

Overview and Findings From the 2016 Inter-Comparison Exercise on Individual Monitoring for External Exposure

H.K. Agyeman

jewel5w@yahoo.com

Ghana Atomic Energy Commission P. O, BOX LG 80 Legon - Accra. Ghana <https://orcid.org/0000-0002-5467-1358>

Research Article

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OVERVIEW AND FINDINGS FROM THE 2016 INTER-COMPARISON EXERCISE ON INDIVIDUAL MONITORING FOR EXTERNAL EXPOSURE.

Contributors:

¹Hephzibah K. Agyeman, ^{1,2}Edith A. Amoatey, ^{1,3}P O. Manteaw, ^{1,2}E. Gyasi, and ^{1,2}P. M. Appiah

AFFILIATIONS

**(1) Radiation Protection Institute
Ghana Atomic Energy Commission
P. O. Box LG 80
Legon - Accra**

**(2) University of Ghana
P.O.BOX LG 25
Legon – Accra**

**(3) Kwame Nkrumah University of Science and Technology
Private Mail Bag, University Post Office,
Kumasi, Ghana**

ABSTRACT

This report gives a detailed activities carried out in the Personnel Dosimetry Laboratory during the Inter – Laboratory exercise in 2016 at the Health Physics Centre in the Radiation Protection Centre in Ghana Atomic Energy Commission organised by the International Atomic Energy Agency (IAEA) on the determination of operational quantities at the Regional and interregional level. for the determination of the operational quantity Hp (10) and Hp (0.07).

Several intercomparison exercises have been organised (IAEA) in Africa region which Ghana is inclusive. In all, Twenty-two (22) countries participated in this exercise including Ghana.

The exercise was based on Individual Monitoring Services and Inter-comparison exercise (RAF/9/057-9001/01) in Accra, Ghana. It was concluded with the organization of an IAEA Regional Meeting on, 31 October - 4 November 2016.

As part of the Inter – Laboratory Exercises, Thermoluminescent Dosimeter (TLD) badges were sent from the Personal Dosimetry Laboratory Ghana participating country to Algeria which is also a participating country to be irradiated at their Secondary Standard Dosimetry Laboratories (SSDLs) to determine their response to linearity, blind test, background, calibration, energy and angular dependence. They were subsequently returned to the various countries, with a Microsoft Excel spreadsheet attachment for the recording of the doses measured by participating countries with their readers to enable the generation of the trumpet curves. The results for response of TLDs (i.e. Evaluated Dose $H_p(10)$ measured in (mSv)) to Linearity, Angular dependence, Energy dependence and Blind test ranged from 0.640 -9.070 mSv, 2.10 -3.310 mSv, 2.58-3.220 mSv and 5.16-19.340 mSv respectively. The evaluated dose $H_p(0.07)$ measured in mSv also follow a similar trend as that of the $H_p(10)$. Ghana's results for the inter-comparison exercise were satisfactory and this gives great confidence in our personal monitoring service.

KEYWORDS; Dose, Secondary Standard Dosimetry Laboratories, Inter – Laboratory Comparism, Energy dependence, Blind Test and Linearity Test.

1.0 INTRODUCTION

The Personnel Dosimetry Laboratory offers monitoring services to different categories of Occupational Exposed Workers who were registered as our clients. All the Occupationally Exposed Workers (OEWs) who were registered as our clients. Are professionals who by virtue of their work uses radioactive sources or radiation in their places of work.

In the previous interlaboratory comparisons-based measuring dosimetric quantities, $H_p(0.07)$ and $H_p(10.0)$ The tendency for systematic estimation for the doses was found. However, in this year 2016, interlaboratory exercises included dose range, of the same $H_p(0.07)$ and $H_p(10.0)$. More

of the participants provided estimates that agreed very well with the physical reference doses provided by the IAEA.

The dose equivalent in soft tissue at an appropriate depth, d , below a specified point on the human body. The soft tissue is ICRU 4-element tissue. The unit of personal dose equivalent is joule per kilogram (J kg^{-1}), and its special name is Sievert (Sv). The specified point is usually given by the position where the individual dosimeter is worn. For the assessment of effective dose a depth of 10 mm is recommended, and for the assessment of equivalent dose to the skin and the lens of the eye, depths of 0.07 mm and 3 mm, respectively, are recommended.

The IAEA provided for dose estimations for reference doses given in terms of dosimetric dose quantities.

Inter-comparisons amongst science laboratories are very important exercises. This allows for the laboratories to measure and evaluate their capacity and competencies as compared to others carrying out similar tasks in other member State. Although accreditation are the desired means of showing a laboratory's competence and credibility, regular inter-comparisons are also a vital means by which a laboratory can show its capacity, competence, and credibility to its clients and stakeholders. The accreditation process; whether international such as the ISO system or from National Competent Bodies such as Standards Authority can be quite expensive for young laboratories. However, by participating in such exercises, upcoming laboratories can build their capacity and improve the reliability and wider acceptability of the results they produce out of their work.

In line with its statutory function on providing for the application of safety standards, the IAEA has been assisting its Member States in their provision of appropriate occupational radiation monitoring for protection purposes. The IAEA has been organizing international and Regional inter-comparisons in the field of external and internal dosimetry since the early 1980's [1 - 3].

In anticipation of the benefits of the inter-comparison process, Ghana through the Radiation Protection Institute (RPI) of the Ghana Atomic Energy Commission (GAEC) decided to partake in the exercise (RAF 9/0/53) and (RAF/9/057-9001/01).

Some of the objectives of this inter-comparison are amongst others:

- (1) To facilitate the estimation of similarities or dissimilarities in the measurements of radiation protection quantities performed,
- (2) To foster exchanges of information and experience relating to the measurement of radiation protection quantities and to develop methods for estimating derived quantities,
- (3) To provide access to resources, which might otherwise not be available to some Member States, for the calibration of radiation protection monitoring devices,
- (4) To provide the opportunity to the Member States to report in those quantities in the frame of the international legal conventions in the field of nuclear safety.

In this respect, the intercomparison of active personal dosimeter for individual monitoring of external exposure from photon and beta radiation was organized as a joint venture project with the African Regional Cooperative Agreement for Research, Development and Training Related to Nuclear Science and Technology (AFRA) which provides a framework for African Member States to intensify their collaboration through programmes and projects focused on the specific shared needs of its members to assess the technical capabilities of all types of personal dosimeters and other new developments available on the market. This report presents the results of the joint intercomparison and gives some recommendations for the proper use of the tested dosimeters.

