A Snapshot of Current Practice of
Occupational Radiation Protection in Industrial Radiography

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Abstract

A Working Group on Industrial Radiography developed and distributed three questionnaires to gain insight into occupational radiation protection in industrial radiography world-wide – one addressed to individual industrial radiographers, another to non-destructive testing (NDT) companies, and a third to national or state regulatory bodies. 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.

The questionnaires addressed qualification and training of radiographers in radiation protection, learning from incidents, systems and procedures in place for safe operation, emergency preparedness and response, and individual monitoring. In this paper some of the main findings are discussed.

Keywords: Radiation Protection, Industrial Radiography

1 Introduction

In 2009 the International Atomic Energy Agency (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 occurs. The Advisory Group (AG) of ISEMIR identified industrial radiography as one of those areas, and in January 2010 the Working Group on Industrial Radiography (WGIR) was formed.

The WGIR agreed with the (AG that the efforts of WGIR should be aimed at supporting the Non-Destructive Testing (NDT) industry in keeping

I. the dose due to normal (justified!) exposure, and
II. the risk of exposure due to radiation accidents

during the performance of industrial radiography as low as reasonably achievable (ALARA).

As part of its initial actions WGIR conducted a world-wide survey to gain insight into the current practice of occupational radiation protection in industrial radiography. WGIR decided that the most important subject areas for NDT companies worldwide to share information on were:

1. qualifications and training of radiographers in radiation protection,
2. learning from incidents (accidents, near misses, deviations from normal operations),
3. systems and procedures in place for safe operation,
4. emergency preparedness and response, and
5. individual monitoring.

2 Development and distribution of questionnaires

A then draft version of the IAEA Specific Safety Guide on Radiation Safety in Industrial Radiography [1] was used as the basis for creating questions for each of the five above-mentioned subject areas. Then three questionnaires were developed – one addressed to individual industrial radiographers (operators) (14 primary questions), another to NDT companies (31 primary questions), and a third to national or state regulatory bodies (RBs) (29 primary questions).

In addition, the operator questionnaire contained questions to obtain information on the source types (X-ray, ^{192}Ir, ^{75}Se, ^{60}Co) and strengths they used and their annual workload in number of radiographic exposures.

Both the companies and the regulatory bodies were asked to provide information about the distributions of individual doses received by operators in their company and in their jurisdiction in 2009, respectively. This information was provided using the dose ranges that have been established in the reports tof the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) [2], to allow easy comparison. The companies were also asked to provide information on their company profile, in particular on the number of industrial radiographers that worked for the company.

Over a period of about one year the operator and company questionnaires were distributed by the WGIR members through their networks, which included international and national NDT societies.

Table 1 Responses to the three Operator, Company and Regulatory Body questionnaires

	Operator Questionnaire			**Company Questionnaire**		**Regulatory Body Questionnaire**			
	Number of operators	**Number of companies**	**Number of countries**	**Number of Companies**	**Number of countries**	**Countries contacted**	**Countries responded**	**RBs contacted**	**RB responses**
Africa	17	7	3	7	4	35	8	35	8
Asia-Pacific	49	34	7	33	6	27	13	35	16
Europe	166	60	16	28	13	49	27	49	27
Latin America	72	17	3	19	4	20	5	20	5
North America	128	33	2	8	2	2	2	3	3
Global	**432**	**151**	**31**	**95**	**29**	**133**	**55**	**142**	**59**

The questionnaire for the regulatory body was distributed by the IAEA. In order to increase the likelihood of responses to the operator and company questionnaires, these were translated into Chinese, Dutch (for operators only), French, German, Portuguese, Russian, and Spanish. All versions of the questionnaires have been published on the website of ISEMIR [3].

A summary of the responses to the three questionnaires is shown in Table 1. For each questionnaire the responses to each item were consolidated in an Excel workbook to allow for statistical analysis and to test various hypotheses on correlations between items.

3 Results and discussion

The statistical analysis of the responses to each questionnaire produced many results and allowed some conclusions to be drawn with respect to the five main subject areas. A full report on the findings will be send to all respondents and will be published on the ISEMIR website [3]. Some of the main findings are presented and discussed in the following sections.

3.1 Qualifications and training of radiographers in radiation protection

The need for radiation protection training in industrial radiography appears to be well accepted and established. On the one hand, the regulatory bodies almost universally stated that they require radiation protection training for radiographers, and on the other hand almost all the NDT companies provided or facilitated initial radiation protection training. The result was that the radiographer responses indicated a high prevalence of radiation protection training, with only 8 responding radiographers (2%) stating that they had not had radiation protection training. It should have been zero radiographers having had no radiation protection training, but nonetheless the result is very much towards the desired situation.

