Medycyna Pracy 2013;64(5):625–630

http://medpr.imp.lodz.pl/en

http://dx.doi.org/10.13075/mp.5893.2013.0061

ORIGINAL PAPERS

Grażyna Krajewska[1]
Krzysztof A. Pachocki[2]

ASSESSMENT OF EXPOSURE OF WORKERS TO IONIZING RADIATION FROM RADIOIODINE AND TECHNETIUM IN NUCLEAR MEDICINE DEPARTMENTAL FACILITIES

OCENA NARAŻENIA PRACOWNIKÓW NA PROMIENIOWANIE JONIZUJĄCE RADIOJODU I TECHNETU W ZAKŁADACH MEDYCYNY NUKLEARNEJ

[1] Central Laboratory for Radiological Protection / Centralne Laboratorium Ochrony Radiologicznej, Warszawa, Poland
Department of Dose Control and Calibration / Zakład Kontroli Dawek i Wzorcowania

[2] National Institute of Public Health – National Institute of Hygiene / Narodowy Instytut Zdrowia Publicznego – Państwowy Zakład Higieny, Warszawa, Poland
Department of Radiation Hygiene and Radiobiology / Zakład Higieny Radiacyjnej i Radiobiologii

Abstract

Background: Due to its use of ionising radiation, the field of nuclear medicine is a unique and significant part of medical diagnostics and patient treatment. The aim of this study was to assess the internal exposure of nuclear medicine employees to radioiodine ^{131}I and technetium ^{99m}Tc as well as to assess the external exposure doses. **Material and Methods:** The radioiodine ^{131}I and technetium ^{99m}Tc contents in the thyroid of staff members (about 100 persons) dealing with these radionuclides have been measured in four departments of nuclear medicine. The measurements were conducted with a portable detection unit for *in situ* measurements of radioiodine and technetium. High sensitivity environmental thermoluminescent dosimeters (TLD) were used to measure the external exposure dose. **Results:** The average values and ranges of radioiodine ^{131}I activity measured in the thyroids of all of the medical units' employees were: 83 Bq (range: 70–250 Bq), 280 Bq (range: 70–4000 Bq), 275 Bq (range: 70–1000 Bq) for technical staff, nuclear medicine staff and hospital services staff, respectively. The mean value of technetium ^{99m}Tc content in the thyroids of nuclear medicine staff was approximately 1500 Bq (range: 50–1800 Bq). External exposure dose rates were in the range of 0.5–10 μGy/h. **Conclusions:** The calculated average effective dose for particular person caused by the inhalation of radioiodine ^{131}I is below 5% of 20 mSv/year (occupational exposure limit). Med Pr 2013;64(5):625–630

Key words: radioiodine ^{131}I, technetium ^{99m}Tc, nuclear medicine, effective dose, occupational exposure

Streszczenie

Wprowadzenie: Ze względu na stosowanie promieniowania jonizującego medycyna nuklearna jest istotną i unikalną gałęzią metod diagnostycznych i leczniczych. Celem podjętych badań była ocena narażenia wewnętrznego pracowników zakładów medycyny nuklearnej na jod promieniotwórczy ^{131}I i technet ^{99m}Tc oraz ocena dawek pochodzących z ekspozycji zewnętrznej. **Materiał i metody:** Pomiary zawartości radiojodu ^{131}I i technetu ^{99m}Tc w tarczycy osób pracujących z tymi radionuklidami (ok. 100 osób) wykonano w 4 ośrodkach medycyny nuklearnej. Zastosowano przenośny zestaw detekcyjny mierzący radionuklidy *in situ*. Dawki pochodzące z ekspozycji zewnętrznej mierzono, wykorzystując środowiskowe dozymetry termoluminescencyjne (thermoluminescent dosimeters – TLD) o dużej czułości. **Wyniki:** Zawartość radiojodu ^{131}I w tarczycy wynosiła średnio: 83 Bq (zakres aktywności: 70–250 Bq) w grupie personelu technicznego, 280 Bq (zakres: 70–4000 Bq) w grupie personelu medycznego i 275 Bq (zakres: 70–1000 Bq) w grupie personelu pomocniczego. Średnia zawartość technetu ^{99m}Tc w tarczycy wynosiła ok. 1500 Bq (zakres: 50–1800 Bq). Otrzymana moc dawek pochodzących z ekspozycji zewnętrznej mieściła się w zakresie 0,5–10 μGy/godz. **Wnioski:** Oszacowana średnia dawka skuteczna pochodząca z inhalacji radiojodu ^{131}I stanowiła mniej niż 5% rocznego limitu dla narażenia zawodowego, które wynosi 20 mSv/rok. Med. Pr. 2013;64(5):625–630