1.1 GENERAL OVERVIEW OF THE PROCESSES OF HOW INTER-COMPARISON EXERCISES ARE CARRIED OUT.

General Summary of the Inter-comparison Process

Below is a general outline of the key steps of a continent-wide scientific inter-comparison exercise.

1. Formal and informal deliberations/consultations between Member States and the IAEA on the conduct of an inter-comparison exercise on a given subject as part of a Technical Cooperation project.
2. Agreement and decision to conduct the inter-comparison exercise on the chosen subject.
3. Identification and selection of the coordinating/focal laboratory(is) for the inter-comparison exercise.

4. Announcement of the intent to conduct the chosen inter-comparison exercise.
5. Official notification and indication of willingness by Member States to participate in the chosen inter-comparison exercise.
6. Circulation of details of the inter-comparison exercise
 - a. Work plan
 - b. Materials needed
 - c. Method, etc.
7. Conduct of the Scientific/Technical work in relation to the inter-comparison exercise by the participating Member States' laboratories
 - a. Dispatch of the prepared samples to the coordinating/focal lab(s)
 - b. Return of the dispatched samples from the coordinating/focal lab(s) back to home country(ies)
8. Collation of results of the inter-comparison exercise.
9. Presentation and Discussion of the results of the inter-comparison exercise at a Workshop
 - a. Peer review
 - b. Identifying and adopting best practices and sharing of ideas and insight of the investigated subject
 - c. Recommendations for improving the processes of the inter-comparison exercise
10. Discussions on the way forward and future collaborations with respect to other Technical Cooperation projects, etc.

Note:

As a Member State participating in the exercise, we may choose to carry out the following

- Preparing a Technical Report on the exercise to be submitted to the Institute.
- Check the possibility and suitability of publishing aspects of the findings of the exercise concerning our laboratory in a journal without breaking the terms and conditions governing the inter-comparison exercise.
- Make presentations at several fora on the subject.

1.2 WHAT THIS PARTICULAR INTER-COMPARISON ENTAILS

As part of this work, some activities must be carried out. They are;

- A. Determination of linearity curve (graph) for doses delivered and measured.
- B. Selection of TLDs
- C. Preparing the TLDs
- D. Codification of the TLDs
- E. Packaging the TLDs
- F. Dispatch of the TLDs for irradiation at irradiation facility (in this instance a laboratory in Algeria)
- G. Receipt of the TLDs for reading with TLD reader
- H. Reading the irradiated TLDs using the HARSHAW 6600 TLD reader
- I. Analyzing the results
- J. Disseminating the results of the inter-comparison as a Presentation/Poster at a Meeting/Workshop/Conference
- K. Explore the possibility of publishing aspects of the results and insight gained in a refereed journal (ONLY if permitted by the terms of agreement / confidentiality provisions of the inter-comparison exercise)

2.0 MATERIALS AND METHODS

2.1 Materials

2.1.1 Thermoluminescent Dosimeter

The most widely used material is the LiF with added magnesium and titanium. TLD100 is LiF:Mg,Ti which consists of 92.5% of ^7Li and 7.5% of ^6Li . Each card consists of four/two chips. In this project, five hundred new two elements TLD 100 were used. The TLD cards are fixed in holders with two aluminum filters of different thicknesses; 0.07mm (for skin dose measurements) and 10mm (for deep dose measurements). One corner of the TLD card is notched to make sure it is placed correctly in the Reader holder system. The Reader holder system protects the cards from the environment and keeps the filtration media which attenuate different types of radiation in order to ensure selective entrapments of the TLD100. Apart from the chips, each card has a unique barcode.

Sixty-five (65) TLDs were sent to Algeria's Secondary Standards Dosimetry Laboratory (SSDL) to be irradiated to determine various type testing qualities and sent back to Ghana for reading and assessment.

2.1.2 HARSHAW 6600 TLD Reader

For this project, the Harshaw Automatic TLD Workstation (Model 6600E) located at the Radiation Protection Institute was the reader used for estimating whole body effective doses recorded by the TLDs. A non-contact heating system is used which utilizes a stream of hot nitrogen gas. Glow curves and data calculated, using algorithm software, are shown on an electroluminescence panel of the Reader. The Reader is interfaced to a computer where all measured data can also be displayed, stored and printed [4]. Up to 200 TLD cards can be placed in the reader.

2.1.3 IRRADIATION FACILITIES

- ^{137}Cs , ^{60}Co , and X-ray irradiation unit
- Calibration bench with positioning devices

Phantoms

- ISO 30 cm x 30 cm x 15cm PMMA Phantom
- ISO rod and/or pillar phantom for extremity dosimeter irradiations

3.0 METHODOLOGY

PROCEDURE FOR DOSIMETERS IRRADIATION

1. **Dosimeter preparation** - Dosimeters were prepared depending on their specification. Dosimeter identification and calibration information were recorded on attached data sheets.
2. **Phantom placement** - Phantom was placed at the proper nominal distance from the source or target.
3. **Dosimeter placement** - Dosimeters were attached to the phantom.
4. **Distance measurement** - Source to the effect centre of the dosimeter was measured and recorded.
5. **Irradiation** - Dosimeters were irradiated as outlined in the plan.
6. **Dosimeter evaluation** - Dosimeters were evaluated using specific methods and software, using the appropriate dose conversion factors.
7. **Calculations:** Using the evaluated data (reported data), the ratios (Reported / True) were calculated

4.0 RESULTS DISCUSSION

Table 1: Results for regional 2016 inter-comparison exercise on individual monitoring for external exposure

