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Decontamination of radioactively contaminated surfaces — Testing of decontamination agents for textiles

Décontamination des surfaces contaminées par la radioactivité — Essai des agents de décontamination pour les textiles

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ISO copyright office
CP 401 • Ch. de Blandonnet 8
CH-1214 Vernier, Geneva
Phone: +41 22 749 01 11
Email: copyright@iso.org
Website: www.iso.org

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Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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This document was prepared by Technical Committee ISO/TC 85 *Nuclear energy, nuclear technologies, and radiological protection*, Subcommittee SC 2, *Radiological protection*.

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This second edition cancels and replaces the first edition (ISO 9271:1992), which has been technically revised.

The main changes are as follows:

— the scope was rephrased and specified;

— opening to further applications;

— adding of symbols of the used measurands;

— improvement of structure;

— improvement in readability;

— adaption to current standards;

— adding a new form in the Annex with description the properties of the agents to be tested.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

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Introduction

Wherever radioactivity is used, there is a risk that textiles can become contaminated through contact with radioactivity in solution or airborne radioactivity.

It is normally necessary to remove this contamination to reduce the risk to staff from accidental intake of the radioactivity on the surface. The ease of decontaminating textiles is therefore an important parameter to consider when selecting materials to use, e.g., for facilities in the nuclear industry, in radionuclide laboratories or nuclear medicine facilities.

This document defines a quantitative method under objective conditions for testing the ease of decontamination of textile fabric. The method enables the comparison of different textile materials to support decisions on textiles for use in different applications.

For the test, radioactive solutions are deposited onto a sample of the material to being studied. The solutions contain radionuclides commonly found in nuclear industry (^{60}Co, ^{137}Cs or ^{134}Cs) and are in aqueous form. The textiles are then cleaned with detergents or cleansing agent, to be tested, and the residual activity on the textiles is measured to give a quantitative measure of the ease of decontamination.

Information obtained from the test method will enable the optimization of the choice of decontamination agents for textiles. This should result in lower demands for materials and water in laundry systems, with consequent savings in the cost of radioactive waste processing operations such as filtration, evaporation, solidification and disposal.

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If the customer desires that suitability of their decontamination agents is to be tested with other radiochemicals containing alpha- and beta- emitting radionuclides, then other procedures and measurement techniques (like liquid-scintillation-counting) are to be used, which are not described in this document.

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Comparative tests can be carried out with all possible combinations of textile materials and radionuclides in homogeneous solutions. Inorganic or organic solutions can be used and they should be based on a solvent which evaporates at room temperature. An assessment of the results of a series of comparative tests is made on the basis of the mean residual pulse rates.

In order to permit the general qualification of a decontamination agent as a single product, this document specifies a test and assessment method based on ^{60}Co and ^{137}Cs applied to internationally standardized cotton fabric. These two radionuclides were selected because they are the most important sources of contamination in the nuclear industry. The cotton fabric selected is the only reference material available in this field. The assessment of the result of a single test is made using an assessment table of final residual pulse rates based on inter-laboratory experiments.

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Decontamination of radioactively contaminated surfaces — Testing of decontamination agents for textiles

1 Scope

This document applies to the testing of the decontamination of textiles, which are contaminated by radioactive materials.

The test method describes the technique to assess the efficiency of decontamination agents (see ISO 7503-1 and ISO 7503-3).

This document applies to the testing of detergents, which may be used in aqueous solutions for the purpose of cleaning radioactively contaminated textiles.

The radionuclides used in this test are those commonly found in the nuclear industry (^{137}Cs, ^{134}Cs and ^{60}Co) in aqueous form. The test can also be adapted for use with other radionuclides and other chemical forms, depending on the customer requirements, if the solutions are chemically stable and do not damage the test specimen.

The test method is not suitable if the radionuclide emits low energy gamma rays, like ^{55}Fe, or low energy beta or alpha particles that are readily attenuated in the textile fabrics, or if the nuclide has a chemical or isotopic interaction with the detergent used in the method (e.g. tritium which could be in several chemical forms).