Refresher training was less well established, with only 70% of regulatory bodies stating that they required refresher training in radiation protection for persons performing on-site radiography. Almost 20% NDT companies reported that they did not provide or facilitate refresher theoretical training in radiation protection, and a larger percentage (40%) reported that they did not provide or facilitate refresher practical training in radiation protection. Clearly there is scope for improvement.

About 85% (364) of the operators indicated that they had received separate radiation protection training in addition to their radiographic testing (RT) training, and 86% (312) of these operators stated that they had a formal radiation protection qualification or certification. Training on emergency response procedures was provided to about 87% (375) of the operators, but only about 65% (247) indicated that they had been involved in practical exercises for creating a safe situation when a source could not be retracted into the source container. Only about 52% (195) operators indicated that they had been in practical exercises for source recovery, but it should also be noted that about 70% of the operators indicated that they are not allowed to perform a source recovery on their own. This makes sense because many countries restrict source recovery to specialist persons. The vast majority of the responding operators felt sufficiently well qualified to work safely (about 95% of the operators), but about 10% replied that they did not feel well prepared for emergency situations, suggesting perhaps a need for improved training in this area.

3.2 Learning from incidents

Rates of occurrence of accidents, near-misses and deviations were reported by the operators and the NDT companies. Table 2 compares the derived rates of incidence from the two questionnaires for each of accidents, near misses and deviations. While there are uncertainties associated with the data, the estimate incident rates from the NDT company data were less than the estimated incident rates from the operator data, especially for near misses and deviations. This would suggest that there is a knowledge gap between what occurs in the field versus what is known by the company management. Statistics from the regulatory body responses gave an accident incidence of nearly 5 accidents per jurisdiction per 5 years.

Table 2 Rate of occurrence of incidents in industrial radiography

	Operator responses		Company responses	
	# per operator per 5 yr.	# per company per 5 yr.	# per operator per 5 yr.	# per company per 5 yr.
Accidents	0.04	4.0	0.03	1.1
Near Misses	0.1	6.2	0.05	1.8
Deviation	0.6	29.3	0.05	1.8

Sharing information about radiation incidents is a well-recognized means for minimizing the likelihood of similar incidents elsewhere, but the level of dissemination appears to be less than desirable. While almost all NDT companies had one or more means for doing this within their companies, there was a sizeable proportion (nearly 40%) that did not appear to share information on incidents with other organizations.

Means for minimizing the likelihood of incidents remains a priority in industrial radiography, and the survey results indicate there is room for improvement in reporting incidents from the field to the company, and from the company to the regulatory body. For the latter, more regulatory bodies should consider establishing an incident database which would then facilitate the dissemination of lessons learned.

3.3 Systems and procedures in place for safe operations

Systems and procedures should be in place for protecting the operator and the public as well as for ensuring that sources and exposure devices meet regulatory requirements and are in good working order.

The best indication of whether such systems and procedures are in place are perhaps the results of the compliance inspections that are performed by the companies themselves and those performed by the regulatory bodies. Each of the following elements was mentioned by the companies and the regulatory bodies, percentages as indicated respectively, as being part of their compliance inspections:

- Proper wearing of passive individual dosimeters (95%, 98%);
- Proper wearing and use of active individual dosimeters (93%, 90%);
- Proper use of survey meters (95%, 96%);
- Proper use of collimators (90%, 88%);
- Proper warning system at the work site (93%, 98%);
- Dose rate at the boundary of the work site within the limits set (92%, 90%);
- Proper use of alarm systems (86%, 96%);
- Proper training and qualifications of radiographers (91%, 100%);
- Operator knowledge of procedures (88%, 96%);
- Pre-operation specific equipment checks (82%, 86%);
- Equipment condition (85%, 98%);
- Emergency preparedness (74%, 96%).

The five most common shortcomings reported respectively by the companies and the regulatory bodies are given in Table 3.

Table 3 Most common shortcomings during compliance inspections by companies and regulatory bodies

Company compliance inspections	Regulatory body compliance inspections
1. No proper use of collimators 2. Dose rate at the boundary of the work site above limits set 3. No proper use of survey meters 4. No pre-operation specific equipment checks being performed 5. Poor operator knowledge of procedures	1. No proper use of survey meters 2. No proper warning system to prevent entry to the work site 3. Poor emergency preparedness 4. No proper use of alarm systems 5. Dose rate at the boundary for the work site not within limits set

It is possible that the results of the shortcomings reflect the different focus of the two forms of inspection – the NDT company inspections perhaps focussing more on whether the radiographer is following company procedures and protocols, while the regulatory body inspections may have a focus on public protection. Nonetheless, all the shortcomings have implications for radiation safety, and that shortcomings are found reinforces the continuing need for inspections.

