Implementation of occupational radiation protection control at university and hospital work places

Håkan B.L. Pettersson
Dept of Radiation Physics, Health Faculty, Linköping University, 581 85 Linköping, Sweden

ABSTRACT
This paper describes the development of the radiation protection organisation and implementation of the radiation protection regulations at the county hospitals of Östergötland and Linköping University, Sweden, both in a historical perspective and the situation today. The workplaces, which comprise some 500 designated radiation workers, include both radiation diagnostics and radiation therapy at the hospitals and education and research using X-ray equipment and accelerators and handling of open radiation sources at the university.
Aspects that are discussed are: (i) local directives and recommendations, (ii) local radiation protection education; formal radiation "drivers licences" and in-house training, (iii) supervision and inspection of workplaces, (iv) control by personnel dosimetry.

The success or failure of radiation protection control is further discussed. Imperative questions are; how do me measure the success/failure and which are the most cost-effective measures to be taken and how does the ALARA principle apply in the day-to-day work? In this context, how and when can inspection type control be transformed to self-assessment?

1. Introduction

This paper describes the occupational radiation protection control at the Linköping university and at the three main hospitals (Linköping university hospital, Norrköping and Motala hospitals) in the Östergötland county of Sweden. Today the university comprises some 27 000 students and 3500 workers of which about 50 are designated as radiation workers. The county hospitals employ about 13 000 people, of which about 500 are designated as radiation workers. The hospitals offer general health care and specialized medicine for some 500 000 inhabitants, plus specialist care (e.g. radiation therapy) for patients recruited in the neighbouring counties.

The radiation work (teaching and research) at the university involves mainly radionuclide handling, but also the use of x-ray technology and to a lesser extent external radiation therapy. For the medical facilities radiology departments are well established at all 3 hospitals. Nuclear medicine (diagnostics and therapy) and external radiation therapy (accelerator beam therapy and brachy therapy) are only carried out at the Linköping university hospital.

2. Radiation protection organization

Since many years the Swedish legislation, through the Radiation Protection Authority (SSI), require that users of ionizing radiation obtain special authorization for their operations. Attached to these licenses are conditions and obligations that must be fulfilled, e.g. provisions for proper training of the personnel, proper handling of radionuclides and radioactive waste, implementation of quality control programs for radiation equipment (e.g. accelerators, x-ray units) and methodologies used. It also requires a well established radiation protection organization. Such formal organisations have been operating for more than 20 years in the Östergötland county, each for the university and for the medical facilities.

The aim of the organization plans is to establish effective co-operation platforms between different worker categories and to describe the methods and means of implementing the radiation protection legislation and directives in the day-to-day work. The plans define the responsibility and liabilities and interplay between the licence holder, the head of the hospitals and the university, the department heads, the users, the radiation protection officer, the medical physicists etc. It also defines the requirements of quality control.

The plans are rather detailed in terms of responsibilities for the department heads, the radiation physics organisation, the radiation protection committee and the special radiation managers at each medical radiation discipline.

Based on the general SSI authorizations the radiation protection officer in charge, the RPO, issues annual local authorisations for each facility or department for which the use of ionizing radiation is limited and not requiring special SSI authorization.

3. **Dose registration**

Regular personal dosimetry

The radiation workers are monitored by personal dosimeters on regular basis. Of a total of about 550 radiation workers about 200 are designated as category A workers, thus requiring monthly dose evaluations and reporting to the authorities (SSI). However, all of the category B workers are also monitored, and evaluated either every month or every 3 month. The dosimetry is based on TL-dosimeters which are normally borne at breast height, thus measuring Hp(10). In addition, TL dosimetry for extremities and eyes are performed for special categories to measure Hp(3) and Hp(0.07), e.g. for those handling high activities of β-emitting radionuclides and for high load x-ray diagnostics, especially interventional radiology. But this monitoring is made on less regular basis. In addition, when new methods or technologies are implemented normally the workers are monitored in the initial period.

Our personal dosimetry procedure is accredited by the SSI and the performance (accuracy) is tested annually by the authorities (SSI).

Currently a new dosimetry system is introduced which will partly replace the TL-dosimetry. The new system is based on the so called direct ion storage principle, i.e. is based on small ionization chambers and semi-conductor detectors (MOSFET) stacked in a small (4.5x4.5x1 cm) holder. This system, which is calibrated to measure both Hp(10) and Hp(0.07), facilitates direct readout by the user in their work place, thus minimising the handling and readout work for the dosimetry department, but most importantly, it gives the opportunity for the user to have a check of their doses instantly, i.e. a type of self-assessment. The readout data is automatically transferred by the intra-net to our host computer data base. The system is well suited for checking the dose burden in training situations and when introducing new methods and new equipment.

