Fifteen years of occupational exposure monitoring in Bosnia and Herzegovina
Petnaest godina lične dozimetrije u Bosni i Hercegovini

B. Bašić[1], A. Beganović*[2,3]

[1]Institute of Public Health of Federation of Bosnia and Herzegovina, [2]Clinical Centre of Sarajevo University, [3]Faculty of Science Sarajevo

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Contents

Section 1

Introduction

Occupational radiation exposure

There is a wide variety of situations in which people at work are exposed to ionising radiation.
However, to distinguish the exposure that should be subject to control by the operating management from the exposure arising from the general radiation environment, the term 'occupational radiation exposure' is taken to mean those **exposures that were received or committed during a period of work** and that can reasonably be regarded as the responsibility of the operating management.
In most of the cases, such exposures are subject to **regulatory control**.

Individual dosimeters

The means of occupational dose monitoring are normally regulated by responsible authority. Usually, personal dosimeters are used for individual dose monitoring. The workers are issued with an appropriate individual dosimeter which provide periodical dose readouts in the chosen physical quantity recommended by ICRU. Dosimeters used in this study are based on property of certain crystalline materials to absorb energy of ionising radiation and re-emit it as visible light upon exposure to high temperature. This property is called **thermoluminescence**.

Individual dosimeters

Personal dosimetry in BiH

Primarily, individual monitoring is used to control occupational exposure and ensure safe working conditions, as well as to demonstrate compliance with the third radiation protection principle – **dose limitation**.

Hence, individual monitoring of exposed workers is a requirement of International Atomic Energy Agency (IAEA) International Basic Safety Standards and national regulation of Bosnia and Herzegovina (BiH).

Personal dosimetry in BiH started in 1960s. It was interrupted in 1990s and continued in 1999 after International Atomic Energy Agency (IAEA) donated a TLD reader and a set of appropriate dosimeters to Radiation Protection Centre (RPC) of the Institute of Public Health of Federation of Bosnia and Herzegovina (FBiH).

Section 2

Materials and Methods

TLD dosimeters and reader

During the analysed period RPC had been equipped with one thermoluminescent reader (Thermo Scientific™ Harshaw TLD Model 4500 Automatic Reader, Waltham, MA, USA). It used more than 3000 TLDs, based on Lithium Fluoride crystal doped with titanium and magnesium to increase the number of traps and luminescence centres (LiF:Mg,Ti).

Minimum detectable limit

Each dosemeter is equipped with either two or four separate detectors, enclosed in a casing with appropriate filters. It is calibrated to measure personal dose equivalent at the reference points of (10 and 0.07) mm, $H_P(10)$ and $H_P(0.07)$, respectively. Its minimum detectable limit (MDL) is approximately 50 μSv. Dosimeters were calibrated in a secondary standard dosimetry laboratory (SSDL) in the radiation field of ^{137}Cs source.

Exposed workers

Majority of TLD users work in medical field, specifically, in diagnostic and interventional radiology.
In special circumstances, where exposure to non-uniform radiation field is expected, professionals were issued additional dosimeters.

Effective dose estimation

Effective dose, E, received by a professionally exposed person is estimated using the available results of $H_P(10)$, which is an operational quantity used for control of effective dose designed for monitoring the strongly penetrating radiation (photons with energy above 12 keV).

In order to measure background dose, we used the unexposed control dosimeters located in the RPC.

In special cases, when the worker is provided with two TLDs that are worn under and above lead apron, effective dose is estimated using measured values from both dosimeters, under and over the apron.

Number distribution ratio

Analysis of dosimetry data was performed to match reports in UNSCEAR Report 2008. In order to assess the impact of high-dose records to the overall average, the UNSCEAR report introduced 'number distribution ratio', NR_E, defined as:

$$NR_E = \frac{N(> E)}{N},$$

where N is the total number of persons, and $N(> E)$ the number of users who received doses higher than E.

Collective dose distribution ratio

In a similar fashion, the annual collective dose distribution ratio, SR_E, is defined as:

$$SR_E = \frac{S(> E)}{S},$$

where S is the collective dose of all workers, and $S(> E)$ collective dose of individuals who received effective dose above E.

Section 3

Results

Number of TLD users

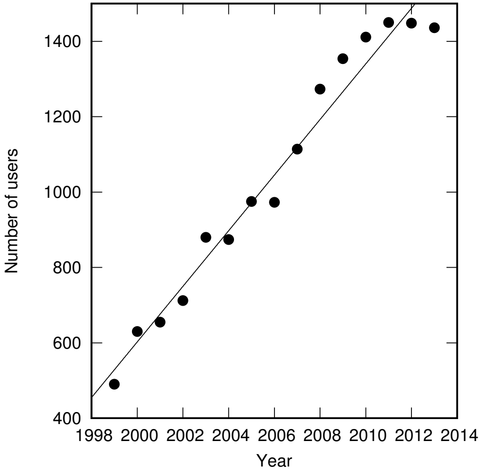

Fig. 1: Increase of number of TLD users in FBiH from 1999 until 2013. The number of occupationally exposed workers covered by TL dosimetry increased by 73 users per year.

