LIQUID SCINTILLATION SPECTROMETER "TRIEL"

USER MANUAL

Helsinki
2021

CONTENS

This user manual is intended to describe the principle of operation, device and design of the liquid scintillation spectrometric radiometers "TRIEL" (hereinafter referred to as the spectrometer) and contains the basic technical data and characteristics, as well as other information necessary for the full use of the technical capabilities of the spectrometer and its correct exploitation.

The manufacturer reserves the right during the manufacturing process to make changes to the design and software that do not affect the metrological characteristics of the spectrometer.

The following designations and abbreviations are adopted in the text of this User Manual (UM):

- DU - detection unit;
- NRN - natural radionuclides;
- PC - personal computer;
- PMT - photomultiplier tube;
- MSA - minimal significant activity;
- MT - measurement technique.

1 Description and operation

1.1 Introduction

1.1.1 The spectrometer is designed to measure the energy distribution of beta and alpha radiation, the activity of beta and alpha emitting radionuclides (for example, ^{3}H, ^{14}C, $^{90}Sr+^{90}Y$, ^{137}Cs, ^{32}P, ^{241}Am, ^{238}Pu, ^{239}Pu, ^{241}Pu, ^{242}Pu, etc.) and their mixtures in samples, as well as specific and volumetric activity in water and solid samples (tap water, water from artesian wells, sea water, water from open reservoirs, mineral and drinking water, packaged in containers, waters of various categories, technological water, wastewater, soil, bottom sediments, building materials, materials, reagents and equipment used for water treatment and water treatment, vegetation, food products, air filters, etc.), made from natural and technological objects on the assumption of a known composition of alpha, beta - emitting radionuclides.

The spectrometer refers to stationary measuring instruments and is intended for use in laboratory conditions. Also, the spectrometer can be used when equipping special vehicles of a mobile laboratory.

The following certified measurement procedures are available for the spectrometer:
"Methodology for measuring the activity of alpha and beta emitting radionuclides in water and solid samples taken from natural and technological objects, using a liquid spectrometric equipment".

1.1.2 Operating conditions of the spectrometer.
The spectrometer should be used under laboratory conditions:

- ambient temperature from +10 to +40 °C;
- relative air humidity up to (70 ± 3)%;
- atmospheric pressure in the range of 101 ± 5 kPa;
- intensity of constant and variable network frequencies of magnetic fields 40 A / m.

1.1.3 The Spectrometer manufactured in terms of the degree of protection against penetration of water, dust and other solid particles corresponds to the group IP52.

Figure 1.1 Liquid scintillation spectrometer "TRIEL"

1.2 Technical characteristics

1.2.1 The main metrological and technical characteristics of spectrometer are shown in Table 1.

Table 1

Parameter	Value
1. Energy range of registered alpha radiation, keV	from 2000 to 10000
2. Energy range of registered beta radiation, keV	from 1 to 4000
3. Range of activity measurement of alpha and beta emitting radionuclides, Bq	from 0.05 to $5 \cdot 10^4$
4. The relative expanded uncertainty (k = 2) of measuring the activity of radionuclides in samples does not exceed,% in the range from 0.05 to 50 Bq in the range from 50 to $5 \cdot 10^4$ Bq	 ±30 ±10
5. Relative energy resolution on the conversion electron line 624 keV of radionuclide ^{137}Cs, %, not more than	18
6. Detection sensitivity to beta radiation of radionuclide, cps/Bq - radionuclide ^{3}H - radionuclide ^{14}C - radionuclide ^{90}Sr+^{90}Y	 0.4 0.95 0.98
7. Integral nonlinearity in the beta energy range from 1 to 4000 keV,%, not more than	± 10
8. Maximum throughput, cps, not less than	$5 \cdot 10^4$
9. Instability of spectrometer indications (energy conversion characteristic) for 24 hours of a continuous operation, %, not more than	±2
10. Time for establishing the operating mode, min, no more	30
11. Time of continuous operation of the spectrometer from AC 220V, h, not less	24
12. The spectrometer is resistant to temperatures in the range	+10°C … +40°C
13. Spectrometers in transport containers are durable to temperatures ranging from minus 10°C to plus 50° C (as well as its rapid change) and ambient relative humidity of 98% at a temperature of 40°C	
14. Spectrometers are resistant to constant magnetic fields up to 40 A / m	
15. Operating conditions • ambient temperature, 0C • relative air humidity,% • atmospheric pressure in the range, kPa • intensity of constant and variable network frequencies of magnetic fields, A / m	 from +10°C to +40°C up to (70±3) 101±5 up to 40
16. The radiometer is powered from the AC power supply with voltage, V with frequency, Hz Power consumption V • A	 220 (+10 % ;- 15 %) 50 ±5 % 5
17. Number of spectrum channels	4096, 2048, 1024
18. PC communication interface (agreed upon when ordering equipment)	USB, RS-485
19 Overall dimension, mm, not more Height x Width x Length	230 x 250 x 480
20 Weight, kg	45

