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Results of the interlaboratory comparisons for the Polish Secondary Standard Dosimetry Laboratory in the field of testing of thermoluminescent detectors in terms of absorbed dose to water

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Laboratory accredited by the Polish Centre for Accreditation, accreditation No AB 1499*

*** an actual scope of accreditation No AB 1499 is available on the PCA website: www.pca.gov.pl**

Introduction

The Polish Secondary Standard Dosimetry Laboratory (**SSDL**) has been accredited by the Polish Centre for Accreditation since April 9, 2014 and has the accreditation certificate No AB 1499. In the scope of this accreditation there is determination of absorbed dose to water, by thermoluminescent dosimetry method.

Every calibration and testing laboratory accredited for the conformity with the norm ISO/IEC 17025 [1] has to **fulfil the requirements of the norm**.

One of these requirements (point 7.7 of the norm) is **monitoring the validity of the tests undertaken**.

At the Polish SSDL, it was decided **that monitoring of the validity of the testing results will include**, among others, **participation in interlaboratory comparison** **(according to the point 7.7.2 of the norm).**

Introduction

According to the point 7.7.3 of the norm, data from monitoring activities shall be analysed and used to both control and improve the process of the laboratory's activities. If the results of the analyses are found to be outside pre-defined criteria, appropriate action shall be taken to prevent not valid results from being reported.

The aim of this study is to **present the results of the interlaboratory comparisons and a simple method of analysis of these results** that can be useful in routine activity of the testing laboratories in the above-mentioned area in order to check if these results are stable in specified limits.

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Material

The material of the study were **the results of the interlaboratory comparisons** between the Polish SSDL and Dosimetry Laboratory of the International Atomic Energy Agency (i.e. IAEA) **conducted from 2004 to 2021**.

These comparisons provided an independent check of the TLD dosimetry system used by Polish SSDL for radiotherapy dosimetry audits.

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Methods

Part 1: Method of the interlaboratory comparisons

The interlaboratory comparisons were carried out **once a year**.

The Polish SSDL provided the IAEA Dosimetry Laboratory with dosimeters to be irradiated in reference conditions. The irradiations in ^{60}Co beam were performed in solid water.
The IAEA Dosimetry Laboratory irradiated 5 dosimeter sets (each set contained 3 dosimeters) irradiated at different dose levels around the dose of interest (i.e.: 1.50, 1.75, **2.00**, 2.25 and 2.50 Gy) and one set with a dose value unknown to the Polish SSDL. All sets were sent back to the Polish SSDL giving the known dose values and asking for the unknown dose value.

At the Polish SSDL, the equation of the linear function M = f (D) was determined (using the least squares method) based on the readings of dosimeters irradiated with known doses. An unknown dose value was determined in the same manner as for the radiotherapy dosimetry audits. The obtained result ($\boldsymbol{D}_{\mathbf{SSDL}}$) was forwarded to the IAEA. Finally, the IAEA reported to the Polish SSDL the dose value that the dosimeters have been irradiated ($\boldsymbol{D}_{\mathbf{IAEA}}$).

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Part 2: Method of the analysis of the interlaboratory comparisons results

The interlaboratory comparisons results were analyzed by the Polish SSDL.

The acceptance criteria of the interlaboratory comparisons results were established at the Polish SSDL.

They were based on the relative percentage value of the combined uncertainty of the measurement of the D_{SSDL} value and D_{IAEA} value, i.e. 3.4% value of D_{SSDL} and D_{IAEA}.

The following acceptance criteria were adopted:

1. **The result of the interlaboratory comparison in a given year was acceptable when the value of $|E_n|$** defined as the quotient of the absolute value of the difference D_{SSDL} and D_{IAEA} values to the square root of the sum of the squared combined uncertainty of D_{SSDL} value and D_{IAEA} value, **did not exceed 1.0**.
2. The trend of changes in the results was correct when the value of the absorbed dose in water determined by TL detectors (D_{SSDL}) and the value of the undisclosed dose absorbed in water (Blind Check: D_{IAEA}) were consistent within the measurement uncertainty, i.e. $\mathbf{D_{SSDL}/D_{IAEA} \in \langle 0.966;1.034 \rangle}$.

