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SURVEY OF INTERNAL DOSE MONITORING PROGRAMMES FOR RADIATION WORKERS

WP 1 in the project OMINEX- (**O**ptimisation of **M**onitoring for **In**ternal **Ex**posure)

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Keywords monitoring, radiation workers, internal doses, fission and activation products, actinides

Abstract

Monitoring of the workforce in the nuclear industries is carried out primarily in order to demonstrate compliance with European Union Basic Safety Standards for the protection of the health of workers against the dangers arising from ionizing radiation. There is however no compilation of information on internal dose monitoring programmes currently in use in the EU countries. Surveys were therefore carried out in which organisations were asked to provide information on the design of their internal dose monitoring programmes and on the costs of these programmes. Information was requested from both EU countries and Associated States. Databases for storage and reporting of all information gained were constructed, and results from the surveys compiled. This work was carried out within the EC 5th Framework Programme project OMINEX (**O**ptimisation of **M**onitoring for **In**ternal **Ex**posure), which aims to provide advice and guidance on designing and implementing internal dose monitoring programmes in the workplace in such a way that best use is made of available resources, while minimising costs. This paper gives the results of the survey of the design of internal dose monitoring programmes. A major conclusion is that, particularly for the actinides, a wide range of approaches to monitoring are in use. There is no consensus on primary monitoring methods. All organisations monitor workers to assess individual doses for entry onto a legal dose record. Cumulative distributions show that most organisations aim to assess doses down to 0.1 – 0.5 mSv.

*T Rahola, G Etherington, P Bérard , B Le Guen, C Hurtgen , M Muikku, S Pusa. Survey of international dose monitoring programmes for radiation workers. WP 1 in the project OMINEX- (**O**ptimisation of **M**onitoring for **In**ternal **Ex**posure). STUK-A203. Helsinki 2004. 49 + 35 s.* Englanninkielinen.

Avainsanat monitorointi, säteilytyöntekijät, sisäinen annos, fissio- ja aktivointituotteet, aktiniidit

Tiivistelmä

Säteilytyöntekijöitä monitoroidaan ensisijaisesti, jotta voitaisiin varmistaa että Euroopan unionin turvallisuusvaatimukset työntekijöiden säteilysuojelusta täyttyvät. Mitään yhteenvetoa EU maissa käytettävistä monitorointiohjelmista ei ole. Siksi tehtiin kyselyjä käytössä olevista ohjelmista ja niiden kustannuksista. Työ tehtiin Euroopan komission viidenteen puiteohjelmaan sisältyvässä projektissa OMINEX (Optimisation of Monitoring for Internal Exposure) jonka tarkoituksena on antaa neuvoja ja ohjausta sisäisten annosten monitorointiohjelmien luomisessa ja implementoimisessa työpaikoilla siten, että olemassa olevat resurssit käytetään mahdollisimman tehokkaasti samalla kuluja minimoiden. Raportissa esitellään kyselytutkimuksen tulokset. Vastaukset on tallennettu tietokantoihin. Selvitettiin minkälaisia sisäisten annosten arviointiin tähtääviä monitorointiohjelmia on käytössä. Päällimmäinen johtopäätös on, että erityisesti aktiniidien kohdalla tavat monitoroida vaihtelevat paljon. Mitään yhtenäistä näkemystä siitä miten annoksia pitäisi arvioida ei löytynyt. Kaikki organisaatiot ilmoittavat monitoroivansa työntekijöitä henkilökohtaisten annosten arvioimiseksi ja annosten rekisteröimiseksi. Kumulatiiviset jakautumat osoittavat , että useimmat organisaatiot pyrkivät arvioimaan niinkin pieniä annoksia kuin 0,1-0,5 mSv.

Contents

1 Introduction

OMINEX (**O**ptimisation of **M**onitoring for **In**ternal **Ex**posure) is a 3-year project funded by the European Commission within its 5th Framework Programme (1). The aim of OMINEX is to provide advice and guidance on designing and implementing internal dose monitoring programmes in the workplace in such a way that best use is made of available resources, while minimising costs. The project is being carried out by a consortium of research/advisory organisations [NRPB (UK), IPSN (France), STUK (Finland), SCK-CEN (Belgium), CEA (France)] and nuclear industry organisations [EdF (France), TVONS (Finland)]. The UK nuclear industry is also providing a significant input.

Monitoring of the workforce in the nuclear industries is carried out primarily in order to demonstrate compliance with European Union Basic Safety Standards for the protection of the health of workers against the dangers arising from ionizing radiation. There is however no compilation of information on internal dose monitoring programmes currently in use in the EU countries. Such information can be collected either by requesting information directly from organisations about their monitoring regimes or by searching the open literature. Up-to-date information can only be obtained by carrying out a survey, however, and so this was the chosen method. The drawback is that participation in such a survey is of course voluntary, and so it is not always easy to obtain responses. The statistical information that can be found in the open literature on methods used for monitoring of internal contamination of workers is very scarce. Trends in worldwide average annual doses to workers were published by UNSCEAR in 1988 as also the trends in worldwide average annual number of monitored workers. No separate trends for internal surveillance was published. Figures 1 and 2 illustrate the above mentioned trends. It can be noted that the average effective doses are decreasing while the numbers of monitored workers are increasing from the period 1975-1979 to 1990-1994.

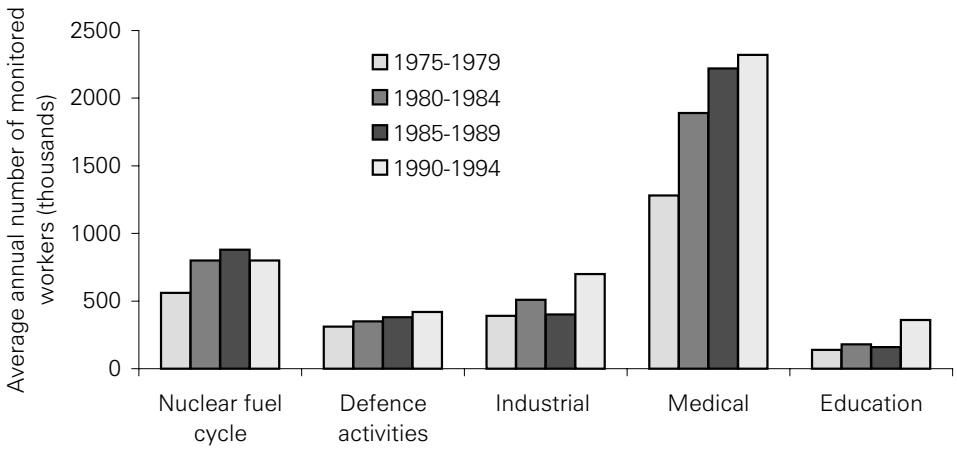

Fig 1. Trends in worldwide average annual number of monitored workers (UNSCEAR)

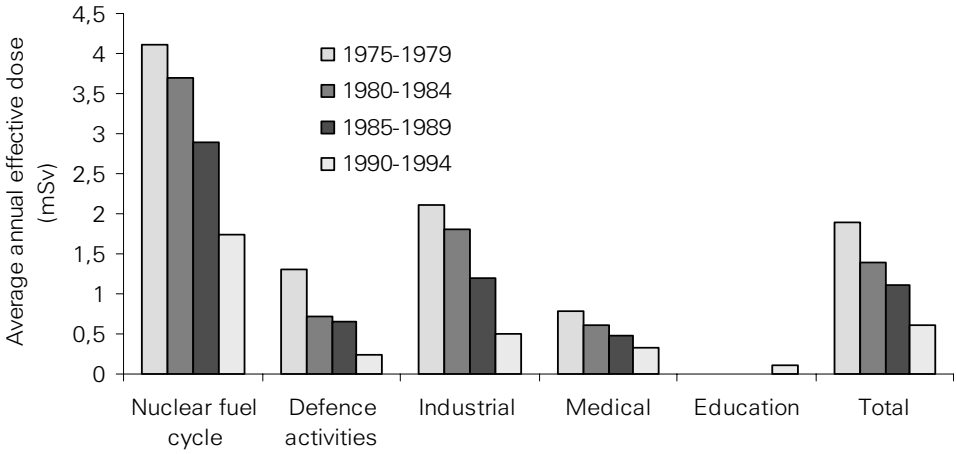

Fig 2. Trends in worldwide average annual doses to workers (UNSCEAR)

2 Methods

Two questionnaires were designed; the first was a 1-page "pre-questionnaire", while the second was a comprehensive questionnaire on the design of internal dose monitoring programmes. Radiation safety experts in industrial organisations were consulted regarding the content of both questionnaires. Both questionnaires are in the form of formatted MS Word™ documents. The monitoring programme questionnaire covers direct (*in vivo*) and indirect (bioassay and air sampling) monitoring for internal exposure to fission and activation products (FAP), and to compounds of uranium, thorium, plutonium, americium and other actinides and to mixed oxide (MOX) material. Separate sections cover routine and special monitoring. Six types of operations were identified. The complete questionnaire is quite long (55 A4 pages), and so to encourage Dosimetry Services to respond, only those parts of the questionnaire that are relevant to the work of a particular organisation was sent out. Identifying appropriate people to whom the questionnaires should be sent was straightforward for countries represented in the consortium. For other countries, however, it was often more difficult and especially more time consuming than expected. Suitable contacts were identified in the relevant organisations in each country; in general, these were radiation protection professionals with direct responsibility for internal dose monitoring in the organisation.

Before sending out the complete questionnaire, the one-page "pre-questionnaire" was distributed in order to establish the radionuclides monitored and monitoring methods used. This information was then used to select those sections of the main questionnaire to be sent to the organisation. Some persons sending in responses did not answer each question unambiguously, which made the analysis difficult in some cases.

Databases were constructed for storage and reporting of all of the information gathered. Responses to the monitoring programme questionnaire were collected in a a Microsoft Access 97™ data base. Data was recorded in 39 tables arranged according to the subtitles in the questionnaire starting with general aspects such as type of operation, number of workers, monitoring practice and purposes of monitoring followed by data on methods of monitoring of fission and activation products and actinides. Data on chemical forms, calibration methods, minimum detectable amounts (MDA), monitoring frequencies and investigation levels were included. Lastly, information on dose assessment methods and dose statistics was recorded. All results from the survey will be kept anonymous.

The monitoring programme questionnaire was sent to every country within the European Union (EU) where internal dose monitoring is carried out, and also to the "Associated States" of the EU. In addition, the questionnaire was sent to organisations in countries with large nuclear power programmes (eg the USA) who might be able to provide useful information.

3 Results

General

Responses to the monitoring programme "pre-questionnaire" were received from 58 organisations, from EU countries (29), from Associated States (10) and from countries outside of the EU/Associated States (19). Table 1 gives the information on number of types of operations and types of monitoring and table 2 types of operation and radionuclides monitored at each type of organisation. About half of the organisations represented nuclear power plants and one third research organisations. Most used is direct *in vivo* monitoring closely followed by bioassay monitoring mostly in research institutes. At nuclear power plants fission and activation products (FAP) are most frequently monitored. In research institutes the need to monitor uranium, plutonium, thorium and americium is clearly seen.

Responses to the monitoring programme questionnaire were received from 29 organisations (50 per cent of those answering the "pre-questionnaire"), 22 from EU countries and 7 from Associated States but none from countries outside of the EU/Associated States. Four EU countries answered that they have routine monitoring only for external dose assessment and would use foreign expertise for internal monitoring and dose assessment if needed. Table 3a gives general information on the number of organisations responding to the survey (WP 1 questionnaire) and the number of workers in the different organisations in EU States, Associated States and other countries. We were not able to get any response to the questionnaire from seven countries that during personal contact explained that they had no established organisation for internal dose monitoring and dosimetry. service. The lack of response may also have been because we did not approach the right person.

Although this survey is not comprehensive across the EU it does present a representative view. The survey provides a representative coverage of the 6 types of operation identified. Size of organisation ranges from 155,000 workers, down to 70 workers; median slightly less than 1000. Some organisations presented a combined response from a large number of sites. Tables 4a and 4b show the distribution of workers in Categories A and B (categorisation of workers is described in EC Directive 96/29/EURATOM (European Commission, 1996)). In fuel fabrication and reprocessing facilities, all classified workers are in Category A. In tables 4a and 4b the percentage of workers in class A and B are presented for the different types of operation including all countries and separately the EU countries.

Many of the organisations have more than one operation but the workers are not specified according to operations. Table 5 gives the number of workers in class A and B in different countries indicating also the types of operation. In the total number of workers in an organisation the workers are included only once although they in the table might be included in more than one type of operation The real number of workers, for example in decomissioning, is not known because some of the organisations are doing several types of operations and only the total number of workers in the organisation is given. It is also important to note that all organisations answering the questionnaire did not give answers to every question.

All organisations report that they have a well-defined pre-planned arrangement for internal dose monitoring. Workers in category A are reported by 18 organisations. Only one of these does not require medical examinations of their category A workers. About one third of the organisations report that they subcontract certain monitoring to outside organisations. Subcontractors are commercial enterprises, national authorities and research institutes. In Germany by law at least part of the measurements must be performed by independent institutions. To investigate the purposes of monitoring three questions were asked: Is monitoring carried out to assess individual doses for entry onto a legal dose record, is monitoring carried out to monitor engineering practices and standards or is monitoring carried out to reassure individual workers that they are not receiving excessive doses? All three alternatives included questions on the minimum dose that is aimed to be assessed and for which radionuclides this applies. The results are presented in Fig.3.

Table 6 illustrates the information collected on the relative use of direct (*in vivo*) and indirect (bioassay and personal air sampling) monitoring methods. Both direct and indirect methods are used for assessment of individual doses.

All but one organisation give values below 2 mSv. In most organisations monitoring is carried out to assess individual doses for entry onto a legal dose record. Monitoring is also carried out to reassure the workers that they are not receiving excessive doses.

When applicable, whole-body and thyroid counting is used also for special monitoring, complemented by other methods. So far, seven organisations have reported on uranium monitoring. For routine monitoring, both direct methods (ie. whole-body and lung counting) and indirect methods (ie. urine monitoring, faecal monitoring and personal air sampling (PAS)), are used. For special monitoring, whole-body and lung counting as well as urine and faecal analyses are used. PAS monitoring is used for routine monitoring and urine analyses are used for special monitoring.