Słowa kluczowe: radiojod ^{131}I, technet ^{99m}Tc, medycyna nuklearna, dawka skuteczna, ekspozycja zawodowa

Corresponding author / Autorka do korespondencji: Grażyna Krajewska, Central Laboratory for Radiological Protection, Department of Dose Control and Calibration, Konwaliowa 7, 03-194 Warszawa, Polska, e-mail: krajewska@clor.waw.pl
Received: 2013, July 16, accepted: 2013, October 30

This study was financially supported by the Ministry of Science and Higher Education / National Research and Development Centre as the second stage of the long-term programme "Improving Work Safety and Conditions; 2011–2013" and managed by the Central Institute for Labour Protection – National Research Institute in Warszawa.

INTRODUCTION

According to the WHO definition, nuclear medicine covers all of the diagnostic and treatment methods that use radioactive isotopic substances in a form open to the body, unlike brachytherapy, which uses sealed radioactive sources and is a part of radiotherapy.

According to the European Commission's (EC's) Radiological Protection Section, around 4–14% of patient radiation exposure resulting from all of the medical examinations is caused by nuclear medicine techniques (1). The actual number of the performed examinations represents a smaller proportion of 2–5%.

At present, the public healthcare system in Poland has 55 operating nuclear medicine departmental facilities and 8 that are private/non-public. These are staffed by 252 doctors, 151 of whom are qualified as nuclear medicine specialists; which corresponds to one specialist per 300 000 inhabitants. In addition, 170 highly qualified staff (biologists, chemists, physicists, electronic engineers and IT specialists) provide indispensable scientific/operational support and are vital for the development of nuclear medicine departments. They are mainly responsible for ensuring that the whole equipment functions effectively and for developing new diagnostic techniques, together with new radiopharmaceuticals. Furthermore, there are approximately 500 other staff at an intermediate-level also involved in nuclear medicine departments, such as technicians, nurses and support workers. The survey demonstrated an average of 22 persons employed per a nuclear medicine department (2).

The aim of his study was to assess the internal radioiodine ^{131}I and technetium ^{99m}Tc exposures of the employees of nuclear medicine, as well as to assess external exposure doses.

Iodine-131 – radioiodine is an important radioisotope of iodine. It has a radioactive decay half-life of about eight days. It is associated with nuclear energy, medical diagnostic and treatment procedures. Iodine-131 can be "seen" by nuclear medicine imaging techniques (i.e., gamma cameras) whenever it is given for therapeutic use, since about 10% of its energy and radiation dose is via gamma radiation.

Technetium ^{99m}Tc is a metastable nuclear isomer of technetium-99, that is annually used in tens of millions of medical diagnostic procedures, making it the most commonly used medical radioisotope. It has a radioactive decay half-life of about 6 hours. At present, molybdenum (^{99}Mo) is used commercially as the easily transportable source of medically used ^{99m}Tc.

MATERIAL AND METHODS

The monitoring assembly of the laboratory in the Central Laboratory for Radiological Protection (CLOR) consists of 2 independent measuring units:

1. A Stationary Unit for measuring radioiodine ^{131}I and technetium ^{99m}Tc with low limit of detection.
2. A Mobile Unit for *in situ* measurements of ^{131}I and ^{99m}Tc which has been mainly provided for fast screening of population in radiological emergency situations, or for monitoring occupationally exposed people outside laboratory.

The commercially available phantom for calibration of these units (the RSD – Radiology Support Devices, Incorporated, USA) comprises a neck and shoulder region (without arms), fitted with a snap-in thyroid shell and a cover-plate. Efficiency calibration is performed 1 time per 3 years with an ^{131}I known activity calibration source. Energy calibration is performed 1 time per 3 months with a known mixture of ^{133}Ba+^{137}Cs sources. The measurements of radioiodine and technetium content of occupationally exposed personnel were performed with a portable detection unit (prod. Canberra-Packard) (Photo 1) which consists of a scintillation NaI(Tl) detector (size: 76×76 mm, resolution: 9%) – battery-powered, portable tube base Multichannel Analyzer Canberra UniSPEC, paired with a notebook computer and Genie-2000 Basic Spectroscopy Software.

