

EUROPEAN COMMISSION

# **RADIATION PROTECTION N° 154**

## **European Guidance on Estimating Population Doses from Medical X-Ray Procedures**

### **ANNEX 2 – Dose Datamed Report 1a**

#### **REVIEW OF NATIONAL SURVEYS OF POPULATION EXPOSURE FROM NUCLEAR MEDICINE EXAMINATIONS IN EIGHT EUROPEAN COUNTRIES**

Directorate-General for Energy and Transport  
Directorate H — Nuclear Energy  
Unit H.4 — Radiation Protection  
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## **Final Report of Contract TREN/04/NUCL/S07.39241**

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This report is one of three that have been prepared under a contract to the European Commission for the 'Development of a harmonised methodology for dose data processing regarding radiodiagnostic imaging procedures in medical applications – DOSE DATAMED'.

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## **Introduction**

Article 12 of the European Directive 97/43/Euratom requires Member States to determine the population radiation dose from medical exposures. Part of the medical radiation exposure is caused by nuclear medicine procedures. Eight of the ten countries participating in this DOSE DATAMED project have performed surveys concerning the population exposure from nuclear medicine procedures in recent years, Belgium [1, 2], Germany [3], Luxembourg [4], Netherlands [5], Norway [6], Sweden [7], Switzerland [8] and the United Kingdom [9]. This report summarizes the methods and results of the surveys that have been undertaken and shows the impact on the population dose of these examinations in each country.

## **1 Methods**

All eight countries assessed the total number of nuclear medicine procedures and the population dose in the year or period of the survey. Data on frequency of the procedures, the amount of activity used, and the kind of radiopharmaceuticals or radionuclides used were collected. Germany and Luxembourg gathered data from health insurance companies for a number of years. For both countries the last year of study, 2002, is used in the comparisons made here. The other six countries used questionnaires to collect data from nuclear medicine departments. Switzerland collected data from nuclear medicine departments for at least one month and these numbers were scaled to a whole year. The radiopharmaceuticals used and the administered activities in Germany were provided by a sample of nuclear medicine departments. In Sweden all nuclear medicine departments are obliged by regulations since 1968 to report annually to the radiation protection authority. This reporting comprises the type and number of all nuclear medicine examinations and treatments performed during a year, together with the average, minimum and maximum activity administered. Luxembourg estimated the average effective dose per examination using several published studies. In the Netherlands it was assumed that the amount of activity per examination that was used was the same as that recommended by the Dutch Nuclear Medicine Association for an adult person. In all the national surveys the average effective dose per procedure was calculated with ICRP dose coefficients relating effective dose to the administered activity [10, 11].

For some countries detailed data for specific diagnostic examinations and therapeutic procedures are available but for others only categorized data are given. In this report the specific data are grouped into broader categories to enable a comparison. In the Belgian and Norwegian surveys only diagnostic imaging procedures are included. Examinations of patients suffering from thyroid cancer were excluded in the Norwegian study. Germany did not include pre-therapeutic uptake examinations of the thyroid. With regard to the effective dose, Belgium did not include lung ventilation procedures. In the other surveys both imaging and non-imaging procedures (e.g. thyroid uptake measurements, plasma volume, etc.) are included and it is not always possible to distinguish between these two categories. Therapeutic nuclear medicine procedures were included in some of the surveys but are left out of the analyses and comparisons made in this review.

Based on the results of the different surveys, examinations of the following five organs are compared; bone, heart, thyroid, lung and kidney. Examinations conducted by positron emission tomography (PET) are considered separately in section 2.3 but are included in the total numbers of examinations and the total collective doses if the examinations were performed during the survey.

