Canada's Nuclear Regulator

# Nuclear Substances in Canada: A Safety Performance Report for 2013



April 2015

Canadian Nuclear Safety Commission
Commission canadienne de sûreté nucléaire

Canada

# *Nuclear Substances in Canada: A Safety Performance Report for 2013*

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## Document availability

This document can be viewed on the CNSC website at nuclearsafety.gc.ca. To request a copy of the document in English or French, please contact:

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## Publishing history

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# Executive Summary

*Nuclear Substances in Canada: A Safety Performance Report for 2013* reviews the regulatory compliance of industries using nuclear substances in Canada in 2013. The report summarizes the performance of holders of 2,480 licences and radiation doses for 22,405 nuclear energy workers from four CNSC-regulated sectors: medical, industrial, academic and research, and commercial. Safety performance is measured by examining:

- licensees' regulatory compliance in select safety and control areas (SCAs)
- occupational doses to workers
- reported events

Based on the information provided in this report, CNSC staff conclude that licensees continue to maintain appropriate safety programs, which include appropriate measures to protect the health and safety of Canadians as well as the environment.

**Occupational doses to workers**

Persons engaged in CNSC-licensed activities may be occupationally exposed to radiation. Regulatory compliance with radiation protection programs ensures that licensees keep doses to persons as low as reasonably achievable. In total, there were 76,196 workers in the nuclear industry whose doses were monitored in 2013. Of these, 22,405 were designated as nuclear energy workers (NEWs). In 2013, workers' occupational exposure to radiation continued to be low, with over 99.9% of workers receiving doses below their respective regulatory dose limits. This followed a trend consistent with previous reporting years. There were no NEWs that exceeded the five-year dose limit of 100 mSv.

There were six cases where, based on dosimetry results, a worker may have exceeded an annual regulatory dose limit. In two of these cases, further investigation revealed that the worker had indeed exceeded a regulatory dose limit. In one of the remaining cases, the investigation revealed that the exposure result on the dosimeter was non-personal, and a dose change request was sent by the licensee and approved by CNSC staff. For the remaining three cases, the investigation conducted by the licensee did not provide sufficient evidence for CNSC staff to conclude with absolute certainty that the exposure was non-personal. In all cases, the licensees responded in accordance with the *Radiation Protection Regulations.* None of the six cases resulted in immediate adverse health consequences to the workers.

**Inspection ratings**

In 2013, 1,627 inspections were conducted across four sectors (medical, industrial, academic and research, and commercial). In general, licensees showed improved compliance ratings in operating performance and radiation protection SCAs.

Of the total number, 1,541 inspections included an evaluation of the operating performance SCA. The trends in all four sectors continued to be positive within this SCA, with all sectors either demonstrating steady improvement or remaining unchanged in 2013. Over 89.2% of inspected licensees were found to demonstrate satisfactory regulatory compliance with the operating performance SCA.

1,534 inspections included an evaluation of the radiation protection SCA. Again, the trends in all sectors continued to be positive within this SCA, with all sectors

demonstrating steady improvement in 2013. The medical and the academic and research sectors showed the most significant improvement. The medical sector demonstrated consistent compliance increases in all its subsectors, including a significant increase in the radiation therapy subsector. Overall, 86.9% of inspected licensees were found to demonstrate satisfactory regulatory compliance. Satisfactory corrective actions were taken by licensees to address non-compliance situations.

**Enforcement actions**

Enforcement actions may be required by the CNSC to ensure that the health and safety of workers, the Canadian public and the environment are being protected. In 2013, 24 enforcement actions were issued, including 22 orders and 2 administrative monetary penalties. Most of these orders continued to be issued to the same industrial subsectors as in previous years. There were 14 orders issued to portable gauge licensees, 5 issued to industrial radiography licensees, 1 issued to a fixed gauge licensee, 1 issued to an X-ray fluorescence analysis licensee and 1 issued to a company that was in possession of fixed gauges without a CNSC licence. All licensees to whom orders were issued have implemented corrective measures to the satisfaction of CNSC staff.

**Reported events**

There were 150 reported events in 2013, a small increase compared with 2012. Two of these events – one from the industrial sector, and one from the medical sector – resulted in a radiation dose to a worker (or a member of the public) in excess of regulatory limits. In all cases, CNSC staff assessed the events and categorized them as low risk, based on evaluation of the radiological impact to persons and the environment.

There were no releases of dispersible nuclear substances to the environment that resulted in an adverse radiological impact on the environment. For all of the events reported, licensees implemented appropriate response measures to mitigate the impacts of the events and to limit radiation exposure to workers and the public.

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# 1 Background

The safe use of nuclear substances in Canada is a reflection of licensees' compliance with the *Nuclear Safety and Control Act*[1] (NSCA) as well the Canadian Nuclear Safety Commission's (CNSC) regulations and specific licence requirements. The Act and its associated regulations require that licensees implement and maintain appropriate programs to ensure safety, take preventative measures to minimize doses to workers and the public, and implement procedures to minimize consequences of work-related events. For the purpose of this report, safety performance is measured by examining the licensees' regulatory compliance in the operating performance and radiation protection areas, as well as reviewing doses to workers and reported events. This report provides information on four CNSC-regulated sectors, which include 2,480 licences as of December 31, 2013.

**CNSC mission**

The CNSC's mission is to regulate the use of nuclear energy and materials to protect health, safety, security and the environment, and to implement Canada's international commitments on the peaceful use of nuclear energy; and to disseminate objective scientific, technical and regulatory information to the public.

For a comprehensive overview of the CNSC and its activities, readers are invited to consult the CNSC's 2013–14 annual report.[2]

**Regulatory process**

The CNSC uses a risk-informed regulatory approach based on transparency, integration of effort, and comprehensive licensing and compliance verification – where resources and regulatory oversight are applied commensurate with the risk posed by regulated activities. Facilities and operations are ranked according to the health and safety risks posed by their licensed activities. The CNSC's regulatory effort, from a licensing and compliance perspective, is based on this ranking.

For the activities covered in this report, the risk-informed regulatory program is applied in the following way:

- each licensed activity is assigned a weighting factor: a coefficient assigned to represent their relative significance in terms of risk
- factors considered in weighting include the form of the nuclear substances (sealed source, unsealed source or radiation device), where the material is being used (public or controlled facility), and the compliance history of licensees performing the licensed activity

[1] Available online at laws-lois.justice.gc.ca/eng/acts/N-28.3

[2] Available online at nuclearsafety.gc.ca/eng/resources/publications/reports/annual-reports

- generally, all licensees are inspected within a given five-year period at a pre-determined frequency, based on their risk ranking

The risk-informed regulatory program is designed to have the following outcomes:

- a risk ranking that recognizes the impact of licensed activity
- effective and informed allocation of regulatory oversight effort, according to the risk ranking by licensed activity, and licensee's performance history
- effective, transparent, consistent and comprehensive regulatory oversight

The key to the CNSC's regulatory approach is its compliance verification and enforcement program, which monitors licensees' conformance with their licences and regulatory requirements. The program includes several tools, including written warnings, requests under subsection 12(2) of the *General Nuclear Safety and Control Regulations*[3], orders, administrative monetary penalties, increased regulatory scrutiny, licensing action, decertification of certified exposure device operators, and decertification of radiation safety officers at Class II nuclear facilities.

In all cases where enforcement actions are required, the CNSC ensures that licensees have taken all necessary corrective actions to be in compliance with CNSC requirements.

# 2 Introduction

This report focuses on the use of nuclear substances and prescribed equipment in medical, industrial and commercial sectors, as well as for academic and research purposes. This safety performance report provides information for the 2013 calendar year. It does not cover uranium mines and mills, waste facilities, dosimetry services, or facilities such as nuclear power plants and nuclear research reactors.

[3] Available online at laws-lois.justice.gc.ca/eng/regulations/sor-2000-202/page-1.html

# 3 Overview

## 3.1 Sectors

### Medical

The medical sector uses nuclear substances and operates accelerators for diagnostic and therapeutic purposes, in hospitals and medical clinics. Medical applications using radiopharmaceuticals are designed to target specific tissues and organs, allowing for the delivery of nuclear substances to specific areas of the body for diagnostic testing or treatment.

**Figure 1:** A radioisotope being administered to a patient using a shielded syringe (source: CNSC)

Diagnostic nuclear medicine studies assist in the diagnosis of medical problems based on the function of the organ, tissue or bone. As shown in Figure 1, radiopharmaceuticals containing nuclear substances such as technetium-99m, gallium-67 and fluorine-18 are administered to patients for imaging purposes. Examples of common nuclear medicine diagnostic procedures include myocardial perfusion scans (to visualize heart function and blood flow), bone scans (to evaluate bone metabolism, infection or tumours), and renal scans (to evaluate kidney function).

Radioisotopes are also used in many therapeutic procedures. For example, iodine-131 is used to treat diseases of the thyroid gland, while other isotopes such as yttrium-90 may be used in conjunction with antibodies for site-specific treatment of certain cancers.

Veterinary nuclear medicine uses techniques similar to those employed in human nuclear medicine. Veterinary clinics across the country offer therapeutic procedures with iodine-131, as well as a wide range of diagnostic services.

Performance results are provided for all licensees in the medical sector, with the following three subsectors highlighted in further detail: 1) diagnostic and therapeutic nuclear medicine; 2) radiation therapy; and 3) veterinary nuclear medicine.

### Industrial

The industrial sector uses nuclear substances in production facilities, or as part of fieldwork or construction. Typical applications include the measurement of physical parameters such as density, moisture content and geological composition in civil engineering. They are also used for material examination in civil engineering, and level and flow rate in industrial facilities (such as oil and gas exploration, mining and manufacturing). These nuclear substances are found in radiation devices known as fixed nuclear gauges (or “fixed gauges”), which monitor production processes in many industries, and in portable nuclear gauges (or “portable gauges”). As shown in Figure 2, portable gauges are often used to measure moisture and density in soil, and the compaction of asphalt in construction. In industrial radiography, nuclear substances are used in exposure devices for the non-destructive examination of materials. Exposure

devices used for industrial radiography are engineered and operated using multiple safety barriers, to reduce the potential for accidental exposure to the source, and use dense material (such as depleted uranium) for its shielding properties.

**Figure 2:** Worker using portable gauge during construction (source: CNSC)

Industrial applications of nuclear substances are as varied as the processes to which they are applied. Specific radioisotopes are chosen based on the type of radiation they emit, the energies of the emissions and the intended application. For example, in industrial radiography, the penetration power of the gamma radiation from cobalt-60 is much greater than that of iridium-192 or selenium-75, but the former requires more shielding and is generally used in stationary applications. Other industrial applications often use californium-252 or americium-241/beryllium (for their neutron-emitting properties) or cesium-137 (for its gamma-emitting properties).

Performance results are provided for all licensees included in the industrial sector, with the following four subsectors highlighted in further detail: 1) industrial radiography; 2) oil well logging; 3) portable gauges; and 4) fixed gauges.

**Academic and research**

Licensed activities in the academic and research sector are conducted in universities, colleges and research laboratories, and focus mainly on biological and biomedical research that primarily uses open (unsealed) nuclear substances. This sector also uses sealed sources, radiation devices and accelerators for teaching (as shown in Figure 3), as well as for pure and applied research.

**Figure 3:** Students conducting a radiation experiment (source: T. Hamilton)

The sector also uses irradiators to irradiate cells or samples in laboratories. Particle accelerators are used in a wide range of pure and applied research ranging from subatomic physics and astrophysics, to investigating alternative methods for medical isotope production, identifying genetic mutations and investigating new materials used in ultra-fast electronics.

Performance results are provided for all licensees included in the academic and research sector, with the following two subsectors highlighted in further detail: 1) laboratory studies and consolidated use of nuclear substances, and 2) high-energy research particle accelerators. Additional detail on high-energy research particle accelerators is provided in Appendix A.

### Update on the CNSC laboratory

As part of its regulatory functions, the CNSC conducts certain activities which are regulated under the NSCA, resulting in the CNSC being self-regulated. To ensure oversight transparency, CNSC management has separated its role as a licensee (which resides within its Technical Support Branch) from its role as a regulator (under the responsibility of its Regulatory Operations Branch).

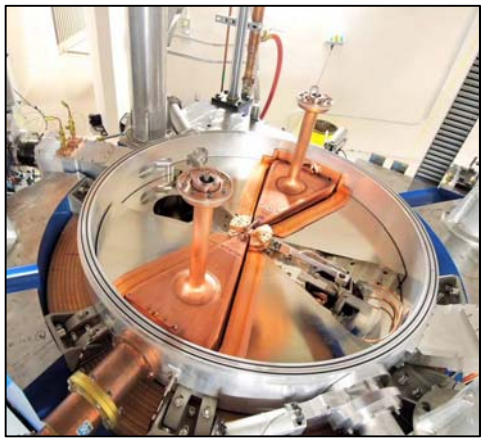
In its role as licensee, the CNSC holds two licences: one for its gamma irradiator (located at its laboratory in Ottawa) and a second one that covers all other activities conducted by the CNSC at its laboratory or elsewhere in Canada. Both licences were issued in accordance with the NSCA, and are regulated using the same licensing and compliance verification processes that would apply to any other licensee.

The CNSC laboratory is responsible for the safe conduct of activities under both licences. It provides radiation instrument calibration and sample analysis services to the CNSC, and also provides training courses and expert advice in selected areas such as field sampling and radiation instrumentation. In this report, the CNSC laboratory is included in the laboratory studies and consolidated use of nuclear substances subsector. Its specific performance results are provided to ensure that the CNSC, as both regulator and licensee, is acting in compliance with regulatory requirements in a transparent manner.

### Commercial

The commercial sector encompasses a number of licensed activities related to the production, processing, storage and distribution of nuclear substances, calibration of radiation detection instruments, as well as servicing of radiation devices and prescribed equipment for commercial gain. Figure 4 shows detail of a cyclotron used for the production of radioisotopes.

**Figure 4:** Isotope production accelerator (cyclotron) (source: University of Alberta)



Nuclear substances are also found in devices that protect the everyday health and safety of Canadians, such as smoke detectors. Such devices may not require a licence for possession by the end user; however, their manufacture and initial distribution in Canada are licensed by the CNSC.

Performance results are provided for all licensees included in the commercial sector, with the following five subsectors highlighted in further detail: 1) operation of isotope production accelerators; 2) processing of nuclear substances; 3) distribution of nuclear substances; 4) servicing of radiation devices and prescribed equipment; and 5) calibration of radiation devices and prescribed equipment.

**Sectors by the numbers**

The overall number of licences in each sector has noticeably changed since 2009, with a decrease of 8.6 percent in 2013 compared to 2009. The change was mostly due to the consolidation of licences held by a single organization (through amalgamation of regional healthcare authorities, or larger companies buying smaller companies to expand their operations). Within the academic and research sector, the decrease in number of licences was also due to schools no longer using nuclear substances for demonstration purposes. The distribution of licences among the four sectors has remained essentially unchanged since 2009. Figure 5 shows the distribution of licences by sector in 2013, and Table 1 shows the number of licences by sector from 2009 to 2013.

**Figure 5:** Distribution of licences in 2013

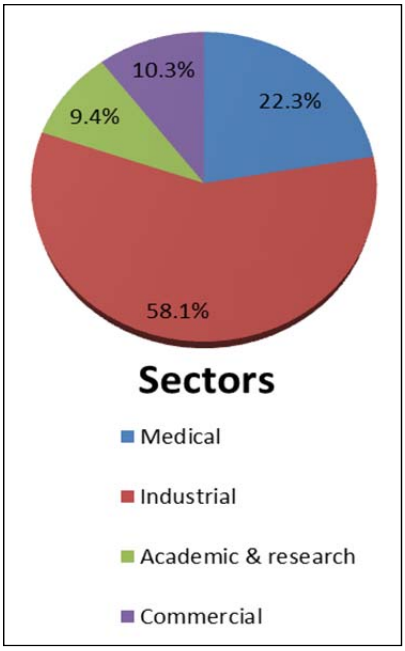



**Table 1:** Number of licences by sector from 2009 to 2013

| Sector | 2009 | 2010 | 2011 | 2012 | 2013 |
|---|---|---|---|---|---|
| **Medical** | 602 | 593 | 568 | 561 | 552 |
| **Industrial** | 1,540 | 1,482 | 1,456 | 1,451 | 1,440 |
| **Academic and research** | 293 | 290 | 276 | 253 | 232 |
| **Commercial** | 278 | 257 | 250 | 248 | 256 |
| **Total** | 2,713 | 2,622 | 2,550 | 2,513 | 2,480 |

## 3.2 Workers

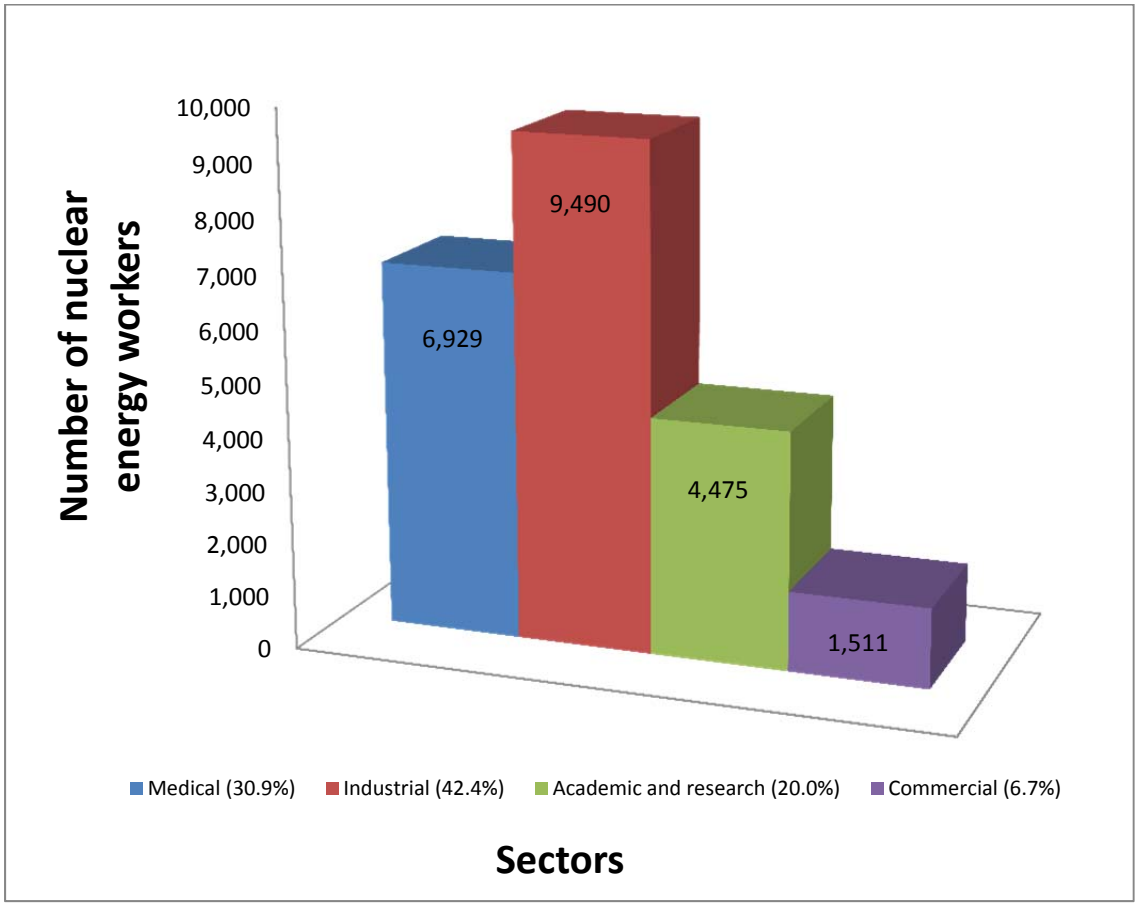
There are two classifications of workers mentioned in this report, as specified in the *Radiation Protection Regulations*: “nuclear energy workers” and “other workers”. The term nuclear energy worker (NEW) indicates a person who is required, in the course of their business or occupation in connection with a nuclear substance or nuclear facility, to perform duties in circumstances which may result in receiving a dose of radiation greater than the 1 mSv per year prescribed limit for any other person. “Other worker” means a person who is either not required to perform these duties, or who is unlikely to receive an annual dose greater than the prescribed limit for any other person while performing duties in connection with a nuclear substance or nuclear facility. This report provides dose information for both types of workers, while primarily focusing on NEWs.

A total of 76,196 nuclear energy workers and “other workers” in the nuclear industry had their doses monitored in 2013. Of these, 22,405 of them were designated as NEWs. The number of workers discussed in this report was extracted from mandatory annual compliance reports submitted by licensees for 2013.

### Nuclear energy workers by the numbers

In 2013, 30.9% of the 22,405 NEWs were employed in the medical sector, 42.4% were employed in the industrial sector, 20.0% were employed in the academic and research sector, and the remaining 6.7% were employed in the commercial sector. Figure 6 shows the number of nuclear energy workers by sector. When compared against the distribution of licences by sector, the academic and research sector employs a significantly greater proportion of NEWs per licence than the other three sectors.

**Figure 6:** Number of nuclear energy workers by sector in 2013

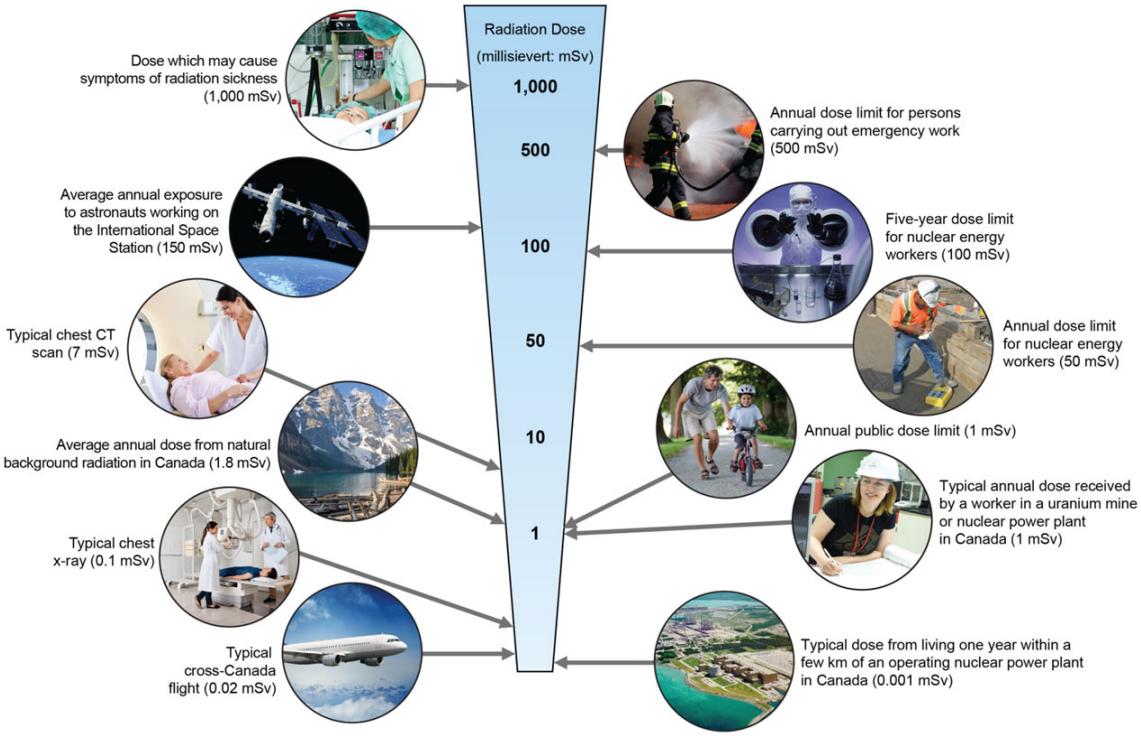



## 3.3 Occupational doses

### Doses in perspective

Non-occupational exposure to radiation can occur in many situations. For example, a person may be exposed to radiation during an airplane flight or by receiving a chest X-ray. Naturally occurring nuclear substances, also referred to as natural background radiation, contribute to exposure received by all persons. The annual average dose from natural background radiation is approximately 1.8 mSv in Canada and 2.4 mSv worldwide. Figure 7 provides some perspective on these situations as they relate to occupational radiation exposures received by workers and the public as a result of activities licensed by the CNSC.