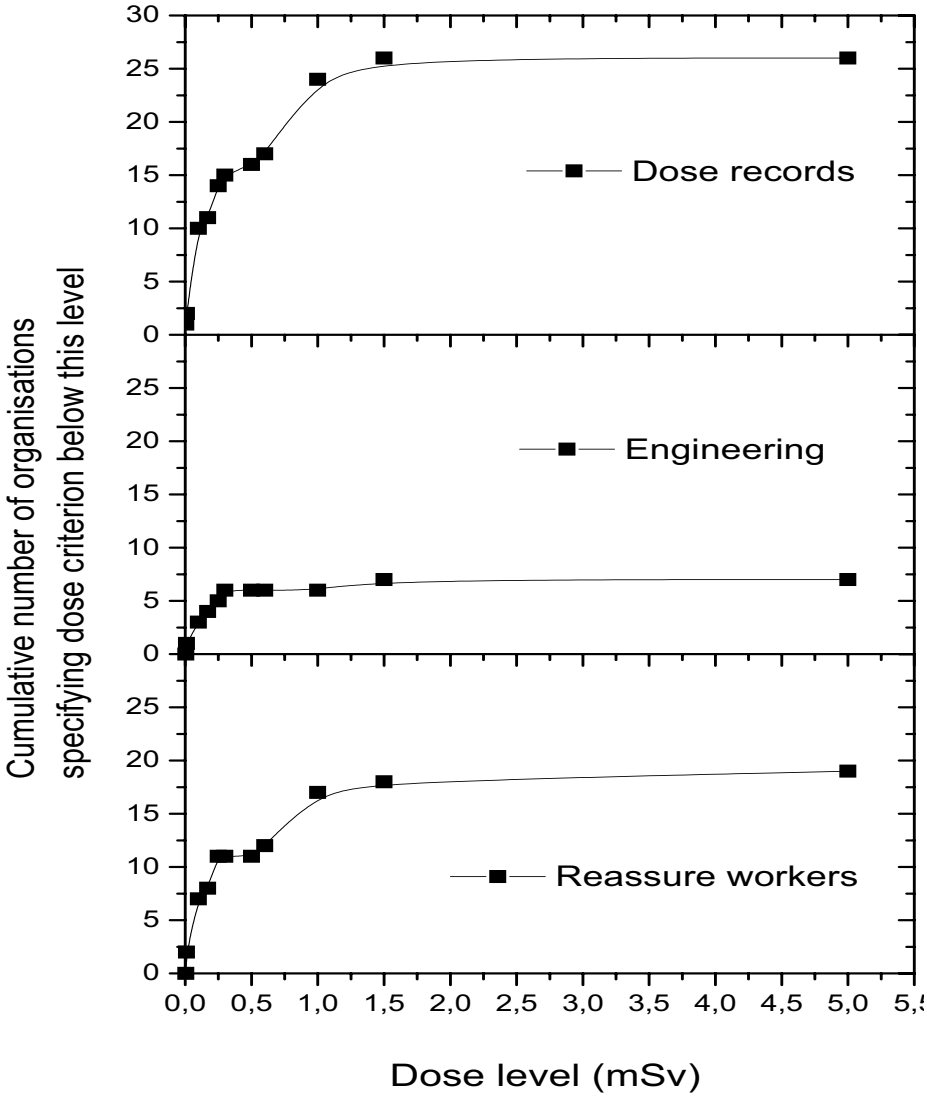

Fig 3. Cumulative number of organisations specifying dose criterion below levels from 0 to 5 mSv.

In table 6 the number of measurements done *in vivo*, *in vitro* and with personal air samplers are given for fission and activation products and for uranium, plutonium and thorium nuclides. Data based on information given both in the pre-questionnaire and the main questionnaire show that at nuclear power plants fission and activation products are mostly monitored with whole-body counting and tritium and/or actinides with bioassay methods.

Routine and special monitoring

Fission and activation products

Routine monitoring is usually carried out to confirm that doses are below a certain level (eg 6 mSv for Category B workers) or to identify unexpected exposures. Special monitoring is performed after an incident, or is triggered for some other reason.

Table 7 presents the chemical form or compound, assumed absorption type and assumed Activity Median Aerodynamic Diameter (AMAD) and the number of organisations reporting each parameter values for ^{60}Co and ^{137}Cs. For ^{60}Co a minority of organisations are using 1 mm rather than 5 mm AMAD and 5 out of 6 organisations assume oxide is Type S. For ^{137}Cs two out of 15 organisations are using 1 mm rather than 5 mm AMAD and 12 out of 15 organisations assume all compounds are Type F.

Table 8 presents the primary monitoring methods for fission and activation products used to determine doses entered onto formal dose records for routine monitoring and table 9 gives the corresponding information for special monitoring . The most commonly monitored fission and activation nuclides are ^{137}Cs, ^{60}Co, ^{131}I, ^{125}I and ^{3}H.

Table 10 shows that 38 per cent of the organisations reporting on ^{60}Co monitoring use whole-body counting and 17 per cent use portal monitoring as screening methods. Only eight organisations reported on follow up monitoring and the most commonly used method then is whole-body counting. It can be assumed that also those who did not report on follow up monitoring would be using the same methods as for routine monitoring. For ^{137}Cs 27 per cent use whole-body counting as screening method and 7 per cent portal monitoring. The method for follow up monitoring seems to be whole-body counting. Only seven organisations answered this question. Apparently plans on how to handle screening after incidents have not been defined. Direct measurement of ^{131}I is the most commonly used screening method (5 out of 10) and the method for follow up monitoring is direct measurement either whole-body counting or direct thyroid measurement. Only four organisations report on follow up methods. For tritium, urine monitoring is the most commonly used screening method (6 out of 10), follow up method is also urine monitoring.

The investigation levels vary from 0.5 to 350 kBq for ^{60}Co with a median of 10 kBq and 1 to 400 kBq for ^{137}Cs with median 100 kBq. For ^{131}I the investigation levels vary from 0.5 to 50 kBq with median 10 kBq and for tritium from 0.1 to 850 kBql^{-1}.

Information was collected on MDAs achieved by *in vivo* and bioassay monitoring. For example, MDAs for *in vivo* measurements of ^{60}Co and ^{137}Cs are mostly below 300 Bq. Figure 4 shows the MDAs and the cumulative number of organisations specifying MDA below a particular level for ^{60}Co, ^{137}Cs and ^{131}I.

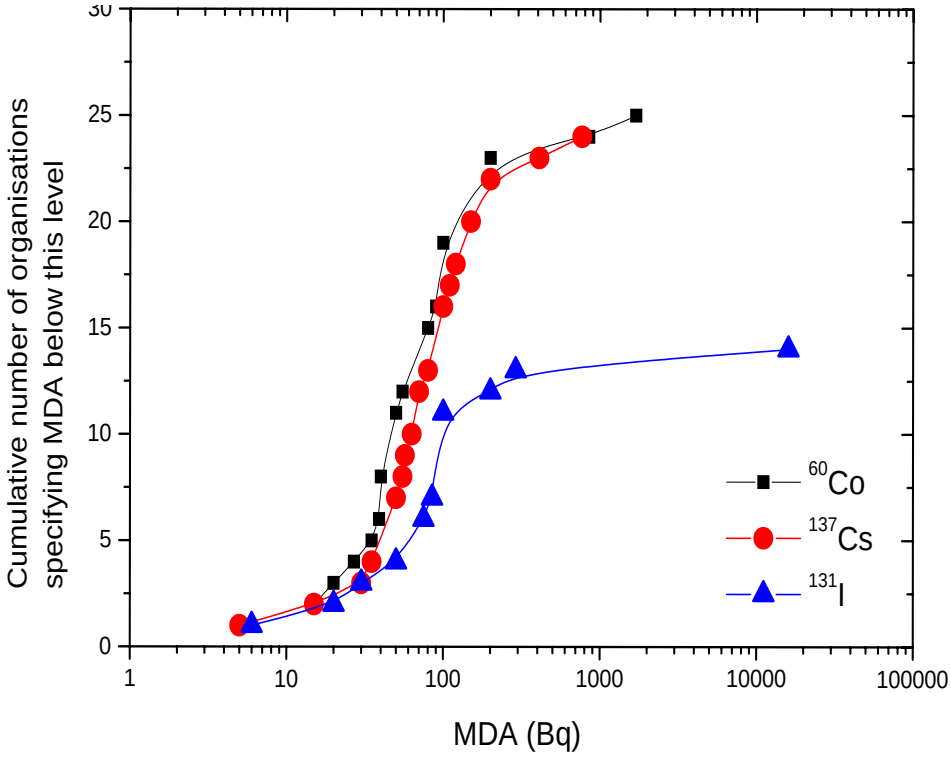

Fig 4. Cumulative number of organisations specifying minimum detectable amounts below a particular level for ^{60}Co, ^{137}Cs and ^{131}I.

Almost all organisations use physical phantom efficiency calibrations – computational methods are not used at all as can be seen in table 11. Computational methods are developed at many institutions but apparently not yet useful for organisations routinely monitoring workers. Only one organisation trusts the calibration for thyroid measurement provided by the manufacturer.

Sampling

The methods for normalisation of urine samples for different elements are shown in table 12 also showing the number of organisations using each method. To collect excretion samples is not popular among the workers and especially unpleasant if the collection period is 24 hours or even longer. According to this survey most commonly used methods are not to normalise at all or to use the creatinine method. Creatinine is produced in muscle tissue by the metabolism of creatine phosphate. In order for the body to maintain a constant creatinine content, the rate of creatinine excretion must equal its rate of metabolic production. It is secreted into the urine. Creatinine clearance provides a measure of the glomerular filtration rate (ICRP). Using the creatinine method one sample is sufficient to calculate the daily excretion. More details are presented in the WP3 report of the OMINEX project.

For fission products, 24 h collection is most common (7 out of 10 organisations). For tritium, out of 9 responses, not to normalise is most common (3 organisations), 2 normalise by volume. Presumably, all also should normalise by volume because activity concentration (Bq/litre) is required.

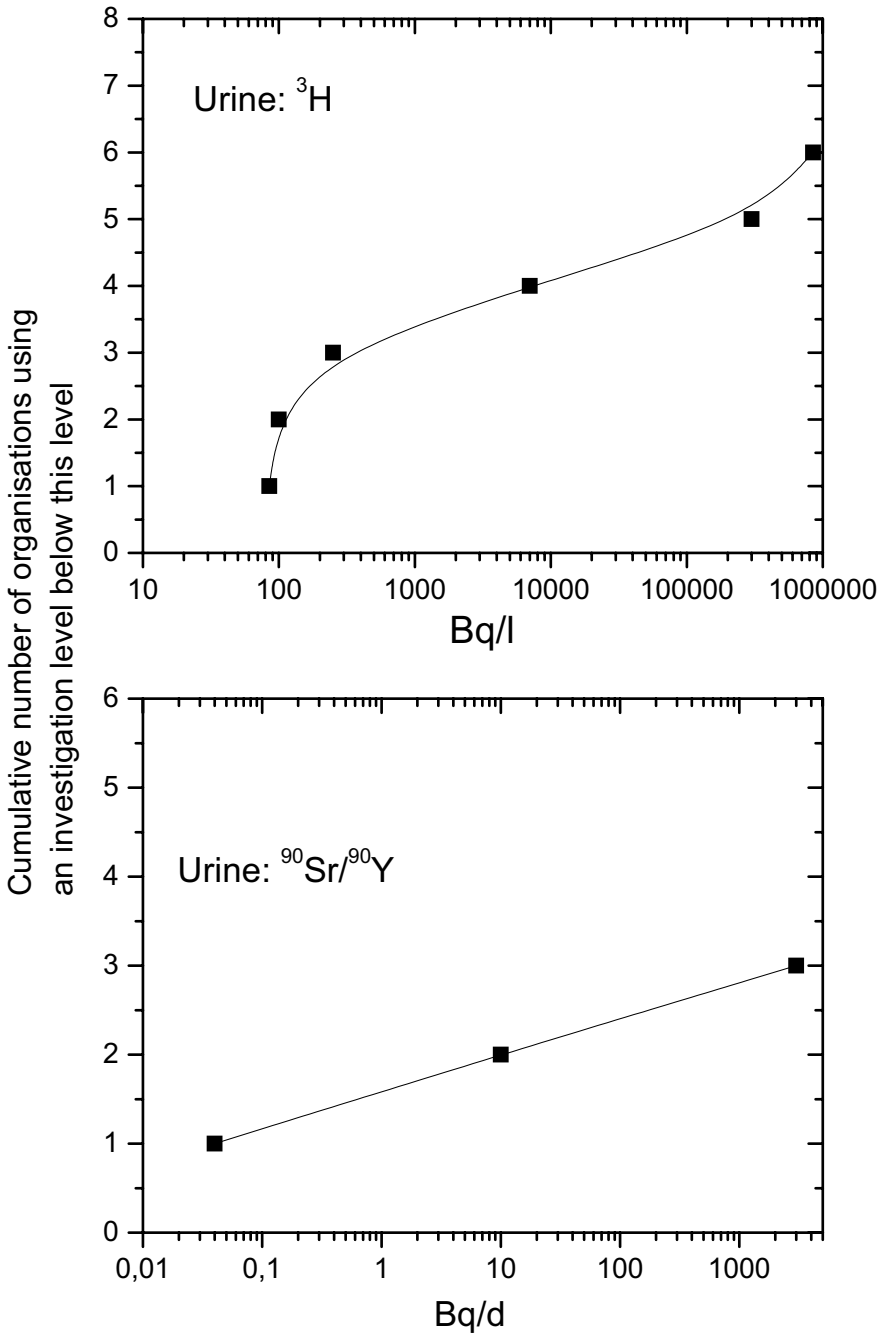

Fig 5. Cumulative number of organisations reporting investigation levels below daily excretion levels shown in the figure.

The times of any potential exposures are usually not known, and so monitoring is carried out at fixed time intervals. Table 13 presents the data collected on the frequency of routine monitoring measurements for α– and β-emitting radionuclides. For a particular radionuclide (or class of radionuclide), monitoring method and frequency, the table shows the number of organisations reporting that monitoring according to this specification is carried out, and the corresponding number of measurements performed. As can be seen, there is no clear consensus on monitoring intervals. For whole body monitoring, the largest number of organisations report a 1-year monitoring interval, but several organisations use much shorter intervals, and a significant number of measurements are carried out with a weekly interval. Similarly, for tritium-in-urine monitoring, five organisations use monitoring intervals of two weeks or less while seven organisations use longer monitoring intervals. The most common monitoring intervals for whole body are 1y (12 out of 24 organisations) and 6 months (7 out of 24). This is rather infrequent, but this type of monitoring intervals may be adequate if main purpose is reassurance monitoring (this information is however not readily available from the questionnaires). For iodine in thyroid monitoring, there is also a very wide range of monitoring intervals, ranging from 1 y (4 out of 17 organisations) to 1 week (1 out of 17 organisations). For tritium in urine, monitoring intervals range from 1 y (2 out of 12) to 1 week (4 out of 12). The one week monitoring interval is unnecessarily short. The uncertainties arising from a 1 y interval are extremely large if it is not a task based monitoring.