## 2 Results

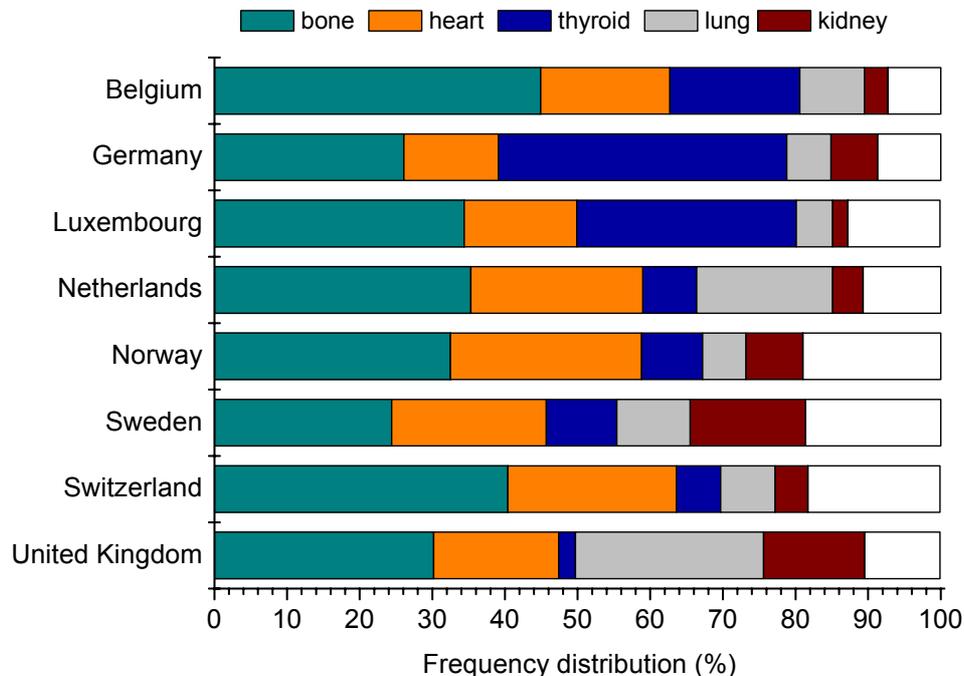
### 2.1 Number of examinations

Table 1 shows the number of examinations per 1000 population per year. The total number of nuclear medicine examinations per 1000 population per year ranges from 11 in the United Kingdom to 56 in Belgium. Notably high are the number of bone scans in Belgium and the number of thyroid examinations in Germany. According to the German survey [3] the high number of thyroid examinations is due to the iodine deficiency in Germany.

**Table 1 Number of nuclear medicine examinations per 1000 population for five different organs and for all nuclear medicine examinations together.**

	Bone	Heart	Thyroid	Lung	Kidney	Total
Belgium ('98-'99)	25	10	10	5	2	56
Germany (2002)	11	5	17	3	3	42
Luxembourg (2002)	13	6	11	2	1	38
Netherlands (2002)	6	4	1	3	1	18
Norway (2004)	4	3	1	1	1	12
Sweden (2005)	3	2	1	1	2	12
Switzerland (2004)	5	3	1	1	1	13
United Kingdom ('03-'04)	3	2	0.3	3	2	11

Figure 1 shows the contribution of the different groups of examinations to the total annual number of nuclear medicine examinations. In all countries the five categories contribute more than 80% to the total. In seven countries bone scans are the most frequently performed examination. Only in Germany thyroid examinations occur more frequently. Thyroid examinations are also often carried out in Luxembourg and Belgium contrary to the United Kingdom where they are relatively rare. In the United Kingdom and the Netherlands lung examinations occur relatively often.



**Figure 1 Relative contribution of five groups of examinations to the total frequency of nuclear medicine examinations.**

## 2.2 Dose

The average effective dose to patients from a nuclear medicine examination depends mostly on the typical amount of activity administered and the radionuclide used. Table 2 shows the mean administered activities estimated for several examinations in each country. There are substantial differences in the mean administered activities between some countries for particular examinations (e.g. there is a factor of 2.5 between the mean activities for thyroid examinations in Germany and Norway). These will lead to corresponding differences in the effective doses that are estimated using the same ICRP dose coefficients in each country [10, 11].

