A dose estimation for persons occupationally exposed to ionizing radiation in Montenegro

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SUMMARY

Background: *Persons occupationally exposed to ionizing radiation are subject to radiation protection due to potential harmful effects of radiation. Dose monitoring of professionally exposed workers is an essential regulatory measure in radiation protection. In Montenegro, which is a small "non-nuclear" country with population of 670.000, the use of radiation sources is limited to common medical applications and a few industrial ones, with estimated 500-600 occupationally exposed individuals.*

Methods: *Centre for Eco-toxicological Research in Podgorica, acting as a technical support organization to regulatory authorities, is the first and only institution in the country performing personal dosimetry service (since 2007). Initial results, obtained using a Harshaw 4500 TLD reader, and as the results of personal electronic dosimeters DOSICARD readings were summarized in present paper.*

Results: *Average equivalent doses per month are found to be 70.3 μSv for physicians and 82.7 μSv for technicians. The highest dose recorded in one month was 1100 μSv for a RTG technician in Nikšić Hospital.*

Conclusion: *Results for all subjects monitored up to now (medical staff) are below internationally recommended dose limits.*

Key words: *Occupational Exposure; Radiation, Ionizing; Radiation Dosage; Thermoluminescent Dosimetry; Radiation Monitoring; Non-Mesh Montenegro*

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INTRODUCTION

Montenegro is a small, developing and "non-nuclear" country (there are no NPP's or other nuclear facilities, no uranium mines or fuel cycle elements). Currently, there is neither a regulatory authority for radiation protection in the country nor a source register. The application of radiation sources is limited mostly to medicine. We estimate there are 100 large X-ray machines for radiological diagnostics, 300 to 400 dental ones, few CT's, several mammography devices and bone densitometers, one linear accelerator for radiotherapy (6 MeV), with another one on the way, an angiography department and a newly re-established nuclear medicine department. A brachytherapy unit is also likely to be put in operation. As to industry, few dozen sources are estimated to be used in mining (coal and bauxite), metal processing (steel and aluminum smelting) and gamma-radiography. Few sources with low activities are found at the university for teaching purposes.

There is no official evidence of workers who are occupationally exposed to ionizing radiation. An estimated number of 500 to 600 persons, based on radiation sources in operation, seem to be adequate and comparable with same figures in the region (size of the country taken into account).

It is not realistic to expect any substantial change in the above sense in the foreseeable future. It is therefore justified to plan and commensurate radiation protection activities in the country according to these estimations.

In this paper we presented the first results of doses measured with occupationally exposed persons in medical institutions: physicians, medical physicists, nurses, technicians and aid staff. The results we obtained were compared with internationally recommended limits (1-4) and were found to be well within.

As a matter of fact, patients are subject to ionizing radiation applied for their medical treatment too – the benefits of application being judged to largely overweight potential harmful effect. However, patient dosimetry was not the subject of the present work.

In former Yugoslavia the control of radiation sources was effectuated by a federal institution in Belgrade. After constitutional changes in 2003 and independence in 2006, this competence was transferred to relevant ministries in the Government of Montenegro. However, the effectuation (including notification, registration, licensing, inspection, enforcement, regulatory independence, etc.) has not been completed yet.

Legal framework is inherited and still based on old Radiation Protection Law (from 1996) (4) and subsequent regulations. These requirements foresee three modes of monitoring of occupationally exposed persons:

- Direct measurements of absorbed dose rates and beam quality control
- Utilization of thermoluminescent dosimeters (TLD), with their regular readouts
- Regular control of health conditions of the exposed individuals

It should be noted that none of these modes does suffice alone – they should rather be practiced all together.

INSTRUMENTATION AND METHODS

Two groups of absorbed dose measurements are performed.

In the Clinical Centre of Montenegro, Podgorica, 36 occupationally exposed staff members were monitored in the departments of radiological diagnostics, nuclear medicine, interventional radiology, and Institute for Pediatric Diseases from April to November 2007. Personal electronic dosimeters DOSICARDs were used. DOSICARD is a personal electronic dosimeter with silicon diode and direct readout (model DOSICARD/E, manufacturer Canberra Eurisys, Loches, France). Energy range is 50 keV to 2 MeV. System measures equivalent gamma-dose. Personal equivalent gamma-dose is shown in terms of Hp (10), according to ICRU-39 recommendations. Measurement range for the dose equivalent is μSv to 10 Sv, with sensitivity 0.04 counts/s per μSv/h (equals 140 counts/μSv)(5).