Investigation levels for special monitoring

Special monitoring is performed after an incident, or is triggered for some other reason. Information was collected on screening methods and follow-up monitoring methods used in special monitoring. Measurements made for screening purposes are interpreted using investigation levels, which are specified either as amounts of activity in the body (Bq) or activity concentration in excreta (Bq/d), or as dose levels (mSv). For ^{60}Co and ^{137}Cs, whole body counting and portal monitoring are the most commonly used screening methods and the method for follow up monitoring is whole-body counting. For ^{131}I, direct measurement is the most commonly used screening method and the method for follow up monitoring is either whole-body counting or thyroid measurement. Figure 6 shows the reported investigation levels for ^{60}Co, ^{137}Cs and ^{131}I. These are in the range 0.5 – 350 kBq for ^{60}Co (median ~ 10 kBq) and in the range 1 – 400 kBq for ^{137}Cs (median ~ 100 kBq).

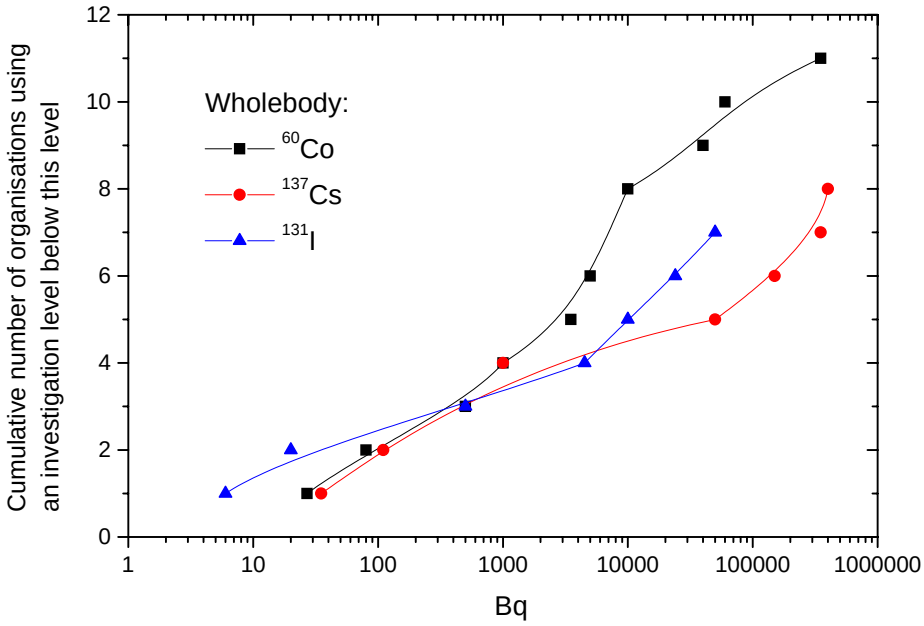

Fig 6. Cumulative numbers of organisations using an investigation level below the levels given in Bq in the figure.

For fission and activation products 12 out of 20 organisations use investigation levels that are associated with dose, and the doses range from 0.1 to 15 mSv.

Actinides

The most commonly monitored elements are uranium, plutonium, thorium and americium. In table 14 there is a compilation of organisations reporting assumed absorption types and AMAD assumptions for different actinide compounds. All organisations assume that the AMAD is 5µm for the above mentioned nuclides.

When applicable, whole-body and thyroid counting is used also for special monitoring, complemented by other methods. Seven organisations have reported on uranium monitoring. For routine monitoring, both direct methods (ie. whole-body and lung counting) and indirect methods (ie. urine monitoring, faecal monitoring and personal air sampling (PAS)), are used. For special monitoring, whole-body and lung counting as well as urine and faecal analyses are used. PAS monitoring is used for routine monitoring and urine analyses are used for special monitoring. Only UK organisations use PAS/SAS as primary monitoring method for actinides.

Tables 19 and 20 illustrate the information collected on the relative use of direct (*in vivo*) and indirect (bioassay and personal air sampling) monitoring methods. The indirect methods are mostly used for actinide monitoring, and are often the only available methods for this class of radionuclides.

Uranium

Eleven organisations answered to questions on chemical compounds, absorption types and natural versus depleted uranium(table 14). Six organisations reported that they do depleted uranium measurements. For U_3O_8, 6 out of 6 organisations assume Type S. However, this compound is sufficiently different from Type S to give rise to significant errors in the interpretation of urine excretion data. For UO_3, UF_4, UO_2F_2, 1 out of 3 organisations assume Type S. This is not justified; significant errors could result in the interpretation of lung monitoring. There appears to be some confusion as to the correct assignment of particular uranium compounds to the default absorption types (F, M or S). Organisations should consult the literature, and/or conduct suitable experimental studies where necessary.

Five different monitoring methods for uranium are listed in table 15. The most commonly used methods are urine and faeces monitoring. The highest numbers of measurements per year are reported for personal air samplers (PAS) and static air samplers (SAS). Total number of workers as well as numbers reported separately for class A and B for organisations using the different methods are given in table 16.

During the last few years interest has been shown to uranium and especially depleted uranium. Questions on uranium compounds and details of monitoring were asked. Only five organisations responded. Only in UK personal air samplers (PAS) are used for routine monitoring. Urine samples are commonly used whereas only two organisations use lung or faecal monitoring routinely. For special monitoring a combination of methods are used.

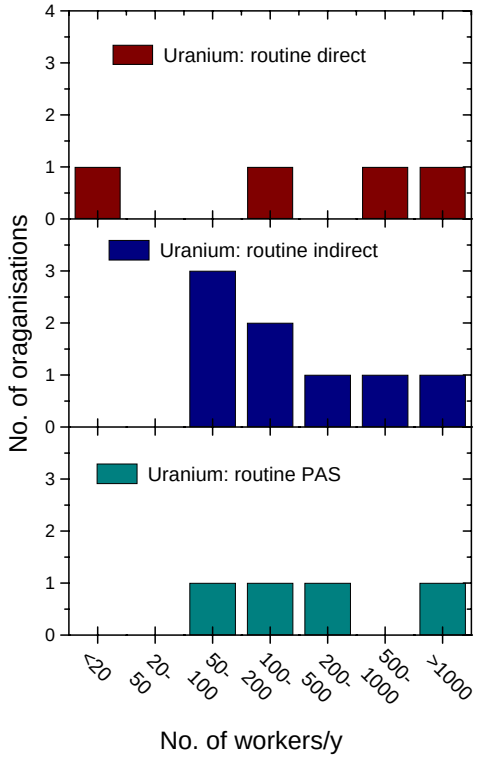

Fig 7. The annual number of workers monitored for uranium directly or indirectly at different organisations

Figure 7 illustrates the annual number of workers monitored for uranium directly or indirectly at different organisations. The numbers vary from ranges of 50-100 to more than 1000. The most common routine method is indirect monitoring. For uranium, 24 hour collection of urine is most common (4 out of 7 organisations).

Five organisations reported their measurement frequency of direct uranium measurements. Three of them monitor workers once a year and two four times per year (Table 17). Urine measurement frequency for different organisations and the related numbers of measurements per year are given in table 18. Three organisations of nine do urine measurements twice per year, five four times per year and one every month. For lung monitoring the most common monitoring interval is 1 year, three out of nine organisations use that. For urine monitoring the most common monitoring intervals are six months (3 out of 8) and three months (4 out of 8). For faecal monitoring the most common monitoring interval is six months (2 out of 3).

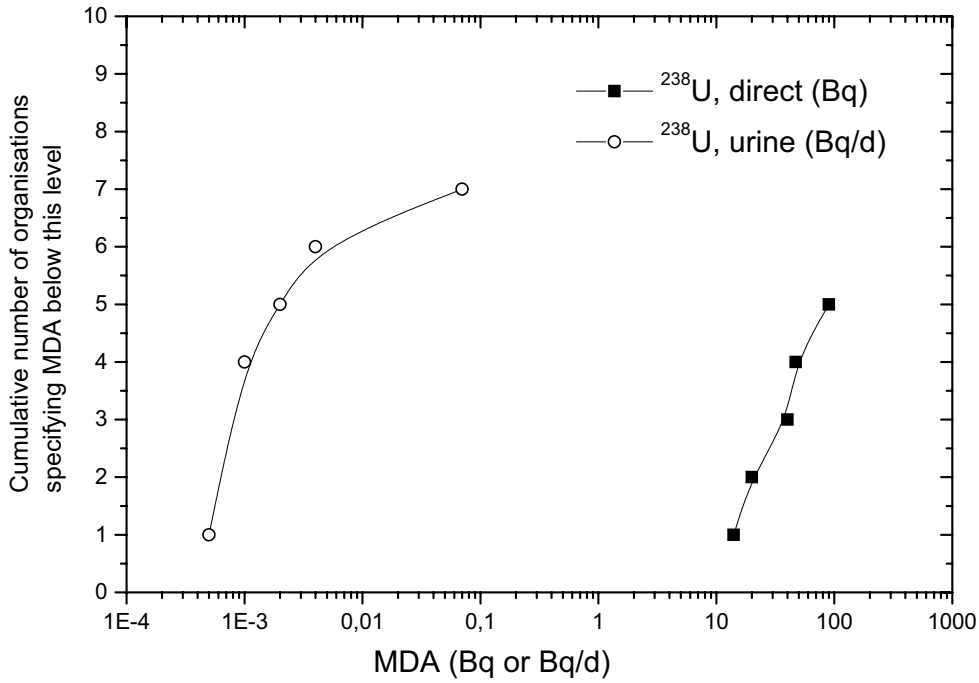

Fig 8. Cumulative number of organisations specifying minimum detectable amounts below the levels indicated in the figure.

Figure 8 illustrates the difference in MDAs for lung and urine excretion measurements for ^{238}U. In the direct measurement the uncertainties in calculating the daily urine excretion are avoided. Information was also collected on urine sampling periods. About half of the organisations reported the use of 24 hour sampling for uranium-in-urine monitoring, with the remainder carrying out normalisation by creatinine determination or by volume. The use of 24 hour sampling eliminates uncertainties resulting from different normalisation methods. The uncertainties involved in using creatinine for normalisation are considered in work package 4 of the OMINEX project. The direct method is favoured by the workers being monitored. Figure 9 shows the cumulative number of organisations using an investigation level expressed as mg uranium per gram of creatinine in urine.

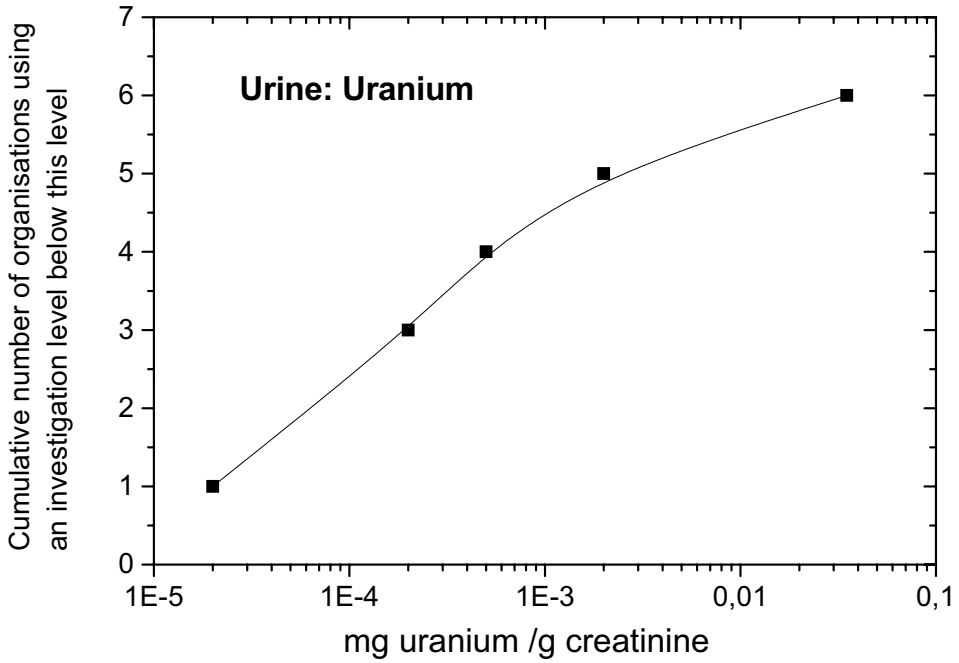

Fig 9. Cumulative number of organisations using an investigation level below the levels indicated in the figure.

Plutonium

Tables 19 and 20 illustrate the information collected on the relative use of direct (*in vivo*) and indirect (bioassay and personal air sampling) monitoring methods. The indirect methods are mostly used for actinide monitoring, and are often the only available methods for this class of radionuclides.

Six organisations report on plutonium monitoring. Three commonly used methods are urine monitoring, combined urine and faeces monitoring and PAS monitoring. One organisation reports using only faeces monitoring. PAS and urine monitoring is used for routine monitoring and urine and faecal analyses for special monitoring The number of workers monitored for plutonium at different organisations vary from less than 20 to more than 1000 (Fig. 10). The highest number of workers are routinely monitored indirectly.

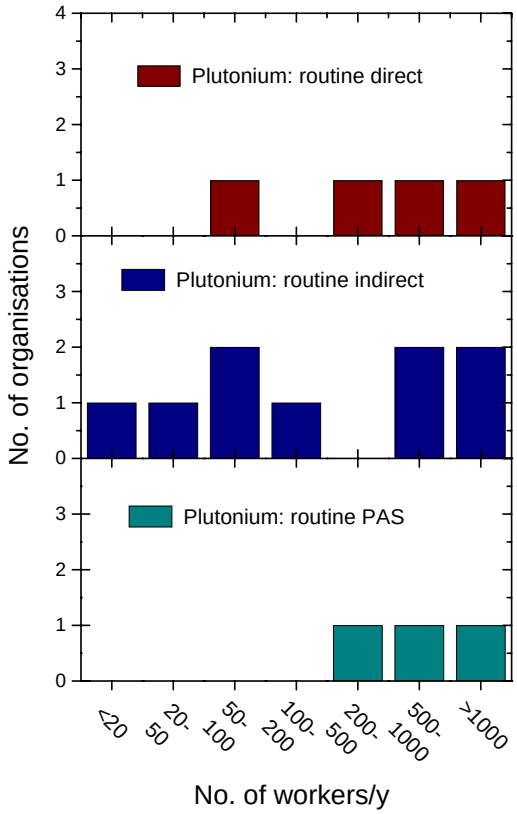

Fig 10. The annual number of workers monitored for plutonium directly or indirectly at different organisations.

All organisations report AMAD 5µm for plutonium and assume absorption type S for the oxide. For plutonium nitrate two out of four organisations assume type M and two out of four assume type S and one organisation did not specify any assumed absorption type. For unknown compounds three organisations report assuming the type S and three type M.