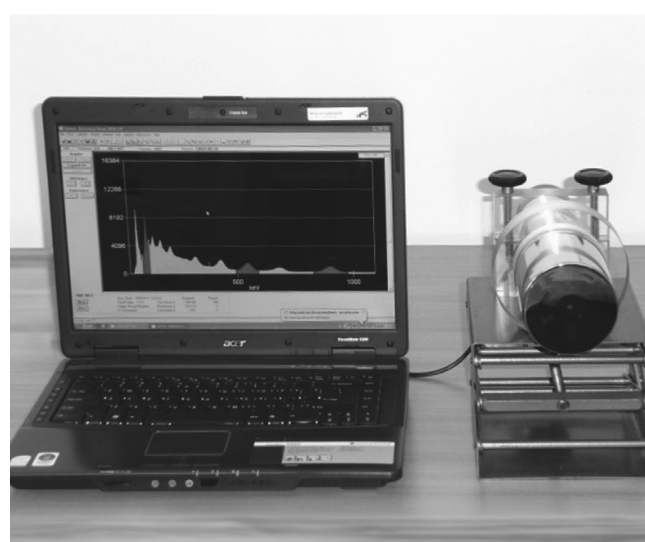

Photo 1. The portable unit with a NaI(Tl) scintillation detector for the measurement of radioiodine ^{131}I and technetium ^{99m}Tc
Fot. 1. Zestaw przenośny z detektorem scyntylacyjnym NaI(Tl) do pomiaru radiojodu ^{131}I i technetu ^{99m}Tc

More detailed information concerning methodology of measurements and dose assessments are described in (3,4). The method of estimating the effective dose in subjects, the occupationally exposed workers, was based on activity measurements of radioactive iodine and technetium in the thyroid (5,6). The doses were calculated with somewhat a conservative assumption that ^{131}I and ^{99m}Tc thyroid content remains constant during the year. The occupational exposure limit of 20 mSv gives the operational level equal to 7 kBq and about 1 MBq for ^{131}I and ^{99m}Tc, respectively.

The radioiodine ^{131}I and technetium ^{99m}Tc contents in the thyroid of staff members (nearly 100 persons) dealing with this radionuclides in 2012 have been measured in 4 departments of nuclear medicine in Poland where thyroid diseases are diagnosed and treated (including one having the highest annual processing of ^{131}I in Poland). They were the following centres:

1. Nuclear Medicine and Endocrine Oncology Units, The Maria Skłodowska-Curie Institute of Oncology (Warszawa, Poland).
2. A Department of Endocrinology and Isotope Therapy, The Military Institute of Medicine (Warszawa, Poland).
3. A Nuclear Medicine Unit, The Military Institute of Medicine (Warszawa, Poland).
4. A Nuclear Medicine Unit, The University Hospital in Cracow (Kraków, Poland).

The measurements were performed with a gamma spectrometry portable detection unit with a scintillation detector NaI(Tl) for *in situ* measurements of radioiodine and technetium.

The geometrical configuration used for monitoring personnel results was identical to that used in the calibration procedure. Typically, the detector was placed at the examined person's neck at the distance of 10 cm, using a 300 s counting time. The background was measured with a detector placed 10 cm away from the available RSD neck phantom, prior to or just following the measurement performed on the persons. The measurements were performed in selected places with the lowest possible background. The MDAs (Minimum Detectable Activities) for mobile unit range from 10–50 Bq for ^{131}I and from 45–50 Bq for ^{99m}Tc. The measurement time was of 300 s and depended on the background condition in particular centres.

All of the individuals actively working with radioiodine and technetium show measurable amounts of this isotopes in their thyroids.

The examined personnel can be divided into some categories (risk categories) according to internal contamination risk connected with unsealed sources of radioiodine ^{131}I and technetium ^{99m}Tc:

I. Technical staff mainly performing routine diagnostic investigation (technicians maintaining scintigraphies and gamma cameras).
II. Nuclear medicine staff (physicians, nurses, medical physicists, radiation protection officers) working with *in vivo* administration of radioiodine ^{131}I and technetium ^{99m}Tc.
III. Hospital service staff (orderlies, cleaners) performing auxiliary activities to the patients (cleaning the rooms, changing bedclothes).