Notes to Table 1.

Metrological characteristics of the spectrometer, such as the efficiency of registration of radiation (sensitivity), background, count rate from control sources, overall dimensions and weight (including the thickness of the shield - lead and tungsten) are determined for each measuring path under the conditions of a specific measuring task of the Customer when the spectrometer is put into operation.

For i.3, the measurement ranges for the activity of beta and alpha emitting radionuclides are determined by the following values:

- the lower limit of measurements - the minimum measurable activity (MMA). MMA is defined as the value of the activity of a radionuclide in a sample, at which the random component of the measurement error for 3 hours will be 50%;
- the upper limit is the maximum statistical load of the spectrometer.

For i.3, the lower limit of the measurement range is determined at a measurement time ***t*** equal to 3 hours, therefore, at a measurement time ***t*** (hour), the lower limit of the measurement range is determined by multiplying by $\sqrt{3/t}$.

The lower limit of the measurement range is determined for the condition of the presence one radionuclide in the sample. If several radionuclides are present in the sample the lower limit of the measurement range for the activity of each of them shifts upward depending on the ratio of the activities of the radionuclides present and it is calculated by the "**ASW3L**" or "**SpectraDec**" software when processing the measured spectrum.

For i.4, the limits of the permissible relative error of activity measurements are given for the case of one radionuclide in the measured sample.

1.3 Spectrometer structure

1.3.1 The spectrometer is a single unit consisting of:

- multichannel analyzers;
- light collection chamber;
- protection chambers (lead and tungsten elements inside the case);
- coincidence PCB, as well as low-voltage and high-voltage electronics units;
- PMT's.

1.3.2 The device is included:

1.3.2.1 Liquid scintillation spectrometer "TRIEL";

1.3.2.2 Computer or tablet PC with "**ASW3L**" software installed. The specific model and complete set of the computer is agreed with the Customer when ordering;

1.3.2.3 Power supply adapter (Output voltage 12-17V. Maximum current 5A) and interface cable (USB or RS-485).

1.3.2.3 Plastic measuring cuvettes 20 ml for measure samples. The number of consumables is agreed with the Customer when ordering;

1.3.2.4 Liquid scintillator "Ultima Gold AB", "AquaLight AB" or similar. The number of consumables is agreed with the Customer when ordering;

1.3.2.5 Emulsifier brand "Triton X-100" or similar. The number of consumables is agreed with the Customer when ordering;

1.3.2.6 Variable volume dispenser;

1.3.2.7 Sealed point radioactive source of ^{137}Cs with activity less than MSA for determining the quenching of a sample as an outer standard;

1.3.2.8 The software package "**ASW3L**" for spectrometer control and spectra processing, the software "**SpectraDec**" spectra processing software;

1.3.2.9 Measurement techniques in accordance with the user's tasks (agreed with the Customer);

1.3.2.10 Set of operational documentation.

1.4 Design and operation

1.4.1 Spectrometer "TRIEL" is a device for registration of pulses arising from the interaction of alpha and beta particles with a liquid scintillator. The amplitude of the recorded pulses is proportional to the energy of the particle that caused them, the pulse count rate is proportional to the activity of the measured counting sample.

The spectrometer consists of a light collection chamber with two PMTs operating in a coincidence circuit and an electronic path that includes a high-voltage unit, a preamplifier, an amplifier, and a multichannel pulse analyzer that measures the amplitudes of pulse signals from the PMT and records the received digital code in the buffer memory and transfers the information to the computer via USB or RS485 interface.