3.4 Emergency preparedness and response

Radiation sources used for industrial radiography purposes have high radiation outputs and are potentially very hazardous. Incidents do occur and it is essential that systems are in place for emergency preparedness and response, in particular an emergency plan for incidents with gamma radiography sources.

Almost all regulatory bodies (98%) stated that they require NDT companies to have an emergency plan; 95% of NDT companies stated that they had an emergency plan; and over 90% of radiographers stated that their NDT company had an emergency plan for site radiography.

The role of the radiographer in an emergency is crucial. Again there seemed to be consistency across the questionnaires with almost 90% of radiographers reporting that they had received training for the roles and responsibilities of radiographers in the emergency plan; and, over 90% of NDT companies stated that their emergency plan was discussed with their radiographers and over 80% reported provided specific training on emergency preparedness and response. The last figure reflects the practice that some countries have requirements to use specialist persons in emergency roles, and hence specific training for radiographers in this role is not seen as appropriate.

Only three-quarters of regulatory bodies required NDT companies to have emergency equipment. However 90% of NDT companies stated that they had emergency equipment for site radiography – primarily long tongs, shielding material, and an emergency or rescue container.

3.5 Individual Monitoring

All regulatory bodies stated that they required radiographers to use passive dosimeters. While about 80% also required the use of active dosimeters, this means that there were about 20% of regulatory bodies who had no expectation that radiographers need to have active dosimeters with alarm functions. Most responders' active dosimeters had audible alarms, but fewer had visual or vibrating alarms. Using active dosimeters that utilize three senses rather than just one would seem to provide additional radiation safety, especially in the often hazardous environment in which the radiography is taking place. It was reassuring that all NDT companies stated that they provided their radiographers with at least one form of dosimeter.

However only 90% of radiographers stated that they knew what occupational doses they received. The implication is that the other 10% did not use dosimeters, either because dosimeters were not provided or the radiographers chose not to use them, or perhaps that they were uninterested in their doses.

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 16,000 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, respectively. 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.