**Table 2 The mean activity administered per examination using Tc-99m (MBq).**

	Bone (phosph(on)ates)	Thyroid (pertechnetate)	Lung (MAA)	Kidney (MAG3)
Belgium	720	130	190	160
Germany*	616	51	142	81
Luxembourg**				
Netherlands	550	100	100	75
Norway	689	141	194	86
Sweden	505	120	120	80
Switzerland	720	96	190	95
United Kingdom	598	75	89	89

\* from [12]

\*\* Luxembourg used average effective doses from different published studies

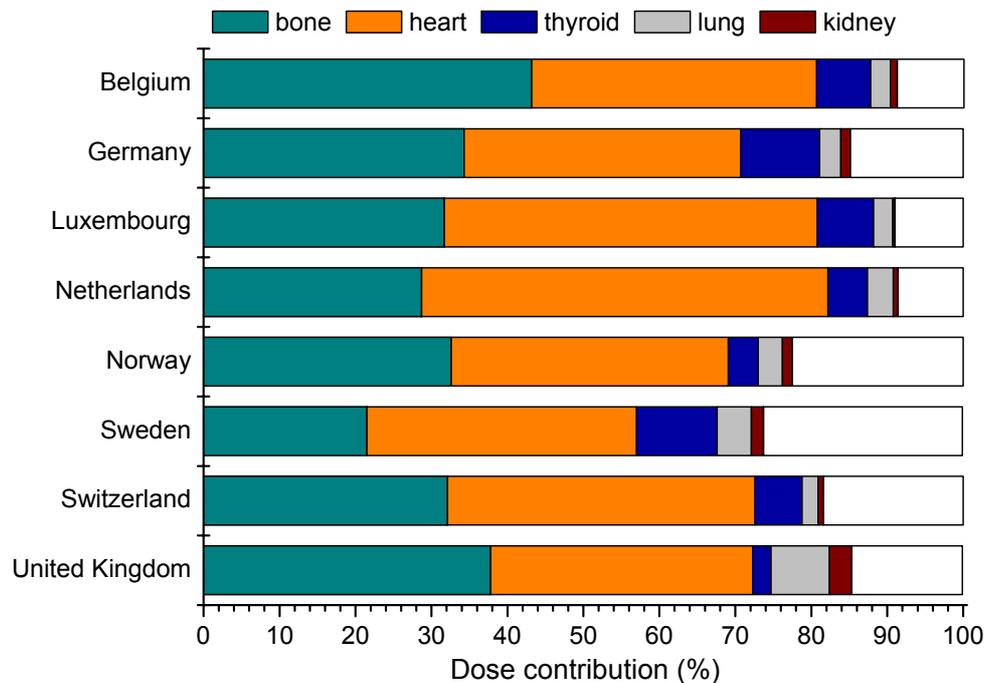
The use of different radionuclides also affects the effective dose per examination. For example, the average effective dose for thyroid imaging using I-123 is about 4 mSv. That is more than twice the highest estimated dose using Tc-99m. In the Netherlands more than 60% of the thyroid imaging was performed with I-123, whereas in Switzerland it was about 30% and the United Kingdom it was only about 6%. In the other countries practically all thyroid imaging was performed with Tc-99m. A frequency/radionuclide-weighted average effective dose for thyroid imaging can therefore vary considerably between countries. Furthermore up-take measurements of the thyroid are performed, normally with I-131, and even here the administered activity can vary considerably between countries. Another example of a substantial difference in effective dose per examination due to the radionuclide used is perfusion of the myocardium. The use of Tl-201 can result in an average effective dose per examination of over 20 mSv while using Tc-99m the dose will stay below 10 mSv. Sweden performed less than 1% of the myocardium examinations with Tl-201, whereas in Norway it was about 6%, in Switzerland about 25% and in the Netherlands it was as much as 35%.

From the frequency, the size of the population and the effective dose per examination, the average annual effective dose per head of population (per caput) was calculated for each country. Table 3 gives the average annual effective dose per caput for the five groups of examinations and the total average annual effective dose per caput due to all diagnostic nuclear medicine examinations. The total average annual effective dose per caput ranges from 0.03 mSv in the United Kingdom to 0.2 mSv in Belgium (Table 3).

