sheet and submit it to the IAEA. To enable the participating laboratories to correct the dose values by the transport dose, all unirradiated dosimeters (in most cases 6 dosimeters) were marked. Seven participants provided mean energy and angle of incidence, one participant provided the mean energy only, and 27 participants did not provide any additional information besides the dose values. A number of participating laboratories (9 in total) showed a distinct energy dependence (more laboratories with film systems than with TLD systems). No marked differences were found in the summary results for different radiation qualities. For the quality W-300, a slight underestimate response of 5 \% – 10 \% compared to the other two qualities was found. No significant differences between mixed qualities (W-80 + W-200) and standard qualities (W-80, W-300) were found in the summarized data.

Two different directions of incidences were applied: 0° (reference direction) and WA+/-80° (wide angle irradiation). Some laboratories (5 in total) showed a distinct increase in the response for wide angle irradiation. The average wide angle irradiation shows higher values than irradiation at the reference direction. This over response is in the range 5 \% – 10 \%. In general, no pronounced angular response was found. Some laboratories show a distinct increase in the response for wide-angle irradiations.

Related to the \( H_p(10) \) measurement capabilities all wide angle irradiations were done for two different dose levels: ‘low dose’ - 3 mSv, 5 mSv, 6 mSv and ‘high dose’ - 20 mSv, 30 mSv. It is possible to compare two different dose levels for the same radiation field. Some laboratories (3 in total) showed a distinct difference in the response for different dose levels (at least for one radiation quality). The average difference in the response between ‘low dose’ and ‘high dose’ for all qualities is in most cases in the range -10 \% to +10 \% for the different participating laboratories. Only when outliers were found was this value far out of the mentioned range in some cases.

Of all 315 individual response values, 47 (representing 15\%) are outside the trumpet curve. Of all 35 participating laboratories which reported values, 22 (representing 63\%) had no outlier. Twenty-six participating laboratories (representing 74\%) had no more than 1 outlier and fulfilled the performance
requirement. One laboratory did not report any value within the trumpet curve. One laboratory did not report any value at all. The highest response values are in the range of 10 (overestimation by a factor of 10!). The lowest response values are in the range of 0.02 and below (underestimation by a factor of 50 – 500!!). In conclusion: 74% of all laboratories fulfil the performance requirement. Some laboratories show a significant over/under estimation of the dose value. (Fig.1).

These fields included a dose range from 3 mSv to 30 mSv, normally incident and wide angle fields for different radiation qualities from the ISO wide spectrum series were used. Nearly 80 % of all participating services satisfied the evaluation criteria on overall accuracy for all fields. The laboratories using TL-dosimeters generally reported better results than laboratories using film dosimeters. It is worth mentioning that 7 of the 35 participating laboratories are receiving assistance under the IAEA Model Project on Upgrading Radiation Protection Infrastructure under which occupational exposure is the second milestone to be achieved by the end of this year. The results of these laboratories are considered excellent.

3. Intercomparison programmes for internal dosimetry

Several intercomparisons have already been organized at national or international levels [14-20]. These previous intercomparisons revealed significant differences in the approaches, methods and assumptions, and consequently in the results. In 1996, the IAEA launched a Co-ordinated Research Project (CRP) on Intercomparison and Biokinetic Model Validation of Radionuclide Intake Assessment. [21]. A total of 25 institutes participated. Nine realistic study cases were prepared. The test scenarios designed were based on either real data or artificially generated data. They covered a wide range of exposure scenarios, time and duration of the intake, single and multiple, but not chronic intakes.
Major inconsistencies can be found in the measurements of quantities and in methods related to internal dosimetry and overexposure situations. There is some concern that some participants are using the newer ICRP dose factors with the older biokinetic models. However, the use of the dose factors should be consistent with the choice of the biokinetic models. As a result, the mixed use of different models and dose factors can lead to results which are not scientifically based and also lead to greater inconsistencies, as shown in a few cases. This issue is viewed as a temporary phenomenon because it is expected that computational tools for implementing the more recent biokinetic models will be more readily available in the near future. Interest in other radionuclides than the ones covered in this intercomparison has been expressed, such as those involved in the nuclear fuel cycle, those used in nuclear medicine or biomedical research (e.g., ³²P, ¹³¹I), or those that are naturally occurring (e.g., thorium).

