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Assessment of Internal Doses in Emergency Situations

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Abstract

The need for assessing internal radiation doses in emergency situations was demonstrated after accidents in Brasil, Ukraina and other countries. Lately more and more concern has been expressed regarding malevolent use of radiation and radioactive materials. The scenarios for such use are more difficult to predict than for nuclear power plant or weapons accidents. Much of the results of the work done in the IRADES project can be adopted for use in various accidental situations involving radionuclides that are not addressed in this report. If an emergency situation occurs in only one or a few of the Nordic countries, experts from the other countries could be called upon to assist in monitoring. A big advantage is then our common platform.

In the Nordic countries much work has been put down on quality assurance of measurements and on training of dose asessment calculations. Attention to this was addressed at the internal dosimetry course in October 2005. Nordic emergency preparedness exercises have so far not included training of direct measurements of people in the early phase of an emergency. The aim of the IRADES project was to improve the preparedness especially for thyroid measurements.

The modest financial support did not enable the participants to make big efforts but certainly acted as a much appreciated reminder of the importance of being prepared also to handle situations with malevolent use of radioactive materials. It was left to each country to decide to which extent to improve the practical skills. There is still a need for detailed national implementation plans. Measurement strategies need to be developed in each country separately taking into account national regulations, local circumstances and resources. End users of the IRADES report are the radiation protection authorities.

Key words

Internal radiation doses, thyroid monitoring, emergency preparedness

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Summary

The need for assessing internal radiation doses in emergency situations was demonstrated after accidents in Brasil, Ukraina and other countries. Studies in Ukraine, Belarussia and the southern parts of Russia after the Chernobyl accident showed an unexpected increase of thyroid cancers in children and young people. Lately more and more concern has been expressed regarding malevolent use of radiation and radioactive materials. The scenarios for such use are more difficult to predict than for nuclear power plant or weapons accidents. Much of the results of the work done in the IRADES project can be adopted for use in various accidental situations involving radionuclides that are not addressed in this report. If an emergency situation occurs in only one or a few of the Nordic countries, experts from the other countries could be called upon to assist in monitoring. A big advantage would then be our common platform.

Most Nordic laboratories doing direct measurements of people participated in earlier NKS projects. A good network of Nordic specialists has been created. In the next few years one generation of radiation safety experts is retiring and will be replaced by a new one with less experience. The project aimed at building up competence and to maintain it among the participants.

In parallell with the NKS-B project NKS-BOK-2.1.2 the five Nordic radiation protection authorities funded the phantoms to be used for calibrations and intercomparisons. These phantoms were used for efficiency calibrations and for validation of quality in the intercomparison excercise. In the earlier project NKS-BOK-2.1.2 a handbook (in Swedish) was prepared. The experience from this project was useful in the IRADES project. The outcome of the IRADES project will also feed into EU funded projects on emergency preparedness like EURANOS (2004-2008) and TMT-handbook, in which work will start in 2006.

In the Nordic countries much work has been put down on quality assurance of measurements and on training of dose asessment calculations. Attention to this was addressed at the internal dosimetry course in Tartu, Estonia in October 2005. Nordic emergency preparedness exercises have not so far included training of direct measurements of people in the early phase of an emergency. The aim of the IRADES project was to improve the preparedness especially for thyroid measurements. These should be done as soon as possible after an alert to give support for decision making and to reassure the general public. The monitoring of I-131 is a standard procedure in radiation laboratories, yet the monitoring of people is not routine work. The aim of IRADES is to improve the situation especially for thyroid measurements which should be done as soon as possible after an alert to give support for decision making.

The modest financial support did not enable the participants to make big efforts but certainly acted as a much appreciated reminder of the importance of being prepared also to handle situations with malevolent use of radioactive materials. It was left to each country to decide to which extent to improve the practical skills.
There is still a need for national implementation plans. More detailed measurement strategies need to be developed in each country separately taking into account national regulations, local circumstances and resources. End users of the IRADES report are the radiation protection authorities.

In view of the close contact between people in the Nordic countries, it is very important to have the same approach/procedure in all countries. This will increase the public reassurance in case of a nuclear emergency situation.

1. Available instruments for thyroid measurements

1.1 Introduction
The Nordic laboratories with altogether 19 whole-body counter systems build the platform of expertise needed to create networks with people trained to use certain monitors when the need arises. These laboratories cannot alone handle rapid measurements of big population groups. In all Nordic countries there are hospitals with Nuclear Medicine Departments. These are equipped with thyroid monitors. The two countries Finland and Sweden with nuclear power plants have naturally most interest in developing their preparedness. This report gives therefore more detailed information on the situation in Finland and Sweden than in the other countries. All countries also participated in the NKS-B-BOK-2.1.2 project. The report from this project includes a handbook giving practical advice: Report NKS-BOK-2.1.2 “Mätning av radioaktiva ämnen i människa i beredskapssituationer. En metodhandbok vid jod och cesium-kontaminering”, see Annex 2.

1.2 Iodine prophylaxis
To gain most from the thyroid measurements the procedure should be started without delay. Direct measurements give individual results and results for groups. An important protective measure is to administer stable iodine in case of exposure to radioactive iodine nuclides. But the protective effect is strongly dependent on time of administration. The effect decreases if the tablet is administered too early or too late. In an expected fallout situation the iodine tablet should preferably be taken 1-6 hours before exposure. For example 50 mg potassium iodide (KI) given 30 minutes after exposure to ^{131}I decreases the dose to the thyroid to six percent of the dose without KI administration. When more than 12 hours has elapsed since the exposure, intake of stable iodine no longer decreases the radiation dose to the thyroid. The iodine tablet is not any “wonderdrug” which would totally prevent any harmful effects on health.

1.3 Details on available instruments
The inventory shows that there are many instruments that could be used especially for thyroid measurements in emergency situations. Some of them would naturally be needed for other measurements. Most of them are not gamma spectrometers but single channel instruments. At hospitals there are instruments for uptake

measurements of I-131 in the thyroid which could easily be used in emergency situations. Some of the instruments are calibrated for ^{131}I others have to be calibrated. The most sophisticated systems are whole-body counters with Ge-detectors and scanning options. In Denmark there are two whole-body counting laboratories, in Finland two, in Norway four and in Sweden twelve. Whole-body counters are however not suitable for rapid measurements of large groups of people. Gammacameras are better suited for whole-body than for thyroid measurements. Whole-body measurements can also be done with the same simple instruments mainly used for thyroid measurements. There are many instruments of gamma spectrometric type available and those can be used for measuring other radionuclides than radioiodine. The malevolant actions will come as surprices for the authorities but even so the response must be rapid. Details about the situation in the different Nordic countries are given below.

1.3.1 Denmark

In Denmark there are two whole-body counters, one at Risö and one at SIS for direct measurements of people. No detailed information has been obtained on the available monitors at hospitals. Also the number of handheld instruments is unknown.

1.3.2 Finland

In Finland there are two whole-body counters at STUK, one stationary and the other mobile installed in a truck. At the University of Helsinki there are also one stationary and one mobile unit for whole-body counting but these two are not used routinely.

Finland is divided into 20 health care districts and the 21st district is the Åland islands in the west. The map in figure 1 shows the districts and the location of the hospitals mainly responsible for actions in special situations. Five of these hospitals are university central hospitals and the rest regional central hospitals. At 27 hospitals there are monitors for I-131 uptake measurements of the thyroid. Most of those monitors show count rates and are not calibrated for content of iodine. The hospitals also have gamma cameras but they are better suited for whole-body than for thyroid monitoring. More information on that can be found in the BOK-2.1.2 report in Annex 2 .

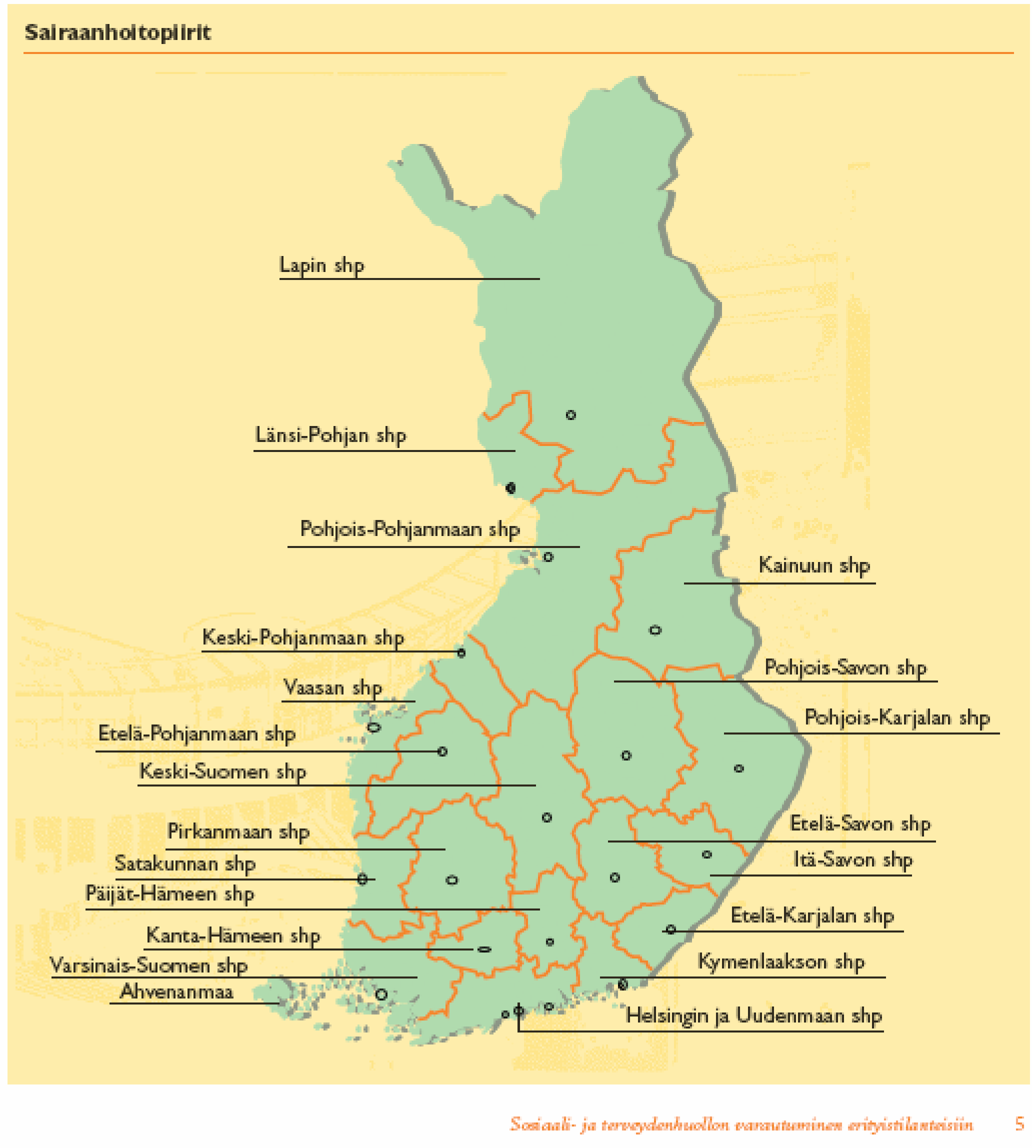

Figure 1. Locations of university and regional central hospitals in Finland.

STUK as the responsible body for radiological emergency preparedness has lately obtained 35 thyroid monitors intended for direct measurements in emergency situations and also five so called lap geometry monitors for whole-body monitoring. All of these are gammaspectrometers and can be used for detection of gammaradiation from 50 to 3000 keV. Ten are of type Inspector 1000 by Canberra and the rest are made in Belarussia by company Atomtek. Fifteen to twenty of these thyroid monitors will be distributed to university and regional hospitals to be used at Nuclear Medicine Departments by physicists that are familiar with this type of equipment. The users will be part of an emergency network and they will be trained at STUK. A more detailed description of the instruments are given in annex 2. At about 20 research and university laboratories there are efficiency calibrated thyroid monitors that could also be included in the monitoring network. No contacts with these organisations have yet been taken.

1.3.3 Norway

At NRPA, there is a stationary whole-body counter and a newly constructed mobile laboratory with a HPGe-detector for whole -body and thyroid measurements in emergency situations. There are also 8 monitors that after calibration could be used for thyroid monitoring. In Norway as in Finland there is a network LORA-KON (LOkal RAdioaktivitetsKONtroll) for measuring activity concentrations in foodstuffs. It might be possible to use that equipment also for thyroid measurements. The number of instruments is about 70 and the distribution in Norway is shown in figure 2. NRPA has also initiated a project to get 40-45 light weight gamma spectrometers for measuring live animals. In an emergency situation these instruments could be used for thyroid measurements after calibration.

