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OCCUPATIONAL AND PUBLIC RADIATION EXPOSURES ARISING FROM THE NORMAL TRANSPORT OF RADIOGRAPHIC RADIATION SOURCES IN GERMANY

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ABSTRACT

Gamma radiation sources are of vital importance in non-destructive testing to ensure integrity of components and structures and are shipped and used in a wide range of portable and non-portable exposure devices commercially available. A nationwide survey of radiographic radiation source shipments in Germany indicates that every year approximately 20 000 – 25 000 shipments are performed by road. The use, handling, and transport of radiographic sources give rise to radiation exposures of both workers (radiographers) and members of the public. However, while a sufficiently large body of information exists on the total dose incurred by radiographers from the use and handling of radiographic sources including their transport, there is generally little information available - if any - to allow some judgment to be made on the transport-related doses and the adequacy and effectiveness of the radiation protection measures to be employed by operators during transport in the public domain. To bridge this gap of information a specifically designed dose assessment program was set out with the objective to quantify the public and occupational radiation doses attributable to the normal transport of portable radiographic radiation sources.

The paper describes the scope and nature of the dose assessment and evaluation program and presents the survey and dose assessment results based on monitoring data and dose estimates. The assessment results available indicate that the radiation doses incurred by radiographers and members of the public during normal transport of gamma radiation sources are generally limited and well below the applicable dose limits.

INTRODUCTION

Radiation sources are widely used for industrial purposes, e.g. for non-destructive material testing, manufacturing, and a broad variety of other applications in civil engineering (e.g. density and humidity gauging at road construction sites). Many of these sources are non-portable and/or used at fixed sites (e.g. for level or thickness gauging) while others are portable devices and routinely transported on publicly accessible roads to remote construction sites, cross-country pipeline installations etc. The results of a recent nationwide survey indicate that the number of radiographic source shipments on publicly accessible transport routes in Germany is in the range of about 20 000 – 25 000 shipments per year. Road transportation is the predominant shipping mode.

The handling, use, and management of industrial radiographic sources including their transport in the public domain give rise to radiation exposures to both transport personnel and members of the public (working or living in close proximity to the radiation source). The radiation doses received by workers can vary significantly depending on a number of factors including the duration and conditions of exposure. However, while a significant body of information exists on the type and magnitude of doses incurred by gamma radiographers there is generally little - if any - information available on the adequacy and effectiveness of the radiation protection measures employed during transport and the radiation doses of industrial radiographers attributable to the movement phase of the radiation source transports. To bridge this gap of information work has been performed on behalf of the German competent authority with the objective to quantify the dose of gamma radiography workers attributable to routine transportation and to allow some judgment to be made on the efficacy of the radiation protection provisions and requirements of the IAEA Transport Regulations [1].

For this purpose a survey has been performed with the aim to gather data on the number and conditions of gamma radiography source shipments, the radiation source characteristics (e.g. radioisotope, activity content), the radiation levels of the employed sources and those within the transport vehicle. The survey was undertaken in close co-operation with the German Society for Non-destructive Testing and covered all major non-destructive testing service companies in Germany. The details of the survey and the survey results are given below.

CHARACTERISTICS OF PORTABLE GAMMA RADIOGRAPHY DEVICES

Industrial radiography sources are routinely transported while being enclosed in specifically designed exposure containers providing appropriate shielding. This apparatus includes an exposure container, a source assembly, and as applicable, a remote control, projection sheath, exposure head, and other accessories designed to enable radiation emitted by a sealed radioactive source to be used for industrial radiography purposes (see Figure 1). The radioactive source is generally completely enclosed and shielded when in rest position and is only exposed (e.g. via remote control) during the short period of carrying out the radiographic inspection. The apparatuses are dual purpose containers serving both as transport package and exposure container (Figure 2).

