ASSESSMENT OF THE AMBIENT DOSE RATE AROUND RESARCH REACTORS BY THERMOLUMINESCENCE DOSIMETERS

by

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Monitoring of radiation levels in and around the nuclear research reactors is essential to safeguarding life and the environment. Background radiation monitoring at the Pakistan Institute of Nuclear Science & Technology (PINSTECH) has been carried out since the early sixties, before the criticality of the 5 MW Pakistan Research Reactor, so as to confirm the safe operation of PINSTECH nuclear facilities. In the present study, ambient dose rate levels were measured around PINSTECH by using TLD–200 (G-2 cards) installed at 15 different locations over a five year period (1998-2002). The mean dose rates for individual locations in the said period ranged from 0.14 0.01 to 0.19 0.03 μSv/h, with a mean value of 0.16 0.03 μSv/h. The cumulative average annual effective dose equivalent spread over 5 years was 204.4 17 μSv. The data were compared with the world and averages in other countries. It was concluded that, from the health hazard point of view, the operation of research reactors and other nuclear facilities at PINSTECH presents no risk to public health.

Key words: environmental radiation, ambient dose rate, annual effective doses, seasonal variation, research reactors, thermoluminescence dosimeter

INTRODUCTION

Humans have been exposed to environmental radioactivity from the beginning of time. Ambient doses normally originate from natural (cosmic/terrestrial) and man-made sources. Cosmic radiation originates from outer space and its intensity in the Earth's atmosphere varies with latitude and, to an even greater extent, with altitude [1]. Terrestrial radiation is emitted from natural radionuclides present in varying amounts in all environmental materials *i. e.* (soils, rocks, air, water, *etc.*). Man-made sources, *i. e.* (fallout from nuclear weapons testing, nuclear accidents, nuclear research laboratories and direct releases from nuclear installations, *etc.*) can also contaminate the environment and increase the level of background radiation [2].

The Pakistan Institute of Nuclear Science & Technology (PINSTECH) is a multinuclear facility where the 10 MW Pakistan Research Reactor (PARR-1), Iodine Production Plant (IPP), 27 kW Pakistan Research Reactor (PARR-2), and Radioactive Waste Management facilities are located.

The PINSTECH site is located at a latitude of 33°39 north and longitude of 73°15 east, Northern Pakistan, its south-eastern fringe 20 km from the federal capital Islamabad which, along with the city of Rawalpindi, is a portion of the Pothohar plateau. The build-up area of the institute quadrangle spreads over nearly 46 000 m^2 and occupies an area of 1.98 km^2 of which 1.58 km^2 is earmarked for the Institute itself and 0.4 km^2 as a residential colony. The population within the 8 km was 80246 (1998 census) with a projected growth rate of 3% to reach ~90236 persons in 2002 [3]. To check the safe operation of the PINSTECH nuclear facilities, a network of 15 thermoluminiscent dosimeters (TLD) stations within 1 km were installed (1998-2002), in order to provide data on the natural background radiation level and determine the contribution of the dose to the public from said sources.

Nowadays, well characterized and calibrated TLD are used worldwide for environmental monitoring, since they can measure doses as low as 0.01 mSv. The advantages of TLD over other techniques are: the linearity of their response to doses, relative energy independence, sensitivity to low doses, reusability, small size, low price and the absence of any need for infield servicing [2, 4].

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In the present study, annual ambient dose rates for the period from 1998 to 2002 were studied and the correlation with different weather conditions presented.

MATERIAL AND METHODS

The network consists of 15 field stations installed about 1.5 m above ground, because radionuclides present in the earth and air exert a radioactive radiation influence at this height [5]. These stations are distributed within and around the PINSTECH boundary, with a distance of 98-793 m from the reactor stack center (60 m in height), as shown in (fig. 1). Stations have also been set up all along the boundary, designed so as to register the radioactive cloud from all directions [5].

Each field station consists of 3 sets of TLD. All the dosimeters were wrapped in polythene sheets to avoid any contamination. These were placed in a Perspex holder and then installed at their specific locations. The TLD are made of calcium fluoride and activated with dysprosium (CaF_2: Dy). They are commercially available as TLD-200 (G-2 card) and manufactured by the HARSHAW Chemical Company (USA) [6]. Each environmental dosimeter contained two TLD chips. All TLD were annealed at 400 °C for 1 hour, followed by 2 hours at 100 °C, so as to eliminate all residual signals without affecting TLD sensitivity. The cards were calibrated by using the irradiation facility of the Secondary Standard Dosimetry Laboratory (SSDL) with a ^{137}Cs source. After irradiation, the TLD were stored in the dark at room temperature (26 °C to 28 °C) for 24 hours. The cards were read using a TLD reader (HARSHAW 2000-B TLD System) under a flow of nitrogen gas at a constant pressure [2, 7].