**Table 3: Average annual effective dose per caput for five different groups of nuclear medicine examinations and for all nuclear medicine examinations together (mSv).**

	Bone	Heart	Thyroid	Lung	Kidney	Total
Belgium ('98-'99)	0.1	0.09	0.02	0.006	0.002	0.2
Germany (2002)	0.04	0.04	0.01	0.003	0.001	0.11
Luxembourg (2002)	0.05	0.08	0.01	0.004	0.0005	0.16
Netherlands (2002)	0.02	0.04	0.004	0.002	0.0004	0.07
Norway (2004)	0.01	0.02	0.002	0.001	0.0006	0.05
Sweden (2005)	0.008	0.01	0.004	0.002	0.0006	0.04
Switzerland (2004)	0.02	0.03	0.004	0.001	0.0005	0.07
United Kingdom ('03-'04)	0.01	0.009	0.0006	0.002	0.0008	0.03

Figure 2 depicts the contribution of the five groups of examinations to the total collective dose from nuclear medicine examinations. Examinations of the bone and the heart are the main contributors to the collective dose in all countries. In Sweden the contribution from these two examination categories is almost 60% and in the other countries it is even more. In Sweden and Norway examinations of the brain are also important regarding the collective effective dose, their contribution being respectively 9% and 7% (not shown here).



**Figure 2 Contribution (%) of five nuclear medicine groups to the population dose from nuclear medicine examinations.**

### 2.3 PET examinations

In most of the national surveys PET examinations are dealt with separately from all other nuclear medicine examinations. PET examinations have been performed in routine clinical practice in some countries since the early 1990s. Since the beginning of this century the possibilities of PET (and more recently combined PET/CT) and the number of examinations have been increasing rapidly, e.g. the frequency of PET examinations more than doubled in Sweden between 2001 and 2005, from 1500 to 3500 examinations per year. In this report no distinction is made between the different kinds of PET examination and only the total numbers of all PET examinations are considered. The average effective dose of a PET examination ranged from 5 mSv in Sweden and Belgium to 7.4 mSv in the Netherlands (combined PET/CT examinations will usually involve higher effective doses).

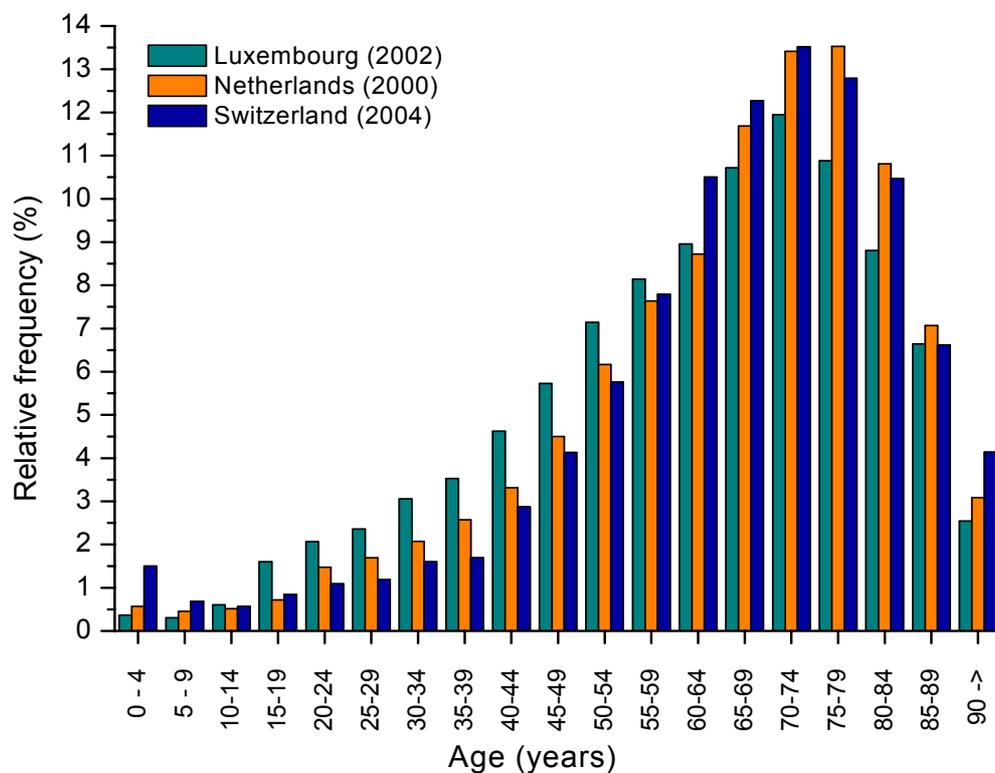
In the Swiss survey (2004), PET examinations contributed 8% to the total frequency (coming third behind bone and heart examinations) and 10% to the total collective dose from all nuclear medicine examinations. In Sweden (2005) the contribution to the total frequency amounted to 3% and in the United Kingdom (2003/04) to 2%. In both these countries PET contributed 5% to the collective dose.