The test method does not apply to the testing of the ability of detergents to remove non-radioactive dirt.

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2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 2174, *Surface active agents — Preparation of water with known calcium hardness*

ISO 2267, *Surface active agents — Evaluation of certain effects of laundering — Methods of preparation and use of unsoiled cotton control cloth*

ISO 3819, *Laboratory glassware — Beakers*

ISO 6330, *Textiles — Domestic washing and drying procedures for textile testing*

ISO 11074, *Soil quality — Vocabulary*

ISO 80000-10, *Quantities and units — Part 10: Atomic and nuclear physics*

ISO/IEC Guide 98-3, *Uncertainty of measurement — Part 3: Guide to the expression of uncertainty in measurement (GUM:1995)*

ISO/IEC Guide 99, *International vocabulary of metrology — Basic and general concepts and associated terms (VIM)*

3 Terms, definitions and symbols

For the purposes of this document, the terms and definitions given in ISO 11074, ISO 80000-10, ISO/IEC Guide 98-3, ISO/IEC Guide 99 and the following apply.

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ISO and IEC maintain terminology databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at https://www.electropedia.org/

3.1 Terms and definitions

3.1.1
contamination
radioactive substances deposited on textiles

3.1.2
contaminated textile specimen
pieces of textile reference materials which are contaminated in a specified manner and which are used to determine the efficiency of decontamination agents

3.1.3
decontamination
complete or partial removal of radioactive *contamination* (3.1.1) by a deliberate physical, chemical, or biological process

[SOURCE: ISO 12749-3:2015, 3.7.11.2]

Note 1 to entry: It is preferred that decontamination does not significantly change the characteristics of the surface.

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3.1.4
specific pulse rate
I_s
pulse rate caused in the measuring apparatus under given geometrical conditions by 1 ml of a contaminant solution

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Note 1 to entry: It is expressed in pulses per minute standardized on 1 ml of the contaminant solution. Pulse rates are derived from count rates applying dead time and background corrections.

3.1.5
residual pulse rate
I_r
pulse rate caused in the measuring apparatus under given geometrical conditions by the residual radionuclide on the tested side of the specimen after *decontamination* (3.1.3)

Note 1 to entry: I_r is expressed in pulses per minute.

3.1.6
mean residual pulse rate
$\overline{I_r}$
arithmetic mean of the residual pulse rate values obtained for the five test specimens contaminated by the same radionuclide

Note 1 to entry: It is expressed in pulses per minute.

3.1.7
standardized mean residual pulse rate
corrected value of the *mean residual pulse rate* (3.1.6)

Note 1 to entry: The correction factor is obtained by dividing a reference value of the specific pulse rate by the pulse rate of a contaminant solution used in the test.

Note 2 to entry: It is expressed in pulses per minute.

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Note 3 to entry: The purpose of the correction factor is to compensate for variations in specific pulse rates of contaminant solutions used in different test laboratories.

3.1.8
final residual pulse rate
$I_{r,fin}$
arithmetic mean of the *standardized mean residual pulse rate* (3.1.7) obtained for ^{60}Co and ^{134}Cs or ^{137}Cs

Note 1 to entry: It is expressed in pulses per minute.

Note 2 to entry: is the pulse rate caused in the measuring apparatus under given geometrical conditions by the residual radionuclide on the tested side of the specimen after *decontamination* (3.1.3).

3.2 Symbols

For the purposes of this document, the following symbols apply.

A	Activity of the radionuclide [Bq]
A_S	Specific activity of the radionuclide [Bq·g^{-1}]
A_E	Activity of the radionuclide in the contaminant solution [Bq]
D_{min}	Distance between the centre point of the contaminated area and the edge of the sensitive detector cross-section [mm]
h	Distance of the contaminated test surface from the detector surface [mm]
m	Mass [g]
M	Molar mass [kg·mol^{-1}]
r	Final volume of contaminant solution [ml]
s	Activity concentration of stock solution [MBq·ml^{-1}]
q	Carrier concentration [mol·l^{-1}]
τ	Carrier concentration of the initial radionuclide solution [mol·l^{-1}]
t	Time [s]
$t_{1/2}$	Half-life [years]
u	Carrier concentration, in moles per litre [mol·l^{-1}]
V	Volume [l]

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4 Principle

A specimen of the textile material is contaminated using a solution containing ^{60}Co and ^{137}Cs or ^{134}Cs. The emission from the specimen is measured using a detector. The specimen made from textile reference material is decontaminated using a solution of the decontamination agent under test. The emission is measured again and the result is compared to the result of the first measurement to quantify the ease of decontamination.