	Dosimeter codification	Quality (ISO 4037)	Energy (keV)	Angle (degree)	Nomina l Dose Hp(10) true (mSv)	Evaluated Dose Hp(10) measured (mSv)	Average background for TLD set (mSv)	Corrected Dose (mSv)	Ratio Hp(10)measured/ Hp(10>true	AVERAGE RATIO	Evaluated Dose Hp(0.07)measured (mSv)
	CAL1	SCs	662	0	2.000	2.250	0.390	1.860	0.93	1.00	2.35
	CAL2		662	0	2.000	2.380	0.390	1.990	1.00		2.25
	CAL3		662	0	2.000	2.580	0.390	2.190	1.10		2.34
	CAL4		662	0	2.000	2.310	0.390	1.920	0.96		2.05
<u>Linearity</u>	L11	SCs	662	0	0.200	0.910	0.840	0.070	0.35	-0.16	0.73
	L12		662	0	0.200	0.950	0.840	0.110	0.55		0.93
	L13		662	0	0.200	0.730	0.840	-0.110	-0.55		0.97
	L14		662	0	0.200	0.640	0.840	-0.200	-1.00		0.42
	L21	SCs	662	0	1.000	1.470	0.840	0.630	0.63	0.57	1.44
	L22		662	0	1.000	1.340	0.840	0.500	0.50		1.24
	L23		662	0	1.000	1.280	0.840	0.440	0.44		1.30
	L24		662	0	1.000	1.540	0.840	0.700	0.70		1.35
	L31	SCs	662	0	2.000	2.370	0.840	1.530	0.77	0.71	2.19
	L32		662	0	2.000	2.060	0.840	1.220	0.61		2.14
	L33		662	0	2.000	2.310	0.840	1.470	0.74		2.18
	L34		662	0	2.000	2.280	0.840	1.440	0.72		2.14
	L41	SCs	662	0	5.000	4.990	0.840	4.150	0.83	0.79	5.11
	L42		662	0	5.000	5.000	0.840	4.160	0.83		5.05
	L43		662	0	5.000	4.540	0.840	3.700	0.74		4.58
	L44		662	0	5.000	4.590	0.840	3.750	0.75		4.56

	Dosimeter codification	Quality (ISO 4037)	Energy (keV)	Angle (degre)	Nomina l Dose Hp(10)t rue (mSv)	Evaluated Dose Hp(10)meas ured (mSv)	Average background for TLD set (mSv)	Corrected Dose (mSv)	Ratio Hp(10)measured/ Hp(10>true	AVERAGE RATIO	Evaluated Dose Hp(0.07)measured (mSv)
	L51	SCs	662	0	10.000	8.650	0.840	7.810	0.78	0.80	8.82
	L52		662	0	10.000	8.940	0.840	8.100	0.81		8.90
	L53		662	0	10.000	8.840	0.840	8.000	0.80		9.36
	L543		662	0	10.000	9.070	0.840	8.230	0.82		9.29
<u>Angular dependence</u>	45A11	Scs N60	662	45	2.000	2.100	0.330	1.770	0.89	1.05	2.19
	45A12		662	45	2.000	2.770	0.330	2.440	1.22		2.36
	45A21		N60	45	2.000	3.220	0.330	2.890	1.45	1.39	3.70
	45A22		N60	45	2.000	3.000	0.330	2.670	1.34		3.14
	60A11		662	60	2.000	2.330	0.330	2.000	1.00	0.96	2.27
	60A12		662	60	2.000	2.180	0.330	1.850	0.93		2.11
	60A21		N60	60	2.000	3.310	0.330	2.980	1.49	1.44	3.06
	60A22		N60	60	2.000	3.120	0.330	2.790	1.40		3.43
<u>Energy dependence</u>	E11	N60	48	0	2.000	3.220	0.570	2.650	1.33	1.25	3.10
	E12	N60	48	0	2.000	3.090	0.570	2.520	1.26		3.12
	E13	N60	48	0	2.000	2.940	0.570	2.370	1.19		2.85
	E14	N60	48	0	2.000	3.020	0.570	2.450	1.23		3.00
	E21	N80	64	0	2.000	2.700	0.570	2.130	1.07	1.10	2.52
	E22	N80	64	0	2.000	2.730	0.570	2.160	1.08		2.65
	E23	N80	64	0	2.000	2.850	0.570	2.280	1.14		2.63
	E24	N80	64	0	2.000	2.830	0.570	2.260	1.13		2.61
	E31	N120	100	0	2.000	2.580	0.570	2.010	1.01	1.05	2.44
	E32	N120	100	0	2.000	2.870	0.570	2.300	1.15		2.54
	E33	N120	100	0	2.000	2.580	0.570	2.010	1.01		2.51
	E34	N120	100	0	2.000	2.680	0.570	2.110	1.06		2.62

	Dosimeter codification	Quality (ISO 4037)	Energy (keV)	Angle (degre)	Nomina l Dose Hp(10)t rue (mSv)	Evaluated Dose Hp(10)meas ured (mSv)	Average background for TLD set (mSv)	Corrected Dose (mSv)	Ratio Hp(10)measured/ Hp(10>true	AVERAGE RATIO	Evaluated Dose Hp(0.07)measured (mSv)
Blind test	BT11	N60 + SCs		0	5.000	5.160	0.570	4.590	0.92	1.01	5.49
	BT12	N60 + SCs		0	5.000	5.420	0.570	4.850	0.97		5.50
	BT13	N60 + SCs		0	5.000	5.210	0.570	4.640	0.93		5.43
	BT14	N60 + SCs		0	5.000	6.620	0.570	6.050	1.21		5.50
	BT21	SCo		0	20.000	18.570	0.570	18.000	0.90	0.88	14.64
	BT22	SCo		0	20.000	16.490	0.570	15.920	0.80		13.05
	BT23	SCo		0	20.000	19.340	0.570	18.770	0.94		14.84
	BT24	SCo		0	20.000	18.670	0.570	18.100	0.91		14.81
Backgroun d	BGC					0.390				0.39	0.40
	BGL1					0.920				0.84	0.46
	BGL2					0.760					0.63
	BGA1					0.320				0.33	0.33
	BGA2					0.330					0.34
	BGE1					0.510				0.57	0.34
	BGE2					0.630					0.37
	BGB1					0.570				0.57	0.26
	BGB2					0.560					0.33
	BG1					0.490				0.44	0.40
	BG2					0.360					0.29
	BG3					0.460					0.33
	BG4					0.430					0.33

