Creation of a measurement protocol for swipe tests using QuantaSmart software.

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Revvity

Introduction

Carrying out a swipe test is certainly one of the more common tasks to be carried out in an isotope laboratory. More general information on wipe tests on the use of suitable swipe materials, solvents etc. is already available with application note[1] and further literature.[2] This application note should therefore focus on the creation of the protocol for a swipe test using the QuantaSmart software.

Basically, swipe tests are based on the ISO standards of the 7503[3] series. The following table shows the activities beyond which measures to reduce them or measures to protect employees must be taken. The activities are given as surface contamination in Bq/cm^2. It is not easy to obtain an exact activity of a surface contamination. The net count rate is obtained from the measured background count rate (ρ_0) and the count rate of the real sample (ρ_g). To determine the area activity, the quench-dependent counting efficiency (ε (Q)) of the sample, the swiped area (S) and the proportion of wipe able activity (F) are also required.

$$c_A = \frac{\rho_g - \rho_0}{\varepsilon(Q) \cdot S \cdot F} \left[\frac{Bq}{cm^2}\right]$$

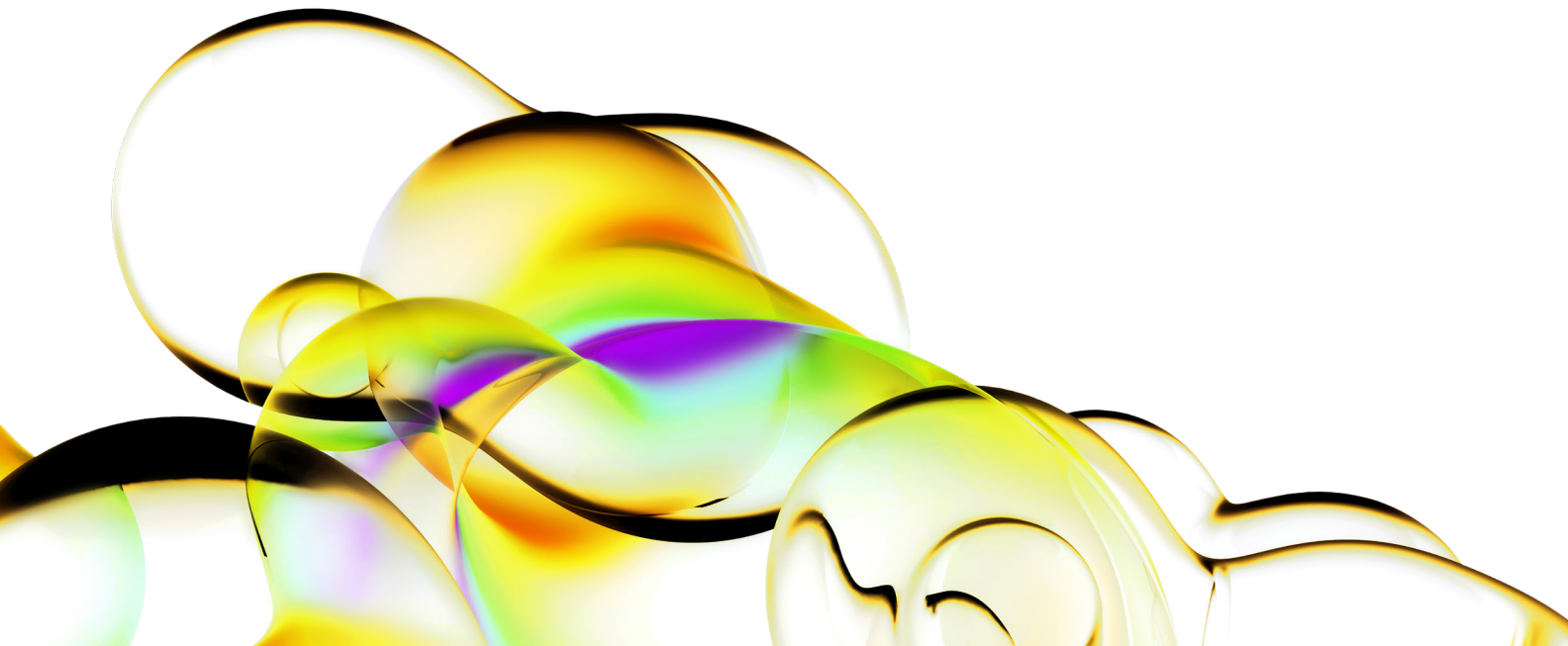

Table 1: Limits of surface contamination according to the German radiation safety regulation.[4)]