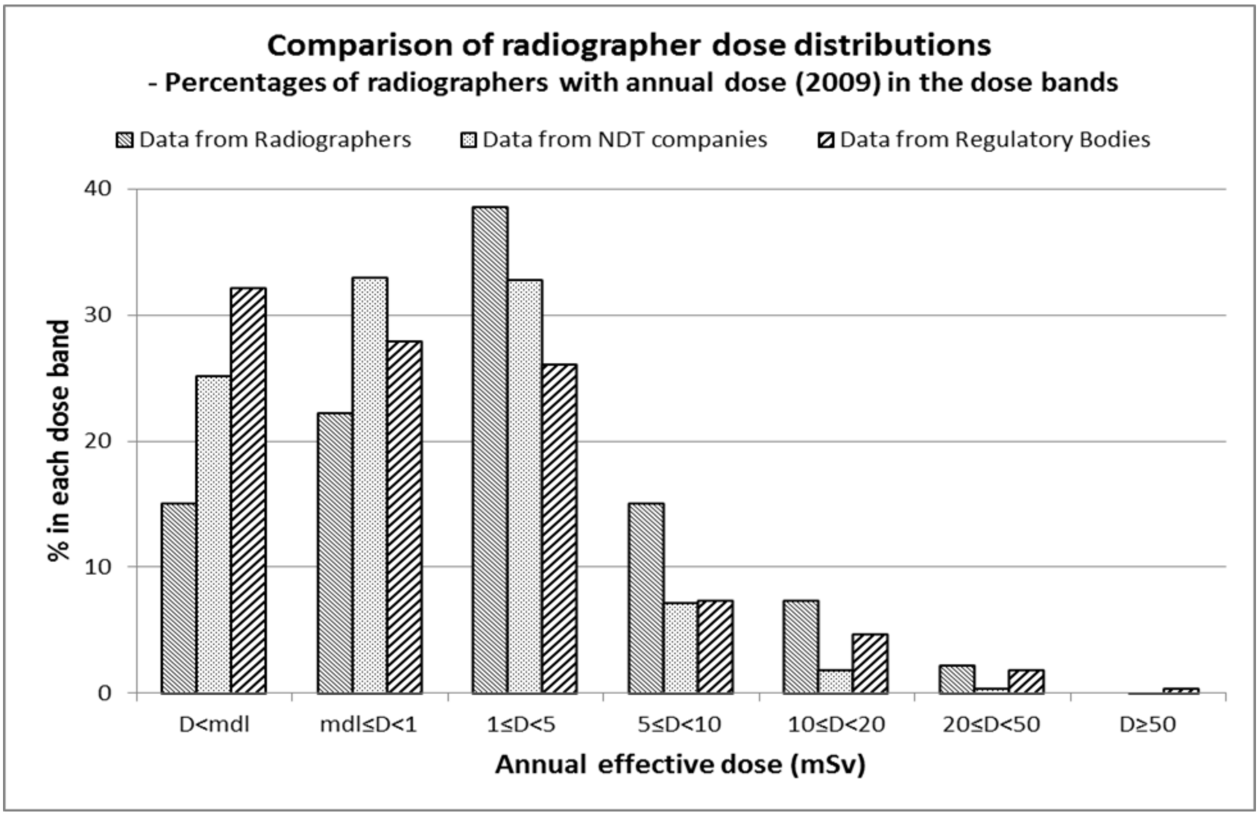

Figure 1 Annual dose distributions for industrial radiographers

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.

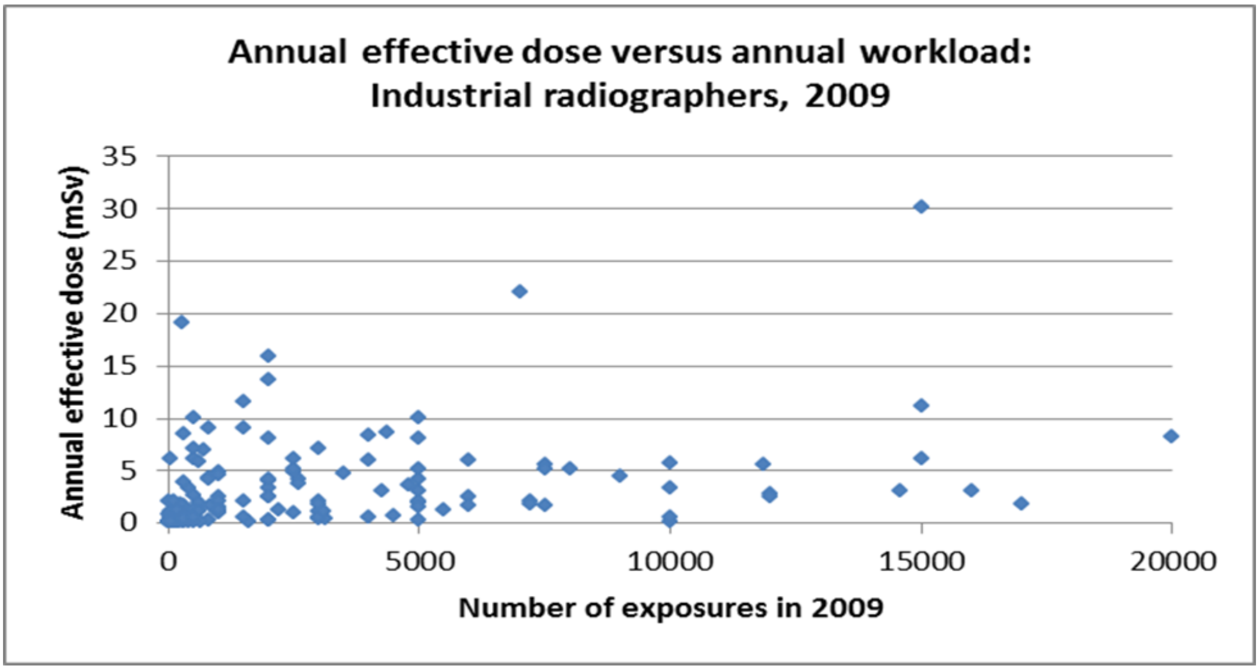

Figure 2 The annual dose for industrial radiographers versus the number of radiographic exposures for that radiographer.

An estimate of 4.8 ± 2.3 µSv for the mean occupational dose per radiographic exposure was derived from operator workload data. This estimate became 2.9 ± 1.2 µSv if radiographers with very low workloads (< 100 exposures per year) were excluded. Differences in the level of NDT training, the type of sources being used, the activity of sources, the use of collimation, or the incidence of events did not have a statistically significant effect on the mean occupational dose per radiographic exposure. However in some cases, indicative relationships were evident, as for example in Figure 3, and with a larger data set more robust relationships could be derived. Such an international database is under development [4].