When urine monitoring is used, normalisation by creatinine is most common (4 out of 9 responses) for plutonium. Two organisations normalise by volume and one does no normalisation.

For lung monitoring, the most common monitoring interval is 1 year (2 organisations out of 4) as shown in table 21. One organisation reports monitoring twice per year and another four times per year. For urine monitoring, monitoring intervals range from 1 month to 1 year (no consensus). Four organisations out of nine do it every three months. For faecal monitoring, most common monitoring is 1 y (3 out of 5), followed by twice per year (2 out of 5).

Americium

Six organisations reported on americium monitoring. All organisations assume AMAD 5 µm and type M for all compounds of americium. The methods for americium routine monitoring are given in table 19 and for special monitoring in table 20. PAS or urine monitoring is used for routine monitoring and lung counting, urine and faecal analyses are used for special monitoring. Lung measurements are used only in connection with indirect methods for both routine and special monitoring. At one organisation more than 1000 workers are monitored routinely using PAS.

Only less than one hundred measurements of americium per year were reported. Many organisations did not give any number of workers. The monitoring intervals for lung measurements varied from two times a year to once every two years. For urine frequency the variation was from every week to once a year and for faeces once or twice a year. For screening and follow up methods both direct and indirect methods are used(Table 22). A majority of organisations use MDA as the investigation level.

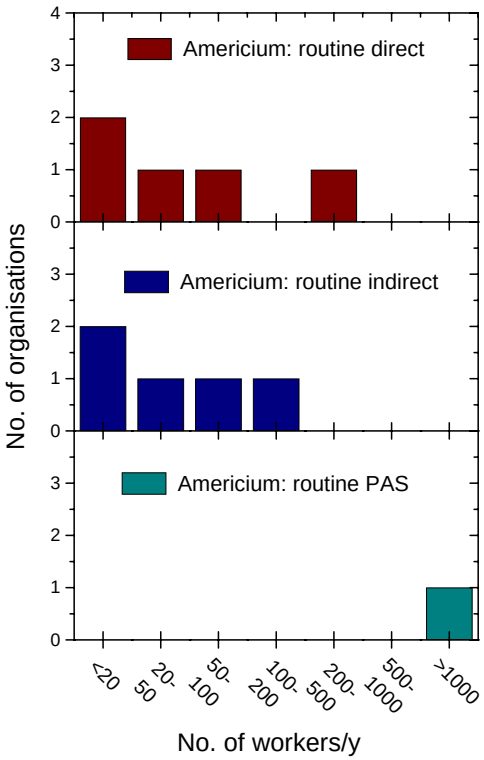

Fig 11. The annual number of workers monitored for americium directly or indirectly at different organisations

Thorium

Four organisations have reported on thorium monitoring. PAS monitoring is used for routine monitoring and urine analyses are used for special monitoring. For thorium all reporting organisations use AMAD 5 µm. Two organisations report assumed absorption type S for oxide. One organisation assumes type M for the nitrate. If the material is ^{232}Th, this is incorrect. Type S is the correct assumption. PAS monitoring is used for routine monitoring and urine analyses are used for special monitoring. Urine monitoring is most commonly used for thorium both for routine and special monitoring. Monitoring intervals vary from once per year to four times a year at the five organisations supplying information. Less than 50 measurements per year were reported to be done. This is a very small portion of the many hundred workers involved. Also for thorium the MDA is used as investigation level or for nose blow 0.5 Bq.

Investigation levels for special monoitoring

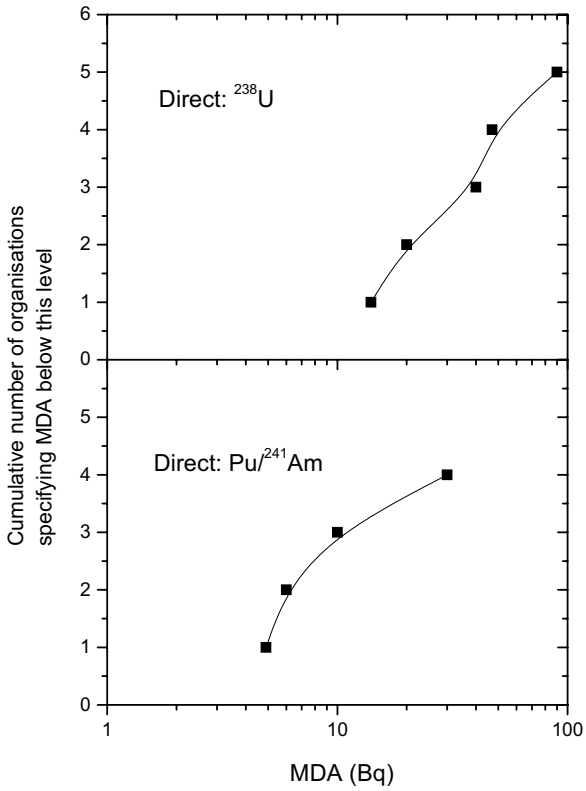

Fig 12. Cumulative number of organisations specifying MDA in Bq below the levels marked in the figure.

Figure 12 shows the MDA and the cumulative number of organisations specifying MDA below a certain level for direct measurements of ^{238}U and ^{241}Am/Pu. Figure 14 shows the MDA (Bq/d) for indirect urine measurements and the cumulative number of organisations specifying MDA below a certain level for uranium, plutonium, thorium and americium.

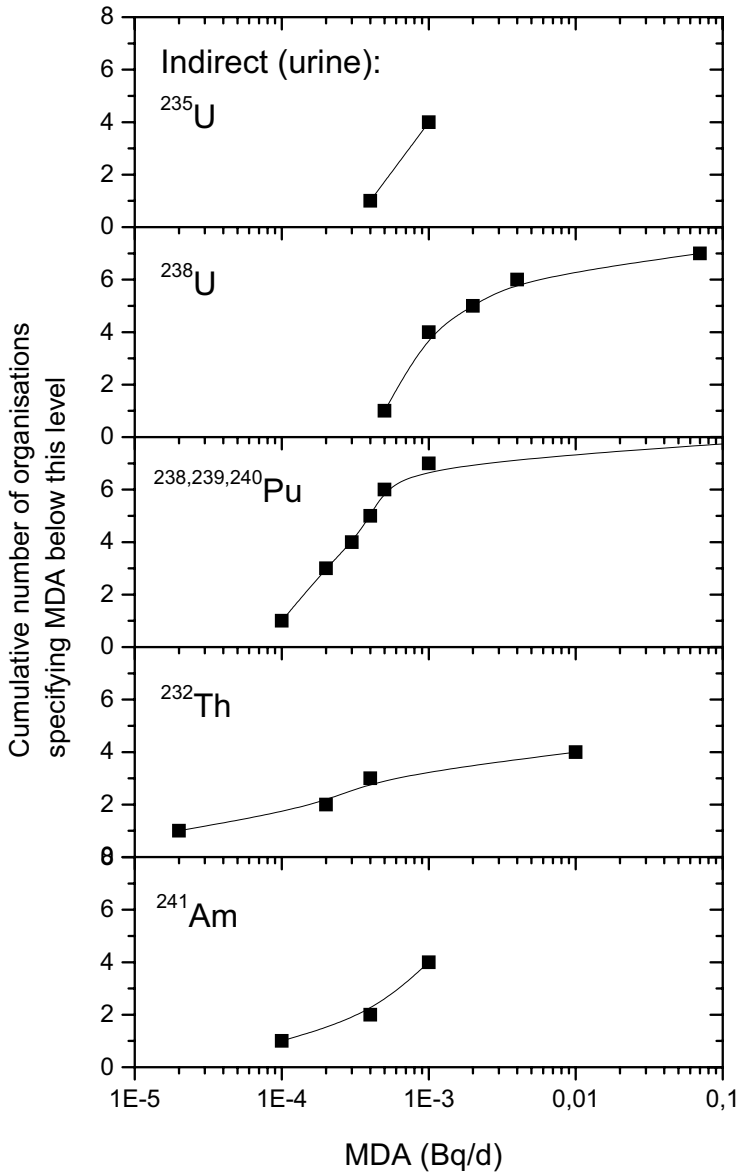

Fig 13. Cumulative number of organisations specifying MDA below levels indicated in the figure as Bqd-1 for urine measurements of ^{235}U, ^{238}U, ^{238,239,240}Pu and ^{232}Th.

Investigation levels for different screening methods in case of special monitoring and method of follow up monitoring are given in Table 22. Urine monitoring is most commonly used for screening. Follow up methods often include a combination of direct and indirect measurements. To try to see a trend in special monitoring a question to be answered was how many workers were controlled annually by special monitoring after routine monitoring had indicated the need. The results are given in table 23 for fission and activation products and actinides annually from 1996 to 2000. It is not possible to see any trend from this material. More should be known about the reasons for special monitoring in each case.

Doses

Dose calculations are primarily done manually or using own software. Of the commercially available dose calculation programs, most popular is LUDEP (12) followed by IMBA and CINDY(3) as can be seen from table 24.

Table 25 shows individual internal dose statistics for the last year before answering the questionnaire as reported by 14 of the responding organisations. Many of the organisations that did not answer this question can be supposed not to have reached the 0,1 mSv level.

Both direct and indirect methods are used for assessment of individual doses. The indirect methods are mostly used for actinide monitoring, and are often the only available methods for this class of radionuclide.

All organisations monitor workers to assess individual doses for entry onto a legal dose record. A minority do it to monitor enginering practices and standards and three thirds to reassure individual workers that they are not receiving excessive doses. Two modes in the distributions can be noted, centred at 0.1 mSv and 1 mSv (Fig 14). Not particularly dependent on the monitoring purpose. For uranium, 4 out of 7 organisations report 0.1 – 15 mSv, for plutonium, 3 out of 7 organisations, 0.1 – 6 mSv and for americium, 4 out of 11 organisations, 5 - 15 mSv. It is not clear why there are organisations reporting minimum doses to be aimed at smaller than 0.1 mSv.

The individual internal dose statistics for the number of cases assessed with doses in the ranges 0.1 – 0.5 mSv, 0.5 – 1 mSv, 1 – 2 mSv, 2 – 5 mSv, 5 – 10 mSv, 10 – 20 mSv and >20 mSv for the last year prior to responding to the questionnaire shows a maximum number of 2017 recorded doses in the lowest range and 216, 105, 17 and 6 respectively in the following four ranges. No doses higher than 10 mSv were reported.

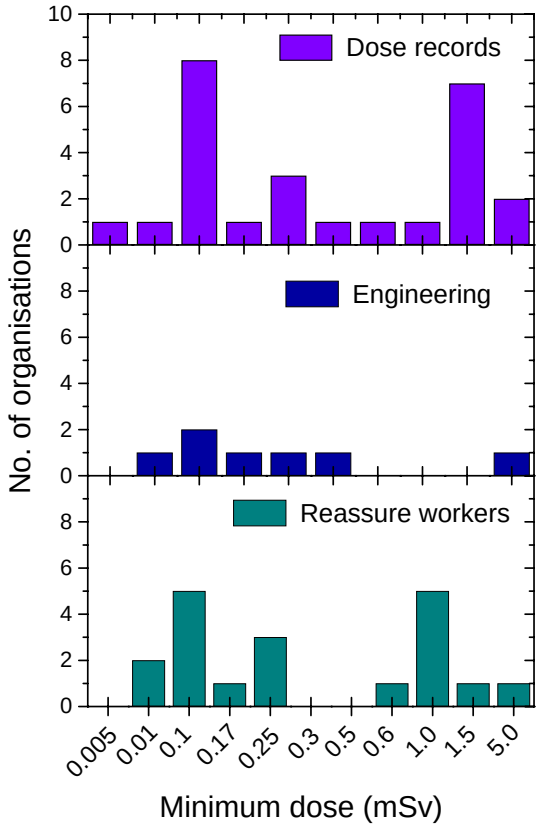

Fig 14. Minimum doses aimed to be assessed for dose records, for monitoring engineering practices and for reassuring workers versus number of organisations.

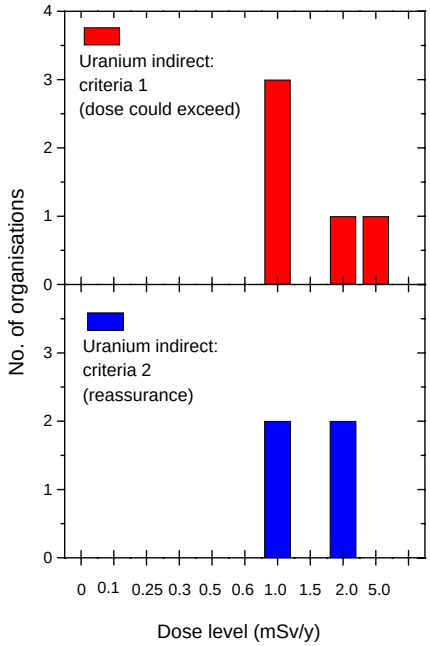

Fig 15. Dose levels for criteria 1 (dose could exceed) and 2 (reassurance) used by organisations monitoring uranium indirectly .

Plutonium:

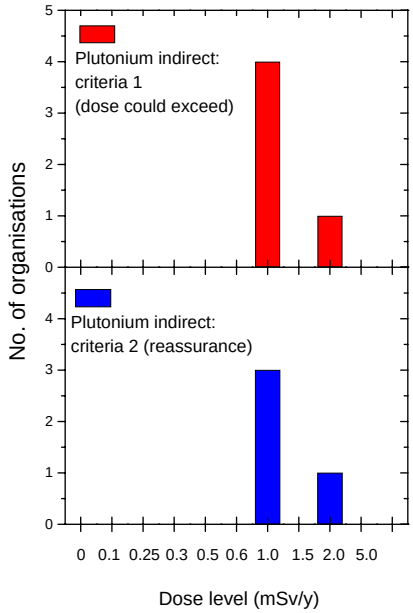

Fig 16. Dose levels for criteria 1 (dose could exceed) and 2 (reassurance) used by organisations monitoring plutonium indirectly.