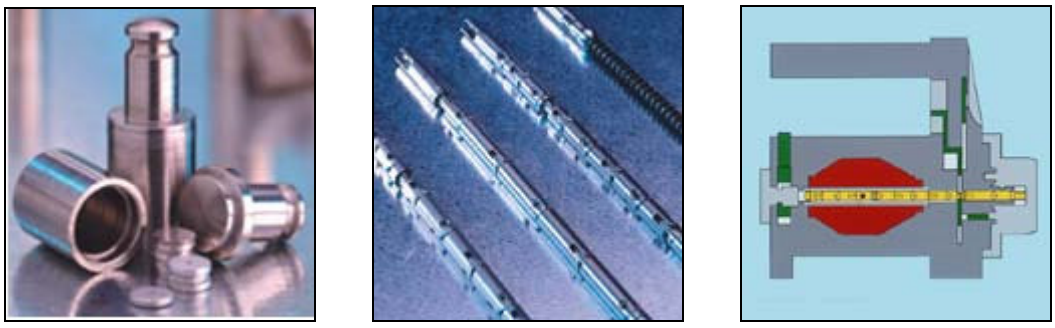

Figure 1 Source capsules containing the radioisotopes (left), source holder (centre) and schematic drawing of an apparatus for industrial gamma radiography (right) (http://www.mds.nordion.com/agiris)

Figure 2 GammaMat TI for industrial gamma radiography; weight approx. 13 kg; Type B(U) approved transport container (http://www.mds.nordion.com/agiris)

DATA COLLECTION AND HANDLING

A questionnaire survey was launched in co-operation with a Division of the German Society for Non-destructive Testing (F-GZP). This Division represents all major accredited non-destructive testing service companies in Germany. The data collection was carried out by mailing a questionnaire form to all members of the F-GZP. The following data were sought and collected for the calendar year 2004:

- number and activity of radiography sources shipped
- type of transport container used and the transport index
- details on the number of shipments and the related mileage
- number of passengers and radioactive sources per conveyance
- annual radiation exposure of personnel
- local dose rate in the driving cab
- expenditure of time for transport related procedures

Survey participation and provision of data was on a voluntary basis. Responses were received from 21 out of 28 contacted service companies; only 17 out of the 21 were routinely involved in transport of gamma radiography sources in the public domain. The survey results and the radiation dose estimates attributable to the transport of gamma radiography devices are given below.

Source characteristics

Iridium-192 and selenium-75 are the most common radioisotopes employed for gamma radiography (see Figure 3). Depending on the field of application other radioisotopes may be used as radiation source. Selection of specific radionuclide depends on the density and thickness of the material to be radiographed. The source activity varied between 0.2 TBq and 3.7 TBq. Most radiography devices are Type A or Type B(U) transport containers (packages), depending on the isotope's activity. The Transport index (TI) of the packages was in the range from 0.1 to 5, this corresponds to a package dose rate at 1 m from the external package surface of 0.001 mSv/h and 0.05 mSv/h, respectively. The maximum radiation level at the surface of the package is

limited to 2 mSv/h by the IAEA Transport Regulations [1] and the International Standard ISO 3999 [2].

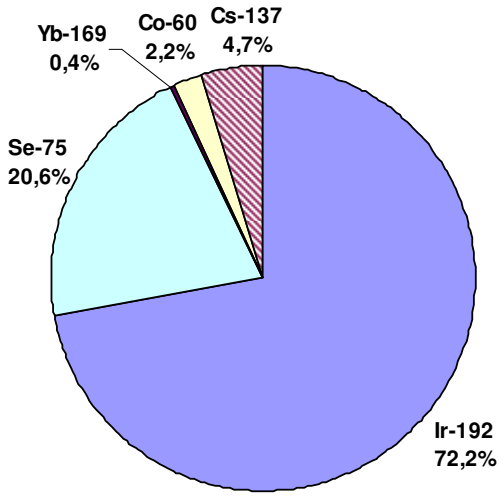

Figure 3 Radioisotopes used in gamma radiography devices in Germany (2004)

Transport conditions

According to the survey data provided, approximately 277 sources have been regularly transported in 2004. The number of annual shipments varied considerably between the service companies. The currently best estimate of the total number of shipments in Germany is in the range of 20 000 – 25 000 per year. Most companies operate as service contractors on a regional level. The travel distance covered per service (one way) ranged from 10 km to 200 km; the average mileage is approximately 65 km (one way). For safety reasons and radiation protection purposes, gamma radiography devices are typically placed inside a fixed transport box in the vehicle with additional lead shielding of several millimetres.