It should be noted that electronic dosimetry is not a justified method for regulatory purposes in Montenegro - the same as in many other countries. Electronic dosimeters are useful, but only indicative instruments.

In another 11 medical institutions in Montenegro (mostly hospitals and RTG practices) 57 persons were monitored from April 2007 to April 2008 by thermoluminescent dosimetry. Contrary to electronic dosimetry, TLD is a justified method for regulatory purposes. These measurements were performed by Personal Dosimetry Laboratory, Centre for Eco-toxicological Research (CETI), Podgorica, using Harshaw 4500 TLD Reader. For penetrating external ionizing radiation, personal dose equivalent Hp (10) is now the internationally recommended operational quantity in the field of radiation protection by individual monitoring. Harshaw 4500 TLD Reader operates under WinREMS software control and applies Harshaw Dose Calculation Algorithm. Thermoluminescent material applied is a highly sensitivity lithiumfluoride (LiF: Mg, Ti chips). LiF has an excellent energy response because it is nearly tissue equivalent. Charge values were: TLD-700 chip (0.15 mm thick - 1000 mg/cm) DEEP DOSE and TLD-700 chip (0.15 mm thick - 17 mg/cm) open window SHALLOW DOSE. Measured background was 74.04 μSv; measurement range for absorbed dose was 100 μGy to 1 Gy with good linearity. Fading was determined by using total integral (< 20% in 3 months without correction, < 5% in 3 months with Harshaw fading correction algorithm or glow curve batch deconvolution, < 2% in each additional 6 months - negligible). Calibration factor RCF was 0.025 nC/μSv for the radiation quality determined by IAEA standards (6). According to irradiation protocol, four dosimeters were placed on a water phantom 30 x 30 x 15 cm at 240 cm distance from ^{137}Cs radiation source, with air kerma 1.75 mGy/h (etalon field).

Relative measurement uncertainty was estimated according to references (7,8) for 5 cards with two charges each and 10 repeated measurements. Cs irradiator (2210 Bicron) was used to check response uniformity, with 10 minutes irradiation time. Cards were annealed 24 hours before irradiation and read out 24 hours after it. Results are shown in Table 1. Measurement uncertainties for these two charges were expressed with 95% confidence level and k=2, i.e. the value measured was for sure in the interval $x_s \pm U$ with $U=k{\cdot}s$. Therefore, confidence intervals for the two charges were 21±3 and 21±4 respectively.

Table 1. Estimated relative measurement uncertainties

Expanded measurement uncertainty (%), k=2		
	Deep dose	Shallow dose
Fading 20 %	20.7	20.7
Fading 5 %	7.33	7.74

RESULTS AND DISCUSSION

Results obtained by the two above described dosimetry methods, and for the two mentioned groups of exposed persons, are shown in Tables 2 and 3. These results were obtained as average values from individual dose measurements, taking into account individual working conditions of exposed persons (9-11). We could further conclude that the average equivalent dose for one month period was 70.3 μSv for physicians and 82.7 μSv for technicians. The highest dose recorded in one month was 1100 μSv for a RTG technician in Niksic Hospital. For all of the subjects monitored the doses were well below internationally recommended limits (20 mSv per year) (4).

Table 2. Average month equivalent doses in Clinical Center Podgorica obtained by DOSICARD personal dosimeters in the period April-November 2007

Department	Physicians	Number	Technicians	Number
Nuclear Medicine	83.9 (9.6)	3	94.0 (7.5)	2
Diagnostic radiology	89.7 (4.2)	2	90.1 (12)	7
Radiotherapy	94.0 (0.7)	2	99.1 (1.0)	4
CT	74.0 (4.7)	2	77.6 (1.4)	2
Interventional cardiology	107 (6.1)	4	94.0 (5.0)	4
Institute for pediatric diseases	94.3 (0.5)	2	104 (14)	2

Table 3. Average month equivalent doses in 11 various medical institutions in Montenegro obtained by personal TLD in the period April 2007-April 2008

Profession	Number	Average deep dose (SD) [μSv]	Average shallow dose (SD) [μSv]
Physicians	19	70.3 (13)	72.3 (13)
Technicians	37	82.7 (22)	88.2 (27)
Engineer	1	122	120

CONCLUSION

Besides the fact that the results shown are the first ones for personal dosimetry obtained in Montenegro, they are also reassuring, since none was surpassing allowed dose limits. In cases where doses were elevated above the average, instructions were given to the staff (both workers themselves and their superiors) on how to reduce the exposures.

Conflict of interest

We declare no conflicts of interest.

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