Methods

Part 3: Statistical analysis of the interlaboratory comparisons results

According to the requirements of the norm, statistical techniques were applied to the reviewing of the results, namely to analyze the association between the $\boldsymbol{D_{SSDL}/D_{IAEA}}$ value in a given year and number of years since 2004 (i.e. the year of the first participation of the Polish SSDL in the interlaboratory comparison).

1. First, **the Shapiro-Wilk test was used to assess the normality of distributions of investigated parameters, i.e.: $\boldsymbol{D_{SSDL}/D_{IAEA}}$**. The *p* values < 0.05 were considered statistically significant.

2. Then, the appropriate correlation coefficient (in this case: **Pearson's correlation**) was used to analyze the association between the D_{SSDL}/D_{IAEA} value in a given year and number of years since 2004. The *p* values of < 0.05 were considered statistically significant. The interpretation of strength of correlation was based on the guidelines for biostatistics [2].

3. Finally, *p* value calculated for each statistical technique was compared to the *p* value which was considered statistically significant. The reader should remember that only for statistically significant *p* value the results of applied test may be valid and then interpretation and inference may be reliable.

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Results – part 1

Table 1 Results of the interlaboratory comparisons in terms of absorbed dose to water.

Year	D_{SSDL} [Gy]	D_{IAEA} [Gy]	$\|E_n\|$
2004	2.013	2.032	**0.20**
2005	1.980	1.976	**0.04**
2006	2.054	2.044	**0.10**
2007	2.040	2.036	**0.04**
2008	1.920	1.934	**0.15**
2009	2.060	2.058	**0.02**
2010	1.976	1.959	**0.18**
2011	2.037	2.029	**0.08**
2012	1.995	1.999	**0.04**
2013	2.036	2.029	**0.06**
2014	1.964	1.960	**0.04**
2015	2.084	2.079	**0.05**
2016	1.905	1.919	**0.15**
2017	2.031	2.039	**0.08**
2018	1.885	1.908	**0.25**
2019	2.027	2.038	**0.11**
2020	1.9835	1.978	**0.06**
2021	1.926	1.917	**0.10**

The minimum value of $|E_n|$ was 0.02 in 2009.

The maximum value of $|E_n|$ was 0.25 in 2018.