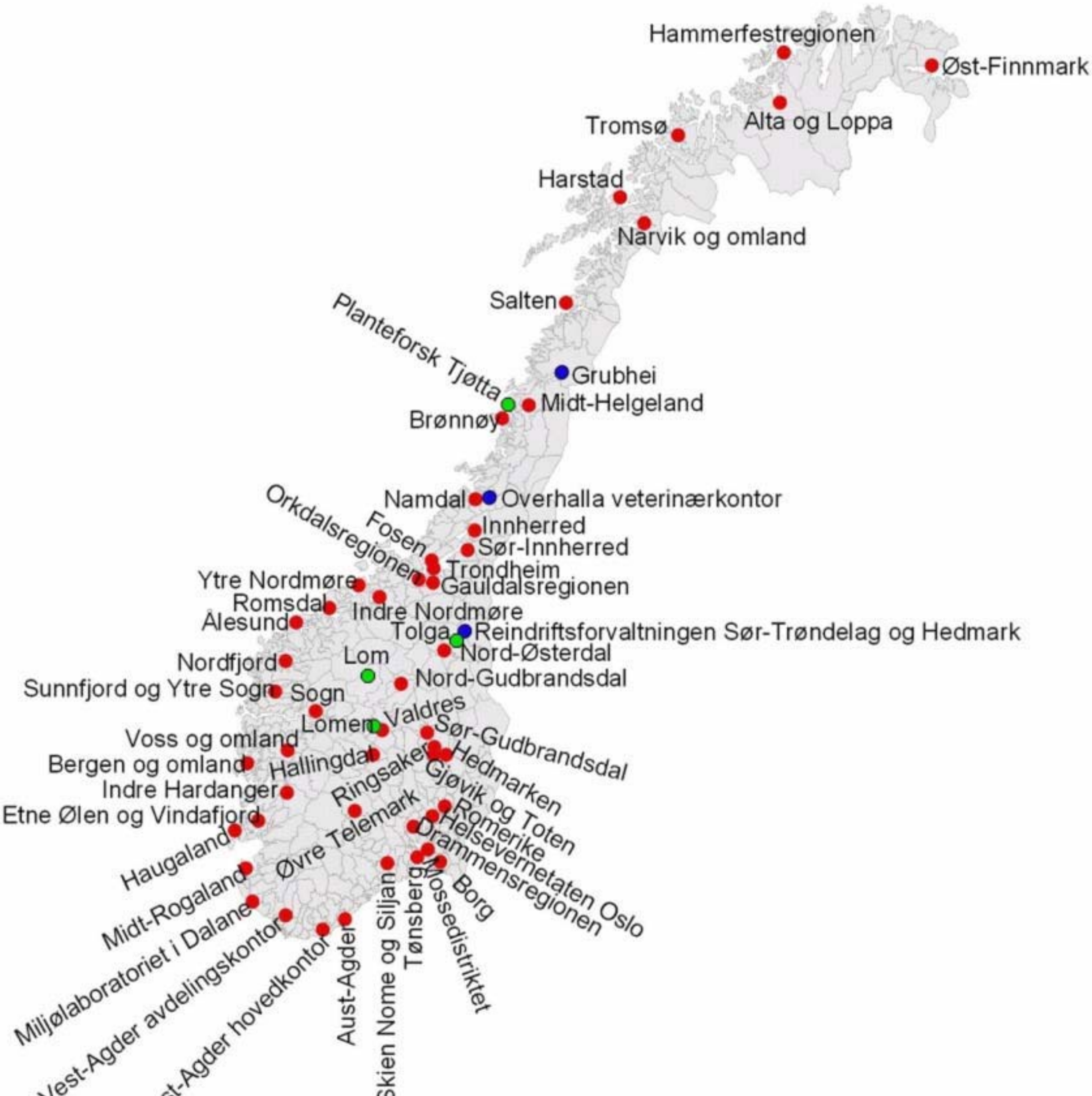

Figure 2. The Lorakon network in Norway. (LOkal RAdioaktivitetsKONtroll):

There are also two whole body counters at the Norwegian research reactors operated by IFE in Halden and in Kjeller mainly for monitoring the nuclear workers. These could, however, be used for public monitoring if the situation calls for it.

Norwegian hospitals with Nuclear Medicine Departments equipped with gamma cameras are listed below. These gamma cameras are more suited for whole body monitoring than thyroid measurements. A digital registry for radioactive sources and practices is under development at NRPA and a list of the different cameras with technical details will be available in the future.

1. Det norske radiumhospital HF, 0310 OSLO
2. Rikshospitalet HF, 0027 OSLO
3. Aust-Agder sykehus HF, 4809 ARENDAL
4. Spesialsykehuset for epilepsi HF, 1303 SANDVIKA
5. Vest-Agder sykehus HF, 4604 KRISTIANSAND
6. Sykehuset Vestfold HF, 3103 TØNSBERG
7. Sykehuset Telemark HF, 3710 SKIEN
8. Sykehuset Buskerud HF, 3004 DRAMMEN
9. Aker universitetssykehus HF, 0514 OSLO
10. Akershus universitetssykehus HF, 1474 NORDBYHAGEN
11. Bærum sykehus HF, 1306 BÆRUM POSTTERMINAL
12. Oppland Sentralsykehus HF, 2629 LILLEHAMMER
13. Oppland Sentralsykehus Gjøvik, 2819 GJØVIK
14. Sentralsjukehuset i Hedmark HF, 2418 ELVERUM
15. Sykehuset Østfold HF, 1603 FREDRIKSTAD
16. Ullevål universitetssykehus HF, 0407 OSLO
17. Universitetssykehuset Nord-Norge HF, 9033 TROMSØ
18. Helse NSS HF, 8092 BODØ
19. Helse Sunnmøre HF, 6026 ÅLESUND
20. Helse Nordmøre og Romsdal HF, 6407 MOLDE
21. Helse Nord Trøndelag HF, 7600 LEVANGER
22. St Olavs Hospital HF, 7006 TRONDHEIM
23. Helse Stavanger HF, 4068 STAVANGER
24. Helse Bergen HF, 5021 BERGEN
25. Helse Førde HF, 6800 FØRDE
26. Fylkessjukehuset i Haugesund, 5528 HAUGESUND

1.3.4 Sweden

In Sweden there are altogether 11 whole-body counters one at SSI and the others at universities, research institutes and nuclear power plants. At all these organisations there are experts to use them. At 32 hospitals there are Nuclear Medicine Departments and of these 18 have reported efficiency calibration for iodine in thyroid (figure 3). At research institutes there are further at least 8 portable thyroid monitors.

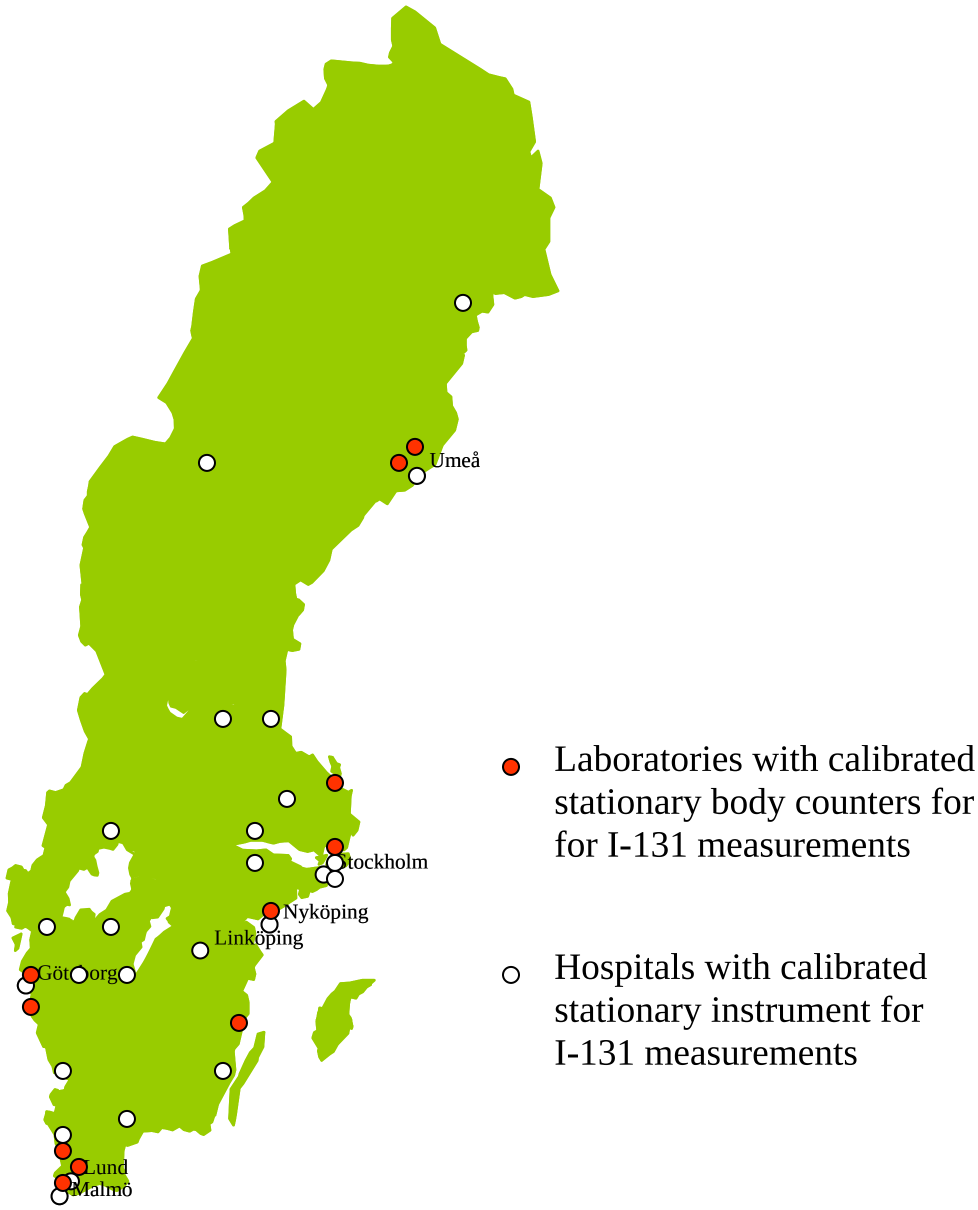

Figure 3. Laboratories and hospitals in Sweden with instrumentation for I-131 measurements.

Table 1. Hospitals in Sweden with instruments for I-131 uptake measurements.

Hospital	Det. Size	Collimator type	Window (%)	Sensitivity (cps/MBq)	
1 Uddevalla					
2 Jönköping	2"	IAEA	25	777	
3 Växjö	5cm	LEAB 42-2	11	700	
4 Danderyd					
5 Östersund	2"*2"	Pinhole	20	767	
6 Halmstad				830	
7 Lund	2"*2"	Eurostandard	20	555	
8 Eskilstuna	6cm*2"	cylindrical	30	740	
9 NÄL					
10 Borås	2"*2"	Leadpipe 25 cm	25	170	
11 Västerås					
12 Helsingborg					
13 Huddinge	3"	IAEA standard	24	800	
14 Kristianstad					
15 Uppsala				saknas	
16 Umeå	3"*2"	Pb 20 mm	23	1320	
17 Sundsvall	5*2cm		20	saknas	
18 Örebro				saknas	
19 Sahlgrenska				saknas	
20 MAS	3"*3"		20	640	
21 Skövde	2"*3"	conic 9cm,dia 80mm	35	1400	
22 Karlskrona					
23 Falun	2"*2"	conic 2"	23	868	
24 Gävle	2"*2"	Eurostandard	16	400	
25 Kalmar	5cm	focusing	25	500	
26 Västervik					
27 Östra sjukhuset					
28 Linköping	4.45	focusing	20	623	
29 Sunderbyn	3"*3"		20	1069	
30 SÖS			20	385	
31 KS				saknas	
32 Karlstad	3"*3"	holecollimator	30	1794	

2. Quality assurance- Efficiency calibration and intercomparison measurements

For quality assurance and especially to fulfill accreditation requirements it is necessary to take part in intercomparison projects. Thanks to NKS it has been possible to arrange intercomparisons of direct measurements of people already in former projects. In the IRADES project calibration and intercomparison excercises of both whole-body and thyroid measurements were offered to all Nordic organisations doing direct activity determinations and internal dose assessments. The results of this action are presented in Annex 1. The results have improved since the former intercomparison and the participants have also used the phantoms for calibration purposes. In Sweden this intercomparison is used as a formal quality assurance validation for whole-body counting measurements.

All the participants were very pleased with the opportunity to use IRINA for calibration and intercomparison. Such excercises are of great value to the laboratories performing whole body and thyroid measurement.

3. Dose assessment

Internal doses can be assessed using direct measurement results or by using information on activity concentrations in inhaled air and in foodstuffs combined with consumption data. Whenever possible direct measurements should be done. Internal dose assessment methods are continuosly developed and tested. Very often assumptions regarding different parameters have to be made and no absolute answer for delivered dose can be given. To participate in dose assessment exercises and discuss the reasons for differing results when using the same data as a starting point is a good way to develop skills. A course on internal dosimetry was arranged in Tartu, Estonia on Wednesday 26 October 2005. The program of this course is given in Annex 5. The dose course presentations are published at the NKS home page.

Bearing in mind the uncertainties involved in dose assessments, it would be an advantage if the Nordic countries used the same dose assessment software. Several dose assessment tools are available on the market.

At the health protection agency HPA (former NRPB) in UK a special software for emergency situations to be used by non experts is developed. A harmonisation not only in the Nordic countries but in Europe would be possible using this software. Doses assessed in this way would be comparable and could be used for information to the general public.