The reported local dose rates in the driving cab were in the range from 0.02 µSv/h (or less than detection limit) to about 2 µSv/h, the lower values were prevailing in small van type vehicles (see Fig 4.2). Radiographic source transport vehicles are typically occupied by two persons, i.e. the driver and the escort. The reason for this is that during radiographic inspections two qualified persons (categorised as appropriately qualified radiation workers) need to be present at the inspection site. Depending on the company size between 2 and 207 radiation workers are entrusted with non-destructive material testing.

INDUSTRIAL RADIOGRAPHER RADIATION DOSES

The radiographer radiation doses available have been derived from routine monitoring data and encompass consequently radiation exposures from both transport operations and from carrying out radiographic inspections in natural background radiation or enhanced radiation environments (e.g. in nuclear power plants).. The exposure data provided (effective doses) are shown in Figure 4 for the various service companies in terms of average and maximum reported doses.

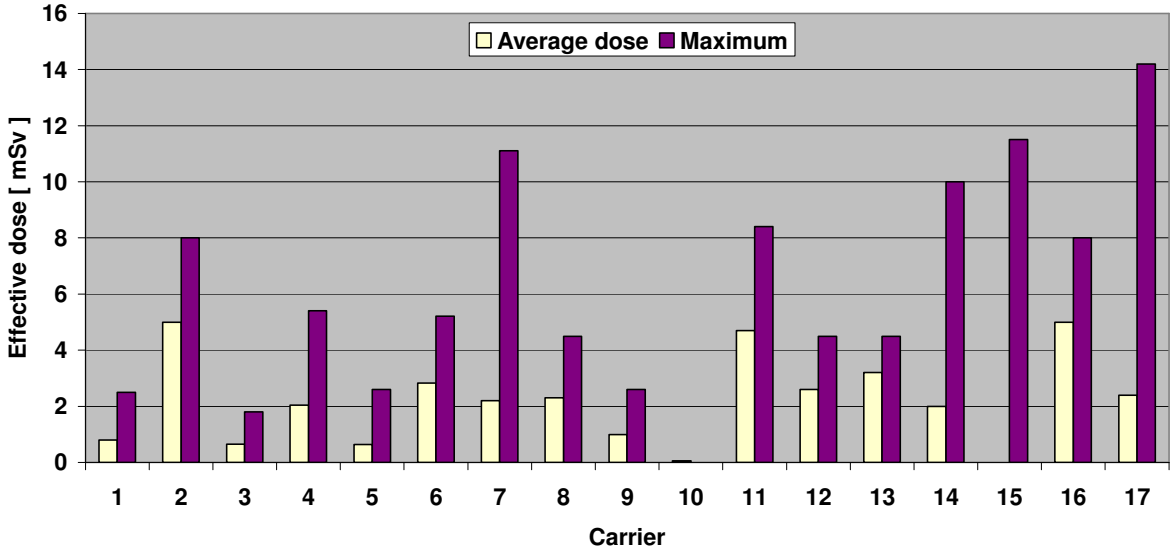

Figure 4 Occupational radiation exposures of radiographers (individual effective dose per year) resulting from the use and transport of gamma radiography sources in 2004 (official radiation monitoring service data)

The data shown indicate that the average radiographer doses are generally below 5 mSv/yr (averaged over the company's radiographic personnel). The highest reported individual radiographer dose is about 14 mSv/yr. The applicable radiation worker dose limit according to the nationally relevant Radiation Protection Ordinance [3] is 20 mSv/yr.

