Current practice of occupational radiation protection in industrial radiography

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Abstract:

In 2010 the working group on industrial radiography (WGIR) developed three questionnaires to gain insight into occupational radiation protection in industrial radiography world-wide – one addressed to individual radiographers, another to non-destructive testing (NDT) companies, and a third to regulatory bodies. Each questionnaire addressed the topics of training in radiation protection, incidents, safety, inspections, emergency plans, and individual monitoring.

The questionnaires were distributed widely over a one year period. Responses were received from 432 industrial radiographers from 31 countries, 95 NDT companies from 29 countries, and 59 regulatory bodies. Selected preliminary findings are presented and discussed.

Initial training of industrial radiographers in radiation protection appears to be well established, with a high prevalence of practical training being included. Refresher training was less well established. Approximately 20% of industrial radiographers have had an accident, near miss or deviation in the last 5 years, with an approximate incidence of 8 accidents per 1000 operators per year.

All regulatory bodies required individual monitoring with passive dosimeters, 80% also requiring the use of active dosimeters. All NDT companies reported providing passive dosimeters, and over 90% also provided active dosimeters. The average annual effective dose for industrial radiographers in 2009, as reported by the radiographers, was 3.4 mSv, with a reported maximum of 30 mSv. Regulatory body data gave an average of 2.9 mSv, with a maximum of 158 mSv. An estimate of 2.9 ± 1.2 µSv for the mean occupational dose per radiographic exposure was derived from operator workload data.

The results from the survey are being used to: design an international database that will be used by end-users to improve their implementation of optimization in occupational radiation protection in industrial radiography; and to develop a “roadmap” tool that enables NDT companies to assess their own performance in radiation protection against accepted practice.

Key words: Industrial radiography, accidents, individual monitoring, occupational exposure

1. Introduction

In 2009 the IAEA launched the Information System on Occupational Exposure in Medicine, Industry and Research (ISEMIR) – a project aimed at improving occupational radiation protection in those areas of radiation use in medicine, industry and research where non-trivial occupational exposures occur. The first task of the Advisory Group of ISEMIR was to identify such areas of radiation use, and to form working groups to address these areas. Industrial radiography was one of the areas identified, and in Jan 2010 the Working Group on Industrial Radiography (WGIR) was formed.

The mandate for WGIR included: to gain a world-wide overview of occupational exposures and radiation protection of personnel in industrial radiography; to identify both good practices and shortcomings, and hence define actions to improve occupational radiation protection; and to set up a system for regularly collecting and analysing occupational doses for individuals in industrial radiography and for dissemination of this information to improve occupational radiation protection.
Hence, as part of its initial actions, WGIR sought to gain insight into occupational radiation protection in industrial radiography world-wide using questionnaires. This paper presents some selected preliminary results from this survey.

2. Methods

Three questionnaires were developed – one addressed to individual industrial radiographers, another to non-destructive testing (NDT) companies, and a third to national or state regulatory bodies. Each questionnaire addressed the topics of training in radiation protection; incidents; safety of the radiographer, the public and sources; inspections; emergency plans; and individual monitoring. The questionnaire for individual industrial radiographers comprised of 14 main questions. The NDT company questionnaire and the regulatory body questionnaire were more complex, comprising 31 and 29 main questions, respectively. To help elicit a wider response both the radiographer questionnaire and the NDT company questionnaire were available in several languages – English, French, German, Russian, Chinese, Spanish and Portuguese, with also Dutch for the radiographer questionnaire. The Regulatory Body questionnaire was in English only.

The questionnaires were distributed widely over an approximate one year period (mid-2010 to mid-2011), primarily using the industry and NDT society contacts of WGIR members and using IAEA contacts with regulatory bodies. Responses from radiographers were anonymous unless the responder wished to be identified.

3. Results

3.1 Caveats

Because of the nature of the distribution of the questionnaires to individual industrial radiographers and to NDT companies, it is likely that those approached represent the better end of the practice spectrum. Hence it is recognised that the survey results cannot purport to be truly representative of the worldwide practice of industrial radiography and all results must be interpreted with this caution. Further, many of the questions involved a radiographer or a company assessing their own habits or performance, and hence are subject to distortions of perception versus reality, thus placing a further caveat on those results.