The principle of the spectrometers operation is based on the complete absorption of the energy of charged particles in a liquid scintillator, emission of this energy in the form of a light flash, conversion of the flash energy into an electrical pulse, and registration of these pulses using two PMTs. After amplification and shaping, the analog signals from each PMT go to the coincidence circuit to isolate the coincidences during the resolving time. The signal from the output of the coincidence system goes to the input of the pulse analyzer, in which it is converted into a digital code proportional to the absorbed energy. The received codes are accumulated in the computer memory and form a spectrum of radiation energies. The software allows you to control the operation of the spectrometer, process spectra, as well as identify radionuclides and calculate activities in the investigated counting samples and samples. The processed results and spectra can be saved as files on computer storage devices or presented in the form of reports.

To solve some radiochemical tasks of identification and measurement of radionuclide activity in samples, it is possible to use measurement techniques, which should take into account the degree of correspondence between the samples and reference standard, the yield coefficients during radiochemical concentration and other corresponding additional contributions to the error in determining the radionuclide activities.

1.4.3 The spectrometer is controlled by the "**ASW3L**" software, which provides control of the equipment through communication protocols, as well as display of energy distribution (spectra), calculation and display of activity, storage and recording of results.

The **"SpectraDec"** software is used to solve the tasks of calculating the activity in samples by decomposition of complex spectra, as well as to carry out analysis in accordance with additional measurement techniques.

The spectra processing algorithm implemented in the software is based on modeling the hardware spectrum of the counting sample with the spectra of individual radionuclides obtained from a previously created library of radionuclides. The model spectrum should be the sum of the spectra of individual radionuclides with coefficients that determine the activity of each radionuclide. The model spectrum should coincide as much as possible with the spectrum of the sample.

Measurement results in the form of reports and spectra are saved as files on a PC disk or printed.

1.4.4 The preparation of a sample is carried out depending on the radionuclide and chemical composition of the sample or by mixing an aliquot of an aqueous sample with a scintillation cocktail. Preliminary concentration or dilution of the sample is also used. After such preparation it is mixed with a scintillator.

1.5 Marking

1.5.1 The marking of the spectrometer meets the requirements of the manufacturer's design documentation and contains the following information:

- the trademark of the manufacturer;
- product name;
- serial number.

1.6 Packaging

1.6.1 The spectrometer should be packed indoors at temperatures from 10 ° C to 40 ° C and relative humidity of the ambient air up to 80%, in the absence of aggressive impurities in the environment.

1.6.3 The power supply unit should be hermetically packed in a plastic or other moisture-proof case.

1.6.5 The shipping box must contain a packing list indicating the name and quantity of packed items.

1.6.6 Technical and shipping documents must be packed in a polyethylene cover.

1.7 Safety features

1.7.1 The operation of the spectrometer must be carried out by persons familiar with this operating manual and instructed in safety.

1.7.2 It is forbidden to turn on the spectrometer when the case is open due to the presence of high (up to 2000 V) voltage in the power supply circuits of the detecting units.

1.7.3 When working with radioactive sources, the radiation safety requirements specified in national rules and regulations must be observed.

2 Installation and measurements

2.1 General instructions

2.1.1 The measurement method assumes that a sample is made from a selected material (technological operations for making a sample are presented in the measurement technique (MT)). Herewith, the technological operations of making a sample from a material should ensure the identity of the radionuclide composition and the equality of the values of the specific activity of radionuclides for the sample and the material from which it was made.

The sample is placed in a measuring chamber (light collection chamber) and measured for a certain time.

2.1.2 Measurement of the activity of radionuclides in samples is carried out by the direct assessment method using a spectrometer, which is pre-calibrated using reference standards of activity, with various degrees of quenching.

2.1.3 The calibration of the spectrometer is performed at the manufacturing stage or during commissioning.

2.1.4 The values of activity, specific activity of radionuclides and uncertainty of the measurement result are calculated automatically, without operator participation, according to the algorithm of the “**ASW3L**” or “**SpectraDec**” software based on the measured spectra of the sample, the background spectrum, the quenching coefficient and the sensitivity coefficients obtained during the calibration of the spectrometer and forming library of radionuclides. The

activity, specific activity of radionuclides in a sample and the values of the uncertainty are determined directly by the reading device, which is used as a PC display or tablet PC.