There is a prototype of a very user friendly dose assessment program developed from IMBA. This could be of great help in emergency situations when non experts are doing measurements.

4. Strategy and conclusions

Measurements of internal contamination have not been regarded as belonging to the first of actions in emergency sitautions. However, lately the threath of malevolant use of radiation has changed the attitude towards early direct measurements of the public. In France mobile measuring equipment not used since the 1980’s is renewed. In Finland light weight gamma spectrometric equipment has been obtained. If there is radioactive iodine in the air and the exposure should be assessed the direct measurements should be started as soon as possible. Annex 4 presents data on the effect of stable KI administration for different age groups. These data illustrate why it is so important to react rapidly in situations involving airborne radioactive iodine. The exposure via e.g. milk appears somewhat later. The dose assessments based on rapid indirect measurements can be verified with direct measurements on people. This is especially important when considering countermeasures like administration of stable iodine. If the results of such measurements are to be made use of already at an early stage there must however also be a possibility to report the results rapidly. The size of the population groups and the duration of the measurements have to be evaluated case by case. It is a big effort to transport people to a distant place for measurements. With the easily transportable measuring equipment available nowadays a better approach is to go to where the people are. This also makes less interference with the life of the people involved.

After the accident in Chernobyl we have learnt that the risk of thyroid cancer for children is larger than was earlier assumed. If the preparedness to do direct thyroid measurements on large groups of people of different ages had been better in the vicinity of Chernobyl, we would now have a better knowledge for performing accurate risk assessment. The individual measurements would also make it possible to sort out people with high contamination levels that would need to be followed more closely for early detection of signs indicating health effects from radiation exposure.

Plans for measurement strategies should be developed in each country separately taking into account national regulations, local circumstances and resources. Nevertheless, in view of the close contact between people in the Nordic countries, it is very important to have the same approach in all countries. This will increase the public reassurance and trust in case of a nuclear emergency situation. The bilateral agreements among the Nordic countries about assistance in emergency situations also emphasizes the importance of cooperation in the field of measurements.

The emergency response organisations are now facing new scenarios beyond the former focus on nuclear reactor accidents or use of nuclear weapons. The possibility of malevolent acts including radioactive material is real and radiation protection authorities should make plans for handling such acts. It is reasonable to believe that terrorist acts will be performed in arreas with high population density in order to create a high level of public distress and anxiety. Thus, more emphasis has to be put on measurements outside routinely used laboratories. This calls for plans concerning:

- mobile equipment
- quality assurance for emergency measurement procedures
- fast exchange of information and central data collection
- training of personnel
- exercises, also for malevolent acts.

One should bear in mind that there should not be a big gap between planned resources and actual available resources in emergency situations. All planning and instructions are of no use if there are no instruments and above all no people trained to use them available in such situations.

This is a challenge to the end users of this IRADES report, namely the radiation protection authorities. The biggest effort will probably be for training and motivating enough staff to be ready to handle the measurements in an emergency situation. These people need not be the best experts in the field but earlier experience with radiation protection instrumentation would be an advantage. The experts would probably be needed for more demanding radiation protection tasks, so the training of other personell to fulfill the measurement tasks is preferred. The experts should, however, give advice, recommendations and support.

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6. List of annexes

Annex 1	Efficiency calibrations and intercomparison measurements
Annex 2	Report NKS-BOK-2.1.2 Mätning av radioaktiva ämnen i människa i beredskapssituationer. En metodhandbok vid jod och cesium-kontaminering
Annex 3	Papers presented at NSFS meeting August 28.-31. 2005 in Rättvik
Annex 4	Effect of stable KI administration
Annex 5	Internal dosimetry course and IRADES project meeting

Annex 1

Intercomparison exercise for whole-body measurements in the Nordic countries

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Abstract
An intercomparison exercise for whole-body measurements has been performed within the framework of the NKS project IRADES (Assessment of Internal Doses in Emergency Situations). The phantom IRINA has been circulated between 13 laboratories in Norway, Sweden and Finland during 2004 and 2005. The reported results show that the participating laboratories in general have well functioning and well-calibrated equipment for measuring whole body radiation.

Contents

INTRODUCTION

Organisations performing whole-body measurement are strongly encouraged to take part in intercomparison exercises for both quality assurance reasons and to fulfil accreditation requirements. To this end, 19 laboratories in the Nordic countries were invited to participate in an intercomparison exercise for whole body measurements in 2004 (12 in Sweden, 2 in Denmark, 3 in Norway and 2 in Finland). The intercomparison exercise was organised within the framework of the NKS project IRADES (Assessment of Internal Doses in Emergency Situations). Out of the 19 invited laboratories, 13 laboratories have performed the measurements and reported the results. Information about contact person, address, phone and email for each participating laboratory can be found in Appendix 3.

THE INTERCOMPARISON EXERCISE

The intercomparison took place during 2004 and 2005. The phantom IRINA was circulated between the participating laboratories for approximately one year, starting in late November 2004.

The participating laboratories

The participating laboratories are shown in **Table 1**. Also shown in **Table 1** is the type of detector and the measurement geometry used by each laboratory. A more detailed description of the equipment and measurement procedures used by each laboratory can be found in Appendices 1 and 2.

Laboratory	Type of detector	Measurement geometry
Barsebäck Kraft AB	HPGe	Chair
Ringhals AB	HPGe	Chair
OKG AB	HPGe	Chair
Forsmarks Kraftgrupp AB	HPGe	Chair
Studsvik AB	HPGe	Chair
Göteborg University	NaI	Scanning bed
Umeå University	HPGe	Chair
MAS University Hospital	NaI	Scanning bed
Lund University	NaI	Chair
STUK stationary unit	HPGe, NaI	Scanning bed
STUK mobile unit	HPGe	Chair
University of Helsinki	NaI	Chair
IFE Halden	NaI	Chair
NRPA	HPGe	Chair

Table 1 *The laboratories participating in the intercomparison exercise.*

The phantom IRINA

The phantom IRINA consists of blocks of tissue equivalent material (polyethylene). The radioactive material is contained in plastic cylinders. Each block has two holes where the radioactive cylinders fit. The blocks can be used to build several different configurations. The advised configuration in this exercise was P4, which represents a grown man with a weight of 70 Kilos. This configuration was chosen so that it would be possible to transport all necessary equipment in an ordinary car. The phantom IRINA was shipped with three sets of sources: Co-60, Cs-137 and Eu-152. Since the aim of the exercise was to perform an intercomparison, the activities of the sources were unknown for the participating laboratories at the time of the measurement. When the results had been reported, the laboratory received information on the correct activity. If necessary, this information could then be used to correct the efficiency calibration.

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The measurement assignments

The advised assignment for laboratories with an HPGe detector was to perform a measurement with the Eu-152 sources. For laboratories with NaI detectors, the advised assignments were to perform measurements with the Co-60 and Cs-137 sources. The laboratories were advised to use standard routines for the measurements if such routines were available. The laboratories were also instructed to perform consecutive measurements for each nuclide so that the reproducibility of the results could be studied. Most laboratories have also done so. The laboratories were further invited, if time permitted, to measure other configurations of the phantom. However, only a few of the laboratories have done so. Finally, the laboratories were invited to measure the activity of one nuclide in the presence of another. However, only one laboratory has done so.

THE RESULTS FROM THE INTERCOMPARISON EXERCISE

The results from the intercomparison exercise are presented below. All activity results are presented as percentage of the reference activity. The reason for this is that the reference activity differed somewhat between some of the reported results laboratories because of the number of radioactive sources that were used. The laboratories were advised to calculate MDA according to the formula given in appendix 1 of reference [1] or provide the formula that was used. Most laboratories have used the advised formula.

The results for Eu-152

Seven laboratories reported results for Eu-152. Note that one of the laboratories reported results for more than one set of measuring equipments. The results are shown in **Figure 1** as percentage of the reference value. The errors bars shown in the figure represent the estimated total error for each measurement. Note that only laboratories using an HPGe detector were advised to perform measurements with the Eu-152 sources. The weighted means of the reported results for Eu-152 from each laboratory are shown in **Figure 3**. The results are shown as percentage of the reference value. The error bars represent the total estimated errors. The reported MDAs for the Eu-152 measurements are shown in **Figure 2**. Note that three laboratories did not provide any information on MDA for the measurements with the ^{152}Eu sources.

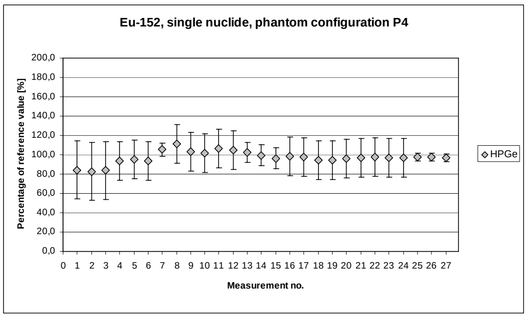

Figure 1 Reported results in percentage of the reference value for Eu-152, single nuclide.

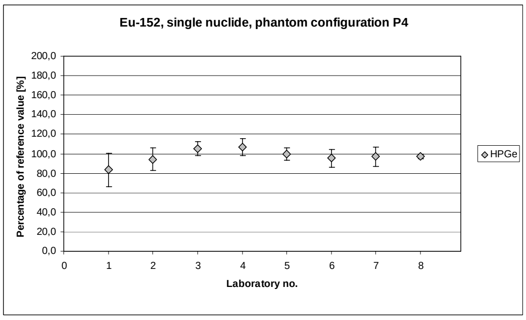

Figure 3 Weighted mean of the reported results from each laboratory in percentage of the reference value for Eu-152, single nuclide.

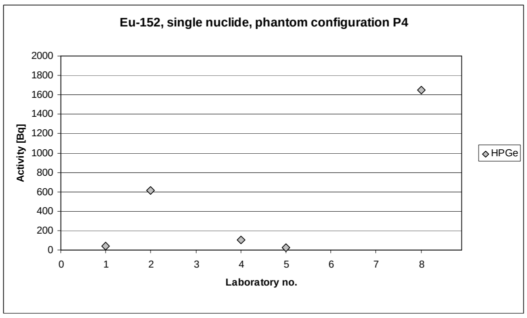

Figure 2 Reported MDA for Eu-152, single nuclide.

The results for Cs-137

Ten laboratories reported results for Cs-137. Note that one of the laboratories reported results for more than one set of measuring equipments. The results when only one nuclide is present in the phantom are shown in **Figure 4** as percentage of the reference value. The filled symbols represent measurements performed with NaI detectors and the grey symbols represent measurements performed with HPGe detectors. The errors bars shown in the figure represents the estimated total error for each measurement (1 S.D.). However, for the measurements numbered 23 to 26 in the figure, the laboratories only provided statistical errors. The weighted means of the reported results for Cs-137 from each laboratory are shown in **Figure 5** as percentage of the reference value. The error bars represent the total estimated errors. Note that the laboratories numbered 9 to 12 only provided statistical errors. The reported MDAs for the Cs-137 measurements are shown in **Figure 6**.

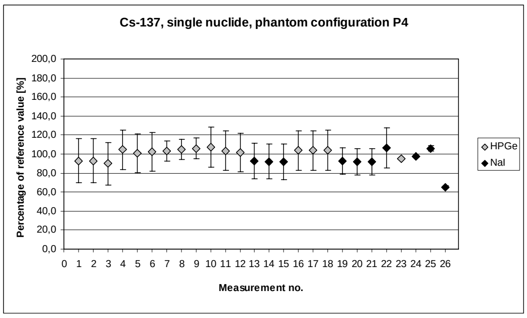

Figure 4 Reported results in percentage of the reference value for Cs-137, single nuclide.

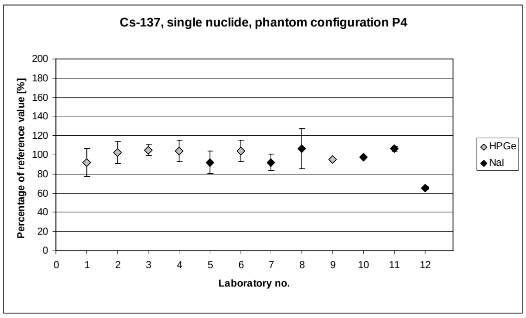

Figure 6 Weighted mean of the reported results from each laboratory in percentage of the reference value for Cs-137, single nuclide.

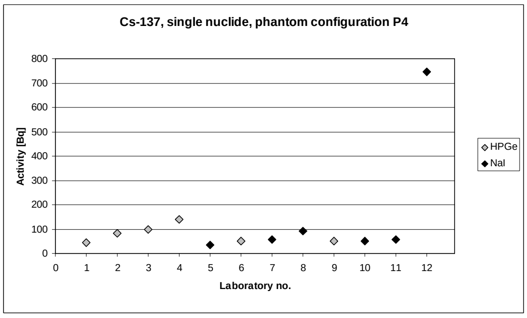

Figure 5 Reported MDA for Cs-137, single nuclide.