**Figure 7:** Doses in perspective




## Dose limits

The CNSC's regulatory dose limit for individuals who are not NEWs is 1 mSv per year, while the limits for a NEW are set at 50 mSv in any one-year dosimetry period and 100 mSv total over a five-year dosimetry period. For certain activities where there is a need for manual handling of nuclear substances, doses to the hands of NEWs are also monitored. These are known as extremity doses, and are subject to a regulatory dose limit of 500 mSv per year. The one-year dosimetry period is from January 1 to December 31 of every year. The current five-year dosimetry period started January 1, 2011 and will end December 31, 2015. For this report, workers who are not NEWs are referred to as "other workers" and are subject to the 1 mSv per year regulatory dose limit.

## Ascertaining effective dose

All licensees are required to ascertain the effective dose received by each person who performs duties in connection with any activity referred to in their licence. In this report, effective dose refers to the dose received by the whole body. Doses may be ascertained by direct measurement (through monitoring) or by estimation, in accordance with the *Radiation Protection Regulations*[4]. Estimation may only be used by licensees if the time and resources required for direct measurements outweigh the usefulness of using that method. The *Radiation Protection Regulations* also stipulate that the licensee must use a licensed dosimetry service for monitoring every NEW that has a reasonable probability of receiving an effective dose of greater than 5 mSv in a one-year dosimetry period. Certain

[4] Available online at laws-lois.justice.gc.ca/eng/regulations/sor-2000-203/page-1.html

types of workers, such as industrial radiography workers, are always required to use a licensed dosimetry service provider.

**When a dose limit is exceeded**

In the event that a worker may have exceeded a regulatory dose limit, licensees are required to remove the worker from any activities that may add to their dose, investigate the cause of the exposure, take action to prevent the reoccurrence of a similar situation, and report to the CNSC. CNSC staff review information provided by the licensee following each investigation. Depending on the circumstances, the Commission (or a designated officer of the Commission) may authorize the worker to return to work, according to the process defined in the *Radiation Protection Regulations.* The return-to-work authorization may specify conditions and prorated dose limits for the remainder of the dosimetry period.

## 3.4 Safety performance measures

This report uses doses to workers, inspection compliance ratings, enforcement actions and reported events as measures which are representative of safety performance in each sector. Inspections performed by CNSC staff provide information on several key measures, two of which are included in this report: operating performance and radiation protection. The CNSC deems these measures to be the most relevant indicators of safety performance for this report. Events reported by licensees, their risk significance, and the change in their frequency from year to year are also provided. Each performance measure is described below.

**Doses to workers**

Doses to workers are verified to ensure that they remain well below the regulatory limits and as low as reasonably achievable (ALARA).[5] The dose data discussed in this report was extracted from mandatory annual compliance reports (ACRs) submitted by licensees. For the reporting year 2013, data from all ACRs are considered. In previous years, the reporting on doses was based on sampling ACRs.

**Operating performance**

Operating performance refers to the licensee's ability to perform licensed activities in accordance with specific operational requirements defined in the *Nuclear Safety and Control Act* (NSCA), regulations and their licence. The licensee is expected to demonstrate that operational and safety requirements are met, that appropriate procedures for the use and maintenance of equipment are provided to workers and that they are followed, and maintain documentation that demonstrates compliance. To verify these program elements, CNSC staff review documents and perform field inspections to assess licensee operational procedures and practices.

[5] Refer to G-129, Rev.1, *Keeping Radiation Exposures and Doses "As Low as Reasonably Achievable (ALARA)".* Available online at nuclearsafety.gc.ca/pubs_catalogue/uploads/G129rev1_e.pdf.

**Radiation protection**

Radiation protection is the safety program every licensee must put in place to ensure that contamination levels and radiation doses received by individuals are monitored, controlled and maintained according to ALARA principles. This objective can be met by monitoring worker doses, posting radiation warning signs, planning appropriately for radiological emergencies, managing oversight of operational activities, instituting effective workplace practices that emphasize time, distance and shielding, and using appropriate protective equipment.

**Enforcement actions**

Enforcement actions are occasionally required by the CNSC to protect the health and safety of workers, the Canadian public and the environment. The CNSC's compliance verification and enforcement program includes several tools. This report provides information on orders, administrative monetary penalties, decertification of certified exposure device operators, and decertification of radiation safety officers at Class II nuclear facilities.

**Reported events**

Licensees are required, under the NSCA and its associated regulations, to immediately report specific events related to their licensed activities to the CNSC. Within 21 days of the initial report, licensees are required to submit a final report to the CNSC on the event. This final report must include an analysis of the cause of the event, as well as the measures taken (or proposed to be taken) by the licensee to prevent reoccurrence. Together, the initial and final reports allow the CNSC to verify whether the licensee has taken appropriate measures to mitigate the impacts of the event, along with adequate corrective actions to prevent reoccurrence.

## 3.5 Compliance ratings

Compliance ratings (also referred to as inspection ratings) are provided for both operating performance and radiation protection and reflect overall performance at a program-wide level. The inspection ratings are based on a licensee's compliance with the NSCA, regulations and their licence requirements.

## 3.6 Data collection

Dose data discussed in this report were extracted from annual compliance reports provided by licensees in 2013. It represents an estimate of the full population of persons engaged in CNSC-licensed activities who may be exposed to occupational radiation. Compliance ratings and non-compliance data, as well as CNSC enforcement actions issued to licensees, were obtained from the CNSC's compliance verification and enforcement program.

To identify five-year trends, safety performance data from 2009 to 2012 is also included.

## 3.7 What's new in this report

### Sector description

Sector descriptions were shortened in this year's report, to focus on sector results rather than descriptions. Detailed sector information can be found in previous versions of this report on the CNSC website[6].

### Inspection ratings for sealed source tracking

Inspection ratings for sealed source tracking, which have been provided in previous versions of this report, will no longer be included. In general, sector trends continued to be very positive for sealed source tracking in 2013, with 98.9% of inspected licensees found to be compliant. Further information on this topic is available in the *National Sealed Source Registry and Sealed Source Tracking System Annual Report*[7], which can be found on the CNSC website.

### Appendices

Additional information on various topics, such as regulatory process and safety performance measures, which have been provided as appendices in previous versions of this report, will no longer be included. More information on these topics can be found in previous versions of this report on the CNSC website[6].

### Stakeholder engagement

Stakeholder engagement information is now included in the report, to provide an overview of the opportunities created by the CNSC for licensees to interact with the regulator outside the scope of compliance inspections. These opportunities have allowed CNSC staff to provide focused information sessions on key issues related to the safe use of nuclear substances in Canada.

### Administrative monetary penalties

Administrative monetary penalties (AMPs) that have been issued over the reporting period will now be a standard item similar to orders and other regulatory actions. Introduced mid-2013 with the passage of *Administrative Monetary Penalties Regulations (Canadian Nuclear Safety Commission)*[8], an AMP is another tool used to enforce CNSC regulatory requirements and can be issued to any individual or corporation subject to the NSCA.

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[6] Available online at nuclearsafety.gc.ca/eng/resources/publications/reports/use-of-nuclear-substances

[7] Refer to nuclearsafety.gc.ca/eng/resources/publications/reports/ssts

[8] Refer to laws-lois.justice.gc.ca/eng/regulations/SOR-2013-139/page-1.html

The details of the CNSC's AMPs program, as outlined in REGDOC 3.5.2, *Compliance and Enforcement: Administrative Monetary Penalties*, can be found on the CNSC website[9].

**Security of nuclear substances**

In May 2013, the Commission approved REGDOC-2.12.3, *Security of Nuclear Substances: Sealed Sources*[10] to provide guidance to licensees and specify detailed security measure requirements for sealed sources. Mandatory compliance with this document will be required in 2015.

Since early 2013, routine inspections performed by CNSC staff have included the verification of requirements identified in REGDOC-2.12.3 as recommended best practices for licensees. Prior to 2013, verification of security requirements was conducted separately. This change to the inspection process will reduce the regulatory burden on licensees by combining safety and security inspections into a single inspection.

Compliance ratings for the security and control of sealed sources will be included in future editions of the report.

[9] Refer to REGDOC-3.5.2, *Compliance and Enforcement: Administrative Monetary Penalties.* Available online at nuclearsafety.gc.ca/eng/acts-and-regulations/regulatory-documents/history/regdoc3-5-2.cfm

[10] Refer to REGDOC-2.12.3, *Security of Nuclear Substances: Sealed Sources*. Available online at nuclearsafety.gc.ca/eng/acts-and-regulations/regulatory-documents/published/html/regdoc2-12-3

# 4 Use of Nuclear Substances: Safety Performance

## 4.1 Overall safety performance

Based on the information provided in this report, CNSC staff have concluded that the use of nuclear substances in Canada is safe and that licensees have continued to maintain their safety programs and take appropriate measures to protect the health and safety of Canadians, as well as the environment.

Occupational doses to workers remained low in 2013, and followed a constant trend when compared with previous years. Overall, more than 99.9% of all workers – including both nuclear energy workers (NEWs) and other workers – received doses below their respective regulatory dose limits. There were no NEWs that exceeded the five-year dose limit of 100 mSv.

There were six cases where, based on dosimetry results, a worker may have exceeded an annual regulatory dose limit. In two of these cases, the investigation revealed that the worker had exceeded a regulatory dose limit. In one of the remaining cases, the investigation revealed that the exposure result on the dosimeter was non-personal, and a dose change request was sent by the licensee and approved by CNSC staff. For the remaining three cases, the investigation conducted by the licensee did not provide sufficient evidence for CNSC staff to conclude with any certainty that the exposure was non-personal. In all cases, the licensees responded in accordance with the *Radiation Protection Regulations.* None of the six cases resulted in immediate health consequences to the workers.

CNSC staff conducted 1,627 inspections in 2013 to verify compliance with regulatory requirements. Of the total number of inspections conducted, 1,541inspections included a focus on the operating performance safety and control area (SCA), while 1,534inspections included a focus on the radiation protection SCA. In general, licensees continued to show satisfactory compliance in these two areas, with 89.2% and 86.9% of inspected licensees found to be compliant. Any corrective actions taken by licensees to address non-compliance situations were also deemed satisfactory. All sectors demonstrated steady improvement in regulatory compliance in 2013, with the exception of a minor decrease in the operating performance rating for the industrial sector.

Throughout 2013, 24 CNSC enforcement actions, in the form of orders and administrative monetary penalties, were issued to protect the health and safety of workers and the environment. All licensees to whom orders were issued have implemented corrective measures to the satisfaction of CNSC staff.

The number of reported events continued to increase in 2013, with licensees reporting 150 events compared with 139 in 2012. All 150 events were assessed by CNSC staff and all were categorized as low risk, based on an assessment of the radiological impact to persons and the environment.

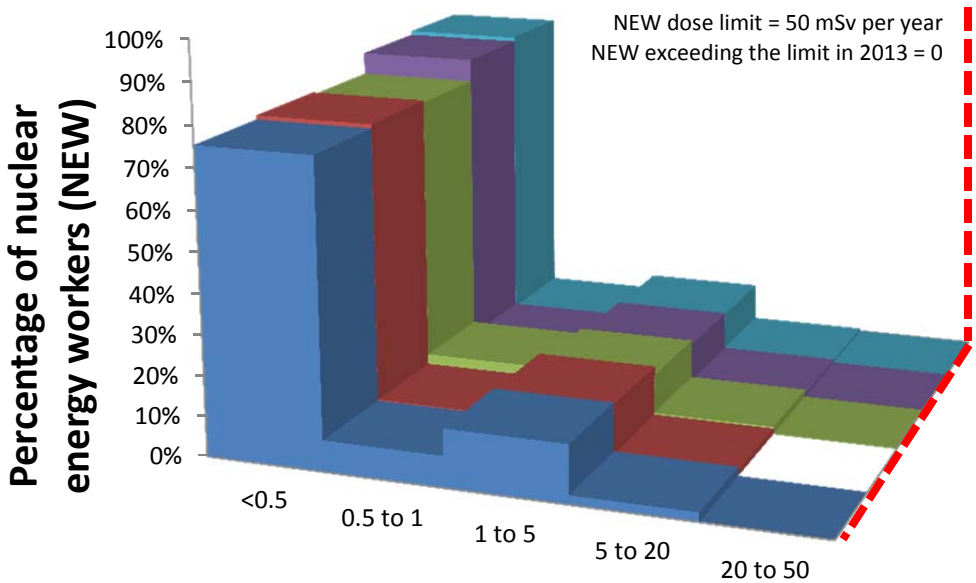
## 4.2 Safety performance trends

### 4.2.1 Doses to workers

Doses to workers remained low in 2013, with 83.3% of NEWs receiving below 1 mSv per year, as shown in Figure 8.

There were six situations where workers may have exceeded the regulatory limits in 2013. More details are provided in section 4.2.5.

**Figure 8:** All sectors combined – Annual effective doses to nuclear energy workers from 2009 to 2013

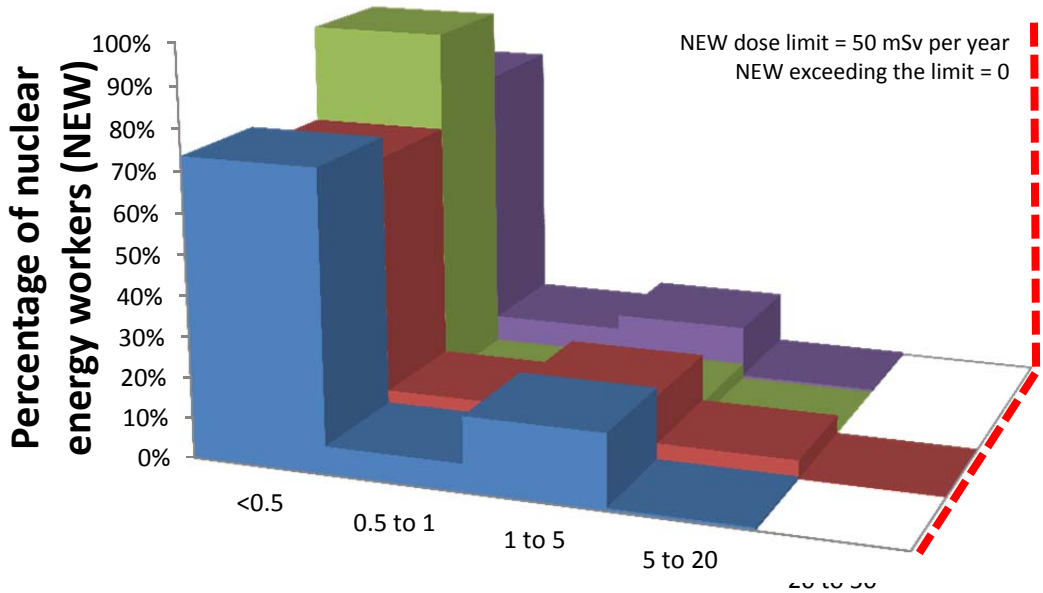



| | <0.5 | 0.5 to 1 | 1 to 5 | 5 to 20 | 20 to 50 |
|---|---|---|---|---|---|
| 2013: 22,405 | 75.5% | 7.8% | 14.4% | 2.3% | 0.05% |
| 2012: 10,305 | 76.5% | 8.0% | 14.0% | 1.5% | 0.00% |
| 2011: 6,992 | 75.9% | 10.5% | 11.8% | 1.9% | 0.03% |
| 2010: 6,856 | 81.4% | 7.2% | 10.6% | 0.8% | 0.01% |
| 2009: 8,969 | 82.4% | 6.6% | 10.3% | 0.7% | 0.01% |

**Dose ranges (mSv)**

Figure 9 shows the dose distribution for NEWs across the four sectors. The differences in doses to workers between sectors continued to reflect the nature of the various activities within those sectors, with NEWs in the industrial radiography, diagnostic and therapeutic nuclear medicine, processing of nuclear substances, and isotope production accelerators subsectors receiving somewhat higher doses relative to NEWs in other subsectors. More details are provided in sections 5.2.1, 6.2.1, and 8.2.1.

**Figure 9:** Sector-to-sector comparison – Annual effective doses to nuclear energy workers in 2013




| | <0.5 | 0.5 to 1 | 1 to 5 | 5 to 20 | 20 to 50 |
|---|---|---|---|---|---|
| Medical (6,929) | 73.7% | 7.0% | 18.6% | 0.8% | 0.0% |
| Industrial (9,490) | 68.7% | 10.1% | 16.4% | 4.7% | 0.1% |
| Academic and research (4,475) | 92.7% | 3.3% | 3.9% | 0.1% | 0.0% |
| Commercial (1,511) | 76.0% | 9.9% | 13.6% | 0.6% | 0.0% |

**Dose ranges (mSv)**

### 4.2.2 Operating performance

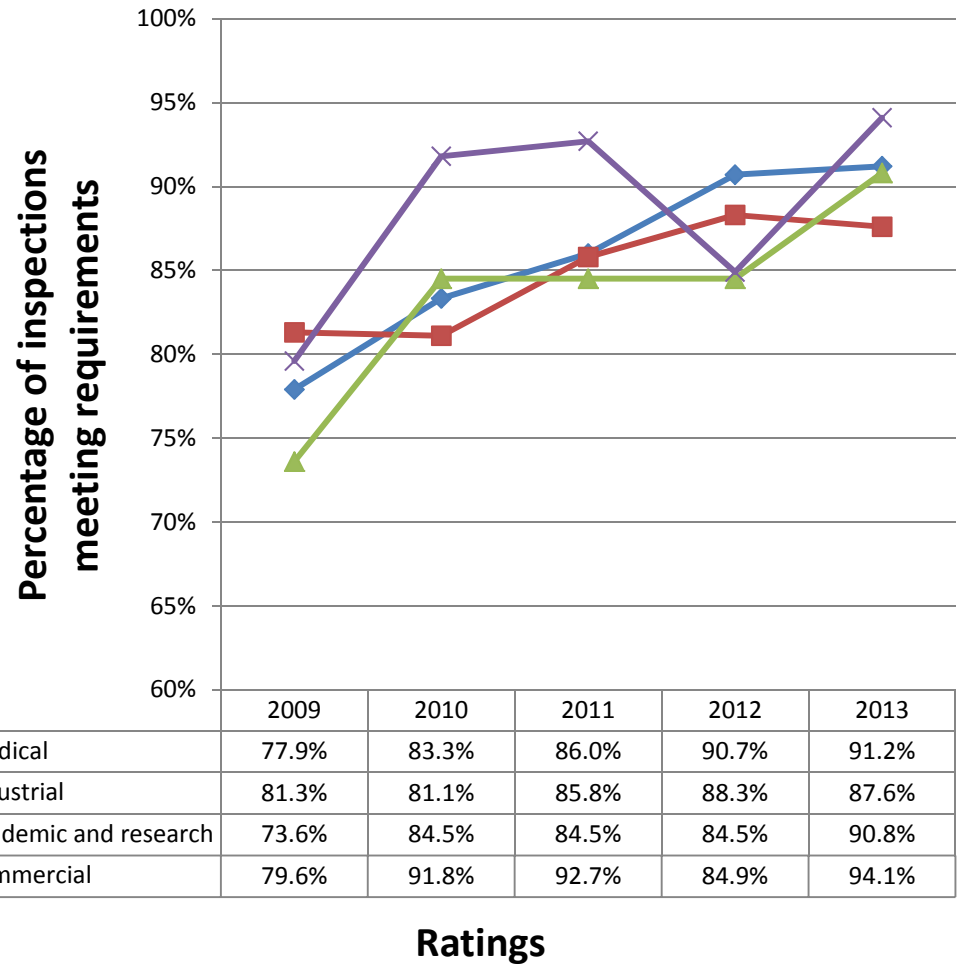
Sector trends continued to be generally positive within this SCA, with 89.2% of inspected licensees found to be compliant. As shown in Figure 10, all sectors demonstrated steady improvement in 2013, with the exception of the industrial sector.

The most noticeable change in 2013 was within the commercial sector. A clearer understanding of CNSC regulatory expectations among servicing subsector licensees has led to a significant improvement in compliance ratings. In 2012, many servicing companies were asked to inform the CNSC of servicing being conducted at Canadian facilities, leading to many first-time field inspections for which the expectations may not have been clearly understood. In 2013, licensees had greater awareness of regulatory requirements, which was reflected in their improved compliance.

The types of non-compliances observed in 2013 varied by sector and activity, but were similar compared with previous years' observations. The majority of non-compliances in the area of operating performance were related to failures to comply with worker

obligations, failures to retain records, procedures not being followed, failures to post licences, or failures to perform sealed source leak tests. For inspections that resulted in ratings below requirements, CNSC staff ensured that all non-compliances were properly addressed and corrected.