2.2 Installing the device

2.2.1 The spectrometer is placed in a room with normal climatic conditions (see i.1.1.2).

2.2.2 The spectrometer is installed at the workplace in such a way that free access to the device and PC is provided.

2.2.3 The exposure dose rate at the place where the spectrometer is installed should not exceed 20 μR/h.

***Attention*: it is forbidden to install the device near high-current and heating equipment (powerful power transformers, electric motors, electromagnets, muffle furnaces, hot plates, radiators of electric and water heating).**

2.2.4 During operation of the spectrometer, it is not recommended to change the spatial position (orientation along the axis) of the scintillation detection units in order to avoid changing the electron focusing of the PMT by the Earth's magnetic field.

2.2.6 Order of the device installation:

- install the spectrometer on the working surface of the laboratory table;
- assemble the PC and connect its component parts to each other;
- connect the device with a PC using a USB or RS-485 cable;
- connect the power supply adapter to the socket on the front of the device and tighten the clamping nut;
- connect the power supply plugs of the computer and spectrometer to grounded sockets.

2.3 Preparing the spectrometer for operation

2.3.1 Before starting work, make an external examination of the device and check the reliability of connecting the connecting cables to the units and blocks.

2.3.2 Turn on the PC. After launch the PC, start the "**ASW3L**" software (See the *"ASW3L" software description [1]*).

2.3.3 Turn on the spectrometer by pressing the button on the front panel.

2.3.4 Establish communication between PC and spectrometer [1] (see Fig. 2.1).

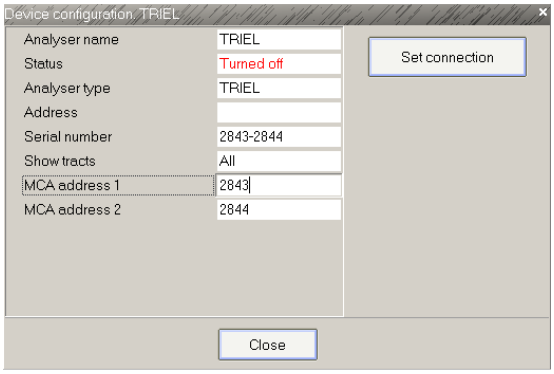

Figure 2.1

2.3.5 The spectrometer is ready for operation 30 minutes after turning on.

2.4 Order of operation on the spectrometer

2.4.1 Prepare the spectrometer for operation in accordance with i.2.3.

2.4.2 Measure the spectrum of the background sample for control the invariability of the intrinsic noise of the alpha and beta spectrometric tract, as well as to take into account the contribution of external gamma radiation and the contribution of the space component to the spectrum of the measuring object.

To measure the spectrum of the background sample it is prepared in accordance with the instructions for the making of samples as part of the applied measurement technique [3].

Next, open the hinged lid located on the upper surface of the device (see Fig. 2.2.1) and put the background sample into the light collection chamber (see Fig. 2.2.2). Then close the lid back.

Figure 2.2.1

Figure 2.2.2

Then in the "**ASW3L**" software it is necessary to set the Preset time to 3600s in the "**Measurement parameters**" window [1] (see Fig.2.3), and start the spectrum measurement.

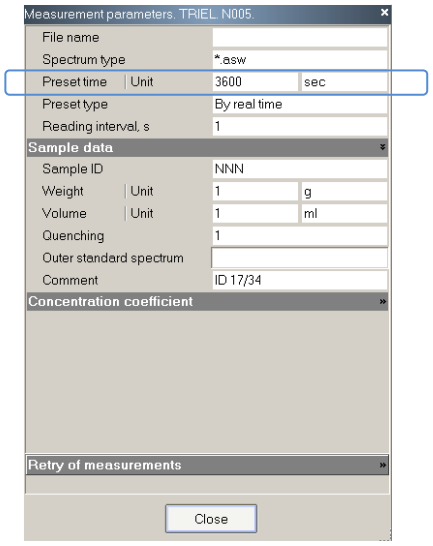

Figure 2.3

After finishing the measurement, save the obtained spectrum under a unique name on the disk. You should also indicate this spectrum in the "**ASW3L**" program as the background in the window "**Calculation parameters**" [1] (see Fig.2.4).