The acceptance criterion: $|E_n| \leq 1.00$

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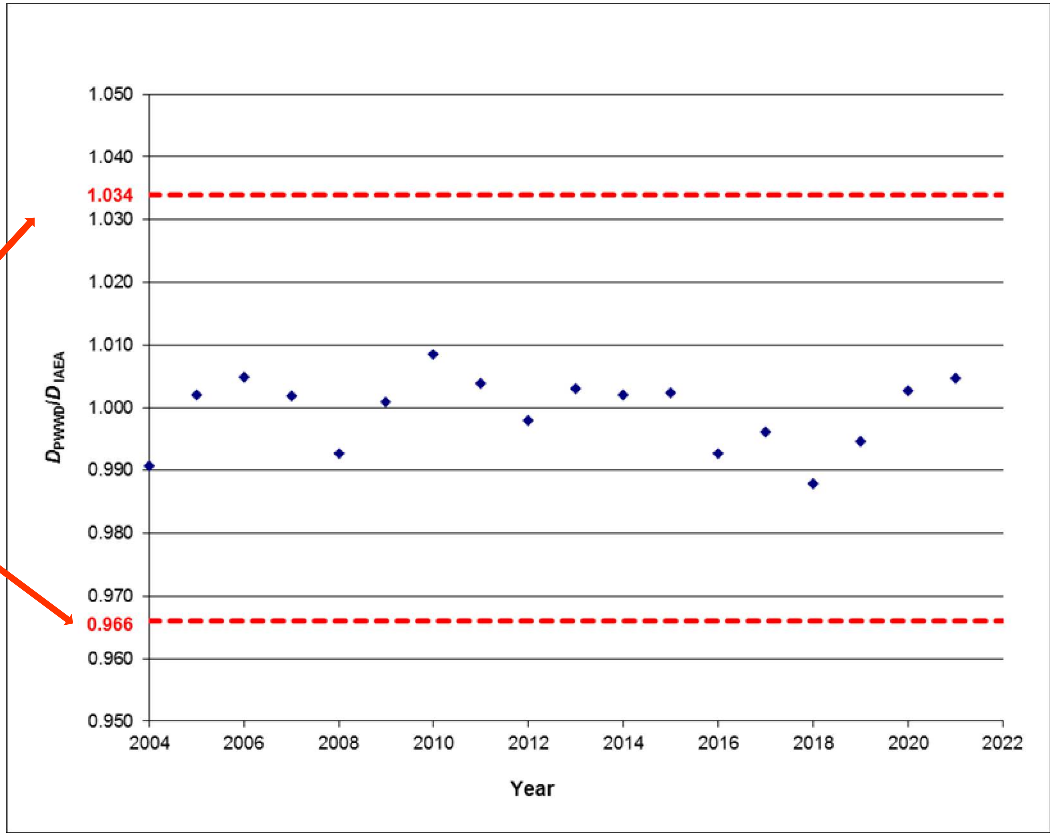
Results – part 2

Fig. 1 Trend of changes in the results of the interlaboratory comparisons during the period 2014-2021.



The red, dashed lines represent the acceptance criterion, i.e. $D_{SSDL}/D_{IAEA} \in \langle 0.966;1.034 \rangle$.

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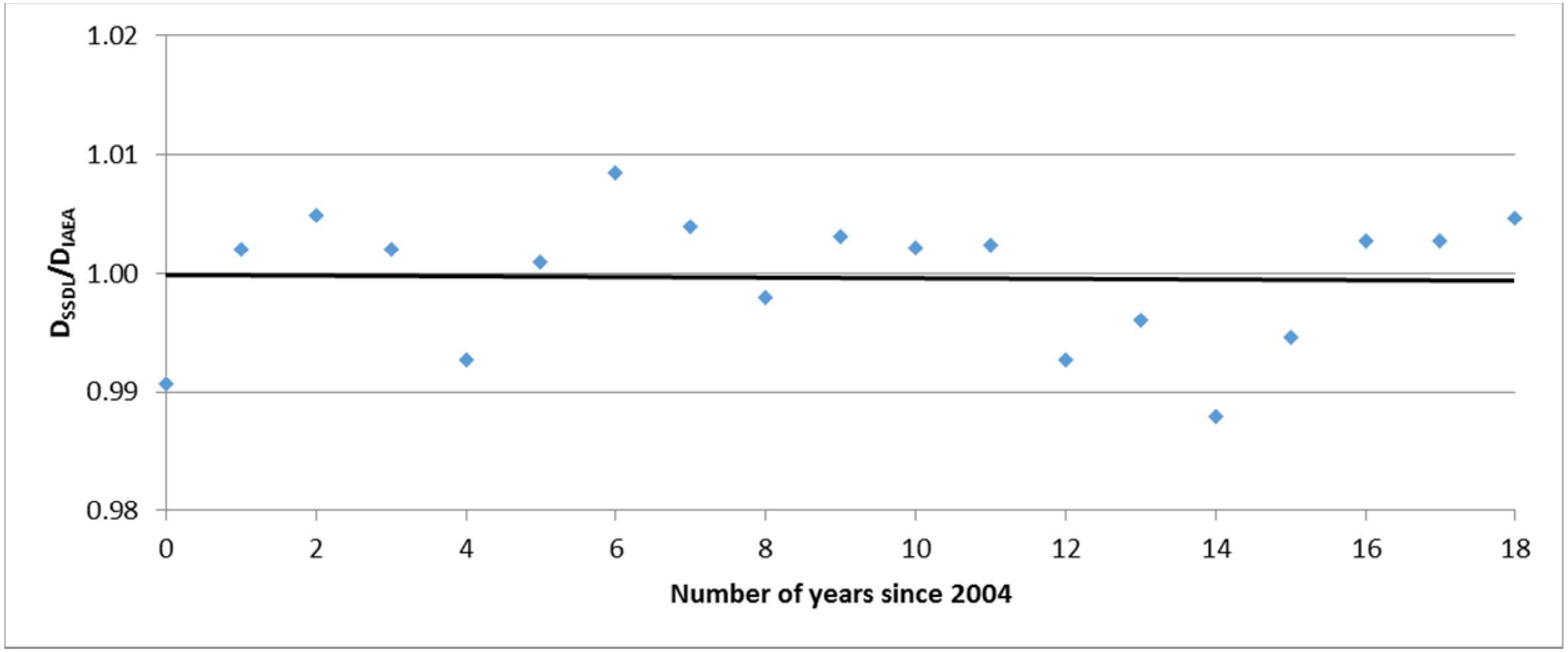
Results – part 3: statistical analysis