As a result of a CRP activity carried out between 1996-1998 was the Intercalibration of In-Vivo Counting Systems Using An Asian Phantom [22]. The detection of inhaled radionuclides that emit only low-energy photons is a problem of particular concern to many Member States. In addition to the objectives already mentioned for any intercomparison, in this case the project was conducted also to assess differences in counting system calibrations introduced by the use of phantoms having Western vs. Asian stature, to provide a calculational calibration using mathematical techniques for comparison with the phantom measurements and to provide participants with a version of Magnetic Resource Image Photon Phantom (MRIPP) containing each facility's detector/measurement system input files necessary for use with the MRIPP programme. A total of 9 institutions participated. The phantom used in the intercomparison was developed by the Japan Atomic Energy Research Institute (JAERI) in Tokai-mura, Japan to represent a typical Japanese plutonium worker. The radionuclides used were ²³⁸Pu, ²⁴¹Am, natural uranium, uranium with a 3% ²³⁵U enrichment, and natural thorium. Thorium was included because of the widespread exposure to thorium in industry, particularly in the production of gas lantern mantles. A blank lung set was provided for background measurements.

Germanium detector systems achieved reasonable agreement for normalized counting efficiency (counts cm⁻² photon⁻¹). Phoswich detectors report differences of as much as a factor of 4 in normalized efficiency. This may be due to differences in detector placement, and analysis of the poorly resolved phoswich spectra. Differences in the adipose tissue content of the chest wall overlaying the lungs can be reasonably well compensated by the use of the concept of muscle equivalent chest wall thickness (MEQ-CWT).

It has been noted that calibration of in-vivo measurement systems for low energy photon emitters presents a particular challenge because of uncertainties related to accurate assessment of the transmission of photons through overlying tissue, and availability of complex phantoms, and well calibrated sources and solutions of radioactive material. Those participants who had been involved in the previous CRP with the Livermore phantom reported that there was not a great deal of difference in the calibrations they obtained from the two different phantoms. Each of the phantoms has structural deficiencies that must be taken into account in their use.

An intercomparison for Determination of Gamma Emitters in Urine Samples was organized in 1999 involving 33 laboratories from both developed and developing Member States [23]. In 2001 a second intercomparison was organized. This time the target was the Determination of the Quantity Activity of Alpha Emitters in Urine Samples. A total of 31 Member States nominated 36 laboratories to participate [24]. A brief description of both exercises follows.

• Gamma Emitters in Urine Samples

The first step of the process is the collection of a sufficient volume of urine from non-exposed people at Cadarache site, France (90 litres of urine). Then the urine was filtered and a non-contamination check run by direct $\gamma$ spectrometry on several 300 ml samples, which is the routine method commonly used in the laboratory. The urine pool was then divided into 3 parts named A, B and C. The volume was determined by weight after measurement of the density of urine.

Part A was the blank sample, divided up into aliquots of approximately 500 ml, which constitutes the A samples. Part B was spiked with 3 different gamma radionuclides: $^{54}$Mn (9.57 Bq L$^{-1}$); $^{137}$Cs (4.76 Bq L$^{-1}$); and $^{60}$Co (6.75 Bq L$^{-1}$). Part C was spiked with the same radionuclides but at a different level of activity: $^{54}$Mn (4.78 Bq L$^{-1}$); $^{137}$Cs(2.86 Bq L$^{-1}$ ) and $^{60}$Co(4.05 Bq L$^{-1}$). Parts B and C were divided up into aliquots of approximately 500 ml. The gamma standard solutions used for spiking come from the “Laboratoire Etalon d’Activité – CERCA – FRAMATOME”.

Activity checks were carried out comparing the result and its associated uncertainty with the target value and its associated uncertainty. Spiking is carried out by the addition of different volumes of standard solutions with the stable corresponding carrier in the B and C pools. A final activity check was carried out after spiking. Distribution in volumes of approximately 500 ml occurs under continuous stirring. Two French laboratories tested the samples and confirmed the spike activities before dispatch. Each reference value was given at the reference date with the uncertainty referring to the different sample preparation steps.