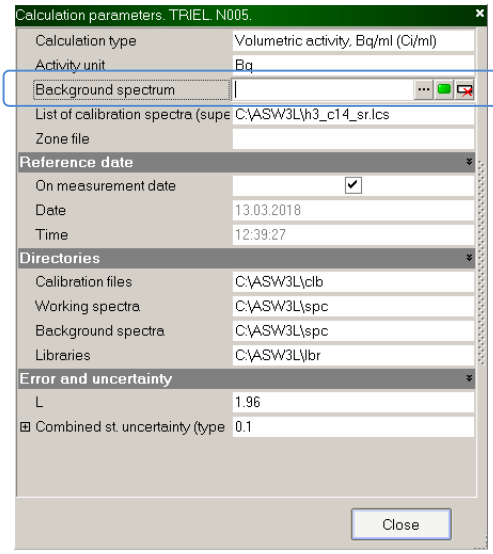

Figure 2.4

2.4.3 Next, start the "**SpectraDec**" software, where it is required to process the spectrum of the background sample. To transmit the background spectrum, you can use the button "Send background spectrum for processing" located in the spectrum toolbar, or load this spectrum directly into the "**SpectraDec**" software [2].

2.4.4 Measure the control sample of the spectrometer in accordance with i.2.5 of this manual.

2.4.5 Implement a measurement of a sample, which consists of two sequential stages - measurement of a sample directly and measurement of a sample with an outer standard:

2.4.5.1 Place the test sample in the light-collection chamber and close the hinged lid.

2.4.5.2 Set the required preset time (3h) in the "**Measurement parameters**" in the "**ASW3L**" software and start the measurement.

2.4.5.3 After finishing the measurement save the obtained spectrum under a unique name on the disk.

2.4.5.4 Measure a sample with an outer standard to determine the quenching parameter by placing a point source with radionuclide ^{137}Cs on the lid of the vial with a sample. Set the preset time for measurement of the sample with an outer standard to 120 - 300 s.

External gamma radiation from a point source creates Compton scattering in the sample volume, the spectrum of which depends on quenching. Sample quenching is determined mathematically from a library of outer standard spectra for various quenching levels.

2.4.5.5 At the end of the measurement save the obtained spectrum under the same name as in i. 2.4.5.3 by adding the postfix "*_ExtCs*" to the file name, and specify this spectrum in the "**ASW3L**" software as spectrum with an outer standard in the field "**Outer standard spectrum**" in the "**Spectrum parameters**"[1] saved in 2.4.5.3.

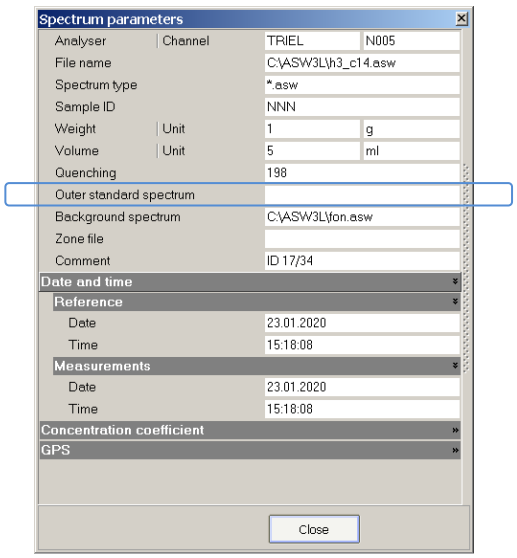

Figure 2.5

2.4.6 To get a result in "**SpectraDec**" software it is necessary to sequentially load the spectrum of the sample and the spectrum of the sample with an outer standard. Similarly, you can use the buttons "**Send sample spectrum**" and "**Send sample spectrum with outer standard**" located in the toolbar of each of the spectra, respectively [1]. The "**SpectraDec**" software will automatically subtract the background spectrum from the spectrum of the investigated sample, calculate the quenching parameter and present on the screen a graph of the decomposition of the experimental spectrum into spectra of standards from the work list. When the user select the menu item "**Model-> Calculation**" or the button 

, the program will calculate the activity of radionuclides in the sample and determine the values of the measurement result uncertainty. After that, the final processing protocol will appear on the screen. The measurement results are output to a report file in HTML format. The user can print the received report or save it to disk (see Fig. 2.6).