**Figure 10:** Sector-to-sector comparison – Inspection ratings of operating performance from 2009 to 2013



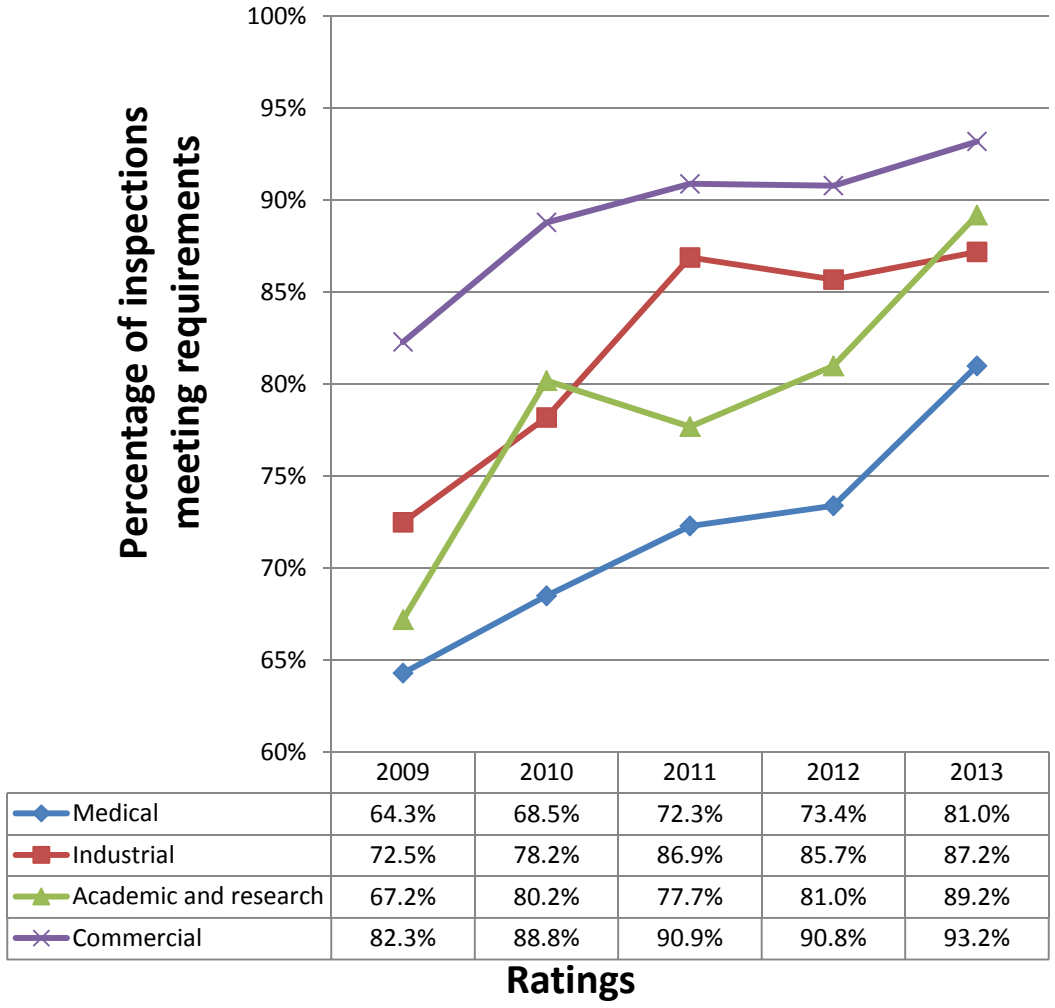

| | 2009 | 2010 | 2011 | 2012 | 2013 |
|---|---|---|---|---|---|
| Medical | 77.9% | 83.3% | 86.0% | 90.7% | 91.2% |
| Industrial | 81.3% | 81.1% | 85.8% | 88.3% | 87.6% |
| Academic and research | 73.6% | 84.5% | 84.5% | 84.5% | 90.8% |
| Commercial | 79.6% | 91.8% | 92.7% | 84.9% | 94.1% |

### 4.2.3 Radiation protection

In general, sector trends continued to be positive within this SCA, with 86.9% of inspected licensees found to be compliant. As shown in Figure 11, all sectors demonstrated steady improvement in 2013, with the medical and academic and research sectors showing significant improvement. The medical sector demonstrated consistent increases in compliance for all its subsectors (with a particularly significant increase for the radiation therapy subsector). Improvement in the academic and research sector primarily reflects better performance in the laboratory studies and consolidated uses of nuclear substances subsector. The types of non-compliances observed in 2013 varied by sector and activity, but were similar compared with previous years' observations.

The majority of non-compliances in the area of radiation protection were related to doses not being kept as low as reasonably achievable, survey meters either not being available or not calibrated, containers or radiation devices not being labelled properly, failures to post signs at boundaries and points of access, and improper storage of nuclear substances. For inspections that resulted in ratings below requirements, CNSC staff ensured that all non-compliances were properly addressed and corrected.

**Figure 11:** Sector-to-sector comparison – Inspection ratings for radiation protection from 2009 to 2013



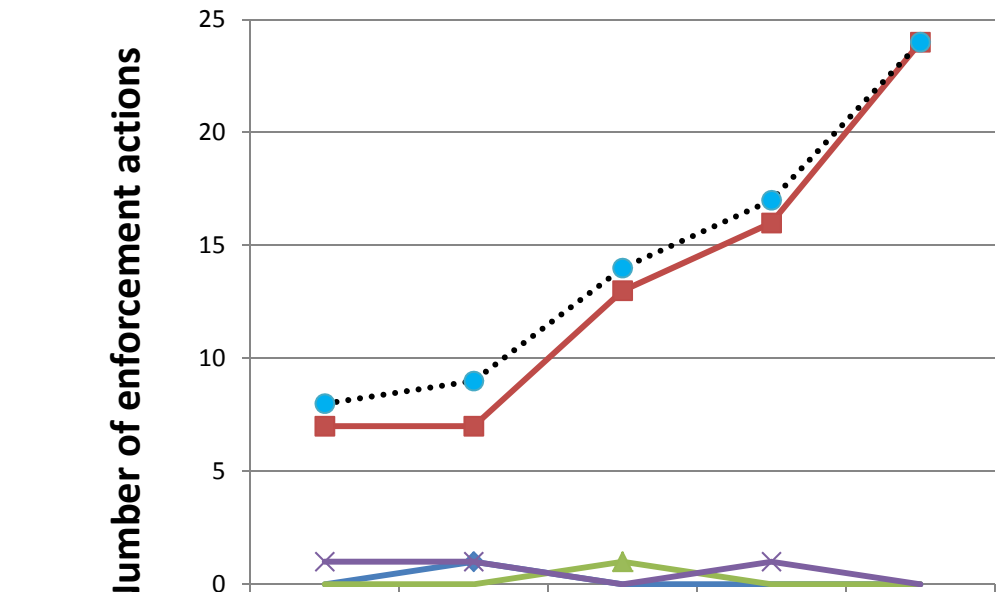

| | 2009 | 2010 | 2011 | 2012 | 2013 |
|---|---|---|---|---|---|
| Medical | 64.3% | 68.5% | 72.3% | 73.4% | 81.0% |
| Industrial | 72.5% | 78.2% | 86.9% | 85.7% | 87.2% |
| Academic and research | 67.2% | 80.2% | 77.7% | 81.0% | 89.2% |
| Commercial | 82.3% | 88.8% | 90.9% | 90.8% | 93.2% |

### 4.2.4 Enforcement actions

In 2013, 24 enforcement actions were issued, including 22 orders and 2 administrative monetary penalties. As shown in Figure 12, the majority of these enforcement actions continued to be issued to licensees in the industrial sector, following a trend from previous years. More details on these enforcement actions are provided in section 6.2.4.

All licensees to whom orders were issued have implemented corrective measures, which were reviewed and found to be satisfactory by CNSC staff.

**Figure 12:** Sector-to-sector comparison – CNSC enforcement actions from 2009 to 2013




| | 2009 | 2010 | 2011 | 2012 | 2013 |
|---|---|---|---|---|---|
| Medical | 0 | 1 | 0 | 0 | 0 |
| Industrial | 7 | 7 | 13 | 16 | 24 |
| Academic and research | 0 | 0 | 1 | 0 | 0 |
| Commercial | 1 | 1 | 0 | 1 | 0 |
| Total | 8 | 9 | 14 | 17 | 24 |

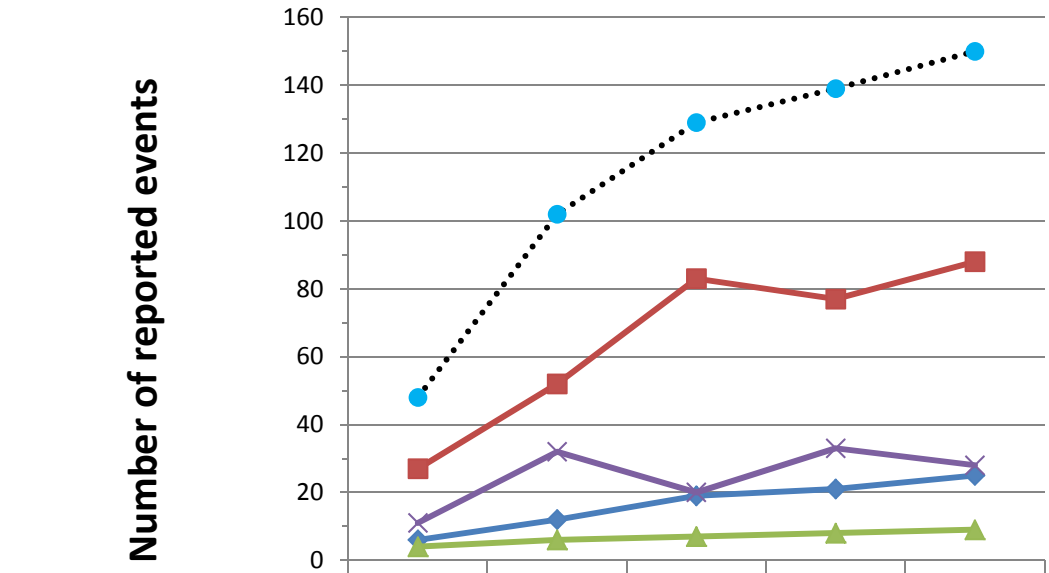
Sectors

### 4.2.5 Reported events

The number of reported events has increased to 150 in 2013, compared with 139 in 2012. All 150 events were assessed by CNSC staff and categorized as low risk, given the radiological impact to persons and the environment. As shown in Figure 13 and Figure 14, this moderate increase was mainly due to a surge in the number of reported events related to security breaches in the industrial sector, as well as spills and contamination events that occurred across all sectors. These security breaches typically involve people entering a restricted work area, established prior to the use of a radiation device or prescribed equipment. Although these events were categorized as security breaches, all of them were a result of workers not following procedures.

The industrial sector continued to generate more than half of all reported events, most of which involved malfunctioning or damaged devices. In the majority of cases, these devices were damaged while being dropped or crushed. More information is provided in section 6.2.5.

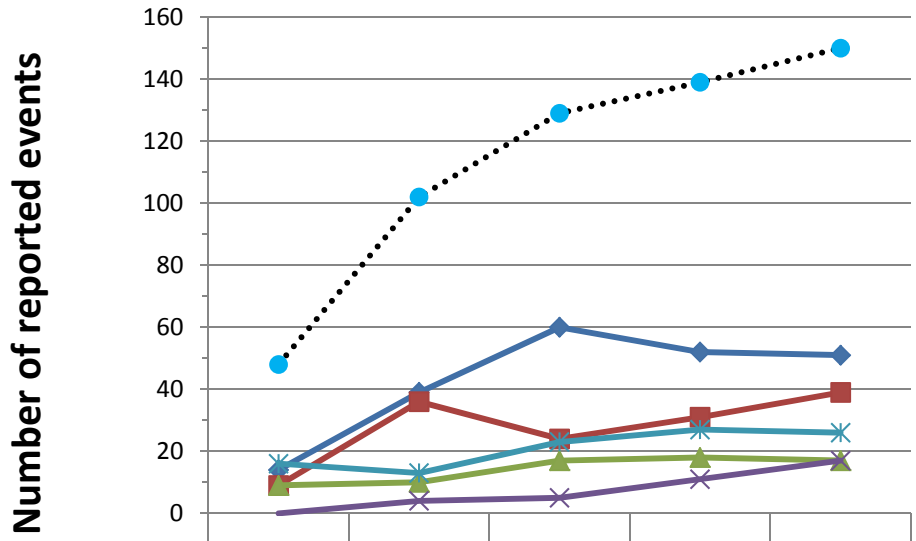
**Figure 13:** Sector-to-sector comparison – Reported events from 2009 to 2013




| | 2009 | 2010 | 2011 | 2012 | 2013 |
|---|---|---|---|---|---|
| Medical | 6 | 12 | 19 | 21 | 25 |
| Industrial | 27 | 52 | 83 | 77 | 88 |
| Academic and research | 4 | 6 | 7 | 8 | 9 |
| Commercial | 11 | 32 | 20 | 33 | 28 |
| Total | 48 | 102 | 129 | 139 | 150 |

Sectors

**Figure 14:** All sectors combined – Reported events from 2009 to 2013




| Types | 2009 | 2010 | 2011 | 2012 | 2013 |
|---|---|---|---|---|---|
| Malfunctioning or damaged devices | 14 | 39 | 60 | 52 | 51 |
| Spills and contamination | 9 | 36 | 24 | 31 | 39 |
| Missing or found nuclear substances | 9 | 10 | 17 | 18 | 17 |
| Breach of security | 0 | 4 | 5 | 11 | 17 |
| Packaging and transport | 16 | 13 | 23 | 27 | 26 |
| Total | 48 | 102 | 129 | 139 | 150 |

There were 17 reported events involving missing or found sealed sources or radiation devices. In 9 of these cases, sealed sources or radiation devices were recovered. These events are further detailed in this report, as well as in the *Lost or Stolen Sealed Sources and Radiation Devices Report,*[11] which is regularly updated.

There were no releases of a dispersible nuclear substance to the environment that had an adverse radiological impact, or which resulted in a person receiving a dose in excess of the regulatory limit for members of the public.

For all of the events reported, the licensees implemented appropriate response measures to mitigate the impacts of the events and to limit radiation exposure to workers and the public.

[11] Available online at nuclearsafety.gc.ca/eng/resources/publications/reports/lost_stolen_ss_rd

**Reported events involving radiation doses to nuclear energy workers**

There was one event reported where a nuclear energy worker (NEW) may have exceeded the regulatory limit of 50 mSv per year. Details of this situation are described below.

Oil well logging

A NEW carrying out oil well logging activities had a dosimeter result which indicated an effective dose of 125.12 mSv for one quarter (three months). This exceeded the effective NEW dose limits of 50 mSv per year and 100 mSv for a five-year dosimetry period.

The licensee investigated the situation and concluded that the dose recorded was primarily non-personal; the high reading was likely due to storing the dosimeter close to the sealed source while the worker travelled to and from the worksite. The licensee concluded that the work carried out by the individual during the dosimeter-wearing period should not have resulted in such a high dose, and should have been comparable with the doses received by other NEWs performing similar duties across the oil well logging subsector. Unfortunately, the individual left the company before the licensee received the dosimeter result, and the licensee had no possible way of contacting the worker to confirm the conclusions of their investigation, due to outdated personal contact information.

CNSC staff did not have enough evidence to confirm that the dose was non-personal, and could not recommend a change to the worker's dose record in the National Dose Registry. However, CNSC staff did conclude that the licensee met, to the best of its abilities, the requirements of the *Radiation Protection Regulations*. Since the CNSC cannot track an individual, it requested the National Dose Registry to notify them immediately if they receive a new dose record for the worker in question. This would enable CNSC staff to contact the worker through the new employer, and follow up on the 125.12 mSv dose. It should be noted that this type of situation – in which the worker could not be contacted – is very infrequent.

**Reported events involving radiation doses to other workers (non-NEWs)**

There were five reported events involving other workers: two in the diagnostic and therapeutic nuclear medicine subsector, one in the industrial radiography subsector, one in the radiation therapy subsector and one in the oil well logging subsector. Two events resulted in a worker receiving a dose which exceeded the regulatory limit of 1 mSv per year. The other three events may have resulted in a dose exceeding the regulatory limit of 1 mSv per year. Details of these situations are described below.

Industrial radiography

A person received an estimated dose of 7 mSv, which exceeded the effective public dose limit of 1 mSv per year.

As presented at the August 22, 2013 Commission meeting, the radiography licensee was contracted to perform radiography work at a metal fabrication facility, when a facility worker was accidentally exposed to radiation when entering a restricted area. Before radiography work took place, the radiographer was assured by the site supervisor that the work area was vacant; however, the radiographer failed to verify the area before using the exposure device. One worker was present inside the large metal pipe, which was only

discovered when the radiographer went to remove the film where the exposure was taking place.

The licensee immediately notified the CNSC following the incident. CNSC staff performed a reconstruction of the event, including dose estimation, based on information provided by the licensee. The facility worker received an estimated dose of 7 mSv.

CNSC staff issued a letter to the affected worker, explaining that he had received a dose of radiation in excess of the regulatory dose limit.

Diagnostic and therapeutic nuclear medicine

An individual working at a nuclear medicine clinic received an annual effective dose of 1.8 mSv, which exceeded the effective public dose limit of 1 mSv per year.

The worker, a secretary, was exposed to patients who had been injected with radioisotopes and were waiting to proceed with their medical procedures. The licensee reported that there was an overflow of patients in the waiting room designated for injected patients; as a result, any additional patients had to wait in an area close to the secretary's desk. The licensee has since established another designated waiting room with proper shielding.

CNSC staff reviewed the dose records for the individual before and after the additional waiting room was put in place, and concluded that the actions taken by the licensee were appropriate for keeping the dose to the worker below the dose limit and as low as reasonably achievable.

Radiation therapy

A radiation therapist, not designated as a NEW, working at a hospital's cancer centre, received an annual effective dose of 1.26 mSv, which exceeded the effective public dose limit of 1 mSv per year.

As presented at the December 9, 2013 Commission meeting, the licensee investigated the situation and concluded that the dose recorded on the dosimeter during one of the quarterly monitoring periods was likely non-personal. The licensee concluded that the dosimeter had likely been left in the treatment room during patient treatment, and submitted documentation requesting the CNSC to proceed with a formal dose change request. CNSC staff found, however, that the information provided by the licensee was not sufficient to conclude with certainty that the dose result was non-personal. As a consequence, no formal change has been made to the individual's dose record in the National Dose Registry.

Diagnostic and therapeutic nuclear medicine

An individual working at a hospital received an annual effective dose of 1.04 mSv, which exceeded the effective public dose limit of 1 mSv per year.

The licensee investigated the situation and concluded that the dose recorded on the dosimeter during one of the quarterly monitoring periods was likely non-personal. The licensee noted that almost all dosimeters transported during the quarter, including the control dosimeters (which are not worn by workers, and are used to measure dose associated with background radiation), had higher than normal results. The licensee

concluded that the dosimeters had likely been inadvertently exposed during transport and submitted documentation requesting the CNSC to proceed with a formal dose change request. CNSC staff found, however, that the information provided by the licensee was not sufficient to conclude with certainty that the dose result was non-personal. As a consequence, no formal change has been made to the individual's dose record in the National Dose Registry.

Distribution of nuclear substances

An individual working for a distribution company had a dosimeter result which reported an effective dose of 54.57 mSv for one quarter (three months), which exceeded the effective public dose limit of 1 mSv per year.

When the licensee received the dose report, the licensee immediately removed the individual from work, notified the CNSC and performed an investigation. During the investigation, the licensee determined that the dose was non-personal since the individual had not been working with radiation sources during that dosimetry period. The employee had actually travelled by plane, and his dosimeter was placed in his checked luggage and exposed to several X-ray scans during the security screening process.

Based on the investigation conducted by the licensee and the subsequent review performed by CNSC staff, it was concluded that the *Radiation Protection Regulations* requirements were met, and the dose was non-personal. As a result, authorization was given for the individual to return to work.

To ensure that the individual's dose record was corrected in the National Dose Registry, the licensee submitted a dose change request to the CNSC, which has been processed and approved.

No immediate health consequences were observed – or are expected – as a result of the events described above.

## 4.3 Stakeholder engagement

The CNSC has created more opportunities for licensees to interact with the regulator, outside the scope of inspection, through CNSC outreach activities across Canada. CNSC staff believe that an increased awareness and better understanding of regulatory requirements may lead to increased safety in the workplace, which would be reflected in improved compliance ratings.

**Outreach sessions**

Outreach is an integral part of the CNSC's objectives. The CNSC has offered an outreach program for licensees using nuclear substances since 2009. The presentations and discussions associated with outreach programs are meant to inform licensees on upcoming and recent regulatory changes, and educate them about the CNSC's expectations for licencing and compliance requirements.

**Industrial radiography working group**

An industrial radiography working group was established in 2009, including both CNSC and industry representatives. The objective was to foster communications between CNSC and the industry, discuss best practices, and stay informed of new developments in the

field from both the technical and regulatory perspectives. This working group meets on a bi-annual basis and continues to provide valuable feedback on the subsector's compliance history. Each May, the working group also holds an annual general meeting with radiography licensees.

**Canadian Radiation Protection Association working group**

There are current plans to develop a working group with the Canadian Radiation Protection Association (CRPA). Although the CRPA does not represent a particular sector, many of the participants are from the medical and academic and research sectors.

**Portable gauge strategy**

A CNSC portable gauge strategy has been developed for portable gauge licensees to promote safety culture within the subsector. This subsector-specific outreach program will begin with a trial session in 2014. CNSC staff believe that improved stakeholder engagement will be effective in addressing ongoing safety issues within this subsector.

**Newsletters**

In 2009, the CNSC introduced the *DNSR Newsletter* – typically published bi-annually, with special editions as needed – as a forum for disseminating information to licensees using nuclear substances in Canada. The newsletter includes articles addressing various regulatory and compliance issues, and is an integral part of the regulator's commitment to keep both licensees and the public informed. Since 2009, a total of 13 regular and special-edition newsletters have been published, including 4 in 2013. While regular editions provide valuable information to licensees in all sectors, special editions tend to focus on a specific subsector as the main audience. The newsletters can be found on the CNSC website[12].

[12] Available online at nuclearsafety.gc.ca/eng/nuclear-substances/directorate-of-nuclear-substance-regulation-newsletter

# 5 Medical Sector

This sector accounted for 552 CNSC licences and 6,929 nuclear energy workers (NEWs) as of December 31, 2013.

## 5.1 Sector summary and overview

**Overall performance**

In general, the medical sector showed gains in safety performance in 2013.

Occupational doses received by NEWs in this sector remained low, with 80.7% receiving doses below 1 mSv. NEWs in the radiation therapy subsector continued to receive extremely low doses, with almost 99.6% receiving doses below 1 mSv.

The medical sector continued to demonstrate good compliance, with 91.2% and 81.0% of inspected licensees found to be compliant in the operating performance and radiation protection areas, respectively. Satisfactory corrective actions were taken by licensees to address non-compliance situations. All subsectors demonstrated continued regulatory compliance improvement in 2013, with the exception of a decrease in the operating performance rating for the veterinary nuclear medicine subsector.

No enforcement actions were issued to licensees in the medical sector in 2013.

There were 25 reported events in 2013, continuing a slow but steady increase in the number of events reported over the past five years. More than half of these events are related to spills or contamination incidents. In all cases, CNSC staff assessed the events and categorized them as low risk, based on the radiological impact to persons and the environment.

**Observations**

Based on informal conversations with licensees, CNSC staff have noticed a reduction in the number of diagnostic nuclear medicine procedures using technetium-99m, following the National Research Universal reactor's temporary shutdown in 2009. This has led to an increased use of alternative imaging techniques such as ultrasound, positron emission tomography (PET) and X-ray. The number of radiation therapy licences has decreased over the past five years, as licensees have moved from individual licences for specific activities to consolidated licences covering multiple activities. This has led to decreased administrative burden on radiation therapy subsector licensees.

## 5.2 Safety performance trends

### 5.2.1 Doses to workers

Occupational doses received by NEWs in the medical sector remained low, with 80.7% receiving doses below 1 mSv.

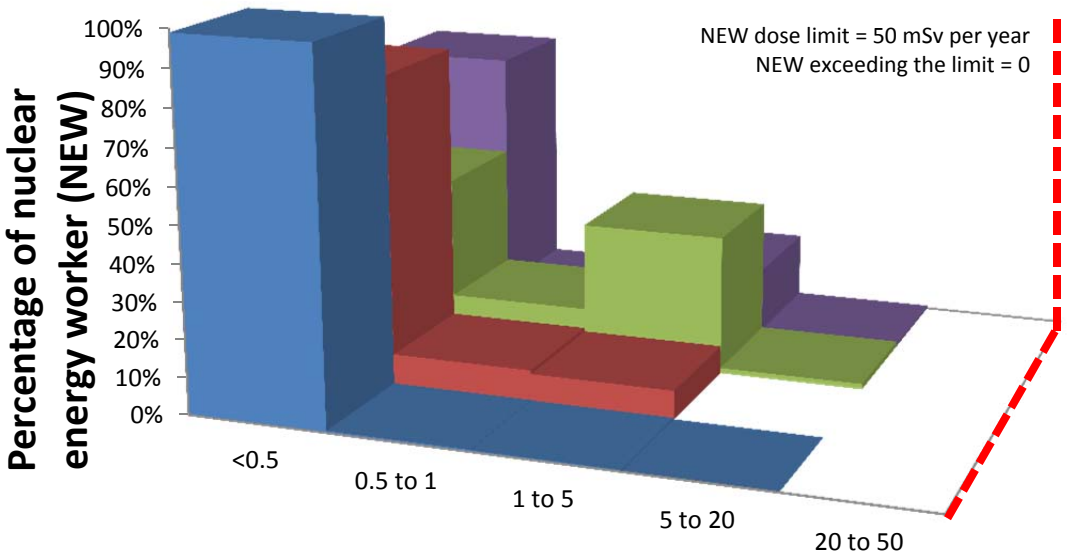
NEWs in the veterinary nuclear medicine subsector continued to receive low doses, with 92.4% receiving doses below 1 mSv and no worker receiving over 5 mSv in 2013.