Histogram of doses

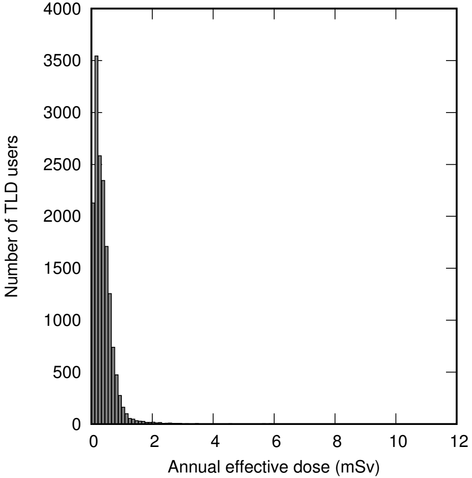

Fig. 2: Histogram of effective doses received by workers in 15 years

Doses over the years

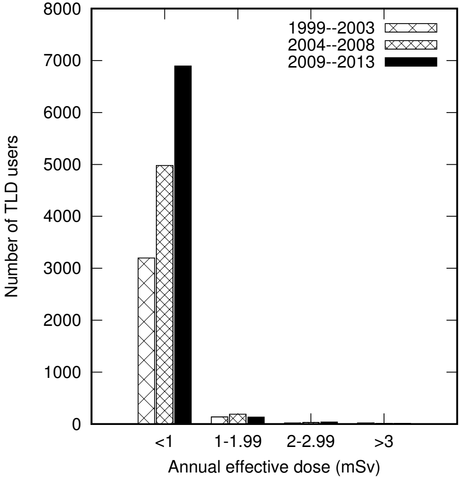

Fig. 3: Total number of TLD users who received doses below 1 mSv, 1–1.99 mSv, 2–2.99 mSv, and above 3 mSv in different time periods.

Doses in all practices

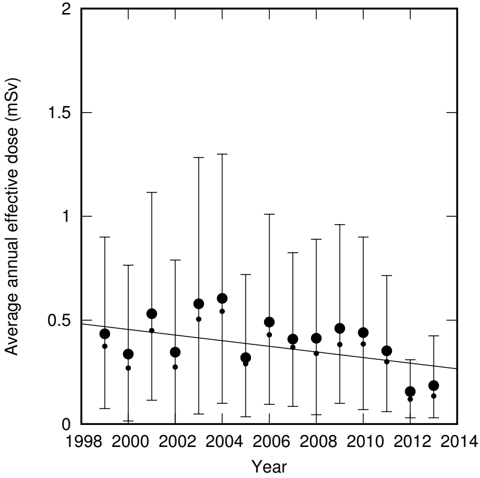

Fig. 4: Average annual effective dose in FBiH from 1999 until 2013 with 5th and 95th percentile bars, and median values represented with small dots. The negative correlation is significant (Pearson's correlation test, $p < 0\ 001$). On average, the dose decreases by 0.018 mSv per year.