• Alpha Emitters in Urine Samples

To prepare the samples, 250 litres of urine from workers at the Marcoule site, France were collected. These workers are systematically monitored for assessing potential intakes of radionuclides. The workers that were selected had never been involved in an actinide-related contamination incident and they did not have a disease that could have affected the urinary excretion of natural metabolites.

The urine mixture contained traces of thiomersal (organic mercury salt), used as a bactericidal preserving agent in order to prevent microbial multiplication. The organic mercury that was present in the samples may induce an error in three sample results from laboratories that use ICPMS, i.e. it may create isobaric interference. The urine mixture was also checked for contamination by natural or artificial radionuclides at levels that would interfere with the measurements.

Another sample preparation phase involves checking the activity and the isotopic purity of the spike solutions. To do this, 10 aliquots of each radionuclide were coprecipitated with a microprecipitate of lanthanum fluoride. Finally, the spiked samples were analysed using the routine lab procedures at Marcoule.

The samples to be analysed contained a small quantity of natural uranium that corresponded to physiological excretion levels for people living in the region of Marcoule who are not exposed to ionizing radiation. This natural uranium activity was quantified as being very close to usual detection limits at a value of 0.2 mBq per sample. This quantity was sufficiently low as to be negligible and, consequently, the urine mixture was qualified to receive the spikes and be dispatched to the participating laboratories.
Sample A did not receive a spike and therefore did not contain any added radionuclides. Sample B was spiked with $^{239}$Pu (12.7 mBq) and $^{241}$Am (11.2 mBq). The total alpha activity of 23.9 mBq was easy to measure. It was about 10 times the laboratories’ normal detection limit or Minimum Detectable Amount (MDA). Sample C was spiked with a standardized solution of natural uranium. The sample therefore contained: 21.5 mBq of $^{238}$U, 0.99 mBq of $^{235}$U, 20.7 mBq of $^{234}$U.

5. Findings and results

- Gamma Emitters in Urine Samples

A total of 33 labs reported results out of the 40 originally nominated to participate. As far as detector the majority of laboratories used germanium detectors. Only one laboratory used a sodium iodine detector. A total of 31 laboratories made a direct measurement of the samples provided. The additional 2 laboratories made the measurements after drying the samples. The volumes of samples used for the measurement varied from 20 to 500 ml. Another laboratory made the measurement on 1 litre. For efficiency calibration, most of the laboratories used mixed gamma standards whose energy range generally goes from 60 KeV ($^{241}$Am) to 1836 KeV ($^{88}$Y). In the majority of the cases, these solutions contained the radionuclides to be determined and quantified. A total of five laboratories used two to four radionuclides. One laboratory used europium. One laboratory used thorium and uranium. Another laboratory used a gel of $^{60}$Co and $^{166m}$Hm and two other laboratories used standards from IAEA (soil standards). Another two laboratories first detected the nature of the radionuclides and then quantified them with the assistance of a special calibration with corresponding standards.

The calibration with europium, used by only one laboratory, always gives lower results, which is rather curious. The fact that europium may induce summit peaks could lead to an underestimation of detector efficiency and an overestimation of the results. Surprisingly, what we observe is the opposite of this. Calibration with specific standards (those to be detected), often gives good results. The calibration with $^{60}$Co and $^{166m}$Hm is perfect except for $^{40}$K. It could be explained by the fact that the holmium gamma spectrum goes from 40 KeV to only 950 KeV. There is no point of calibration at a higher energy than the energy of $^{60}$Co (1330 KeV). Calibration with uranium and thorium gives excellent results particularly for the high energy of potassium. The spectrum of thorium goes from 40 KeV to 2615 KeV, with 2 peaks at a high energy.

The result distribution consists of a synthesis of the results of the statistically selected laboratories with the response in the intervals –10% to +10% and –15% to +15%. The distribution of the results in the third interval: -25% to +50%, which is recommended by ISO and ANSI, is also calculated (Table II).
Table II. Distribution of results per sample/radionuclides and grouped in three different response intervals.