NEWs in the radiation therapy subsector continued to receive extremely low doses, with 99.6% of them receiving doses below 1 mSv. Only one worker received over 5 mSv (5.99

mSv) in 2013. For this particular case, the licensee reported the quarterly dose finding as an event, and investigated the cause of the unusual reading. However, the cause of the unusual reading was not identified. The following four quarterly dose readings for this individual were in line with the expected values in this subsector.

As Figure 15 indicates, NEWs in the diagnostic and therapeutic nuclear medicine subsector continued to receive higher doses than other medical subsectors. This is likely a result of directly administering nuclear substances to patients and working constantly in an environment where these patients are in close proximity to health professionals. The doses received by these NEWs are typically higher when compared with NEWs across all four sectors, surpassed only by industrial radiography NEWs. Doses received by NEWs in the diagnostic and therapeutic nuclear medicine subsector from 2009 to 2013 are shown in Figure 16.

**Figure 15:** Medical sector performance comparison with select subsectors – Annual effective doses to nuclear energy workers in 2013

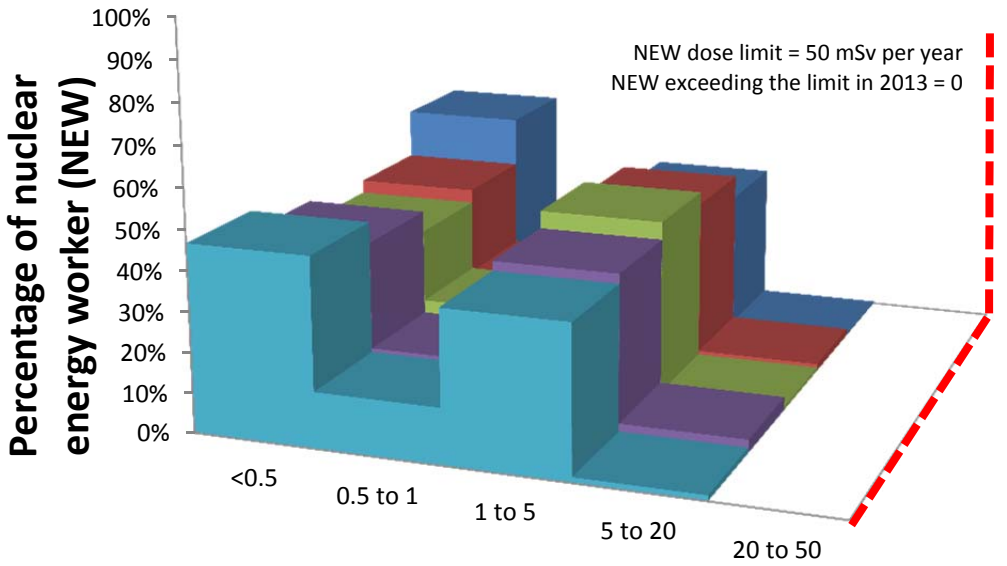



| | <0.5 | 0.5 to 1 | 1 to 5 | 5 to 20 | 20 to 50 |
|---|---|---|---|---|---|
| Radiation therapy (2,959) | 99.0% | 0.5% | 0.4% | 0.03% | 0.0% |
| Veterinary nuclear medicine (105) | 83.8% | 8.6% | 7.6% | 0.0% | 0.0% |
| Diagnostic and therapeutic nuclear medicine (3,272) | 46.8% | 14.0% | 37.8% | 1.4% | 0.0% |
| Medical sector (6,929)* | 73.7% | 7.0% | 18.5% | 0.8% | 0.0% |

**Dose ranges (mSv)**

* The total number of NEWs shown in this row is the aggregate for the entire medical sector, including subsectors not highlighted in this report.

**Figure 16** Diagnostic and therapeutic nuclear medicine subsector performance – Annual effective doses to nuclear energy workers from 2009 to 2013




| | <0.5 | 0.5 to 1 | 1 to 5 | 5 to 20 | 20 to 50 |
|---|---|---|---|---|---|
| 2013: 3,272 | 46.8% | 14.0% | 37.8% | 1.4% | 0.0% |
| 2012: 1,963 | 41.6% | 14.9% | 40.2% | 3.3% | 0.0% |
| 2011: 551 | 36.3% | 18.1% | 44.6% | 0.9% | 0.0% |
| 2010: 771 | 39.6% | 17.3% | 41.4% | 1.8% | 0.0% |
| 2009: 585 | 52.1% | 11.6% | 35.7% | 0.5% | 0.0% |

**Dose ranges (mSv)**

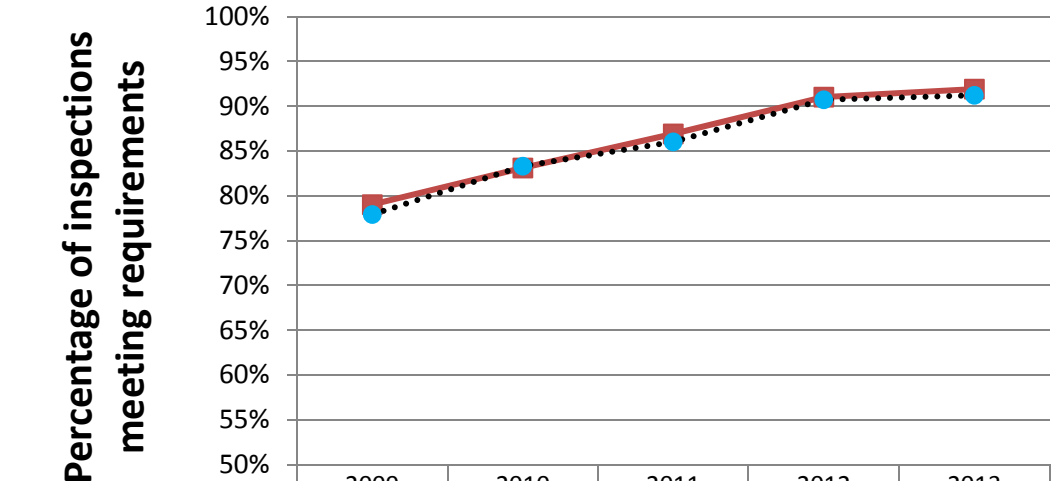
### 5.2.2 Operating performance

The overall compliance for operating performance in the medical sector was 91.2% in 2013, as shown in Figure 17. This safety and control area continued a trend of steady improvement since 2009, when only 77.9% of inspected licensees were found to be compliant. Since diagnostic and therapeutic nuclear medicine subsector inspections account for the majority (81.6%) of all medical operating performance inspections, compliance changes in the subsector will be strongly reflected in the overall medical sector compliance.

Since there were few inspections in the radiation therapy and veterinary nuclear medicine subsectors, their trend lines are not provided in Figure 17.

Observed non-compliances in the medical sector were mainly related to failures to follow procedures specified in their CNSC licences, failures to comply with worker obligations, failures to perform sealed source leak tests, and failures to retain records.

**Figure 17:** Medical sector performance comparison with select subsectors – Inspection ratings of operating performance from 2009 to 2013




| | 2009 | 2010 | 2011 | 2012 | 2013 |
|---|---|---|---|---|---|
| Diagnostic and therapeutic nuclear medicine (inspections) | 79.0% (219) | 83.1% (195) | 86.9% (214) | 91.0% (166) | 91.9% (235) |
| Radiation therapy (inspections) | 75.0% (8) | 90.0% (10) | 75.0% (8) | 83.3% (6) | 83.3% (30) |
| Veterinary nuclear medicine (inspections) | 55.6% (9) | 83.3% (5) | 81.8% (11) | 100.0% (6) | 85.7% (7) |
| Medical sector (inspections)* | 77.9% (290) | 83.3% (258) | 86.0% (264) | 90.7% (205) | 91.2% (297) |

Ratings

* The total number of inspections shown in this row is the aggregate for the entire medical sector, including subsectors not highlighted in this report.

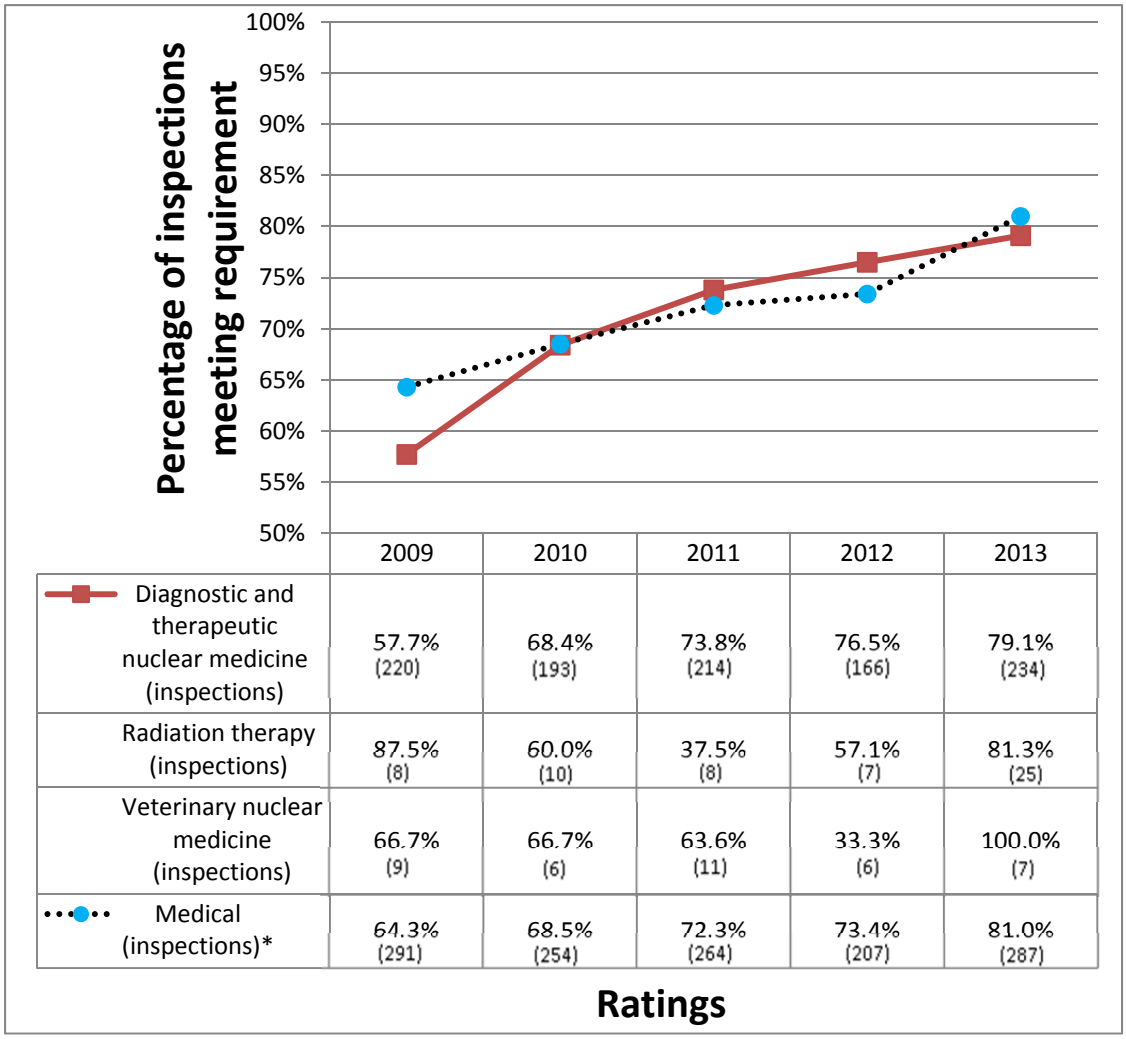
### 5.2.3 Radiation protection

The overall compliance for radiation protection in the medical sector was 81.0% in 2013, as shown in Figure 18. This safety and control area continued to show steady improvement since 2009, when only 62.5% of inspected licensees were found to be compliant. Since diagnostic and therapeutic nuclear medicine subsector inspections account for the majority (81.5%) of all medical operating performance inspections, compliance changes in the subsector will be reflected in the overall medical sector compliance.

Since there were few inspections in the radiation therapy and veterinary nuclear medicine subsectors, their trend lines are not provided in Figure 18.

Observed non-compliances in the medical sector were mainly related to containers not being properly labelled, contamination criteria not being followed, survey meters being not available or properly calibrated, and doses not being as low as reasonably achievable.

**Figure 18:** Medical sector performance comparison with select subsectors – Inspection ratings of radiation protection from 2009 to 2013




| | 2009 | 2010 | 2011 | 2012 | 2013 |
|---|---|---|---|---|---|
| Diagnostic and therapeutic nuclear medicine (inspections) | 57.7% (220) | 68.4% (193) | 73.8% (214) | 76.5% (166) | 79.1% (234) |
| Radiation therapy (inspections) | 87.5% (8) | 60.0% (10) | 37.5% (8) | 57.1% (7) | 81.3% (25) |
| Veterinary nuclear medicine (inspections) | 66.7% (9) | 66.7% (6) | 63.6% (11) | 33.3% (6) | 100.0% (7) |
| Medical (inspections)* | 64.3% (291) | 68.5% (254) | 72.3% (264) | 73.4% (207) | 81.0% (287) |

* The total number of inspections shown in this row is the aggregate for the entire medical sector, including subsectors not highlighted in this report.

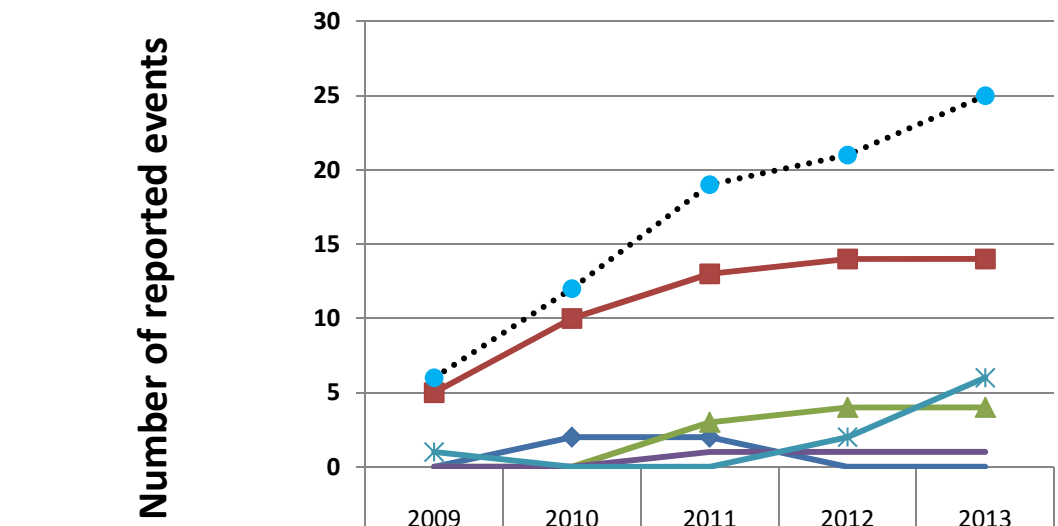
### 5.2.4 Enforcement actions

No enforcement actions were issued to licensees in the medical sector in 2013.

### 5.2.5 Reported events

There were 25 events reported in the medical sector in 2013, all classified as low risk. Of the 25 events, 14 were spills or contamination, 6 were related to packaging and transport, 4 involved missing or found nuclear substances, and 1 was related to a security breach. As shown in Figure 19, the number of reported events has increased significantly over the past five years.

**Figure 19:** Medical sector – Reported events from 2009 to 2013




| | 2009 | 2010 | 2011 | 2012 | 2013 |
|---|---|---|---|---|---|
| Malfunctioning or damaged devices | 0 | 2 | 2 | 0 | 0 |
| Spills and contamination | 5 | 10 | 13 | 14 | 14 |
| Missing or found nuclear substances | 0 | 0 | 3 | 4 | 4 |
| Breach of security | 0 | 0 | 1 | 1 | 1 |
| Packaging and transport | 1 | 0 | 0 | 2 | 6 |
| Total | 6 | 12 | 19 | 21 | 25 |

Types

### Spills or contamination

The 14 reported events related to spills or contaminations in the medical sector occurred during the handling of unsealed nuclear substances. Most of these events resulted from nuclear medicine technologists dropping vials and spilling liquid – either while withdrawing it from vials, or when an intravenous line was inadvertently disconnected. Since typical isotopes used in the medical sector have half-lives ranging from a few hours to a few days, spills are easily addressed by licensees with minimal impact on clinical operations.

### Missing or found nuclear substances

There were four reported events involving missing nuclear substances:

- One involved a licensee reporting a missing source after the replacement of the sealed sources from a gamma knife device at a hospital. Upon inspection, the device servicing staff were able to confirm that the source was displaced within the device and not actually missing. The source was repositioned within the

equipment shortly afterwards. Since this Category 2[13] sealed source was contained within the prescribed equipment, there was no radiation exposure in excess of the regulatory limit to hospital staff or members of the public.

- Two involved the loss of low-risk cobalt-57 markers used with nuclear medicine imaging cameras (to differentiate left and right on patient images). The markers were lost between imaging sessions, and the licensee's efforts to recover the sources were unsuccessful. Cobalt-57 is a Category 5 sealed source and presents very low risk to health and safety, due to its extremely low activity – which is comparable to that found in commercial smoke detectors.
- One involved a missing iodine-125 brachytherapy seed following a treatment procedure. The licensee investigated the event and concluded that the seed was likely dropped by a technologist during its transfer from a pathology recovery container to the original glass stock vial, ending up in normal waste. One seed is very low-risk and poses no threat to workers or the public.

**Security breach**

There was a security breach at a hospital while an overnight quality-control procedure was being performed on a diagnostic imaging camera. The maintenance department had failed to notify the nuclear medicine department of scheduled maintenance work. As a result, contract workers entered the hospital to replace lighting where the procedure was being performed. The procedure involved using a point source of technitium-99m, with an estimated activity (at the time of the incident) of 15.2 MBq. Dose estimates were calculated, and it was determined that the contract workers received a maximum dose of approximately 0.075 mSv, which is well below the applicable regulatory dose limit of 1 mSv per year. The licensee has taken measures to prevent reoccurrence.

**Packaging and transport**

There were six reported events related to packaging and transport. Three involved packages delivered to wrong locations, two involved incorrect package labelling, and the last event involved a package received with external contamination.

In the three cases where the packages were delivered to wrong locations, the nuclear substances were delivered to locations not listed on a CNSC licence. In one case, two packages containing technetium-99m (used for imaging purposes) were mistakenly delivered to an unauthorized location by the shipping company. In another case, a package containing cobalt-57 markers (used for patient positioning) was sent to a hospital under construction.

In the third case, a package containing iridium-192 seeds used for radiation therapy was delivered to a hospital's radiology department rather than the radio-oncology department.

[13] For information about the categories of sealed sources, refer to nuclearsafety.gc.ca/eng/nuclear-substances/licensing-nuclear-substances-and-radiation-devices/sealed-source-tracking.cfm#a6

In all three cases, the packages remained unopened and secured until arrangements were made for their transport to the proper licensed locations. In all cases, licensees have revised their protocols involving the delivery of packages to hospitals.

There were two cases of packages not labelled in accordance with the *Packaging and Transport of Nuclear Substances Regulation*[14]. In both cases, appropriate corrective measures were taken by licensees to the satisfaction of CNSC staff.

In one event, a package containing iodine-131 was returned from a hospital's nuclear medicine department to the radiopharmaceutical supplier, who discovered external contamination above regulatory limits. A review showed that contamination checks were not performed prior to returning the package. The licensee has implemented effective measures to help prevent any future events of this nature.

**Summary statement**

None of these events had any adverse radiological effects on the environment or resulted in workers receiving doses in excess of the regulatory limits. In all cases, licensees implemented adequate response measures to mitigate the impacts of the events, and to limit radiation exposure to workers and radiological impacts on the environment.

[14] Available online at laws-lois.justice.gc.ca/eng/regulations/SOR-2000-208

# 6 Industrial Sector

This sector accounted for 1,440 CNSC licences and 9,490 nuclear energy workers (NEWs) as of December 31, 2013.

## 6.1 Sector summary and overview

### Overall performance

In general, the industrial sector showed gains in safety performance in 2013.

Occupational doses received by NEWs in this sector remained low, with 78.8% receiving doses below1 mSv. Doses received by NEWs in the industrial radiography subsector were slightly higher in 2013 when compared to 2012, but noticeably lower in comparison to 2011. This was mainly due to an observed increase in work for radiographers in 2013, especially those in the oil and gas industry.

The industrial sector continued to demonstrate good compliance, with satisfactory ratings given to 87.6% and 87.2% of inspected licensees in the operating performance and radiation protection areas, respectively. Satisfactory corrective actions were taken by licensees to address non-compliance situations. Overall, all subsectors demonstrated steady improvement in regulatory compliance in 2013, with the exception of fixed gauges.

The CNSC issued 24 enforcement actions to the industrial sector in 2013, including 22 orders and 2 administrative monetary penalties. Most of these continued to be issued to the industrial radiography and portable gauges subsectors.

There were 88 reported events in 2013 compared with 77 in 2012, with more than half of these events related to malfunctioning or damaged devices. In all cases, CNSC staff assessed the events and categorized them as low risk, based on the radiological impact to persons and the environment.

### Observations

In Canada, the use of nuclear substances in industrial applications continues to be extensive. The use of portable gauges is directly linked to the large number of infrastructure projects (such as roads and bridges), as well as the construction of public buildings (such as hospitals and schools). The oil well logging and industrial radiography services are strongly linked to the oil and gas industry, which continues to be robust – particularly in northern Alberta, British Columbia and southern Saskatchewan.

### Inspection program

The CNSC inspection program was revised in 2013 to increase its focus on the portable gauge subsector. The number of inspections in this subsector has increased by approximately 12%. The CNSC has also developed an outreach strategy, focusing on portable gauge licensees, to help them deal with ongoing safety issues.

Inspection results in 2013 indicate a decreased compliance in both operating performance and radiation protection for the fixed gauge subsector. The inspection frequency was subsequently changed from every five years to every three years (effective 2014), to provide enhanced regulatory oversight for this subsector.

## 6.2 Safety performance trends

### 6.2.1 Occupational doses

Doses received by NEWs in the industrial sector remained low, with 78.8% receiving doses below 1 mSv.

NEWs in the portable gauge subsector continued to receive low doses, with 85.9% receiving below 1 mSv, and no workers receiving over 20 mSv in 2013.

