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OCCUPATIONAL EXPOSURE AT RESEARCH REACTORS, ISOTOPE PRODUCTION, AND APPLIED HEALTH PHYSICS IN PAKISTAN DURING 2003-2007

by

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Occupational exposures of radiation workers due to external sources of radiations in three major categories of work *i. e.*, Pakistan Research Reactors (PRR), Isotope Production Plant (IPP) and Applied Health Physics (AHP) were measured using thermoluminescent dosimeters and reported in this article for the period 2003 to 2007. It has been found that average annual effective doses remained in the range of 1.52-3.36 mSv, 0.91-3.19 mSv, and 0.24-2.63 mSv at PRR, IPP, and AHP, respectively, during the said period. All doses are well below the annual dose limit of 20 mSv and found to be comparable with the doses received by the workers in other parts of the world. No over exposure case has been identified during the period. It can be concluded that radiation workers of PINSTECH are well trained and observe the principles of radiation protection. Doses are analogous with UNSCEAR report and other countries of the world, in the same fields.

Key words: thermoluminescent dosimeter, occupational exposure, effective dose, research reactor, isotope production, health physics

INTRODUCTION

The term "occupational exposure" has been used by the International Labour Organization (ILO) referring "exposure of worker during a period of work" [1]. Occupational exposure defined by International Atomic Energy Agency (IAEA) safety standard is "*All exposure of workers incurred in the course of their work, with the exception of exposures excluded from the standards and exposures from practices or sources exempted by standards*" [2]. There are different categories of work in which people may be exposed to ionizing radiation. United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) categorized occupational exposures by the type of radiation work for analysing the exposure data and for better comprehension of the risk associated with the use of radiation [3].

Pakistan research reactors (PRR), isotope production plant (IPP), and applied health physics (AHP) are three major categories of active work at Pakistan Institute of Nuclear Science and Technology (PINSTECH). There are two research reactors at PINSTECH, Pakistan Research Reactor-I (PARR-I) and Pakistan Research Reactor-II (PARR-II). PARR-I, is 10 MW swimming pool type research reactor and is used for research, training of manpower and irradiation of samples. PARR-II is a 30 kW miniature neutron source reactor and is mainly used for neutron activation analysis and teaching purposes. Workers of IPP are involved in the production of ^{131}I, ^{99m}Tc generator, and despatch of radiopharmaceutical kits to all the nuclear medical centres in the country. Health physicists supervise radiation work and enforce radiation protection procedures to ensure that the work is being carried out according to the code of practice issued for the safe use of radiation at institute [4].

Occupational exposure of workers engaged in work at PRR, IPP, and AHP, was measured by Radiation Dosimetry Laboratory (RDL), using thermoluminescent dosimeters (TLD) during the period from 2003 to 2007. Period of five consecutive years has been selected to check compliance with annual as well as five year dose limits (20 mSv averaged over 5 consecutive years, 50 mSv in any single year, during 5 consecutive years and 100 mSv during 5 consecutive years) as recommended by International Commission on Radiological Protection (ICRP) and Pakistan Nuclear Regulatory

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Authority (PNRA) [5, 6]. This paper describes the occupational exposure trend at PRR, IPP, and AHP during the period from 2003 to 2007.

THERMOLUMINESCENT DOSIMETRY

Occupational exposure of radiation workers at the Institute was measured by TLD. TLD is reusable and has a linear dose response over a wide range of photon energies [7]. TLD made by Harshaw (now Thermo) known as TLD 100, 600, and 700 were used in this study. These TLD contain lithium fluoride (LiF) phosphorus in different isotopic compositions making them suitable for measurement of radiation doses due to beta-gamma and neutron radiation [7].

TLD card enclosed in plastic holder was worn by the worker on the chest for the personal dose assessment. Used dosimeters were read on a fully automatic and computerized Harshaw TLD Workstation Model 8800. Hot nitrogen gas was used to heat the TLD in this reader. TL-signal was collected between 110 °C to 300 °C. Normally, dosimeters were found to be zeroed in the normal read out process, however, the dosimeters were re-read to remove any residual signal for better accuracy. Occupational doses were measured in term of $H_P(10)$ by applying conversion coefficient [8, 9]. Doses were corrected for chip-to-chip inherent variations in the sensitivity by employing element correction factors (ECC) and fading factors (FF) of the period for which the dosimeter was used. Value of minimum detectable limit (MDL) and recording level for LiF is 0.01 mSv. In routine, the service was provided on monthly basis. All the steps involved in operating personal monitoring service *i. e*., from dose calculation to preparation of dose reports and maintenance of dose history were carried out using locally developed software RaDLab [10].