<table>
<thead>
<tr>
<th>Radionuclide</th>
<th>% of labs. Within -10% to +10%</th>
<th>% of labs. Within -15% to +15%</th>
<th>% of labs. Within -25% to +50%</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Sample B</td>
<td>Sample C</td>
<td>Sample B</td>
</tr>
<tr>
<td>$^{137}$Cs</td>
<td>80%</td>
<td>64%</td>
<td>80%</td>
</tr>
<tr>
<td>$^{54}$Mn</td>
<td>71%</td>
<td>69%</td>
<td>90%</td>
</tr>
<tr>
<td>$^{60}$Co</td>
<td>86%</td>
<td>72%</td>
<td>90%</td>
</tr>
<tr>
<td>$^{40}$K</td>
<td>55%</td>
<td>66%</td>
<td></td>
</tr>
</tbody>
</table>

The poor results for the measurement of natural potassium confirm the difficulties of calibration and measurement at a high energy: difficulties of calibration due to low detector efficiency and difficulties of measurement when the $\gamma$ emission rate is low, which is the case for $^{40}$K (10.7% of emission).

As far as the spiked radionuclides are concerned, better results are given for the higher activities as expected. The activity level of sample B is higher than the level of sample C. The results of sample B are better than those of sample C (except for Cs in the interval –15% to +15%). The differences between the results of the two samples decrease when the interval is enlarged, a better homogeneity of the results appears for the interval –15% to +15 % for the samples B and C. All laboratories are included in the response interval –25% to +50% (except for Potassium).

Analysis of the results confirmed that the choice of good standards for calibration remains a key point for the metrology of gamma emitters. The result distribution consists of a synthesis of the results of the statistically selected laboratories in the intervals –15% to +15%. On average, 86% of the laboratories are less than 15% from the target value, whatever the nature and the activity of the radionuclides. All laboratories are included in the response interval –25% to +50% (except for potassium). Therefore, we could conclude that occupational monitoring assessments in the case of an intake of gamma emitters are highly satisfactory.

- **Alpha Emitters in Urine Samples**

Of the 36 labs originally nominated to participate, a total of 26 laboratories reported results. A technical questionnaire was prepared and submitted to the participants to collect information on the techniques used.

There are considerable differences in the way laboratories concentrate the radionuclide to be measured. About 10% of laboratories do not follow a radionuclide concentration phase. The type of tracer chosen by some laboratories probably caused difficulties in interpreting the alpha spectrometry results. For example, laboratories that used natural uranium or $^{238}$U (more or less associated with $^{234}$U) or $^{233}$U must have run into major difficulties in deconvoluting the spectra for sample C. About 18% of the laboratories involved in the intercomparison did not provide us with any information. No relevant
new information was found related to the tracers used, the source preparation and the measurement techniques.

Sample A did not receive a spike and therefore did not contain any added radionuclides. However, it did contain traces of natural uranium. Many laboratories detected radionuclides that were not present in the sample. In these cases, a revision of the procedure at the laboratory was recommended.

Sample B did not receive uranium as spike. However, it did contain traces of natural uranium. It is interesting to analyse the isotopic ratio $^{234}\text{U}$ to $^{238}\text{U}$ for the labs that found uranium in both samples A and B. For some labs, the isotopic ratio is very different from one sample to the other. As a reminder, the urine samples A and B came from the same mixture without any uranium spike. Therefore, those differences for one lab and between labs can only be explained by laboratory contamination during chemical steps or during alpha measurements or by erroneous interpretation of alpha spectrometry. In this case, a revision of the procedure at the laboratory was recommended.

In sample C some laboratories described an isotopic composition quite different from that universally recognized for natural uranium. For sample C, the isotopic ratio ranges from 0.87 to 1.28. These fluctuations compared to the theoretical ratio of 0.96 (the natural uranium isotopic ratio) are closer than for samples A and B. We conclude that the uncertainty regarding this ratio decreases as the activity to measure decreases. But it is necessary to be prudent in interpretation of alpha spectrometry for dosimetric purposes mainly when the activity measured is very low. The verification measurements carried out at Marcoule confirm the calibration certificate values. As with samples A and B, some laboratories had quantified radionuclides that were not present in the sample. For some laboratories, the activities measured were considerably below the Detection Limit (DL) or the MDA.