Dose history

The radiation physics department at the Linköping university hospital has been responsible for the personal dosimetry operations since 1976, thus having collecting dose records of annual personal doses for almost 30 years. The dosimetry was initially based on film detectors, but then replaced by TL-based detectors in the early ‘80s. The dose readings today (since 1998), are converted to personal dose equivalent, Hp(10) (or Hp(3), Hp(0.07)), whereas the historical dose data represent a “dose in soft tissue at the position of the dosimeter”.

Figure 1 show the collective doses (manSv) and mean annual doses (mSv) for all categories of workers during the period 1976-2003. There is a marked and steady decrease in annual doses and subsequently also in collective doses, despite increased work activity, especially in the radiology and radiation therapy areas. The annual doses today can in most cases be regarded as trivial, both in terms of risk and when compared to the annual dose limits.

However, individuals and certain categories of workers may obtain annual doses that are significant. Figure 2 shows the temporal dose distribution for radiology workers, i.e. radiologists and radiology nurses. The same time-trend is present but the maximum doses do not follow such a trend, showing max annual doses from about 2 to 14 mSv. Factors that likely have had influence on dose reductions are e.g. increased education and training, change of x-ray equipment from over coach to under coach x-ray tubes, a general improved awareness of radiation risks etc. Figure 3 shows the corresponding dose distribution for personnel of the nuclear medicine diagnostic department. The trend of decreasing doses is

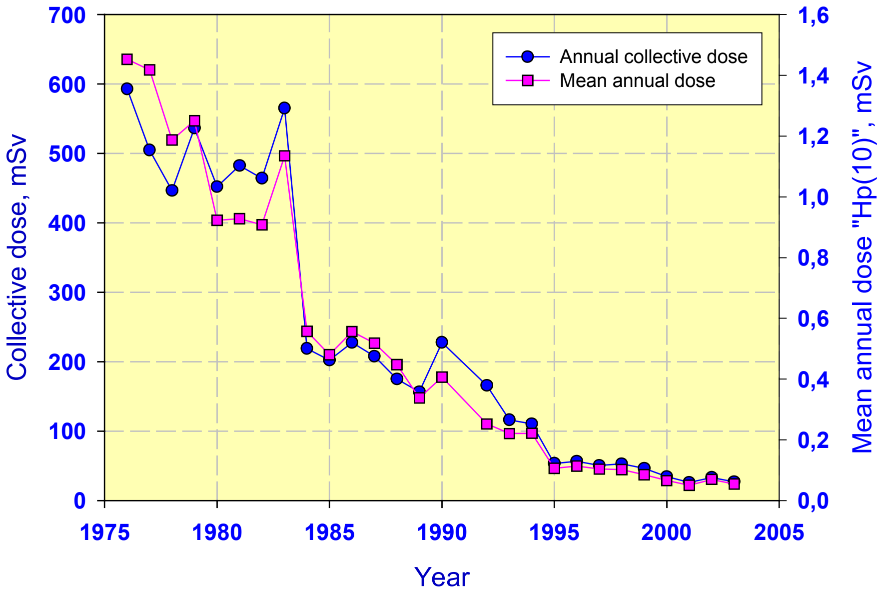

Fig. 1. Annual collective and mean individual doses for radiation workers at the Östergötland county hospitals and the University of Linköping