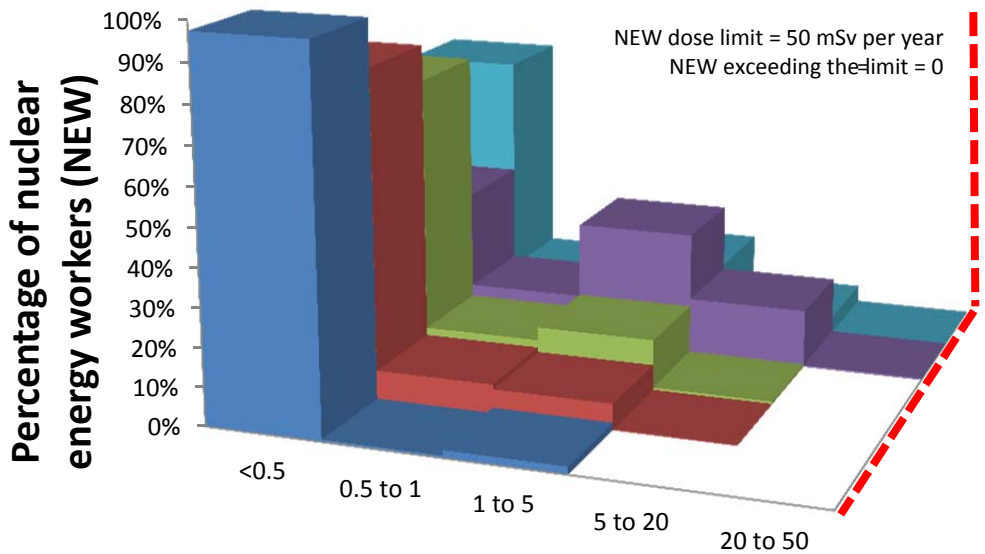
NEWs in the oil well logging subsector also continued to receive low doses, with 93.1% of workers receiving below 1 mSv. Three workers received over 5 mSv (highest dose: 7.91 mSv) in 2013.

NEWs in the fixed gauge subsector continued to receive extremely low doses, with 98.0% of workers receiving below 1 mSv. Most workers in the fixed gauge subsector – nearly 34,000 in total – are not designated as NEWs, since the doses they receive are very low, partially because very few of them handle nuclear substances or devices. Those who do handle fixed gauges may at times perform servicing work, resulting in higher doses than most other workers in this subsector.

Doses received by NEWs in the industrial radiography subsector were slightly higher in 2013 when compared to 2012, but noticeably lower when compared to 2011. This was due mainly to an observed increase in work for exposure device operators in 2013, especially those in the oil and gas industry. There is typically less rotation of NEWs when a pipeline is being built in remote locations. All NEWs in the industrial radiography subsector received doses below the regulatory dose limit, and none have exceeded this limit since reporting began in 2008. The increase in doses was not related to safety performance, as the industrial radiography subsector has typically received higher compliance ratings in operating performance and radiation protection when compared with other industrial subsectors. In fact, both of these safety and control areas showed improvement in 2013, compared to 2012.

Figure 20 shows the differences in doses received by workers at the subsector level. As the figure indicates, NEWs in the industrial radiography subsector continued to receive higher doses than other industrial subsectors. Industrial radiography doses are typically higher when compared with NEWs across all four sectors. This is a result of working in close proximity to exposure devices containing high activity sources.

**Figure 20:** Industrial sector performance comparison with select subsectors – Annual effective doses of nuclear energy workers in 2013



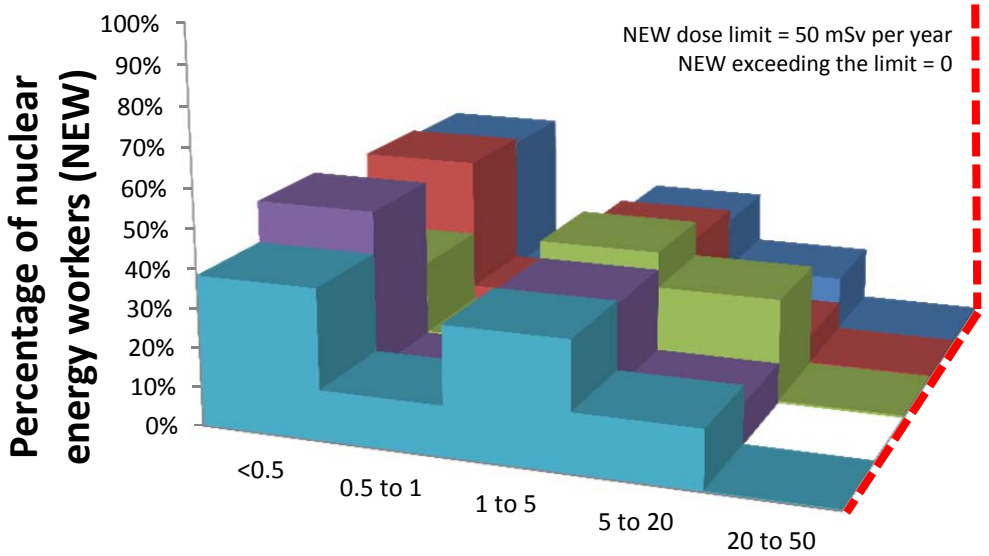

| | <0.5 | 0.5 to 1 | 1 to 5 | 5 to 20 | 20 to 50 |
|---|---|---|---|---|---|
| Fixed gauge (502) | 97.4% | 0.6% | 2.0% | 0.0% | 0.0% |
| Oil-well logging (2,249) | 85.2% | 8.0% | 6.8% | 0.1% | 0.0% |
| Portable gauge (3,678) | 76.0% | 9.9% | 13.4% | 0.7% | 0.0% |
| Radiography (2,670) | 38.4% | 13.0% | 32.9% | 15.3% | 0.4% |
| Industrial sector (9,490)* | 68.7% | 10.1% | 16.4% | 4.7% | 0.1% |

**Dose ranges (mSv)**

* The total number of NEWs shown in this row is the aggregate for the entire industrial sector, including subsectors not highlighted in this report.

The doses received by NEWs in the industrial radiography subsector from 2009 to 2013 are shown in Figure 21.

**Figure 21:** Industrial radiography subsector performance – Annual effective doses to nuclear energy workers from 2009 to 2013




| | <0.5 | 0.5 to 1 | 1 to 5 | 5 to 20 | 20 to 50 |
|---|---|---|---|---|---|
| 2013: 2,670 | 38.4% | 13.0% | 32.9% | 15.3% | 0.4% |
| 2012: 461 | 49.2% | 8.2% | 31.9% | 10.6% | 0.0% |
| 2011: 324 | 27.2% | 8.6% | 36.4% | 27.2% | 0.6% |
| 2010: 123 | 47.2% | 12.2% | 31.7% | 8.1% | 0.8% |
| 2009: 133 | 45.9% | 9.8% | 28.6% | 15.0% | 0.8% |

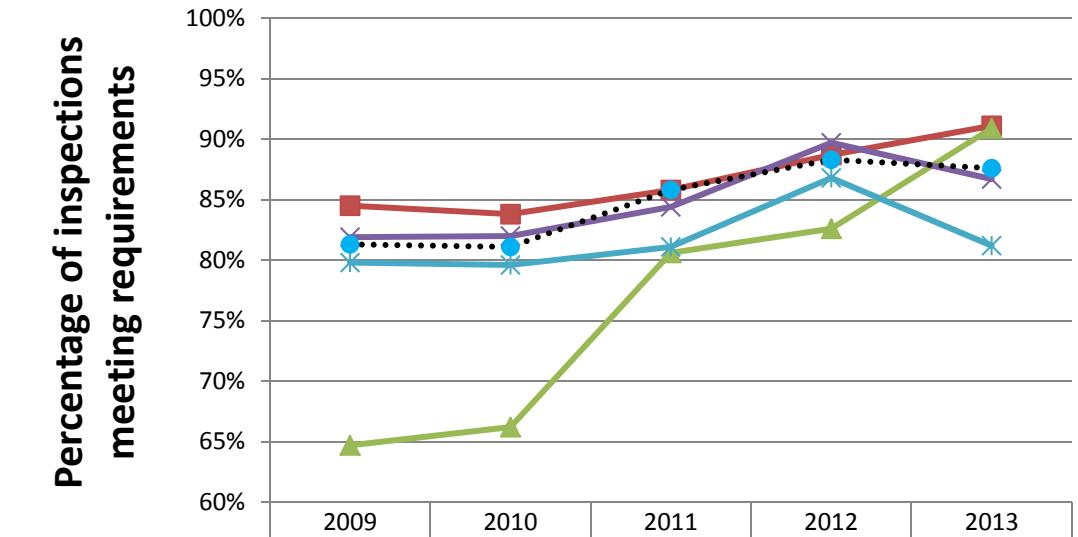
**Dose range (mSv)**

### 6.2.2 Operating performance

The overall compliance for operating performance in the industrial sector was 87.6% in 2013, as shown in Figure 22. This safety and control area has shown improvement since 2009, when 81.3% of inspected licensees were found to be compliant. However, the sector shows a decline when compared with 88.3% in 2012, due to a decrease in the compliance rating for the fixed gauge and the portable gauge subsectors.

Observed non-compliances in the industrial sector were related to failures to comply with worker obligations, failures to retain records, failures to perform sealed source leak tests, failures to post licences, and failures to follow procedures specified in their CNSC licences.

**Figure 22:** Industrial sector performance comparison with select subsectors – Inspection ratings of operating performance from 2009 to 2013




| | 2009 | 2010 | 2011 | 2012 | 2013 |
|---|---|---|---|---|---|
| Radiography (inspections) | 84.5% (181) | 83.8% (240) | 85.8% (226) | 88.7% (275) | 91.1% (224) |
| Oil well logging (inspections) | 64.7% (34) | 66.2% (71) | 80.6% (72) | 82.6% (69) | 90.9% (66) |
| Portable gauges (inspections) | 81.9% (415) | 82.0% (317) | 84.4% (398) | 89.7% (369) | 86.7% (412) |
| Fixed gauges (inspections) | 79.8% (159) | 79.6% (103) | 81.1% (122) | 86.8% (151) | 81.2% (197) |
| Industrial (inspections)* | 81.3% (769) | 81.1% (771) | 85.8% (932) | 88.3% (884) | 87.6% (958) |

**Ratings**

* The total number of inspections shown in this row is the aggregate for the entire industrial sector, including subsectors not highlighted in this report.

### 6.2.3 Radiation protection

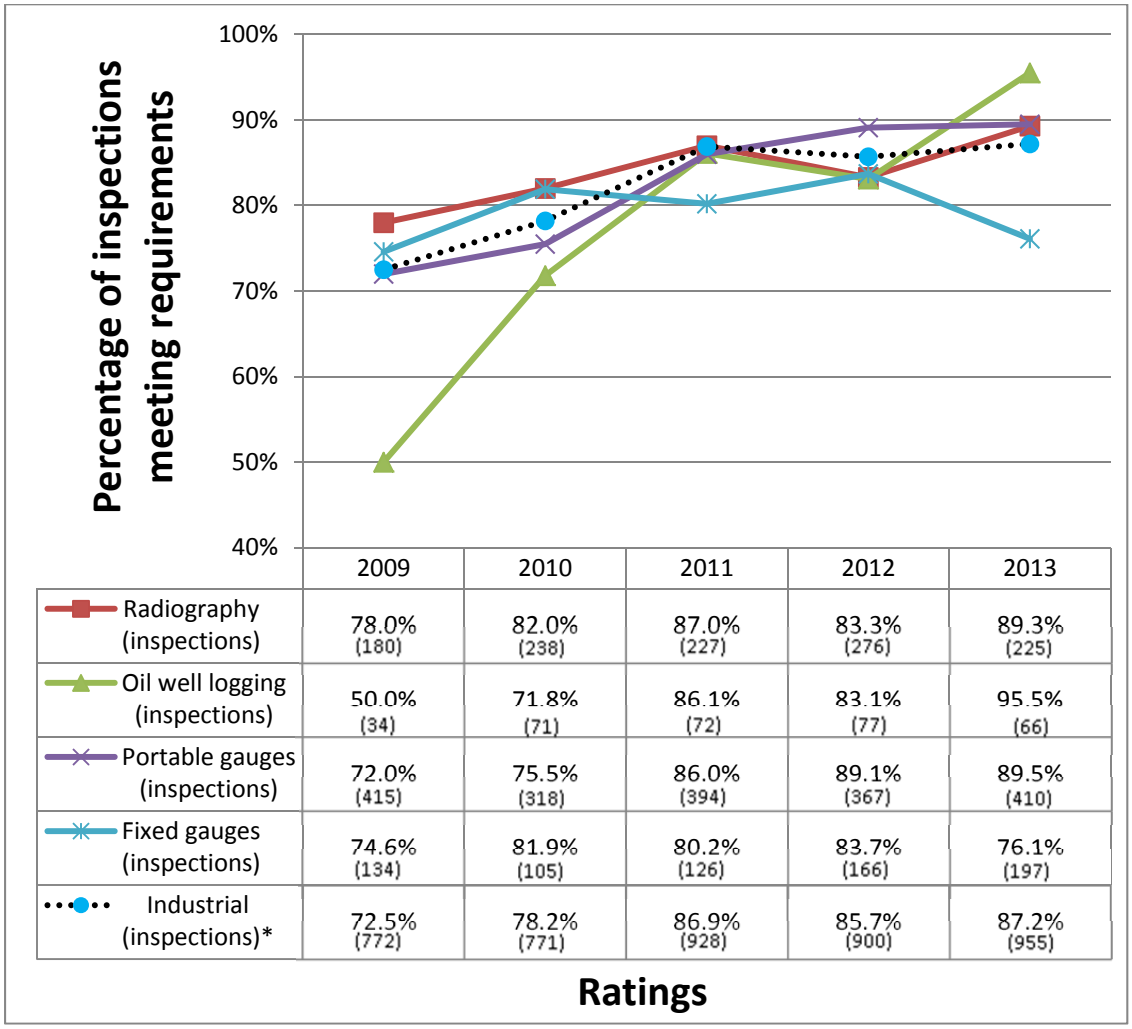
The overall compliance for radiation protection in the industrial sector was 87.2% in 2013, as shown in Figure 23. Despite minor changes over the past two years, this safety and control area has steadily improved since 2009, when only 72.5% of inspected licensees were found to be compliant.

The most noticeable change in 2013 was within the oil well logging subsector, where there was an improvement in compliance ratings – from 83.1% in 2012 to 95.5% in 2013.

Another change was a decrease in compliance ratings within the fixed gauge subsector – from 83.7% in 2012 to 76.1% in 2013.Observed non-compliances in the industrial sector were related to doses not being kept as low as reasonably achievable, survey meters not being available or properly calibrated, containers or radiation devices not labelled

properly, failures to properly ascertain or record doses, failures to post signs at boundaries and points of access, and improper storage of nuclear substances.

**Figure 23:** Industrial sector performance comparison with select subsectors – Inspection ratings of radiation protection from 2009 to 2013




| | 2009 | 2010 | 2011 | 2012 | 2013 |
|---|---|---|---|---|---|
| Radiography (inspections) | 78.0% (180) | 82.0% (238) | 87.0% (227) | 83.3% (276) | 89.3% (225) |
| Oil well logging (inspections) | 50.0% (34) | 71.8% (71) | 86.1% (72) | 83.1% (77) | 95.5% (66) |
| Portable gauges (inspections) | 72.0% (415) | 75.5% (318) | 86.0% (394) | 89.1% (367) | 89.5% (410) |
| Fixed gauges (inspections) | 74.6% (134) | 81.9% (105) | 80.2% (126) | 83.7% (166) | 76.1% (197) |
| Industrial (inspections)* | 72.5% (772) | 78.2% (771) | 86.9% (928) | 85.7% (900) | 87.2% (955) |

* The total number of inspections shown in this row is the aggregate for the entire industrial sector, including subsectors not highlighted in this report.

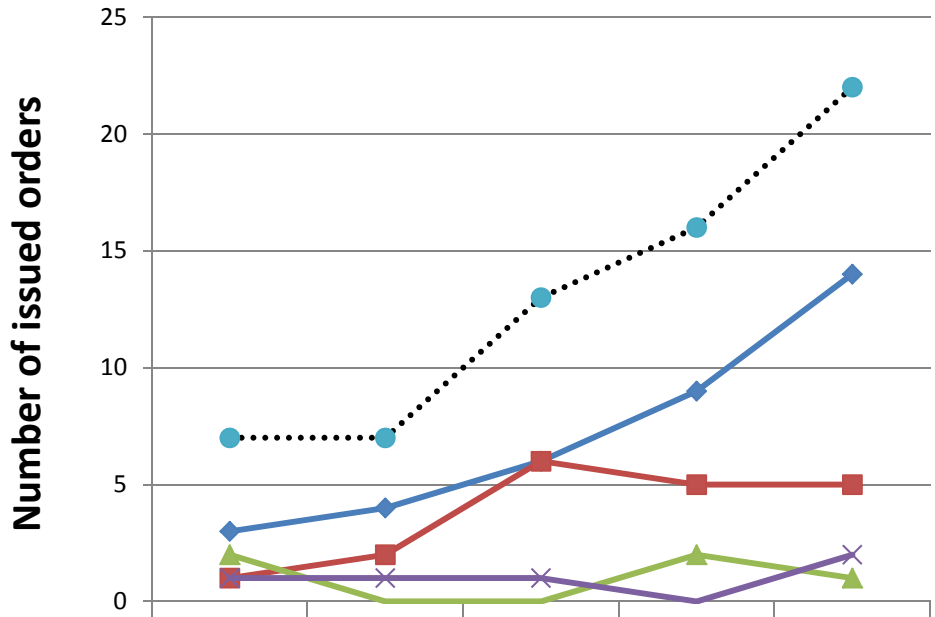
### 6.2.4 Enforcement actions

The CNSC issued 24 enforcement actions to the industrial sector, including 22 orders and 2 administrative monetary penalties. As shown in Figure 24, there were 14 orders issued to portable gauge licensees, 5 issued to industrial radiography licensees, 1 issued to a fixed gauge licensee, 1 issued to an X-ray fluorescence analysis licensee and 1 issued to a company that was in possession of fixed gauges without a CNSC licence. The number of orders issued to the portable gauge subsector has increased steadily since 2010, and more significantly in 2013. This increase is most likely due to more field inspections in 2013. In response to the increasing number of enforcement actions in this subsector, the CNSC

has developed a strategy to reach out to portable gauge licensees in an effort to increase their level of safety. More details are provided in section 6.3.

All licensees to whom orders were issued have implemented corrective measures to the satisfaction of CNSC staff.

**Figure 24:** Industrial sector – Summary of orders by type of licensed activity from 2009 to 2013




| | 2009 | 2010 | 2011 | 2012 | 2013 |
|---|---|---|---|---|---|
| Portable gauges | 3 | 4 | 6 | 9 | 14 |
| Radiography | 1 | 2 | 6 | 5 | 5 |
| Fixed gauges | 2 | 0 | 0 | 2 | 1 |
| Other | 1 | 1 | 1 | 0 | 2 |
| Total | 7 | 7 | 13 | 16 | 22 |

Subsectors

For more information on enforcement actions, consult the "Regulatory action" page on the CNSC website[15].

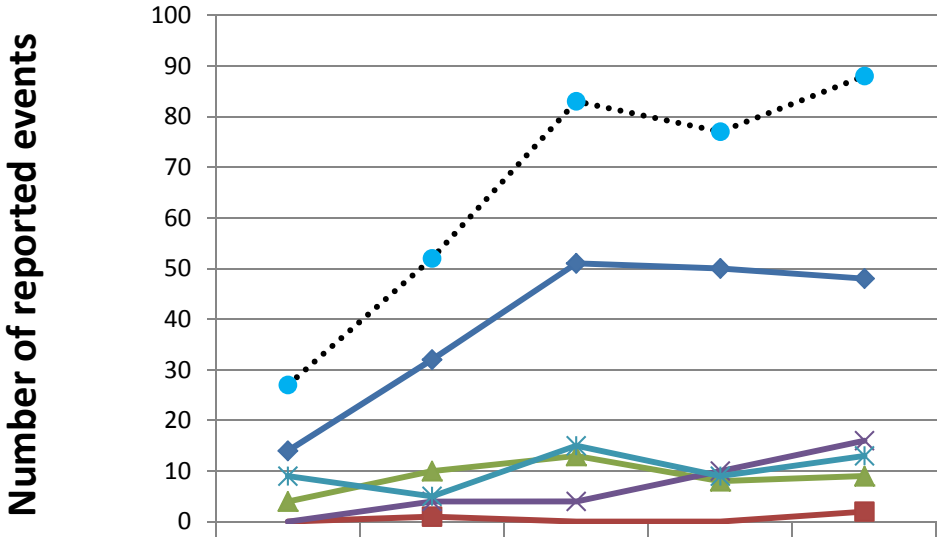
### 6.2.5 Reported events

There were 88 events reported in the industrial sector in 2013, all classified as low risk. Of these 88 events, 48 were related to malfunctioning or damaged devices, 16 were related to security breaches, 13 were related to packaging and transport, 9 involved missing or found nuclear substances, and 2 involved spills or contamination. As shown in

[15] Refer to nuclearsafety.gc.ca/eng/acts-and-regulations/regulatory-action

Figure 25, the number of reported events has tripled over the past five years – from 27 in 2009 to 88 in 2013. Although, the number of reported events has increased significantly, this was most likely due to licensee's better understanding of event-reporting requirements, as a result of CNSC outreach efforts.

**Figure 25:** Industrial sector – Reported events from 2009 to 2013




| Types | 2009 | 2010 | 2011 | 2012 | 2013 |
|---|---|---|---|---|---|
| Malfunctioning or damaged devices | 14 | 32 | 51 | 50 | 48 |
| Spills and contamination | 0 | 1 | 0 | 0 | 2 |
| Missing or found nuclear substances | 4 | 10 | 13 | 8 | 9 |
| Breach of security | 0 | 4 | 4 | 10 | 16 |
| Packaging and transport | 9 | 5 | 15 | 9 | 13 |
| Total | 27 | 52 | 83 | 77 | 88 |

**Malfunctioning or damaged devices**

There were 48 events related to damaged or malfunctioning devices, with 39 of them involving damaged devices and 9 involving malfunctioning devices.

Of the 39 events related to damaged devices:

- 22 events involved portable gauges which were hit or run over by vehicles at construction sites
- 11 events involved fixed gauges sustaining a drop or impact
- 5 events involved damage to exposure devices after a drop or an impact
- 1 event involved a damaged X-ray fluorescence analyzer

There were no reports of sealed source leakage following these events.

Of the 9 malfunctioning devices, all involved failure of an exposure device where the sealed source failed to retract into the shielded position. All were taken out of service and evaluated as required by the regulations.

**Spills or contamination**

There were two reported events involving non-personal contamination during the use of subsurface tracers for oil-well logging operations. In both cases, the licensee implemented adequate response measures to mitigate the impact of the events.

**Missing or found nuclear substances**

There were eight events involving missing nuclear substances, and one event involving found nuclear substances.