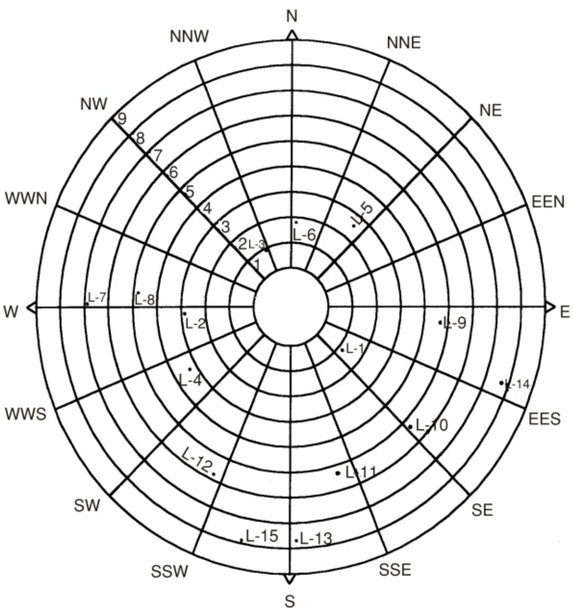

Figure 1. Location map for measurement of ambient dose rate by TLD around the PINSTECH boundary

The installed TLD were routinely replaced with new ones every three months. The collection of old TLD and their replacement with new ones is a simultaneous process. The replaced cards were evaluated and results compiled.

RESULTS AND DISCUSSION

The field stations are denoted by code numbers from L-1 to L-15, as shown in fig. 1. Measured ambient dose rates are listed in tab. 1. It shows that the mean dose rates ranged from 0.14   0.01 to 0.19   μSv/h,with a mean value of 0.16   0.03 μSv/h which is twice as high as the background level of 0.08   μSv/h. The background level was based on the shutdown period of PARR-1, from November 1990 to October 1991, during which it was upgraded from 5 MW to 10 MW [3].

Table 1. Ambient dose rate [Svh^{-1}] for a period from 1998 to 2002

Location	1998	1999	2000	2001	2002	MEAN	S.D.
L-1	0.16	0.14	0.13	0.14	0.15	0.14	0.011
L-2	0.16	0.12	0.15	0.15	0.14	0.14	0.015
L-3	0.13	0.14	0.18	0.16	0.17	0.15	0.021
L-4	0.18	0.15	0.18	0.18	0.16	0.17	0.014
L-5	0.13	0.1	0.14	0.19	0.28	0.16	0.070
L-6	0.13	0.12	0.16	0.18	0.2	0.15	0.033
L-7	0.17	0.15	0.17	0.21	0.23	0.18	0.033
L-8	0.2	0.15	0.18	0.21	0.22	0.19	0.028
L-9	0.12	0.11	0.13	0.21	0.21	0.15	0.050
L-10	0.13	0.11	0.14	0.21	0.24	0.16	0.056
L-11	0.12	0.13	0.16	0.24	0.23	0.17	0.056
L-12	0.13	0.14	0.17	0.22	0.23	0.17	0.045
L-13	0.16	0.09	0.16	0.18	0.2	0.15	0.041
L-14	0.16	0.12	0.17	0.21	0.19	0.17	0.034
Mean	0.16	0.12	0.16	0.19	0.20	0.16	0.033

The results of annual effective ambient dose along with the distance and direction from the stack (center) around the PINSTECH boundary are given in tab. 2. The annual effective dose equivalent was estimated using the following formula [8]

D_{eff} = outdoor doses   occupancy factor   effective dose equivalent   total time:
D_{eff} = outdoor dose (nGy/h)   0.2   0.7 (Sv/Gy)   8 760 (h/year).

where 0.2 is the outdoor occupancy factor, 0.7 Sv/Gy is the quotient of the effective dose equivalent rate to the absorbed air-dose rate, and 8 760 are total hours in a year [8].