In Germany PET examinations were included in the category 'other' together with haematology examinations. The number of examinations in this category more than

doubled in the period from 1996 to 2002. In the Netherlands PET contributed less than 1% to the total number of examinations in 2002 but showed a considerable increase by 2005. In Belgium the number of PET examinations multiplied more than ten times between 1999 and 2004 [13]. In Luxembourg no PET facility existed at the time of their survey in 2002 but the first one was installed in 2003. Norway first started with regular clinical PET examinations in 2005.

## 2.4 Age distribution

In Luxembourg, the Netherlands and Switzerland data on the age distribution of patients undergoing nuclear medicine examinations were available. Figure 3 shows the relative distribution of nuclear medicine examinations per 5-year age group. The distribution is normalised to the number of people in the respective age group. It can be seen that the shape of the distribution is similar in each country and that patients undergoing nuclear medicine examinations are mostly elderly people.



**Figure 3: Relative age distribution of patients undergoing nuclear medicine examinations in Luxembourg, Netherlands and Switzerland.**

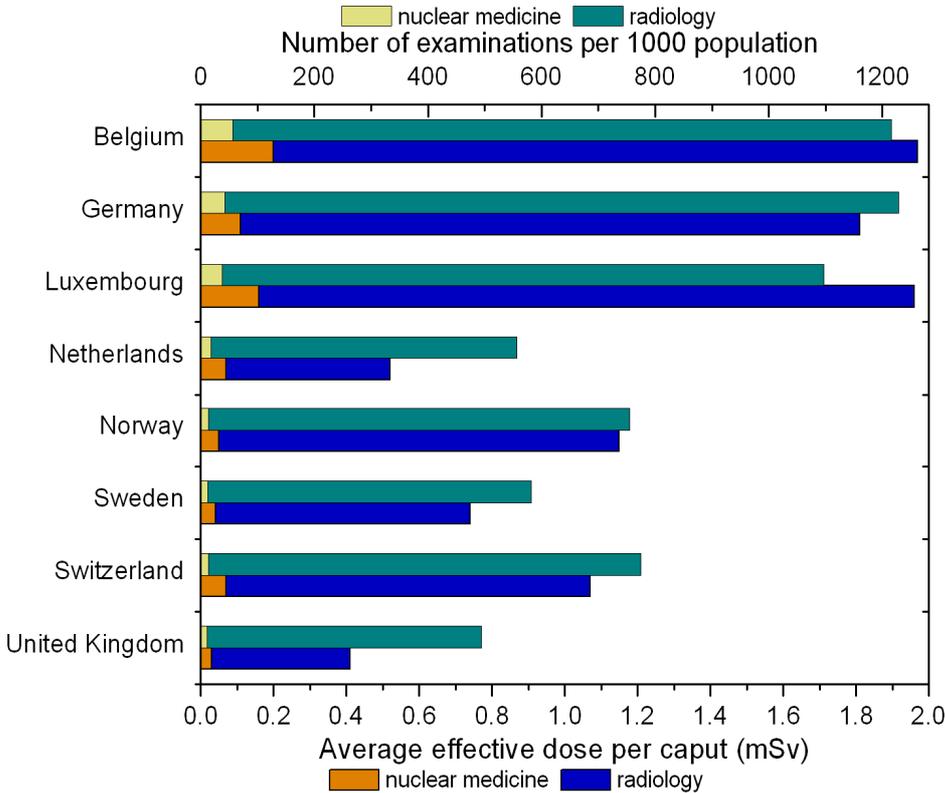
## 2.5 Contribution of nuclear medicine to the medical radiation exposure