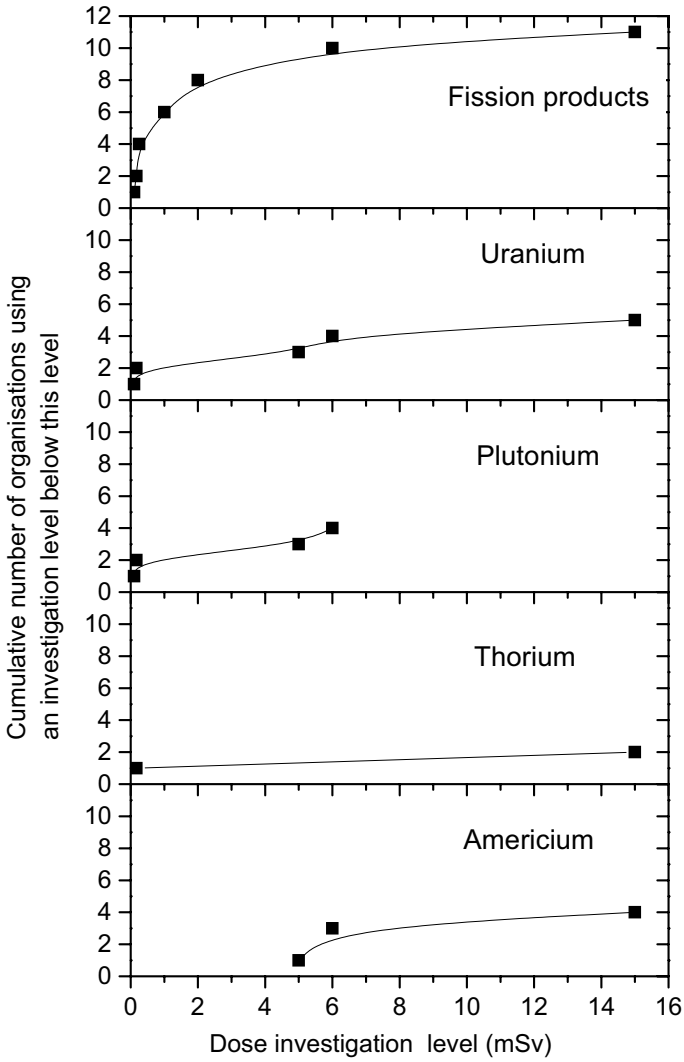

Fig 17. Cumulative number of organisations using investigation levels below levels from 0,1 to 15 mSv for fission products, uranium, plutonium, thorium and americium.

Figure 17 shows dose investigation levels and cumulative numbers of organisations using an investigation level below a certain level for fission products, uranium, plutonium, thorium and americium.

Table 25 gives the individual internal dose statistics for the year before answering the questionnaire. It can be seen that only six doses reported were between five and ten millisieverts, all the rest below that range. The maximum amount (2017 doses) was reported to be in the range 0,1 to 0,5 millisievert.

4 Conclusions

The survey provides a representative coverage of the six types of operation identified and a sufficient numbers of workers. All responses were not complete which shows in the tables where all numbers do not add up as expected. The material included in this report is large enough to meet the requirements of getting a good overview of the monitoring situation today.

The majority of organisations carry out whole-body counting measurements for ^{60}Co, ^{137}Cs and other fission and activation nuclides(FAP). Fewer organisations carry out iodine-in-thyroid monitoring than FAP monitoring. No explanation can be found in the results of the survey. For actinides, all methods are more or less equally likely : lung, urine, faeces, PAS, SAS, nose blow, (Portal monitor!). No particular relationship with radionuclide was found. There are several instances of clearly inappropriate methods being used as nose blow screening for tritium exposures and use of portal monitors for actinide monitoring. The main difference between routine and special monitoring is the use of combinations of direct and bioassay monitoring for special monitoring. Special monitoring is also more case dependent.

A major conclusion is that, particularly for the actinides, a wide range of approaches to monitoring are in use. There is no consensus on primary monitoring methods. Apart from whole-body counting for fission and activation products there is no consensus on monitoring intervals (MI).

There appears to be some confusion as to the correct assignment of particular uranium compounds to the default absorption types (F, M or S). Organisations should consult the literature, and/or conduct suitable experimental studies where necessary.

All organisations monitor workers to assess individual doses for entry onto a legal dose record. A minority do it to monitor enginering practices and standards and three thirds to reassure individual workers that they are not receiving excessive doses. Two modes in the distributions can be noted, centred at 0.1 mSv and 1mSv, not particularly dependent on the monitoring purpose.

A wide range of investigation levels was found. For fission and activation products , 12 out of 20 organisations use investigation levels that are associated with dose, and the doses range from 0.1 to 15 (!) mSv.

Cumulative distributions show that most organisations aim to assess doses down to 0.1 – 0.5 mSv. This is lower than is required by EURATOM directive which indicates that doses above 1 mSv should be assessed for Cat B

workers. From the point of view of legislative requirements, it is not necessary to assess doses below 1 mSv. The EURATOM Directive defines exposed workers as those workers who could receive doses in excess of the public dose limits. This could mean that some organisations are expending unnecessary effort in assessing doses at ~ 0.1 mSv. Some organisations might have sensitive measurement systems for other purposes and in that case the effort is the same assessing a dose of 0,1 or 1 mSv. The legislative requirements consider the total dose not only the internal dose. . For fission and activation products the external dose is normally the higher and the internal dose low in comparison. For actinides the situation is the opposite.

The number of radiation workers in different countries is generally not reported. The number of workers surveilled for internal doses even less. With the resources allocated to WP 1 in the OMINEX project it was not possible to approach every organisation in Europe with workers exposed to internal contamination. All organisations the WP 1 questionnaire was sent to did not respond. In some countries there are no arrangements for internal contamination measurements. If the risk for internal contamination does not involve very many workers there is a possibility to send people or samples to be measured in another country. The aim of the OMINEX project was not to evaluate this kind of arrangement. The material included in this report is large enough to meet the requirements of getting a good overview of the monitoring situation today.

The results of the OMINEX survey can be compared with information published by NUREG in the United States.The internal doses divided in steps from less than 1 mSv to 1-5, 5-10, 10-20 and more than 20 mSv show a rather similar distribution in USA and Europe but a trend towards lower doses in Europe as found in the OMINEX survey (Fig 18).

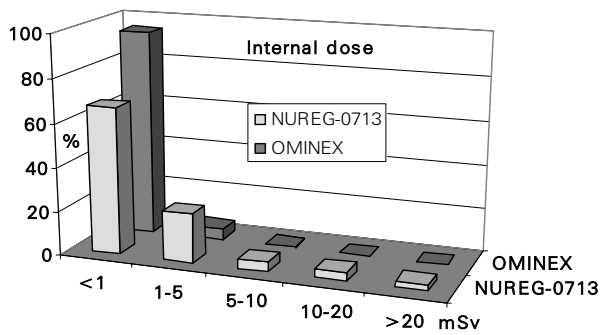

Fig 18. Comparison of distribution of internal doses in five different ranges from the OMINEX survey and corresponding data presented by NUREG.

5 Acknowledgements

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7 Tables

Table 1. Types of operation and numbers of organizations using certain types of monitoring for routine and special situations

Type of operation	Number of organization	Type of monitoring			Monitoring		
		In vivo	Bioassay	SAS PAS	Routine	Special	Both
NPP	34	33	15	7	8	4	27
Reprocessing	2	2	2	-	-	-	1
Fuel fabrication	7	6	6	2	3	2	5
Decommissioning	6	5	6	1	2	2	5
Research	19	17	12	5	3	5	16
Non-nuclear	3	3	3	2	2	2	2

Table 2. Types of operation and numbers of organizations monitoring for certain radionuclides

Type of operation	Number of organisation	Radionuclides monitored					
		FAP	U	Pu	Th	Am	MOX
NPP	34	33	5	6	1	4	-
Reprocessing	2	2	2	2	1	2	-
Fuel fabrication	7	5	7	6	4	5	1
Decommissioning	6	5	6	6	3	6	1
Research	19	17	11	9	5	12	2
Non-nuclear	3	3	2	2	2	3	1

Table 3. Organisations responding to survey, and numbers of workers in EU countries, Associated States and Other countries

Type of Operation	EU Countries			Associated States			Other countries		
	No. of organi-zations	Total no. of workers [1]		No. of organi-zations	Total no. of workers [1]		No. of organi-zations	Total no. of workers [1]	
		Cat. A [2]	Cat. B [2]		Cat. A [2]	Cat. B [2]		Cat A	Cat B
Nuclear power plant	13	86360	12952	3	7575	-	1	-	-
Reprocessing	2	10500	-	0	-	-	0	-	-
Fuel Fabrication	5	11150	-	0	-	-	0	-	-
Decommis-sioning	7	13450	3200	0	-	-	0	-	-
Research Centre	12	17019	9189	2	25	15	1	-	-
Non-nuclear industry	6	2950	3200	0	-	-	0	-	-
Other									

Table 4 a. Type of operation and percentage of workers in categories A and B (all countries included).

	No of workers A+B categories	Category A workers (%)	Category B workers (%)
NPP	106 887	88	12
Fuel fabrication	11 150	100	-
Reprocessing	10 500	100	-
Research centre	26 248	65	35
Decommissioning	16 650	81	19
Non-nuclear industry	6 150	48	52
Total	117 485	84	16

Table 4 b. Type of operation and percentage of workers in categories A and B (all EU countries included).

	No of workers A+B categories	Category A workers (%)	Category B workers (%)
NPP	99 312	87	13
Fuel fabrication	11 150	100	-
Reprocessing	10 500	100	-
Research centre	26 208	65	35
Decommissioning	16 650	81	19
Non-nuclear industry	6 150	48	52
Total	109 870	83	17

Table 5. Number of category A and category B, permanent and contract workers in the six identified types of organizations.

Country	NPP	Re-proc	Fuel Fab.	De-comm	Re-search	Non-nuclear	Cat A	Cat B	Perma-nent	Con-tract
Austria					Yes		150	0	500	100
Belgium					Yes		408	32		
Bulgaria	Yes									
Czech Republic					Yes		25	15	70	0
Czech Republic	Yes						3200	0	1010	2190
Finland					Yes					
Finland	Yes						350	1160	670	1100
France					Yes		3511	5957		
France	Yes						57300	8782	28324	37758
Germany	Yes			Yes	Yes	Yes	2000	3000		
Germany	Yes						1500	10	680	1500
Germany					Yes					
Germany	Yes		Yes	Yes	Yes	Yes	650		400	250
Hungary					Yes				187	
Italy				Yes	Yes	Yes	300	200	3000	50
Lithuania	Yes						4375		3187	1188
Norway	Yes									
Norway					Yes					
Spain	Yes				Yes		10000		2500	2500
Spain			Yes	Yes	Yes	Yes			90	180
Sweden	Yes						1500		300	1200
Sweden	Yes						710	0	1036	934
Sweden	Yes						1600		1100	500
Sweden	Yes						250		370	160
Sweden						Yes				
UK	Yes			Yes	Yes				3000	350
UK		Yes							120	0
UK	Yes	Yes	Yes	Yes			10500	0	7500	3000
UK	Yes	Yes	Yes	Yes	Yes	Yes			822	120
Total	17	2	5	7	15	6	98329	19156	54866	53080

Table 6. Number of in vivo, in vitro and PAS measurements of fission and activation products(FAP), uranium, plutonium and thorium nuclides per year.

	No of in vivo measurements/y	No of in vitro measurements/y	No of PAS mesurements/y
FAP	19394	6605	-
U	1135	5210	222650
Pu	2420	11141	372300
Th	-	39	1825

Table 7. Assumed ^{60}Co and ^{137}Cs compounds, absorption types and AMADs in different organisations.

Element/ Radionuclide	Compound	Assumed Absorption Type (F,M,S)	Assumed AMAD (μm)	No. of organisations
^{60}Co	Co oxide	M	5	2
	Co oxide	S	5	5
	Co oxide	not specified	1	1
	Other	M	1	1
	Other	M	5	2
	Other	S	1	2
	Other	S	5	4
	Other	S	worst case	2
^{137}Cs	Any	F	1	2
	Any	F	5	10
	Any	M	5	1
	Any	not specified	1, worst case	2

Table 8. Primary routine monitoring methods used to determine doses entered onto formal dose records.

	Fission and activation products, Routine									
	Nuclide									
Method	^{137}Cs	^{60}Co	^{131}I	^{125}I	^{3}H	^{14}C	^{32}P	^{35}S	^{90}Sr/^{90}Y	Other
WBC	18	17	7	2					2	6
WBC+urine	1									
WBC+urine+faeces		1								
WBC+lung										
Urine					13	4	4	2	3	
Urine+faeces	1	1	1						1	1
Urine+expired air						1				
Lung		1								
Quick scanner		1	1	1						
Thyroid monitor			8	5						
Thyroid+urine			2	1						
PAS	1	1							1	

Table 9. Primary special monitoring methods used to determine doses entered onto formal dose records.

	Fission and activation products, Special									
	Nuclide									
Method	^{137}Cs	^{60}Co	^{131}I	^{125}I	^{3}H	^{14}C	^{32}P	^{35}S	^{90}Sr/^{90}Y	Other
WBC	15	14	5	3						3
WBC+urine	3	2								
WBC+urine+faeces	1	2	1	1					1	
WBC+lung		1								2
Urine					13	5	5	5	6	1
Urine+faeces	1	1	1						2	1
Urine+expired air						1				
Lung										
Quick scanner										
Thyroid monitor			9	5						
Thyroid+urine			4	3						
PAS										

Table 10. Screening and follow up methods and investigation levels of ^{60}Co, ^{137}Cs, ^{131}I and tritium for special monitoring

Radio-nuclide	Screening Method	Investigation level, median (range)	No. of organisations (% of total)	Follow up Monitoring (no. of organisations using this method)
^{60}Co	Whole body	10 kBq (0.5-350 kBq)	11 (38)	whole body (7), urine+faeces (1)
	Urine	?	2 (7)	
	Portal	>MDA, 2000-3000 Bq	5 (17)	
	PAS	40 DACh	1 (3)	
	SAS	if>LD, case specific	3 (10)	
	Nose blow	if>LD, case specific	2 (7)	
^{137}Cs	Whole body	100 kBq (1-400 kBq)	8 (27)	whole body (7), urine (1)
	Urine	?	2 (7)	
	Portal	if > LD, 600 Bq	2 (7)	
	PAS	40 DACh	1 (3)	
	SAS	if>LD, case specific	2 (7)	
	Nose blow	if>LD, case specific	2 (7)	
^{131}I	Whole body	10 kBq (0.5-50 kBq)	7 (24)	in vivo thyroid monitoring (3), urine (1)
	Urine	?	2 (7)	
	Portal	if>LD	1 (3)	
	PAS		0	
	SAS	if>LD	1 (3)	
	Nose blow	if>LD	1 (3)	
Tritium	Urine	>MDA, 0.1-850 kBq/l	6 (21)	urine (8)
	Portal	if>LD	2 (7)	
	SAS	if>LD	1 (3)	
	Nose blow	if>LD	1 (3)	

Table 11. Efficiency calibration method for direct measurements.

