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GUIDE ST 7.1

Monitoring of Radiation Exposure

STUK • SÄTEILYTURVAKESKUS • STRÅLSÄKERHETSCENTRALEN
RADIATION AND NUCLEAR SAFETY AUTHORITY

STUK

GUIDE
25 February 2000 ST 7.1

Monitoring of Radiation Exposure

This Guide is valid as of 1 May 2000 until further notice. It replaces ST Guide 1.6 "Monitoring of Radiation Exposure and Registration of Doses", issued on 10 October 1995.

Helsinki 2001
Oy Edita Ab
ISBN 951-712-432-5
ISSN 1456-8160

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Authorisation

Under section 70, paragraph 2, of the Radiation Act (592/1991), STUK – Radiation and Nuclear Safety Authority (Finland) issues general instructions, known as Radiation Safety Guides (ST Guides), concerning the use of radiation and operations involving radiation.

The Radiation Act stipulates that the party running a radiation practice is responsible for the safety of the operations. The responsible party is obliged to ensure that the level of safety specified in the ST Guides is attained and maintained.

Translation. Original text in Finnish.

This Guide includes the requirements relating to the implementation of Council Directive 96/29/Euratom; OJ No. L 159, 29.6.1996, p. 1.

1 General

Chapter 9 of the Radiation Act (592/1991, amendment 1142/1998) prescribes the responsibilities of the party running a radiation practise (hereafter the responsible party) to organise radiation protection for occupationally exposed workers. Chapter 3 of the Radiation Decree (1512/1991, amendment 1143/1998) specifies in more detail the procedures relating to the monitoring of radiation exposure. In accordance with section 32 of the Act, more specific requirements and guidelines for carrying out the monitoring of radiation exposure are provided by the Radiation and Nuclear Safety Authority (STUK).

This Guide specifies the requirements for the monitoring of radiation exposure in instances where radiation is used. In addition to workers, this Guide covers students, apprentices and visitors. This Guide shall also apply to exposure from natural radiation, as defined in section 46 of the Radiation Act and section 28 of the Radiation Decree. The monitoring of radiation exposure in nuclear power plants is dealt with in YVL Guide 7.10 and 7.11.

This Guide defines the concepts relevant to the monitoring of radiation exposure and provides guidelines for determining the necessity of monitoring and subsequently arranging such in different operations. In addition, this Guide specifies the criteria for the approval and regulatory control of the dosimetric service.

2 Definitions and Concepts

Radiation work means work in which the radiation exposure of a worker may exceed one of the dose limits for members of the public prescribed in section 6 of the Radiation Decree. Workers engaged in radiation work shall be classified into category A or B in accordance with section 10 of the Radiation Decree.

External radiation means radiation directed to the human body outside the body.

Internal radiation means radiation emitted by radioactive substances that have entered the body.

Monitoring of radiation exposure means **individual monitoring** and **monitoring of working conditions**.

Individual monitoring means the measurement of external radiation, the determination of radioactive substances that have entered the body, and interpretation of the results of measurements to assess the individual dose. In addition, individual monitoring includes the registration of doses that have been assessed.

Monitoring of working conditions means the control of the various factors affecting exposure to radiation in the workplace, with the purpose of verifying exposure, preventing unnecessary exposure, or ascertaining the need for individual monitoring. In addition, monitoring of working conditions includes the registration of the results of the measurements.

Dosimetric service means a body responsible for

- the calibration and reading of dosemeters and other individual monitoring devices, and for the assessment of doses, or
- the measurement of radioactivity in the human body or in biological samples, and for the assessment of doses,

whose capacity to act in this respect is recognized by STUK.

3 General Requirements

The monitoring of radiation exposure shall be organised, to whatever extent is required by the nature and scope of the radiation practice, in such a way that the exposure to radiation of each worker engaged in radiation work can be

determined. The radiation doses received at work and the personal data of workers monitored shall be reported to the Dose Register of STUK as instructed in ST Guide 7.4.

Section 34 and 34 b of the Radiation Act specifies the safekeeping of data on the doses of category A workers. The results of measurements carried out for monitoring working conditions relevant to any individual radiation exposure shall be retained in the same way. Such measurements are e.g. thyroid measurements and skin contamination measurements.

