PINSTECH-198

First National Intercomparison of Personal Dosimetry for Dosimetry Service Providers in PAEC
(PINST/INT/9/01/2005-06)

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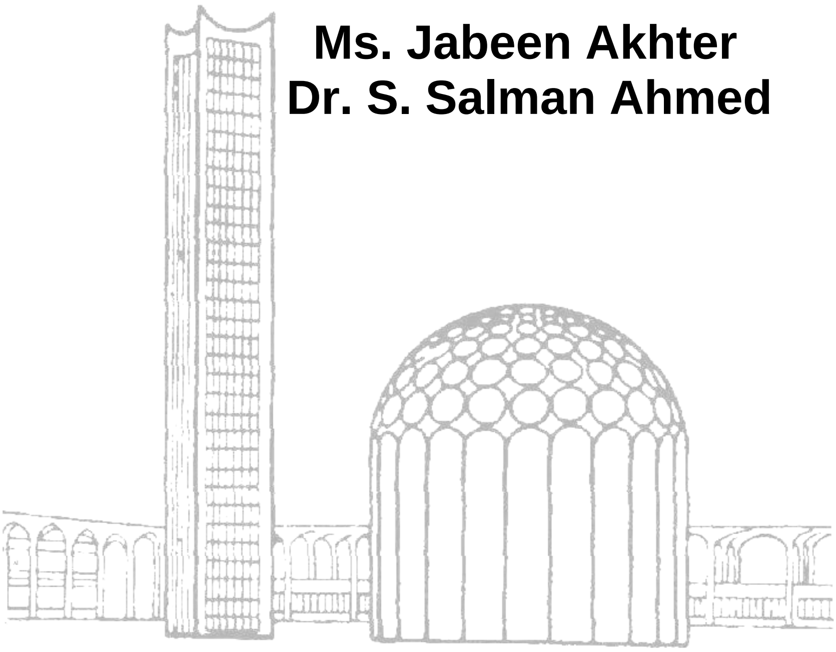

Approved by
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ABSTRACT

Health Physics Division, PINSTECH, has conducted an intercomparison exercise for PAEC organizations which are responsible for providing personal dosimetry services for the assessment of occupational doses of radiation workers. The exercise was on voluntary basis and it was designed to harmonize the procedure of individual dose monitoring techniques in terms of new ICRP operational quantities of personal dose equivalent H_p (10) for photons. Cobalt-60 and Cesium-137 protection level sources were used for irradiation. The dosimeters were exposed to radiation in the range of 0.46 to 24.20 mSv. Irradiations were performed in Secondary Standard Dosimetry Laboratory (SSDL) at HPD, PINSTECH according to IAEA/WHO standards. The performance of the participating laboratories was judged by trumpet curve that provides the acceptable limits on overall accuracy for occupational dose monitoring at 95% confidence level according to international standards. The response of measured dose/standard true dose (H_m/H_t) lies in the range of 0.66 to 1.11 for ^{60}Co and 0.84 to 1.17 for ^{137}Cs. This report describes the procedure and results of the intercomparison exercise.

1. INTRODUCTION

Radiation Dosimetry Group of Health Physics Division (HPD), PINSTECH has been participating in IAEA & IAEA/RCA projects of intercomparison of personal dosimeters since 1990. These intercomparisons were intended for dosimetry laboratories, responsible for providing the external Radiation Dosimetry Services. The group has participated in more than ten intercomparison exercises of personal dosimetry arranged by IAEA at regional and international level. These intercomparison exercises were carried out for the measurement of doses due to beta, gamma and neutrons in air, on phantom as well as in mixed field of radiation.

After acquiring relevant experience in the field of personal dosimetry, Health Physics Division PINSTECH conducted an intercomparison exercise in the field of personal dosimetry within the country. The objectives of the intercomparison were [1, 2].

- To disseminate knowledge in the field of personal dosimetry to other service providers.
- To assess the personal doses in terms of new operational quantities H_p (10).
- To achieve/ensure the harmonization of results.
- To provide access to the participants to standardize radiation qualities for calibration of their dosimetry systems.

Keeping in view of the above objectives, PINSTECH invited all the representatives of PAEC service providers' institutes to participate in the intercomparison of personal dosimetry. Four establishments from Pakistan Atomic Energy Commission (PAEC) participated in the exercise, out of which one establishment did not submit the final results. To initiate the intercomparison programme a one-day meeting of the representative/participants from the above-mentioned establishments was arranged at HPD, PINSTECH. The agenda of this meeting was:

- To discuss the feasibility/schedule of intercomparison
- To discuss current status of personal dosimetry and associated problems
- Any other relevant issue

In the meeting, contact persons/technical coordinators were selected to conduct the technical work for the intercomparison from their respective institute. The participating laboratories were registered. Annexure ‘A’ is the registration form. Code numbers were assigned to every participating laboratory to keep all the correspondence/work/results of individual laboratory under a confidential cover without mentioning the name of the institute.

Before starting the irradiations a questionnaire was sent to each participating laboratories to obtain the information regarding the type of personnel dosimeter employed, their characteristics, the calibration procedures and use of radiological quantities for Personal Dose monitoring results etc. [2]. Annexure ‘B’ is the questionnaire.

2. DESCRIPTION OF THE INTERCOMPARISON PROGRAMME

2.1 Dosimeters

For intercomparison exercise, each laboratory was asked to send 25 personal dosimeters enclosed in the proper holders of the type, being used in their routine personal dose monitoring service. Out of which 15 dosimeters were exposed to gamma radiation (^{60}Co and ^{137}Cs sources) on different dose levels at Secondary Standard Dosimetry Laboratory (SSDL), PINSTECH. Five were kept as “reserved” dosimeters and the remaining five were used for the measurements of “Transportation dose/Controls”. Annexure ‘C’ depicts the identification/scheme of dosimeters. After irradiation all the dosimeters were returned to their respective institutes.