External exposure doses were measured in several areas of nuclear medicine facilities – in patients' rooms (isolation wards) – control rooms, rooms for radionuclide administration, radionuclide laboratories, receptions, waiting rooms. High sensitivity environmental thermoluminescent dosimeters (TL dosimeters type MCP-N-ultrasensitive doped termoluminescent LiF: Mg, Cu, P and RE-2000A high precision TLD reader (from Mirion Technology (Rados)) were used for the measurements. The dosimeters were exposed for approximately 100 days. The results present net external exposure, without background. The measured background dose rate fitted in the range 0.05–0.08 μGy/h.

RESULTS

Employees of nuclear medicine are exposed to iodine and technetium isotopes, which are intravenously (^{131}I, ^{99m}Tc) or orally (^{131}I) applied to patients in the form of radiopharmaceuticals.

Internal contamination by inhalation occurs when breathing air exhaled by the treated patients. Isotopes of iodine and technetium are accumulated in the thyroid gland of the exposed persons.

The results of measurements of iodine and technetium activity are presented in Table 1. All of the individuals dealing with iodine show measurable amounts of the radioiodine in their thyroids (Figure 1 and 2).

The average measured activity in the thyroid of the nuclear medicine staff was on average 243 Bq, with the range of 70–4000 Bq. The average and range of radioiodine ^{131}I activity measured in the thyroids of all of the medical units' employees were, respectively, for:

- technical staff – 83 Bq (70–250 Bq) – category I,
- nuclear medicine staff – 280 Bq (70–4000 Bq) – category II,
- hospital service staff – 275 Bq (70–1000 Bq) – category III.

Table 1. The radioiodine ^{131}I and technetium ^{99m}Tc content and effective doses assessment for the personnel of nuclear medicine department
Tabela 1. Zawartość radiojodu ^{131}I i technetu ^{99m}Tc oraz oszacowana dawka skuteczna u personelu zakładów medycyny nuklearnej

Medical unit Ośrodek medyczny	Category Kategoria	^{131}I content in the thyroid Zawartość ^{131}I w tarczycy [Bq] range zakres	^{131}I content in the thyroid Zawartość ^{131}I w tarczycy [Bq] mean średnia	Effective dose from the inhalation of ^{131}I Dawka skuteczna z inhalacji ^{131}I [mSv]	Value of ^{99m}Tc content in the thyroid (mean) Zawartość ^{99m}Tc w tarczycy (średnia) [Bq]	Occupational exposure limit Limit dla ekspozycji zawodowej [%]
1	I	100–250	110	0.33	600	
	II	100–4 000	400	1.20	50	
	III	100–1 000	270	0.81	100	3.9
	ogółem / total	100–4 000	260	0.78		
2	I	70–100	80	0.24	< MDA	
	II	260–650	480	1.44	< MDA	
	III	70–850	400	1.20	< MDA	4.8
	ogółem / total	70–850	440	0,96		
3	I	70–70	70	0.21	< MDA	
	II	70–320	110	0.33	< MDA	
	III	70–620	240	0.72	< MDA	
	ogółem / total	70–620	130	0.42		2.1
4	I	70–70	70	0.21	< MDA	
	II	70–530	130	0.39	1 800	
	III	190–200	190	0.57	200	2.0
	ogółem / total	70–530	140	0.39		

1 – Nuclear Medicine and Endocrine Oncology Units, The Maria Skłodowska-Curie Institute of Oncology / Zakład Medycyny Nuklearnej i Endokrynologii Onkologicznej, Centrum Onkologii – Instytut im. Marii Skłodowskiej-Curie, Warszawa, Poland.
2 – A Department of Endocrinology and Isotope Therapy, The Military Institute of Medicine / Zakład Endokrynologii i Terapii Izotopowej, Wojskowy Instytut Medyczny, Warszawa, Poland.
3 – A Nuclear Medicine Unit, The Military Institute of Medicine / Zakład Medycyny Nuklearnej, Wojskowy Instytut Medyczny, Warszawa, Poland.
4 – A Nuclear Medicine Unit, The University Hospital in Cracow / Ośrodek Medycyny Nuklearnej, Szpital Uniwersytecki, Kraków, Poland.
I – technical staff / pracownicy techniczni.
II – nuclear medicine staff / pracownicy medycyny nuklearnej.
III – hospital service staff / pracownicy obsługi szpitala.
MDA – minimum detectable activity (for ^{99m}Tc, it is equal 45 Bq) / minimalna wykrywalna aktywność (dla ^{99m}Tc wynosi 45 Bq).

