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Bilateral comparisons in the field of testing of thermoluminescent detectors in terms of absorbed dose to water for radiation therapy level audits – a practical guide to the statistical analysis of the results

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

Introduction

The Secondary Standards Dosimetry Laboratory (SSDL) in Poland has been accredited by the Polish Centre for Accreditation for the conformity with the ISO/IEC 17025 standard since April 2014. In the scope of accreditation No. AB 1499 there is testing of thermoluminescent detectors in terms of absorbed dose to water, by thermoluminescent dosimetry method. As an accredited laboratory Polish SSDL has to fulfill the requirement concerning monitoring the validity of the tests undertaken. We decided that this monitoring included participation in bilateral comparisons between the Polish SSDL and Dosimetry Laboratory of the International Atomic Energy Agency (IAEA).

The aim of this study is to present a practical guide to the statistical analysis of the results of bilateral comparisons that can be useful in routine activity of the testing laboratories in the above-mentioned area in order to check if results are stable in specified limits.

Material and methods

We analyzed the results of bilateral comparisons conducted annually over the period **2004-2023**. These comparisons were conducted according to a procedure established by the IAEA and consisted of comparing the TLD dose reported by Polish SSDL ($\boldsymbol{D_{SSDL}}$) with the dose value reported by the IAEA ($\boldsymbol{D_{IAEA}}$).The acceptance criteria of the result were established at the Polish SSDL and 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. $\boldsymbol{D_{SSDL}/D_{IAEA} \in \langle 0.966;1.034 \rangle}$.

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 (variable Y) and number of years since 2004 (variable X)**.

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* value of < 0.05 was 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 because only for statistically significant *p* value the results of applied test may be valid and then interpretation and inference may be reliable.

Results and discussion

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

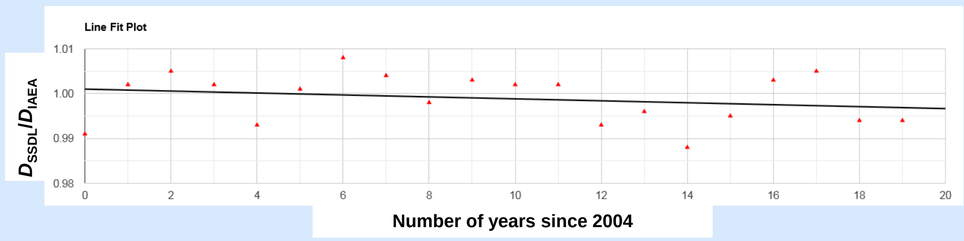
The acceptance criterion: $D_{SSDL}/D_{IAEA} \in \langle 0.966;1.034 \rangle$

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

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

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

Year	D_{SSDL} [Gy]	D_{IAEA} [Gy]	$\lvert E_n \rvert$	D_{SSDL} / D_{IAEA}	Number of years since 2004
2004	2.013	2.032	0.20	0.991	0
2005	1.980	1.976	0.04	1.002	1
2006	2.054	2.044	0.10	1.005	2
2007	2.040	2.036	0.04	1.002	3
2008	1.920	1.934	0.15	0.993	4
2009	2.060	2.058	0.02	1.001	5
2010	1.976	1.959	0.18	1.008	6
2011	2.037	2.029	0.08	1.004	7
2012	1.995	1.999	0.04	0.998	8
2013	2.036	2.029	0.06	1.003	9
2014	1.964	1.960	0.04	1.002	10
2015	2.084	2.079	0.05	1.002	11
2016	1.905	1.919	0.15	0.993	12
2017	2.031	2.039	0.08	0.996	13
2018	1.885	1.908	0.25	0.988	14
2019	2.027	2.038	0.11	0.995	15
2020	1.9835	1.978	0.06	1.003	16
2021	1.926	1.917	0.10	1.005	17
2022	1.958	1.969	0.11	0.994	18
2023	2.080	2.093	0.13	0.994	19



Outliers' detection method: Tukey Fence, *k* = 1.5. **The data doesn't contain outliers.**

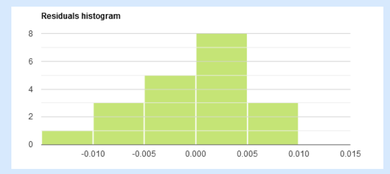
Table 2 Strength of linear relationship [2]

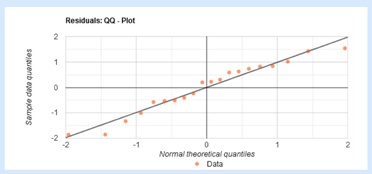
Correlation coefficient value: *r*	Strength of linear relationship
at least 0.8	very strong
0.6 up to 0.8	moderatly strong
0.3 to 0.5	fair
less than 0.3	poor

The Pearson's correlation

Significance level: (α) = 0.05

Parameter	Value
Pearson correlation coefficient (*r*)	-0.2321
r^2	0.05386
P-value	0.3248
Covariance	-0.007605
Sample size (n)	20
Statistic	-1.0123





The normality assumption was checked based on the Shapiro-Wilk Test (α = 0.05).
It is assumed that **residuals' distribution** does follow a normal distribution (p-value is 0.4321), or more accurately, **we can't reject the normality assumption**.

Results of the Pearson correlation indicated that there is a non significant poor negative relationship between *X* and *Y*, ($r(18) = -0.232$, $p = 0.325$).

All the results were acceptable in the analyzed period.
Since there is a 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 bilateral comparisons results from 2004 to 2023**. These results are in line with our expectations, as the time elapsed between the first (in 2004) and the last (in 2023) participation of the Polish SSDL in bilateral comparisons should not significantly affect the result of these comparisons - to ensured the validity of the results issued by the Polish SSDL to radiation therapy centers in Poland.

Conclusions

All the results of bilateral 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 significant trend of changes in bilateral comparisons results from 2004 to 2023**.
The presented statistical analysis of the results of bilateral comparisons can be useful in the routine activity of accredited testing laboratories performing not only 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