2.2 Irradiation Laboratory

All the irradiations were performed at Secondary Standard Dosimetry Laboratory (SSDL) at HPD, PINSTECH. SSDL is a member of the IAEA/WHO network of Secondary Standard Dosimetry Laboratories. Its measurements are traceable to NPL, Teddington UK and IAEA dosimetry laboratory, Austria. SSDL regularly participates in IAEA Postal Dose Intercomparison exercises. In a recent IAEA/RCA Intercomparison of Personal Dosimetry Project RAS/9/018 conducted by JAERI, JAPAN to check the field reference value of irradiation at regional level by Glass Dosimeters, the results of SSDL, PINSTECH were declared, “The Best” by JAERI-Japan with the 0.19% deviation from the target value among the fifteen laboratories of the region [3]. All irradiations in this intercomparison were performed according to international standards as per recommendation of IAEA.

2.3 Radiation Sources

The Protection level ^{137}Cs and ^{60}Co gamma sources were used for irradiating the dosimeters. Sets No. 1 & 2 were exposed to ^{60}Co (1173.2 keV 1332.5 keV) while Sets No. 3, 4 & 5 were exposed to ^{137}Cs source (662 keV). At the time of irradiation of dosimeters the activity of ^{60}Co source was 3.182×10^{9} Bq having the dose rate of 1.083 mGy/hr at the distance of one meter, while the activity of ^{137}Cs source was 4.81×10^{11} Bq having the dose rate of 35.81 mGy/hr at the distance of one meter. Annexure 'C' depicts the Identification/Scheme of Dosimeters for irradiation.

2.4 Irradiation Conditions

All the dosimeters were exposed to radiation in air under the same condition. The radiation field size at dosimeter irradiation position was 45×45 cm^2 and source to dosimeters distance was one meter. The beam geometry was horizontal. The centre of the radiation beam was set by laser beam while the side laser beam was used for the setting of distances. The dosimeters were aligned in the central area of the beam. The values of H_p (10) were obtained from the values of exposure (air kerma) by multiplication of the conversion factors recommended by the ICRU for photon energies [4].

2.5 Phantom

ICRP/IAEA Polymethyl Meth acrylate (PMMA) water Phantom was used for the irradiation of dosimeters. The dimensions of the phantom were 30x30x30 cm^3. The dosimeters were kept on the front surface of phantom at the distance of one meter from the centre of the radiation beam. The positions of dosimeters were perpendicular to the beam area and they were fixed in Styrofoam.

3. RESULTS AND DISCUSSION

The results of all laboratories were analyzed on the basis of Trumpet Curve. Trumpet curve defines the maximum positive and negative percentage deviation from the True/Standard dose values and provides the acceptable limits on overall accuracy / performance for occupational dose monitoring at 95% confidence level according to international standards. It is not only a general requirement but also a performance test on the precision of dose measurement. Therefore, analyzing the results in term of this curve provided the performance/accuracy of the different laboratories in the field of personal dosimetry. Figure-1 is a typical Trumpet curve for photons. This curve is described by the following expression [5, 6].

$$\left[\frac{H_m}{H_t}\right]_{UpperLimit} = 1.5\left[1+\frac{H_0}{2H_0+H_t}\right]$$

and

$$\left[\frac{H_m}{H_t}\right]_{LowerLimit} = \frac{1}{1.5}\left[1-\frac{2H_0}{H_0+H_t}\right]$$

or more explicitly

$$\frac{1}{1.5}\left[1-\frac{2H_0}{H_0+H_t}\right] \le \frac{H_m}{H_t} \le 1.5\left[1+\frac{H_0}{2H_0+H_t}\right]$$

Where

$$1.5 \ge H_m/H_t \ge 1/1.5 \text{ for } H_t \approx H_a = 20\ mSv)$$

$$2.0 \ge H_m/H_t \ge 0 \text{ for } H_t = H_r,\quad H_r \ge 0.085 mSv.$$

H_0	*The lowest dose for which trumpet curve can be used, taken as 0.085 mSv*
H_m	*Measured / Reported dose*
H_t	*True /Standard delivered dose*
H_a	*Dose limit for the period of one year*
H_r	*Minimum recording level for the period of one month*

The doses measured by laboratory No. 01 are summarized in Table-1. The response H_m/H_t (measured dose/standard delivered dose) lies in the range of 0.90 to 1.11 All the doses measured by laboratory No. 01 were on higher side than the standard true dose value except for the category-2 (1.91 mSv) where the measured dose was on lower side than the standard true dose. The analysis of the results provided the minimum -10% and maximum +11% deviation from the true/standard dose values. All the results lie within accuracy curve (Trumpet curve) and there is no outlier. All the data points are in the good agreement with the coordinating laboratory. Figure 2 shows the performance/accuracy curve for laboratory No. 01.

The laboratory No. 02 did not submit the final result.

The results of the laboratory No. 03 are summarized in Table-2. The response H_m/H_t lies in the range of 0.66 to 1.17. The results measured by laboratory No. 03 for the categories 1 & 2 (0.46 & 1.91 mSv) were on lower side when compared with the standard true dose values while all other measured doses were on higher side than the standard dose values. The analysis of the results provided the minimum -34% and maximum +17% deviation from the true/standard dose values. All the results lie within performance accuracy curve and are in good agreement with the coordinating laboratory. Figure 3 shows the performance/accuracy curve for laboratory No. 03

The results measured by laboratory No. 04 are depicted in Table-3. The response H_m/H_t lies in the range of 0.82 to 0.96. All the values measured by the laboratory No. 04 both in case of ^{137}Cs and ^{60}Co sources were on lower side than the standard true doses delivered at SSDL, PINSTECH however, lie within the performance accuracy curve and are in good agreement with the coordinating laboratory. The analysis of the results provided the minimum -18% and maximum -04% deviation from the true/standard dose values. Figure 4 shows performance/accuracy curve for laboratory No. 04.