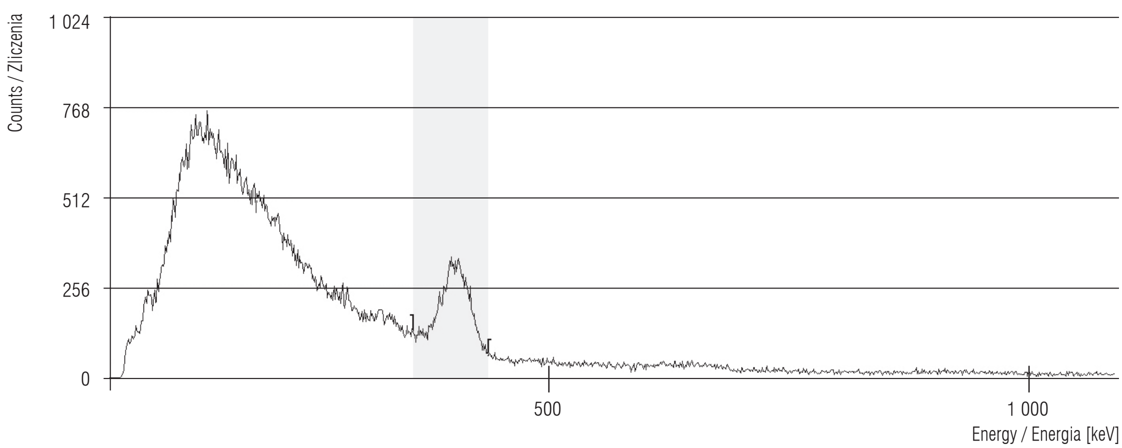

Fig. 1. The spectrum of radioiodine ^{131}I with the 364-keV photopeak found in the thyroid of an exposed worker in a nuclear medicine department
Ryc. 1. Widmo radiojodu ^{131}I (widoczny fotopikiem o energii 364 keV) zebrane z tarczycy eksponowanego pracownika zakładu medycyny nuklearnej

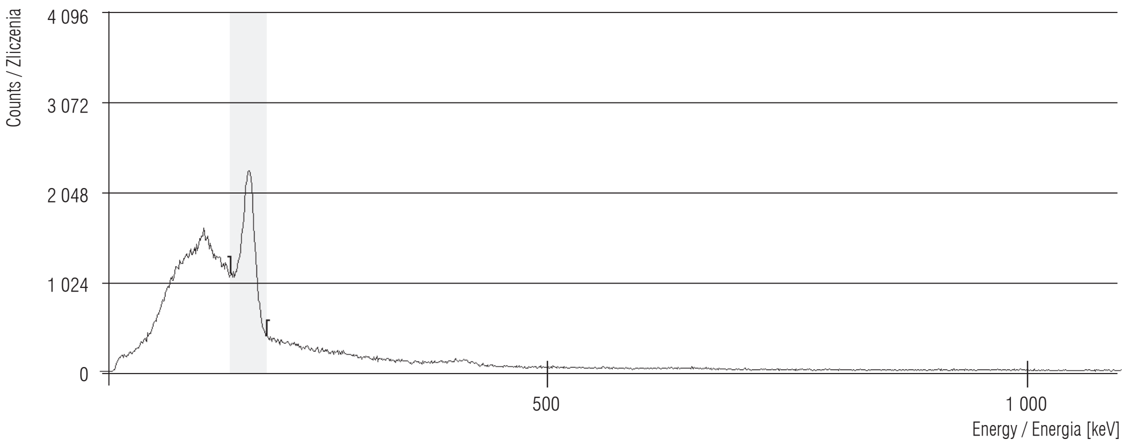

Fig. 2. The spectrum of technetium ^{99m}Tc with the 144-keV photopeak found in the thyroid of an exposed worker in a nuclear medicine department
Ryc. 2. Widmo technetu ^{99m}Tc (widoczny fotopikiem o energii 144 keV) zebrane z tarczycy eksponowanego pracownika zakładu medycyny nuklearnej

The technical, nuclear medicine and hospital service staff are about 25%, 55% and 20% of the total staff of medical units, respectively. On the basis of the measurement results, the effective committed dose was calculated for the radioiodine ^{131}I inhaled for each particular person. The calculated average effective committed dose per an exposed person is below 5% of 20 mSv/year (the dose limit for occupational exposure).