Isotope	Max. surface contamination outside a radiation safety area (Bq/cm²)†	Max. surface contamination in a control area (Bq/cm²)†	Max. surface contamination in a surveillance area (Bq/cm²)†
^{3}H	100,0	10000,0	1000,0
^{14}C	100,0	10000,0	1000,0
^{32}P	100,0	10000,0	1000,0
^{40}K	10,0	1000,0	100,0
^{90}Sr§	1,0	100,0	10,0
^{226}Ra§	1,0	100,0	10,0
^{241}Am	0,1	10,0	1,0

* Revvity (Germany) GmbH, Ferdinand-Porsche Ring 17, 63110 Rodgau-Jügesheim, Deutschland.
† Values according to Appendix 4, Table 1, Column 5 and §58 of the StrlSchV from 29.11.2018.
§ Values for these nuclides including possible daughter nuclides.

The wipe able activity F, the percentage of surface contamination that can be measured is difficult to determine. Tests with known standards of a substance are conceivable, but such tests are also only of limited validity and only give approximately correct values for the chemical used. The ease with which a substance can be swiped depends on its chemistry and physics, for example on the polarity of the substance. These factors determine how well the substance is adsorbed on the surface. In an isotope laboratory, however, several differently labelled substances are generally used, for which different wiping effectiveness results.

For this reason, a very conservative value for the wiping effectiveness is generally used, so that an existing contamination is never underestimated. A wiping effectiveness of 10% is almost always exceeded with glass fiber filters (see Literature #1). A value of F = 0.1 can therefore be used, which is also proposed in ISO 7503-2. For such a value, areas of around 100 cm² should be swiped. Since emulsifying cocktails are used in most cases, which can hold both purely organic and water-soluble samples, a certain amount of water is required in the samples to enable the cocktail to form micelles. Small round filters with a diameter of 25 mm are well suited and can easily be placed in a 20 ml scintillation vial. 70% alcohol is often well suited for moistening the filter. A suitable emulsifying cocktail is Ultima Gold or Ultima Gold LLT.

Creation of a measurement report

In this example, a measurement protocol is to be created with ^{3}H, medium energy nuclides such as ^{14}C, ^{35}S, ^{33}P etc and nuclides of higher energy such as ^{36}Cl, ^{40}K, ^{32}P, ^{89}Sr etc. Therefore, the entire measurement window is normally divided into three areas. Basically, a simple CPM protocol or a DPM protocol can be used to carry out a swipe test. A CPM protocol is particularly practical if contamination from only one known nuclide is expected.