The overall response (H_m/H_t) for measurements of doses in case of ^{60}Co and ^{137}Cs sources, for all the participating laboratories lies in the range of 0.66 to 1.11 and 0.84 to 1.17 respectively. Figure 5 and Figure 6 are the overall distribution of intercomparison results of all the participating laboratories for ^{60}Co and ^{137}Cs sources in term of trumpet curve respectively. Figures 7, 8 and 9 are the graphical representation of measured doses/standard true doses against radiation fields (^{60}Co and ^{137}Cs) of laboratory No. 01, 03 and 04 while, Figures No. 10 & 11 depicts the graphical representation of overall response of H_m/H_t for ^{60}Co and ^{137}Cs sources respectively. The analysis of data indicated that participants measured the doses relatively more accurately in the case of ^{137}Cs than ^{60}Co. Cesium-137 being a mono energetic beam quality provided the best results.

All the participating laboratories met the 1/1.5 to I.5 range of trumpet curve requirement for all different categories of doses. [7]. The laboratory No. 01 under estimated the dose only in case of category 2 (1.91 mSv), while all other doses were over estimated than the standard true dose values delivered at SSDL. The laboratory No. 03 under estimated the low dose categories both in case of set Nos. 1 & 2 (0.46 &

1.91 mSv), while all other doses were over estimated. The laboratory No. 04 under estimated all doses both in case of ^{137}Cs and ^{60}Co for all the five categories.

From the radiation protection point of view, to assess the dose on the higher side (over estimation) than the delivered true dose value is considered good than the assessment of dose on the lower side (under estimation) from the true dose value. As it can be seen from the trumpet curve that provides minimum -30% and maximum +50% deviation from the true/standard dose value at 10 mSv. The laboratory No. 01 & 03 under estimated the three & six readings, out of fifteen respectively, while Laboratory No. 04 under estimated all the fifteen reading of low and high doses. In such a situation it is recommended to obtain a correction factor and apply to improve the efficiency and accuracy in the measurement of low or high doses categories wherever it is needed in the field of personal dosimetry.

It was recorded by the questionnaire completed by the participants that every laboratory is using different type of Thermoluminescence dosimeters (TLD) for the measurement of personal doses. It is a good practice because Thermoluminescence dosimetry is reliable, efficient and accurate technique of dose monitoring. All the laboratories used ^{60}Co and ^{137}Cs sources for calibration. Only one laboratory used ^{90}Sr source for calibration. (This laboratory didn't complete the exercise). The maximum total estimated uncertainty in irradiation at SSDL was of the order of $\pm$2.8%. Table-4 summarizes the results of first national intercomparison exercise.

4. CONCLUSION

The following intended basic objectives were achieved through this intercomparison:

- Education and creating awareness among the service providing personnel in the field of personal dosimetry for measurement of occupational doses according to international standards.

- Measurement of personal doses of workers in terms of new ICRP operational quantities of personal dose equivalent H_p (10) for high energies photons.

- Harmonization of procedure of individual dose monitoring at country level.

As a result of this exercise, all the participating laboratories were in a position to express their dose results in terms of H_p (10) as recommended by ICRP/IAEA for personal dosimetry. Before this Intercomparison all the laboratories were expressing their results in terms of effective dose and the unit used was μSv, mGy and mrem. The low as well as high doses were measured quite satisfactorily for high energy photons.

5. RECOMMENDATIONS

- A second Intercomparison exercise should be conducted for low and high energy photons.

- The participating laboratories may obtain correction factors from this Intercomparison to improve their dose estimation in future.

- The new ICRP operational quantities of personal dose equivalent i.e. $H_p(10)$ may be used for personal dose assessment in future.

6. ACKNOWLEDGEMENT

The authors wish to express their thanks to Dr. M. Jahangir, DG, PINSTECH for his administrative and financial support. Thanks are also due to all the members of Radiation Dosimetry and Secondary Standard Dosimetry laboratories of Health Physics Division, PINSTECH for their help and carrying out the technical work during the exercise.

7. REFERENCES

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Table-1

Dose Values Reported/Measured By Laboratory No. 01

Dosimeter	Radiation Quality	Standard/Delivered Dose H_p (10)	Reported Dose H_p (10)	Result/ Response	Status
ID	keV	mSv	mSv	Quotient Q (Reported/Standard)	
1-1	^{60}Co (1250)	0.46	0.48	1.04	OK
1-2			0.47	1.02	OK
1-3			0.51	1.11	OK
2-1	^{60}Co (1250)	1.91	1.73	0.90	OK
2-2			1.86	0.97	OK
2-3			1.82	0.95	OK
3-1	^{137}Cs (662)	7.26	8.03	1.11	OK
3-2			7.79	1.07	OK
3-3			7.37	1.02	OK
4-1	^{137}Cs (662)	16.34	16.94	1.04	OK
4-2			17.80	1.09	OK
4-3			17.34	1.06	OK
5-1	^{137}Cs (662)	24.20	24.71	1.02	OK
5-2			25.61	1.06	OK
5-3			24.63	1.02	OK

Table-2

Dose Values Reported/Measured By Laboratory No. 03

Dosimeter	Radiation Quality	Standard/Delivered Dose H_p (10)	Reported Dose H_p (10)	Result/ Response	Status
ID	keV	mSv	mSv	Quotient Q (Reported/Standard)	
1-1	^{60}Co (1250)	0.46	0.44	0.96	OK
1-2			0.43	0.93	OK
1-3			0.30	0.66	OK
2-1	^{60}Co (1250)	1.91	1.76	0.92	OK
2-2			1.71	0.89	OK
2-3			1.69	0.89	OK
3-1	^{137}Cs (662)	7.26	7.42	1.02	OK
3-2			7.62	1.05	OK
3-3			7.76	1.07	OK
4-1	^{137}Cs (662)	16.34	19.12	1.17	OK
4-2			17.69	1.08	OK
4-3			17.28	1.06	OK
5-1	^{137}Cs (662)	24.20	25.54	1.06	OK
5-2			26.93	1.11	OK
5-3			26.65	1.10	OK