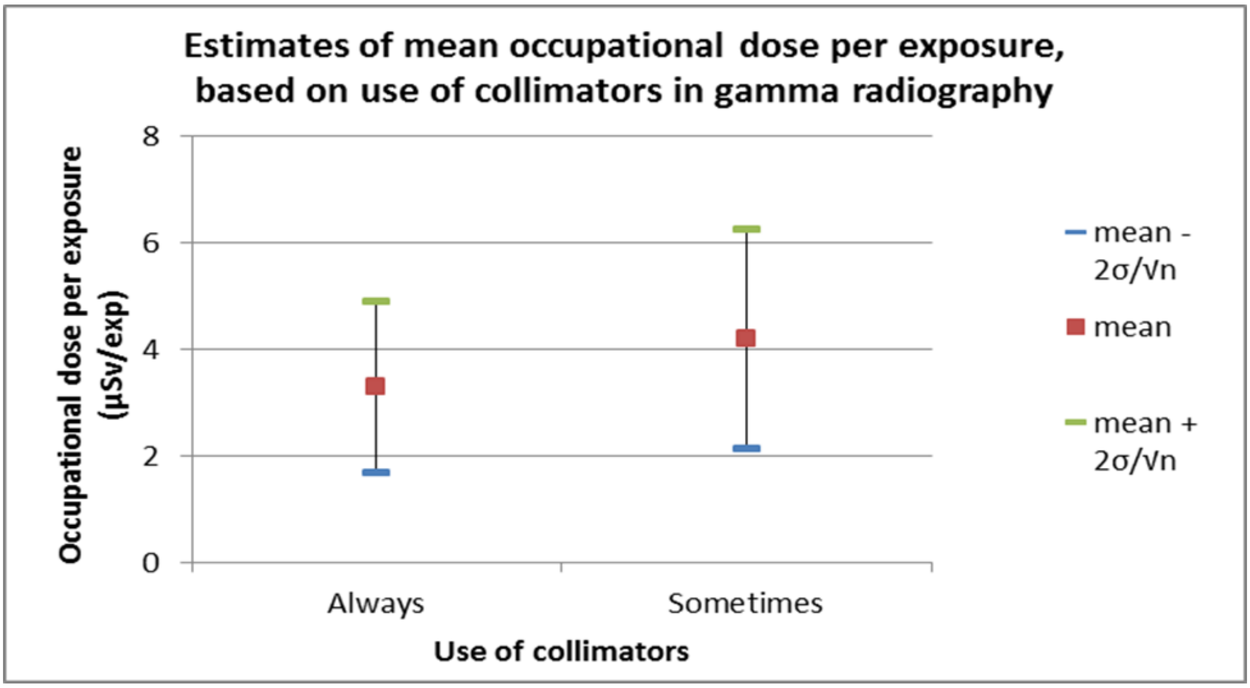

Figure 3 Estimates of mean occupational exposure per radiographic exposure, as a function of collimator use with γ sources.

The role of investigation levels could be more widely utilized. Less than two-thirds of NDT companies reported that they had established their own investigation levels, although a higher percentage said that the regulatory body had set such a level. All NDT companies should be using investigation levels. Of those that did have investigation levels, almost half reported that they had not performed any investigations in the last 5 years. This could be indicative of good practice, or it could suggest that investigation levels are set too high.

4 Conclusion

A world-wide survey of occupational radiation protection in industrial radiography was performed. The results from the survey need to be interpreted with caution as the methods for distribution of the questionnaires to radiographers and NDT companies probably means that those that responded represent the better end of the practice spectrum. Nonetheless, from the results discussed in this paper, it could be concluded that:

- Initial radiation protection training for radiographers is reasonably well established, but there is room for improvement especially with respect to refresher training and practical emergency response training.
- The frequency of occurrence of incidents (accidents, near missed and deviations) is not trivial, and methods such as better incident reporting, analysis, feedback and sharing lessons learned need to be better utilized.
- Collimators and diaphragms are not being used as often as they should be.
- Survey meters are not as widely available as they should be.
- Individual monitoring, as reported, is well established, with passive and, usually, active dosimeters. The establishment and use of investigation levels needs to be improved.
- Warning systems to prevent entry to the work area during site radiography were not always as effective as desired. Better communication at the site is indicated.
- Emergency plans were widely prevalent, but there seemed to be some issues regarding specific training for radiographers with respect to emergencies.
- Occupational doses received by radiographers varied considerably, with no correlation with radiographic workload.

In summary, the survey results indicate that there is a need for improved implementation of the radiation protection principle of optimization of protection and safety.

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