The distribution of the regulatory body questionnaire was systematic – contact was attempted for all IAEA Member States.
Notwithstanding the above caveats, some useful insight into current radiation protection practice in industrial radiography was gained, and selected results are presented below.

3.2 Number of responses

Responses were received from 432 industrial radiographers from 31 countries and employed by approximately 150 different NDT companies, 95 NDT companies from 29 countries, and 59 regulatory bodies.

3.3 Radiation protection education and training
Initial training of industrial radiographers in radiation protection appears to be well established, with a high prevalence of practical training being included. Responses from the industrial radiographers indicated that the great majority had had radiation protection training either as part of their NDT training or in addition to their NDT training or both. Only 8 out of 432 responding operators (2%) appeared to have not had radiation protection training, either as part of the NDT training or as separate training.

Almost all NDT companies (93 out of 95) stated that they provided or facilitated radiation protection training for their radiographers. Requirements for refresher training are less well established, with about three-quarters of the NDT companies providing theoretical refresher training with a mean duration of 17 hours per cycle, and about half of the NDT companies providing practical refresher training with a mean duration of 16 hours per cycle.

Almost all regulatory bodies (58 out of 59) stated that they require a person wishing to perform on-site radiography to have had radiation protection training to an acceptable level. 70% of RBs (41 out of 59) stated that they required refresher training in radiation protection for persons performing on-site radiography and, for these regulatory bodies, the average interval between refresher courses was 4 years.

3.3 Incidents (deviations, near misses and accidents)
Approximately 20% of industrial radiographers stated that had had an accident, near miss or deviation (with respect to radiation) in the last 5 years. Reported incidence of accidents (events that led to increased occupational exposure) was approximately 8 accidents per 1000 radiographers per year. Most radiographers (87%, 71 out of 82) who had had incidents in the last 5 years said that they always reported them to their NDT company. Less than half the radiographers who had reported incidents believed that their company had, in turn, reported these to the regulatory body; 20% believed the company did not report the incidents; and one-third did not know.

40% of NDT companies (35 out of 87) stated that they had had an incident (accident, near miss or deviation) in the last 5 years. Conversely, 85% (72 out of 85) reported that they had had no accidents in the last 5 years. Scaling the company responses by the number of radiographers employed by each respective company gave an estimate of 6 accidents per 1000 radiographers per year – a similar but slightly lower figure to that obtained from the radiographer questionnaire.

All NDT companies with accidents that resulted in individual exposures higher than the annual dose limits (11 out of 11) were said to have been reported to the regulatory body. For accidents with elevated individual exposures lower than the annual dose limits, 70% (57 out of 82) were said to have been reported to the regulatory body.

Approximately 80% of regulatory bodies provided statistics on the number of notified events in the last 5 years. There were 34 notified accidents with elevated individual exposures greater than the annual dose limit from 50 RBs, giving an average of 0.7 such accidents per jurisdiction per 5 years. For accidents with elevated individual exposures less than the annual dose limit, there were 181 notified accidents, from 48 RBs, giving an average of nearly 4 such accidents per jurisdiction per 5 years. Combining these gives approximately one notification of an accident per regulatory body per year.

3.4 Individual monitoring
All regulatory bodies stated that they required individual monitoring with passive dosimeters, 80% also requiring the use of active dosimeters. All NDT companies stated that they provided their industrial radiographers with at least one form of dosimeter. 88% (84 out of 95) provided their

industrial radiographers with passive dosimeters, and 93% (82 out of 95) provided active dosimeters. 76% (72 out of 95) of companies stated that they provide both forms.

Over 90% of radiographers (387 out of 423) stated that they knew what occupational doses they received. The mean number of times per year that the operator was informed about their dose was 11 times, and the median number was 12 times. This was consistent with 1 month or 4 weeks being the most commonly reported monitoring period (73%).

Over 200 radiographers reported their annual occupational effective dose for the year 2009: The average was dose for 2009 was 3.4 mSv, with a reported maximum annual effective dose of 30 mSv. While the majority of radiographers (76%) stated that they received an annual effective dose of less than 5 mSv in 2009, nearly one-quarter received a dose between 5 and 20 mSv, and a small percentage (2%) received a dose greater than 20 mSv.