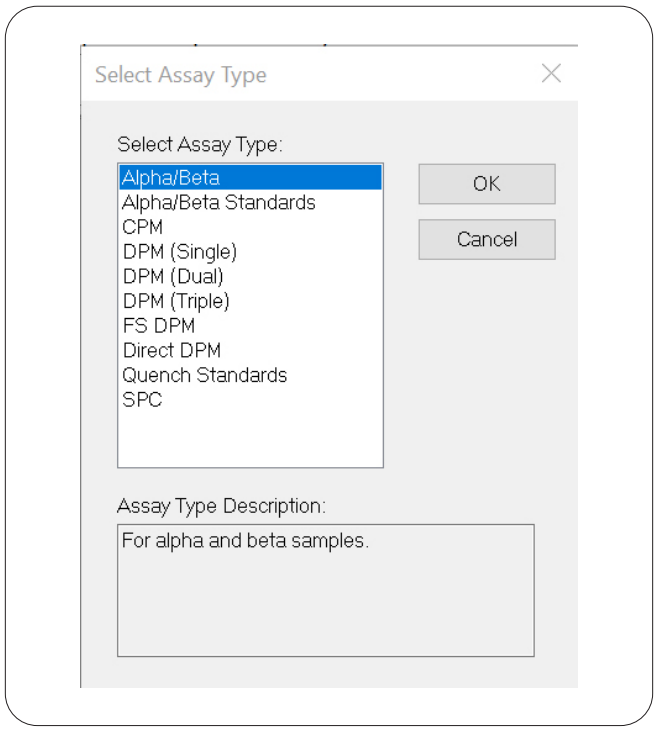

Figure 1: Available protocol types in a Tri-Carb or Quantulus GCT

In such a case, a fixed energy window can be used, for which the counting yield was once determined using a standard. The counting rate is then converted into an activity using a constant factor. At the same time, it must be assumed that all samples contain approximately the same quench. Such a way of working is no longer practical if several nuclides were used, and measurements have to be carried out simultaneously in different energy windows. This then requires additional spill corrections, which can be very time-consuming for many samples if done manually. An example of a DPM (triple) protocol with 3 windows is described below, as is possible in Tri-Carb (an option in some models) and Quantulus GCT systems. A DPM protocol is then more suitable for such an application but requires the existence of quench curves. If the creation of such a protocol is selected, the "Assay Definition" window appears with up to seven tabs, enabling the editing of the protocol as shown in Figure 2.