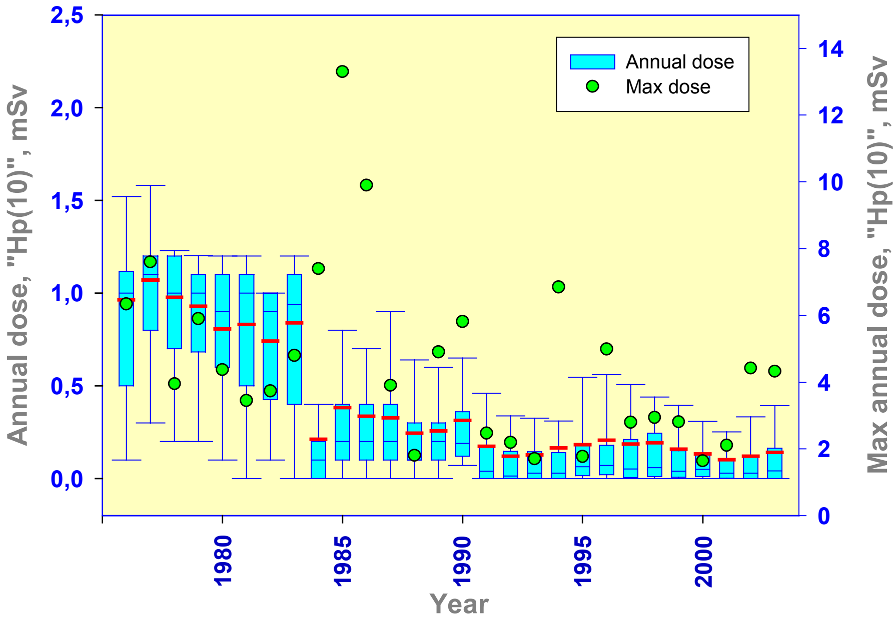

Fig. 2. Annual individual doses for radiation workers at the radiology department of the Linköping University hospital (box plots of 10th, 25th, 75th, 90th percentiles in the box and 5th and 95th percentiles as error bars).

evident but is probably reaching a plateau in the early ´90s. The reasons for reduced exposure are not evident, but factors that may influence are: 1) until the end of the ´80s the nurses were obliged to sit-in with the patient during the gamma camera examinations, 2) move to new facilities and hot-labs in the mid ´80s, with better protection equipment (e.g. portable whole body lead shields), 3) introduction of mandatory radiation protection education and training for all personnel (see below) in the late ´80s. However, by introducing a new diagnostic technique, ^{18}F-FDG-PET, in 1998 using high radionuclide activities, may have increased the annual doses slightly (see Fig. 3).

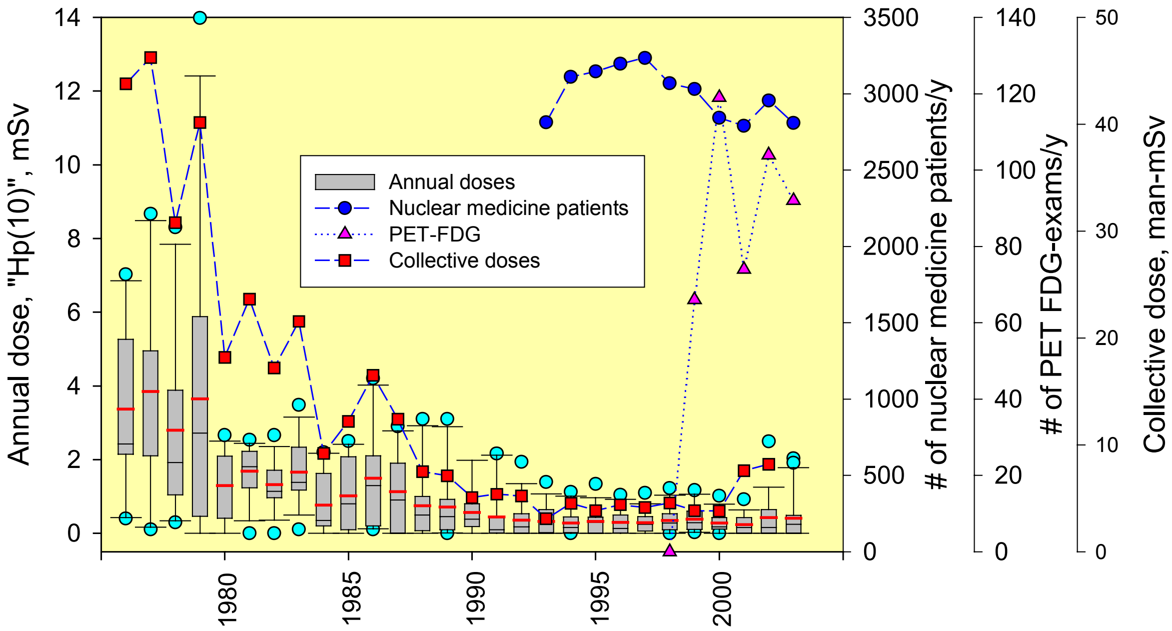

Fig. 3. Annual collective doses and distribution of annual doses for radiation workers at the nuclear medicine department of the Linköping university hospital (box plots of 10th, 25th, 75th, 90th percentiles in the box and 5th and 95th percentiles as error bars).

