Robustness study in SSNTD method validation: indoor radon quality

D. C. S. Dias; N. C. Silva and R. L. Bonifácio

Brazilian National Commission for Nuclear Energy/Laboratory of Poços de Caldas/Radon and Quality Departments, 37701-247, Poços de Caldas, Minas Gerais, Brazil.

danilacdias@gmail.com

ABSTRACT

Quality control practices are indispensable to organizations aiming to reach analytical excellence. Method validation is an essential component to quality systems in laboratories, serving as a powerful tool for standardization and reliability of outcomes. This paper presents a study of robustness conducted over a SSNTD technique validation process, with the goal of developing indoor radon measurements at the highest level of quality. This quality parameter indicates how well a technique is able to provide reliable results in face of unexpected variations along the measurement. In this robustness study, based on the Youden method, 7 analytical conditions pertaining to different phases of the SSNTD technique (with focus on detector etching) were selected. Based on the ideal values for each condition as reference, extreme levels regarded as high and low were prescribed to each condition. A partial factorial design of 8 unique etching procedures was defined, where each presented their own set of high and low condition values. The Youden test provided 8 indoor radon concentration results, which allowed percentage estimations that indicate the potential influence of each analytical condition on the SSNTD technique. As expected, detector etching factors such as etching solution concentration, temperature and immersion time were identified as the most critical parameters to the technique. Detector etching is a critical step in the SSNTD method – one that must be carefully designed during validation and meticulously controlled throughout the entire process.

Keywords: indoor radon, robustness, validation.

1. INTRODUCTION

Radon gas is a natural radionuclide and its inhalation represents on average over 50% of the annual dose of radiation to which men are subjected. The World Health Organization and the International Atomic Energy Agency recommend the control of human exposure to this gas, which is found in rocks and soils and it penetrates living environments and concentrates indoors. It is therefore recommended that radon monitoring be conducted based on quality control procedures (WHO, 2016).

Quality assurance is a broad concept, applying to a variety of fields. In the realm of analytical techniques, it includes all aspects that may influence the quality of a measurement. Validation of analytical methods is a fundamental component of quality systems. To validate a technique means producing evidence of reliability and performance with regards to specific requirements for the intended application (LOPES, 2014).

The achievement of method robustness can be described as the ability to obtain reliable results in the presence of unexpected variations of an analytical technique. The term "robustness" or "ruggedness" was coined in the analytical industry by Youden and Steiner (1975), upon proposing an experiment to verify whether variables of a laboratory test would influence the response of a method (VANDER HEYDEN; MASSART, 1996).

This quality parameter is an essential indicative of reliability and especially important when validating an analytical procedure, as well as when proposing a new technique as a reference method or standard (APHA, 2012). Thus, it can be applied to validation of indoor radon techniques such as SSNTD (LEONARDI et al., 2015).

2. MATERIALS AND METHODS

One of the goals of a robustness study is to identify critical factors (variables) to a method, and to assess the degree of their influence when they fluctuate. The Youden test may be applied to the study of this parameter by estimating the impact of these variations (APHA, 2012).

The approach involves the identification of analytical factors which are relevant to the outcome of an assay and it is based on the Plackett–Burman method, introduced in 1946, which gives information on individual factors, but not on their interactions. This partial factorial design involves 4n experiments, where n is the amount of levels applied to it. In this design, the maximum number of factors that can be considered is 4n – 1. For instance, a 12-experiment design should consider 11 factors to be assessed (ANALYTICAL METHODS COMMITTEE, 2013).

In the current robustness study, a two level / 7 factor partial design was defined, when extreme values (high – A, B, C… and low – a, b, c… levels) were established for each factor in relation to the ideal (nominal) value established in the method (INMETRO, 2011; APHA, 2012). Thus, 8 experiments were conducted, each with a different combination of factors and levels, as indicated by Tables 1 and 2.

Table 1. Factors' high and low levels applied at Youden test.

FACTORS	**Low level (X)**	**Ideal method values**	**High level (x)**
Etching solution temperature (A/a)	93° C	98° C	98° C
Etching time (B/b)	50 min	60 min	70 min
Etching solution density (NaOH) (C/c)	1,178 g.cm^{-3}	1,181 g.cm^{-3}	1,195 g.cm^{-3}
Neutralising solution concentration (CH_3COOH) (D/d)	1%	2%	5%
Neutralising solution immersion time (E/e)	5 min	20 min	30 min
Antistatic solution concentration (F/f)	0,05%	0,10%	1%
Detector storage time prior to etching (G/g)	up to 8 hours	up to 48 hours	168-176 hours

Table 2. Partial factorial design of 7 factors and 8 experiments.

