DOSE ASSESMENT OF OCCUPATIONALLY EXPOSED WORKERS IN MONTENEGRO: AN OVERVIEW

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IAEA-CN-300-Poster ID 103

1. INTRODUCTION

The application of radiation sources is limited mostly to medicine in Montenegro. We estimate there are 80 large X-ray units for conventional radiology, 150 dental ones, 22 CTs, a 22 mammography devices, several bone densitometers, two angiography units, two linear accelerators for radiotherapy) and a newly re-established nuclear medicine department. Most of these are located in public hospitals. As to industry, a few dozen sources are estimated to be used in mining (coal and bauxite), metal processing (steel and aluminum smelting) and gamma-radiography. Lately, veterinary practices are procuring themselves with X-ray units; some 10 of them are currently in operation in the country. There are also about 25 X-ray units for controlling various goods and personal items at border points, airports and maritime ports, as well as in selected state institutions. A few of these are mobile scanners for the control of trucks, containers and general load.

In Montenegro, occupationally exposed individuals are divided into two categories: A (controlled persons) and B (supervised persons). Controlled persons of Category A exchange dosimeters each month of the year and they are required to do medical examination once a year, while dosimeters of supervised persons are read every third month, and they are doing the medical examination every three years. 98 persons belong to Category A (controlled persons). The purpose of this paper is to demonstrate the difference in doses received by occupationally exposed individuals at various workplaces, while performing various medical or non-medical procedures.The number of professionally exposed persons is estimated at 600.

2. INSTRUMENTATION AND METHODS

Thermoluminescent dosimeters (TLD) are routinely used in the monitoring of persons occupationally exposed to ionizing radiation. The TL material used in the Center for Ecotoxicological Research Podgorica (CETI) is based on lithiumfluoride, doped with magnesium (Mg) and titanium (Ti) in small amounts, it has two crystals that are found in compartments with filters that allow determination of equivalent doses H *(10) and H (0.07). Measurement uncertainties for these two charges were expressed with 95 % confidence level and k = 2. i.e. the measured value was surely within the interval. Relative measurement uncertainty was estimated according to references for 5 cards with two chips each and 10 repeated measurements. System for measurement of personal dose equivalent for the whole body is composed of: commercial TLD -100, 4500 dosimeter reader (Harshaw), WinREMS program (Windows based Radiation Evaluation and Management System), TI dosimeter program and irradiator.

3. RESULTS

The number of monitored persons for external radiation in different working fields (medical, industry, veterinary and other fields) in the period from 2014 to 2018, where an increase of 18 % can be observed.To assess doses two methods were applied: *(1) the measurement of the ambient equivalent dose, H*(10) using ionization chambers routinely utilized during workplace monitoring; and (2) the measurement of the personal equivalent dose, Hp(10), using thermoluminescent dosemeters routinely utilized during individual monitoring.* According to the recommendations of the International Atomic Energy Agency (IAEA), persons occupying these working positions should wear two dosimeters. There are several different methods for estimating the dose equivalent with two dosimeters. To estimate the equivalent doses we used one of the most popular methods according to the Niklason et al. (N method) formula:

$$E = 0.06(H_{os} - H_u) + H_u,$$

Where are: H_{os} is equivalent dose is measured with TL dosimeters placed on the surface of lead aprons and H_u is equivalent dose is measured under the lead apron

Table 1. Mean annual dose of occupational groups (Category A) averaged over 5-y periods