Table-3

Dose Values Reported/Measured By Laboratory No. 04

Dosimeter	Radiation Quality	Standard/Delivered Dose H_p (10)	Reported Dose H_p (10)	Result/ Response	Status
ID	keV	mSv	mSv	Quotient Q (Reported/Standard)	
1-1	^{60}Co (1250)	0.46	0.41	0.90	OK
1-2			0.39	0.84	OK
1-3			0.41	0.89	OK
2-1	^{60}Co (1250)	1.91	1.70	0.89	OK
2-2			1.56	0.82	OK
2-3			1.83	0.96	OK
3-1	^{137}Cs (662)	7.26	6.52	0.90	OK
3-2			6.07	0.84	OK
3-3			6.38	0.88	OK
4-1	^{137}Cs (662)	16.34	14.07	0.86	OK
4-2			13.95	0.85	OK
4-3			14.70	0.90	OK
5-1	^{137}Cs (662)	24.20	21.99	0.91	OK
5-2			20.59	0.85	OK
5-3			21.98	0.91	OK

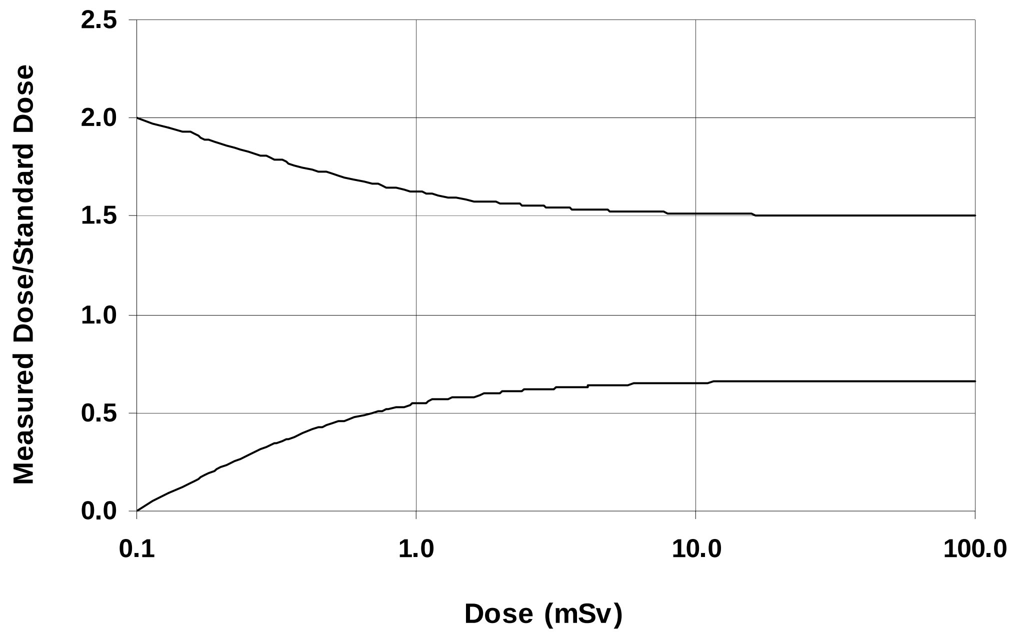

Figure-1: - Typical Trumpet Curve for Photons.