Measurement method	Calibration method	No. of organizations
Whole body	Provided by manufacturer	0
	Physical phantom	24
	Computational method	0
Thyroid	Provided by manufacturer	1
	Physical phantom	20
	Computational method	0

Table 12. Normalisation of urine samples for monitoring of fission and activation products(FAP), tritium and actinides

Element	Normalisation method	No. of organizations
FAP except tritium	By volume	0
	By creatinine	3
	No normalisation (24 h collection)	7
	Bulked	1
Tritium	By volume	2
	By creatinine	1
	No normalisation (24 h collection)	3
	Bulked	1
Uranium	By volume	3
	By creatinine	1
	No normalisation (24 h collection)	4
Plutonium	By volume	2
	By creatinine	4
	No normalisation (24 h collection)	1
	Bulked	2
Thorium	No normalisation (24 h collection)	2
Americium	No normalisation (24 h collection)	4
	Bulked	1

Table 13. Monitoring intervals for direct and indirect methods for fission and activation products.

Radio-nuclide	Method	Monitoring frequency (times/y)	For this material, method and monitoring interval range: No. of organisations	No. of measurements/y
Fission and activation products except iodine	Whole body	1	12	6824
		2	7	2150
		4	2	480
		6	1	220
		12	1	1720
		52	1	8000
	Urine (tritium)	1	2	20
		4	1	5
		6	1	200
		12	3	2960
		24	1	?
		52	4	>3600
	Urine (Sr/Y)	2	1	>1000
		4	1	100
		?	1	10
Iodine (^{131}I)	Direct	1	4	5365
		2	1	?
		4	1	100
		12	4	2440
		26	1	?
		52	1	10
		other (occasionally, when needed, self checking etc.)	5	350

Table 14. Assumed actinide compounds, AMADs and absorption types in different organisations.

Element/ Radionuclide	Compound	Assumed Absorption Type (F,M,S)	No. of organizations
Uranium	U_3O_8	*S*	6
	UO_2	S	7
all assume	UO_3	M	2
AMAD 5 μm	UO_3	S	1
	UF_4	M	2
	UF_4	S	1
	UF_6	F	2
	UO_2F_2	F	2
	UO_2F_2	S	1
	Metallic U	S	2
	Other,	F	5
	unknown	M	2
		S	4
Plutonium	PuO_2	S	6
	$Pu(NO_3)_4$	M	2
all assume AMAD 5 μm	$Pu(NO_3)_4$	S	2
	$Pu(NO_3)_4$	not specified	1
	Unknown	M	3
	Unknown	S	3
Thorium	Oxide	S	2
	Nitrate	M	1
all assume AMAD 5 μm	Unknown	S	1
	Unknown	F,M,S	1
Americium	AmO_2	M	5
all assume AMAD 5 μm	$Am(NO_3)_3$	M	3
	Other/ unknown	M	5

Table 15. Monitoring methods and number of organisations using each method and number of measurements per year.

Uranium		
Method	No of organizations	Number of measurements/y
Urine	10	5280
Faeces	4	1000
Direct/lung	10	>1135
PAS	4	222650
SAS	2	32850

Table 16. Number of organisations using different methods and total number of workers as well as numbers reported for class A and B.

Uranium Method	No of organizations	Total no of workers	No of workers in category A	No of workers in category B
Urine	10	267405	74819	17971
Faeces	4	96763	61461	14739
Direct/lung	10	201113	17111	9157
PAS	4	14912	10500	-
SAS	2	3470	-	-

Table17. Frequency of direct uranium measurements and number of measurements per year

Direct measurements Frequency 1/y	Number of organizations	Number of measurements/y
1	3	125
4	2	1010
Total	5	1135

Table 18. Urine measurement frequency for different organisations and the related numbers of measurements per year

Urine measurements, uranium Frequency 1/y	Number of organizations	Number of measurements/y
2	3	1990
4	5	2090
12	1	1200
Total	9	5280

Table 19. Routine monitoring methods for uranium, plutonium, thorium and americium determination

Actinides, Routine				
	Nuclide			
Method	U	Pu	Th	Am
Lung	1			
Urine	3	3	2	2
Urine+faeces	2	3	1	3
Urine+lung	1			1
Urine+air sampling	1			
Faeces		1		
Faeces+urine+lung	1			1
Faeces+lung				1
PAS	2	3	1	2
SAS+PAS	1			
PAS+urine	1			

Table 20. Special monitoring methods for uranium, plutonium, thorium and americium determination

Actinides, Special				
	Nuclide			
Method	U	Pu	Th	Am
Lung	1			
Urine	4		1	
Urine+faeces	5	9	2	3
Urine+lung	2			
Urine+air sampling				
Faeces			1	
Faeces+urine+lung	1	1		6
Faeces+lung	1		1	1
PAS				
SAS+PAS				
PAS+urine				
WBC+bioassay	1			

Table 21. Monitoring intervals of actinides using different methods

Element	Method	Monitoring frequency (times/y)	For this material, method and monitoring interval: No. of organizations	No. of measure-ments/y
Uranium	Lung	1	3	125
		4	2	1010
	Urine	2	3	1990
		4	5	2090
		12	1	1200
	Faeces	1	1	?
		2	2	1000
Plutonium	Lung	1	2	1300
		2	1	1000
		4	1	50
	Urine	1	2	306
		2	2	1000
		4	4	5570
		12	1	4200
	Faeces	1	3	341
		2	2	1000
Americium	Lung	0.5	1	25
		1	1	?
		2	1	40
	Urine	1	1	4
		2	2	?
		12	1	?
		52	1	?
	Faeces	1	1	4
		2	1	?
Thorium	Lung	1	1	?
	Urine	1	2	35
		4	1	4
	Faeces	1	1	6

Table 22. Screening and follow up methods and investigation levels used for special monitoring

Uranium	Lung	if > MDA	3 (10)	lung+urine+faeces (2),
	Urine	values not in same units	5 (17)	lung+urine (1), lung (1), urine (4)
	Faeces	if>MDA	3 (10)	
	PAS	1-40DACh	2 (7)	
	SAS	if>MDA, 1.2DACh	3 (10)	
	Nose blow	if>MDA, 0.2-6 Bq	3 (10)	
	Portal	if>MDA	1 (3)	
Plutonium	Lung	if>MDA	2 (7)	lung+urine+faeces (1),
	Urine	if>MDA, 0.5-0.8mBq/d	5(17)	urine + faeces (2), lung (1), faeces (1)
	Faeces	if>MDA, 8 mBq/d	4 (14)	
	PAS	1.2-40 DACh	2 (7)	
	SAS	if>MDA	2 (7)	
	Nose blow	if>MDA, 0.2-0.5Bq	4 (14)	
	Portal	if>MDA	1 (3)	
Thorium	Urine	if>MDA, 0.5mBq/d	3 (10)	urine (3)
	Faeces	if>MDA	1 (3)	
	PAS	40 DACh	1 (3)	
	SAS	case specific	1 (3)	
	Nose blow	0.5 Bq	1 (3)	
Americium	Lung	if>MDA	2 (7)	lung+urine+faeces (1), faeces (1), head+urine (1)

Table 23. Number of persons controlled by special monitoring annually from year 1996 to year 2000 for fission products and actinides

Radio-nuclide	No. of organizations	No. of persons/y year 1996	No. of persons/y year 1997	No. of persons/y year 1998	No. of persons/y year 1999	No. of persons/y year 2000
Fission products	21	567	1269	887	830	1607
Uranium	7					134
Plutonium	8	55	120	514	294	765
Thorium	4	21	60	21	0	0
Americium	11	74	118	234	164	112

Table 24. Methods of dose calculation

Organisation	Manual calculation	Own software	LUDEP	CINDY	IMBA	Other method
1						RETEX
2	Yes				Yes	
3	Yes					
4		Yes			Yes	
5	Yes		Yes			German guideline
6		Yes	Yes	Yes		CALIN
7		Yes				IMIE
8		Yes	Yes	Yes		IMI
9	Yes					
10		Yes				
11	Yes		Yes			
12	Yes		Yes			
13	Yes	Yes	Yes			IMIE
14	Yes		Yes			MONDAL/MONDES
15	Yes		Yes			
16		Yes	Yes	Yes		
17						ICRP-30 model/Nuclear-Data
18	Yes					
19		Yes				
20	Yes		Yes		Yes	
21	Yes					
22	Yes		Yes			
23	Yes	Yes				RETEX
24	Yes	Yes	Yes			
25		Yes				INDAC
26		Yes				
27						
Total	15	12	12	3	3	10

Table 25. Individual internal dose statistics for the last year

Organization	0,1-0,5 (mSv)	0,5-1 (mSv)	1-2 (mSv)	2-5 (mSv)	5-10 (mSv)	10-20 (mSv)	>20 (mSv)
1	10	3	1				
2	1374	100	44	5	0	0	0
3							
4	198	18	8	3	1	0	0
5							
6			1	1			
7		4	2				
8	50	3			5	0	0
9	1						
10							
11		11	1				
12	18	3	0	0	0	0	0
13	3						
14							
15							
16	244	42	25	5	0	0	0
17	6	3	1				
18	0	0	0	0	0	0	0
19	15	15	16	2	0	0	0
20	93	14	6	1	0	0	0
21							
22	0	0	0	0	0	0	0
23							0
24							
25							
26							
27	5						
TOTAL	2017	216	105	17	6	0	0

OMINEX **24.7.2001** **ANNEX 1**

Pre-questionnaire to determine scope of monitoring programme

1. Name : _____ **Organisation :** _____

2. In which format would you prefer to receive the OMINEX questionnaire ?

Word 97 document by e-mail	☐
Wordperfect 8.0 document by e-mail	☐
Text (.txt) file by e-mail	☐
Hard copy by post	☐
Other (specify)	_____

3. Type of Operation **Remarks**

Nuclear power plant	☐
Reprocessing	☐
Fuel fabrication	☐
Decommissioning	☐
Research centre	☐
Non-nuclear industry	☐

4. Type of monitoring

***In vivo* monitoring**	☐
Bioassay (urine, faeces, etc) monitoring	☐
Air sampling	☐

5. Radionuclides Monitored

Fission/Activation products	☐
U	☐
Th	☐
Pu	☐
Am	☐
MOX	☐
Other actinides	☐

6. Does your organisation carry out:

Routine monitoring	☐
Special (incident) monitoring	☐

ANNEX 2

QUESTIONNAIRE ON INTERNAL DOSE MONITORING PROGRAMMES

Instructions for use
Use the right hand SCROLL BAR (or the middle button/wheel on your mouse) to scroll through the document.
Use the PageUp / PageDown keys (or TAB and SHIFT TAB) to move between fields.
Click on the shaded fields to make an entry.
To copy sections of the questionnaire, first open the Forms Toolbar in MS Word (View/Toolbars/Forms), and then click on the Protect Form icon to unlock the form.

OMINEX (**O**ptimisation of **M**onitoring for **In**ternal **Ex**posure) is a 3-year project funded by the European Commission within its 5th Framework Programme. The aim of the project is to develop advice on occupational exposure monitoring programmes. The result should be improvements in the accuracy and reliability of assessed internal doses, better use of available resources, and reduction in costs of monitoring. The project is being carried out by a consortium of research/advisory organisations [NRPB (UK), IPSN (France), STUK (Finland), SCK-CEN (Belgium), CEA (France)] and nuclear industry organisations [EdF (France), TVONS (Finland)]. The UK nuclear industry is also providing a significant input.

With this questionnaire, we aim to collect comprehensive information on current monitoring practice throughout the EU, in the countries that are associated to the EU, and in other countries with significant nuclear power programmes. We hope you will spend some time to complete those parts of the questionnaire that are relevant to your area of work. All information collected will be kept anonymous. The results of the project will be presented at a Training Course that will be held in late-2003. All those contributing to this survey will be provided with information on the Training Course during the final year of the project.

Thank you for you co-operation. Assistance in completing this questionnaire can be obtained from : tua.rahola@stuk.fi
More information on OMINEX can be found at :
http://dbs.cordis.lu/fep/FP5/FP5_PROJl_search.html
or obtained from the Scientific Coordinator :
george.etherington@nrpb.org.uk .

CONTENTS

Note.
You will be sent only those sections that are relevant to your work

SECTION 1, GENERAL

Name: _____
Position: _____
Organisation: _____
Country: _____

Type of Operation		Complete sections :	Remarks
Nuclear power plant	☐	1, A2, 4	
Reprocessing	☐	1, A2, A3, 4	
Fuel fabrication	☐	1, A2, A3, 4	
Decommissioning	☐	1, A2, A3, 4	
Research centre	☐	1, A2, A3, 4	
Non-nuclear industry	☐	1, A2, A3, 4	

Number of workers

Number of classified workers
Number of non-classified workers
Number in category A
Number in category B
Number of permanent staff
Number of contract staff

Use appropriate classification. Category A and B are defined in article 25 of Directive 96/29/EURATOM. Enter " - " if not applicable.

Medical examination for radiation work ?

6-monthly ☐
Annually ☐
Once every two years ☐
Other (specify) ☐

Monitoring Practice

Does your organisation have well-defined, pre-planned arrangements for internal dose monitoring ? ?

If NO, please respond to this questionnaire by providing information on typical monitoring regimes.

Does your organisation sub-contract some of its monitoring to other organisations ? ?

If YES, please describe, and give contact information :

Purposes of monitoring

Is monitoring carried out to assess individual doses for entry onto a legal dose record ? ?

If YES, what is the minimum dose that you aim to assess for this purpose? **mSv**
For which radionuclides does this apply ?

Is monitoring carried out to monitor engineering practices and standards ? ?

If YES, what is the minimum dose that you aim to assess for this purpose? **mSv**
For which radionuclides does this apply?

Is monitoring carried out to reassure individual workers that they are not receiving excessive doses ? ?

If YES, what is the minimum dose that you aim to assess for this purpose ? **mSv**
For which radionuclides does this apply ?

A2. FISSION & ACTIVATION PRODUCTS

Radionuclide	Monitored ? (Y/N)	Chemical Form or Compound	Assumed Absorption Type[1]	Assumed AMAD[2] (μm)
^{60}Co	?			
^{137}Cs	?			
^{125}I	?			
^{131}I	?			
^{3}H	?			
^{14}C	?			
^{32}P	?			
^{35}S	?			
^{90}Sr/^{90}Y	?			
Other (specify)	? ? ?			

1. F, M or S (or D, W, or Y), or enter specific parameter values (eg f_r, s_r, s_s) if used
2. *AMAD – Activity Median Aerodynamic Diameter*

What (if any) assumptions are made about the absorption of ultrafine or soluble components of these materials ?

Primary monitoring method(s) used to determine doses entered onto formal dose record
(eg. PAS, lung monitoring, urine, faeces, etc.)