Table 4 shows the total annual number of nuclear medicine examinations per 1000 population and the average annual effective dose per caput for each country. This table also indicates that the number of nuclear medicine examinations contributes 2%-5% to the total frequency of all radiological (excl. dental) and nuclear medicine examinations together. The contribution of nuclear medicine examinations to the collective effective dose from diagnostic medical exposures (excl. dental) ranges from 4% to 14%. It must be taken into account that the year in which the radiology survey took place in a country is not always the same year as in which the nuclear medicine survey took place.

**Table 4 Overview of the number of examinations and the effective dose per caput. The third column shows the contribution of nuclear medicine examinations to the total frequency of all radiological (excl. dental) and nuclear medicine examinations. The last column shows the contribution of nuclear medicine examinations to the total collective effective dose from all medical examinations (excl. dental).**

	Number per 1000 population	Contribution to total frequency (%)	Effective dose per caput (mSv)	Contribution to total medical exposure (%)
Belgium	56	5	0.2	10
Germany	42	3	0.11	6
Luxembourg	38	3	0.16	8
Netherlands	18	3	0.07	14
Norway	12	2	0.05	4
Sweden	12	2	0.04	5
Switzerland	13	2	0.07	7
United Kingdom	11	2	0.03	7

Figure 4 displays the proportion of nuclear medicine examinations and radiological examinations (excl. dental) both in terms of frequency and collective effective dose.



**Figure 4: Overview of the annual frequency of radiological and nuclear medicine examinations and the resulting average annual effective dose per caput**

### 3 Discussion

Calculating the patient exposure from nuclear medicine examinations is more straightforward than from radiology examinations (DD Report 1). The effective dose from a nuclear medicine examination depends mostly on the amount of activity administered and the radiopharmaceutical used and on patient related parameters such as size and

biokinetics, the latter being strongly dependent on the presence of disease or abnormalities. It does not depend on the kind of imaging equipment, the equipment parameters, the exposure time or the number of images taken, as is the case for x-ray examinations. In the surveys discussed in this report, the average effective dose per procedure was simply calculated using ICRP dose coefficients relating effective dose to administered activity for the radiopharmaceutical used.

However, the definition of examinations (or examination groups) included in a survey can differ to a certain extent between countries. The distinction sometimes is made between imaging and non-imaging examinations, sometimes it is not. Some surveys exclude pre-therapeutic uptake examinations of the thyroid, e.g. in Germany, or examinations of patients suffering from thyroid cancer, e.g. Norway, while in other studies it is not always clear whether such examinations are included or not. Switzerland for example reported an average effective dose of 5.4 mSv for examinations of the thyroid [8], which included all examinations of the thyroid performed with different radionuclides (Tc-99m, I-123 and I-131), whereas the average effective dose of 0.7 mSv for thyroid examinations reported in Germany [3] was based on examinations using almost only Tc-99m. As mentioned before, therapeutic procedures are not included in this review but it is not always obvious if diagnostic examinations of a patient who is (probably) going to have therapy (particularly for thyroid cancer), or if follow-up examinations after therapy, are included in the different surveys.

Except for the explanation of iodine deficiency in Germany [3] in relation to the number of thyroid examinations there are no obvious reasons for the differences in frequency seen between countries for other types of examination.

The use of a mean administered activity per examination based solely on that which is recommended by the national association of nuclear medicine for an average adult patient (as was done in the Netherlands) may not be entirely representative of the real situation. However, in the UK survey it was found that most nuclear medicine centres used administered activities that were very close to those recommended by the national authority.

In some countries the nuclear medicine survey did not take place in the same year as the radiology survey. This might influence the part nuclear medicine contributes to the total medical exposure, although there does not seem to be a real difference between the contribution of nuclear medicine in countries where the surveys took place in the same year compared to countries where that was not the case.