Quality assurance

Since 1990 Radiation Dosimetry Laboratory has been participating in "Intercomparison of personal dosimetry exercises" arranged by IAEA at regional and international level to check the accuracy, harmonization of measurement procedure, and for quality assurance. These intercomparison exercises were carried out for the measurement of doses due to low/high energy photons, beta and neutrons in free air, on phantom as well as in mixed field of radiations. Results of RDL, always met the accuracy criteria for personal dosimetry and were found to be within the trumpet curve provided by IAEA for personal dosimetry.

Calibration was carried out in Secondary Standard Dosimetry Laboratory (SSDL), on 30 cm 30 cm 30 cm polyethylene methacrylate (PMMA) water phantom using protection level gamma sources (^{60}Co and ^{137}Cs). SSDL is a member of the IAEA/WHO network of secondary standard dosimetry laboratories. Its measurements are traceable to National Physical Laboratories (NPL), Teddington, UK, and IAEA Dosimetry Laboratory, Austria. SSDL regularly participates in IAEA postal dose intercomparison exercises to check the field irradiation values. Results of SSDL were always in good agreement with IAEA. Neutron calibration was performed on thermal column of 10 MW research reactor (PARR-I).

RESULT AND DISCUSSION

Occupational doses of PINSTECH radiation workers employed in three major categories of work *i. e*., PRR, IPP, and AHP were monitored during 2003-2007 and are discussed here. 50% of radiation workers at PINSTECH are employed in these three categories of work. About 6000 TLD were processed during the period to estimate personal dose equivalent $H_p(10)$ (in short personal dose). In general $H_p(10)$ can provide a good measure of effective dose without underestimation or excessive overestimation [11]. None of the workers received neutron dose during 2003-2007. Table 1 depicts the number of radiation workers in the said categories of work along with their annual average doses on yearly basis during 2003-2007. It can be seen that annual average effective dose (AAED) of workers remained in the range of 1.52-3.36 mSv, 0.91-3.19 mSv, and 0.24 -2.63 mSv, at PRR, IPP, and AHP, respectively. All the workers received doses well below the annual limit of 20 mSv. Comparison of AAED values among PRR, IPP, and

Table 1. Number of monitored workers and their AAED at PRR, IPP, and AHP during 2003-2007

Year	Category	Number of monitored workers	Annual average effective dose [mSv]
2003	PRR	54	1.52
	IPP	31	0.89
	AHP	15	0.30
2004	PRR	54	3.15
	IPP	31	1.64
	AHP	16	0.24
2005	PRR	52	1.77
	IPP	31	2.97
	AHP	16	1.09
2006	PRR	44	2.29
	IPP	37	3.03
	AHP	17	1.03
2007	PRR	43	3.36
	IPP	39	2.99
	AHP	17	2.63

AHP showed the highest value in PRR followed by IPP, and then AHP. Workers at PRR received relatively higher doses because of repair and maintenance of the reactor, disposal of active resins used in the pool water demineralising unit, regeneration of recirculation demineraliser and larger number of irradiated samples in 2004 and 2007 [12]. AHP workers received relatively lower doses than PRR and IPP. This was expected because workers at AHP mainly supervise the radiation work for the radiological safety of workers and all are well aware of radiation protection practices.

To see the dose distribution in a more explicit way, number of workers of PRR, IPP, and AHP were distributed in predefined effective dose intervals as per pattern of UNSCEAR report [3]. Tables 2, 3, and 4 depict the number of workers and their AAED in different dose intervals during 2003-2007. It can be seen from these tables that 95%, 96%, and 100% of the workers in PRR, IPP, and AHP, respectively, lies in the dose range of 0.01 mSv to 4.99 mSv. Number of workers towards the high dose ranges is nil. Nobody received dose more than the annual limit of 50 mSv in any single year during 2003-2007 in PRR, IPP, and AHP. Therefore, no over exposure case *i. e*., dose >100 mSv in five years, has been observed in any of the three categories during 2003-2007.

The AAED over the block of five consecutive years at PRR, IPP, and AHP are found to be 2.41 mSv, 2.37 mSv, and 1.06 mSv, respectively, for 2003-2007 (fig. 1). These doses are comparable with the doses received by workers in the same categories of work in other countries. AAED of reactor operation workers at Organic Cooled Research Reactor WR-1 in Canada and Karlsruhe Nuclear Research Centre in Germany, lie in the range of 5.70-9.30 mSv and 2.20-3.17 mSv, respectively, for the period of 1973 to 1978 [13, 14]. While the AAED of health physics workers at Organic Cooled Research Reactor WR-1 in Canada and Karlsruhe Nuclear Research Centre in Germany, lie in

Table 2. Distribution of number of workers and their AAED in various effective dose intervals at PRR during 2003-2007