The results for Co-60

Ten laboratories reported results for Co-60. Note that one of the laboratories reported results for more than one set of measuring equipments. The results when only one nuclide is present in the phantom are shown in **Figure 7** as percentage of the reference value. The filled symbols represent measurements performed with NaI detectors and the grey symbols represent measurements performed with HPGe detectors. The errors bars shown in the figure represent the estimated total error for each measurement (1 S.D.). However, for the measurements numbered 20 to 23 in the figure, the laboratories only provided statistical errors. The weighted means of the reported results for Co-60 from each laboratory are shown in **Figure 9** as percentage of the reference value. The error bars represent the total estimated errors. Note that the laboratories numbered 8 to 11 only provided statistical errors. The reported MDAs for the Co-60 measurements are shown in **Figure 8**.

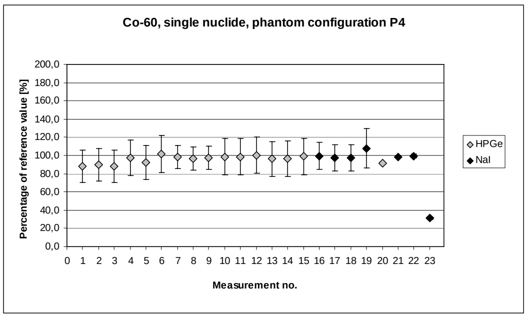

Figure 7 Reported results in percentage of the reference value for Co-60, single nuclide.

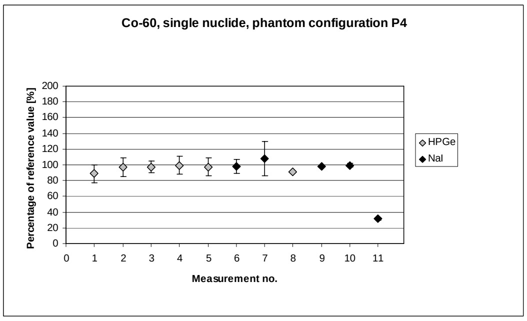

Figure 9 Weighted mean of the reported results from each laboratory in percentage of the reference value for Co-60, single nuclide.

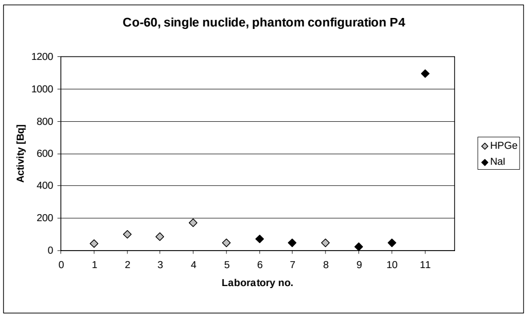

Figure 8 Reported MDA for C0-60, single nuclide.

The results with phantom configuration P1

Two laboratories reported results for measurements with phantom configurations, other than P4. Both laboratories had chosen the configuration P1, which represents a child of weight 24 kg. The results of the measurements are shown in ***Figure 10***. Both laboratories used NaI detectors for the measurements. The filled symbols in the figure represent measurements of Cs-137 and the grey figures represent measurements of Co-60.

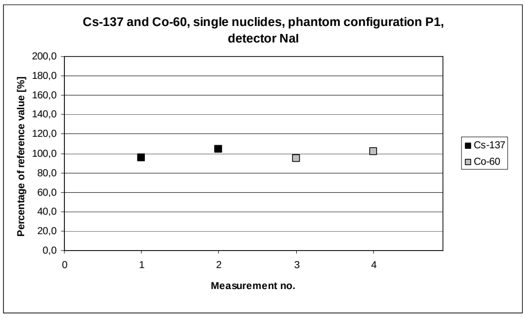

Figure 10 Reported results for measurements with phantom configuration P1.

The results for Cs-137 and Co-60 in the presence of the other nuclide

One laboratory reported results for Cs-137 and Co-60 when one nuclide was measured in the presence of the other nuclide. The results are shown in ***Figure 11***. All measurements were performed using a NaI detector. The filled symbols represent measurements of Cs-137 and the grey symbols represent measurements of Co-60. The square symbols represent measurements with configuration P4 and the triangular symbols represent measurements with configuration P1.

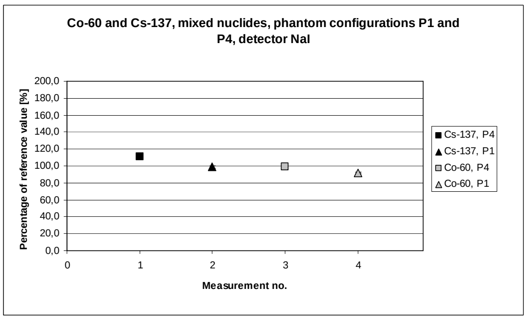

Figure 11 Reported results for measurements of Cs-137 and Co-60 in the presence of the other nuclide.

REFERENCES

[1] Mätinstruktion för IRIN

APPENDIX 1 - EQUIPMENT

Partici-pant	Producer of meas-urement equip-ment	Type of detector (NaI, Ge,…)	Number of and size of the detector/s	Geome-try (bed, chair, scan-ner,…)	Measurement cham-ber (size, material, etc.)	Background measurement (measurement time, empty/phanto m)	Method of calculation, software
Barse-bäck Kraft AB	-	HPGe, Ortec Pop-Top	1, 55% rel. eff.	Chair	h=1610, w=830, d=950, wall thickness 120 (mm)	Empty, 600 sec	EG&G Ortec Gammavi-sion 6.01
Ringhals AB	Intertechn ique EGPC 43	Ge	1, 43% rel. eff.	Chair	800*950*1600 (in-side), wall thickness 150 Fe (mm)	Empty, 600 sec	ABACOS from Can-berra Nu-clear
OKG AB	WBC-6000 Nuclear data chair	HPGe (GI-tract and lungs), NaI(Tl) Thyroid	2 HPGe 20% rel. eff., 1 NaI(Tl) 1" x 1.5"	Chair	Ca 12 m^2, low activity concrete	Empty, 50000 sec	ICRP30, Abbacos plus
Fors-marks Kraft-grupp AB	-	Ge	1 Ge, rel. eff. 50%, d=69 mm, l=57.5 mm	Chair	h=1970, w=1230, l=1650 (mm), wall thickness 130 mm steel plus 20 mm lead	Empty	Software from ND
Studsvik AB	Canberra GC5019-7935-7	HPGe	1 HPGe, 50% rel.eff.	Chair	h=1600, w=900, l=1400 (mm), wall thickness 120 mm Fe plus 20 mm lead	48 000 sec	Software GENIE 2000
Göteborg Univer-sity	-	NaI (be-low+above)	2 NaI, 5" x 4" (di-ameter x length)	Scanner	The chamber is placed inside a room with iron-ore walls (600-900 mm thick). The chamber has iron walls (150 mm thick) with 4 mm lead on the inside.	Inactive phan-tom, 960 sec	Analysis with AccuS-pec, manual calculation
Umeå Univer-sity	-	HPGe, NaI	1 HPGe 36% rel. eff. Ortec p-type, 1 NaI 3"3"	Chair	Lead chamber placed in a hoforsit room	Water phantom 70 kg, 182976 sec.	Net counts in the photo peaks when measuring phantom and background
MAS Univer-sity hos-pital	-	NaI(Tl)	2 NaI(Tl), d=12.7, 10.2 (cm)	Scanning bed	Iron chamber 200 mm with 3 mm lead coat-ing on the inside, h=1950 (mm), area=2700x2800 mm^2	Phantom Irinia, 1000 sec.	Maestro EG&G Ortec
Lund Univer-sity	-	NaI	1 NaI, 20 x 10 cm	Chair	Iron chamber	Inactive phan-tom, 60000 sec	Stripping method in Excel
STUK (scan-ning bed)	-	HPGe, NaI(Tl)	1 HPGe 28% rel. eff., d=53 mm, l=57 mm 1 HPGe 80% rel.eff., d=75 mm, l= 94 mm 4 NaI(Tl) 5"x4"	Scanning bed	Old iron (1500 mm thick) with thin lead (3mm) and copper (4 mm) lining, outer dimensions h=2300, w=2400, l=4100 (mm)	Inactive BO-MAB type phantom filled with sugar, 1800 sec	In-house software (Gamma-software for Ge)

Partici-pant	**Producer of meas-urement equip-ment**	**Type of detector (NaI, Ge,…)**	**Number of and size of the detector/s**	**Geome-try (bed, chair, scan-ner,…)**	**Measurement cham-ber (size, material, etc.)**	**Background measurement (measurement time, empty/phanto m)**	**Method of calculation, software**
STUK (mobile WBC)	-	HPGe	1 HPGe, 90% rel eff., d=82 mm, l=83 mm	Modified chair	The chair (made of lead) is placed in a truck	Inactive phan-tom made of sugar bags, 1000 sec	In-house Gamma-software
Univer-sity of Helsinki	-	NaI	1 NaI, 3”x8”	Chair	Old iron (1500 mm thick) with thin Pb and Cu lining, outer di-mensions h=2100, w=1390, l=2430 (mm)	Inactive phan-tom, 167 619 sec	Oxford PCAP card & its soft-ware
IFE, Halden	-	NaI	1 NaI, 3”x 3”	Chair	Room in the basement, ca 13 m^2	Empty phantom, P4 model. 600 sec.	Genie 2000
NRPA	-	HPGe	1 HPGe, Ortec electric cooled. Rel. eff. 50%	Chair	The chair is shielded with 50 mm lead in the back. It is mounted inside a mobile (20 feet) container.	Empty P4 phan-tom, 3700 sec.	Ortec Gamma Vision and Canberra Genie 2000

APPENDIX 2 – COMMENTS ON EQUIPMENT AND MEASUREMENT PROCEDURES

Participant	**Further information**
Barsebäck Kraft AB	The detector is normally cooled using an X-cooler compressor. If necessary, the detector can be mounted on equipment with LN_2-cooling. Barsebäck Kraft AB use a DSpec digital multi channel analyzer from Ortec.
OKG AB	The program calculates the activity for ^{152}Eu based on each gamma line in the spectrum. The end result is the mean value of the result for all gamma lines in the spectrum, where the highest and the lowest value have been excluded. The used geometry P4 is modified to fit WBC-6000, which has a limited vision (collimated geometry) for the two HPGe detectors. Note that MDA is calculated according to the formula used at OKG as MDA= (2.71+4.65*sqrt(BG))*decay/(E*g-exch..*T), where decay is the decay correction and g-exch. is the gamma exchange.
Forsmarks Kraft-grupp AB	MDA is calculated as MDA=(2.71+4.65*sqrt(B))decay/e*b*LT*q, where B=background sum, decay=decay factor, e=efficiency, b=abundance, LT=elapsed live time and q=sample quantity.
Studsvik AB	The total uncertainty of the measurement of activity in man is estimated bearing the following comments in mind. The distance to the detector can differ 0-2 cm. The whole body counter is calibrated using P5, which is 15 kg lighter than P4. Some of the electronic equipment has been changed. However, a consistency check with IRINA last year showed that the measurements were still correct and no adjustment of the calibration was necessary. The positioning of the phantom contributes to the uncertainty. An additional contribution to the uncertainty comes from the fact that IRINA is made of plastics with different , which differs from tissue. Finally, the uncertainty increases when measuring a person who is either heavier or lighter than P5.
Göteborg University	The laboratory, which is partly situated below ground, has walls, floor and ceiling made of iron-ore concrete (0.6-0.9 m). All building material, paint etc., has been carefully selected to contain as low levels of natural radioactivity as possible. A double iron chamber with walls of 150 mm thick iron from old battleships is placed in the laboratory. The iron chambers are coated with 4 mm thick lead from old English church roofs on the inside. An air conditioning system supplies the laboratory with filtered air of constant temperature. To prevent that the temperature rises in the iron chambers when patients are inside, an additional fan that changes the air inside the iron chamber via an absolute filter eight timed per hour is used. In this way, the pressure inside the iron chambers is higher than the pressure in the laboratory, which, in turn, is higher than the pressure in the surrounding facilities. This system with a constant over pressure is necessary to prevent radon from surrounding building material to leak into the iron chambers. In the left iron chamber (system 1), there are two movable NaI detectors (5”x4”) mounted on rails on the floor and in the ceiling (scanning-bed geometry), one above and one below the bed. The system allows the detectors to be moved over the bed both manually and linearly along as well as parallel to the bed. The upper detector can be replaced by a 5” x ¼”) NaI detector with a thin entrance window or an HPGe detector.
STUK	NaI(Tl) detectors have been used to determine ^{137}Cs content for the scanning bed equipment.

APPENDIX 3 – CONTACT INFORMATION

Participant	Contact person	Address	Telephone number	Fax number	E-mail
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Annex 2

NKS-BOK-2.1.2

Mätning av radioaktiva ämnen i människa i beredskapssituationer.

En metodhandbok vid jod och cesium-kontaminering

INLEDNING OCH SYFTE

Uppskattningar av interna stråldoser baseras på direkta mätningar av människor eller också indirekt på mätningar av utsöndringsprodukter eller födoämnen. För jod kan uppskattningarna även bygga på mätningar av luftkoncentration. Mätningarna utförs oftast i syfte att bestämma (uppskatta) intaget av radioaktiva ämnen och den interna stråldosen beräknas sedan utifrån metaboliska och dosimetriska modeller.