## **4 Conclusions**

Nuclear medicine examinations only contribute 4%-14% to the total medical radiation exposure in terms of collective effective dose. The contribution to the examination frequency is even smaller and lies between 2%-5%.

Those countries with the highest frequency and per caput doses from nuclear medicine examinations (Belgium, Germany and Luxembourg) also have the highest frequency and per caput doses from radiological (x-ray) examinations.

The main contributors to the annual collective effective dose from nuclear medicine are examinations of the bone and of the heart. In terms of frequency, examinations of the thyroid and lung are also important.

Nuclear Medicine examinations are most frequently performed on elderly people.

Data for recent years in the national surveys reported here indicate that the use of PET and combined PET/CT scans is rapidly increasing. In view of the relatively high effective doses for these procedures (particularly PET/CT), these examinations are likely to make a major contribution to the collective dose from nuclear medicine in most developed countries in the near future.

## References

1. Geest De E. A multicenter study of the administered activity in nuclear medicine departments in Belgium. Presentation at the Annual Congress of the European Association of Nuclear Medicine (EANM) – Vienna, Austria 31/08 - 04/09, 2002.
2. Geest De E., A multicenter study of the administered activity in nuclear medicine departments in Belgium. Poster at the 11<sup>th</sup> International Congress of the International Radiation Protection Association (IRPA) – Madrid, Spain 23 - 28 may 2004.
3. Stamm-Meyer A, et al. Diagnostic nuclear medicine procedures in Germany between 1996 and 2002, Application frequencies and collective effective doses. *Nuklearmedizin* 45:1-9, 2006.
4. Shannoun F. Medizinische Strahlenexposition in Luxemburg, Erhebung und Bewertung der Häufigkeit und Dosis radiologischer Untersuchungen zwischen 1994 und 2002. *Ecomed MEDIZIN*, 2005. ISBN: 3-609-16321-6.
5. Meeuwse EJ. National Institute for Public Health and the Environment (RIVM), Laboratory for Radiation Research. Personal communication. Netherlands 2007.
6. Olerud HM. Norwegian Radiation Protection Authority (NRPA). Personal communication. Norway 2007.
7. Swedish Radiation Protection Authority (SSI). ). web publication *Isotopstatistik för nukleärmedicinsk verksamhet* <http://www.ssi.se/isotop/index.asp> (in Swedish) 2007.
8. Roser H.W. Nuklearmedizinische Patientendosen und diagnostische Referenzwerte in der Schweiz. Institut für Radiologie, Universitätsspital Basel, Schweiz.
9. Hart D, Wall BF. A survey of Nuclear Medicine in the UK in 2003/04. HPA-RPD-003. Health Protection Agency 2005. ISBN 0 85951 560 5. (can be freely obtained on [www.hpa.org.uk/radiation](http://www.hpa.org.uk/radiation)).
10. ICRP 53. The International Commission on Radiological Protection. Radiation dose to patients from radiopharmaceuticals. ICRP Publication 53, *Annals ICRP*, 18 (1-4), 1987. ISBN 0 08 035591 9.
11. ICRP 80. The International Commission on Radiological Protection. Radiation dose to patients from radiopharmaceuticals. ICRP Publication 80. 28 (3), 1998. Addendum to ICRP 53. Also includes Addendum 1 to ICRP Publication 72. ISBN 0 08 043 5734.
12. Hacker M, Schnell-Inderst P, Noßke D et al. Radiation exposure of patients undergoing nuclear medicine procedures in Germany during 1996 and 2000: Multicenter evaluation of age- and genderspecific patient data. *Nuklearmedizin* 44: 119-30, 2005.
13. Cleemput I, Dargent G, Poelmans J, Camberlin C, Van den Bruel A, Ramaekers D. HTA Positronen Emissie Tomografie in België. KCE Reports vol. 22A. Ref. D2005/10.273/29. Brussel:Federaal Kenniscentrum voor de Gezondheidszorg (KCE), Oktober 2005.