Separate contaminant solutions containing ^{60}Co and ^{137}Cs or ^{134}Cs (carrier concentration: 10^{-5} mol·l^{-1}; pH 4) are prepared. 100 µl samples of these solutions are counted using a large area radiation detector. The specific pulse rates of contaminant solutions are calculated using the results from the count.

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Specimens of the material under test are first treated with the contaminant solutions over a defined area and subsequently decontaminated with demineralized water. The residual pulse rate, I_r, is determined by measuring the contaminated samples.

The standardized mean residual pulse rates $\overline{I_{r,n}}$ for each radionuclide are calculated. The arithmetic mean of the respective values for ^{60}Co and ^{137}Cs or ^{134}Cs (final residual pulse rate, $I_{r,fin}$) is used to assess the ease of decontamination by means of a classification which has been compiled empirically.

5 Apparatus

In addition to ordinary laboratory apparatus, the following equipment shall be used for testing the ease of decontamination of textiles.

5.1 Beakers

Two beakers, of the low-form type, having a capacity of 2 000 ml and in accordance with requirements given in ISO 3819.

5.2 Radiation detector

A detector and associated electronics are required for determining the pulse rate. Suitable detectors are solid scintillation (e.g. NaI(Tl), $LaBr_3$(Ce), $CeBr_3$) and semi-conductor types selective for gamma-ray (see Reference [8]).

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NOTE The sensitivity and the efficiency depend on the size of the scintillator crystal or the semi-conductor detector

The minimum size of the sensitive area of the detector shall be a circle having a diameter of 30 mm, but in practice, the geometrical requirement specified normally necessitates the use of a larger sensitive area.

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To comply with geometrical requirements, the ratio $\frac{D_{min} - 12,5}{h}$ shall not be less than 3,

where

D_{min} is the smallest distance, in millimetres, from the centre point of the contaminated area, as projected onto the detector cross-section, to the edge of the sensitive detection area

h is the distance, in millimetres, of the contaminated test surface from the detector surface (see Figure 1).

If the geometrical requirement $\frac{D_{min} - 12,5}{h} \geq 3$ is not met, a detector having a circular sensitive area of not less than 30 mm in diameter may be used, provided that

a) for the determination of the specific pulse rate (see 8.1), the 100 µl of contaminant solution is applied to the centre of the textile specimen

b) the net pulse rate of 100 µl of contaminant solution measured under these geometrical conditions is not less than 200 000 pulses per minute (see 8.1).

The geometrical requirements for a radiation detector are illustrated in Figure 1.

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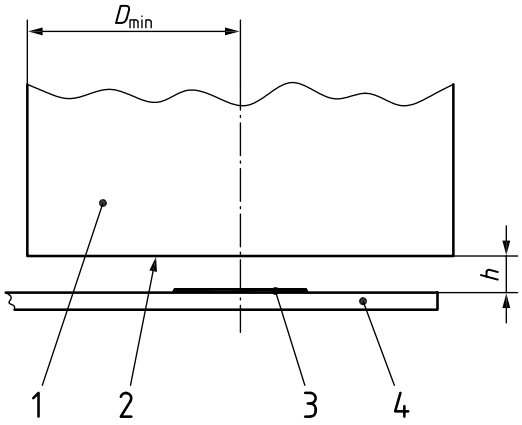

Key

1	detector	h	distance, in millimetres
2	sensitive area of detector	D_{min}	smallest distance, in millimetres
3	contaminated area		
4	test specimen		

Figure 1 — Geometrical requirements for a radiation detector (cross-section)

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5.3 Pipettes

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Two pipettes with disposable tips, having a capacity of 100 µl.