The graphs below are the Inter-comparison results in the form of a Trumpet Curve

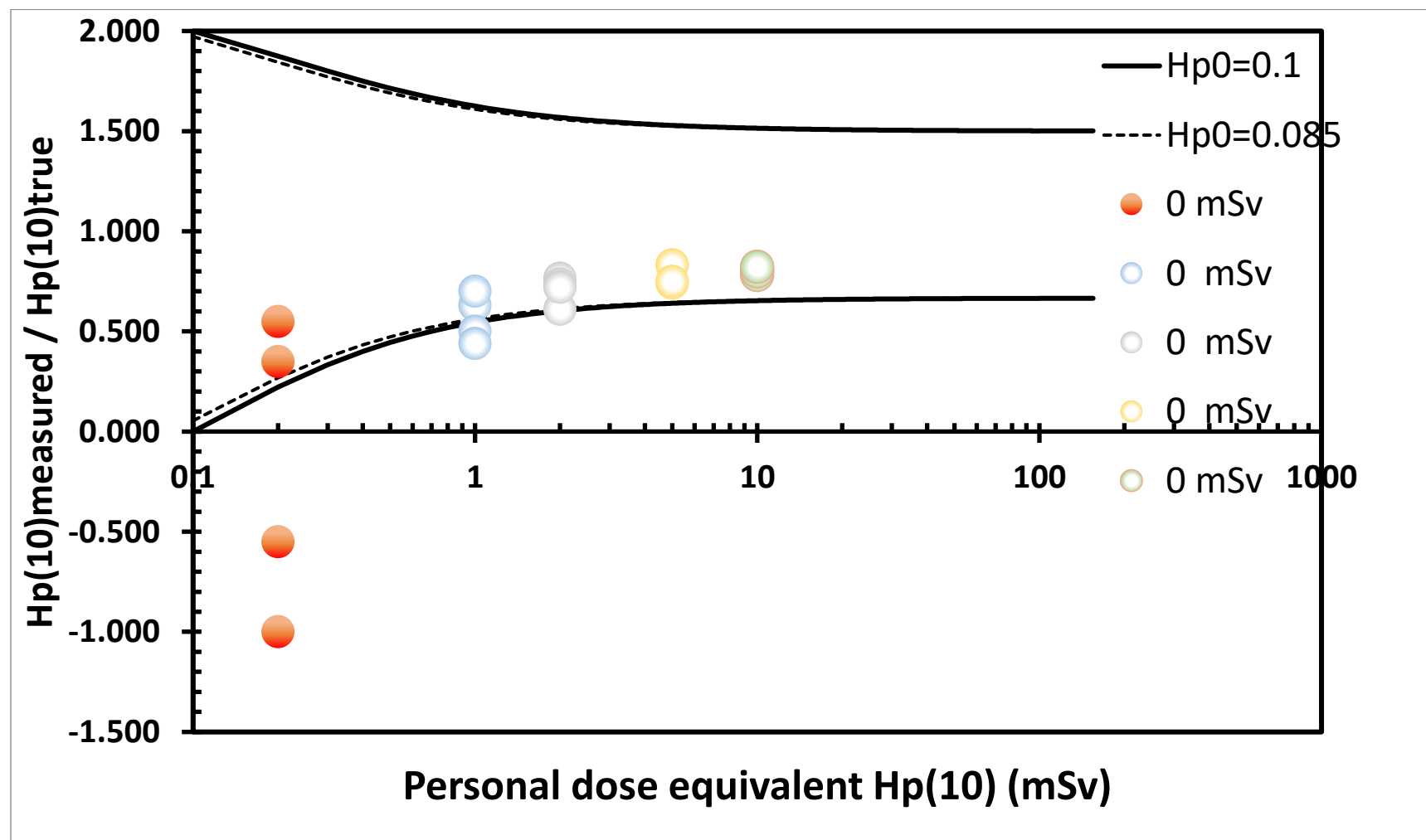


Fig. 1: Linearity (All results)

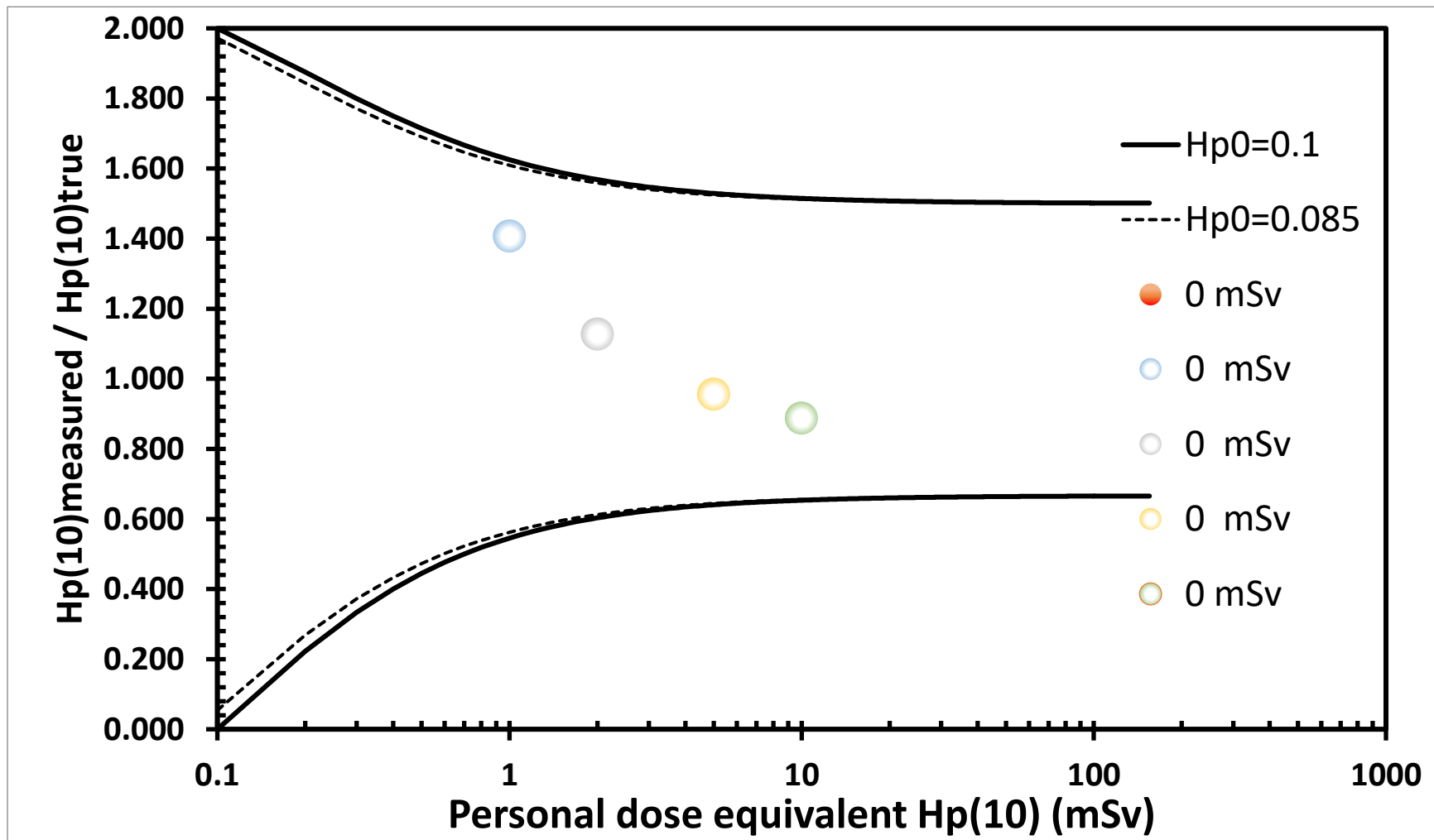


Fig. 2: Linearity (Average)