Examples of dose assessments of particular procedures are given in Figures 4 and 5 showing the expected doses to workers based on short-term TL-measurements of doses to eyes, thyroid, hands/fingers and trunk and normalised to a typical number of sessions per worker per year or day. Such assessments are made on regular basis, especially when new procedures are introduced.

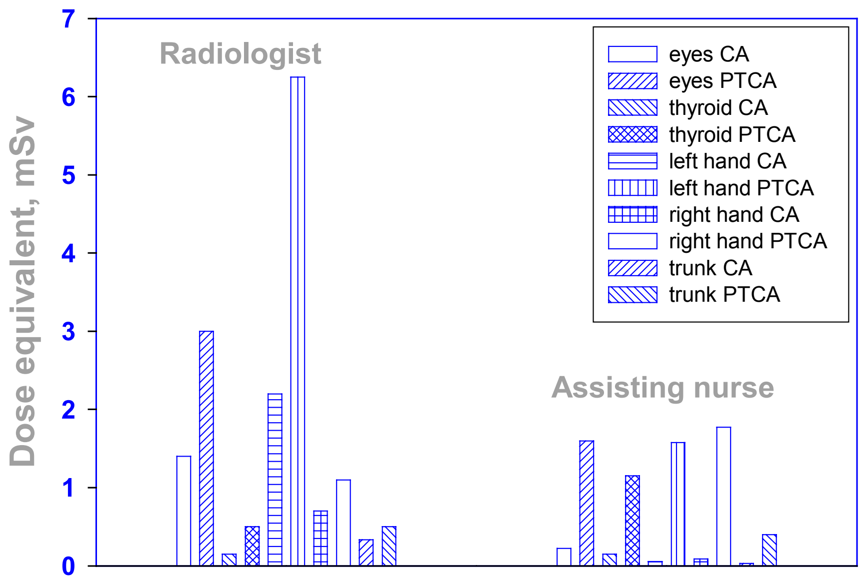

Fig. 4. Workers doses at diagnostic/interventional thorax radiology procedures (CA & PTCA) given for an expected 50 sessions/y per worker.

Internal dosimetry

Historically internal dosimetry of workers at our facilities has not been given very much attention. It has been assumed that at normal use of radionuclides the protection by e.g. using fume/LAF hoods, protective clothing and good laboratory practice in general, the risk of internal exposure is negligible, and that the external dosimetry is a good enough indicator of the radiation environment.

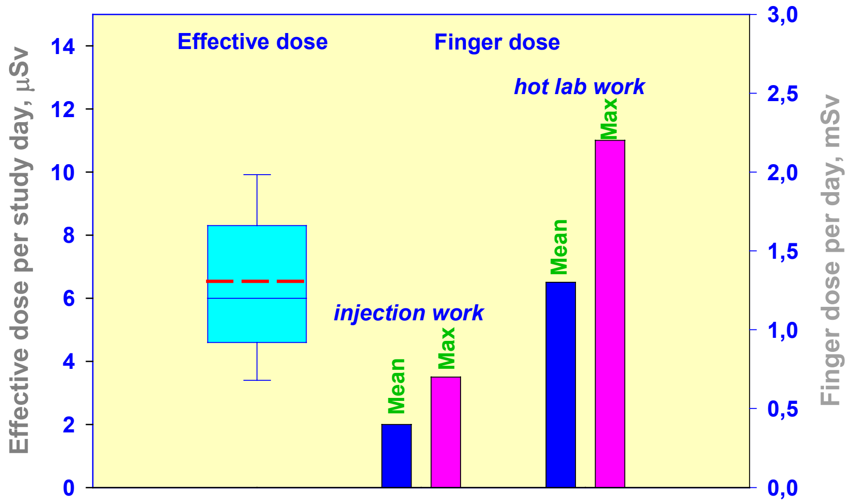

Fig. 5. Daily nuclear medicine nurses doses at ^{18}F-FDG-PET procedures. (box plots of 10th, 25th, 75th, 90th percentiles in the box and 5th and 95th percentiles as error bars). Data from Anna Olsson *et al., Radiation Physics Dept, Linköping University.*

Even today the internal dose burden is only checked occasionally. Studies performed on assumed critical groups have shown very small intakes of radionuclides. Figure 6 show the ^{125}I thyroid content