Radionuclide	**Monitoring method(s)**	
	Routine monitoring	Incident (special) monitoring
^{60}Co		
^{137}Cs		
^{125}I		
^{131}I		
^{3}H		
^{14}C		
^{32}P		
^{35}S		
^{90}Sr/^{90}Y		
Other (specify)		

Note. If different techniques are used depending on magnitude of dose, please give this information in the table

A2. FISSION & ACTIVATION PRODUCTS
A2.1 ROUTINE MONITORING

Purposes of routine monitoring

Is routine monitoring carried out :

To assess individual doses for entry onto a legal dose record ? **?**

To trigger special investigations or monitoring ? **?**

A2. FISSION & ACTIVATION PRODUCTS
A2.1 ROUTINE MONITORING
A2.1.1 DIRECT (*IN VIVO*) MONITORING

Number of persons measured each year

- ☐ **none**
- ☐ **< 20**
- ☐ **20 -50**
- ☐ **50 -100**
- ☐ **100 -200**
- ☐ **200 -500**
- ☐ **500-1000**
- ☐ **>1000**

Criteria for selecting individuals for monitoring

Anticipated/possible that dose could exceed	*** mSv/year**	☐
Reassurance that dose does not exceed	*** mSv/year**	☐
Work with monitored radionuclide exceeds	*** % of work time**	☐
Specific risk assessment (eg related to activity or containment levels)		☐
Other (specify)		

*** Enter as appropriate**

All meeting these criteria	☐
Representatives from working groups	☐
Random selection	☐

WHOLE BODY ?

			Minimum detectable activity
Radionuclides monitored	**^{60}Co**	☐	**Bq**
	^{137}Cs	☐	**Bq**
	^{90}Sr/^{90}Y	☐	**Bq**
	gross gamma	☐	**Bq**
Other (specify)		☐	**Bq**

Preparation of person for *in vivo* measurement ?

		Only if :
Shower	☐	☐
Wear clean clothing	☐	☐

		Number of measurements
Weekly	☐	
Monthly	☐	
3-monthly	☐	
6-monthly	☐	
Annually	☐	
Other (specify)	☐	

Efficiency calibration method

Provided by manufacturer	☐
Phantom	☐
Numeric phantom	☐
Other (specify)	☐

THYROID ?

^{131}I ☐

Minimum detectable activity
Bq
Number of measurements

Weekly	☐
Monthly	☐
3-monthly	☐
6-monthly	☐
Annually	☐
Other (specify)	☐

Efficiency calibration method

Provided by manufacturer	☐
Phantom	☐
Numeric phantom	☐
Other (specify)	☐

PORTAL MONITOR ?

Minimum detectable activity
Bq
Number monitored each year

entrance	☐
exit	☐

Efficiency calibration method

Provided by manufacturer	☐
Phantom	☐
Numeric phantom	☐
Other (specify)	☐

A2.	**FISSION & ACTIVATION PRODUCTS**
A2.1	**ROUTINE MONITORING**
A2.1.2	**INDIRECT (BIOASSAY) MONITORING**

Number of persons measured each year

none	☐
< 20	☐
20 -50	☐
50 -100	☐
100 -200	☐
200 -500	☐
500-1000	☐
>1000	☐

Criteria for selecting individuals for monitoring

Anticipated/possible that dose could exceed	*** mSv/year**	☐
Reassurance that dose does not exceed	*** mSv/year**	☐
Work with monitored radionuclide exceeds	*** % of work time**	☐
Specific risk assessment (eg related to activity or containment levels)		☐
Other (specify)		

**** Enter as appropriate***

All meeting these criteria	☐
Representatives from working groups	☐
Random selection	☐

SAMPLING

Urine samples: Fission and Activation Products	**?**	
Fixed volume ?	☐	
Variable volume (eg single voiding) ?	☐	**Volume =**
Normalised to 24 h by creatinine content ?	☐	
Normalised to 24 h by volume ?	☐	
Total collection of 24-hour sample ?	☐	
Urine samples taken over * days and bulked together ?	☐	
Other sampling protocol (specify)		

Faecal samples: Fission and Activation Products	**?**
Single voiding ?	☐
Total collection for 24 hours	☐
Samples taken over * days and bulked together ?	☐
Other sampling protocol (specify)	

Sampling at WORK ONLY ☐
HOME ONLY ☐
or HOME+WORK ☐

**** Enter value***

MONITORING

Minimum detectable activity

For urine sampling interval, enter U in box
For faecal sampling interval, enter F in box

Minimum detectable activity

^{90}Sr/^{90}Y in urine	**?**	**Bq/d**
^{90}Sr/^{90}Y in faeces	**?**	**Bq/d**

Number of measurements

Weekly
Monthly
3-monthly
6-monthly
Annually
Other (specify)

For urine sampling interval, enter U in box
For faecal sampling interval, enter F in box

Minimum detectable activity

gross beta, urine	**?**	**Bq/d**
gross beta, faeces	**?**	**Bq/d**
gross gamma, urine	**?**	**Bq/d**
gross gamma, faeces	**?**	**Bq/d**

Number of measurements

Weekly
Monthly
3-monthly
6-monthly
Annually
Other (specify)

For urine sampling interval, enter U in box
For faecal sampling interval, enter F in box

Minimum detectable activity

Other (specify)	**?**	**Bq/d**

Number of measurements

Weekly	☐
Monthly	☐
3-monthly	☐
6-monthly	☐
Annually	☐
Other (specify)	☐

A2. FISSION & ACTIVATION PRODUCTS
A2.2 INCIDENT (SPECIAL) MONITORING

This section only requests information that is specific to incident monitoring. Please ensure that the previous section (A2.1) is completed as fully as possible.

Number of persons monitored during each of the last 5 years

in 1996
in 1997
in 1998
in 1999
in 2000

Screening methods and indicators used to initiate internal monitoring :

Are the investigation levels (used to trigger/initiate follow-up monitoring) associated with a dose level ? **?**

Dose Investigation level :

mSv
% of ALI

Radio-nuclide	**Investigation Levels / units** (eg nose blow activity / Bq)						
	Screening method						
	SAS	PAS	Nose blow / nasal smear	Whole body or lung counting	Portal monitor	Urine	Faeces
^{60}Co							
^{137}Cs							
^{125}I							
^{131}I							
^{3}H							
^{14}C							
^{32}P							
^{35}S							
^{90}Sr/^{90}Y							
Other							
Units							

Note. If the investigation level is any measurement above the minimum detectable amount (however defined), enter **"> MDA"**

Other criteria used to trigger follow-up monitoring (eg a particular event) ?

Procedure after investigation level exceeded?

Intervention level

mSv
% of ALI

Procedure after intervention level exceeded (eg medical intervention)?

Remarks

Follow up monitoring

Radio-nuclide	Follow up monitoring				
	Monitoring method(s)	Measurements made on : (days after intake) (eg day 1, 3, 5, 30)	OR	No. of measure-ments	Start/end (days after intake) (eg day 1 to day 60)
^{60}Co					
^{137}Cs					
^{125}I					
^{131}I					
^{3}H					
^{14}C					
^{32}P					
^{35}S					
^{90}Sr/^{90}Y					
Other					

Note : If necessary, give typical values

A3. ACTINIDES

Actinides Monitored

U	☐	**Complete A3.1**
Th	☐	**Complete A3.2**
Pu	☐	**Complete A3.3**
Am	☐	**Complete A3.4**
MOX	☐	**Complete A3.5**

Other ☐ **Complete** A3.6

A3.1 URANIUM

Chemical Compound	Assumed AMAD (μm)	Assumed Absorption Type (F,M,S) (or Inhalation Class, D,W,Y)	OR	Absorption parameters used (f_r, s_r, s_s, f_b, s_b)
Ammonium diuranate (ADU)				
Uranyl nitrate				
Uranium peroxide				
Uranium tributyl phosphate				
UO_2F_2				
UF_4				
UF_6				
UO_3				
U_3O_8				
UO_2				
metallic U				
Other (specify)				
Unknown				

What (if any) assumptions are made about the absorption of ultrafine or soluble components of these materials ?

Chemical Compound	Natural ? (Y/N)	Depleted ? (Y/N)	Enriched ?		
			< 3.5 wt%	3.5 – 50 wt%	> 50 wt%
Ammonium diuranate (ADU)	?	?	?	?	?
Uranyl nitrate	?	?	?	?	?
Uranium peroxide	?	?	?	?	?
Uranium tributyl phos-phate	?	?	?	?	?
UO_2F_2	?	?	?	?	?
UF_4	?	?	?	?	?
UF_6	?	?	?	?	?
UO_3	?	?	?	?	?
U_3O_8	?	?	?	?	?
UO_2	?	?	?	?	?
metallic U	?	?	?	?	?
Other (specify)	?	?	?	?	?
Unknown	?	?	?	?	?

Primary monitoring method(s) used to determine doses entered onto formal dose record
(eg. PAS, lung monitoring, urine, faeces, etc.)

Chemical Compound	Monitoring method(s)	
	Routine monitoring	Incident (special) monitoring
Ammonium diuranate (ADU)		
Uranyl nitrate		
Uranium peroxide		
Uranium tributyl phos-phate		
UO_2F_2		
UF_4		
UF_6		
UO_3		
U_3O_8		
UO_2		
metallic U		
Other (specify)		
Unknown		

Note. If different techniques are used depending on magnitude of dose, please give this information in the table

A3.1 URANIUM
A3.1.1 ROUTINE MONITORING

Purposes of routine monitoring

Is routine monitoring carried out :

To assess individual doses for entry onto a legal dose record ? ?

To trigger special investigations or monitoring ? ?

Note : If necessary, duplicate the following sections and complete separately for each material.

A3.1	**URANIUM**
A3.1.1	**ROUTINE MONITORING**
A3.1.1.1	**DIRECT (*IN VIVO*) MONITORING**

Number of persons measured each year

- **none** ☐
- **< 20** ☐
- **20 -50** ☐
- **50 -100** ☐
- **100 -200** ☐
- **200 -500** ☐
- **500-1000** ☐
- **>1000** ☐

Criteria for selecting individuals for monitoring

- **Anticipated/possible that dose could exceed * mSv/year** ☐
- **Reassurance that dose does not exceed * mSv/year** ☐
- **Work with monitored radionuclide exceeds * % of work time** ☐
- **Specific risk assessment (eg related to activity or containment levels)** ☐
- **Other (specify)**

*** Enter as appropriate**

- **All meeting these criteria** ☐
- **Representatives from working groups** ☐
- **Random selection** ☐

LUNG ?

Minimum detectable activity
Bq ^{235}U
Bq ^{238}U
Number of measurements

Weekly	☐
Monthly	☐
3-monthly	☐
6-monthly	☐
Annually	☐
Other (specify)	☐

Efficiency calibration method

Provided by manufacturer	☐
Phantom	☐
Numeric phantom	☐
Other (specify)	☐

A3.1 URANIUM
A3.1.1 ROUTINE MONITORING
A3.1.1.2 INDIRECT (BIOASSAY) MONITORING

Number of persons measured each year

none	☐
< 20	☐
20 -50	☐
50 -100	☐
100 -200	☐
200 -500	☐
500-1000	☐
>1000	☐

Criteria for selecting individuals for monitoring

Anticipated/possible that dose could exceed	*** mSv/year**	☐
Reassurance that dose does not exceed	*** mSv/year**	☐
Work with monitored radionuclide exceeds	*** % of work time**	☐
Specific risk assessment (eg related to activity or containment levels)		☐
Other (specify)		

** Enter as appropriate*

All meeting these criteria	☐
Representatives from working groups	☐
Random selection	☐

Measurements

Total uranium ? ☐
Measurement technique (eg gross alpha)?
Isotope specific ? ☐

URINE MONITORING **?**

Minimum detectable activity
Bq/d (^{234}U)
Bq/d (^{235}U)
Bq/d (^{238}U)
OR
nanogram/d (total U)

Urine samples

Fixed volume ? ☐ **Volume =**
Variable volume (eg single voiding) ? ☐
Normalised to 24 h by creatinine content ? ☐
Normalised to 24 h by volume ? ☐
Total collection of 24-hour sample ? ☐
Urine samples taken over * days and bulked together ? ☐
Other sampling protocol (specify)

Sampling at WORK ONLY ☐
HOME ONLY ☐
or HOME+WORK ☐

**** Enter value***

Number of measurements

Weekly ☐
Monthly ☐
3-monthly ☐
6-monthly ☐
Annually ☐
Other (specify) ☐

FAECAL MONITORING **?**

Minimum detectable activity
Bq/d (^{234}U)
Bq/d (^{235}U)
Bq/d (^{238}U)
OR
nanogram/d (total U)

Faecal samples

Single voiding ? ☐
Total collection for 24 hours ☐
Samples taken over * days and bulked together? ☐
Other sampling protocol (specify)

Sampling at WORK ONLY ☐

HOME ONLY ☐
or HOME+WORK ☐

**** Enter value***

Number of measurements

Weekly	☐
Monthly	☐
3-monthly	☐
6-monthly	☐
Annually	☐
Other (specify)	☐

A3.1	**URANIUM**
A3.1.1	**ROUTINE MONITORING**
A3.1.1.3	**PERSONAL AIR SAMPLING**

Number of persons measured each year

none	☐
< 20	☐
20 -50	☐
50 -100	☐
100 -200	☐
200 -500	☐
500-1000	☐
>1000	☐

Criteria for selecting individuals for monitoring

Anticipated/possible that dose could exceed	*** mSv/year**	☐
Reassurance that dose does not exceed	*** mSv/year**	☐
Work with monitored radionuclide exceeds	*** % of work time**	☐
Specific risk assessment (eg related to activity or containment levels)		☐
Other (specify)		

**** Enter as appropriate***

All meeting these criteria	☐
Representatives from working groups	☐
Random selection	☐

PERSONAL AIR SAMPLING ?

Minimum detectable activity
Bq (total U)
OR
Bq/d (^{235}U)
Bq/d (^{238}U)

Number of measurements

Daily ☐
Weekly ☐
Monthly ☐
Other (specify) ☐

Information on PAS programme :
Sampler type
Is the TOTAL or the RESPIRABLE fraction measured?
Flow rate
Assumed breathing rates

Protection factors when Personal Protective Equipment (PPE) used
Type of PPE **Protection factor**

Measurement : **GROSS ALPHA** ☐
or SPECTROMETRIC ☐

Are PAS results used for individual dose assessments ? **?**
Are PAS samples bulked together before measurement ? **?**
If so how many, or over what time period ?