The radiographer doses attributable to the movement phase of radiographic source shipment have been estimated from the reported survey data including:

- local dose rate in the driving cab
- average travel time and mileage per road transport

In addition, as a conservative assumption it has been assumed that a radiographer travels annually 230 days with a radiographic source on the vehicle. Other transport-related steps like e.g. loading and unloading operations have not explicitly been considered in the dose estimation.

The results of this assessment approach are shown in Figure 5. The maximum annual effective dose resulting from transport of gamma radiography sources is on the order of 450 µSv. This dose is within the range of the natural radiation dose resulting from external radiation in Germany (0.7 mSv/a on average with regional variations). In most cases the estimated radiation exposures of radiation workers due to the transport of gamma radiography sources (movement phase) were well below 100 µSv/a. Variations in estimated annual worker doses reflect primarily the company-specific transport conditions, i.e. the effective dose calculated per transport (round trip) which varied from 0.04 µSv to about 2 µSv.

In gamma radiography source applications, the transport personnel additionally undertake the loading/unloading of radiography devices. This is in contrast to most common practices, e.g. in the transport sector of radiopharmaceuticals. In order to verify the assessment results and to determine the dose fraction related to loading and unloading operations radiation dose

measurements have been carried out at one of the participating service companies for non-destructive testing. For this purpose a radiographer team (driver and escort) was equipped with digital personal dosimeters which allow for time-dependent dose measurements during all transport stages. The measured radiographer doses per transport related to loading and unloading processes of the devices varied between 0.1 µSv (or below detection limit) and 0.7 µSv. The latter value occurred during a rather unusual transport of two sources of Ir-192 with a high total activity of 4.6 TBq. Based on this monitoring data, the additional dose contribution for transport related processes like loading and unloading has been estimated to be below 100 µSv per year. The dose assessment as well as the monitoring results support the conclusion that the transport related occupational radiographer doses are generally less than 1 mSv per year and thereby small compared to the doses incurred by radiographers from the use and handling of gamma radiation sources during non-destructive inspections.