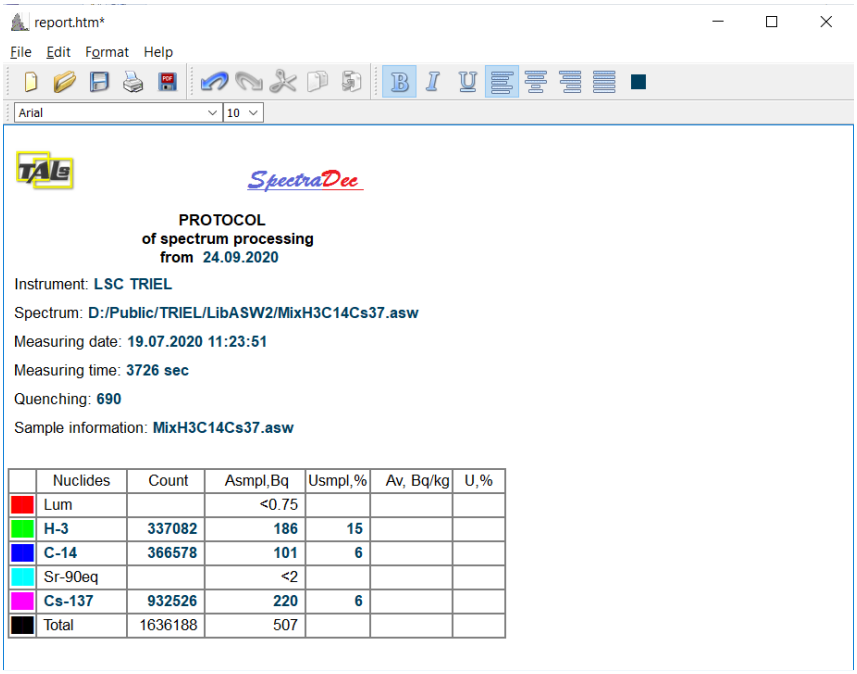

Figure 2.6

2.4.7 To calculate the activity of radionuclides in the sample and the uncertainty of the measurement result in the "**ASW3L**" software, press the button  in the spectrum toolbar of the investigated counting sample. A table with measurement results will appear at the bottom of the spectrum window or in a separate window (see Fig.2.7). This table contains the columns '**Nuclide**', '**Activity, Bq**', the relative error of modeling the spectrum '**Acc. error,%**', as well as the graphs of the calculated specific activities, absolute and relative errors of their determination.

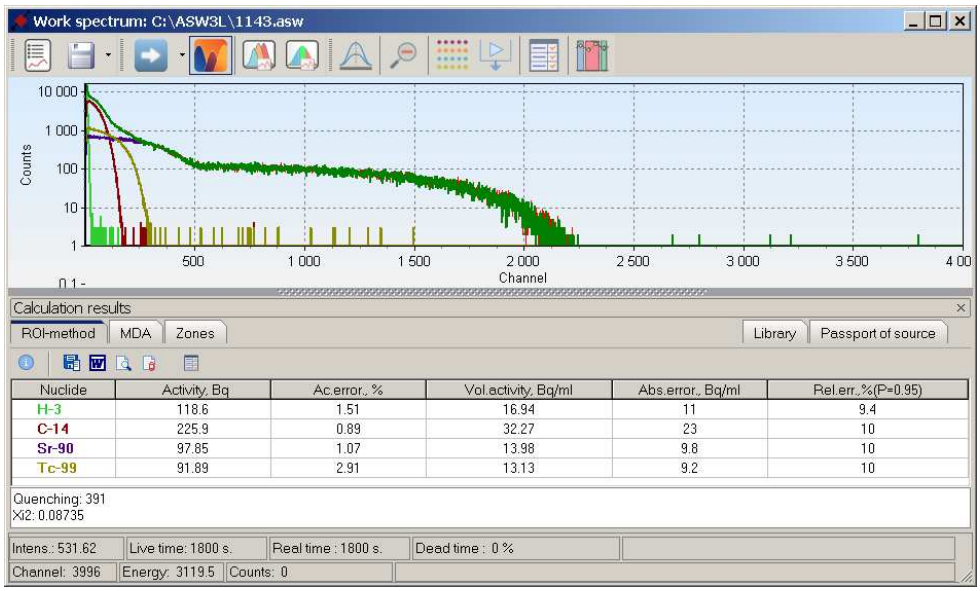

Figure 2.7

The obtained result can be printed out or saved to the current database using the corresponding buttons located above the table of results [1].