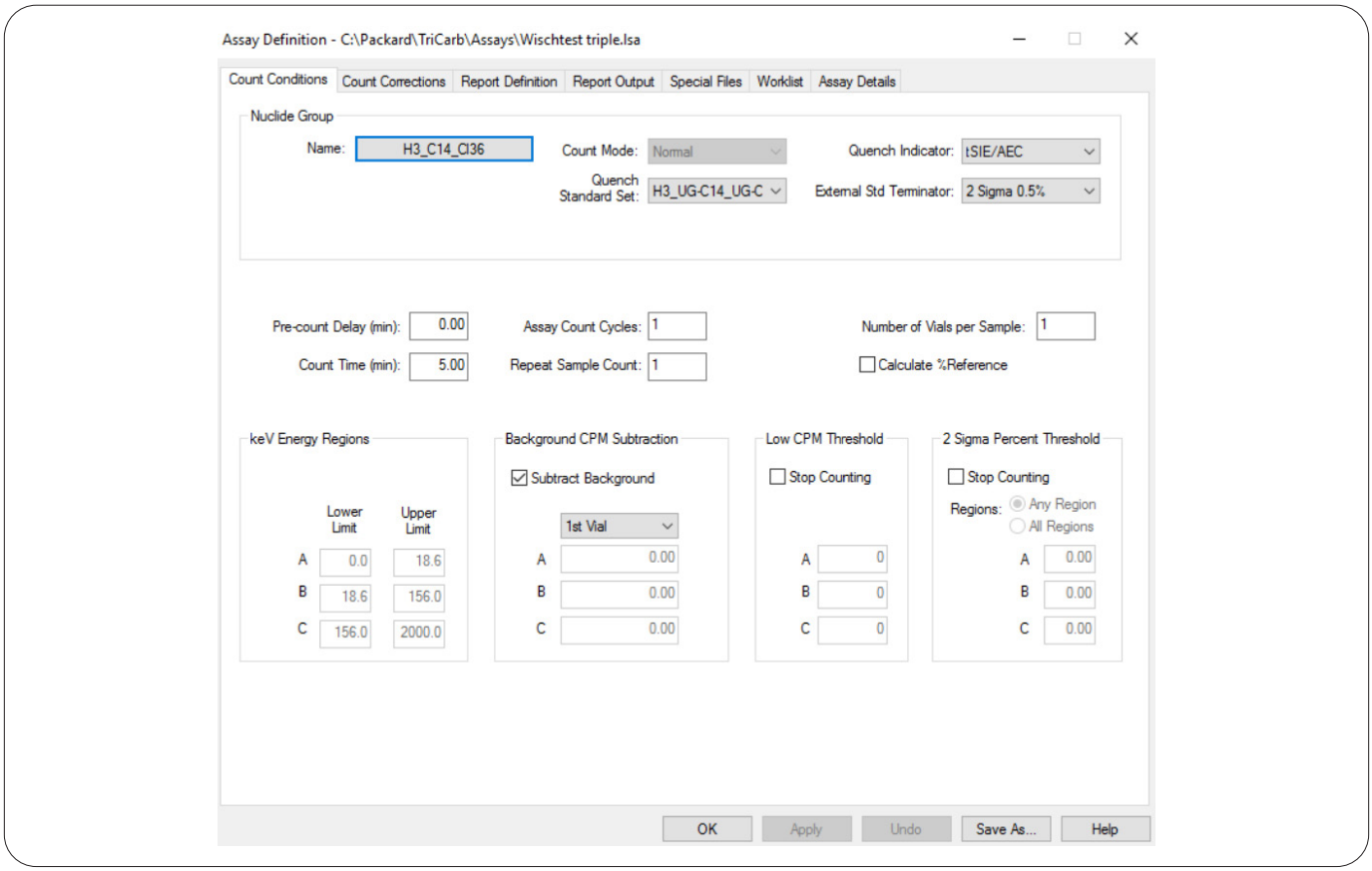

Figure 2: The "Count Conditions" tab in the Assay Definition window

In the "Nuclide Group" area at the top left of this tab, a name must be assigned by clicking the button. The "Sample Nuclide Groups" window opens. A name is assigned here, the three energy windows are defined, and the associated quench curves are selected. In this example, a window of 0-18.6 KeV for ^{3}H, the ^{14}C window of 18.6-156 KeV and the high-energy window of 156-2000 KeV are selected, although ^{36}Cl from this example has an end point of the energy window at approximately 710 KeV. This then also allows the detection of other even more energetic nuclides. Occasionally, the middle window is extended up to 250 KeV to include nuclides like ^{33}P in this window. The ^{14}C window can also be used for the nuclide ^{35}S without major errors, since the energy window is only slightly more energetic. Once the entries have been made in this window, please confirm with OK. The "Count Conditions" tab appears again. The defined name from the "Sample Nuclide Groups" window now appears as the name. The three quench curves selected in the previous window are now shown with their names in the Quench Standard Set pull down menu. The default Quench indicator tSIE/AEC should be used as a quench indicator for a DPM (triple) assay. With AEC (Automatic Efficiency Correction), the window is automatically moved depending on the quench in order to keep the spill of higher-energy nuclides in the window of low-energy nuclides constant and minimal. To limit the measurement time for the external standard, the "External Std Terminator" should be left at "2 Sigma 0.5%".

This leads to good counting statistics for the determination of the tSIE value and thus to a very small uncertainty for the counting efficiency resulting from statistical variations of the tSIE.

For medium and higher energy nuclides, the uncertainty of the counting efficiency in the typical quench ranges is <0.1 to a maximum of 0.15%, while for ^{3}H the uncertainty is approximately 0.5 to 1.0%. However, this is almost negligible due to the significantly greater uncertainty of wiping effectiveness. According to ISO 7503, ISO 11929 must be used when determining the characteristic quantities. In the middle area of the Count Condition window, the default settings can be applied almost anywhere. For a certain counting statistic, a measuring time of 3-5 minutes per sample is recommended. This is sufficient to achieve a detection limit of 1 Bq/cm² even in a simple Tri-Carb in the normal count mode, as is required, for example, for ^{90}Sr outside the radiation protection range, even if the wiping effectiveness is very uncertain. However, even such a small contamination is often not acceptable for low-level laboratories to rule out contamination of other samples. Correspondingly lower detection limits may then have to be obtained with longer measuring times. For α-emitters with even lower maximum surface contamination of e.g. 0.1 Bq/cm² this may require longer measuring times. "1st Vial" should be activated in the "Background CPM Subtraction" area. To do this, a background sample must later be placed in the first position of the samples in the rack. The background determined in this way is subtracted from all other swipe samples as a background.

The background sample should be made in the same vial type, with the same filter and cocktail as in the real swipe samples.

The "Count Corrections" index tab can be skipped. The default settings can be applied here.

Creation of the report

The content of the report must now be defined on the "Report Definition" tab. The report should have activated the "Assay Definition Block" in the "Report Block Data" section of the Report Definition tab. This documents all important parameters for the measurement. In addition, the counting rates CPMA, CPMB and CPMC should be activated in the "Report Fields" for the results table, as well as the resulting surface contamination DPM1, DPM2 and DPM3 or better the information as Bq1/cm², Bq2/cm² and Bq3/cm². In addition, the quench parameters SIS and tSIE should also be documented. To get the data in Bq/cm² it is necessary to create three additional lines. This can be done with the "Add" button below the "Report Fields" table. The "Equation" window appears as shown in Figure 3.