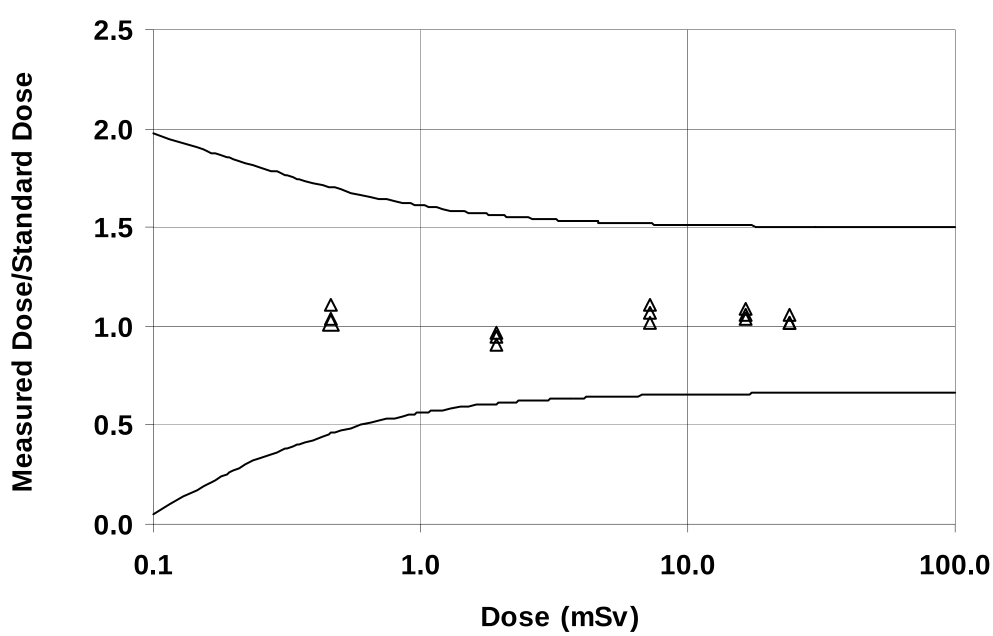

Figure-2: - Performance/Accuracy Curve of for Laboratory No. 01

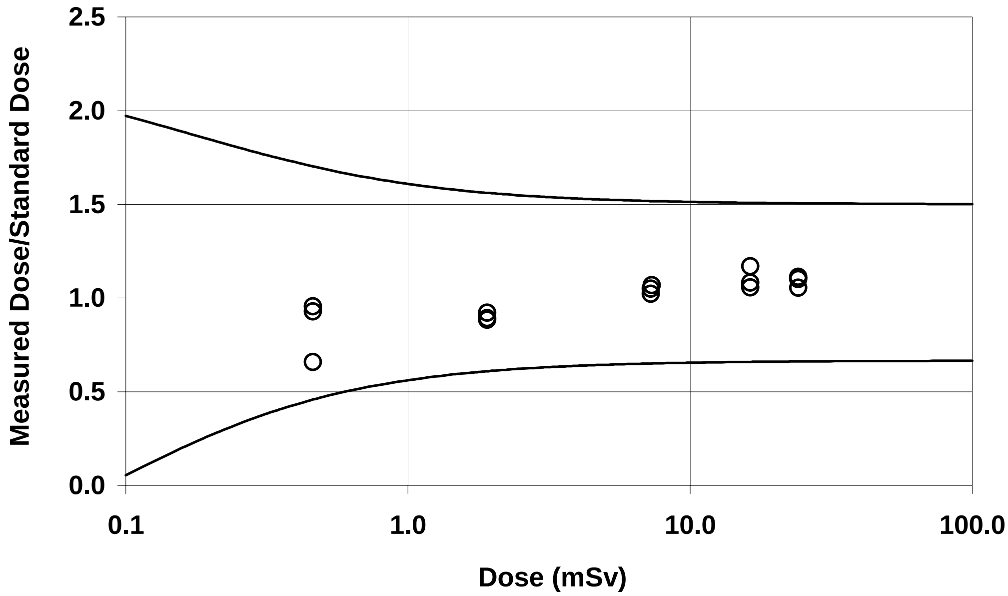

Figure-3: - Performance/Accuracy Curve for Laboratory No. 03

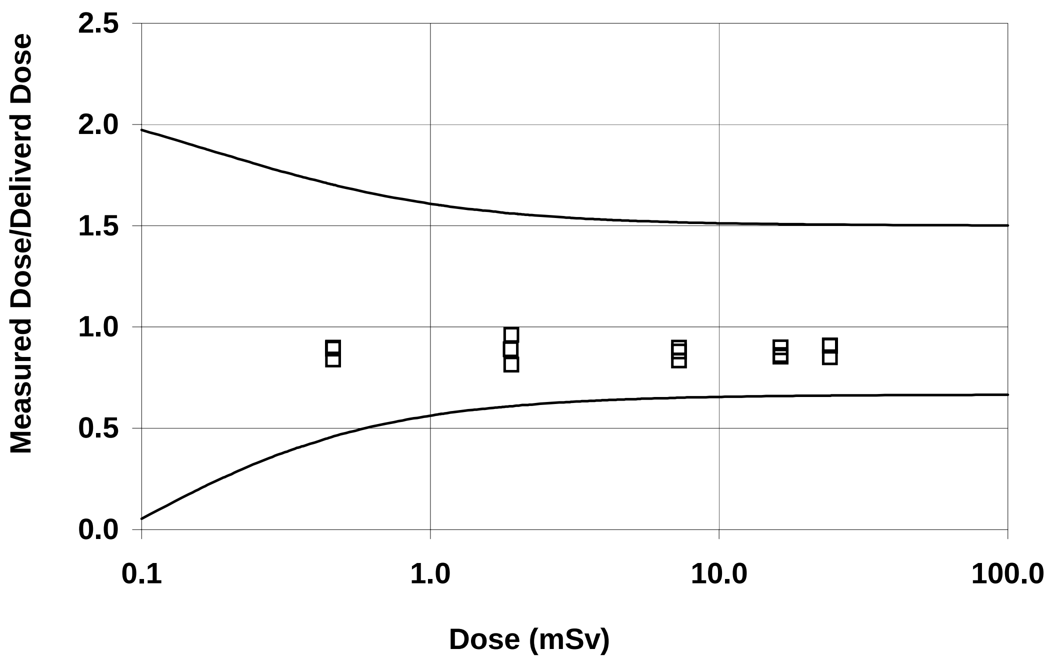

Figure-4: - Performance/Accuracy Curve for Laboratory No. 04

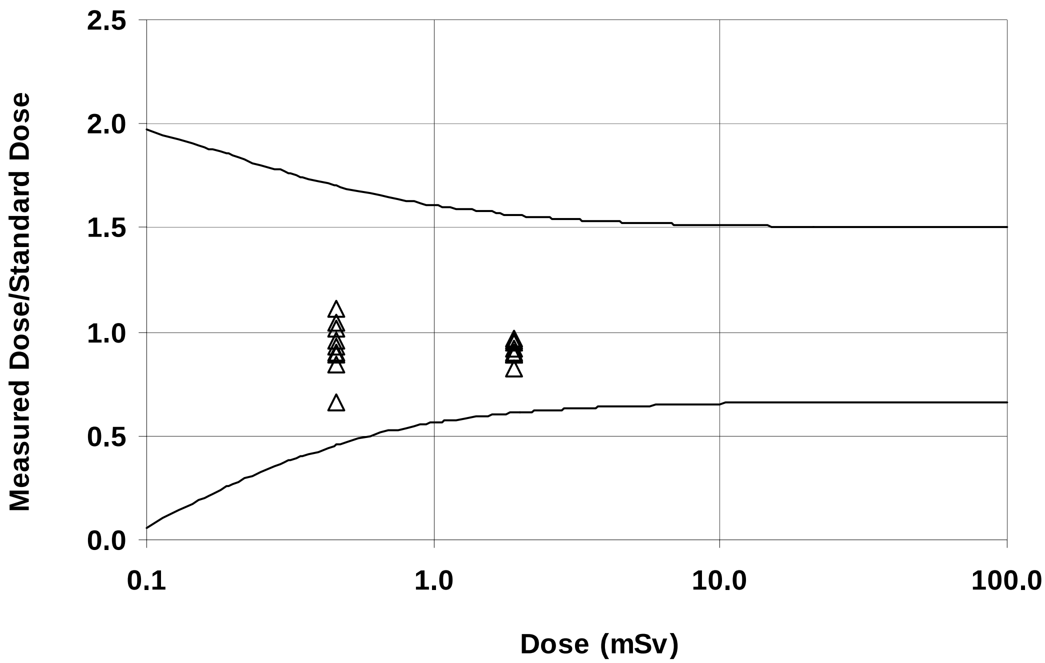

Figure-5: - Distribution of Intercomparison Results of all Participating Laboratories for ^{60}Co