Erfarenheterna från olyckor där många människor kontaminerats internt av radioaktiva ämnen har visat på ett behov av att snabbt kunna kontrollmäta många människor. Både för kontroll av kontaminationssituationen men också för att i efterhand kunna uppskatta stråldoserna från kontaminationen.

Med en adekvat kalibrering, kan många handinstrument användas för mätningar av intern kontamination vid en olyckshändelse som resulterar i att radioaktiva ämnen sprids till omgivningen. Instrument med NaI-detektorer kan registrera ett fåtal kBq ^{131}I i sköldkörteln, vilket motsvarar en effektiv dos på under 1 mSv. För ^{137}Cs, kan helkroppsinnehåll på 20-50 kBq registreras (ger <1 mSv). Instrument med GM-rör är c:a 5 gånger mindre känsliga.

Beroende på situationen kommer mätningarna att tjäna olika syften. Vid situationer då interkontaminationen kan tänkas vara hög blir det mätningar för att klarlägga om det behövs medicinsk behandling eller om det krävs andra mätningar för noggrannare dosimetri. Mätningarna är också viktiga för kommande dos-uppföljning. Vid de tillfällen när exponeringen kan vara utsträckt i tiden är det lämpligt att genomföra upprepade mätningar. För jod kan mätningarna upprepas med en veckas mellanrum och för cesium 4 ggr per år. På grund av den relativt korta halveringstiden för jod-131 är det viktigt att mätningarna startar så snart som möjligt.

Handboken innehåller beskrivning av instruktioner och procedurer för dessa situationer, men behöver kompletteras med detaljerade instruktioner för de aktuella instrument som avses att användas. I första hand har situationer med jod eller cesiumkontaminering varit i åtanke när handboken skrivits. Handboken kan ses som en del i en beredskapsplan och anpassas till lokala förhållanden.

MÄTNINGAR MED HANDINSTRUMENT

Thyroideamätning (sköldkörtel) av ^{131}I med handinstrument

Förberedande skede

ü Välj lämplig lokal för mätningarna.
- 4 Lokalen bör helst vara belägen i ett område som inte drabbats av nedfall. Om detta inte är möjligt väljs en lokal i en byggnad med hög skärmningsfaktor, t.ex. källare i stenhus.
- 4 Lokalen bör vara så stor att väntrum och mätrum kan iordningsställas. Tvättmöjligheter (dusch) är önskvärt.

ü Arrangera lokalen för mätning och omhändertagande av personer som ska mätas.
- 4 Ställ i ordning väntrum med skogräns och utrymme för ytterkläder.

- 4 Avgränsa ett utrymme för mätning. Hotet är att utrymmet blir kontaminerat. Personer som kommer för mätning lämnar skor och ytterkläder redan innan de kommer till det avgränsade området.
- 4 Arrangera för insamling av kontaminerade kläder och skor.

ü Granska tvättmöjligheter (om sådana finns).
- 4 Kontrollera i så fall att det finns tillräckligt med handdukar, mätdräkter, tvål, schampo etc. Ordna service för tvätt.

ü Förbered mätinstrumenten.
- 4 Kontrollera apparaturen. Skydda detektorn med en plastpåse. Placera, om möjligt, ut "limmattor" på strategiska ställen.
  Se till att mätinstruktioner för instrumenten finns tillgängliga.

Aktionsskede

Minns att det är viktigt att behandla dem som kommer till mätning lugnt och vänligt. De är sannolikt mera bekymrade än du. Visa inte din egen oro, prata inte för mycket, koncentrera dig på vad du gör och förklara gärna varför.

ü Kontrollera personernas eventuella ytkontamination redan före skogränsen. Var lugn och vänlig.

ü Minns kontaminationsrisken, undvik kontamination.

ü Personen klär av sig ytterkläderna och tar av sig skorna vid ytterdörren

Mätning:

ü Koppla på apparaten.

ü Välj mättid (100 s eller motsvarande för det instrument som används)

ü Skriv in personens namn och andra uppgifter i mätblankett (Bilaga 1)

ü Håll detektorn vid halsgropen på den person som ska mätas, se bild. (För cesium se separat instruktion nedan)

ü Starta mätningen.

ü Notera resultatet och fyll i mätblanketten.

ü Håll (tryck lätt) detektorn mot personens lår och gör en bakgrundsmätning under samma tid som personmätningen, se bild.

ü Notera resultatet och fyll i mätblanketten.

ü Kontrollera att blanketten är korrekt ifylld.

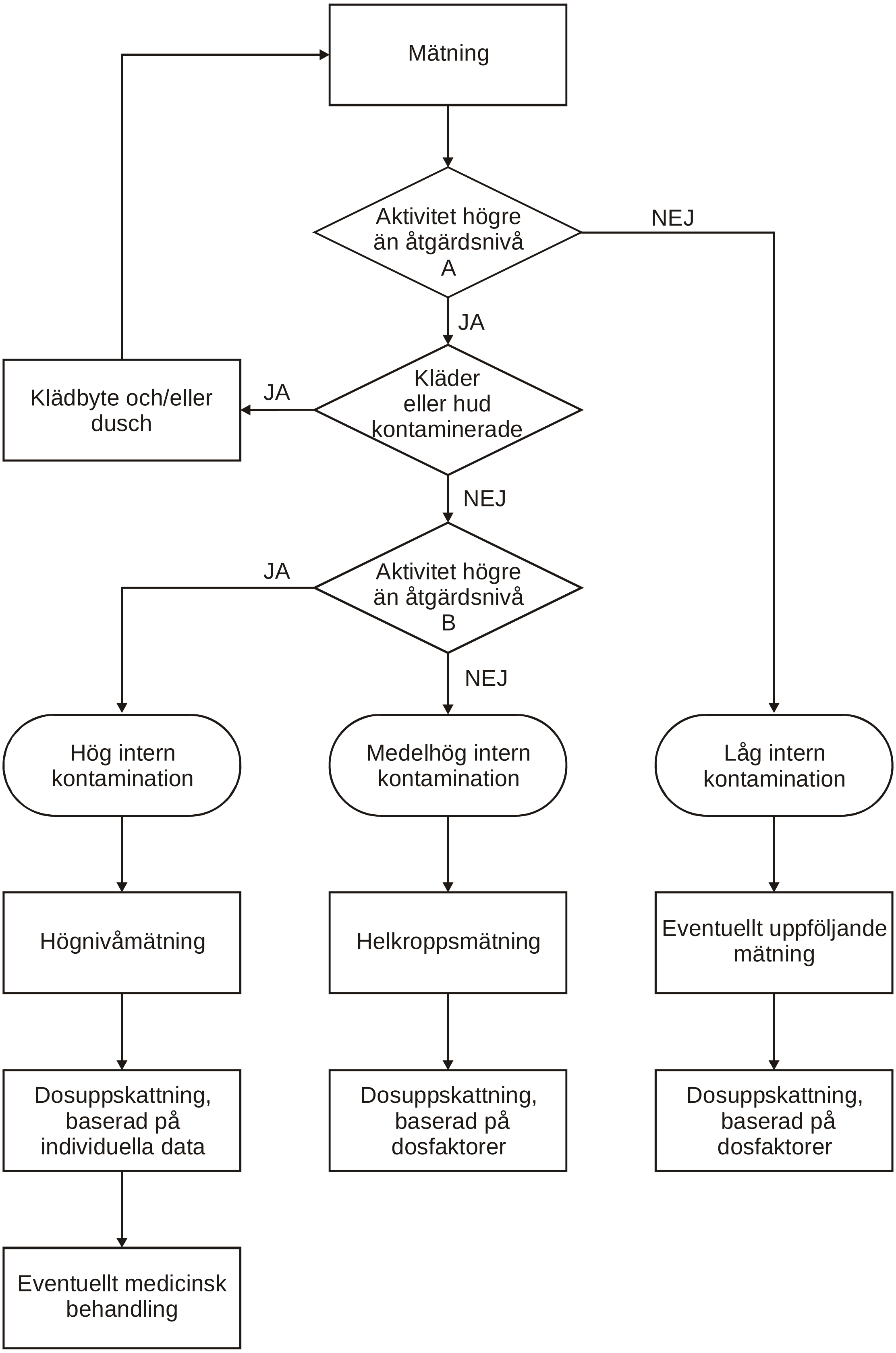
Kom ihåg lagar och förordningar angående registrering av personuppgifter. Inga uppgifter ges åt utomstående utan medgivande av personen det gäller. Minns din tystnadsplikt. Inga utomstående i mätutrymmena. Mediarepresentanter får närvara endast med särskilt tillstånd.

Mätning av jod-131 i sköldkörteln

Bakgrundsmätning till mätning av jod-131 i sköldkörteln

Beslut om åtgärder

Figur 1 nedan anger IAEA:s rekommendation för åtgärder i samband med kontrollmätningar av stora befolkningsgrupper (IAEA, 1994).



Figur 1 *Rekommenderade åtgärder vid mätning.*

Enligt Figur 1 bestäms två åtgärdsnivåer, A och B, sådana att dessa aktiviteter av ^{131}I i sköldkörteln ger en viss stråldos. Åtgärdsnivåerna och motsvarande aktiviteter för jod eller eventuellt andra radionuklider meddelas vid den uppkomna situationen av landets strålskyddsmyndighet.

De personer som har ett sköldkörtelinnehåll av ^{131}I med aktivitet mindre än A löper inte en oacceptabelt stor risk för skador på grund av strålningen, men kan behöva följas upp med känsligare utrustning på ett senare stadium för exempelvis epidemiologiska studier.

Personer med en sköldkörtelaktivitet mellan A och B bör undersökas med känsligare utrustning (helkroppsräknare) för en noggrannare bestämning av aktiviteten. För dessa personer beräknas stråldosen utgående ifrån tabellerade data (doskoefficienter).

För de som har en intern kontamination som överstiger aktiviteten B krävs i regel särskild mätutrustning för noggrann dosbestämning. Dessa personer kan också komma att behöva medicinsk vård för att minska risken för framtida men.

Sammanställning av några mätinstrument

Tabell 1 och **Tabell 2** nedan visar resultatet av en kalibrering av några förekommande instrument för stråldosmätning. Kalibreringsfaktorer anges för vuxna respektive barn, då mätinstrumentet är i kontakt med halsen. Beroende på hur respektive instrument visar mätresultatet anges kalibreringsfaktorn i enheterna σSv/h/Bq respektive cps/Bq.

Tabell 1*. Kalibrering av handinstrument för mätning av ^{131}I i tyreoidea (vuxna). Instrumentet i kontakt med halsen.*

Fabrikat	Typ	Detektortyp	Detektorstorlek	Kalibreringsfaktor (σSv/h/Bq alt. cps/Bq)
BICRON	ANALYST	NaI(Tl)	2" Δ 2"	0,041
SAPHYMO-STEL	SPP2	NaI(Tl)	1" Δ 2"	0,012
Exploranium	Gr-110s	NaI(Tl)	1.5” Δ 1.5” Δ 2.0”	0,021
Mini Insrtuments	6-90 Scaler-Ratemeter	NaI(Tl)	1”	0,0045
RNI	10	GM-rör		0,000016
SAPHYMO-Phy	ADB/AD-6	Plastscint.	3" Δ 3"	0,013
SAPHYMO-Phy	ADB/AD-3R	GM-rör		0,000013
Automess	AD-b/AD-6	Plastscint.	3" Δ 3"	0,013
Automess	6150 AD3 R	GM-rör	18 Δ 8 mm ∴	0,000013
Fabrikat Ryssland	SRP-88	NaI(Tl)	25 Δ 40 mm	0,0012
Morgan	Minimonitor 900	NaI(Tl)	25 Δ 19 mm ∴	0,0042
Morgan	Minimonitor 900	NaI(Tl)	2,5 Δ 32 mm ∴	0,0093

Tabell 2*. Kalibrering av handinstrument för mätning av ^{131}I i tyreoidea (barn). Instrumentet i kontakt med halsen.*

Fabrikat	Typ	Detektortyp	Detektorstorlek	Kalibreringsfaktor (σSv/h/Bq alt. cps/Bq)
SAPHYMO-STEL	SPP2	NaI(Tl)	1" Δ 2"	0,020
Exploranium	Gr-110s	NaI(Tl)	1.5” Δ 1.5” Δ 2.0”	0,036
RNI	10	GM-rör		0,000039
SAPHYMO-Phy	ADB/AD-6	Plastscint.	3" Δ 3"	0,013
Automess	AD-b/AD-6	Plastscint.	3" Δ 3"	0,022
Fabrikat Ryssland	SRP-88	NaI(Tl)	25 Δ 40 mm	0,0019
Morgan	Minimonitor 900	NaI(Tl)	25 Δ 19 mm ∴	0,0059
Morgan	Minimonitor 900	NaI(Tl)	2,5 Δ 32 mm ∴	0,015

^{137}Cs-mätning med enkel apparatur

Mätning av ^{137}Cs i hela kroppn kan också göras med enkel utrustning, t.ex. enkanals spektrometrar, i situationer där det är viktigt att kunna mäta en stor grupp människor snabbt utan stora krav på noggrannhet. Vid dessa mätningar placeras detektorn i knät på personen som ska mätas och personen kan antingen sitta upprätt eller böja sig över detektorn (s.k. Palmer- eller Lappgeometri), se bild. Om personen böjer sig över detektorn blir känsligheten högre, men å andra sidan ger den upprätta positionen möjlighet att mäta även mindre flexibla personer, t.ex. barn, gravida kvinnor, äldre och sjuka. Även s.k. ryggeometri kan användas, se bild.