For most laboratories, the $^{235}\text{U}$ activity was very close to their detection limits. Only nine laboratories provided results that could be used statistically. Only one laboratory was excluded. The values provided are above the target value. Deconvolution of the alpha spectra is probably the explanation for these results. It is surprising that some laboratories which carry out activity measurements to analyse uranium do not identify or quantify the $^{234}\text{U}$, which contributes just as much to internal dosimetry as $^{238}\text{U}$.

The exercise was very useful for the participating laboratories. On average, 90% of the laboratories are within –25% to 50% of the target values, which is recommended by ISO and ANSI standards. This trend is applicable whatever the nature and the activity of the radionuclides. Table III summarizes the results. The results evidence that occupational monitoring assessment in the case of an intake of alpha emitters is satisfactory through the measurement of human urine. The performance of the laboratories participating in this exercise is very good.
Table III. Distribution of the results per sample and radionuclide.

<table>
<thead>
<tr>
<th>Radionuclides</th>
<th>Sample B</th>
<th></th>
<th></th>
<th>Sample C</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Number of outliers</td>
<td>% of labs. Within –25 to 50%</td>
<td>Number of outliers</td>
<td>% of labs. Within –25 to 50%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>239Pu</td>
<td>1</td>
<td>90%</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>241Am</td>
<td>1</td>
<td>87%</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>234U</td>
<td>-</td>
<td>-</td>
<td>1</td>
<td>100%</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>235U</td>
<td>-</td>
<td>-</td>
<td>1</td>
<td>100%</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>238U</td>
<td>-</td>
<td>-</td>
<td>2</td>
<td>91%</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

7. Current and future activities

An international intercomparison on Measurements of the quantity “activity” of radionuclides in simulated human organs started in January 2001 and is expected to last until mid-2004. A total 38 Member States and 70 laboratories are participating. Four different types of phantoms are used: a BOMAB, JAERI, Thyroid and a newly developed Knee phantom for bone dosimetry. When the latest intercomparison has been completed, the IAEA intends to start an international intercomparison of methods used to derive estimates of intake from measured activities in simulated human organs, determination of the quantity activity of alpha-emitting radionuclides in human faeces and in human breath.

An international intercomparison on Measurements of the quantity $Hp(10)$ in mixed neutron-gamma field started in April 2003 and is expected to last until mid-2005. A total 32 Member States are participating. Two phases are included, a ‘type test’ irradiation for a few radiation qualities and simulated workplace fields. The first phase is already finished and the results will be available soon.

At the same time, the IAEA is involved in a joint venture project with the European Dosimetry Group (EURADOS) to assess the technical capabilities of all types of electronic personal dosimeters and other new developments available on the market and under development. A joint intercomparison is being organized and then we will be in a position to assess the performance and to recommend to Member States the proper devices.

Several regional intercomparisons have been held or are currently ongoing, namely:
• In **East Asia** region a third phase of the Hp(10) intercomparison is finishing in mid 2004, in the frame of the Regional Co-ordination Agreement (RCA).

• In **Latin America** region a second phase of the Hp(10) intercomparison is also finishing during 2004. Three new exercises are now being launched for measurement of activity in urine samples, thyroid phantom and dose calculation in internal dosimetry and thus in the frame of Regional Coordination Agreement (ARCAL).

• A new intercomparison is starting in the **West Asia** region for measuring Hp(10). In each case the intercomparison focuses on regional needs and provides an excellent forum for problem solving with the service providers and for information exchange and training.

8. **Conclusions**

Comprehensive guidance and recommendations are given through development of safety related documents. Direct support for application of these guidelines and recommendations to meet Member States’ needs is provided through expert advice; national, regional and interregional training courses; fellowships; and/or provision of equipment and supplies.

Several intercomparison events were organized covering all aspects involved in dose assessment due to external sources of radiation and intake of radionuclides. Some of them revealed significant differences in the approaches, methods and assumptions, and consequently in the results. The participants in such intercomparison exercises recognized the importance of these activities as evidence of good dosimetric performance for their quality management systems and related laboratory accreditation processes. They strongly stressed that the IAEA should continue acting as a focal point for fostering information exchange and training in all forms, focused on measurement and dosimetry techniques. The IAEA should take an active role in the establishment of a network of laboratories to be involved in internal dosimetry for radiation protection purposes. This networking would provide for better information exchange during any such project.

9. **References**