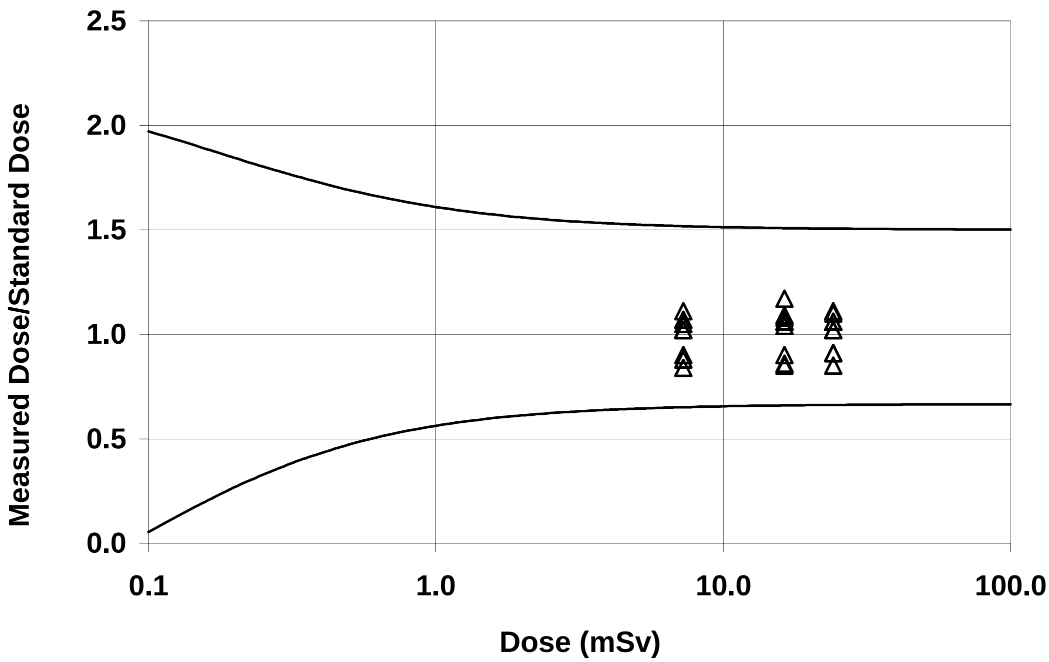

Figure-6: - Distribution of Intercomparison Results of all Participating Laboratories for ^{137}Cs

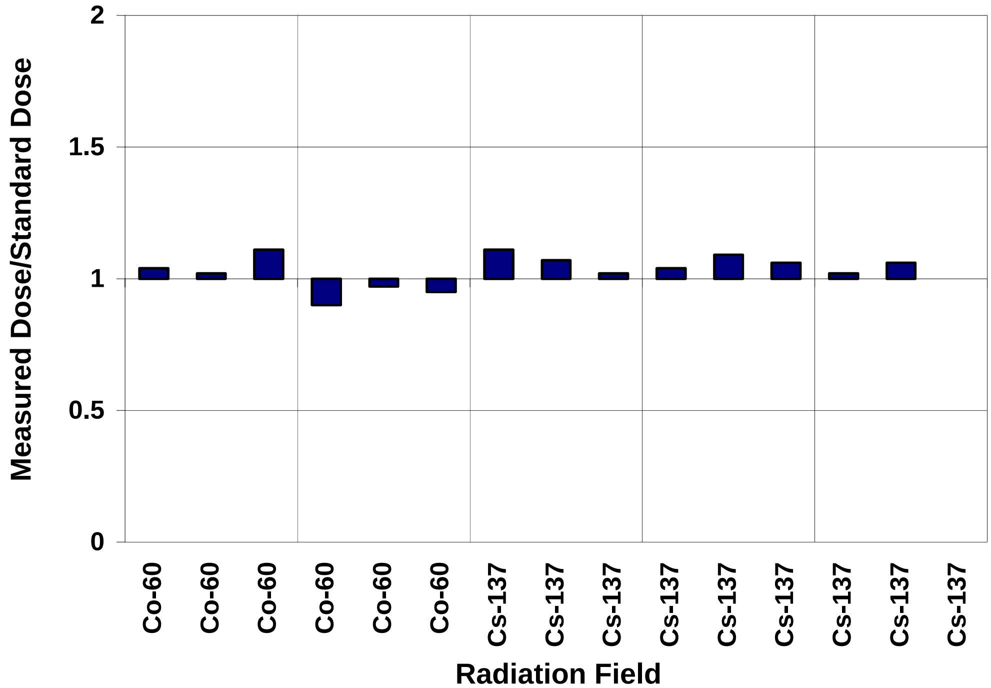

Figure-7: - Graphical Representation of Measured Dose/Standard True Dose Against Radiation Fields of Laboratory No. 01