3.1 Individual Monitoring

The purpose of individual monitoring is to determine the radiation dose which each worker has received. Individual monitoring shall be arranged for all category A workers. For category B workers it is appropriate to arrange individual monitoring, if the individual radiation doses repeatedly exceed the dose limits for members of the public prescribed in section 6 of the Radiation Decree. Chapter 4 of this guide contains a list of instances where individual monitoring must be implemented. Individual monitoring shall be based on individual measurements carried out by an approved dosimetric service.

If substantial amounts of radioactive substances may enter the body, an appropriate monitoring system for determining internal contamination shall be arranged. If the work causes skin contamination to such an extent that it cannot be disregarded from the radiation protection point of view, the skin dose shall also be assessed.

If individual dose measurement is not possible e.g. due to malfunctioning of a dosemeter, or if it is suspected that the dose has been assessed incorrectly, the individual dose shall be determined through calculation based on the measurements carried out for monitoring the working conditions or the results of the measurements concerning other workers that have been monitored. The responsible party is responsible for the assessment of the dose.

3.2 Monitoring of Working Conditions

The purpose of monitoring working conditions is to detect changes occurred in the working environment and to assess their impact on radiation exposure. Monitoring of working conditions includes measurements of the dose rate of external radiation, contamination measurements in the workplace, and checking whether the safety devices are working as intended. In addition, the monitoring of working conditions includes the registration of work hours in instances where it is necessary to assess a worker's exposure to radiation and the quantity of exposure.

The monitoring of working conditions is compulsory in all workplaces where radiation work is carried out. The monitoring of working conditions shall be arranged in such a way that a proper classification of workers into category A and B can be ensured. In addition, by means of control measurements it shall be possible to determine individual radiation exposures retrospectively, if a special need arises e.g. due to exceptional exposure. For this reason, it is often appropriate to arrange the monitoring of working conditions also for category B workers based on individual monitoring.

To detect changes occurred in the working environment in places where radiation equipment and sealed sources are used

- the radiation sources shall be properly marked
- the dose rate of external radiation shall be monitored in the vicinity of the radiation sources
- measurements of contamination shall be carried out, whenever necessary, and
- non-changing conditions and operational safety of the radiation sources shall be ensured by monitoring the tightness of sealed sources, adequacy of radiation shieldings, and checking that safeguards and personal protective equipment are serviceable and correctly used.

In the handling of unsealed sources, radioactive substances can enter the body with inhaled air,

through the mouth, wounds or skin. In places where unsealed sources are used, adequate ventilation, proper use of protective devices and proper choice of working methods shall be ensured. If, in addition, contamination in the workplace is regularly measured and the contamination level remains low, it is not necessary, except in certain special cases, to determine radioactive substances in the body.

In places where unsealed sources are used, contamination shall be monitored by regular measurements to ascertain the need for monitoring radiation exposure. Targets to be measured include worktops, tools, clothing and skin. ST Guide 6.1 specifies in more detail the action levels and other requirements concerning contamination. If radioactive substances have escaped into the air that is inhaled in such quantities that it is of relevance to radiation exposure, their activity concentrations shall be determined through air sampling. When the inhaled air is suspected to be or found contaminated, and no measurement results are available, the activity concentration shall be calculated from the amount of radioactive substance escaped, taking the volume and air exchange rate in the room into account. During contamination measurements, the contaminating radionuclides shall be determined, if they are otherwise not known. The physical and chemical state of the radionuclides shall also be determined, if it is of relevance to the assessment of the radiation dose.

The following information shall be provided concerning the results of monitoring the working conditions:

- date of the measurements
- external dose rates, including radiation type and energy
- activity of the contaminating radioactive substances in the air and on surfaces, including the type and physical and chemical state of the contaminating substances
- duration of exposure of the workers, if it is required for calculating the doses, or
- a statement that no radiation exposure or contamination was found.

The results shall be stored in such a way that they can, if necessary, also be used for the assessment of individual doses retrospectively.