Year	Department	Angiography			Cardiology			Nuclear medicine			Radiotherapy		
	Working fields	N	x±sd (mSv)	Max	N	x±sd (mSv)	Max	N	x±sd (mSv)	Max	N	x±sd (mSv)	Max
2014	Physicians	5	2.5±.1.2	4.4	2	4.1±.0.8	4.7	4	1.2±.0.1	1.2	11	0.6±.0.2	0.9
	Nurse	4	1.6±0.7	2.5	0	/	/	0	/	/	0	/	/
	Technicians	*	*	*	2	1.2±0.2	1.4	3	1.2±0.2	1.2	6	0.8±0.2	1.1
	Physicist	0	/	/	0	/	/	0	/	/	4	0.7±0.1	0.9
2015	Physicians	6	3.4±2.8	8.5	2	2.8±.0.1	2.9	4	1.1±.0.2	1.2	11	0.8±.0.3	1.5
	Nurse	5	2.7±2.0	5.9	0	/	/	0	/	/	0	/	/
	Technicians	3	1.1±0.5	1.5	2	1.4±0.3	1.6	3	0.7±0.3	1.2	6	0.8±0.2	1.0
	Physicist	0	/	/	0	/	/	0	/	/	4	08±0.1	1.0
2016	Physicians	6	1.6±0.5	2.1	2	2.4±.0.1	2.9	4	1.0±.0.2	1.0	11	07±.0.2	1.2
	Nurse	5	1.5±0.3	1.8	0	/	/	0	/	/	0	/	/
	Technicians	3	1.0±0.4	1.4	2	2.0±1.4	2.0	3	0.9±0.1	1.0	6	0.7±0.2	0.9
	Physicist	0	/	/	0	/	/	0	/	/	4	0.6±0.1	0.7
2017	Physicians	6	1.7±0.6	2.3	3	1.7±.0.6	2.1	4	0.8±.0.2	1.1	11	0.6±.0.1	0.7
	Nurse	5	1.7±0.6	2.3	0	/	/	0	/	/	0	/	/
	Technicians	3	0.8±0.1	0.9	3	1.8±1.3	3.3	2	0.8±0.1	0.8	6	0.8±0.2	1.3
	Physicist	0	/	/	0	/	/	0	/	/	4	0.7±0.1	0.8
2018	Physicians	6	1.8±0.6	2.3	3	1.4±.0.6	1.7	4	0.8±.0.2	1.1	11	0.7±.0.1	0.7
	Nurse	5	1.1±0.2	1..3	0	/	/	0	/	/	0	/	/
	Technicians	3	0.9±0.1	1.0	3	1.2±0.5	1.4	2	0.9±0.1	0.8	6	0.9±0.2	1.2
	Physicist	0	/	/	0	/	/	0	/	/	3	0.8±0.1	0.8

* they did not carry two dosimeters; **N**-number occupational exposed persons

Table 2. Mean annual dose of occupational groups (Category B)

Year	Department	Hospital		Health Care Centre		Non Medical	
	Working fields	N	x±sd (mSv)	N	x±sd (mSv)	N	x±sd (mSv)
2014	Physicians	26	0.8±0.2	12	0.7±.0.2	0	/
	Technicians	52	0.7±0.2	26	0.8±0.2	46	0.7±0.1
	Physicist	0	/	/	/	0	/
2015	Physicians	26	0.6±0.1	12	0.6±.0.1	0	/
	Technicians	52	0.7±0.5	26	0.7±0.1	46	0.6±0.1
	Physicist	0	/	/	/	0	/
2016	Physicians	26	0.7±0.1	12	0.6±.0.1	0	/
	Technicians	52	0.7±0.2	26	0.6±0.1	46	0.6±0.1
2017	Physicians	26	0.6±0.1	12	0.6±.0.1	0	/
	Technicians	52	0.6±0.1	26	0.6±0.1	46	0.7±0.1
	Physicist	0	/	/	/	0	/
2018	Physicians	26	0.7±0.1	12	0.8±.0.1	0	/
	Technicians	52	0.8±0.1	26	0.8±0.1	46	0.9±0.1
	Physicist	0	/	0	/	0	/

Results of two mentioned groups of exposed persons are shown in Tables 1 and 2. In Table 1 results are shown for 46 exposed workers in Category A in the Clinical Centre of Montenegro for the period beginning 2014 to end 2018. The equivalent dose for occupationally exposed individuals in the department of angiography and cardiology were calculated by using the Niklason formula. The highest doses recorded in one month were 8.5 mSv for physicians and 5.9 mSv nurses in angiography. The highest mean annual dose was found with a practitioner in angiography department, amounting to 3.4 mSv. In the same period, we have analysed 116 exposed persons belonging to Category B in 20 medical institutions in Montenegro (mostly hospitals). These results were obtained as cumulative annual values from individual dose measurements, taking into account individual working conditions of exposed persons. Mean yearly equivalent dose values for medical doctors are 0.7 mSv and 0.8 mSv for technicians/operators. In non-medical sector, doses for operators are similar. The highest mean yearly dose for category B is 1.5 mSv. Tables 1 and 2 shows average values of the annual equivalent dose for the same period in order to determine the differences in doses, which at various work places receive occupationally exposed persons. The results we obtained were compared with internationally recommended limits and were found to be well within.

4.CONCLUSION

Results for all subjects monitored up to now are below internationally recommended dose limits. Since the beginning, through the monitoring of occupationally exposed persons, especially workers who belong to Category A, we have been facing certain problems which include: (i) irregular exchange of dosimeters, (ii) long period of exchange of dosimeters (iii) persons who carry two dosimeters often swap the internal (under the apron) and external dosimeter (above the apron), (iv) insufficient education of occupationally exposed persons in the field of protection against ionizing radiation and (v) lack of confidence in the distribution of reports

INTERNATIONAL CONFERENCE ON OCCUPATIONAL RADIATION PROTECTION (CN-300)
GENEVA, SWITZERLAND; 05-09 SEPTEMBER 2022