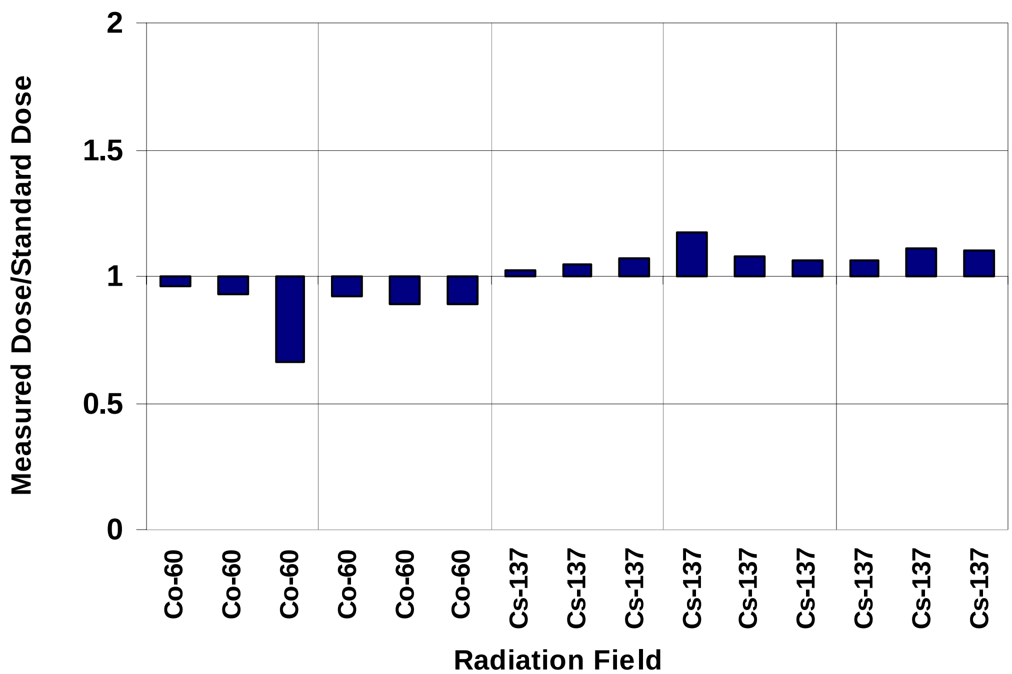

Figure-8: - Graphical Representation of Measured Dose/Standard True Dose Against Radiation Fields of Laboratory No. 03

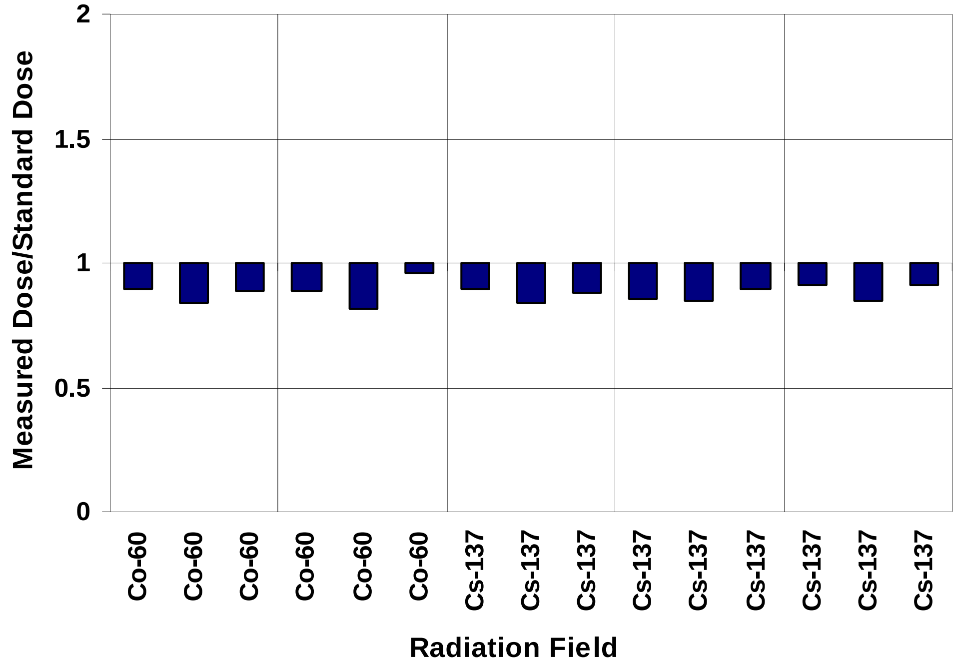

Figure-9: - Graphical Representation of Measured Dose/Standard True Dose Against Radiation Fields of Laboratory No. 04

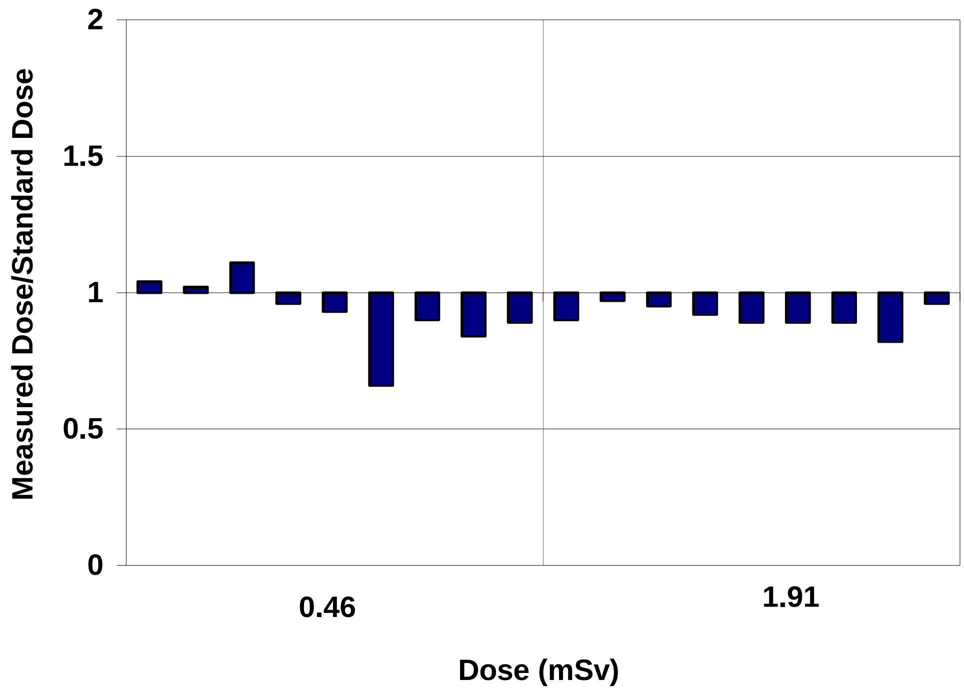

Figure-10: - Graphical Representation of Overall Response of Measured / Standard True Dose for ^{60}Co