Of the eight events related to missing nuclear substances:

- One event involved an exposure device containing a Category 2 sealed source, initially reported as lost (since it had not been delivered on the expected day). The package was located shortly after within the warehouse, and was delivered to the licensee. Since the exposure device was packaged in accordance with the *Packaging and Transport of Nuclear Substances Regulations*, no one was exposed to radiation above regulatory dose limits.
- Three events involved inventory checks that revealed that some fixed gauges were lost; one, containing a Category 4 sealed source, was recovered after the licensee conducted an inventory check. The remaining two gauges – one containing a Category 4 sealed source and one containing a Category 5 sealed source – have not been recovered, and the event is still under investigation.
- Three events involved portable gauges containing Category 4 sealed sources, with two stolen from vehicles and one lost during transport. One of the two stolen gauges and the portable gauge lost during transport were recovered shortly after they were reported missing, either by local authorities or by the licensee. The other stolen portable gauge is still missing, but the vehicle has since been located and returned to the owner. This event is still under investigation.

One event involved two hygrometers containing Category 5 sealed sources, reported as missing following an inventory check. The two hygrometers have not been recovered, and the event is still under investigation. The one report of found nuclear substances involved a truck carrying scrap metal originating from a licensee, which triggered portal alarms at a metal recycling facility. The item was identified as a dewpoint detector (which contains a low-risk sealed source) and was retrieved from the load. The licensee recovered the device and properly stored it for future disposal.

**Breach of security**

All 16 events related to breaches of security involved people entering a restricted area that had been established prior to the use of radiation devices. 14 cases involved industrial radiography exposure devices, and 2 involved fixed gauges. In all but one case, the person received a dose well below the public regulatory dose limit of 1 mSv. The case where a member of the public received a dose above the regulatory dose limit is described in section 4.2.5.

In one event, a maintenance contractor entered a restricted area that had been established for use of a fixed gauge. The gauge had not been removed from the vessel, and the contractor did not wait until it was safe to enter to perform maintenance work. The gauge was subsequently removed and securely stored, allowing work to resume. Dose estimates were calculated, and the licensee determined that the contractor received a dose below the regulatory dose limit of 1 mSv per year.

Although these events were categorized as security breaches, each resulted from a lack of control in the workplace. As a result, licensees have taken measures satisfactory to CNSC staff to prevent recurrence.

**Packaging and transport**

There are thousands of shipments of radiation devices every year in the industrial sector, such as portable gauges transported to construction sites, or exposure devices transported in the field for welding inspections. In 2013, there were 13 events involving packaging and transport. Of these events, seven involved portable gauges, three involved exposure devices, and three involved oil well logging sources. All events were minor accidents involving vehicles transporting nuclear substances, with no reported damage to the packages after the accidents.

**Summary statement**

None of these events had any adverse radiological effects on the environment. However, one event resulted in a worker receiving a dose in excess of the public regulatory limit. In all cases, licensees implemented adequate response measures to mitigate the impact of the events and to limit radiation exposure to workers, as well as the radiological impact on the environment.

## 6.3 Stakeholder engagement

An industrial radiography working group was established in 2009, and includes both CNSC and industry representatives. The objective was to encourage more effective communications between the CNSC and the industry, discuss best practices and stay informed of new developments in the field (from both the technical and regulatory perspectives). The working group meets on a regular basis, and continues to provide valuable feedback on issues of mutual concern related to regulatory requirements of the subsector.

A special summer edition of the CNSC's DNSR newsletter[16] was issued in 2013, with content geared directly to the industrial radiography subsector. The articles contained information on CNSC expectations for source recovery operations, posting of radiation warning signs, and erecting barriers during industrial radiography operations. It also described the new Canadian Standards Association Exposure Device Operator certification guide. This new guide will replace the CNSC's current regulatory guide *Certification of Exposure Device Operators*, and addresses the most current safety,

[16] Available online at nuclearsafety.gc.ca/eng/nuclear-substances/directorate-of-nuclear-substance-regulation-newsletter

security and regulatory requirements for the industry. More information on this guide can be found by visiting the CNSC website[17].

In 2013, CNSC staff developed a strategy to reach out to portable gauge licensees to promote a more positive safety culture within the subsector. This subsector-specific outreach program will begin with a trial session in 2014. CNSC staff believe that improved industry engagement will be effective in addressing ongoing compliance issues within the portable gauge subsector.

[17] Refer to nuclearsafety.gc.ca/eng/nuclear-substances/exposure-device-operators

# 7 Academic and Research

This sector accounted for 232 CNSC licences and 4,475 nuclear energy workers (NEWs) as of December 31, 2013. See Appendix Afor further detail on high-energy research particle accelerators.

## 7.1 Sector summary and overview

**Overall performance**

In general, the academic and research sector showed gains in safety performance in 2013.

Occupational doses received by NEWs in this sector remained low, with 96.0% receiving doses below 1 mSv.

The academic and research sector continued to demonstrate good compliance, with satisfactory ratings given for 90.8% and 89.2% of inspected licensees in the operating performance and radiation protection areas, respectively. Satisfactory corrective actions were taken by licensees to address non-compliance situations. The laboratory studies and consolidated use subsector demonstrated continued regulatory compliance improvement in 2013.

No enforcement actions were given to the academic and research sector in 2013.

There were nine reported events in 2013. In all cases, CNSC staff assessed the reported events and categorized them as low risk, based on the radiological impact to persons and the environment.

**Observations**

There has been a steady decrease in the number of laboratory studies and consolidated use of nuclear substances licences over time, with a recent 20% drop – from 205 licences in 2009 to 164 licences in 2013. This change accounted for most (67.2%) of the decrease in the overall number of academic and research licences since 2009, with institutions finding alternative methods of performing the same research using techniques not requiring the use of nuclear substances.

**Inspection program**

Based on past safety performance ratings and the risk level associated with these licensed activities, the CNSC has revised its inspection program cycle for the laboratory studies and consolidated use subsector in 2013. The CNSC inspection program has been revised from annual inspections to every two years. Desktop reviews of documentation for operational and radiation protection program activities were implemented, as an alternative to site inspections. During this transition, onsite inspections were performed for approximately 15% of licences, with results compared against findings from the desktop reviews. The inspection findings of onsite inspections were consistent with the desktop reviews of documentation related to operational and radiation programs.

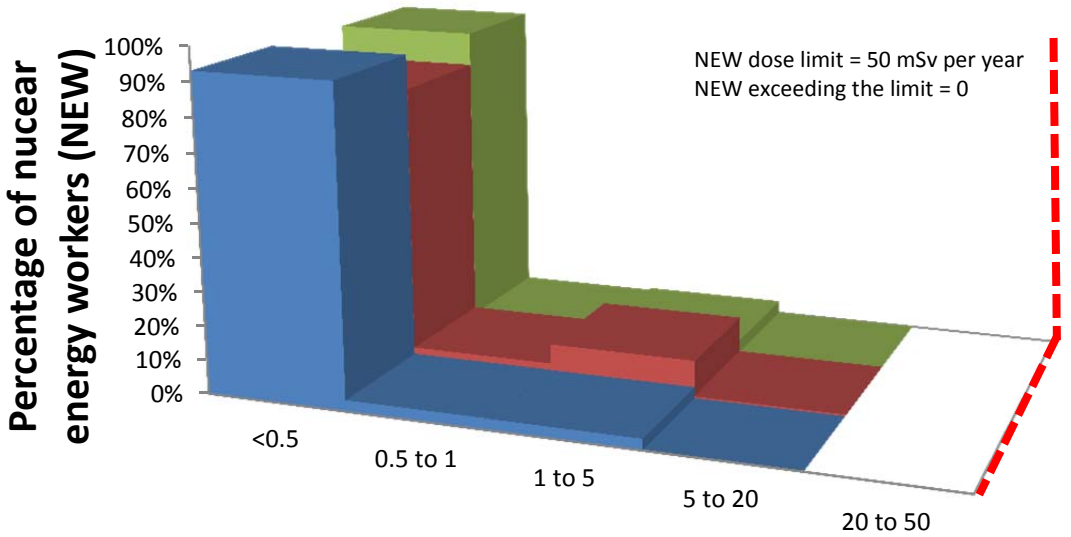
## 7.2 Safety performance results and trends

### 7.2.1 Doses to workers

The doses received by academic and research NEWs continued to be extremely low, with 96.0% of NEWs receiving doses below 1 mSv and only four workers receiving over 5 mSv (highest dose: 6.71 mSv). Doses to NEWs in the laboratory studies and consolidated uses of nuclear substances subsector remained generally unchanged, with 96.7% receiving a dose below 1 mSv.

Figure 26 shows the differences in worker doses between the academic and research subsectors. As the figure indicates, NEWs at locations conducting laboratory studies or consolidated uses, as well as those NEWs at high-energy research particle accelerator facilities, received extremely low doses.

**Figure 26:** Academic and research sector performance comparison with select subsectors – Annual effective doses of nuclear energy workers in 2013




| | <0.5 | 0.5 to 1 | 1 to 5 | 5 to 20 | 20 to 50 |
|---|---|---|---|---|---|
| Laboratory studies and consolidated use of nuclear substances (3,708) | 93.3% | 3.4% | 3.3% | 0.1% | 0.0% |
| High energy research particle accelerators (413) | 83.1% | 5.3% | 11.1% | 0.5% | 0.0% |
| Academic and research sector (4,475)* | 92.7% | 3.3% | 3.9% | 0.1% | 0.0% |

**Dose ranges (mSv)**

* The total number of NEWs shown in this row is the aggregate for the entire academic and research sector, including subsectors not highlighted in this report.

**CNSC laboratory**

Among the workers included in Figure 26 are the CNSC employees, designated as NEWs, that are working at the CNSC laboratory. Their number has increased from three in 2009 to six in 2013, with all of them receiving doses below 1 mSv. A detailed breakdown of the doses received by NEWs at the CNSC laboratory from 2009 to 2013 is provided in Table 2.

**Table 2:** Annual effective doses to nuclear energy workers at the CNSC laboratory from 2009 to 2013

| | Total number of NEWs | <0.5 (mSv per year) | 0.5 to 1 (mSv per year) | 1 to 5 (mSv per year) | 5 to 20 (mSv per year) | >20 (mSv per year) |
|---|---|---|---|---|---|---|
| **2009** | 3 | 2 | 0 | 1 | 0 | 0 |
| **2010** | 3 | 3 | 0 | 0 | 0 | 0 |
| **2011** | 4 | 4 | 0 | 0 | 0 | 0 |
| **2012** | 5 | 5 | 0 | 0 | 0 | 0 |
| **2013** | 6 | 6 | 0 | 0 | 0 | 0 |

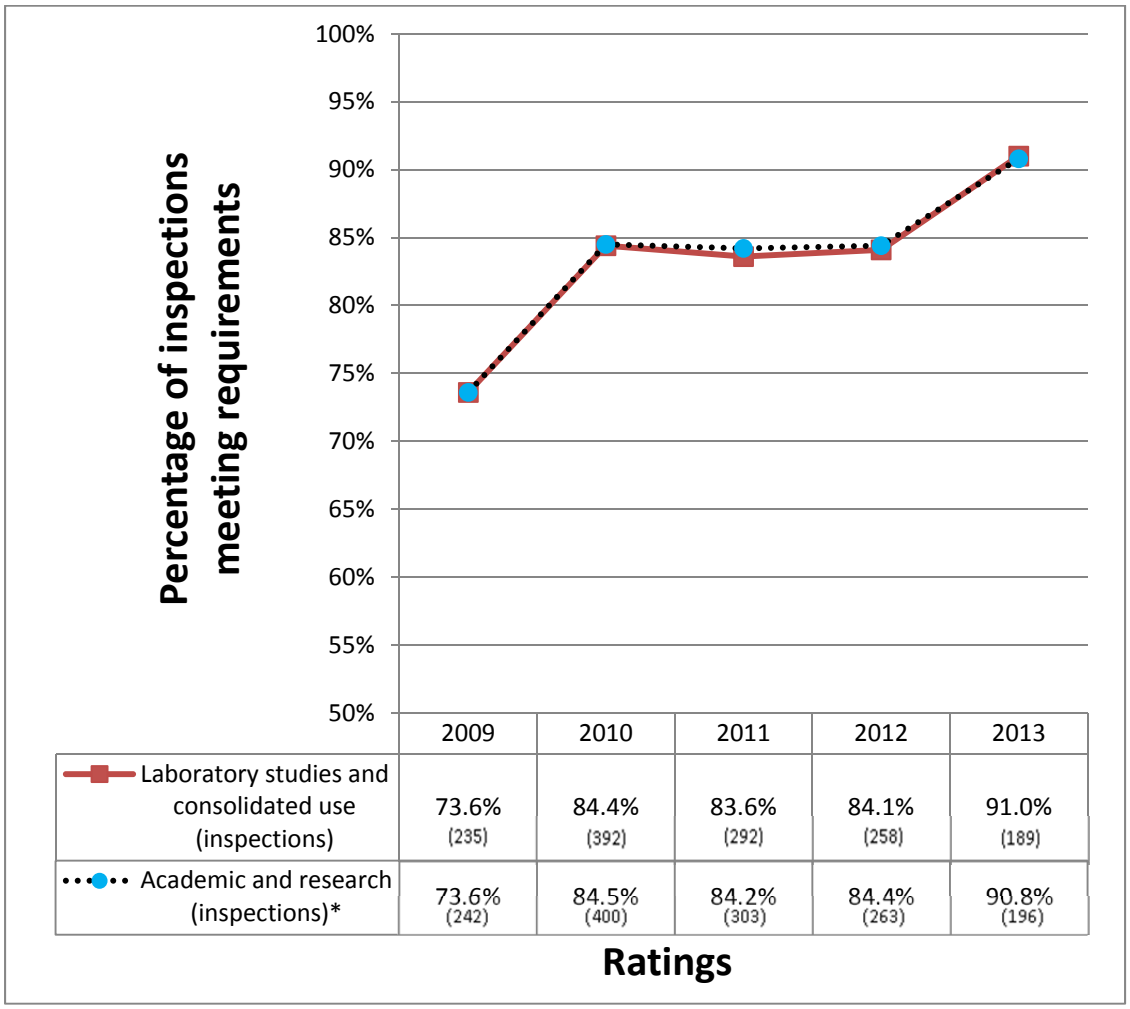
### 7.2.2 Operating performance

The overall compliance for operating performance in the academic and research sector was 90.8% in 2013, as shown in Figure 27. This safety and control area continued a trend of steady improvement since 2009, when only 73.6% of inspected licensees were found to be compliant.

The CNSC laboratory was inspected in 2013, and its operating performance compliance rating was satisfactory.

Observed non-compliances in the academic and research sector were related to failures to comply with worker obligations, inappropriate posting of radiation warning signs, failures to retain records, failures to post a licence, and failures to perform sealed source leak tests.

**Figure 27:** Academic and research sector performance comparison with select subsectors – Inspection ratings of operating performance from 2009 to 2013




| | 2009 | 2010 | 2011 | 2012 | 2013 |
|---|---|---|---|---|---|
| Laboratory studies and consolidated use (inspections) | 73.6% (235) | 84.4% (392) | 83.6% (292) | 84.1% (258) | 91.0% (189) |
| Academic and research (inspections)* | 73.6% (242) | 84.5% (400) | 84.2% (303) | 84.4% (263) | 90.8% (196) |

* The total number of inspections shown in this row is the aggregate for the entire academic and research sector, including subsectors not highlighted in this report.

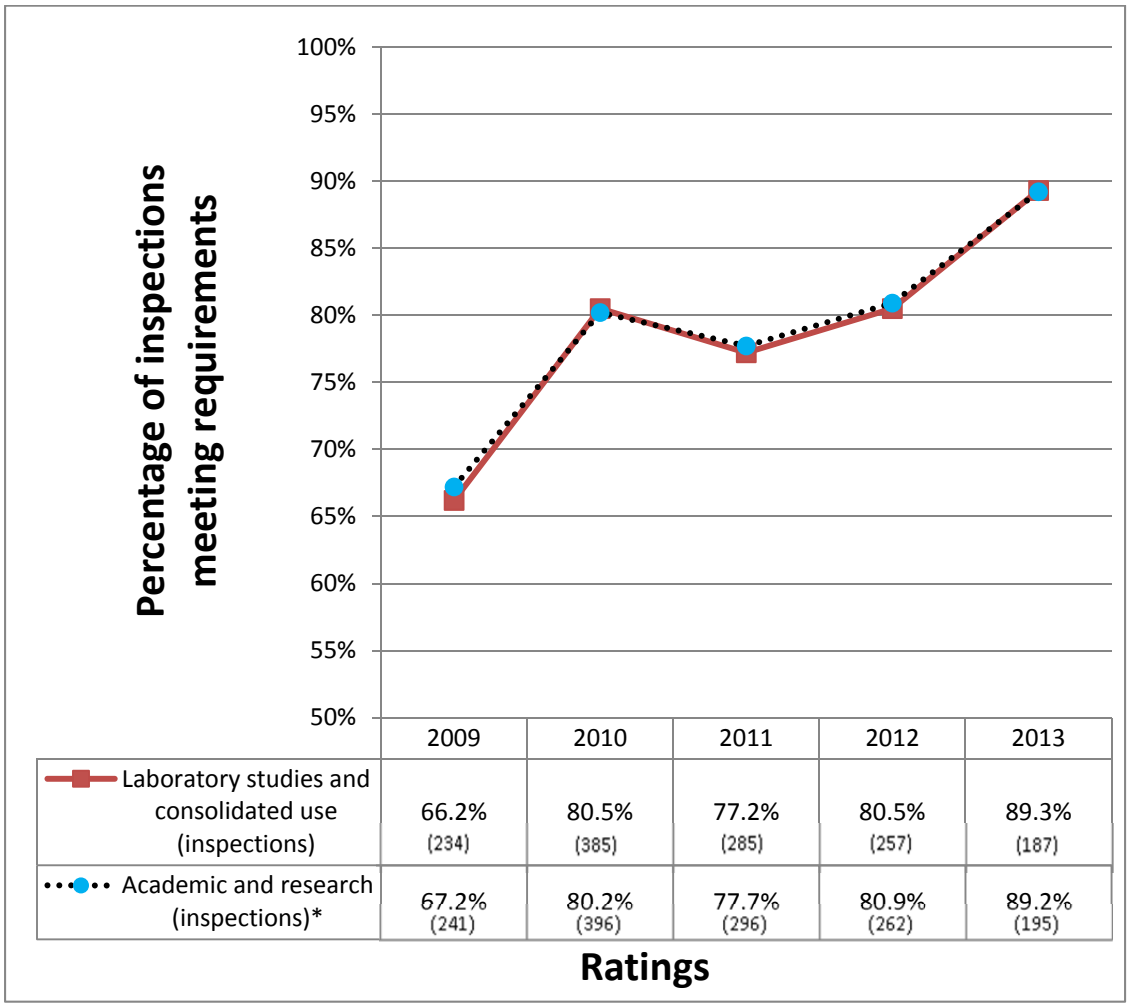
### 7.2.3 Radiation protection

The overall compliance for radiation protection in the academic and research sector was 89.2% in 2013, as shown in Figure 28. This safety and control area continued a trend of steady improvement since 2009, when only 67.2% of inspected licensees were found to be compliant.

The CNSC laboratory was inspected in 2013, and its radiation protection compliance rating was satisfactory.

Observed non-compliances in the academic and research sector were limited. Those observed were related to improper storage of nuclear substances, containers or radiation devices not being labelled properly, and failures to post signs at boundaries and points of access.

**Figure 28:** Academic and research sector performance comparison with select subsectors – Inspection ratings of radiation protection from 2009 to 2013




| | 2009 | 2010 | 2011 | 2012 | 2013 |
|---|---|---|---|---|---|
| Laboratory studies and consolidated use (inspections) | 66.2% (234) | 80.5% (385) | 77.2% (285) | 80.5% (257) | 89.3% (187) |
| Academic and research (inspections)* | 67.2% (241) | 80.2% (396) | 77.7% (296) | 80.9% (262) | 89.2% (195) |

* The total number of inspections shown in this row is the aggregate for the entire academic and research sector, including subsectors not highlighted in this report.

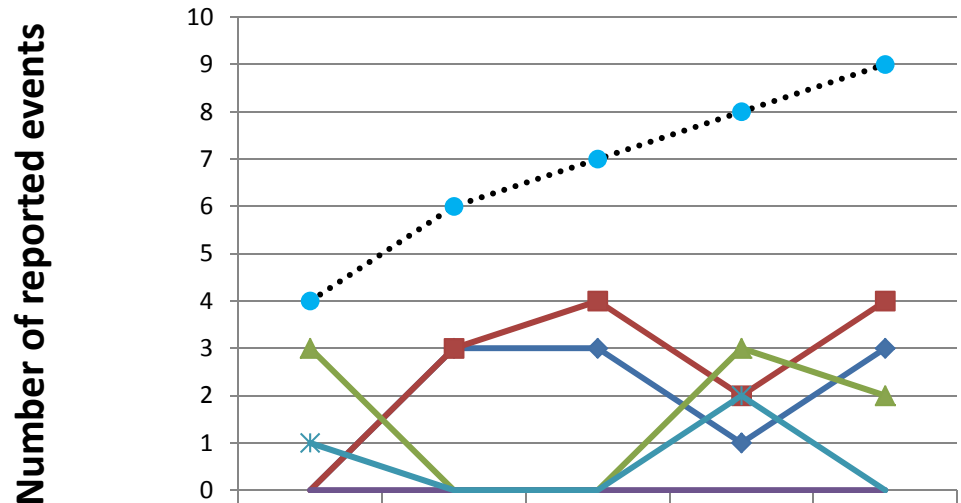
### 7.2.4 Enforcement actions

No enforcement actions were issued to licensees in the academic and research sector in 2013.

### 7.2.5 Reported events

There were nine events reported in the academic and research sector in 2013, all classified as low risk. Of those nine events, four were related to spills or contamination, three were related to malfunctioning or damaged devices, and two involved missing or found nuclear substances. The three events related to malfunctioning or damaged devices involved safety-system malfunctions at high-energy particle accelerator facilities. The number and types of reported events for the academic and research sector are shown in Figure 29.

**Figure 29:** Academic and research sector – Reported events from 2009 to 2013




| | 2009 | 2010 | 2011 | 2012 | 2013 |
|---|---|---|---|---|---|
| Malfunctioning or damaged devices | 0 | 3 | 3 | 1 | 3 |
| Spills and contamination | 0 | 3 | 4 | 2 | 4 |
| Missing or found nuclear substances | 3 | 0 | 0 | 3 | 2 |
| Breach of security | 0 | 0 | 0 | 0 | 0 |
| Packaging and transport | 1 | 0 | 0 | 2 | 0 |
| Total | 4 | 6 | 7 | 8 | 9 |

Types

### Malfunctioning or damaged devices

There were three events related to safety system malfunctions at high-energy particle accelerator facilities. Details of these events are provided in Appendix A.

### Spills or contamination

There were four reported events related to spills or contamination. Of these four events, two spills occurred during the handling of unsealed nuclear substances. In both cases, the licensee implemented adequate response measures to mitigate the impact of these events.

In one event, contamination was found in a fume hood during a routine thyroid screening, while establishing background radiation levels. In another event, contamination was discovered in a research lab at a hospital. In both cases, appropriate corrective measures were taken by licensees to the satisfaction of CNSC staff.

### Missing or found nuclear substances

Two events related to missing or found radioactive sources were also reported:

- One event involved a kit containing five Category 5 radiation detector check sources, which was lost by the carrier during shipment to the licensee. These

sources were never recovered, but presented no risk to the public or the environment due to the very small quantities of radioactive material they contained.

- One event involved three older Category 5 check sources, which were found in a tool kit at the CNSC headquarters. These sources presented no risk to the public or the environment, as they had already decayed to background levels.