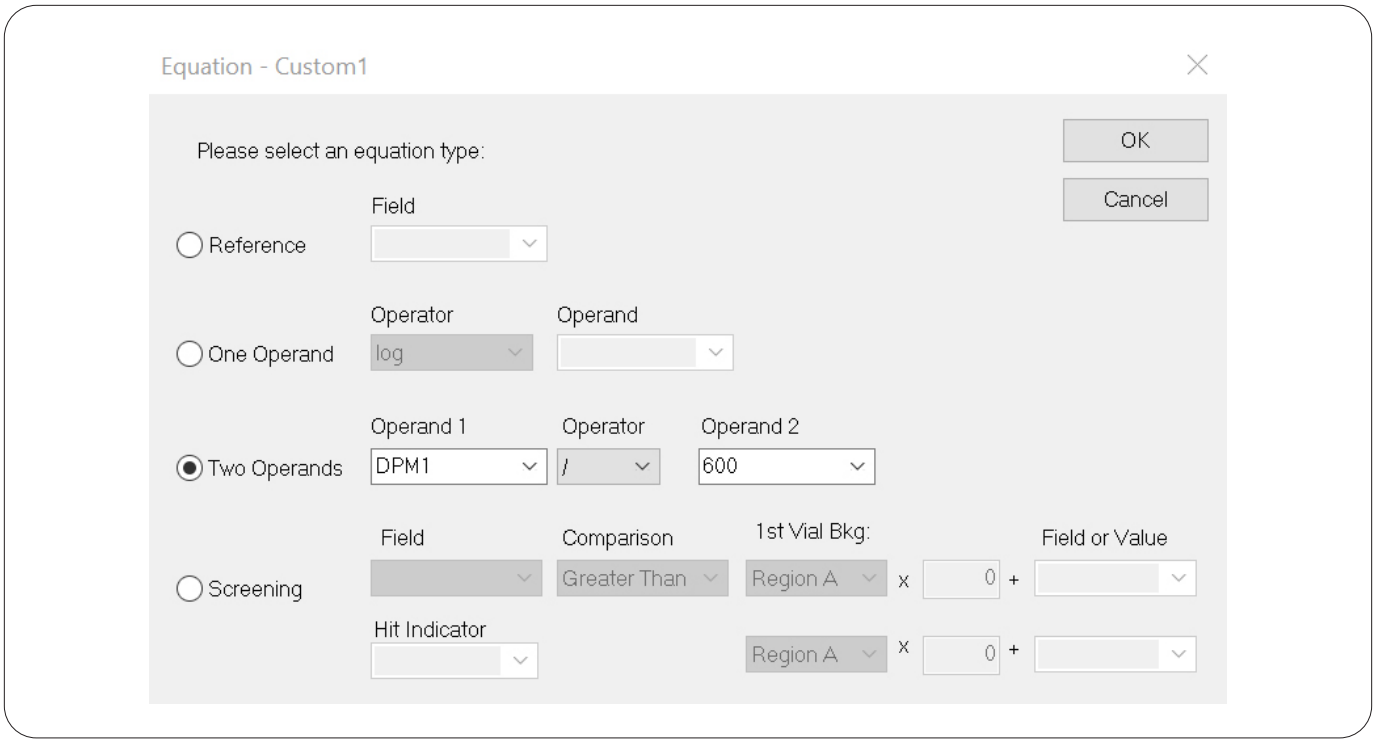

Figure 3: The Equation window allows defining simple calculations

By selecting “Two Operands” you can convert from DPM1 to Bq/cm2 in a simple equation and analogously for DPM2 and DPM3.

The division by 600 is obtained by converting DPM to Bq (division by 60), also by converting the swiped area from 100 cm^2 to one cm^2 (division by 100) and by correcting the swiping efficiency of 10% (multiplication factor 10).

In order to see the headline of the columns for surface contamination “Bq/cm^2” in the report, in the “Name” column of the “Report Fields” table, the default name “Custom 1” must be overwritten with “Bq1/cm^2”. Similarly, “Custom 2” and “Custom 3” are overwritten for the other two columns.

If other formulas have already been defined in the same report definition, the numbers behind “Custom” are higher because they are numbered consecutively.

On the “Report Output” tab you can define whether the report should be printed (preset) and/or saved as a file in various formats. Excel formats or Rich Text Files (RTF) are particularly popular formats. The latter are formats that can be imported directly into Word.

The “Special Files” index card is not necessary and can be skipped.

The “Worklist” tab is not installed in every system but is available on most systems as an option. In the Worklist each sample can be given an individual name. This can be used to document more precisely where the swipe test was carried out, as shown in the example in Figure 4. The good thing about the worklist is the fact that once a sample list has been created, it can be saved in a library and later used for other protocols. Since swipe tests are often taken at precisely defined points, this is helpful when a new protocol will be used with the same Worklist. When performing swipe tests using ethanol to moisten filter papers, care should be taken to ensure that the alcohols are used in the same amounts for background measurements. The ethanol available on the market is now mainly based on bioethanol, which contains the natural ^{14}C content existing in the atmosphere. This currently leads to approximately 13.7 DPM/g carbon (value for the year 2018).