Table 2. Annual effective dose (Sv) for a period 1998-2002

S. No.	Location	Direction	Distance [m]	1998	1999	2000	2001	2002	Mean
1	L-1	SE	112	196.2	180.0	162.5	180.9	198.0	183.5
2	L-2	W	285	200.3	155.3	190.9	193.2	171.7	182.3
3	L-3	NNW	98	167.6	171.7	220.8	141.0	208.5	181.9
4	L-4	SW	320	220.8	204.4	223.8	230.0	205.4	216.9
5	L-5	NE	250	167.6	139.0	171.7	242.2	246.5	193.4
6	L-6	N	162	163.5	147.2	205.4	226.9	248.4	198.3
7	L-7	W	695	249.4	188.1	220.8	257.5	275.9	238.3
8	L-8	W	475	212.6	188.1	211.6	257.5	282.1	230.4
9	L-9	E	483	147.2	143.1	168.6	257.5	263.7	196.0
10	L-10	SE	535	163.5	143.1	153.3	266.7	294.3	204.2
11	L-11	SSE	530	151.3	159.4	205.4	297.4	288.2	220.3
12	L-12	SSW	595	163.5	171.7	205.4	269.8	282.1	218.5
13	L-13	S	770	204.4	118.6	196.2	223.8	251.4	198.9
14	L-14	EES	745	196.2	151.3	211.6	263.7	233.0	211.1
15	L-15	SSW	793	122.6	110.4	199.3	251.4	279.0	192.5
Mean				181.8	158.1	197.0	237.3	248.5	204.4
Standard deviation				33.1	26.2	22.5	40.0	37.8	17.5
Range (min.-max.)				122.6-249.4	110.4-204.4	153.3-223.8	141.0-297.4	171.7-294.3	181.9-238.3

The annual dose ranges from 110.4 to 297.4 μSv, with the mean value of 204.4   17 μSv. It is evident from the data that the dose rate at the same location varied from year to year. This variation may be attributed to different levels of cosmic rays in different seasons/weather conditions. A gradual increase in the trend of the data has been observed for the annual mean values from 1998 to 2002. However, in 1999, a slight decrease was observed.

The results for each location are summarized in fig. 2 showing a comparison of the annual effective dose in terms of maximum, minimum, and average values at each location throughout the study period. Figure 2 depicts that the location-wise dose values do not show any definite pattern, although slight random variations were observed. These variations may be due to seasonal fluctuation in soil moisture balance, meteorological conditions, as well as the variability inherent in the placement, preparation, and calibration of TLD [2]. In addition to these factors, predominant wind direction, annual release and distance from the PARR-I stack also affect the ambient dose measured at these locations [9].

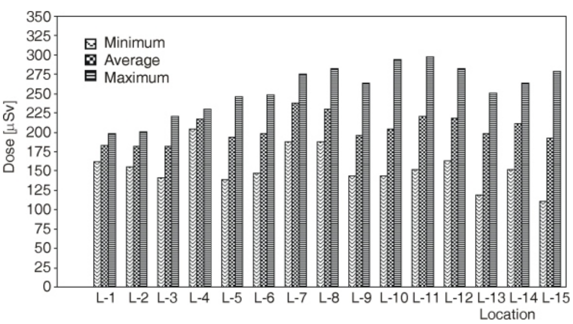

Figure 2. Comparison of annual effective dose of each location from 1998 to 2002

Location-wise analysis indicates that the maximum ambient dose was found for field stations L-11 and L-10. Perhaps this is due to the distance of these field stations from the stack, *i. e.* 530 m with a SSE and 535 m with a SE direction, respectively, as well as to the fact that these sites are located near the Radioactive Waste Management site and PARR-2. Figure 2 also shows that L-12, L-15, L-8, and L-7 have nearly equal values at different distances and directions than other locations. This maybe due to the fact that these stations are located at the most dominant wind directions *i. e.* W and SSW.

The four individual sites, L-1, L-2, L-3, and L-4, with different distances and directions, are located within the internal boundary of the PINSTECH buildings. They show a sequence of increasing ambient dose with respect to the distance from the stack (center) of PARR-I, because releases from the stack increase the dose level at farther distances within the limited area (1120 m is max. vicinity area), [9, 10] and the same sequence is shown at field stations L-5, L-6, L-13, L-14, and L-9, located at the external boundary of the PINSTECH buildings. L-9, with a distance of 483 m and L-14, with a distance of 745 m at an E and EES direction, respectively, and the remaining sites also show the same trend of equal distribution of the dose at PINSTECH as shown in fig. 2.

A typical quarterly maximum, minimum, and average variation in the ambient dose rate for the pe-