The black, solid line represents the line fitted to the results.

Fig. 2 Trend of changes in the results of the interlaboratory comparisons during the period 2014-2021.

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Results – part 3: statistical analysis

The Shapiro-Wilk test

Analyzed data: D_{SSDL}/D_{IAEA}

Significance level (α): 0.05

The Shapiro-Wilk test did not show a significant departure from the normality, $W(19) = 0.913$, $p = 0.085$

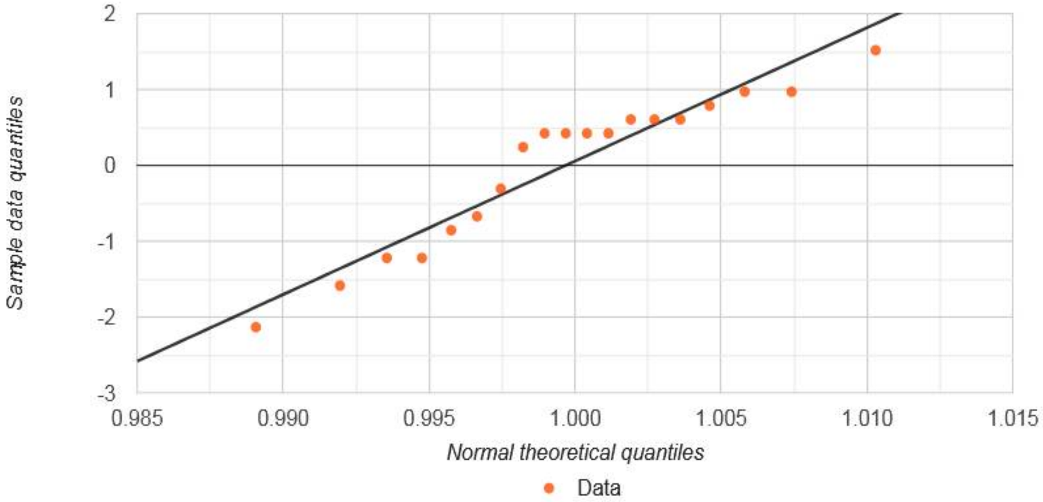

Fig. 3 Q-Q plot for D_{SSDL}/D_{IAEA} values

Table 2 Results of the interlaboratory comparisons in terms of absorbed dose to water.