Almost 200 radiographers reported the maximum dose they received in any of the monitoring periods in 2009. Results were normalized to a 1 month monitoring period: Nearly 70% of operators (122 out of 181) had a maximum monthly dose in 2009 of less than 1 mSv; one radiographer had a maximum monthly dose in 2009 exceeding 20 mSv; and, 4% of operators (7 out of 181) had a maximum monthly dose in 2009 exceeding 5 mSv.

76 NDT companies provided banded annual dose data for a total of 3375 industrial radiographers for the year 2009. Over half (58%) had an estimated annual effective dose less than the 1 mSv. A small percentage (0.3%) had an estimated annual effective dose greater than or equal to the dose limit of 20 mSv.

60% of regulatory bodies (34 out of 55) stated that they have direct access to a national or state database of individual doses for industrial radiographers and other workers involved in NDT. 33 regulatory bodies were able to supply annual dose data for industrial radiographers for the year 2009: The average annual effective dose for nearly 18,000 monitored industrial radiographers, from 33 countries, was 2.9 mSv, with a reported maximum annual effective dose of 158 mSv. While the vast majority of industrial radiographers (86%) received an annual effective dose of less than 5 mSv in 2009, nearly 350 persons (2%) received a dose greater than 20 mSv, and nearly 50 persons (0.3%) received a dose greater than 50 mSv.

Nearly 200 radiographers provided their approximate annual workload – number of exposures in 2009, with an average of just under 3000 exposures and a median of 1000. Based on data from 141 radiographers who provided both annual doses and workloads, the estimate of mean occupational dose per exposure was 4.8 ± 2.3 μSv. If data for radiographers with very low workloads are excluded (less than 100 exposures per year), 129 data points remained giving an estimate of mean occupational dose per exposure of 2.9 ± 1.2 μSv.

4. Discussion

Caution must be exercised in drawing conclusions from the survey results, as discussed in sub-section 3.1 on caveats above. Nevertheless some comments follow.

The need for radiation protection training in industrial radiography appears to be well accepted, with a reported high prevalence of initial theoretical and practical training. The use of refresher training could however be improved.

Accidents, near misses and deviations are widely recognized as being a characteristic of industrial radiography [1], and the results of this survey provide such confirmation – they do occur. It is likely that the reported values in the survey are an underestimate. It is interesting to note that the accident rate estimate from the radiographer data was higher than the estimate based on company data, suggesting that what happens “in the field” may not necessarily be known back in the company, and even less likely by the regulatory body. Means for minimizing the likelihood of incidents remains a priority.

Figure 1 shows a comparison of the occupational dose distributions for industrial radiographers in 2009 assessed from the different questionnaires. The radiographer data are for 234 radiographers, the NDT company data are for nearly 3500 radiographers, and the regulatory body data are for over 16000 radiographers. Reassuringly, there is broad agreement with the average annual effective dose from the radiographers' data and the regulatory bodies' data being 3.4 and 2.9 mSv. Some differences are however evident. For example, both the regulatory body data and the NDT company data show a higher proportion of radiographers receiving an annual dose less than 1 mSv – 60% and 58% respectively, while the radiographer data gave a lower proportion of 37%. Conversely, the radiographer-based data would suggest about twice as many radiographers receiving an annual dose in the range 5 – 20 mSv compared with the NDT company and regulatory body data, namely 22% versus 9% and 12% respectively. The role of individual monitoring in industrial radiography is undisputed, with the need for good record keeping and regular review.

Figure 2 shows the distribution of annual effective dose for industrial radiographers versus their reported annual workloads. Clearly there is no correlation. This emphasizes that occupational radiation protection in industrial radiography is not being effectively optimized. Many factors can potentially affect occupational exposure in industrial radiography and there needs to be a systematic approach to the implementation of optimization of protection. The results of the survey are being used in this respect in two ways.

The first is a "road map" – a software tool that will enable NDT companies to assess their own performance in radiation protection against accepted practice. It is divided into 4 sections, namely: 1. Qualifications & training of industrial radiographers in radiation protection; 2. Learning from incidents (deviations from normal, near misses and accidents); 3. Systems and procedures in place for safe operation; and, 4. Emergency Preparedness and Response. In each of these sections there are a series of questions addressing particular aspects of each of these topics.