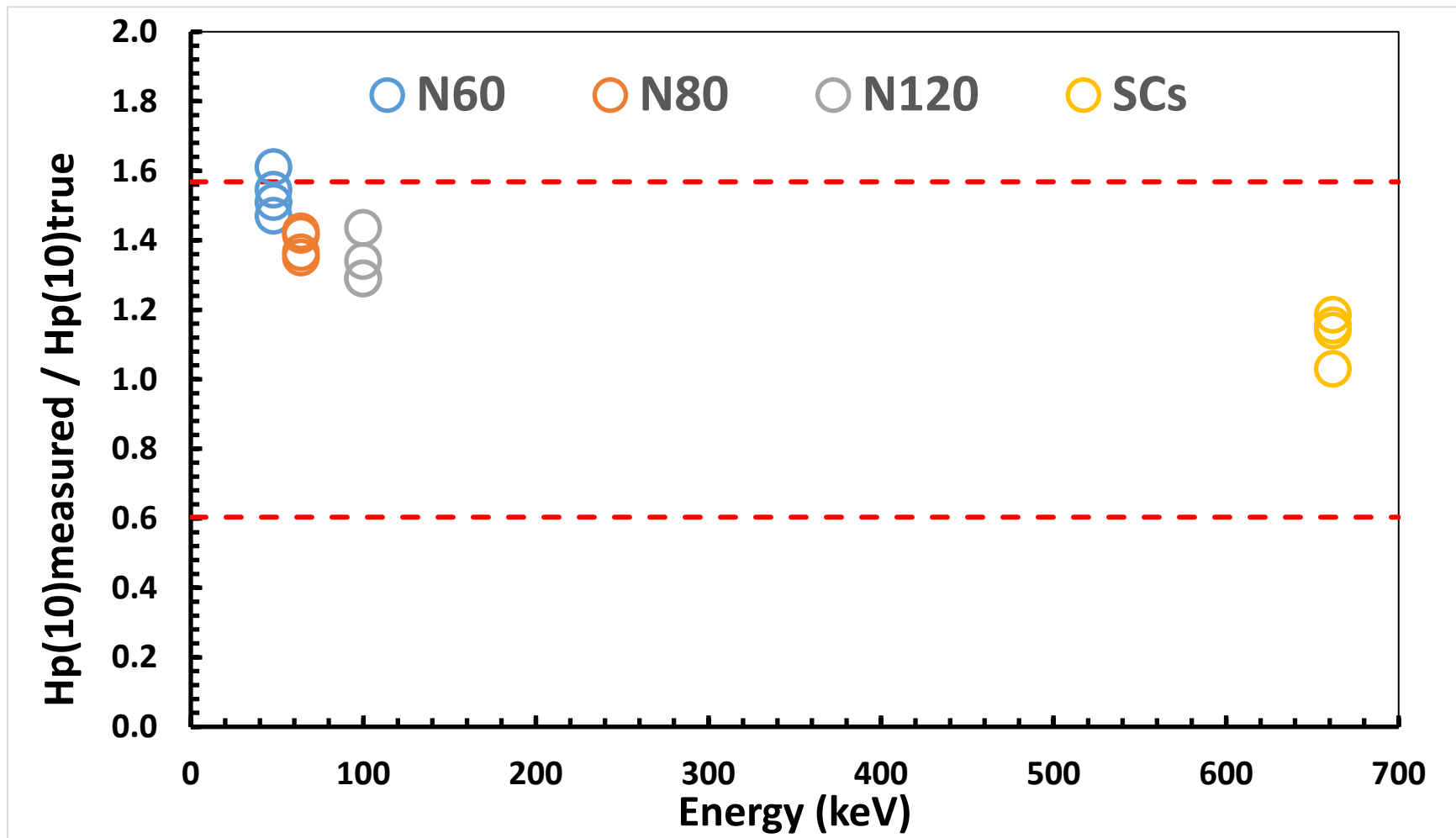


Fig. 3: Energy Dependence (All results)