D_{SSDL} / D_{IAEA}	Number of years since 2004
0.991	0
1.002	1
1.005	2
1.002	3
0.993	4
1.001	5
1.008	6
1.004	7
0.998	8
1.003	9
1.002	10
1.002	11
0.993	12
0.996	13
0.988	14
0.995	15
1.003	16
1.003	17
1.005	18

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Results – part 3: statistical analysis

The Shapiro-Wilk test

Analyzed data: number of years since 2004

Significance level (α): 0.05

The Shapiro-Wilk tests did not show a significant departure from the normality, $W(19) = 0.961$, $p = 0.592$

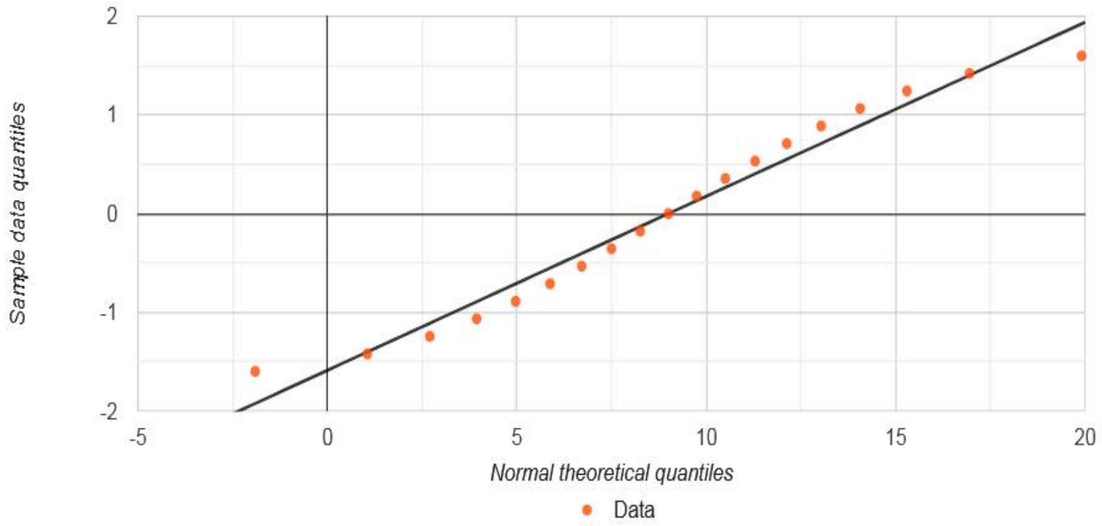

Fig. 4 Q-Q plot for number of years since 2004

Table 2 Results of the interlaboratory comparisons in terms of absorbed dose to water.

D_{SSDL} / D_{IAEA}	Number of years since 2004
0.991	0
1.002	1
1.005	2
1.002	3
0.993	4
1.001	5
1.008	6
1.004	7
0.998	8
1.003	9
1.002	10
1.002	11
0.993	12
0.996	13
0.988	14
0.995	15
1.003	16
1.003	17
1.005	18

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Results – part 3: statistical analysis

The Pearson's correlation

Since *p*-value > α for the Shapiro-Wilk tests for both parameters: D_{SSDL}/D_{IAEA} and number of years since 2004, we assumed that both variables were normally distributed.

Therefore we used the Pearson's correlation to analyze the association between the D_{SSDL}/D_{IAEA} value in a given year and number of years since 2004.

Significance level (α): 0.05

Results of the Pearson correlation indicated that there is a non significant very poor negative relationship between X variable (number of years since 2004) and Y variable (D_{SSDL}/D_{IAEA}), ($r(17) = -0.0216$, $p = 0.930$).