5.4 Two polytetrafluoroethylene (PTFE) or quartz ampoules

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Two polytetrafluoroethylene (PTFE) ampoules for preparation of the contamination solution

or

two quartz ampoules for the activation of the inactive stock solution in the neutron reactor are required.

5.5 Thermostat

A thermostat for setting and maintaining the test temperature at 60 °C.

5.6 Storage bottles

Two polytetrafluoroethylene (PTFE) bottles for storage the radioactive stock solution are required.

NOTE Other fluorinated materials of similar chemical resistance are possible alternatives to polytetrafluoroethylene (PTFE), such as polytetrafluoroethylene/perfluoropropylene (PTFE/PFP), perfluoro alkoxyl alkane (PFA) and poly(vinylidene fluoride) (PVDF).

5.7 Drying cabinet

Drying cabinet for drying the textile specimens in their respective holders.

5.8 Mounting

Ten holders for test specimens (5 for each radionuclide), made of poly(methyl methacrylate) (PMMA), serving as positioning aids for the contamination step (see Annex A).

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Each holder shall contain a flat silicone rubber ring (45 mm · 25 mm ·2 mm) made of unfilled material having a Shore A hardness value of not more than 60.

NOTE 1 Unfilled, unpigmented, fluorinated silicone rubber has been found particularly suitable for this purpose.

Before using for the first time, the rubber rings shall be cleaned using the organic solvent mixture (composed of benzene (boiling range from 60 °C to 80 °C) and isopropanol (minimum content 99 %) in a mixing ratio of 1:1 by volume) and repeat the wiping operation a third time using a tissue heavily soaked in pure water. The rings should only be reused after careful decontamination.

NOTE 2 Ten holders, five for each radionuclide, reduce the time needed to carry out the test and help to prevent cross-contamination.

5.9 Cage-stirrer apparatus

A cage-stirrer apparatus for six test specimens shall be used in accordance with Annex B. The apparatus shall be equipped with a motor allowing the stirrer to be rotated at 100 r/min.

6 Contamination and decontamination agents

6.1 Contaminant solutions

6.1.1 Composition of contaminant solutions

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The test specimens shall be contaminated by the radionuclides ^{60}Co and ^{137}Cs or ^{134}Cs, contained in separate solutions.

The use of other radionuclides in aqueous solutions which may be more suitable in terms of type and chemical behaviour for the envisaged purpose of the textile fabrics can be adopted, subject to consultation with the testing laboratory.

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However, the contaminant solutions shall be chemically stable and shall not degrade the test specimens. The decontaminated samples shall be stable in order to allow the residual contamination to be measured. Special measurement techniques may be required in the case of radionuclides the emissions of which are subject to absorption.

The activity concentration of the contaminant solution shall be such that an evaporated 100 µl sample produces a pulse rate of not less than 200 000 pulses per minute in the detector, after correction for dead time and background.

NOTE An activity concentration of 0,2 MBq ml^{-1} is usually sufficient to fulfil the requirement.

The radionuclides shall be used with a carrier concentration of (1,0 ± 0,1)·10^{-5} mol·l^{-1} in a solution of nitric acid with a pH-value of (4,0 ± 0,2). To make sure that the activity concentration does not change the pH-value of the contaminant solution is checked monthly or before use. This shall be done using a sample of each contaminant solution.

6.1.2 Preparation of the contaminant solutions

6.1.2.1 Apart from Co^{2+} and Cs^{+} ions and the corresponding nitrate ions, the radionuclide stock solutions shall not contain any constituents, which remain in the residue when the solutions have been evaporated as described in 6.1.2.6.

All reagents used shall be of analytical grade (pro analysis) or better.

6.1.2.2 With the help of the data available for the activity concentrations of the ^{134}Cs or ^{137}Cs and ^{60}Co stock solutions, the quantities of these solutions to be used for preparing the desired quantities of

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