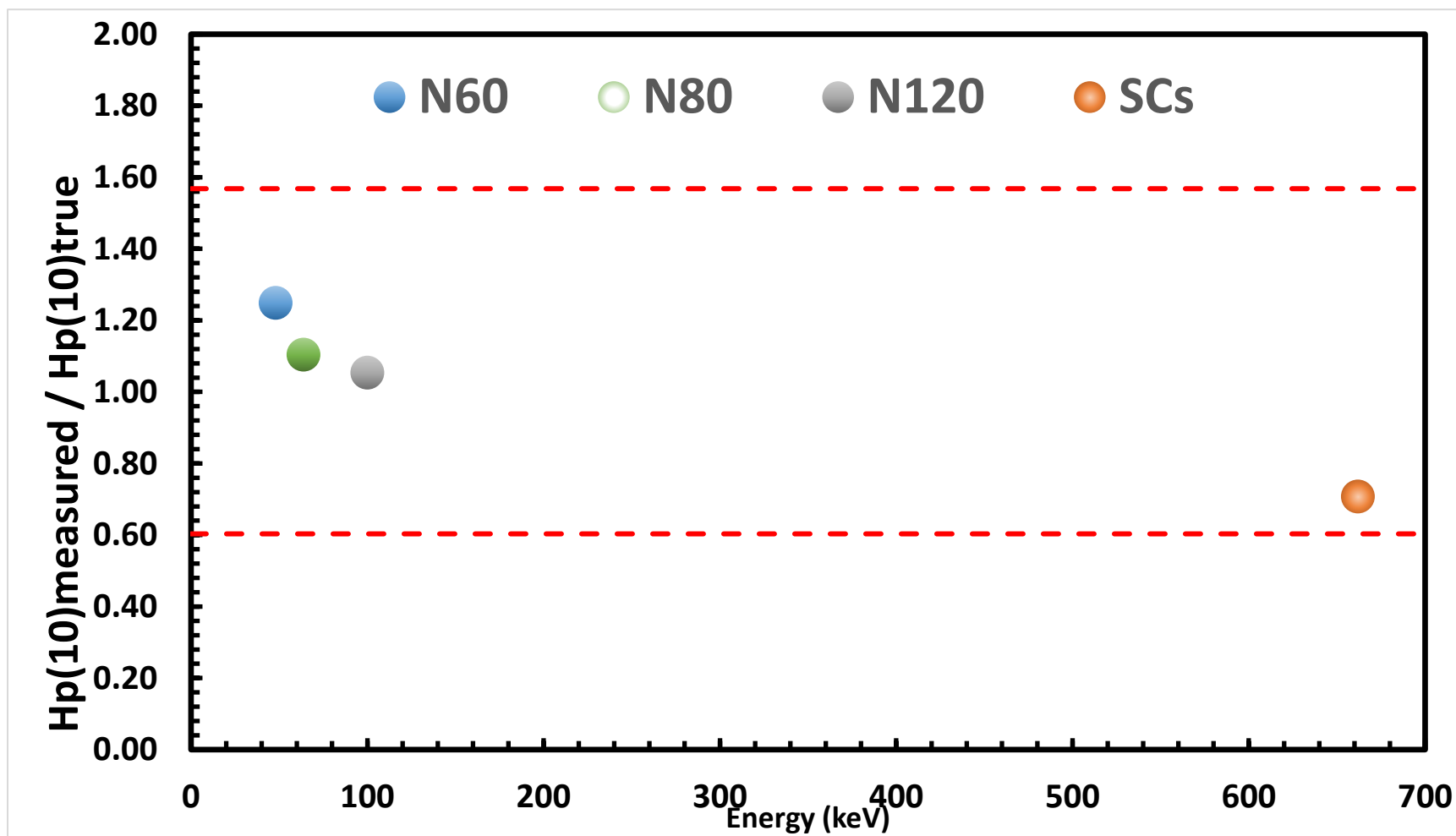


Fig. 4: Energy Dependence (Average)

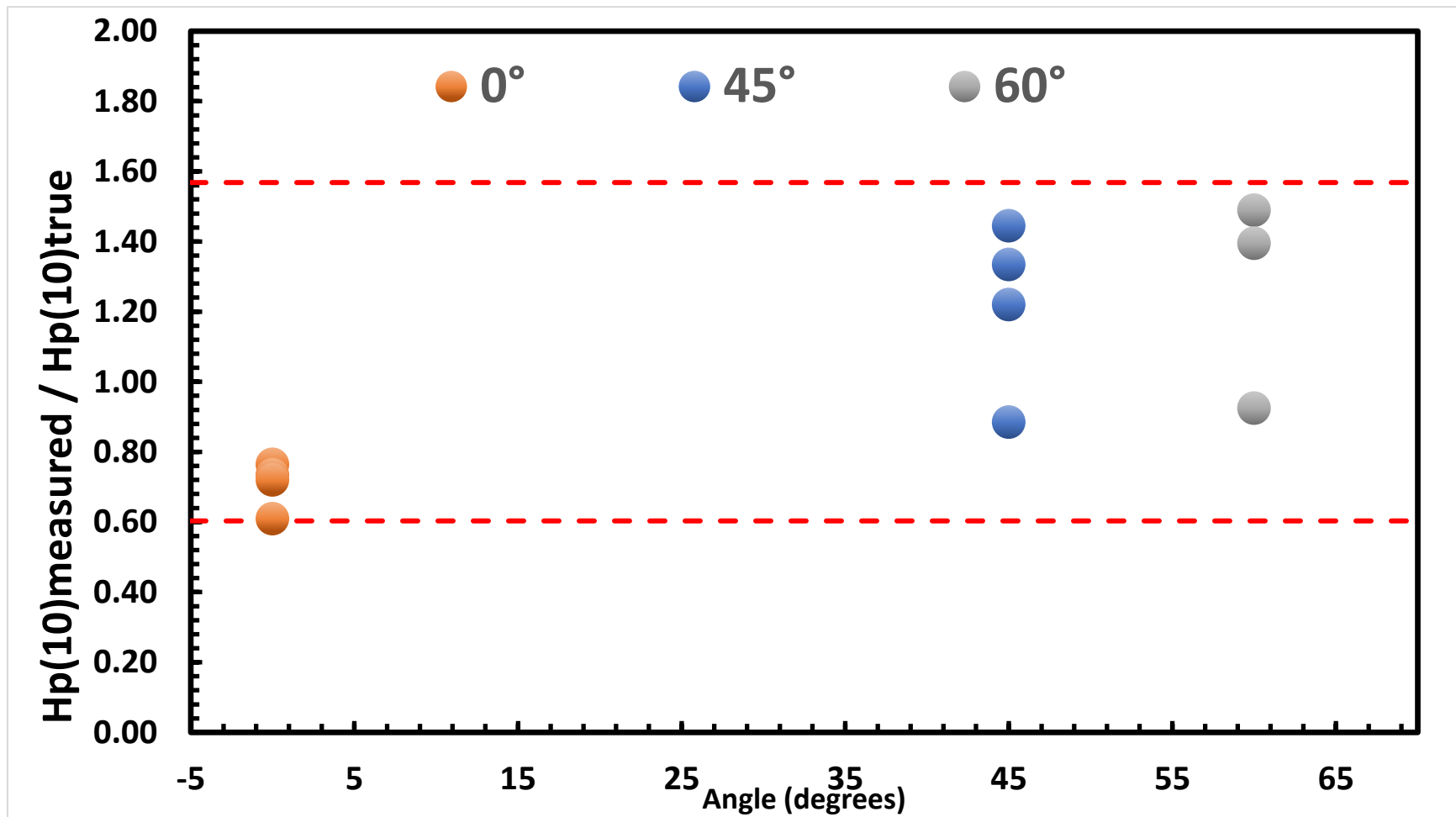


Fig. 5: Angular Dependence (All results)