4 Need for Monitoring

4.1 External Radiation

Individual monitorig of occupationally exposed workers is required at least in the following instances:

1. medical or veterinary X-ray examination, when a person performing radiography or fluoroscopy works close to the primary beam
2. radiotherapy and the performance of quality control measurements on radiotherapy equipment
3. radionuclide therapy, unless the handling of the patient is of only short duration or the patient has been treated with radiopharmaceuticals emitting only beta radiation
4. the handling of unshielded radioactive substances
   - if the activity of radionuclides emitting gamma radiation handled at one time exceeds 100 MBq
   - if the activity of radionuclides emitting beta radiation handled at one time exceeds 10 MBq and the maximum energy of the beta radiation is higher than 300 keV
5. industrial radiography
6. use of diffraction, fluorescence or comparable equipment, if the radiation beam is directed outside the equipment
7. installation, repair and servicing of high-activity radiation sources, or radiation sources with a high dose rate, for which a safety license is required
8. work on a research reactor, particle accelerator, at a sterilisation plant or other irradiation plant
9. other operations with radiation sources, when the individual monitoring is required by the terms of a safety license or other document.

For the monitoring of exposure caused by neutron radiation, a dosemeter suitable for this purpose shall be used. Individual monitoring

shall be arranged if the dose is or can be larger than 2 mSv per year.

Individual monitoring is usually necessary in work involving the installation, testing and servicing of radiation sources for which a safety license is required. In addition, during such work a survey meter showing the dose rate or an alarm dosemeter shall be used. The holder of the safety license shall also organise the monitoring for outside workers carrying out repairs and servicing. However, monitoring is not necessary if the outside worker has a dosemeter of his own.

Individual monitoring is not necessary in the following instances:

1. radiography, when the operator of the X-ray equipment is located in a separate control room, which is well shielded and has not been classified as a controlled area (for controlled area, see ST Guide 1.6)
2. dental radiography forming part of a dentist's normal work
3. work in areas where the radiation equipment or sources are so well shielded that the body or a part of the body cannot be exposed to the primary beam or radiation in any other way. These are e.g. industrial radiometric equipment.
4. if radionuclides emitting only beta radiation with a maximum energy of 300 keV or lower are used.

The operational quantity to be used in individual monitoring is personal dose equivalent $H_p(10)$ for penetrating photon radiation (deep dose) and $H_p(0,07)$ for soft photon radiation and beta radiation (surface dose). For additional information on the quantities, see ST Guide 7.2.

4.2 Internal Radiation

The need for monitoring exposure caused by internal radiation depends on the working conditions, type of work, and the activity of the handled substance and the physical and chemical characteristics of the radionuclide to be handled. The necessity of monitoring shall be clarified when there is a risk of radioactive substances entering the body or skin contamination.

The need for individual monitoring shall be clarified on the basis of measurements carried out for the monitoring of working conditions by assessing the internal doses as laid down in ST Guide 7.3.

Individual monitoring shall be organised when

- working in a laboratory of type A
- handling radioactive substances in an easily volatile or dusty form and in such quantities that it is of relevance to radiation exposure
- handling iodine isotopes in such quantities that it is of relevance to radiation exposure (especially ^{131}I, ^{125}I, ^{123}I)
- working in rooms where radionuclides or radiopharmaceuticals are produced
- monitoring is required according to the terms of a safety license or other document.

A dose caused by internal radiation can be assessed by measuring the amount of radioactive substances in the body directly from the body or part of the body or through excretion analyses. If activity concentration in the air is used as the basis for the assessment, the dose shall be calculated on the basis of the measurements carried out for the monitoring of working conditions and the time of exposure.

5 Practical Measures

5.1 External Radiation

Individual doses from external radiation are usually determined by thermoluminescence dosemeters (*personal dosemeter*). For category A workers, the length of the monitoring period is usually one month, for others a period not exceeding three months. If a worker has been classified as a category A worker exclusively because of accidental exposure (potential radiation exposure), the length of the monitoring period can be longer than one month. In this case, the worker shall use an electronic dosemeter with continuous read-out suitable for the

purpose or an alarm dosemeter to detect abnormal exposure.