Analytical Factors	Experiments							
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**
A/a	A	A	A	A	a	a	a	a
B/b	B	B	b	b	B	B	b	b
C/c	C	c	C	c	C	c	C	c
D/d	D	D	d	d	d	d	D	D
E/e	E	e	E	e	e	E	e	E
F/f	F	f	f	F	F	f	f	F
G/g	G	g	g	G	g	G	G	g
Results ($kBq.m^{-3}.h$)	**s**	**t**	**u**	**v**	**w**	**x**	**y**	**z**

According to Youden and Steiner (1975), the impact of each factor is evaluated by comparing the averages of high and low levels experiment results (s through z). For instance, to assess the effect of factor etching time (B/b), Equation 1 is applied as follows:

$$\text{Effect}\,(B/b) = \frac{\mathrm{s+t+w+x}}{4} - \frac{\mathrm{u+v+y+z}}{4}$$

In that,

s, t, w, x = results in experiments where high level of etching time was used (B).

u, v, y, z = results in experiments where low level of etching time was used (b).

Finally, the percentage impact (%) of each factor is expressed by dividing the difference obtained by the global average of 8 results. This percentage demonstrates the potential change of system responsiveness when the variable in question is altered in the range indicated.

3. RESULTS AND DISCUSSION

The Youden test allowed 8 different results from each experiment, with a mean of 325 kBq.m^{-3}.h. The difference calculated for each variable was then divided by the global mean value, resulting in the percentages indicated on Table 3.

Upon evaluation, 3 variables were established as the most critical to the method: etching solution temperature (39.8 %), density (27.5 %) and etching time (56.2 %). The result corresponds to the available literature, where it is recommended variations of temperature and density not to exceed ± 1° C and ± 0.001 g.cm^{-3}, respectively, for its notable sources of error in the SSNTD method (LEONARD, et al, 2015; TASL, 2012).

Table 3. Impact results (%) from each variable

VARIABLES	Identification (High/Low)	Impact (%)
Etching solution temperature	A/a	39.8
Etching time	B/b	56.2
Etching solution density (NaOH)	C/c	27.5
Neutralising solution concentration (CH_3COOH)	D/d	9.2
Neutralising solution immersion time	E/e	0.3
Antistatic solution concentration	F/f	5.8
Detector storage time prior to etching	G/g	8.8

The power of influence of the 3 critical factors can also be seen from the results of measurements obtained in the study of robustness. The experiment involving their combination at their lowest values produced the lowest result in kBq m^{-3}. At the same token, the experiment involving the critical factors at their 3 high levels produced the highest result of all 8 experiments.

Despite not reaching the highest impact percentages, the neutralising solution concentration (9.2%) and detector storage time prior to etching (8.8%) are conditions that must be carefully controlled as well during detector analysis. However, their low percentages do not allow an accurate assessment of their individual influence.

4. CONCLUSION

The current study elucidated the most critical variables in a SSNTD method of indoor radon measurement, which when controlled, may contribute to providing reliable data and results. Robustness may be considered one of the most important parameters to be evaluated in validation activities, once it allows the recognition of potential sources of problems within analytical techniques.

5. ACKNOWLEDGMENTS

The authors would like to thank CNEN-LAPOC, CAPES and CNPq for financial support.

REFERENCES

1. AMERICAN PUBLIC HEALTH ASSOCIATION (APHA). **Standard methods for the examination of water and wastewater**, 22 ed. Washington, DC, New York: American Public Health Association, 2012.

2. ANALYTICAL METHODS COMMITTEE. Analytical Division of the Royal Society of Chemistry. Experimental design and optimisation (4): Plackett-Burman designs. **Anal Methods-UK**. AMC Technical Briefs, AMCTB n.55, 2013.

3. INSTITUTO NACIONAL DE METROLOGIA, QUALIDADE E TECNOLOGIA (INMETRO). **DOQ-CGCRE-008: Orientação sobre validação de métodos analíticos**. Rev. 04, jul. 2011. Disponível em: <http://www.inmetro.gov.br/sidoq/arquivos/Cgcre/DOQ/DOQ-Cgcre-8_04.pdf>. Acesso em 15 jul. 2016.

4. LEONARDI, F.; et al. A step towards accreditation: A robustness of etching process. **Appl Radiat Isotopes**, Italy, n. 102, p. 93-97, May 2015.

5. LOPES, I.; et al. Implementation of the quality management system at the Laboratory of Radiological Protection and Safety (LPSR) in Portugal. **Accred Qual Assur**, Bobadela, n. 19, p. 355-360, Sep. 2014.

6. TRACK ANALYSIS SYSTEMS LTD (TASL). **Radon and Neutron dosimetry system. A complete system for etching, scanning and analyzing TASTRACK plastic nuclear track detector**. Bristol, United Kingdom, Oct. 2012.

7. VANDER HEYDEN, Y; MASSART, D. L. Chapter 3. Review of robustness in analytical chemistry. **Data Handl Sci Techn**, Belgium, v. 19, p. 79-147, 1996.

8. YOUDEN, W. J; STEINER, E. H. **Statistical Manual of the Association of Official Analytical Chemists**, Association of Official Analytical Chemists ed., Arlington, 1975, p. 33-36, 70-71, 82-83.

9. WORLD HEALTH ORGANIZATION (WHO). **Manual da OMS Sobre Radônio em Ambientes Internos. Uma Perspectiva de Saúde Pública**. Tradução do Instituto de Radioproteção e Dosimetria. 1 ed. Rio de Janeiro, 2016.