Den minsta detekterbara aktiviteten i denna typ av mätningar har uppskattats till 1 – 2 kBq för ^{137}Cs (∂50 %) [Zvonova *et al.*, 1995]. Osäkerheterna i mätningen beror på dels personens läge vid mätningen och dels på bakgrunden som skärmas till viss del av personen. Eftersom mätningarna ofta utförs i områden med hög bakgrund kan den senare faktorn vara problematisk då den är svår att uppskatta. Jämförelser med reguljära helkroppsmätare har dock visat en god överensstämmelse och metoden kan betraktas som tillförlitlig om man är medveten om de korrektioner (bakgrund m.m.) som måste göras.

Förberedande skede

ü Välj lämplig lokal för mätningarna.
   4 Lokalen bör helst vara belägen i ett område som inte drabbats av nedfall. Om detta inte är möjligt väljs en lokal i en byggnad med hög skärmningsfaktor, t.ex. källare i stenhus.
   4 Lokalen bör vara så stor att väntrum och mätrum kan iordningsställas. Tvättmöjligheter (dusch) är önskvärt.

ü Arrangera lokalen för mätning och omhändertagande av personer som ska mätas.
   4 Ställ i ordning väntrum med skogräns och utrymme för ytterkläder.
   4 Avgränsa ett utrymme för mätning. Hotet är att utrymmet blir kontaminerat. Personer som kommer för mätning lämnar skor och ytterkläder redan innan de kommer till det avgränsade området.
   4 Arrangera för insamling av kontaminerade kläder och skor.

ü Granska tvättmöjligheter (om sådana finns).
   4 Kontrollera i så fall att det finns tillräckligt med handdukar, mätdräkter, tvål, schampo etc. Ordna service för tvätt.

ü Förbered mätinstrumenten.
   4 Kontrollera apparaturen. Skydda detektorn med en plastpåse. Placera, om möjligt, ut "limmattor" på strategiska ställen.
   Se till att mätinstruktioner för instrumenten finns tillgängliga.

Aktionsskede

Minns att det är viktigt att behandla dem som kommer till mätning lugnt och vänligt. De är sannolikt mera bekymrade än du. Visa inte din egen oro, prata inte för mycket, koncentrera dig på vad du gör och förklara gärna varför.

ü Kontrollera personernas eventuella ytkontamination redan före skogränsen. Var lugn och vänlig.

ü Minns kontaminationsrisken, undvik kontamination.

ü Personen klär av sig ytterkläderna och tar av sig skorna vid ytterdörren

Mätning:

ü Koppla på apparaten.

ü Välj mättid (100 s eller motsvarande för det instrument som används)

- Skriv in personens namn och andra uppgifter i mätblankett (Bilaga 2)
- Starta mätningen.
- Notera resultatet och fyll i mätblanketten.
- Gör en bakgrundsmätning på en person som inte är kontaminerad under samma tid som personmätningen.
- Notera resultatet och fyll i mätblanketten.
- Kontrollera att blanketten är korrekt ifylld.

Kom ihåg lagar och förordningar angående registrering av personuppgifter. Inga uppgifter ges åt utomstående utan medgivande av personen det gäller. Minns din tystnadsplikt. Inga utomstående i mätutrymmena. Mediarepresentanter får närvara endast med särskilt tillstånd.

Sammanställning av några mätinstrument

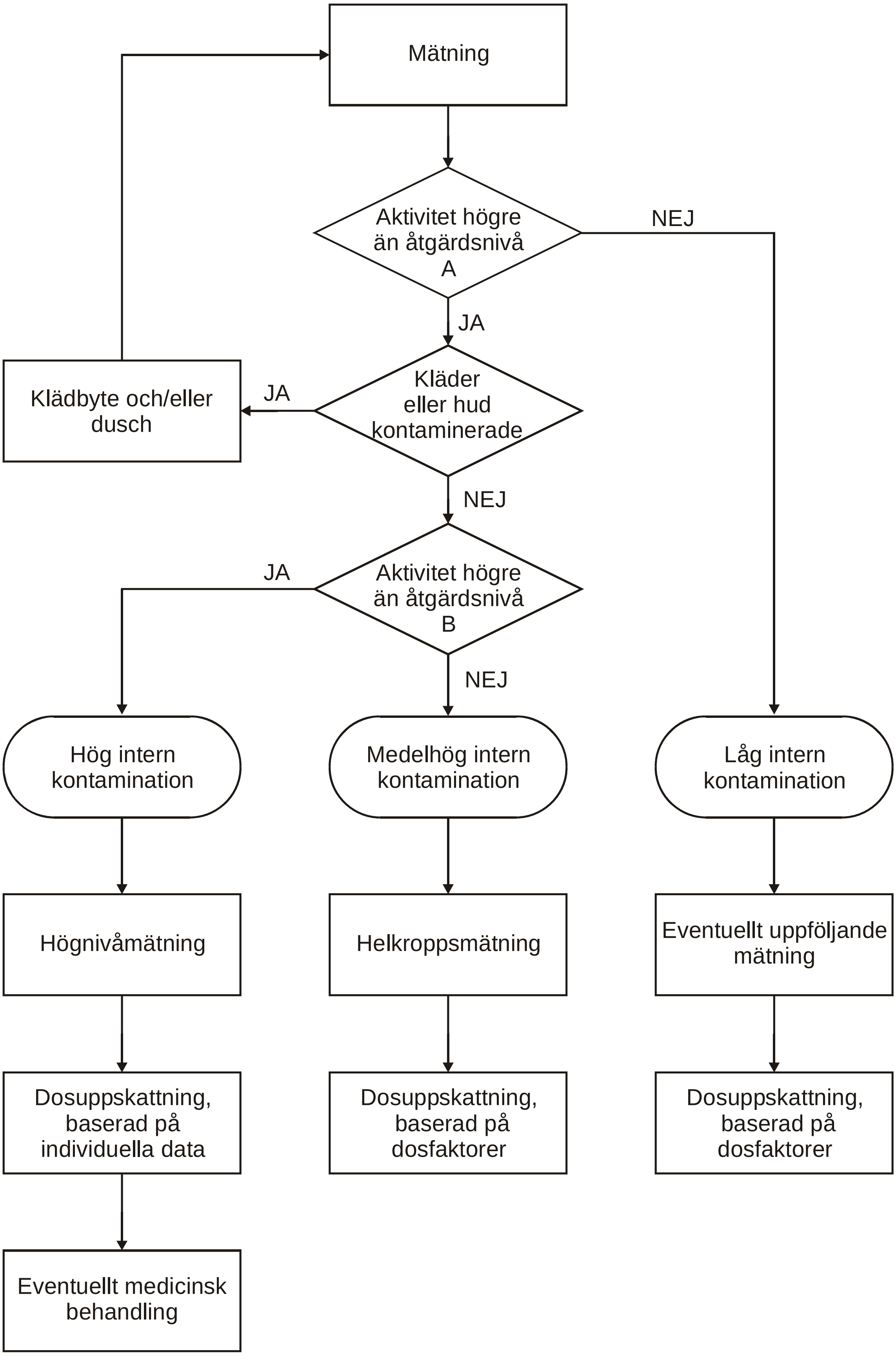
Tabell 3 nedan visar resultatet av en kalibrering av några förekommande instrument för stråldosmätning. Kalibreringsfaktorer anges för vuxna för två olika mätgeometrier, ”Palmer-geometri” och ”Rygg-geometri”. Beroende på hur respektive instrument visar mätresultatet anges kalibreringsfaktorn i enheterna σSv/h/Bq respektive cps/Bq.

***Tabell 3**. Kalibrering av handinstrument för mätning av ^{137}Cs i människa (vuxna) för två olika mätgeometrier.*

Fabrikat	Typ	Detektortyp	Detektorstorlek	Mätgeometri	Kalibreringsfaktor (σSv/h/Bq alt. cps/Bq)
BICRON	ANALYST	NaI(Tl)	2" Δ 2"	Rygg	0,0025
BICRON	ANALYST	NaI(Tl)	2" Δ 2"	Palmer	0,0039
SAPHYMO-STEL	SPP2	NaI(Tl)	1" Δ 2"	Palmer	0,00079
RADOS	SRV-2000	GM-rör		Palmer	0,0000006
Exploranium	Gr-110s	NaI(Tl)	1.5” Δ 1.5” Δ 2.0”	Palmer	0,0010
Exploranium	Gr-110s	NaI(Tl)	1.5” Δ 1.5” Δ 2.0”	Rygg	0,0011
RNI	10	GM-rör		Palmer	0,0000013
RNI	10	GM-rör		Rygg	0,00000063
Morgan	Minimonitor 900	NaI(Tl)	25 Δ 19 mm ∴	Rygg	0,000095
Morgan	Minimonitor 900	NaI(Tl)	2,5 Δ 32 mm ∴	Rygg	0,00038
Morgan	Minimonitor 900	NaI(Tl)	25 Δ 19 mm ∴	Palmer	0,000095
Morgan	Minimonitor 900	NaI(Tl)	2,5 Δ 32 mm ∴	Palmer	0,00038
Fabrikat Ryssland	SRP-88	NaI(Tl)	25 Δ 40 mm	Rygg	0,000057
Fabrikat Ryssland	SRP-88	NaI(Tl)	25 Δ 40 mm	Palmer	0,00010

Beslut om åtgärder

Figur 3 nedan anger IAEA:s rekommendation för åtgärder i samband med kontrollmätningar av stora befolkningsgrupper (IAEA, 1994). Enligt figur 3 bestäms två åtgärdsnivåer, A och B, sådana att dessa aktiviteter av ^{137}Cs ger en viss stråldos. Åtgärdsnivåerna och motsvarande aktiviteter för cesium eller eventuellt andra radionuklider meddelas vid den uppkomna situationen av landets strålskyddsmyndighet.



Figur 3 *Rekommenderade åtgärder vid mätning.*

^{131}I OCH ^{137}CS MÄTNING MED GAMMAKAMERA OCH JOD-MONITOR

Mätning med gammakamera

Gammakameror som finns på många sjukhus kan utgöra en viktig resurs i samband med kontaminationsmätningar av ett stort antal människor i en beredskapssituation. På sjukhusen finns också personal som har erfarenhet av dessa mätningar.

Wallström et al. (1995) har vid undersökningar av två olika kameror funnit att minsta detekterbara aktivitet (MDA) beror på *(1)* avståndet från mätobjektet, *(2)* det energiintervall som används vid mätningen och *(3)* om kameran används med eller utan kollimator. MDA var lägst då kameran placerades nära kroppen och användes utan kollimator. Nackdelarna med denna mätkonfiguration är att kameran kan behöva balanseras (med avseende på mekanisk stabilitet) för att kompensera för kollimatorn och att känslighetens variation med mätobjektets storlek blir större vid små avstånd.

Bakgrundens variation, vid mätningar med gammakamera i en beredskapssituation, utgör den främsta källan till mätresultatens osäkerhet. Denna beror i första hand på variationer i omgivningens strålnivå och skärmning av personer som befinner sig i närheten av kameran. Speciellt skärmningseffekten kan vara omfattande och även svårhanterlig eftersom den varierar med storleken på de skärmande personerna.

Som ett exempel på MDA och känslighet vid mätning med gammakamera visas i Tabell 4 några uppmätta data från fantommätningar (Wallström et al., 1995).

***Tabell 4**. Minsta detekterbara aktivitet och känslighet vid mätning av ^{137}Cs och ^{131}I med gammakamera i olika konfigurationer (kollimatorval och detektorhöjd).*

Energi-intervall (keV)	Kollimator	Fantom-storlek (kg)	MDA ^{137}Cs i helkropp (kBq)		MDA ^{131}I i thyroidea (kBq)		Känslighet ^{137}Cs i helkropp, centralt (cps/kBq)		Känslighet ^{131}I i thyroidea, över halsen (cps/kBq)	
			5 cm	35 cm	10 cm	40 cm	5 cm	35 cm	10 cm	40 cm
50-450	Ingen	14	0,25	0,90			78	24		
		61	0,40	1,0	0,10	0,45	46	21	170	47
		93	0,45	1,1			39	18		
	LEGP	14	0,80	2,3			9,1	3,3		
		61	2,1	3,5	0,80	2,5	3,8	2,2	9,8	3,4
		93	2,3	4,2			3,0	1,7		
	HEGP	14	3,6	8,5						
		61	12		13	17				
		93	11	17						
550-750	Ingen	14	0,30	1,3			12	3,2		
		61	0,70	2,0	1,5	9,0	5,4	2,2	2,6	0,47
		93	1,6	3,2			2,2	1,2		
	LEGP	14	1,1	2,9			2,9	1,1		
		61	2,5	4,9	4,5	20	1,2	0,64	0,67	0,16
		93	3,0	5,8			0,93	0,52		
	HEGP	14	7,0	17						
		61	13	31	26	47				
		93	11	27						

Mätning med jod-monitor.