The presence of technetium ^{99m}Tc was observed in gamma-ray spectra in the thyroids of persons working with molybdenum generators. The mean value of technetium ^{99m}Tc content in the thyroid of nuclear medicine staff was about 1500 Bq (the range from 50 Bq to 1800 Bq).

In addition, the workers are exposed to external radiation, the source of which is the patient treated with radiopharmaceuticals.

The maximum external exposure dose rates were measured in the rooms of the hospitalized patients (range: 8–10 μGy/h) and their bathrooms (approximately 1 μGy/h). Smaller values were detected in the antechambers to isolation rooms (approximately 0.8 μGy/h), the radiochemical laboratory and in the waiting rooms where patients stay (approximately 0.5–0.6 μGy/h).

CONCLUSIONS

The results of the measurement of the radioiodine ^{131}I content in the thyroid of staff members working with radioiodine in four Departments of Nuclear Medicine do not show any correlation between the measured radioiodine ^{131}I levels and risk categories. The average values of radioiodine ^{131}I thyroid contents calculated for the particular medical unit item differ remarkably. These differences do not necessary depend on radioiodine ^{131}I activity used in the particular medical unit, but rather on its specific and complex working conditions, staff training and other factors.

In about 50% of the occupationally exposed people, the iodine levels were at the limit of detection of the used measurement unit. The estimated levels of radioiodine ^{131}I activity in the thyroids of these workers were low. In the other cases, the activity levels of radioiodine ^{131}I in the thyroids of the examined employees varied within the ranged of 100–4000 Bq. There is no apparent correlation between the measured radioiodine ^{131}I levels and risk categories. Nevertheless, nuclear medicine staff and hospital service staff demonstrate higher radioiodine ^{131}I thyroid levels when compared to technical staff. The elevated activity of iodine was present in nurses (professional category II) (900–2000 Bq of iodine), as well as in medical physicists, one of whom is a radiological protection inspector (RPI) (900–4000 Bq of iodine).

On the basis of the measurement results, the effective dose for particular person due to the inhalation of ^{131}I was calculated with somewhat a conservative assumption that radioiodine ^{131}I thyroid content remains constant during the whole year. For the occupational exposure limit of 20 mSv, it gives the reference radioiodine ^{131}I thyroid level equal to 7 kBq.

The maximum dose in the examined workers was less than 1 mSv and did not exceed 5% of the annual limit for occupational exposure, which is 20 mSv.

The committed effective doses from the inhalation of ^{99m}Tc are negligible in relation to the doses from radioiodine.

Due to the short residence time of the medical staff (about 1 h/day), in the areas with the highest level of external doses (i.e. isolation rooms for patients treated with radioiodine), external dose should not exceed 2 mSv.

REFERENCES

1. European Commission Unit H.4 – Radiation Protection. Review of national surveys of population exposure from nuclear medicine examinations in eight European countries. Report No. 154, Annex 2 – Dose Datamed Report 1a. Luxembourg: Directorate-General for Energy and Transport; 2008.
2. Pachocki KA, Sackiewicz-Słaby A. Determining the current status and potential of nuclear medicine in Poland. Rocz Panstw Zakl Hig. 2013;64(3):243–50.
3. Krajewska G. Laboratory for monitoring of radioiodine in thyroid for population in emergency situation, Annual Report 1996–1997. Warszawa: CLOR; 1998.
4. Krajewska G, Krajewski P. Thyroid monitoring system for measurement of iodine content in thyroid of occupationally exposed personnel. Radiat Prot Dosimetry. 2000;89(3–4):215–20.
5. Methods for assessing occupational radiation doses due to intakes of radionuclides. Safety Reports Series No. 37, Vienna: IAEA; 2004.
6. Assessment of occupational exposure due to intake of radionuclides. Safety Guide No. RS-G-1.2, Vienna: IAEA; 1999.