A representative from a NDT company would answer the questions in the road map, based on current practice in their company. The response to each question is then scored by comparing it with a measure of good practice. The measure for good practice, for each question, is based either on the relevant third quartile value from the distribution of responses from the survey or on a value given in an international standard. Different weightings are applied to questions, depending on their relative importance, as established by an international group of experts. The scores for each section are summed and the results are presented to the user, including a graphical schematic that gives a quick visual overview of how the NDT company compares with current good practice. Areas that have been identified as being below par could then be addressed by the NDT company to improve occupational radiation protection in their facility. The road map tool will be available on the ISEMIR pages of the IAEA's ORPNET website at:
http://www-ns.iaea.org/tech-areas/communication-networks/norp/isemir-web.htm .

The second means is the ISEMIR international database that is being developed to provide a tool that can be used by end-users to improve their implementation of optimization in occupational radiation protection in particular targeted areas. The database will have a section dedicated to industrial radiography. For a given NDT company, the database will contain information on individual industrial radiographers, including their occupational doses, radiographic workloads, level of NDT training, radiation protection training, sources used, percentage of site radiography, use of collimators, survey meters, and number of events. The metric for assessing optimization of radiation protection will be dose per radiographic exposure, and this will be able to be correlated with any of the aforementioned attributes. Global and regional analyses will provide statistics on the relationships between dose and the personnel attributes. NDT facilities will be able to benchmark their own facility and individual radiographers' performances against global or regional data. Individuals and facilities will be anonymised in the database.

Figure 3 illustrates how the ISEMIR international database would assist. The graph shows occupational dose per radiographic exposure as a function of whether collimators are always used or only sometimes used when performing radiography with gamma sources. For the sample from the questionnaire, the mean for the former was 3.3 mSv, and the latter 4.2 mSv. The difference was not statistically significant, but it illustrates the analysis that could be made with the potential power of a larger international database.

The industrial radiography section of the database will also have a module devoted to incidents – accidents, near misses and deviations from normal. This module is intended to be a tool to provide information that should lead to a reduction in the occurrence of incidents in Industrial Radiography. Its features will include examples of incidents for training; the ability to search for incidents related to a given factor, such as cause, equipment, conditions; provision of details on actual corrective actions implemented; and promotion of lessons learned.

Once developed, NDT facilities all around the world will be encouraged to actively participate in the database to enable it to become a viable tool for implementing optimization of occupational radiation protection.

5. Conclusions

A world-wide survey of occupational radiation protection in industrial radiography was performed over a period of about one year, from mid-2010 to mid-2011. Preliminary results indicate that radiation protection training is taking place, but that incidents involving radiation do occur and that occupational doses can be significant. There is a clear need for improved implementation of the radiation protection principle of optimization of protection and safety.

The results from the survey are being used to: design the ISEMIR database that will be used by end-users to improve their implementation of optimization in occupational radiation protection in industrial radiography; and to develop a "roadmap" tool that enables NDT companies to assess their own performance in radiation protection against accepted practice.