Jod-monitorer som också finns på många sjukhus kan utgöra en viktig resurs i samband med kontaminationsmätningar av ett stort antal människor i en beredskapssituation. På sjukhusen finns också personal som har erfarenhet av dessa mätningar.

Jodmonitorerna används i diagnostiskt syfte i sjukvården och är speciellt avsedda för mätning av ^{131}I i sköldkörteln. Ett exempel på sådan utrustning är Nukleus – jodmonitor (256-kanals analysator) försedd med 2” NaI(Tl)-detektor och bakgrundsskydd av bly där känsligheten är 0.001 cps/Bq.

Mätprocedur och rapportering

Mätningarna utförs i enlighet med de procedurer som normalt används vid sjukhuset/lasarettet. Rapportering sker förslagsvis enligt blanketten i bilaga 3.

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Personblankett: Mätning av ^{131}I med handinstrument Bilaga 1

Personuppgifter

Namn	Personnummer (12 siffror)
Hemadress	Telefonnummer hem
	Telefonnummer arbetsplats
Arbetsplatsadress	Yrke

Vikt (kg)	Längd (cm)

Övriga uppgifter/anmärkningar

Mätuppgifter

Mätplats	
Monitortyp	Serienummer
Ytterligare uppgifter	

Resultat

Datum	Tidpunkt	Avstånd (cm)	Avläst resultat thyroidea (σSv/h)	Avläst resultat lårbakgrund (σSv/h)	Nettoresultat (σSv/h)	Kalibreringsfaktor (σSv/h/kBq)	Aktivitet (kBq)

Mätningen utförd av
Sign.

Rekommenderade åtgärder
Datum (yy-mm-dd), Sign.
Namnförtydligande

Personblankett: Mätning av ^{137}Cs med handinstrument   Bilaga 2

Personuppgifter

Namn		Personnummer (12 siffror)
Hemadress		Telefonnummer hem
		Telefonnummer arbetsplats
Arbetsplatsadress		Yrke
Vikt (kg)	Längd (cm)	

Övriga uppgifter/anmärkningar

Mätuppgifter

Mätplats	
Monitortyp	Serienummer
Ytterligare uppgifter	

Resultat

Datum	Tidpunkt	Mätgeometri Rygg/Palmer	Avläst resultat (σSv/h)	Avläst resultat bakgrund (σSv/h)	Nettoresultat (σSv/h)	Kalibreringsfaktor (σSv/h/kBq)	Aktivitet (kBq)

Mätningen utförd av
Sign.

Rekommenderade åtgärder
Datum (yy-mm-dd), Sign.
Namnförtydligande

Personblankett: Mätning av ^{137}Cs och ^{131}I med gammakamera och jodmonitor

Personuppgifter

Namn	Personnummer (12 siffror)
Hemadress	Telefonnummer hem
	Telefonnummer arbetsplats
Arbetsplatsadress	Yrke

Vikt (kg)	Längd (cm)

Uppgifter om exponeringen

Exponeringsdatum (yy-mm-dd)
Exponeringsförhållanden

Mätuppgifter

Mätplats	Mätdatum (yy-mm-dd)	Mätning nummer
Mätutrustning och geometri (avstånd, gammakamera med/utan kollimator, etc.)		
Mättid (s)	Ytterligare uppgifter	

Resultat

Radionuklid	Räknehastighet, netto (cps)	Bakgrund (cps)	Känslighet (Bq/cps)	Aktivitet (kBq)

Mätningen utförd av	Rekommenderade åtgärder
Sign.	Datum (yy-mm-dd), Sign.
	Namnförtydligande

Annex 3

Paper presented at NSFS meeting August 28.-31. 2005 in Rättvik

Measurements in Emergency Situations aiming at Assessment of Internal Doses

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Abstract: Internal doses can be assessed using results from direct measurements or by using information on activity concentrations in inhaled air and in foodstuffs combined with inhalation and consumption data. Whenever possible direct measurements should be done as soon as possible after an alert to give support for decision making and to reassure the general public. Experiences from accidents where many people have been internally contaminated by radionuclides have demonstrated the need of rapid measurements of large groups of people. The measurements are important both for control of the contamination situation and for later dose assessment.

In the Nordic countries much work has been put down on quality assurance of direct measurements, mostly whole-body counting and on training of dose assessment. This work has been partly funded by NKS. A good network of Nordic specialists has also been created. Nordic emergency preparedness exercises have not included training of rapid measurements of people, thyroid monitoring for I-131 and whole-body for Cs-137, in the early phase of an emergency. There should not be a big gap between planned resources and actual available resources in emergency situations. All planning and instructions are of no use if there are not instruments and people trained to use them available in a sudden accidental situation.

Introduction

Assessment of internal radiation doses can be done using results from direct measurement of people or indirectly by excreta measurements Oliveira et al,IAEA(1994), IAEA(1999), Wallström et al(1999). Especially for iodine estimations can be made using air concentration data in the early phase of an accident. Activity concentration in foodstuffs combined with consumption data can be used later. The aim of measurements is most often to determine the intake of radioactive substances. The internal radiation dose is then assessed using metabolic and dosimetric models.

The external exposure dominates after a nuclear explosion. In a nuclear power plant accident inhalation is the dominating route of exposure at least during the first days after the accident. Ingestion via food and drink becomes important after the radionuclides enter the food-chains. This depends strongly on the time of the year and the growing season.

In cases with high internal contamination the purpose of measurements is to help in deciding if medical treatment or other types of measurement for more exact dosimetry is needed. The measurements are also important for future dose assessment. In situations with prolonged exposure repeated measurements are recommended. Whenever possible direct measurements should be started as soon as possible after an alert to give support for decision making and to reassure the general public.

An alternative method would be to collect urine samples from people in a certain region. The samples could be pooled and sent to another place even far away for measurement. This would give acceptable results for groups in that region but with a certain time delay..

A handbook in Swedish was published as the result of a Nordic NKS project Rahola et al(2002). The handbook contains instructions and descriptions of procedures to handle emergency situations. Supplementary information on detailed instrument specific instructions will further be needed. Mainly iodine and caesium contamination were taken into account in this first version of the handbook. The handbook can be regarded as part of a preparedness plan but it should not be used as such but adopted to local circumstances.

This paper concentrates on direct methods of measurements of people and gives general advice on what to take into account in emergency preparedness planning and on how to do dose assessment.

Methods

After adequate efficiency calibration many simple hand-held instruments can be used for measurement of internal contamination after accidents resulting in environmental contamination. Registration of a few kBq ^{131}I in the thyroid is possible using instruments with NaI-detectors corresponding to an effective dose below 1 mSv. The corresponding data for ^{137}Cs are body burdens of 20-50 kBq. Instruments with GM-detectors need about 5 times higher activities for detection. Lately light weight gammaspectrometers have appeared on the market. Two such instruments are described in another paper presented at this conference Muikku (2005).

To gain most from the thyroid measurements the procedure should be started without delay. An important protective measure is to administer stable iodine in case of exposure to radioactive iodine nuclides. The protective effect is strongly dependent on time of administration. The effect decreases if the tablet is administered too early or too late regarding time of exposure. In an expected fallout situation the iodine tablet should preferably be taken 1-6 hours before exposure. When more than 12 hours has elapsed after intake administration of stable iodine no longer decreases the radiation dose to the thyroid. After the early phase thyroid measurements could be repeated weekly and whole-body measurements of caesium four times a year.

A good review of available software for calculation of internal radiation doses was presented by Ansoborlo et al in 2003. It is necessary to train to use these programs in routine everyday work to be able to do the calculations in a stressing emergency situation. Rapid estimations can naturally be done using dose factors found in ICRP recommendations (1994,1995,1996,1997), IAEA (1996) and in national regulations.

Conclusions

The results obtained with the rapid monitoring methods can be used for different purposes such as:

1. decision of need to administer stable iodine at places to which the radioactive cloud arrives later
2. decision of need to make repeated measurements with higher precision
3. actions in a later phase, especially the protection of certain critical groups
4. later epidemiological studies.

This type of monitoring should be arranged at easily accessible places such as hospitals, health care centres, schools etc. Preferably the place should be in an uncontaminated or slightly contaminated area. From regions with high contamination levels it is better to transport people to be measured to areas better suited for measurement.

To ensure a rapid start of measurement procedures the equipment to be used should be calibrated in advance and also tested regularly. The performance of measurements requires that trained users can rapidly be sent to places decided after assessment of the situation in question. The plans for measurement strategies should be developed in each country separately taking into account national regulations, local circumstances and resources. Nevertheless, in view of the close contacts between people in the Nordic countries, it is very important to have the same approach in all countries. This will increase the public reassurance in case of a nuclear emergency situation. The bilateral agreements among the Nordic countries about assistance in emergency situations also emphasize the importance of cooperation. It is also important to remember that there should not be a big gap between planned resources and actual available resources in emergency situations. All planning and instructions are of no use if there are not instruments and trained people to use them in such demanding situations. In the NKS project IRADES an inventory of available instruments for thyroid monitoring has been done and measurement strategies are developed.

After the accident in Chernobyl an active interest in improving whole-body counting techniques was seen. Intercomparison exercises were started by different organisations in many countries Rahola et al(1994),Thieme et al(1998). This is most important from a quality control point of view. Quality control aspects are as important when doing rapid measurements as when doing normal whole-body counting. Special instructions should be prepared for different types of measurements in emergency situations and regular training arranged.

In many countries the general public knows that it is possible to do direct measurements on people and will not accept prognoses based only on external radiation and foodstuff measurements. In the future it will be necessary to do also direct measurements on people for reassurance of the public even if such measurements would not be necessary from a strict radiation protection point of view.

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Muikku M, Rahola T(2005) Portable thyroid monitor for detection of I-131 in emergency situations. Presented at this conference.

Irades Paper presented at NSFS meeting in Rättvik 28.-31.8.2005

Portable thyroid monitors for detection of ^{131}I in emergency situations

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Abstract: The need for assessing internal radiation doses in emergency situations is evident. Studies done in Ukraine, Belarussia and the southern parts of Russia after the Chernobyl accident have shown an unexpected increase of thyroid cancers in children and young people. Direct measurements give both individual results and results for groups. In the past two years, Radiation and nuclear safety authority - STUK has obtained 35 monitors for thyroid measurements in the field conditions. The monitors work as spectrometers, which makes it possible to do real time spectrum analysis in the field.

Introduction

The aim of this work is to improve the preparedness for thyroid monitoring in emergency situations. The need for assessing internal radiation doses in emergency situations have been demonstrated after accidents in Brasil, Ukraine and other countries. Studies done in Ukraine, Belarussia and the southern parts of Russia after the Chernobyl accident have shown an unexpected increase of thyroid cancers in children and young people. Direct measurements, which should be done as soon as possible after an alert to give support for decision making, give both individual results and results for groups.

Results and discussion

In the recent years, Radiation and nuclear safety authority - STUK has obtained 25 Atomtex RKG-AT1320 monitors and ten Canberra InSpector 1000 monitors for thyroid measurements in the field conditions. The AT1320 thyroid monitor consists of a detector with 1”x1” NaI(Tl) crystal, control unit and lead collimator (Figure 1, left). The construction of the InSpector 1000 thyroid monitor is similar apart from the size of the NaI(Tl) crystals which is 2”x2” (Figure 1, right). The energy resolutions of the crystals are better than 8 %. The monitors work as spectrometers making it possible to do real time spectrum analysis in the field. The collected spectrum is shown on the display of the control unit. It is possible to store spectra in the detection unit, from where they can be later on transferred to a PC. The energy stabilization is done before starting measurements using a ^{137}Cs source. Likewise the background control and sensitivity check (also with ^{137}Cs source) are carried out before measurements.

Figure 1. Left: RKG-AT1320 thyroid monitor: NaI(Tl) detector, control unit, charger, ^{137}Cs control source and cables. Right: InSpector 1000 thyroid monitor: In addition to spectrum acquisition mode the Inspector monitor can be used in dose rate mode or in nuclide identification mode.

The aim of thyroid monitoring is to determine the ^{131}I activity in the thyroid with minimal interference from activity in the rest of the body. This is achieved by placing a shielded or a collimated detector near the neck at the position of the thyroid. However, both RKG-AT1320 and InSpector 1000 thyroid monitors are planned to be movable and easy to carry. During measurement the RKG-AT1320 detection unit planned to be held in hand, although it can also be placed to a stand. Thus, the weight of the detection unit can not be more than a couple of kilograms. The collimator used in the present RKG-AT1320 measurement set-up is made of 5 mm thick lead and it weights about 1 kg (Figure 2, left). Assessment of the contribution to the detector response from radioiodine in blood and in surrounding measurement area can be made by placing the detector over a different area in of the body (e.g. thigh) [1]. For thyroid measurements, InSpector 1000 monitor is positioned into a table-top lead shield of 12.5 kg weight (Figure 2, right).