Year	Categories	Effective dose intervals		
		0.01-0.99 [mSv]	1.0-4.99 [mSv]	5.0-9.99 [mSv]
2003	Workers	7	47	–
	AAED	0.81	1.62	–
2004	Workers	2	46	6
	AAED	0.65	2.80	6.68
2005	Workers	1	51	–
	AAED	0.99	1.78	–
2006	Workers	0	44	–
	AAED	0	2.28	–
2007	Workers	3	35	5
	AAED	0.48	3.23	5.91

Table 3. Distribution of number of workers and their AAED in various effective dose intervals at IPP during 2003-2007

Year	Categories	Effective dose intervals		
		0.01-0.99 [mSv]	0.01-0.99 [mSv]	0.01-0.99 [mSv]
2003	Workers	19	12	–
	AAED	0.37	1.76	–
2004	Workers	8	23	–
	AAED	0.81	1.93	–
2005	Workers	1	26	4
	AAED	0.95	2.59	5.87
2006	Workers	2	33	2
	AAED	0.79	2.92	6.87
2007	Workers	1	37	1
	AAED	0.75	2.97	5.60

Table 4. Distribution of number of workers and their AAED in various effective dose intervals at AHP during 2003-2007

Year	Categories	Effective dose intervals	
		0.01-0.99 [mSv]	1.0-4.99 [mSv]
2003	Workers	14	1
	AAED	0.20	1.72
2004	Workers	16	–
	AAED	0.24	–
2005	Workers	11	5
	AAED	0.67	2.00
2006	Workers	11	6
	AAED	0.68	1.67
2007	Workers	1	16
	AAED	0.77	2.79

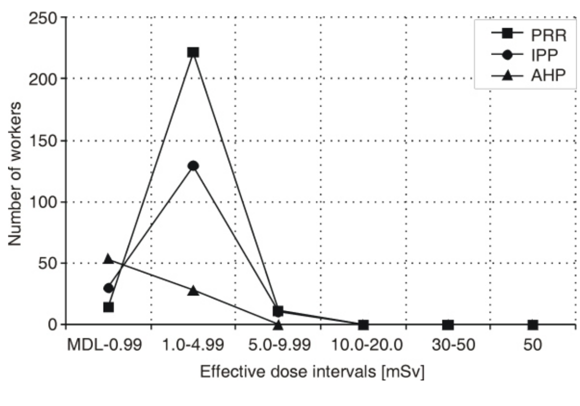

Figure 1. Number of workers in various effective dose intervals in PRR, IPP, and AHP during a block of five years (2003 to 2007)

the range of 2.90-6.50 mSv and 3.48-4.86 mSv, respectively, for the period of 1973 to 1978 [13, 14] AAED values [3] for the workers of IPP are 2.69 mSv for Argentina, 1.98 mSv for India, 2.97 mSv for Hungary, 2.45 mSv for Canada, 1.48 mSv for Thailand, and 4.46 mSv for China, while the world average for isotope production plant is 2.95 mSv during the period of 1994 to 1999 [3]. Values are comparable to Pakistan where the reported value is 2.37 mSv during 2003-2007.

CONCLUSIONS

Personal dose equivalent $H_p(10)$ due to external sources of radiation was estimated using TLD. Analysis of the data showed that nobody crossed any relevant personal dose limit during 2003-2007. Therefore, it can be concluded that the radiation workers at PINSTECH are well trained and follow the code of practice.

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ПРОФЕСИОНАЛНА ОЗРАЧЕНОСТ У ИСТРАЖИВАЧКИМ РЕАКТОРИМА, ПРОИЗВОДЊИ ИЗОТОПА И МЕДИЦИНСКОЈ ФИЗИЦИ У ПАКИСТАНУ ОД 2003-2007. ГОДИНЕ

У раду је документована професионална озраченост радника услед спољашњих извора зрачења у истраживачким реакторима, постројењима за производњу изотопа и медицинској физици, од 2003. до 2007. године, установљена мерењем термолуминисцентним дозиметрима. Утврђено је да се у овом периоду средња годишња ефективна доза коју приме радници налазила у домену 1.52 mSv – 3.36 mSv за истраживачке реакторе, 0.91 mSv – 3.19 mSv за производњу изотопа и 0.24 mSv – 2.63 mSv за медицинску физику. Све дозе су знатно испод границе годишње дозе од 20 mSv и упоредиве су са дозама које су примили радници у другим деловима света. У овом периоду није утврђен ни један случај прекорачења границе озрачености. Може се закључити да су радници у пољу повишеног зрачења у Пакистанском институту за нуклеарне науке и технологију добро увежбани и да се придржавају начела заштите од зрачења. Дозе су сличне онима у UNSCEAR извештају, као и у другим земљама у свету за ову делатност.

Кључне речи: термолуминисцентни дозиметар, професионална озраченост, ефективна доза, истраживачки реактор, производња изотопа, медицинска физика