2.5 Reference measurement

Reference measurements are carried out in order to periodically check the performance of the spectrometer, as well as control the metrological characteristics.

2.5.1 Open the hinged lid of the light collection chamber, place the control sample in the chamber and close the hinged lid.

2.5.2 Set preset time from 300 to 1200s in "**Measurement parameters**" of "**ASW3L**" software and start measurement.

2.5.3 At the end of the measurement save the spectrum of the control sample to disk under a unique name.

2.5.4 Measure a control sample with an outer standard to determine the quenching parameter by placing a point source with ^{137}Cs radionuclide on the top of the control sample vial. Set the preset time of the measurement for control sample with an outer standard to 120 - 300 s.

2.5.5 At the end of the measurement save the spectrum of the control sample with an outer standard to disk under the same name as in i.2.5.3 by adding the postfix "*_ExtCs*" to the file name, or, you should specify this spectrum in the "**ASW3L**" program as a spectrum with an outer standard in "**Spectrum parameters**" [1] saved in i.2.5.3.

2.5.5 Calculate the activity of radionuclides in the "**ASW3L**" software or load the sequentially obtained spectra into the "**SpectraDec**" software and also carry out the calculation.

2.5.6 The obtained values of the activity of radionuclides of the control sample should not differ from the certified values by more than 10%.

3 Storage

3.1 Prior to commissioning the spectrometer is stored in the warehouse in the manufacturer's packaging at an ambient temperature of + 5°C to + 40°C and relative humidity up to 80% at a temperature of + 25 ° C without moisture condensation.

3.2 Unpacked spectrometer is stored at ambient temperature from + 10°C to + 40°C and relative humidity no more than 80% at + 25°C.

4 Transportation

4.1 The spectrometer can be transported by all types of transport at temperatures from -25°C to +55°C in additional packaging made from polyethylene and foam rubber with a thickness of at least 50 mm. The rate of temperature change in the compartments where the device is transported should not exceed 10°C/min.

4.2 The packed spectrometer must be placed and fixed in the vehicle so that its stable position is ensured and the possibility of impacts against the vehicle walls is excluded.

4.3 The position of the transport container with the spectrometer during transportation must comply with warning signs and inscriptions on the transport container.

4.4 Transportation of the spectrometer by cargo transportation without a shipping container is not allowed.

5 Disposal

5.1 The disposal of the spectrometer is carried out in accordance with the established procedure and does not have a harmful effect on the environment.

6 Manufacturer's warranty

6.1 The manufacturer guarantees the compliance of the spectrometer with the basic parameters and technical data and characteristics specified in this User Manual, provided that the consumer observes the rules and conditions of operation, transportation and storage.

6.2 The warranty period of operation is 12 months from the date of putting the spectrometer into operation or after the expiration of the warranty storage period.

6.3 The warranty storage period is 6 months from the date of acceptance of the product by the representative.

6.4 If the spectrometer fails during the warranty period, the owner is entitled to a free repair.

Note: in case of violation of the seals on the spectrometer, as well as mechanical and other damage to the blocks and accessories of the spectrometer through the fault of the consumer, claims for quality are not accepted and warranty repairs are not carried out.

6.5 The warranty period is extended for the period from filing a complaint to the re-commissioning of the spectrometer by the manufacturer.

6.6 Warranty and post-warranty repairs are carried out by the manufacturer.

6.7 The warranty expires upon the expiration of the warranty period.

6.8 The manufacturer's representative enterprise provides service maintenance of the product during the entire period of post-warranty operation on a contractual basis. For service questions, please contact:

Manufacturer's address:

TALS Oy
Y-tunnus: 2746601-1
Postal address: 00160 Helsinki, Finland
Merikasarminkatu 12 L 4
Phone: +358449411711
info@tals.eu / www.tals.eu

Literature

1. Description of the software "ASW3L". 2020
2. Software "SpectraDec 4.01". Operation manual.
3. "Methodology for measuring the activity of alpha and beta emitting radionuclides in water and solid samples taken from natural and technological objects, using a liquid spectrometric equipment".