Doses in diagnostic and interventional radiology

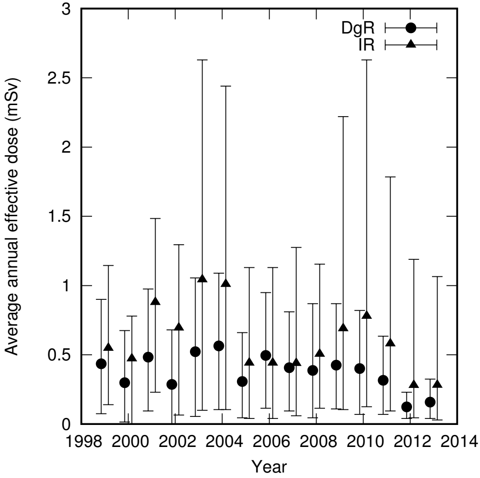

Fig. 5: Average annual effective dose in diagnostic and interventional radiology

Doses in nuclear medicine and radiotherapy

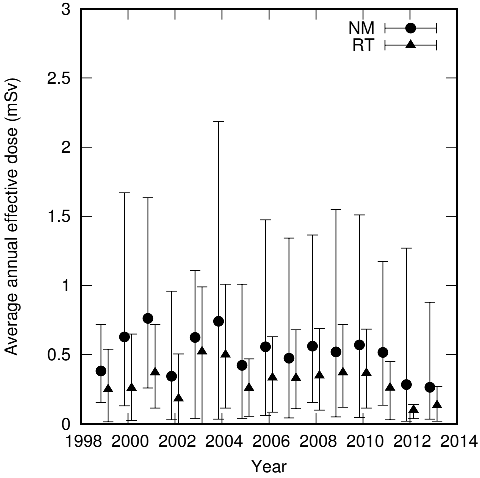

Fig. 6: Average annual effective dose in nuclear medicine and radiotherapy

Doses in dental and veterinary radiology

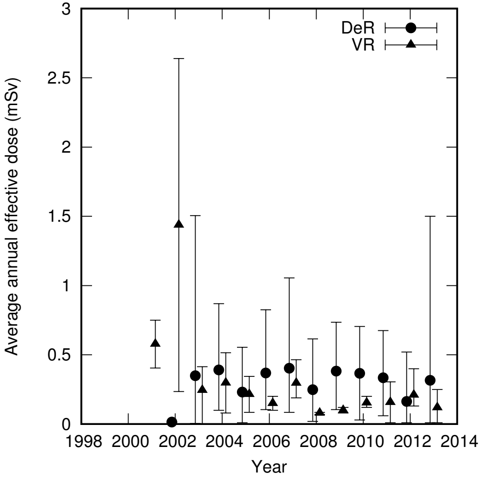

Fig. 7: Average annual effective dose in dental and veterinary radiology

Doses in industry

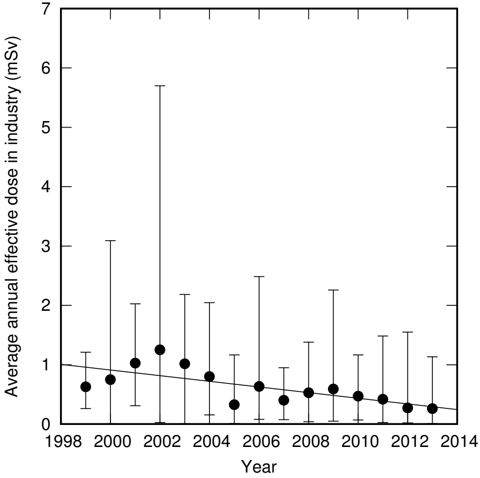

Fig. 8: Average annual effective dose in industry in FBiH

Average annual doses in different practices

		E (mSv)		
		1999–2003	2004–2008	2009–2013
Practice	Diagnostic radiology	0.409	0.428	0.282
	Interventional radiology	0.753	0.555	0.528
	Nuclear medicine	0.553	0.546	0.428
	Radiotherapy	0.324	0.349	0.233
	Dental radiology	0.335	0.322	0.309
	Veterinary radiology	0.681	0.205	0.153
	Industry	0.989	0.498	0.411
	TOTAL	0.454	0.442	0.317

Section 4

Discussion

Number of workers

In the selected 15-year period of individual monitoring no doses above the limit (20 mSv per year) were reported. Majority of the professionals received doses less than 1 mSv/a.
Number of those who received more than 1 mSv per year remained the same through the years (approx. 40), while the total number of TLD users doubled.
This disproportional change affects the number distribution ratio NR_1, that changes from 0.056 in 1999–2003 period to 0.026 in 2009–2013. In 2009–2013 the highest NR_1 among different professions was in interventional radiology (0.167).
This, however, will most likely be changed. Preliminary results, for period 2014–2017, showed that PET-CT procedures could give rise to occupational doses in nuclear medicine.

Annual effective dose

Figure 4 illustrates how annual effective dose (average and median) in FBiH changes from 1999 until 2013 with 5th and 95th percentile bars. The negative correlation is found to be significant (Pearson's correlation test, $p < 0\ 001$). On average, the dose decreases by 0.018 mSv per year. The change is mainly caused by increase in number of workers and significant changes in radiological technologies.

Dental radiology and industry

In dental radiology, however, there have been 2 individuals who received doses above 1 mSv in 2003. This result is unusual, because they both worked with low-dose intraoral x-ray units. One could conclude that two dentists were not following all radiation safety protocols.

NR_E in industry had its maximum value in 1999–2003, when almost all exposed workers were involved in industrial radiography and non-destructive testing of metals. After other workers in industry were issued dosimeters, the relative number of those receiving dose above 1 mSv per year has decreased.

Nuclear medicine

Unlike in diagnostic radiology and radiotherapy, workers in nuclear medicine might be exposed to unsealed sources of ionizing radiation, which are usually in liquid form. This puts them in a risk of radioactive contamination.

Effective doses received by nuclear medicine workers can range widely between different individuals, just like in the case of interventional radiology. The highest doses are received by staff performing daily elution of Mo-99/Tc-99m generator. The range between 5th and 95th percentile was found to be 1.27 mSv during the observed 15-year period.

Industry

The doses in industry have decreased over the years, on average by 0.048 mSv per year. There are two possible reasons, one of them is decline in demand for industrial radiography in the years after the post-war reconstruction in Bosnia and Herzegovina ended, and the other, which is more plausible – more individuals are categorized as exposed workers and issued dosimeters, while their doses are below 0.5 mSv per year.

Section 5

Conclusion

Conclusion

During 1999–2013 no exposed worker in Federation of Bosnia and Herzegovina received a dose above the professional exposure dose limit. The maximum reported dose was 10.4 mSv for a worker in industrial radiography.
In total, the average annual effective dose in 2009–2013 period for all professions in FBiH is 0.317 mSv.
The number of radiologists/radiographers who received doses above 1 mSv in 2009–2013 period dropped from 17 to only 3.
Preliminary results showed that introduction of PET-CT could give rise to occupational doses in nuclear medicine.

Thank you