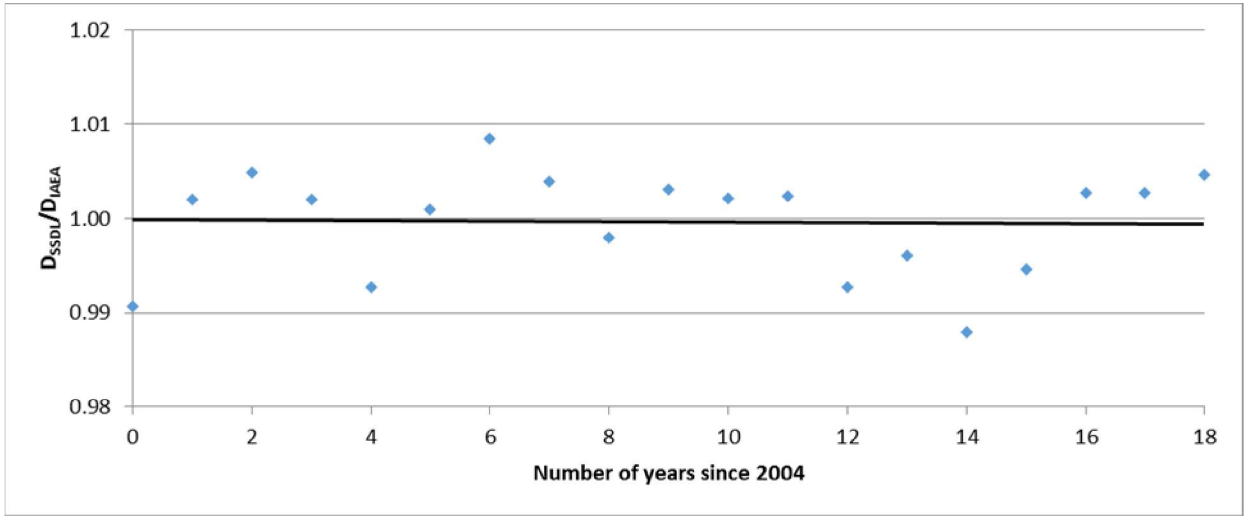

Fig. 2 Trend of changes in the results of the interlaboratory comparisons during the period 2014-2021.

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Results – part 3: statistical analysis

Table 3 Strength of linear relationship [2]

Correlation coefficient value: *r*	Strength of linear relationship
at least 0.8	very strong
0.6 up to 0.8	moderatly strong
0.3 to 0.5	fair
less than 0.3	poor

Since there is a very poor negative correlation between the variable X and the variable Y, but this correlation is not significant, as shown by the Pearson correlation, we can assume that there is no **trend of changes in the interlaboratory comparisons results from 2004 to 2021**.
These results are in line with our expectations because the time elapsed since the first participation of the Polish SSDL in the interlaboratory comparison should not significantly affect the result of these comparisons - to assure validity of the results issued to Polish SSDL clients.

Therefore, **there was no need to take appropriate action to prevent incorrect results from being included in the test results reported to Polish SSDL clients**.

Moreover, **there was no need to perform any corrective actions specified in the current edition of the Polish SSDL management system document.**

In addition, **there was no need to analyze the situation in the context of the risk of testing being not-conforming to the established procedure and to take appropriate actions set out in other document establishing the procedure for such non-conforming work**.

Conclusions

All the results of the interlaboratory comparisons for the Polish Secondary Standard Dosimetry Laboratory in the field of testing of thermoluminescent detectors in terms of absorbed dose to water **were acceptable in the analyzed period**.

The obtained results indicated that **there was no trend of changes in the interlaboratory comparisons results from 2004 to 2021**.

The presented analysis of the results of the interlaboratory comparisons is useful in routine activity of the testing laboratories carrying out tests of the thermoluminescent detectors in terms of absorbed dose to water.

References

[1] INTERNATIONAL ORGANIZATION FOR STANDARDIZATION, General requirements for the competence of testing and calibration laboratories, ISO/IEC 17025:2017, ISO, Geneva (2017)

[2] Chan YH, Biostatistics 104: Correlation Analysis. Singapore Med J 2003; Vol 44(12): 614-619