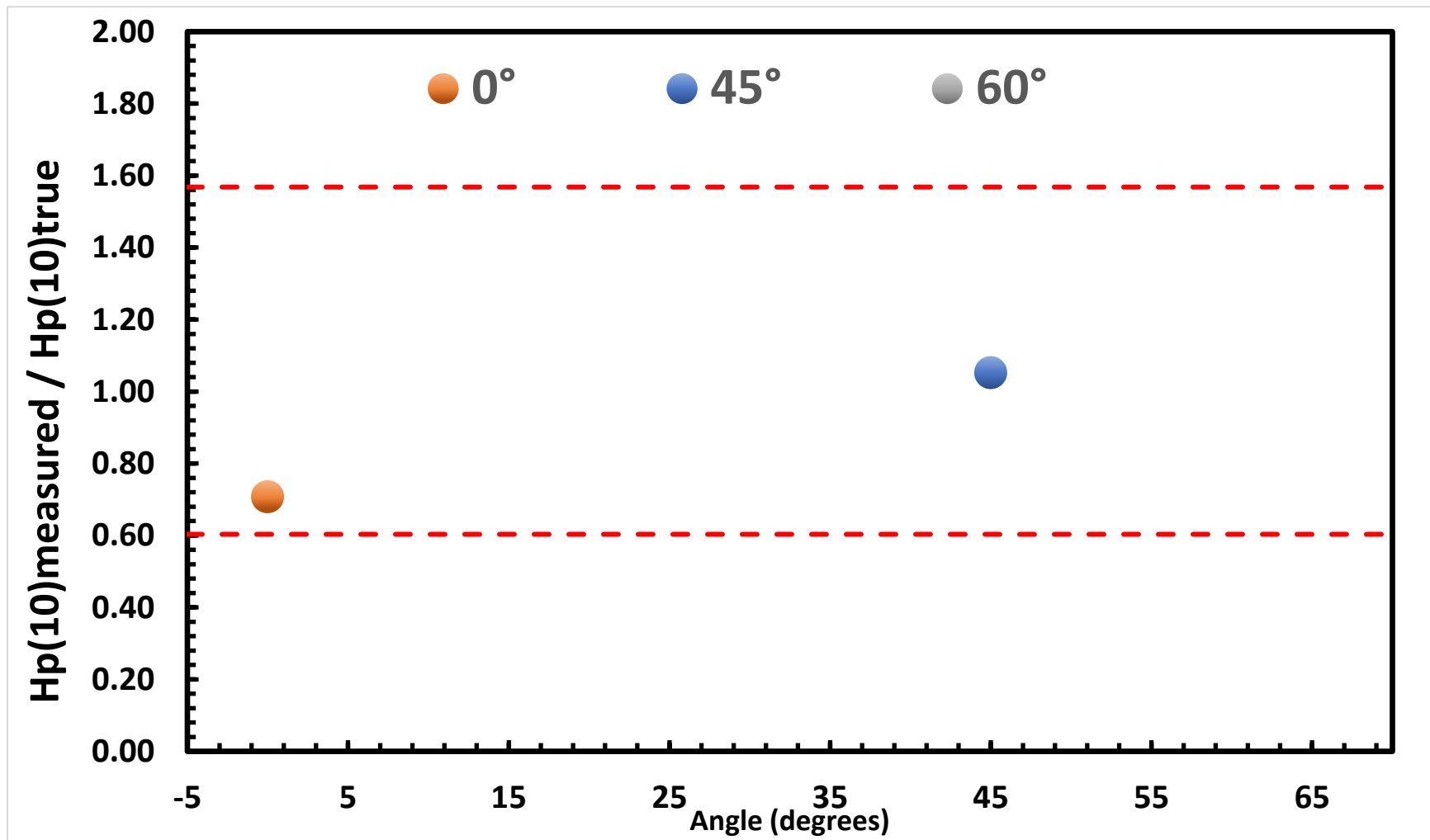


Fig. 6: Angular Dependence (Average)