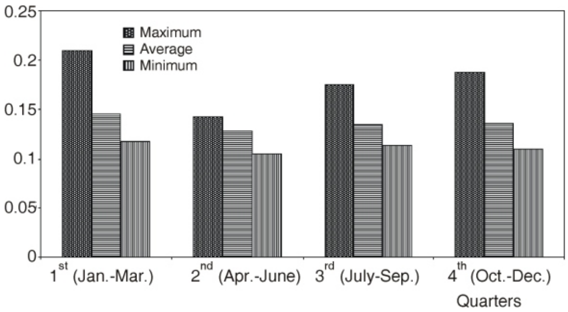

Figure 3. Quarter wise comparisons from 1998 to 2002

riod from 1998 to 2002 is shown in fig. 3. There are many factors which distort the dose rate under the influence of the meteorological or synoptical situation or local sources of radionuclides and carriers from remote sources, *etc*. [5]. On the basis of this study, the average annual effective dose for different quarters was found to be in the following order: $1^{st} > 4^{th} > 3^{rd} > > 2^{nd}$. This is due to the fact that the 1^{st} (January-March) and the 4^{th} (October-December) quarters are mainly winter/autumn seasons in which the cold weather may affect the dose rate for two reasons. Firstly, the winter monsoon, in which air downpour brings natural radionuclides present in the higher atmosphere down to the ground. Heavy precipitation of radionuclides results in higher concentrations of radon daughters and their activity at ground level. Secondly, due to low temperatures (3.9 °C to 32.7 °C), the cool stable layer of air in the lower atmosphere tends to limit the dispersion of natural airborne radionuclides [11]. These factors result in the increase of the ambient dose rate during the winter season. The 2^{nd} (April-June)0 and $3r^{d}$ (July-September) quarters are mainly spring and summer months of the year with temperatures ranging from (17 °C to 39.7 °C). In contrast to the winter season, during summer months air streams are warm and mostly of maritime origin and contain less radioactivity [11]. Thus, the lowest ambient radiation level is to be expected during these quarters.

A comparison of the present study with similar works using the TLD technique reported in literature in countries around the world is given in tab. 3. In the case of Hong Kong [11] and Italy [12], the mean values of the absorbed dose per hour are converted to an annual rate. Table 3 shows that the present measured value is less then that of Italy, India [9], Bangladesh, Iran, China, Japan, Denmark, and the world average [13]. The value acquired in this study is slightly higher than that of Hong Kong. All these countries have comparable results, with the exception of China, Iran, and Bangladesh, where the values were found to be higher than those reported for Pakistan and other countries worldwide.

CONCLUSION

The measured values of annual effective ambient dose at PINSTECH range from 110 to 297 μSv, with the mean value of 204 μSv for the study period from 1998-2002. These values are less than world average values. They are, thus, safe and pose no significant health hazard. On the basis of this TLD study, it was concluded that the operation of research reactors and other nuclear facilities at PINSTECH pose no health hazard.

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Table 3. Comparison of the present study with different countries of the world

Name of country	Latitude	Longitude	Annual dose [μSv]	Reference
Hong Kong China	22.11 N	114.14 E	140.54	Wong *et al*., (1996)
North west Italy	41.54 N	12.29 E	753.36	Losana *et al*., (2001)
India (RAPS)	28.37 N	77.13 E	765	Basu *et al*., (1999)
Dhaka, Bangladesh	30.16 N	90.52 E	1576	Miah, M. I., (2001)
Isamabad, Pakistan	30.00 N	70.00 E	204.4	Present study
Ramser, Iran	36.54 N	50.40 E	10.200	UNSCEAR, (2000)
Yangjiang, China	39.55 N	116.20.E	3510	UNSCEAR, (2000)
Japan	36.00 N	138.00 E	430	UNSCEAR, (2000)
USA	39.91 N	77.02 W	400	UNSCEAR, (2000)
Denmark	55.41 N	12.34 E	330	UNSCEAR, (2000)
World average	–	–	390	UNSCEAR, (2000)

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ОДРЕЂИВАЊЕ ЈАЧИНЕ АМБИЈЕНТАЛНЕ ДОЗЕ ОКО ИСТРАЖИВАЧКИХ РЕАКТОРА ПОМОЋУ ТЕРМОЛУМИНИСЦЕНТНИХ ДОЗИМЕТАРА

Надгледање нивоа зрачења у истраживачким нуклеарним реакторима и око њих незаобилазно је у обезбеђивању живота и животне средине. Контрола зрачења из природе у Пакистанском институту за нуклеарне науке и технологију спроводи се од раних шездесетих година, пре достизања критичности пакистанског истраживачког реактора снаге 5 MW, са намером да се утврди сигуран рад институтских нуклеарних постројења. У овом раду, приказана су мерења нивоа јачине амбијенталне дозе око Института помоћу дозиметара типа ТЛД-200 (Г-2 карта) постављених на 15 различитих места у периоду од пет година (1998-2002). Средња јачина доза на појединим местима у назначеном периоду износила је од 0.14 0.01 до 0.19 0.03 Sv/h, са средњом вредношћу од 0.16 0.03 μSv/h. Кумулативна средња годишња, ефективна еквивалентна доза, која се односи на пет година, била је 204.4 17 Sv. Подаци су упоређени са светским и средњим вредностима у другим земљама. Закључено је да са гледишта здравственог ризика, рад нуклеарних реактора и других нуклеарних постројења у Институту не представљају опасност за здравље становништва.

Кључне речи: зрачење из природе, јачина амбијенталне дозе, годишња ефективна доза, сезонска промена, истраживачки реактор, термолуминисцентни дозиметар