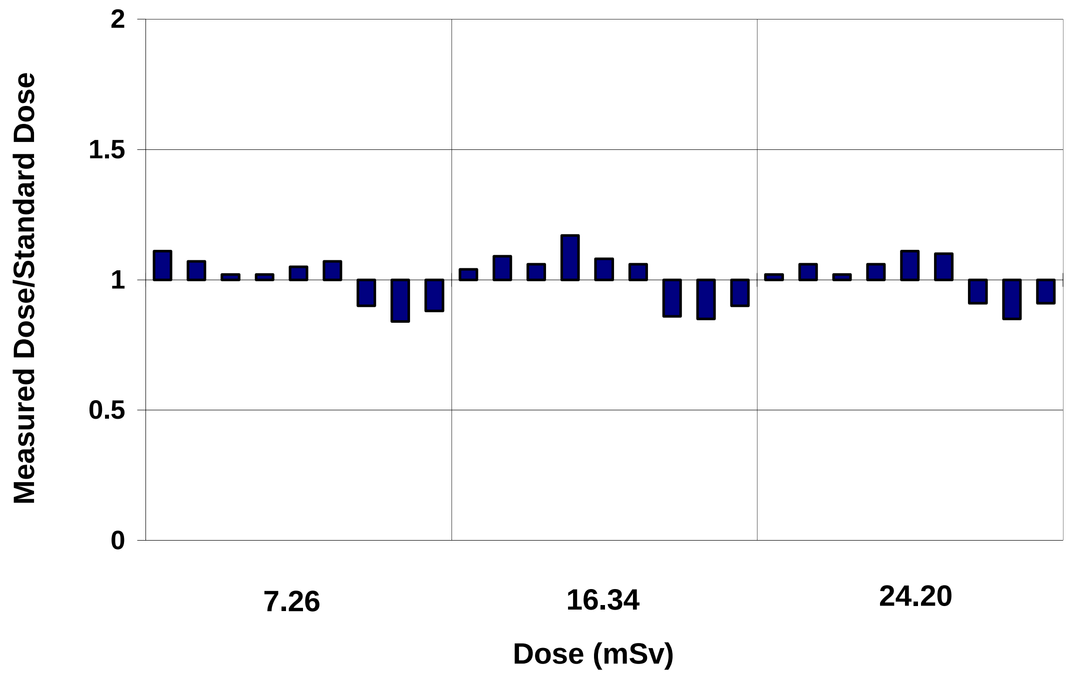

Figure-11: - Graphical Representation of Overall Response of Measured Dose/Standard True Dose for ^{137}Cs

Set. No.	Irradiation Source	Delivered Dose H_p (10)	No.. of Dosimeters Irradiated	Performance H_m/H_t
1	^{60}Co	0.46	12	0.66-1.11
2	^{60}Co	1.91	12	0.82-0.97
3	^{137}Cs	7.26	12	0.84-1.11
4	^{137}Cs	16.34	12	0.85-1.17
5	^{137}Cs	24.20	12	0.85-1.11

Table-4: - Summary of Results of First National Intercomparison for High Energy Photons

Annexure 'A'

Pakistan Institute of Nuclear Science & Technology

P. O. Nilore, Islamabad

Health Physics Division

Registration Form

(National Intercomparison of Personal Dosimetry for Service Providers)

1	Registration/Code No. For concerned institute	**PINSTECH / 2005-06/INT_________**
2	Name of Institute/Laboratory	______________________________ ______________________________ ______________________________ ______________________________
3	Head of the Institute	
4	Name of Dosimetry Service that will be used in Intercomparison	
5	Name of Contact person / Technical Coordinator	
5.1	Designation	
5.2	Address	
5.3	Telephones: Office: Mobile:	
5.4	E-Mail	
10	Fax	

Annexure 'B'

QUESTIONNAIRE FOR PARTICIPATING LABORATORIES

A General Information

Name of the Laboratory	
Head of the Laboratory	
Name &Address of Contact person for the intercomparison	
Address	
Fax:	
Tel:	Office Mobile
E-mail	

B Characteristics of dosimeters to be used in intercomparison

1.0	**Type of dosimeter**	
1.1	TLD/Film /Electronic / any other	
1.2	Unit in which the personal dose is measured	
1.3	Energy dependence of the dosimeter	Yes/No
1.4	Estimated error in the reported dose?(Please enter value)	
2.0	**Routine Measurement of Personal Dose**	
2.1	For high energy gamma only	Yes/No

2.2	For low energy gamma only	Yes/No
2.3	The total personal dose without discriminating between Low energy (X-rays) and high energy Gamma	Yes/No
2.4	Gamma+ beta (without discriminating between gamma and beta)	Yes/No
2.5	Neutron dose only	Yes/No
2.6	The total personal dose (without discriminating between neutrons and Gamma)	Yes/No
2.7	The personal dose (measuring both parts neutron and the photon component separately)	Yes/No
2.8	Range of measurement of dose (Please enter value) Minimum to Maximum	
2.9	Range of measurement of energy of incident radiation on the dosimeter (Please enter value)	
	Photons	
	Neutrons	
	Beta	
3.0	**Calibration of Dosimeters**	
3.1	Are calibration dosimeters exposed in air?	Yes/No
3.2	Are calibration dosimeters exposed on phantom?	Yes/No
3.3	Type of Phantom being used	
3.4	What radiation qualities are used for calibration (Please enter values for keV/ MeV)	
3.5	Is correction factor for energy dependence applied?	Yes/No
3.6	Is calibration factor derived, by Single exposing or multiple exposures?	
3.7	Is the calibration traceable to primary or secondary standards?	Yes/No

Annexure 'C'

Identification/Scheme of Dosimeters

Set No.	ID of Dosimeter	No. of Dosimeters	Radiation Sources
1	1-1	3	^{60}Co 1173 & 1332 keV
	1-2		
	1-3		
2	2-1	3	^{60}Co 1173 & 1332 keV
	2-2		
	2-3		
3	3-1	3	^{137}Cs 662 keV
	3-2		
	3-3		
4	4-1	3	^{137}Cs 662 keV
	4-2		
	4-3		
5	5-1	3	^{137}Cs 662 keV
	5-2		
	5-3		
Background	BG -1	5	
	BG -2		
	BG-3		
	BG -4		
	BG -5		
Reserved	Res-1	5	
	Res-2		
	Res-3		
	Res-4		
	Res-5		