**Summary statement**

None of these events had any adverse radiological effects on the environment, or resulted in workers receiving doses in excess of the regulatory limits. In all cases, licensees implemented adequate response measures to mitigate the impacts of the events and to limit radiation exposure to workers, or any radiological impact on the environment.

# 8 Commercial Sector

This sector accounted for 256 CNSC licences and 1,511 nuclear energy workers (NEWs) as of December 31, 2013.

## 8.1 Sector summary and overview

**Overall performance**

In general, the commercial sector showed gains in safety performance in 2013.

Occupational doses received by NEWs in this sector remained low, with 85.8% receiving doses below 1 mSv.

The commercial sector continued to show strong compliance ratings in the operating performance and radiation protection areas, with 94.1% and 93.2% of inspected licensees found to be compliant, respectively. Satisfactory corrective actions were taken by licensees to address non-compliance situations. Most subsectors demonstrated steady improvement in regulatory compliance in 2013.

There were 28 reported events in 2013, compared with 33 in 2012 – most of them related to spills or contamination. In all cases, CNSC staff assessed the events and categorized them as low risk, given the radiological impact to persons and the environment.

**Observations**

The commercial sector continued to experience growth in the isotope production and processing areas. There has been an increase of nearly 45% in the number of isotope production facilities since 2010 – from 12 in 2010 to 16 in 2013. This surge can be attributed to two main reasons. One is the increased use of PET isotopes for cancer diagnosis and follow-up. The other is the increased interest in exploring alternative technologies (such as PET cyclotrons) for the production of technetium-99m.

**Inspection programs**

There was a decrease in the number of inspections performed in the distribution of nuclear substances subsector in 2013. Since they are inspected on a frequency ranging from two to three years and most were inspected in 2012, only a few were due for inspections in 2013. Of the 41 distribution licences, 9 are licences related to the distribution of smoke detectors; moving forward, the CNSC will only be inspecting licensee facilities that import smoke detectors.

## 8.2 Safety performance trends

### 8.2.1 Doses to workers

Doses received by NEWs in this sector remained low, with 85.8% receiving doses below 1 mSv.

NEWs in the servicing subsector continued to receive low doses, with 91.9% receiving below 1 mSv; no worker received over 5 mSv in 2013.

NEWs in the calibration subsector continued to receive low doses, with 84.6% receiving below 1 mSv and only 3 workers receiving over 5 mSv (highest dose: 7.65 mSv) in 2013.

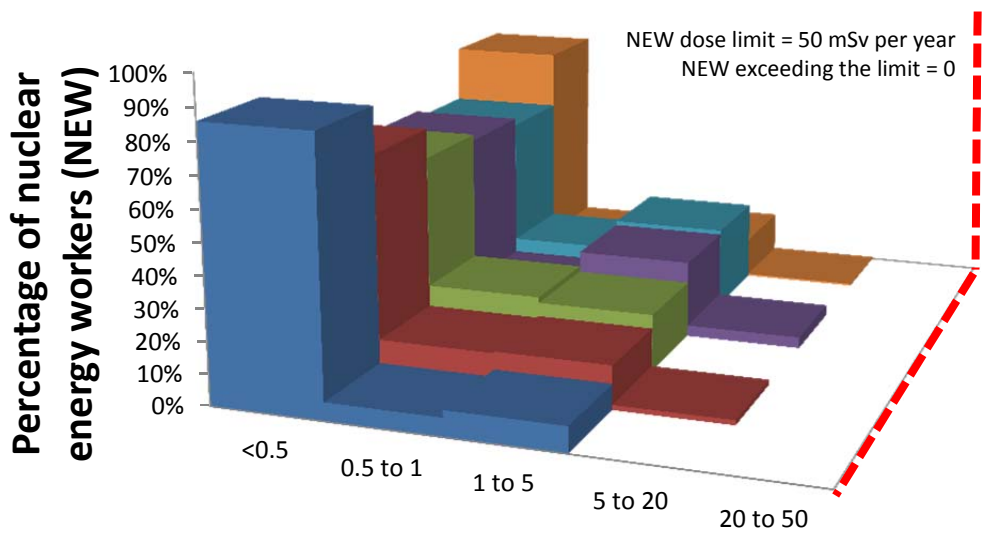
NEWs in the distribution of nuclear substances subsector continued to receive low doses: 81.8% of workers received below 1 mSv, and no worker received over 5 mSv in 2013.

NEWs in the processing of nuclear substances subsector continued to receive higher doses when compared with the other subsectors in the commercial sector, with 73.8% receiving below 1 mSv; no worker received over 5 mSv in 2013.

Doses received by NEWs in the isotope production accelerator subsector remained generally constant when compared with previous years, with 71.6% receiving below 1 mSv and only 6 workers receiving over 5 mSv (highest dose: 17.47 mSv) in 2013.

Figure 30 shows the differences in worker doses between the various commercial subsectors. NEWs in the processing of nuclear substances and isotope production accelerator subsectors continued to receive relatively higher doses than those in other commercial subsectors, due to their manual handling of nuclear substances and activated cyclotron components.

**Figure 30:** Commercial sector performance comparison with select subsectors – Annual effective doses to nuclear energy workers in 2013



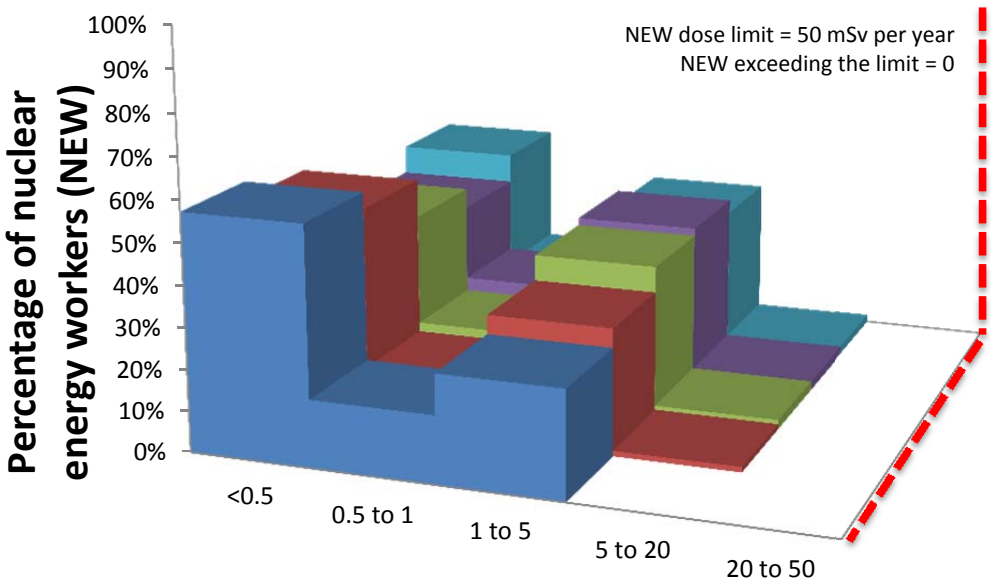

| | <0.5 | 0.5 to 1 | 1 to 5 | 5 to 20 | 20 to 50 |
|---|---|---|---|---|---|
| Servicing (577) | 86.0% | 5.9% | 8.2% | 0.0% | 0.0% |
| Calibration (188) | 71.3% | 13.3% | 13.8% | 1.6% | 0.0% |
| Distribution (110) | 61.8% | 20.0% | 18.2% | 0.0% | 0.0% |
| Isotope production (169) | 59.8% | 11.8% | 24.9% | 3.6% | 0.0% |
| Processing of nuclear substances (256) | 57.4% | 16.4% | 26.2% | 0.0% | 0.0% |
| Commercial sector (1,511)* | 76.0% | 9.9% | 13.6% | 0.6% | 0.0% |

**Dose ranges (mSv)**

* The total number of NEWs shown in this row is the aggregate for the entire commercial sector, including subsectors not highlighted in this report.

Doses received by NEWs in the processing of nuclear substances subsector from 2009 to 2013 are shown in Figure 31.

**Figure 31:** Processing of nuclear substance subsector performance – Annual effective doses to nuclear energy workers from 2009 to 2013

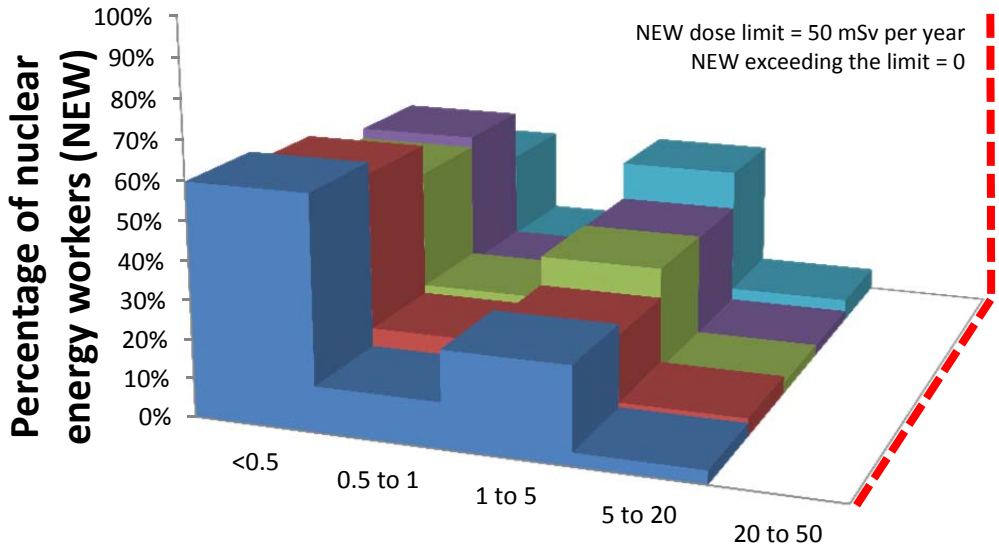



| | <0.5 | 0.5 to 1 | 1 to 5 | 5 to 20 | 20 to 50 |
|---|---|---|---|---|---|
| 2013: 256 | 57.4% | 16.4% | 26.2% | 0.0% | 0.0% |
| 2012: 240 | 53.3% | 14.6% | 30.8% | 1.3% | 0.0% |
| 2011: 310 | 43.9% | 16.8% | 37.1% | 2.3% | 0.0% |
| 2010: 244 | 38.9% | 20.1% | 38.9% | 2.1% | 0.0% |
| 2009: 267 | 46.1% | 16.5% | 35.6% | 1.9% | 0.0% |

**Dose ranges (mSv)**

Doses received by NEWs in the isotope production accelerators subsector from 2009 to 2013 are shown in Figure 32.

**Figure 32:** Isotope production accelerators subsector performance – Annual effective doses to nuclear energy workers from 2009 to 2013

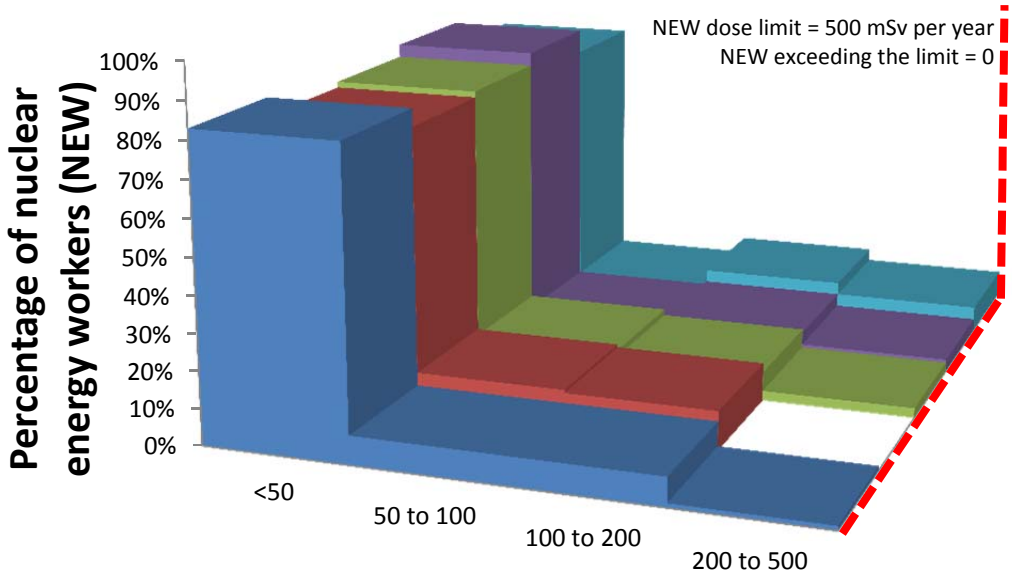



| | <0.5 | 0.5 to 1 | 1 to 5 | 5 to 20 | 20 to 50 |
|---|---|---|---|---|---|
| 2013: 169 | 59.8% | 11.8% | 24.9% | 3.6% | 0.0% |
| 2012: 127 | 56.7% | 16.5% | 22.0% | 4.7% | 0.0% |
| 2011: 145 | 49.0% | 18.6% | 29.7% | 2.8% | 0.0% |
| 2010: 116 | 51.7% | 16.4% | 29.3% | 2.6% | 0.0% |
| 2009: 106 | 38.7% | 16.0% | 39.6% | 5.7% | 0.0% |

**Dose ranges (mSv)**

Due to the need to manually handle nuclear substances (associated with dispensing and quality assurance testing during radioisotope production), doses to the hands of NEWs in certain subsectors are also monitored, and are subject to a regulatory dose limit of 500 mSv per year. The extremity doses received by NEWs in the isotope production accelerators subsector from 2009 to 2013 are shown in Figure 33. The extremity doses received improved slightly, with 90.9% of NEWs receiving below 100 mSv, compared with 89.4% in 2012. Overall, extremity doses received by NEWs in this subsector continued to be low, with only 2 workers receiving over 200 mSv (highest dose: 282.8 mSv) in 2013.

**Figure 33:** Isotope production accelerators subsector performance – Annual extremity doses to nuclear energy workers from 2009 to 2013




| | <50 | 50 to 100 | 100 to 200 | 200 to 500 |
|---|---|---|---|---|
| 2013: 164 | 83.0% | 7.9% | 7.9% | 1.2% |
| 2012: 123 | 78.0% | 11.4% | 10.6% | 0.0% |
| 2011: 114 | 79.6% | 9.7% | 8.0% | 2.7% |
| 2010: 113 | 83.2% | 6.2% | 7.1% | 3.5% |
| 2009: 85 | 76.5% | 5.9% | 10.6% | 7.1% |

**Dose ranges (mSv)**

### 8.2.2 Operating performance

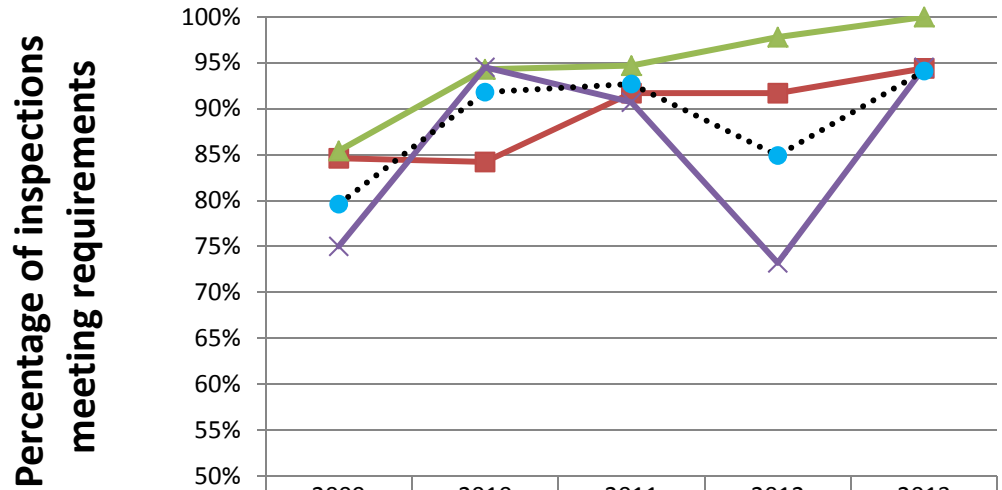
The overall compliance in 2013 for operating performance in the commercial sector was strong at 94.1%, as shown in Figure 34. Despite significant fluctuations in operating performance in the servicing subsector over the past two years, this safety and control area has steadily improved since 2009, when only 79.6% of inspected licensees were found to be compliant.

The most noticeable change in 2013 was within the servicing subsector. The 2012 report had registered a noticeable compliance drop in this subsector, which was associated with first-time field inspections. Licensees now have a clearer understanding of regulatory requirements, which has led to a significant improvement in compliance ratings – from 73.2% in 2012 to 94.5% in 2013.

Since there were only a few inspections for the calibration subsector, its trend line is not provided in Figure 34.

Observed non-compliances in the commercial sector were related to failures to follow procedures specified in their CNSC licences, failures to post licences, failures to perform sealed source leak tests, failures to comply with worker obligations, and failures to retain records.

**Figure 34:** Commercial sector performance comparison with select subsectors – Inspection ratings of operating performance from 2009 to 2013




| | 2009 | 2010 | 2011 | 2012 | 2013 |
|---|---|---|---|---|---|
| Processing of nuclear substances (inspections) | 84.6% (13) | 84.2% (19) | 91.7% (12) | 91.7% (12) | 94.4% (18) |
| Distribution of nuclear substances (inspections) | 85.4% (41) | 94.3% (35) | 94.7% (19) | 97.8% (46) | 100.0% (19) |
| Servicing (inspections) | 75.0% (60) | 94.5% (73) | 90.7% (43) | 73.2% (56) | 94.5% (55) |
| Calibration (inspections) | 81.0% (21) | 100.0% (11) | 100.0% (12) | 100.0% (9) | 88.9% (9) |
| Commercial (inspections)* | 79.6% (162) | 91.8% (158) | 92.7% (123) | 84.9% (139) | 94.1% (119) |

**Ratings**

* The total number of inspections shown in this row is the aggregate for the entire commercial sector, including subsectors not highlighted in this report.

### 8.2.3 Radiation protection

The overall compliance for radiation protection in the commercial sector was 93.2% in 2013, as shown in Figure 35. This safety and control area continued a trend of steady improvement since 2009, when only 82.3% of licensees were found to be compliant.

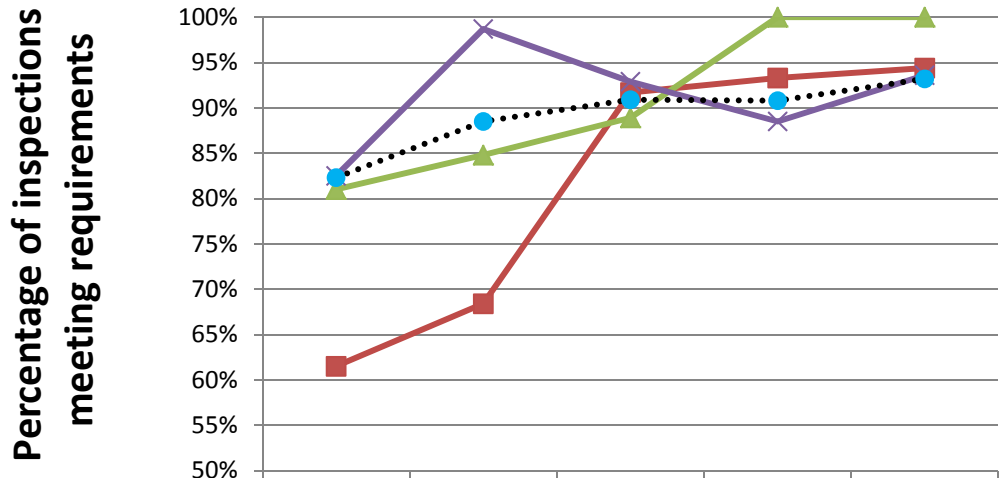
The most noticeable change was within the servicing subsector, where compliance ratings improved from 88.5% in 2012 to 93.6% in 2013. This change was partly due to more effective communication of regulatory requirements between CNSC and licensees,

through the increased use of onsite CNSC inspections while servicing work was being conducted.

Since there were only a few inspections for the calibration subsector, its trend line is not provided in Figure 35.

Observed non-compliances in the commercial sector were limited. They were related to survey meters not being available or properly calibrated, improper storage of nuclear substances, doses not being kept as low as reasonably achievable, and failures to post signs at boundaries and points of access.

**Figure 35:** Commercial sector performance comparison with select subsectors – Inspection ratings of radiation protection from 2009 to 2013




| | 2009 | 2010 | 2011 | 2012 | 2013 |
|---|---|---|---|---|---|
| Processing of nuclear substances (inspections) | 61.5% (13) | 68.4% (19) | 91.7% (12) | 93.3% (15) | 94.4% (18) |
| Distribution of nuclear substances (inspections) | 81.0% (42) | 84.8% (33) | 88.9% (18) | 100.0% (45) | 100.0% (19) |
| Servicing (inspections) | 82.5% (57) | 98.7% (77) | 92.9% (42) | 88.5% (61) | 93.6% (47) |
| Calibration (inspections) | 90.5% (21) | 100.0% (11) | 100.0% (12) | 100.0% (8) | 88.9% (9) |
| Commercial (inspections)* | 82.3% (158) | 88.5% (160) | 90.9% (121) | 90.8% (142) | 93.2% (118) |

**Ratings**

* The total number of inspections shown in this row is the aggregate for the entire commercial sector, including subsectors not highlighted in this report.

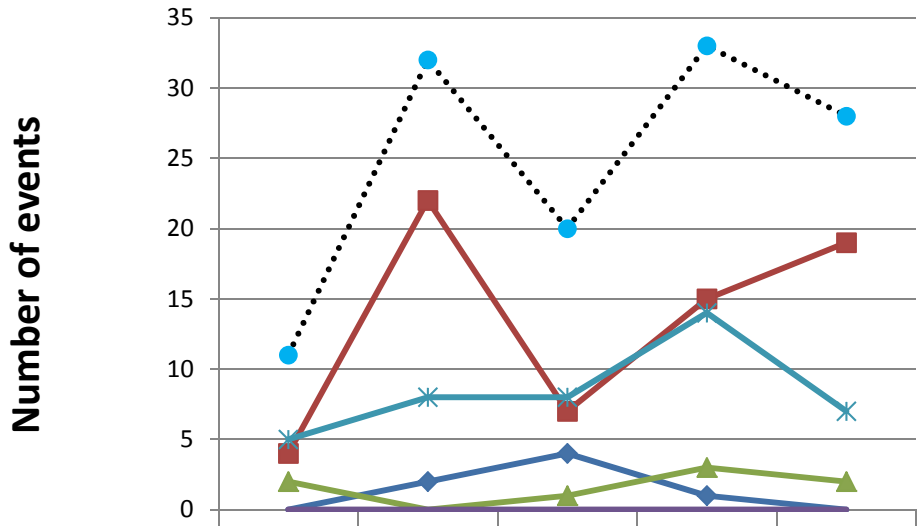
### 8.2.4 Enforcement actions

No enforcement actions were issued to licensees in the commercial sector in 2013.

### 8.2.5 Reported events

There were 28 events reported in the commercial sector in 2013, all classified as low risk. Of these 28 events, 19 were related to spills or contamination, 7 were related to packaging and transport, and 2 involved missing or found nuclear substances. The number of reported events over the last five years is shown in Figure 36.