STATIC AIR SAMPLING **?**

Minimum detectable activity
Bq (total U)
OR
Bq/d (^{235}U)
Bq/d (^{238}U)

Number of measurements

Daily ☐
Weekly ☐
Monthly ☐
Other (specify) ☐

Information on SAS programme :

Sampler type
Flow rate
Assumed breathing rates
Measurement : GROSS ALPHA ☐
or SPECTROMETRIC ☐
Are SAS results used for individual dose assessments ? ?
If so, is a fixed PAS/SAS ratio assumed ? ?
PAS:SAS ratio

A3.1	**URANIUM**
A3.1.1	**ROUTINE MONITORING**
A3.1.1.4	**COMBINATION OF MONITORING METHODS**

If a combination of monitoring methods is used, please explain briefly how the monitoring programme is organised (For example "Daily PAS samples are taken, and 24-hour urine samples are taken for the same individuals every 3 months") :

A3.1	**URANIUM**
A3.1.2	**INCIDENT (SPECIAL) MONITORING**

This section only requests information that is specific to incident monitoring. Please ensure that the previous section (A3.1.1) is completed as fully as possible.

Number of persons monitored during the last year
Screening methods and indicators used to initiate internal monitoring :
Are the investigation levels (used to trigger/initiate follow-up monitoring) associated with a dose level ? ?

Dose investigation level : **mSv**
% of ALI

Uranium compound	**Investigation Levels / units** (eg nose blow activity / Bq)						
	Screening method						
	SAS	PAS	Nose blow / nasal smear	Lung Counting	Portal monitor	Urine	Faeces
Ammonium diuranate (ADU)							
Uranyl nitrate							
Uranium peroxide							
Uranium tributyl phosphate							
UO_2F_2							
UF_4							
UF_6							
UO_3							
U_3O_8							
UO_2							
metallic U							
Other (specify)							
Unknown							
Units							

Note. If the investigation level is any measurement above the minimum detectable amount (however defined), enter **"> MDA"**

Other criteria used to trigger follow-up monitoring (eg a particular event) ?

Procedure after investigation level exceeded?

Intervention level

mSv
% of ALI

Procedure after intervention level exceeded (eg medical intervention) ?

Remarks

Follow up monitoring

Uranium compound	**Follow up monitoring**				
	Monitoring method(s)	Measurements made on : (days after intake) (eg day 1, 3, 5, 30)	OR	No. of measure-ments	Start/end (days after intake) (eg day 1 to day 60)
Ammonium diuranate (ADU)					
Uranyl nitrate					
Uranium peroxide					
Uranium tributyl phos-phate					
UO_2F_2					
UF_4					
UF_6					
UO_3					
U_3O_8					
UO_2					
metallic U					
Other (specify)					
Unknown					

Note : If necessary, give typical values.

A3.3 PLUTONIUM

Chemical Compound	Assumed AMAD (μm)	Assumed Absorption Type (F,M,S) (or Inhalation Class, D,W,Y)	OR	Absorption parameters used (f_r, s_r, s_s, f_b, s_b)
PuO_2				
$Pu(NO_3)_4$ (pure)				
$Pu(NO_3)_4$ (+ corrosion products)				
Other (specify)				
Unknown				

What (if any) assumptions are made about the absorption of ultrafine or soluble components of these materials ?

Chemical Compound	^{238}Pu (Y/N)	^{239,240}Pu (Y/N)	^{241}Pu (Y/N)	^{238,239,240}Pu : ^{241}Am ratio	^{238,239,240}Pu : ^{241}Pu ratio
PuO_2	?	?	?		
$Pu(NO_3)_4$ (pure)	?	?	?		
$Pu(NO_3)_4$ (+ corrosion products)	?	?	?		
Other (specify)	?	?	?		
Unknown	?	?	?		

Primary monitoring method(s) used to determine doses entered onto formal dose record
(eg. PAS, lung monitoring, urine, faeces, etc.)

Chemical Compound	Monitoring method(s)	
	Routine monitoring	Incident (special) monitoring
PuO_2		
$Pu(NO_3)_4$ (pure)		
$Pu(NO_3)_4$ (+ corrosion products)		
Other (specify)		
Unknown		

Note. If different techniques are used depending on magnitude of dose, please give this information in the table

A3.3 PLUTONIUM
A3.3.1 ROUTINE MONITORING

Purposes of routine monitoring

Is routine monitoring carried out :

To assess individual doses for entry onto a legal dose record ? **?**

To trigger special investigations or monitoring ? **?**

Note : If necessary, duplicate the following sections and complete separately for each material

A3.3 PLUTONIUM
A3.3.1 ROUTINE MONITORING
A3.3.1.1 DIRECT (*IN VIVO*) MONITORING

Number of persons measured each year

none ☐
< 20 ☐
20 -50 ☐
50 -100 ☐
100 -200 ☐
200 -500 ☐
500-1000 ☐
>1000 ☐

Criteria for selecting individuals for monitoring

Anticipated/possible that dose could exceed	*** mSv/year**	☐
Reassurance that dose does not exceed	*** mSv/year**	☐
Work with monitored radionuclide exceeds	*** % of work time**	☐
Specific risk assessment (eg related to activity or containment levels)		☐
Other (specify)		

**** Enter as appropriate***

All meeting these criteria	☐
Representatives from working groups	☐
Random selection	☐

LUNG ?

Minimum detectable activity
Bq ^{238}Pu
Bq ^{239,240}Pu

Are ^{241}Am measurements performed to assess Pu lung content ? ?

Bq ^{241}Am

Number of measurements

Weekly	☐
Monthly	☐
3-monthly	☐
6-monthly	☐
Annually	☐
Other (specify)	☐

Efficiency calibration method

Provided by manufacturer	☐
Phantom	☐
Numeric phantom	☐
Other (specify)	☐

A3.3	**PLUTONIUM**
A3.3.1	**ROUTINE MONITORING**
A3.3.1.2	**INDIRECT (BIOASSAY) MONITORING**

Number of persons measured each year

none	☐
< 20	☐
20 -50	☐
50 -100	☐
100 -200	☐
200 -500	☐
500-1000	☐
>1000	☐

Criteria for selecting individuals for monitoring

Anticipated/possible that dose could exceed	*** mSv/year**	☐
Reassurance that dose does not exceed	*** mSv/year**	☐
Work with monitored radionuclide exceeds	*** % of work time**	☐
Specific risk assessment (eg related to activity or containment levels)		☐
Other (specify)		

**** Enter as appropriate***

All meeting these criteria	☐
Representatives from working groups	☐
Random selection	☐

URINE MONITORING **?**

Minimum detectable activity
Bq/d (^{238}Pu)
Bq/d (^{239,240}Pu)

Urine samples

Fixed volume ?	☐	**Volume =**
Variable volume (eg single voiding) ?	☐	
Normalised to 24 h by creatinine content ?	☐	
Normalised to 24 h by volume ?	☐	
Total collection of 24-hour sample ?	☐	
Urine samples taken over * days and bulked together ?	☐	
Other sampling protocol (specify)		

Sampling at WORK ONLY	☐
HOME ONLY	☐
or HOME+WORK	☐

**** Enter value***

Number of measurements

Weekly	☐
Monthly	☐
3-monthly	☐
6-monthly	☐
Annually	☐
Other (specify)	☐

FAECAL MONITORING ?

Minimum detectable activity
Bq/d (^{238}Pu)
Bq/d (^{239,240}Pu)

Faecal samples

Single voiding? ☐
Total collection for 24 hours ☐
Samples taken over * days and bulked together ? ☐
Other sampling protocol (specify)

Sampling at WORK ONLY ☐
HOME ONLY ☐
or HOME+WORK ☐

**** Enter value***

Number of measurements

Weekly	☐
Monthly	☐
3-monthly	☐
6-monthly	☐
Annually	☐
Other (specify)	☐

A3.3	**PLUTONIUM**
A3.3.1	**ROUTINE MONITORING**
A3.3.1.3	**PERSONAL AIR SAMPLING**

Number of persons measured each year

none	☐
< 20	☐
20 -50	☐
50 -100	☐
100 -200	☐
200 -500	☐
500-1000	☐
>1000	☐

Criteria for selecting individuals for monitoring

Anticipated*/possible* that dose could exceed	*** mSv/year**	☐
Reassurance that dose does not exceed	*** mSv/year**	☐
Work with monitored radionuclide exceeds	*** % of work time**	☐
Specific risk assessment (eg related to activity or containment levels)		☐
Other (specify)		

*** Delete / enter as appropriate**

All meeting these criteria	☐
Representatives from working groups	☐
Random selection	☐

PERSONAL AIR SAMPLING ?

Minimum detectable intake
Bq (Pu-alpha)
OR
Bq (^{238}Pu)
Bq (^{239,240}Pu)

Number of measurements

- **Daily** ☐
- **Weekly** ☐
- **Monthly** ☐
- **Other (specify)** ☐

Information on PAS programme :
- **Sampler type**
- **Is the TOTAL or the RESPIRABLE fraction measured?**
- **Flow rate**
- **Assumed breathing rates**

Measurement : **GROSS ALPHA** ☐ **or SPECTROMETRIC** ☐

Are PAS results used for individual dose assessments ? ?
Are PAS samples bulked together before measurement ? ?
If so how many, or over what time period ?

Protection factors when Personal Protective Equipment (PPE) used

Type of PPE	Protection factor

STATIC AIR SAMPLING ?

Minimum detectable intake
Bq (Pu-alpha)
OR
Bq (^{238}Pu)
Bq (^{239,240}Pu)

Number of measurements

- **Daily** ☐
- **Weekly** ☐
- **Monthly** ☐
- **Other (specify)** ☐

Information on SAS programme :

Sampler type
Flow rate
Assumed breathing rates
Measurement : GROSS ALPHA ☐
or SPECTROMETRIC ☐
Are SAS results used for individual dose assessments ? ?
If so, is a fixed PAS/SAS ratio assumed ? ?
PAS:SAS ratio

A3.3	**PLUTONIUM**
A3.3.1	**ROUTINE MONITORING**
A3.3.1.4	**COMBINATION OF MONITORING METHODS**

If a combination of monitoring methods is used, please explain briefly how the monitoring programme is organised (For example "Daily PAS samples are taken, and 24-hour urine samples are taken for the same individuals every 3 months") :

A3.3	**PLUTONIUM**
A3.3.2	**INCIDENT (SPECIAL) MONITORING**

This section only requests information that is specific to incident monitoring. Please ensure that the previous section (A3.3.1) is completed as fully as possible.

Number of persons monitored during each of the last 5 years
in 1996
in 1997
in 1998
in 1999
in 2000

Screening methods and indicators used to initiate internal monitoring :

Are the investigation levels (used to trigger/initiate follow-up monitoring) associated with a dose level ? ?

Dose Investigation level :

mSv
% of ALI

Chemical compound	**Investigation Levels / units** (eg nose blow activity / Bq)						
	Screening method						
	SAS	PAS	Nose blow / nasal smear	Lung Counting	Portal monitor	Urine	Faeces
PuO_2							
$Pu(NO_3)_4$ (pure)							
$Pu(NO_3)_4$ (+corrosion products)							
Other (specify)							
Unknown							
Units							

Note. If the investigation level is any measurement above the minimum detectable amount (however defined), enter **"> MDA"**

Other criteria used to trigger follow-up monitoring (eg a particular event) ?

Procedure after investigation level exceeded?

Intervention level

mSv
% of ALI

Procedure after intervention level exceeded (eg medical intervention) ?

Remarks

Follow up monitoring

Chemical compound	Follow up monitoring				
	Monitoring method(s)	Measurements made on : (days after intake) (eg day 1, 3, 5, 30)	OR	No. of measure-ments	Start/end (days after intake) (eg day 1 to day 60)
PuO_2					
$Pu(NO_3)_4$ (pure)					
$Pu(NO_3)_4$ (+corrosion products)					
Other (specify)					
Unknown					

Note : If necessary, give typical values.

Note : If necessary, give typical values

A3.6 OTHER ACTINIDES

Please duplicate section A3.6 if necessary

Radionuclide	Chemical Compound	Assumed AMAD (μm)	Assumed Absorption Type (F,M,S) (or Inhalation Class, D,W,Y)	OR	Absorption parameters used (f_r, s_r, s_s, f_b, s_b)
	Unknown				

What (if any) assumptions are made about the absorption of ultrafine or soluble components of these materials ?

Radionuclide	Chemical Compound	Fixed isotopic ratio ? (Y/N)	… with which radionuclide? (eg $^{nnn}??$: ^{239}Pu)	Ratio
		?		
		?		
		?		
		?		
	Unknown	?		

Primary monitoring method(s) used to determine doses entered onto formal dose record
(eg. PAS, lung monitoring, urine, faeces, etc.)

Radionuclide	Chemical Compound	Monitoring method(s)	
		Routine monitoring	Incident (special) monitoring
	Unknown		

Note. If different techniques are used depending on magnitude of dose, please give this information in the table.

A3.6 OTHER ACTINIDES
A3.6.1 ROUTINE MONITORING

IS THE ROUTINE MONITORING PROGRAMME FOR THIS ACTINIDE IDENTICAL TO THAT FOR ONE OF THE ACTINIDES SPECIFIED IN SECTIONS A3.1, A3.2, A3.3, A3.4, OR A3.5 ?

?

If YES, specify actinide :
check that A3.*x* is completed fully, and then go to A3.6.2

If NO, we will contact you to request further information

A3.6	OTHER ACTINIDES
A3.6.2	INCIDENT (SPECIAL) MONITORING

IS THE INCIDENT MONITORING PROGRAMME FOR THIS ACTINIDE IDENTICAL TO THAT FOR ONE OF THE ACTINIDES SPECIFIED IN SECTIONS A3.1, A3.2, A3.3, A3.4, OR A3.5 ?

?

If YES, specify actinide :
and check that A3.x.2 is completed fully.

If NO, we will contact you to request further information

SECTION 4	DOSE ASSESSMENT AND DOSE STATISTICS

Method

Manual calculation	☐
Own software	☐
LUDEP	☐
CINDY	☐
IMBA	☐
Other (specify)	☐

Routine Monitoring: Intake assumptions

Single acute intake at mid-point of monitoring interval	☐
Continuous chronic intake	☐
"Best fit" to monitoring data	☐
Other (specify below)	☐

Is contribution from previous intakes subtracted ? ?

Individual internal dose statistics for the last year (to)

Range (mSv)	Number in range
low doses possible, but not assessed	
0.1 - 0.5	
0.5 - 1	
1 - 2	
2 - 5	
5 - 10	
10 - 20	
> 20	

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STUK-A186 Ammann M, Sinkko K, Kostiainen E, Salo A, Liskola K, Hämäläinen R P, Mustajoki J. Decision analysis of countermeasures for the milk pathway after an accidental release of radionuclides. Helsinki 2001.

STUK-A185 Sinkko K, Ammann M, Kostiainen E, Salo A, Liskola K, Hämäläinen R P, Mustajoki J. Maitotuotteisiin kohdistuvat vastatoimenpiteet ydinonnettomuustilanteessa. Helsinki 2001.

A full list of publica-tions is available from

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