To monitor the dose to a foetus a new monitoring period shall commence immediately once the pregnancy has been declared.

An alarm dosemeter or an alarming survey meter shall be used, in addition to a dosemeter, in industrial radiography and irradiation or comparable plants. Similar alarm devices shall be used in installation, repair and servicing work if the nature of the work imposes a risk of the body being exposed to the primary beam.

If there is a risk that persons during a visit in a controlled area may receive a dose that exceeds the recording level, radiation exposure of the visitors shall be monitored in a suitable manner. In such cases, it is usually advisable to use a suitable electronic dosemeter with a continuous read-out or a dosemeter that is immediately readable after use. For a group of visitors it is also possible to use group dosemeters, the number of which shall be at least two. Doses larger than 0.1 mSv shall be registered and reported to the Dose Register. Visitors and the doses they have received shall be registered.

Outside workers, who work in a controlled area carrying out e.g. research work, studies or installation, repair and servicing work, shall be monitored in the same way as the regular workers.

The doses to a worker's hands may be significant in interventional radiology, in some repair and servicing tasks and when unsealed sources are handled, such as labelling a radiopharmaceutical or injecting it into a patient. Assessment of the doses to hands (fingers) is especially important when new working methods or radioactive substances are taken into use and when the exposure they generate is insufficiently known.

The doses to hands are usually measured by finger dosemeters containing a suitable thermoluminescence material as a radiation detector. Measurement of the doses to fingers is often difficult and needs to be performed carefully because the dose differs in individual fingers and parts of the fingers. When a hypodermic syringe is used, for example, the measured values may be multiple depending on the measurement point. It is important to place the dosemeter on the part of the finger where the largest dose is most likely to occur.

In jobs where a finger dosemeter is an unreasonable hindrance to the work, it is sufficient if the doses to hands are measured during a typical working month, and the annual dose is estimated from the measurement result. Monitoring of the exposure of hands shall be implemented if the estimated annual dose is 150 mSv (three tenths of the annual dose limit for hands) or larger.

When there is exposure to gamma radiation, the dose to the eyes is estimated from a deep or surface dose measured by a personal dosemeter. When X-radiation is used, the dose to the eyes is estimated from a surface dose measured on a lead rubber apron on the chest. A separate measurement of the dose to the eye is necessary in those special cases where it is not possible to assess the dose to the eye from the dose measured on the apron. In such cases, a dosemeter attached to a headband can be used, for example.

Individual monitoring shall be arranged for a person who regularly assists a patient, e.g. helps to immobilise the patient during an X-ray examination. Because radiation is scattered from the patient, it is important that the dosemeter be worn on the side of the worker's body facing the patient. This practice is also applicable to veterinary X-ray examinations where an animal must be immobilised during the examination.

Part of the body is shielded from radiation when a protective apron or other personal protective devices and clothing are used. Because the dose limit to the eye is usually the first to be exceeded, the dosemeter shall be placed outside the protective apron to make it possible, using the same dosemeter, to estimate the dose to the eye.

In tasks where the exposure is very high (the dosemeter reading exceeds 20 mSv annually), the effective dose shall be determined by an extra dosemeter placed under the protective apron.

The dosemeter shall be placed on the body in such a way that it is not shielded by any part of the body, and such that it is as perpendicular as possible to the direction of the incidence of the radiation. Usually the best point is the chest of the worker, and attached to the work clothes. If it is not necessary to measure beta radiation, the dosemeter can, for practical reasons, be placed in the breast pocket of the work clothes. The front side of the dosemeter should always be facing the incidence of radiation.

When not in use, dosemeters shall be stored in a place where they are not exposed to any radiation except background radiation. The temperature and humidity of the storage place shall not essentially deviate from those of normal room air. Dosemeters shall also be shielded from ultraviolet radiation and intense light.

5.2 Internal Radiation

Radionuclides such as ^{3}H, ^{14}C and ^{35}S, which emit only beta radiation with a maximum energy of 300 keV, practically cause exposure only when they enter the body. Monitoring shall take the form e.g. urine or other excretion analyses. The same applies to the use of radionuclides which emit only alfa radiation.