**Figure 36:** Commercial sector – Reported events from 2009 to 2013




| Types | 2009 | 2010 | 2011 | 2012 | 2013 |
|---|---|---|---|---|---|
| Malfunctioning or damaged devices | 0 | 2 | 4 | 1 | 0 |
| Spills and contamination | 4 | 22 | 7 | 15 | 19 |
| Missing or found nuclear substances | 2 | 0 | 1 | 3 | 2 |
| Breach of security | 0 | 0 | 0 | 0 | 0 |
| Packaging and transport | 5 | 8 | 8 | 14 | 7 |
| Total | 11 | 32 | 20 | 33 | 28 |

**Spills or contamination**

There were 19 events involving spills or contamination; 3 events were related to releases of carbon-11 at facilities producing radioisotopes, while the remaining 16 events were related to contamination during the handling of unsealed sources at processing facilities.

The three releases involving carbon-11 (C-11) all occurred as a result of equipment failures during the production or processing of C-11 in gaseous form. In each case, the C-11 vented via the nuclear ventilation system. Licensees producing C-11 are required to have mitigation measures in place, which will minimize the potential dose to any person in the event of such unintentional releases. The maximum potential exposure to any person resulting from these releases was 0.00015 mSv, or 0.015% of the public dose limit. In each case, the licensee implemented measures to prevent reoccurrence of the

malfunction which caused the release, and those measures were acceptable to CNSC staff.

Among the remaining 16 events, 11 involved incidents of contamination during the handling of iodine-131 or technetium-99m. Most were due to broken or spilled vials and contamination of hands and wrists during processing, while others occurred during uncapping or recapping of syringes. The other five events involved the Positron Emission Tomography isotope fluorine-18. One involved contamination due to the handling of a cracked vial. Three were due to valves malfunctioning during isotope production – and, every time, the nuclear substance was contained within the hot cell or the containment drawer. The last event involved contamination detected within a non-occupied ceiling crawlspace above the processing hot cells. It was attributed to an inadequate seal around the electrical connections to the hot cell. In all 16 cases, the licensee implemented measures to prevent reoccurrence, and those measures were reviewed and found to be acceptable by CNSC staff.

Since these nuclear substances have half-lives ranging from a few hours to a few days, spills and contamination are easily addressed by licensees.

**Missing or found nuclear substances**

In 2013, there were two events related to missing or found nuclear substances. In one instance, a source holder (containing a Category 4 sealed source) was discovered at a scrap metal recycling facility, when the radiation portal monitor was triggered. From the investigation performed by the licensee, the radiation device had not been disposed of in accordance with the regulations. As a result, the licensee has revised its servicing procedures, subject to CNSC staff review.

The second event involved a package containing a portable gauge (Category 4 sealed source) lost during transport and subsequently found. The package was delayed at the shipping warehouse, due to heavy volume and bad weather conditions. The package was located within the shipping warehouse, and the consignee took possession of the package approximately one week later than expected.

**Packaging and transport**

There were seven reported events related to packaging and transport. Four of these involved packages not received on the expected date. In all four cases, the packages were located by the carrier and delivered the following day.

In one event, a broken vial of iodine-131 was discovered in a package, upon receipt. There was no spread of contamination outside the package. The licensee conducted an investigation into how the vial was broken, and determined it was caused by improper handling of the package during transport. As a result, the licensee conducted tests on its Type A packages, and has implemented improvements to the satisfaction of the CNSC.

In another event, a package was received with internal contamination. As a result, the licensee has revised its shipping procedures, to the satisfaction of CNSC staff.

The other event was a minor accident involving a vehicle carrying medical isotopes in Type A packages. There were no injuries and no reported damages to the packages, following the accident.

**Summary statement**

None of these events had any adverse radiological effects on the environment, or resulted in workers receiving doses in excess of the regulatory limits. In all cases, licensees implemented adequate response measures to mitigate the impacts of the events and to limit radiation exposure to workers, as well as the radiological impact on the environment.

## 8.3 Stakeholder engagement

At the Canadian Radiation Protection Association 2013 annual general meeting, CNSC staff conducted a dedicated workshop focusing on the regulation of cyclotron facilities. Licensees provided very positive feedback for this outreach activity, and commented that they were able to demonstrate improved compliance through a better understanding of CNSC expectations.

# 9 Conclusion

Based on the information provided in this report, CNSC staff have concluded that the use of nuclear substances in Canada is safe, and that licensees continued to maintain appropriate safety programs and take appropriate measures to protect the health and safety of Canadians, as well as the environment.

Occupational doses to workers remained low in 2013, and followed a consistent trend when compared with previous years. Overall, more than 99.9% of all workers – including nuclear energy workers and other workers – received doses below their respective regulatory limits. There were no NEWs that exceeded the five-year dose limit of 100 mSv.

There were six cases where, based on dosimetry results, a worker may have exceeded an annual regulatory dose limit. In two of these cases, further investigation revealed that the worker had indeed exceeded a regulatory dose limit. In one of the remaining cases, the investigation revealed that the exposure result on the dosimeter was non-personal, and a dose change request was sent by the licensee and approved by CNSC staff. For the remaining three cases, the investigation conducted by the licensee did not provide sufficient evidence for CNSC staff to conclude with absolute certainty that the exposure was non-personal. In all cases, the licensees responded in accordance with the *Radiation Protection Regulations.* None of the six cases resulted in immediate adverse health consequences to the workers.

CNSC staff conducted 1,627 inspections to verify compliance with CNSC regulatory requirements in 2013. Of the total number of inspections conducted, 1,541 inspections included a verification of the safety and control area (SCA) of operating performance, while 1,534 inspections included a verification of the radiation protection SCA. In general, licensees continued to show satisfactory compliance in operating performance and radiation protection areas, with satisfactory ratings given to 89.2% and 86.9% of inspected licensees, respectively. Satisfactory corrective actions were taken by licensees to address non-compliance situations. All sectors demonstrated steady regulatory compliance improvement in 2013, with the exception of a decrease in the operating performance rating for the industrial sector.

Throughout 2013, the CNSC issued 24 enforcement actions – including 22 orders and 2 administrative monetary penalties – in the four industry sectors covered by this report. All licensees to whom orders were issued have implemented corrective measures to the satisfaction of CNSC staff.

The number of reported events continued to increase in 2013, with licensees reporting 150 events (compared with 139 in 2012). This increase was mainly due to a greater number of reported events related to spills and contamination incidents, as well as breaches of barriers in the industrial sector. In all cases, CNSC staff assessed the events and categorized them as low risk, based on consideration of the radiological impact to persons and the environment.

# Appendix A Overview of High-Energy Research Particle Accelerator Facilities

## TRIUMF Accelerators Inc.

**Figure 37:** Inside the 520 MeV cyclotron (source: TRIUMF)

TRIUMF Accelerators Inc. (TRIUMF) is Canada's national laboratory for nuclear and particle physics research and related sciences. TRIUMF is also a major producer of radioisotopes used for medical diagnostic procedures. It is owned and operated as a joint venture by a consortium of 18 Canadian universities. TRIUMF operates one 520 mega-electron-volt (MeV) cyclotron accelerator facility – shown in Figure 37 – along with four smaller cyclotrons facilities and two linear accelerator facilities. The main cyclotron has been in operation for almost 40 years.

### Licensing

The CNSC operating licence issued to TRIUMF includes a licence condition handbook, which defines key documents and compliance criteria for the facility. The authority to make changes to the licence condition handbook has been delegated to a designated officer, with the provision that such changes must not reduce the facility's overall level of safety. Multiple changes were combined into two sets of revisions to the licence condition handbook in 2013. The majority of these changes were administrative in nature, and included updates to TRIUMF documents related to:

- the radioactive waste management program
- the ISACII linear accelerator facility vault exclusion area
- the site preliminary decommissioning plan
- the training program

New TRIUMF procedures for the packaging and transport of nuclear substances were also submitted and added to the licence condition handbook.

Two of the changes were related to facility design alterations. These were:

- Modifications to the shared entrance maze between the 520 MeV cyclotron vault and the electron hall, including changes to the functional requirements for the associated door interlocks and Area Safety Unit (ASU). These changes were necessary to accommodate the eventual installation of the new ARIEL superconducting electron linear accelerator within the electron hall.
- Reconfiguration of the "shield plug" between beam-line 1A and the 520 MeV cyclotron vault, to facilitate the future installation of an ultra-cold neutron experimental facility in what was formerly the M13 experimental area.

## Compliance activities

One inspection was conducted at TRIUMF in 2013. The inspection focused on:

- the training program (which ensures that TRIUMF employs a systematic approach to evaluating and delivering training, to ensure that staff have the necessary knowledge to safely carry out their duties)
- the packaging and transport of nuclear substances

Other areas addressed during the inspection included site security and conventional health and safety issues, as well as follow-up on reported incidents. TRIUMF was required to implement corrective actions to address eight specific non-compliances noted during the inspection. None of these non-compliances presented a significant hazard to persons, the environment or the maintenance of security. In addition, nine recommendations were made for potential improvements to procedures.

The inspection was conducted near the end of 2013. At the time of writing, only four of the required corrective actions had been fully addressed by the licensee. The remaining four corrective actions are all longer term in nature, and relate either to improvements to the training program or the preparation and submission of updated analysis reports. CNSC staff are monitoring progress on the remaining actions. Acceptable progress has been demonstrated, and it is expected that all actions will be completed by the end of 2014. TRIUMF has also implemented all nine recommendations made during the inspection.

In addition to onsite inspections, compliance monitoring activities included a review of mandatory reports submitted by the licensee. These reports include follow-up on corrective actions identified during previous inspections, and an annual compliance report (which must be submitted every year, summarizing facility operations). Some of the parameters included in TRIUMF's annual compliance report are:

- major safety and regulatory compliance-related activities undertaken by various key working groups and committees
- significant changes and improvements to the facility and related safety systems
- results of ongoing monitoring of radiation dose rates throughout the site
- testing and calibration of radiation monitors and access-control systems
- radiation doses incurred by all staff and contractors
- accelerator operating statistics
- site emissions and environmental monitoring results
- plans for any significant future changes to the site

Overall, the information provided indicates that operations continued to comply with regulatory requirements. Combined airborne and liquid effluent releases from the site remained stable – at the normal, extremely low levels expected for TRIUMF. Occupational doses to workers are included in the academic and research sector results, in Figure 26 of this report.

## Enforcement actions

There were no enforcement actions issued to TRIUMF in 2013.

## Reported events

In 2013, TRIUMF reported two events related to the malfunction of safety-related systems.

In August 2013, the containment system for a xenon-123 gas target (used for medical isotope production on a cyclotron) failed to function properly following a target window rupture. As a result, approximately 10% of the target activity was released via the nuclear ventilation system. The maximum potential dose to the general public associated with this release was 0.000047 mSv, or 0.005% of the general public dose limit. The licensee has implemented corrective measures, which are acceptable to CNSC staff, to prevent such releases in the event of any future target window ruptures.

In October 2013, TRIUMF reported that the calibration testing of the stack monitor had demonstrated that the stack monitor for one of the nuclear exhausts had not been functioning properly for an extended period of time. As a result, the airborne emissions for the period from 2009 to 2012 were under-reported. The routine annual test procedure was not sufficient to identify this problem, which was detected through a much more complex test, performed only recently. Revised total site release estimates for TRIUMF indicate that, despite this problem, releases over that time period remained extremely low, averaging 0.91% of the derived release limit (DRL), which is equivalent to 0.0091 mSv dose to an exposed member of the general public. The maximum total release in any one year was 1.18% DRL, which is equivalent to 0.0118 mSv. TRIUMF has implemented modifications to their calibration procedures, which will ensure that any similar degradation in detector response will be readily detected in the future. CNSC staff will monitor implementation of these revised procedures, as part of the ongoing compliance program for the facility.

Neither of these events had any adverse radiological effects on the environment, or resulted in workers or the general public receiving doses above regulatory limits.

## Compliance ratings

Performance ratings for TRIUMF are categorized into fourteen safety and control areas (SCAs). These ratings are derived from the compliance activities, reported events and enforcement actions described in the preceding three sections. The 2013 performance ratings for TRIUMF are summarized in Table 3. The “below expectations” rating for the fitness for service SCA is a direct consequence of the two reported events described above.

**Table 3:** Performance ratings for TRIUMF in 2013

| Safety and control area | Rating |
|---|---|
| Management system | Satisfactory |
| Human performance management | Satisfactory |
| Operating performance | Satisfactory |
| Safety analysis | Satisfactory |
| Physical design | Satisfactory |
| Fitness for service | Below expectations |
| Radiation protection | Satisfactory |
| Conventional health and safety | Satisfactory |
| Environmental protection | Satisfactory |
| Emergency management and fire protection | Satisfactory |
| Waste management | Satisfactory |
| Security | Satisfactory |
| Safeguards and non-proliferation | Satisfactory |
| Packaging and transport | Satisfactory |

## Major projects and developments

The Advanced Rare IsotopE Laboratory (ARIEL) project at TRIUMF is now well underway. This project involves developing a high-power superconducting electron accelerator, to expand Canada's capabilities to produce and study isotopes for physics and medicine. ARIEL is licensed separately from the remainder of TRIUMF. The original construction licence was issued in 2013. The main ARIEL laboratory building and beam-line tunnel have been constructed, and the former Proton Hall has been renovated to house the new electron accelerator, which is being custom designed and built by TRIUMF. In December 2013, a licence was issued to test the first major component of the accelerator. More information on this project can be found on the TRIUMF website.[18]

TRIUMF is also leading a collaborative effort with several other Canadian facilities to deliver an alternative technology for producing technetium-99m, the world's most commonly used medical isotope. This goal of this project is to enable the use of existing medical cyclotrons to produce technetium-99m without the need for a nuclear reactor. More information on this project can be found on the TRIUMF website.[19]

[18] Available online at triumf.ca/ariel

[19] Available online at triumf.ca/home/for-media/medical-isotopes

## Canadian Light Source Inc.

Canadian Light Source Inc. (CLS) operates a synchrotron facility (shown in Figure 38), on the University of Saskatchewan campus. The facility consists of three major accelerator systems: a 300 mega-electron-volt (MeV) linear accelerator, a booster ring that accelerates electrons up to 2.9 giga-electron-volt (GeV), and a storage ring that keeps electrons circulating at 2.9 giga-electron-volts (GeV) for several hours. The facility produces synchrotron radiation that is used as a light source for experiments in diverse fields such as biology, materials research, atomic and molecular science, earth sciences, pharmaceuticals, biomedical research and electronics. Synchrotron radiation is electromagnetic radiation produced by magnetic bending of high-energy electrons in a storage ring by different devices (magnets, wigglers, and undulators). The light ranges from infrared through the visible spectrum to ultraviolet and X-rays. The experiments take place in optical beam lines tangential to the storage ring. The facility has been in operation since 2006.

**Figure 38:** CLS research facility (source: CNSC)

### Licensing

The CNSC operating licence issued to CLS includes a licence condition handbook, which defines key documents and compliance criteria for the facility. The authority to make changes to the licence condition handbook has been delegated to a designated officer, with the provision that such changes must not reduce the facility's overall safety level. No changes were made in 2013 to the licence condition handbook.

### Compliance activities

One inspection was conducted at CLS in 2013. The inspection focused on the following areas:

- the management system (which covers the framework that establishes the processes and programs required to ensure that CLS achieves its safety objectives)
- the training program (which ensures that CLS employs a systematic approach to evaluating and delivering training, to ensure that staff have the necessary knowledge to safely carry out their duties)

CLS was required to implement corrective actions to address thirteen specific non-compliances noted during the inspection. None of these non-compliances presented a significant hazard to persons, the environment or the maintenance of security.

At the time of writing, eleven of the thirteen required corrective actions had been fully addressed by CLS. The remaining two actions are all longer-term in nature. One relates to implementing a systematic approach to training for all CLS staff, and one relates to management system requirements for tracking the calibration of measurement equipment. CNSC staff are monitoring progress on the remaining actions via mandatory periodic reporting by the licensee. Acceptable progress has been demonstrated to date.

In addition to onsite inspections, compliance monitoring activities included the review of mandatory reports submitted by the licensee. These reports include follow-up on corrective actions identified during previous inspections, as well as an annual compliance report (which must be submitted every year, summarizing facility operations). Some of the parameters included in CLS's annual compliance report are:

- significant changes and improvements to the facility, beam lines and related safety systems
- radiation measurements performed throughout the facility
- testing of safety systems, including the access control systems
- radiation doses received by all staff, users and contractors
- unusual events
- accelerator operating statistics
- sealed source inventory
- plans for any significant future changes to the site

Overall, the information provided indicates that operations continue to comply with regulatory requirements. Occupational doses to workers are included in the academic and research sector results in Figure 26 of this report.

## Enforcement actions

There were no enforcement actions issued to CLS in 2013.

## Reported events

In 2013, CLS reported one event related to the malfunction of a safety-related system.

The accelerator is interlocked with twenty-four radiation monitoring stations. Each station operates independently, and has alarms which sound if dose rates above a preset threshold are detected. The radiation monitor signals are also sent to the control room, and are interlocked such that any alarm will stop the injection of the beam into the synchrotron.

The malfunction occurred in a device which controls the signals sent to and received from four of these detectors. This communication error was detected by the operator and corrected immediately. There was no adverse impact on the health and safety of persons or the environment. CLS has implemented measures, which are acceptable to CNSC staff, to prevent recurrence of similar malfunctions in the future.

## Compliance ratings

Performance ratings for CLS are categorized into fourteen safety and control areas (SCAs). The ratings are derived from the compliance activities, reported events and enforcement actions described in the preceding three sections. The 2013 performance ratings for CLS are summarized in Table 4. The "below expectations" rating for both the management system and the human performance management SCAs are based on the results of this inspection described above.

**Table 4:** Performance ratings for CLS in 2013

| Safety and control area | Rating |
|---|---|
| Management system | Below expectations |
| Human performance management | Below expectations |
| Operating performance | Satisfactory |
| Safety analysis | Satisfactory |
| Physical design | Satisfactory |
| Fitness for service | Satisfactory |
| Radiation protection | Satisfactory |
| Conventional health and safety | Satisfactory |
| Environmental protection | Satisfactory |
| Emergency management and fire protection | Satisfactory |
| Waste management | Satisfactory |
| Security | Satisfactory |
| Safeguards and non-proliferation | Not applicable[20] |
| Packaging and transport | Satisfactory |

## Major projects and developments

The Medical Isotope Project (MIP) at CLS consists of a 40 kW, 35 MeV linear electron accelerator facility within the CLS building, but it is entirely separate from the synchrotron. The facility is intended to investigate an alternative technology for producing molybdenum-99 (which is used to generate technetium-99m, the world's most commonly used medical isotope). More information on this project can be found on the CLS website.[21]

The MIP is licensed separately from the remainder of CLS. The original construction licence was issued in December 2011 and was revoked in February 2013, following the issuance of an operating licence for commissioning the facility. In May 2013, an inspection was performed at MIP pursuant to this operating licence, and no deficiencies were noted. Commissioning began near the end of 2013; there was no production of molybdenum-99 in 2013.

[20] As Canadian Light Source Inc. does not conduct any licensed activities subject to safeguards obligations, there is no rating associated with this particular safety area.

[21] Available online at lightsource.ca/operations/medicalisotopes/

# Appendix B Abbreviations and Glossary

These abbreviations are also defined when first used in the text.

ALARA
: as low as reasonably achievable

CLS
: Canadian Light Source Inc.

CNSC
: Canadian Nuclear Safety Commission

GBq
: gigabecquerel

MBq
: megabecquerel

MeV
: mega-electron-volt

MIP
: Medical Isotope Project

mSv
: millisievert

NEW
: nuclear energy worker

NSCA
: *Nuclear Safety and Control Act*

PET
: Positron Emission Tomography

TRIUMF
: TRIUMF Accelerators Inc.

**cyclotron**

A particle accelerator that speeds up particles in a circular motion until they hit a target at the perimeter of the cyclotron. Some cyclotrons are used to produce medical isotopes. (*cyclotron*)

**effective dose**

The sum of the products, in sievert, obtained by multiplying the equivalent dose of radiation received by and committed to each organ or tissue by a specific weighting factor established for each of these organs or tissues. (*dose efficace*)

**enforcement**

The set of activities associated with re-establishing compliance with regulatory requirements. *(application)*

**exposure device**

A radiation device designed for carrying out gamma radiography, including any accessory to the device such as a sealed source assembly, a drive mechanism, a sealed source assembly guide tube and an exposure head. *(appareil d'exposition)*

**five-year dosimetry period**

A period of five calendar years beginning on January 1 of the year following the year in which the *Radiation Protection Regulation* come into force, and every period of five calendar years after that period. *(période de dosimétrie de cinq ans)*

**fixed nuclear gauge**

A radiation device attached to a structure and that enables the nuclear substance contained in it to be used for its radiation properties to measure process-related parameters (e.g., liquid flow, liquid level). *(jauge nucléaire fixe)*

**medical linear accelerator**

An accelerator that produces high-energy photons (X-rays) for therapeutic purposes by delivering controlled doses of radiation in a collimated beam. *(accélérateur linéaire médical)*

**natural background radiation**

Radiation that is emitted from naturally occurring radioactive materials in the earth and from cosmic rays. *(rayonnement naturel)*

**nuclear energy worker**

A person who is required, in the course of his or her business or occupation in connection with a nuclear substance or nuclear facility, to perform duties in circumstances where there is a reasonable probability that the person may receive a dose of radiation that is greater than the public dose limit of 1 mSv per year. *(travailleur du secteur nucléaire)*

**nuclear medicine technologist**

A medical radiation technologist certified by the Canadian Association of Medical Radiation Technologists. The nuclear medicine technologist works in the field of nuclear medicine and performs various duties such as preparing and administering radiopharmaceuticals, taking images of different organs and bodily structures, using computers to process data and enhance images, analyzing biological specimens, and working closely with all members of the healthcare team. *(technologue en médecine nucléaire)*

**one-year dosimetry period**

A period of one calendar year beginning on January 1 of the year following the year in which the *Radiation Protection Regulations* come into force, and every period of one calendar year after that period. *(période de dosimétrie d'un an)*

**other worker**

A worker who has not been designated as a nuclear energy worker and is subject to the public dose limit of 1 mSv per year. *(autre travailleur)*

**portable nuclear gauge**

A portable radiation device that enables the nuclear substance contained in it to be used for its radiation properties to measure material property (e.g., material thickness, density, moisture content). *(jauge nucléaire portative)*

**prescribed equipment**

Equipment prescribed by section 20 of the *General Nuclear Safety and Control Regulations*. *(équipement réglementé)*

**radiation device**

A device that contains more than the exemption quantity of a nuclear substance and that enables the nuclear substance to be used for its radiation properties for various purposes such as industrial radiography, oil exploration, road construction and industrial processes. *(appareil à rayonnement)*

**radiopharmaceutical**

A drug containing a radioactive substance that is used in medical imaging and cancer treatment. *(produit radiopharmaceutique)*

**recommendation**

A written suggestion to effect an improvement based on good industry practice. A recommendation is not an indication of non-compliance with regulatory requirements, and the recipient is not obliged to accept the recommendation. *(recommandation)*

**sealed source**

A radioactive nuclear substance in a sealed capsule or in a cover to which the substance is bonded, where the capsule or cover is strong enough to prevent contact with or the dispersion of the substance under the conditions for which the capsule or cover is designed. *(source scellée)*

**unsealed source**

A radioactive nuclear substance that is not contained in a sealed capsule or in a cover to which the substance is bonded. *(source non scellée)*