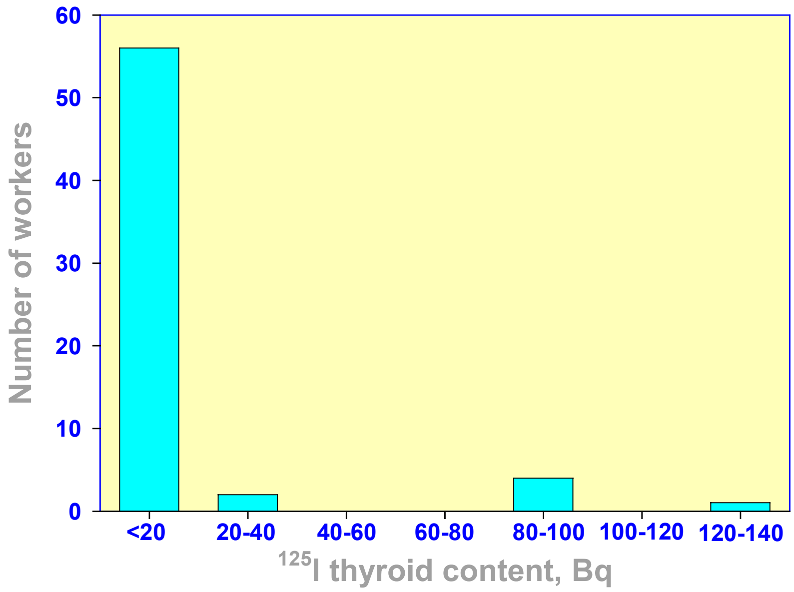

Fig. 6. Thyroid content of ^{125}I for personnel involved in ^{125}I lab work at the Linköping University Hospital and at the Linköping University.

of workers handling ^{125}I, both at the Linköping university and university hospital, indicating a very small dose burden. A similar study on personnel handling ^{131}I, i.e. physicists, nurses administrating ^{131}I to the patient, nurses handling both the in- and out-patients, all showed thyroid levels less than the detection limit (<20 Bq). Also studies on the body burden from ^{3}H uptake, i.e. by urine analysis, generally indicate non significant uptake.

However, there are areas which has not yet been studied, for example for personnel preparing ^{99m}Tc-based radiopharmaceuticals and for personnel involved in the ^{18}F-FDG PET studies. Such studies are under way.

Radiation accidents

The radiation work at our facilities has been very fortunate regarding radiation accidents. During the last 30 years no severe accidents has occurred. Less severe accidents or mishaps occur at intervals, e.g. contamination of hands or protective clothing in radionuclide handling, mishaps during administration of radionuclides, but normally the personnel doses are moderate. The most severe accident involved exposure of a hand in 1984 and a finger in 1997 (total exposure area of a few mm^2) from research x-ray diffraction equipment. Dose reconstruction of the 1984 event revealed skin doses of up to 90 Gy. The results of the medical follow up is not known. For the 1997 event dose reconstruction by TL-dosimetry and simulation by MC-calculations revealed a finger dose of 8-10 Gy. Skin erythema was observed a few days after the exposure, but the skin healed completely after 1-2 months, and the medical experts believe no long term health effects will occur.

Classification of workers

Based on the personal dose history (Fig. 1), most workers and worker categories show annual doses far below the annual limits and below the level for classification as category A radiation worker. Still, in reality about 30% of the workers are classified into category A. The cat. A comprise of all radiologists at the radiology, thorax radiology and cardiology, nurses at the thorax radiology department, all nurses and doctors at the radiotherapy department (external and radioisotopes), nurses at the nuclear medicine department, and all hospital physicists. No university employee is classified in cat. A. Hence, the classification is based on work places rather than individual dose history, a rather conservative approach but convenient from an administrative point of view. Since cat. A classification carries extra costs for monthly dose readings and annual health examinations/declarations there is now, at times of extensive cost cutting, a debate whether re-classification should be made to reduce costs.

4. Supervision and inspections

Controlled and supervised areas

The classification of radiation work areas in the Östergötland county has mainly been based on the authority recommendations. However, the dose history show that in recent years only in very exceptional cases the annual doses are close to or above the limits set out for classification as controlled areas (annual effective dose >6 mSv). Only the nuclear medicine and radiology departments in Linköping would therefore qualify as controlled areas. However, the work area classification also includes considerations regarding risk of accidents and mishaps and considerations regarding exposure of the eyes, skin and extremities. Therefore all working areas involving x-ray diagnostics and research, radiotherapy and nuclear medicine have been designated as controlled areas. All remaining areas of stationary radiation work have been classified as supervised areas.