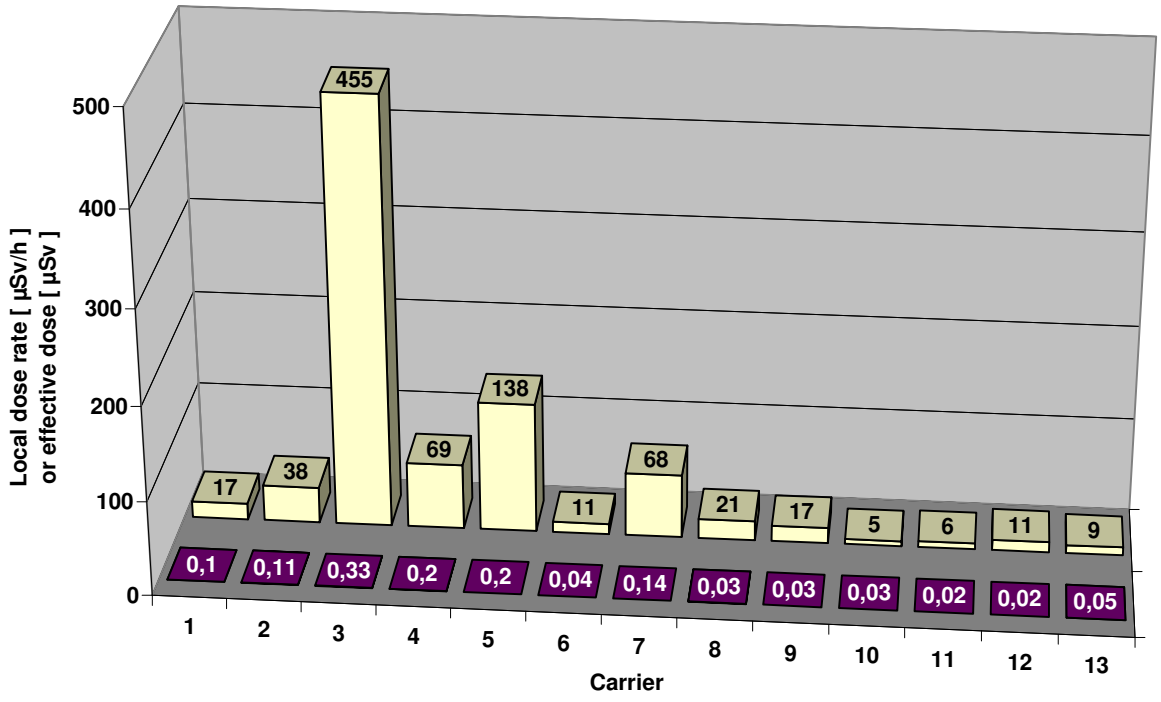

Figure 5 Local dose rate (red) measured in the driver's cab and annual effective doses of personnel (yellow) resulting from carriage of gamma radiography sources (movement phase only)

RADIATION DOSES TO THE GENERAL PUBLIC

In addition to occupationally exposed radiographers, members of the public along the transport path may also be exposed to the radiation emerging from passing gamma radiography sources. Individuals, who may be more extensively exposed to radiation from those radiation source shipments due to their place of residence or living habits than other individuals, constitute the so-called critical group. In the case of gamma radiography source shipments the critical group individuals are generally permanent residents or passers-by of transport routes which are regularly used by transport vehicles, e.g. the access road of a service company for non-destructive testing.

The assessment of individual radiation doses of the general population (critcal group individuals) is based on an exposure analysis for routine transport conditions. To adequately describe the assumed exposure conditions of residents/passers-by along the transport route, two exposures paths contributing to the overall individual dose were taken into account:

- First, an exposure component from all shipments, while the transport vehicle passes by the critical group individual at a speed of 5 km/h in a source-receptor distance of 2 m.
- Second, an exposure component from 10 percent of all shipments, while the vehicle stops for 2 minutes in close proximity to the critical group individual, e.g. at a traffic light.

According to the survey results the average dose rate in 2 m distance from the transport vehicle could be estimated to be below 1 µSv/h. Assuming that residents and passers-by (critical group individuals) are exposed to the conditions mentioned above and even with conservative assumptions regarding the number of shipments of gamma radiography sources, the maximum unshielded (free-air) radiation doses along the transport routes will not exceed 30 µSv per year. The applicable regulatory dose limit (effective dose) for the population is 1 mSv per year.

CONCLUSIONS

A survey has been performed for 2004 with the objective to determine the type, magnitude and characteristics of industrial radiographic source shipments and the attendant transport related occupational and public radiation exposures in Germany. Doses to critical group individuals of the general population were estimated to be below 30 µSv per year. This value is well below the relevant regulatory dose limit of 1 mSv per year. The radiation dose assessment results for workers indicate that the transport related radiographer doses are generally less than 1 mSv per year and thereby well below the relevant dose limit of 20 mSv per year. The assessment results available support the conclusion that implementation and application of the international transport safety standards and requirements ensure an acceptable level of protection of transport workers and the general public for normal conditions of transport. However, additional radiation doses are accumulated by radiographers from the use and handling of radiography sources while carrying out radiographic inspections. The data available demonstrate that the additional doses generally constitute the predominant fraction of the total dose incurred by industrial radiographers.

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REFERENCES

1. International Atomic Energy Agency (IAEA): IAEA Safety Requirements No. TS-R-1, Regulations for the Safe Transport of Radioactive Material, Vienna, 2005.
2. International Standard: ISO 3999 Radiation protection – Apparatus for industrial gamma radiography – Specifications for performance, design and tests, 2004.
3. Radiation Protection Ordinance (StrlSchV) of July 20, 2001, as amended September 1, 2005.