References

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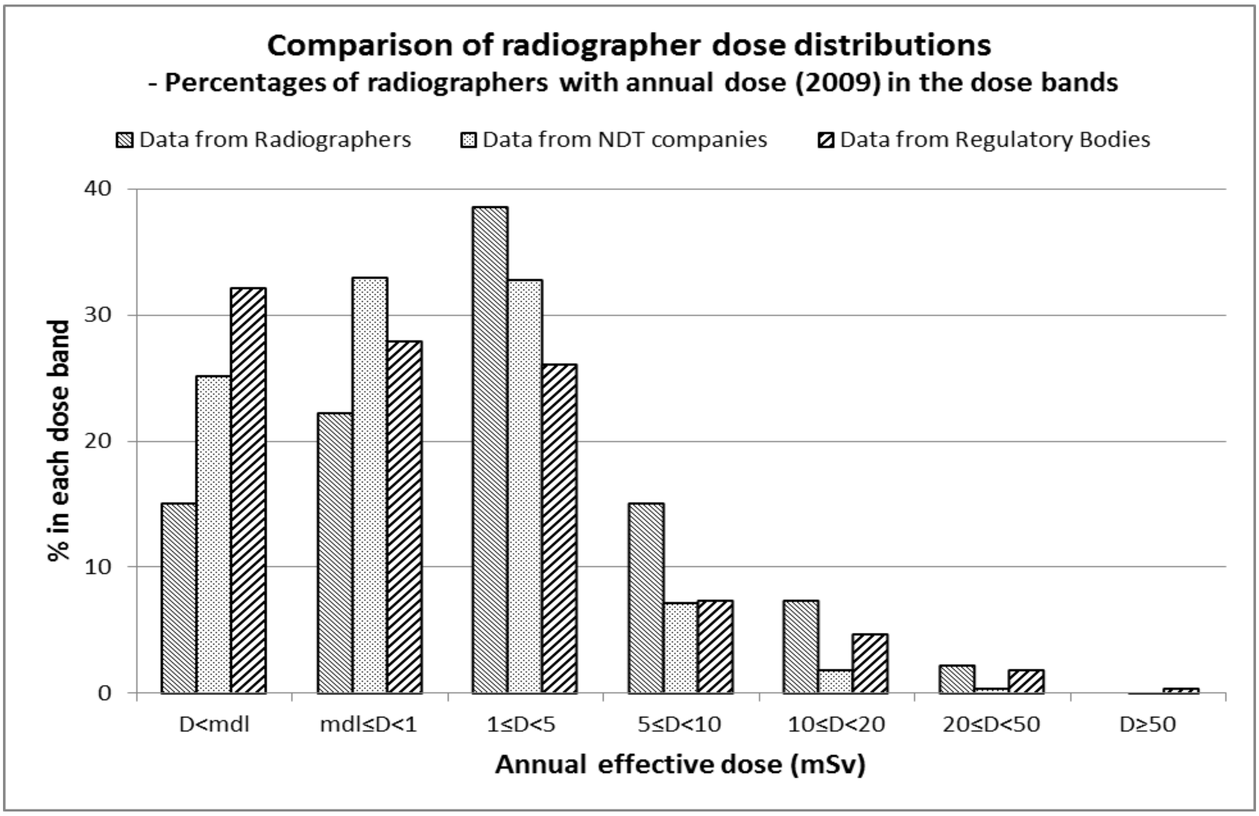

Figure 1. Comparison of the annual dose distributions for industrial radiographers derived from the data from the radiographer questionnaire, the NDT company questionnaire and the regulatory body questionnaire. Note, 'mdl' means the minimum detection limit of the dosimetry system.