Local inspections are attached to the local authorisations issued by the RPO, i.e. the RPO is expected to make annual inspections at those work places. The inspections are non-formal and have the purpose of discussing radiation protection problems with the contact persons and educators, reviewing local guidelines and written procedures and checking protective equipment and radiation detectors. In addition the radiation workers may contact the RPO to discuss radiation protection issues whenever needed. A well working inspection procedure is built on good personal contacts of the RPO and by avoiding “policing” attitudes.

Areas/departments that are not inspected by the RPO on regular basis are those having individual authority licensing, i.e. the medical radiology department, the nuclear medicine department and the radiation therapy department. These activities all have hospital physicist working closely with the medical staff, thus enabling on-site radiation protection supervision. Radiation protection problems of more general type are also discussed in the radiation protection committees (radiology, nuclear medicine, radiotherapy) where the department heads and radiation protection specialists are present.

5. Education

Education and training in radiation protection has during the years been mandatory for all radiation workers in accordance with the legislation and obligations of the licence holders. The extent and organisation was further formulated in the 2000 authority statutes. For some categories such education and training is part of their basic education, e.g. hospital physicists, nurses specialist in radiology, radiation therapy and nuclear medicine, whereas others, e.g. doctors in oncology, radiology, surgery and nurses in other medical disciplines, engineers and researchers may have a very basic or no education and training in radiation protection. Now formal education and training, including written consent (“drivers licences”), are mandatory for many radiation workers in hospitals, e.g. nurses and doctors in radiology for operating x-ray equipment and in oncology for operating accelerators and brachy therapy equipment, for nurses and engineers for operating nuclear medicine equipment, for nurses operating blood irradiators etc. The aim of the training is often both in respect of radiation safety of the patient and of the personnel.

In the case of research staff, education is organised by the RPO in the form of formal 1-2 week courses. The courses are supposed to be given annually, but due to lack of resources in practice less regularly. These courses are aiming at educating personnel that can function as local educators at their work places.

Education and training has become a very important part of the work process putting high demands on both educators, licence holders and personnel. Educators are often the RPO, the hospital physicists or specially trained nurses and engineers. It is a very difficult task to timely organise education and training for new employees and training for all personnel in case of introducing new equipment. Resources, both financial and manpower, to handle this properly is lacking and the licence holders and people in charge of personnel issues need to put more emphasis to this in the future.

6. Conclusion and Discussion

The radiation protection work at the hospitals of the Östergötland counties and the Linköping university show steadily annually decreasing radiation risks for the workers. This is, of course, encouraging for the both workers, licence holders and the radiation protection specialists and it shows that the radiation protection work is paying off. However, in recent years, due to heavy demands of operational cost cuts, the level of radiation protection has been put under scrutiny. How can we motivate continued spending in radiation protection in the light of very low annual doses for the workers? In the light of the ALARA principle, is it reasonable to spend even more money to try to reduce the doses even further?

One way of quantification is by a cost-benefit approach. In recent years the annual collective doses has amounted to about 100 mSv, compared to the situation some 20 years ago with collective doses of about 500 mSv. There are of course many factors to explain the dose reduction, such as increased and improved education and training, improved protective shielding, improved techniques etc., but if we consider all this being radiation protection actions, one can conclude that over the last 20 years about 5 manSv have been saved. If we assume that up to 100 000 US$ can be a reasonable amount of money to be spent on radiation protection in order to reduce the collective dose by 1 manSv, a dose saving of 5 manSv would correspond to about 500 000 US$ to be spent. The real costs for the expanding radiation protection work during the last 20 years by far exceed this amount, i.e. the cost-benefit approach is in this case a rather ineffective instrument to justify the increased spending on radiation protection. However, there are many other aspects involved, such as the psychological value of proper radiation protection and dose assessment for the personnel, and, especially in medicine, the awareness of good radiation protection which have impact on optimisation of diagnostic examinations. But, as pointed out previously, in the near future we can probably expect demands for cutting costs for radiation protection, thus a need to optimise the use of the radiation protection budget.

Acknowledgements

The author thanks the radiation protection engineer at the Radiation Physics Dept in Linköping, Ms. Solweig Hellman, for providing the historical dose records.