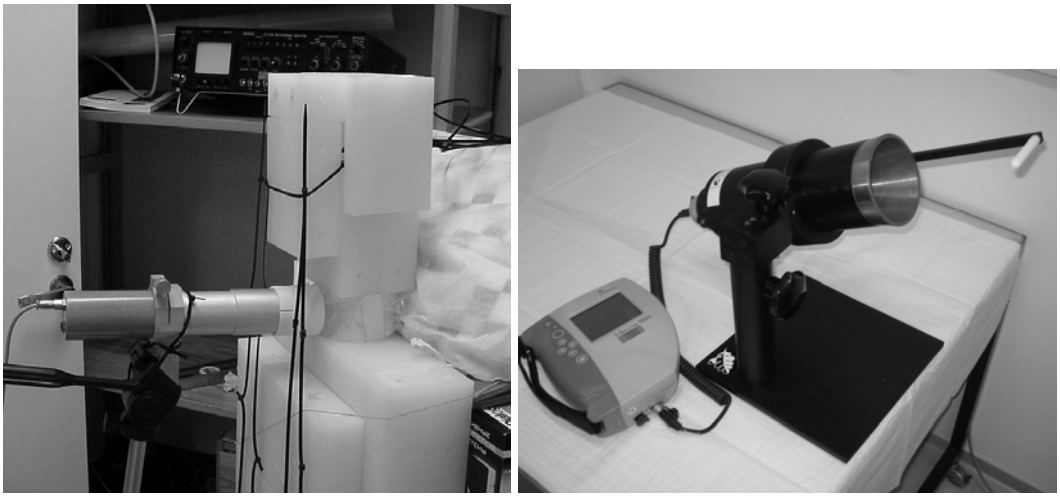

Figure 2. Left: RKG-AT1320 thyroid monitor in a 5 mm lead collimator and an adult phantom in measurement distance of 7 cm. Right: InSpector 1000 thyroid monitor in a table-top lead shield.

The detection efficiency depends greatly on the distance between the detector and thyroid. To get good statistics in a short time the detector should be placed as close to the neck as possible. The exact position of the thyroid must be known in order to get right results in the close geometry. If the detection distance is longer, is not so crucial to place the detector exactly on the thyroid. Two measurement distances were used in the calibration of the RKG-AT1320 thyroid monitors, 7 cm and 20 cm. Three calibrations were done for both distances: adult, teenager (14 years old) and child (6 years old). The St. Petersburg thyroid phantom and whole body phantom with ^{40}K rods were used in the calibration. Two capsules filled with ^{131}I solution were placed in the thyroid phantom. The minimum detectable activities (MDAs) when using the measurement time of 100 s in normal conditions are about 2000 Bq and 330 Bq for 20 cm and 7 cm detection distances, respectively. If longer time of 600s is chosen, the MDAs are significantly lower: 760Bq and 120 Bq for 20 cm and 7 cm distances, respectively. The set-up with 7 cm detection distance is about six times more efficient than that with 20 cm distance.

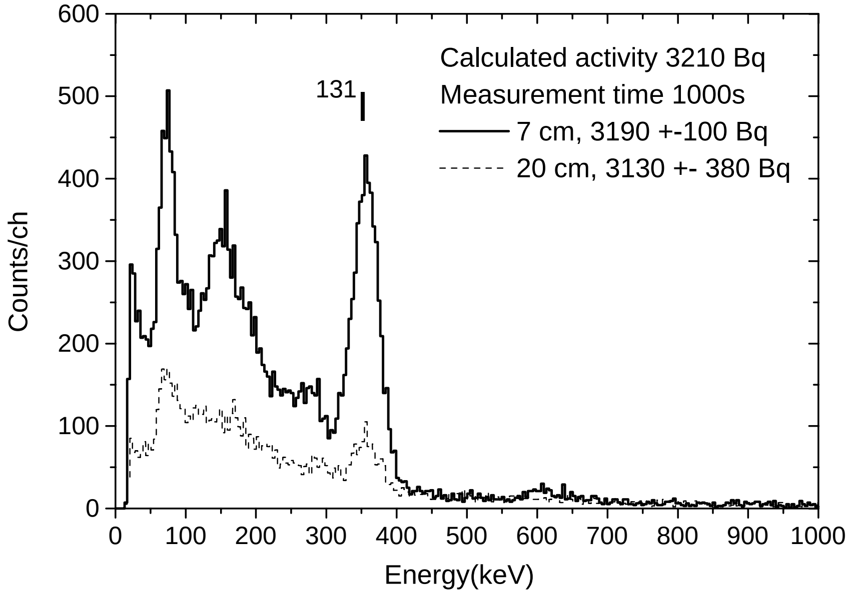

Figure 4. Gamma-ray energy spectra collected from a ^{131}I thyroid phantom (distances 7cm and 20 cm).

The use of a lead collimator - even though the thickness of the collimator is only a few millimetres - reduces significantly the low-energy background resulting from scattered ν-rays. This is illustrated in Figure 5, where a ν-ray energy spectra collected from a ^{131}I thyroid phantom with and without the 5 mm lead collimator is shown. A ^{137}Cs source has been placed in the vicinity of the thyroid monitor to demonstrate the background radiation from surroundings in a fallout situation. These tests have also been carried out using RKG-AT1320 thyroid monitor. InSpector 1000 monitors will be calibrated and similar tests will be done during summer 2005.

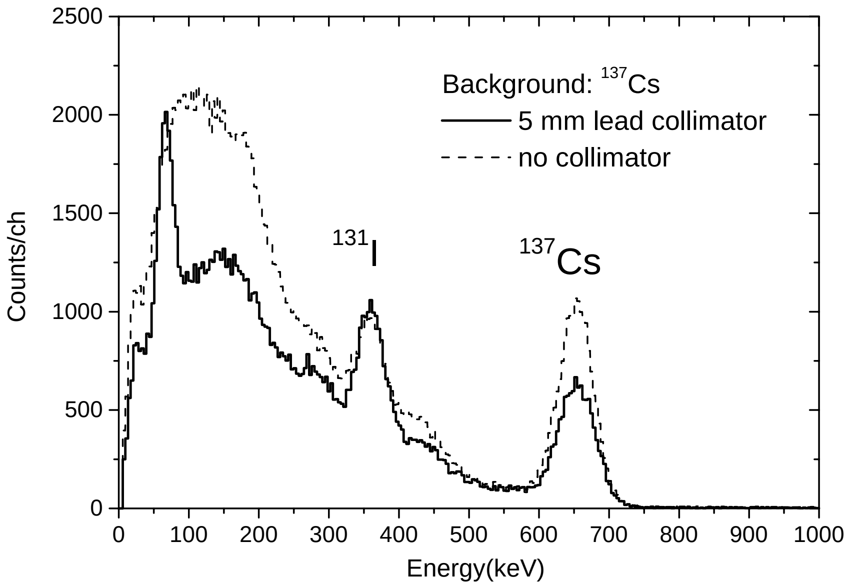

Figure 5. Gamma-ray energy spectra collected from a ^{131}I thyroid phantom with and without the 5 mm lead collimator.

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Annex 4

Effect of stable potassiumiodide administration

Table 1. The protective effect of KI on the thyroid. a) Time of ^{131}I:n by inhalation, when no stable iodine is administered, b) when 50 mg potassiumiodide is administered 30 minutes after exposure.

	Time of radioactive I in organ (h)	
Organ	a)	b)
thyroid	63,7	3,9
blood, inorganic	9,1	11,8
blood, organic	2,4	0,1
bladder	1,9	2,5
lung	0,2	0,2
whole body	77,2	18,5

For example 50 mg potassiumiodide given 30 minutes after exposure to ^{131}I:n decreases the dose to the thyroid to six percent of the dose with no KI administration. In a possible fallout situation the iodide tablet should be taken 1-6 hours before exposure. The protective effect of stable iodine decreases if the tablet is administered too early or too late. When more than 12 hours has elapsed after intake the administration of stable iodine no longer decreases the radiation dose to the thyroid. Although the administration of stable iodide may decrease the dose to the thyroid the time of ^{131}I in the whole body is reduced only to a quarter. For more shortlived iodine isotopes this effect is further enhanced, the thyroid can effectively be protected but the number of radioactive decays in the whole body does not decrease highly and the dose to other organs might even be increased because of the administration of stable iodide. The KI tablet is not any wonderdrug, which would totally prevent any harmful effects on health.

Example
What is the committed equivalent dose to the thyroid for people in different age groups (age < 1, 1,5, 10, 15 and older than 17 years) when

a) people drink more than 0,4 liters of milk daily for 10 days and the ^{131}I concentration is 30 Bq/l,
b) the same persons inhale air with a ^{131}I concentration of 1000 Bq/m^3 for one hour (lung absorption class F and particle size (AMAD) 1 εm).

The inhalation rates and conversion factors for the committed equivalent dose to thyroid are given in Table 2. Values for males are used for adults and over 15 years old. The inhalation rate for women is taken as 80 % of that for men.

Age, years	< 1	1	5	10	15	Adults
Inhalation rate (m^3/d)	2,86	5,20	8,76	15,28	20,1	22,18
Conversion factor for ingested iodine (Sv/Bq)	$3,7 \cdot 10^{-6}$	$3,6 \cdot 10^{-6}$	$2,1 \cdot 10^{-6}$	$1,0 \cdot 10^{-6}$	$6,8 \cdot 10^{-7}$	$4,3 \cdot 10^{-7}$
Conversion factor for inhaled iodine (class F) (Sv/Bq)	$1,4 \cdot 10^{-6}$	$1,4 \cdot 10^{-6}$	$7,3 \cdot 10^{-7}$	$3,7 \cdot 10^{-7}$	$2,2 \cdot 10^{-7}$	$1,5 \cdot 10^{-7}$

a) Since all drink the same amount of milk the intake is the same for evrybody $10d \cdot 0,4 l/d \cdot 30\, Bq/l = 120 Bq$. Using the conversion factors above the committed equivalent dose to the thyroid is

Age, years	< 1	1	5	10	15	Adults
committed equivalent dose to thyroid (mSv)	0,44	0,43	0,25	0,12	0,08	0,05

Iodine is totally absorbed in blood and 30% of the intake is transferred to the thyroid from which it is excreted with a biological halftime of 80 days. Since ^{131}I emits only beta- and gammaradiation the weighting factor is 1. The committed effective doses are only 5% of the equivalent doses because the weighting factor for the thyroid is 0,05.

In reality children drink much more milk than adults which increases the doses to children.

b)
The intake is $S = 1/24 d \cdot hengitysnopeus \cdot m^3/d \cdot 1000\, Bq/m^3$ and the committed equivalent dose is thus breathing rate

Age, years	< 1	1	5	10	15	Adults
Inhalation rate (m^3/d)	2,86	5,20	8,76	15,28	20,1	22,18
Intake(Bq)	119	217	365	637	838	924
Committed equivalent dose to thyroid (mSv)	0,17	0,30	0,27	0,24	0,18	0,14

As can be seen from the table the equivalent dose to a one year old is only twice that of adults although the difference in dose factors is more than eightfold.

Annex 5

NKS- B- IRADES

Programme
12.10.2005

Internal dosimetry course and IRADES project meeting

Tartu, Estonia, Wednesday 26 October 2005

Wednesday 26 October 2005

9:00	Opening remarks	Tua Rahola/STUK
9:15	Introduction to internal dosimetry	Maarit Muikku and Tua Rahola/STUK
10:15	Dose calculation using software IMBA ∉ Presentation of IMBA ∉ Demonstration with case studies	Alan Birchall/HPA-NRPB
11:15	Refreshments	
11:45	IMBA and statistics	AlanBirchall/HPA-NRPB
12:15	Lunch	
13:15	First experiences with IMBA	Nils Addo/Studsvik
13:30	New software suitable for nonexperts in emergency situations	Alan Birchall/HPA-NRPB
14:00	Inventory of thyroid monitors in the Nordic countries	Rolf Falk/SSI
14:30	Report on intercomparison and calibration	Jan Johansson/SSI
15:00	Refreshments General information and discussion	

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Abstract

The need for assessing internal radiation doses in emergency situations was demonstrated after accidents in Brasil, Ukraina and other countries. Lately more and more concern has been expressed regarding malevolent use of radiation and radioactive materials. The scenarios for such use are more difficult to predict than for nuclear power plant or weapons accidents.
Much of the results of the work done in the IRADES project can be adopted for use in various accidental situations involving radionuclides that are not addressed in this report. If an emergency situation occurs in only one or a few of the Nordic countries, experts from the other countries could be called upon to assist in monitoring. A big advantage is then our common platform.
In the Nordic countries much work has been put down on quality assurance of measurements and on training of dose asessment calculations. Attention to this was addressed at the internal dosimetry course in October 2005.
Nordic emergency preparedness exercises have so far not included training of direct measurements of people in the early phase of an emergency. The aim of the IRADES project was to improve the preparedness especially for thyroid measurements.
The modest financial support did not enable the participants to make big efforts but certainly acted as a much appreciated reminder of the importance of being prepared also to handle situations with malevolent use of radioactive materials. It was left to each country to decide to which extent to improve the practical skills.
There is still a need for detailed national implementation plans.
Measurement strategies need to be developed in each country separately taking into account national regulations, local circumstances and resources.
End users of the IRADES report are the radiation protection authorities.

Key words: Internal radiation doses, thyroid monitoring, emergency preparedness

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