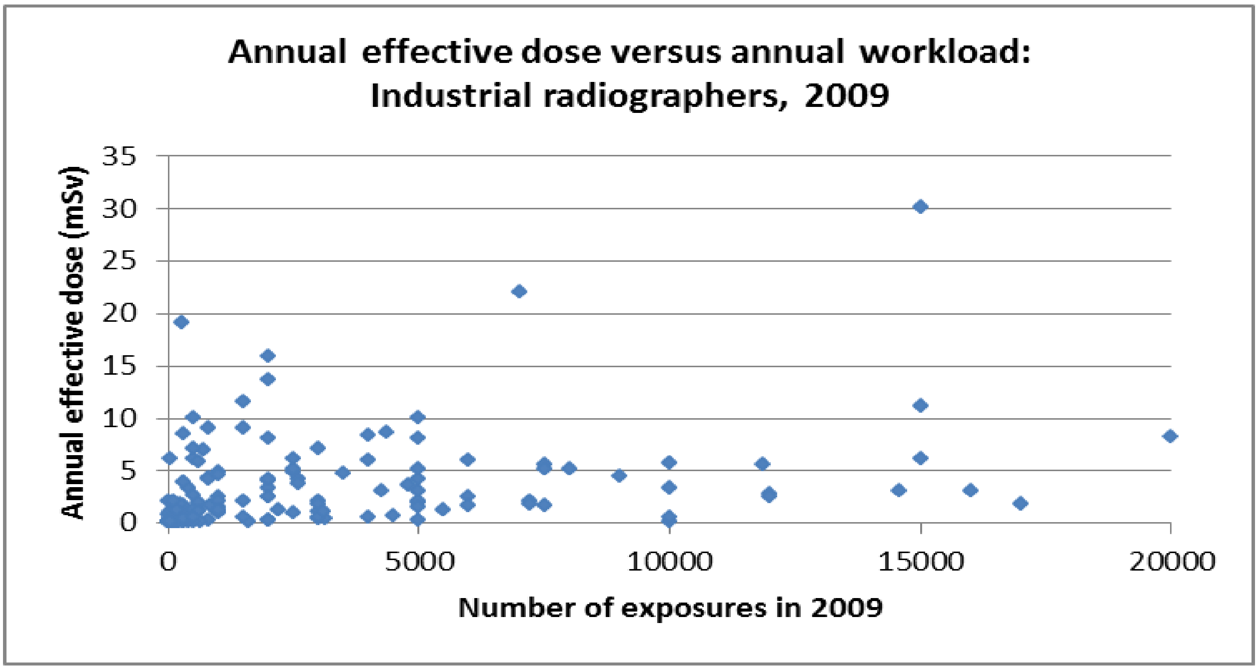

Figure 2. The annual effective dose in 2009 for industrial radiographers versus the number of radiographic exposures for that radiographer. There was no correlation between dose and workload.

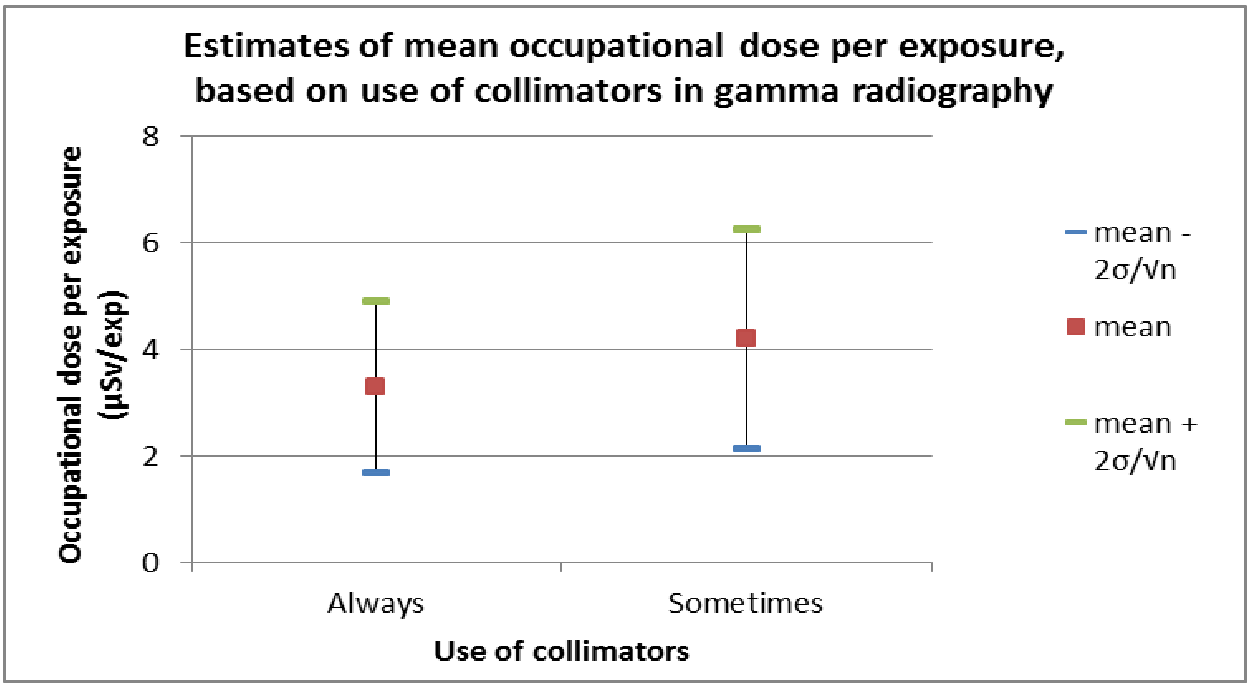

Figure 3. Estimates of mean occupational dose per radiographic exposure when performing industrial radiography with gamma sources, as a function of whether collimators are always used or only sometimes used. The mean for the former was 3.3 mSv, and the latter 4.2 mSv. For the sample from the questionnaire, the difference was not statistically significant, but it illustrates the potential power of a larger international database.