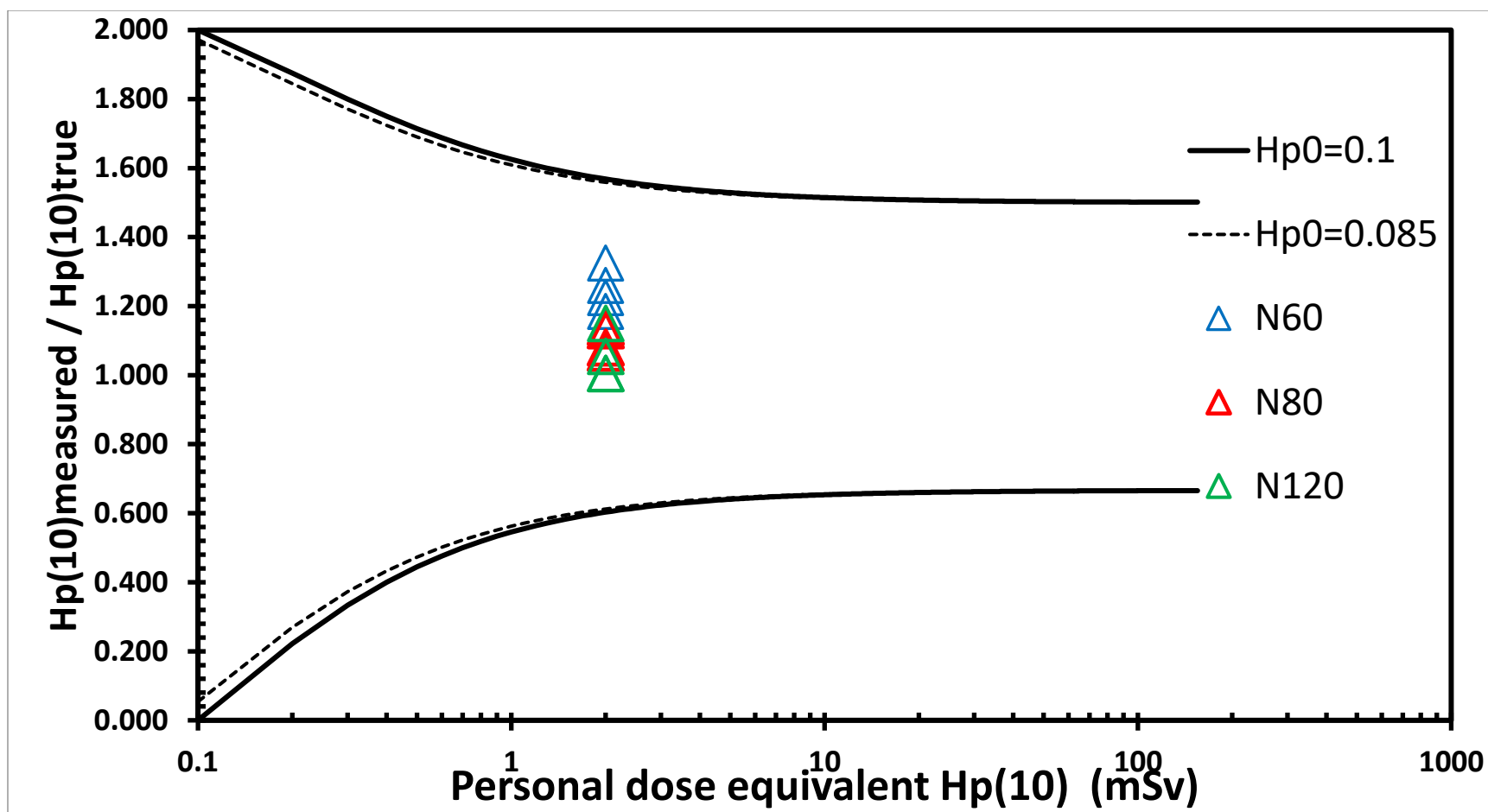


Fig. 7: Energy Dependence

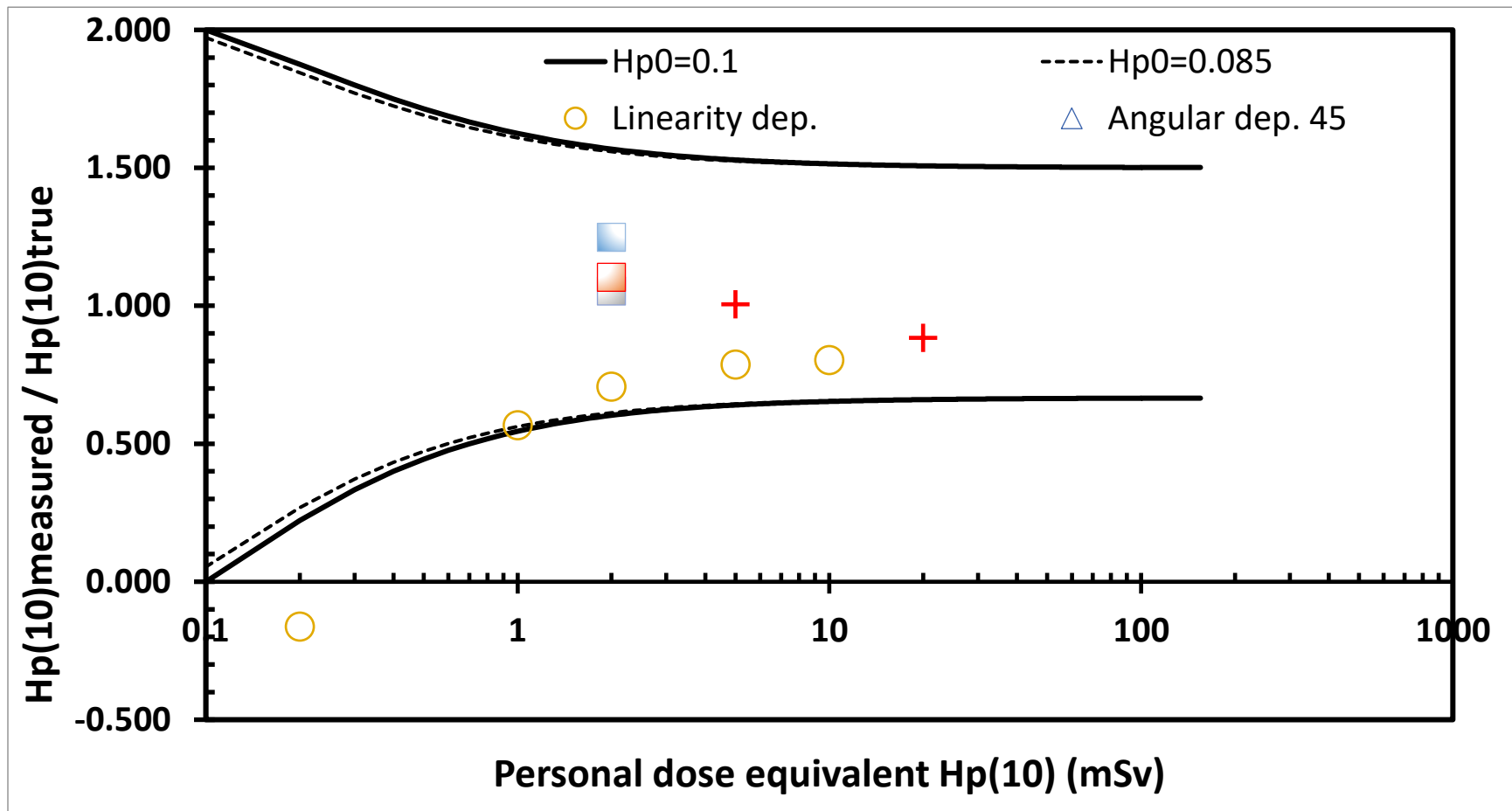


Fig. 9: Summary of average results for all tests

The linearity results are generally in good accordance with the performance standards tested. However, the results for the low doses i.e. 0.2 mSv, didn't fit in the trumpet curve, due to the dosimeters recording over estimated doses. This can be significantly improved by increasing the number of dosimeters to be irradiated simultaneously to deliver a particular dose.

The angular response to photon radiation was tested at an angle of 45° and 60° the relative angular response at those angles for the eight (8) tested dosimeters is shown in Table 1 and Fig.

5. It can be observed that all the dosimeters present a satisfactory angular response to ^{137}Cs .

The results of the inter-comparison exercise showed a good energy response with both individual and average values. The results for the Hp(0.07) also followed a similar trend as that of the Hp(10)

Blind tests also showed very good results for both single and average values.

RECOMMENDATIONS

The following recommendations are made;

- The RPI must continue to participate regularly in such inter-comparison exercises.
- The RPI must develop the capacity to be the host laboratory for future regional or sub-regional inter-comparison exercise

5.0 CONCLUSION

This inter-comparison exercise gave Ghana the opportunity to improve the dosimetry system for efficient monitoring of Occupationally Exposed Workers (OEWs); In general, the results are satisfactory but the system can be improved by corrective actions and incorporating uncertainty budgets in the monitoring procedure.

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