The activity of gamma emitters in the body can be determined with appropriate equipment such as a whole body counter, gamma camera or other radiation meter suitable for the purpose.

When iodine isotopes are handled in an easily volatile form, the amount of iodine accumulated in the thyroid shall be monitored in order to detect internal contamination. A sufficiently sensitive radiation meter shall be used for the measurements. A suitable monitoring device is, for example, a NaI(TI) detector.

Notable internal contamination can occur during labelling work with radioactive iodine. If the labelling work is carried out more frequently than once a month, the amount of iodine accumulated in the worker's thyroid shall be measured every two weeks. If the labelling work is carried out less frequently then once a month, the measurement shall be done after each labelling event. It is recommended that the measurement be performed after one day of the labelling work.

A register shall be kept of the results of the measurements. If the activity found in the thyroid is greater than 5 kBq, the results shall be reported to STUK for recording to the Dose Register.

6 Effective Dose and Equivalent Dose

Dose limits have been set for effective dose as well as for the equivalent dose to the eyes, skin, hands and feet. These quantities are not measurable with a dosemeter. Calculating the effective dose and equivalent dose is described in ST Guide 7.2. In most cases, a deep dose (H_p (10)) measured by a personal dosemeter can be considered a sufficiently good approximation of the effective dose from external radiation. A surface dose (H_p (0.07)) measured by a personal dosemeter can, correspondingly, be regarded as a good approximation of the equivalent dose to the skin and to the eye. The effective dose from internal radiation shall be assessed by using the dose conversion factors specified in ST Guide 7.3.

If a deep dose measured is noticeably large (approaching the annual dose limit or exceeding it), this shall be reported to STUK, and the effective dose shall be calculated separately and to an accuracy such that it can be compared with the dose limit.

In X-ray diagnosis, the relationship between a deep dose measured on a lead rubber apron and the effective dose depends on the radiation

type, energy and the direction of incidence of the radiation, as well as the body structure and protective equipment used. Typically, this relationship varies from 10 to 60, i.e. the effective dose is obtained by dividing the measured deep dose by the number 10 to 60.

Correspondingly, the relationship between a deep dose measured under a protective apron and the effective dose varies from 0.6 to 10. The relationship between a deep dose and the effective dose is explained in more detail in ICRP Publication 74 (Conversion Coefficients for use in Radiological Protection against External Radiation).

The relationship between the equivalent dose to the eye and the surface dose measured at chest height depends on the direction of the incidence of the radiation and the radiation energy used. In typical working situations this relationship varies from 0.8 to 1.6.

7 Approval of Dosimetric Service

Individual monitoring shall be based on individual measurements carried out by a dosimetric service. The dosimetric service is subject to approval and regulatory control by STUK. A precondition for the approval is that the responsible laboratory is either accredited or it is inspected by STUK. During the inspection STUK will decide, on the basis of documents and, if necessary, tests, whether the dosimetric service meets the general requirements specified below. Detailed requirements are based on report EUR 14852.

Approval and running the service requires that

- the measuring system has been tested or inspected and is suitable for the operations in question
- the training of the operators of the system and the operating organization is adequate for running the service in question
- a quality control programme is in use to verify the reliability of the measurements
- the calibration of the measuring system has been traced to a national or an international metrology laboratory.

The approval is periodical and can be renewed. Running the service requires that the measured doses are reported to the Dose Register in accordance with the instructions provided by STUK.

STUK will occasionally test the operation of the dosimetric service by irradiating dosemeters in the Metrology Laboratory at STUK. The measuring equipment and methods used for the determination of internal radiation exposure will be inspected from case to case.

8 Working Abroad

For persons working in an other EU member state, individual monitoring shall be arranged by authorization of the radiation safety authorities in the country concerned. When a person is working in a non-EU country, individual monitoring shall be arranged in accordance with this Guide, if the employer is Finnish. In most cases, a Finnish dosimetric service can then be used. Section 35 of the Radiation Act specifies the reporting of radiation work carried out abroad to the Dose Register.

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