The following two pages show a possible report for a swipe test as it is obtained with the protocol described above.

The report on the next page was saved as a rich text file and imported directly into this Word document without any changes. In the QuantaSmart software, this printout was changed to “landscape” in the “Files” menu under “Printer Setup” so that all the information in the report fits on one line. This improves the clarity of the documentation.

Assay Definition

Assay Description:

Assay Type: DPM (Triple)
Report Name: Report1
Output Data Path: C:\Packard\Tricarb\Results\Ron\Wischtest triple\20200518_1101\Replay_20200518_140922
Raw Results Path: C:\Packard\Tricarb\Results\Ron\Wischtest triple\20200518_1101\20200518_1101.results
RTF File Name: C:\Packard\Tricarb\Results\Ron\Wischtest triple\20200518_1101\Replay_20200518_140922\Report1.rtf
Comma-Delimited File Name: C:\Packard\Tricarb\Results\Ron\Wischtest
triple\20200518_1101\Replay_20200518_140922\Report1.csv
Assay File Name: C:\Packard\TriCarb\Assays\Wischtest triple.lsa

Additional Data Files Generated with this Protocol:
Report1
[Excel] Report1.csv
[RTF] Report1.rtf

Count Conditions

Nuclide: H3_C14_Cl36
Quench Indicator: tSIE/AEC
External Std Terminator (sec): 0.5 2s%
Pre-Count Delay (min): 0.00
Quench Sets:
Low Energy: H3_UG
Mid Energy: C14_UG
High Energy: Cl36
Count Time (min): 5.00
Count Mode: Normal
Assay Count Cycles: 1 Repeat Sample Count: 1
Number of Vials/Sample: 1 Calculate % Reference: Off

Background Subtract

Background Subtract: On - 1st Vial
Low CPM Threshold: Off
2 Sigma % Terminator: Off

Regions	LL	UL	Bkg Subtract
A	0.0	18.6	1st Vial
B	18.6	156.0	1st Vial
C	156.0	2000.0	1st Vial

Count Corrections

Static Controller: On Luminescence Correction: Off GCT: Off
Colored Samples: n/a Heterogeneity Monitor: n/a PAC: Disabled
Coincidence Time (nsec): 18 Delay Before Burst (nsec): 75 PAC Strength: n/a Auxiliary Spectrum: n/a

Cycle 1 Results

S#	Count Time	CPMA	CPMB	CPMC	Bq1/cm2	Bq2/cm2	Bq3/cm2	SIS	tSIE	MESSAGES	SMPL ID
1	10.00	2.92	9.28	3.00	0.00	0.00	0.00	418.12	319.44	B	1st Vial Bkgnd
2	5.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	326.27		Door
3	5.00	0.00	1.76	0.00	0.00	0.00	0.00	0.00	306.82		wipe area A1
4	5.00	0.62	0.58	0.00	0.00	0.00	0.00	1652.12	308.33		wipe area A2
5	5.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	303.20		wipe area A3
6	5.00	0.00	0.32	0.00	0.00	0.00	0.00	0.00	314.20		wipe area B1
7	5.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	302.53		wipe area B2

Figure 4: Example printout from a swipe assay protocol using three energy windows

Literature

1.) Revvity LSC Application Note, Swipe Assays, December 2017.

2.) R. H. W. Edler; An Introduction to the Scintillation Technology for the Measurement of Radionuclides, 1st Edition, Bremen 2020, ISBN 978-3-00-020422-7.

3.) ISO 7503-1:2018, Measurement of radioactivity – Measurement and evaluation of surface contamination – Part 1: General principles; ISO 7503-2:2016, Measurement of radioactivity – Measurement and evaluation of surface contamination – Part 2: Test method using wipe-test samples; ISO 7503-3:2018, Measurement of radioactivity – Measurement and evaluation of surface contamination – Part 3: Apparatus calibration.

4.) German radiation safety regulation for protection against ionizing radiation (Strahlenschutzverordnung – StrlSchV) from 29th November 2018 (BGBl. I S. 2034, 2036).

5.) German guideline for leakage tests on closed radioactive sources, version from 7th September 2012.

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