

**Procedure for determining the activity
concentrations of caesium isotopes in seawater
by gamma spectrometry**

D-Cs-MWASS-01

Authors:

S. Hintze

C. Weidig

S. Schmied

A. Gottschalk

J. Herrmann

Federal coordinating office for seawater, suspended particulate matter
and sediment

(Leitstelle für Meerwasser, Meeresschwebstoff und -sediment)

Procedure for determining the activity concentrations of caesium isotopes in seawater by gamma spectrometry

1 Scope

The procedure described in the following is suitable for gamma spectrometric analysis of the activity concentrations of caesium isotopes in seawater according to the IMIS-routine programme of the AVV IMIS [1]. Detection limits of Cs-134 and Cs-137 of a few bequerels per cubic metres of seawater can be achieved there.

One advantage of this procedure is the elimination of transporting large water quantities by performing an ion exchange process usually already on board.

This procedure can also be used for determining very low Cs-137 activity concentrations in oceanic deep water with minor modifications.

2 Sampling

Different sampling devices are used for the sampling of seawater depending on the sampling depth.

Near-surface seawater from depths between three to five metres is pumped directly into plastic containers by using the ship's seawater pump. Water depth between 50 m to near bottom depths is sampled with special water scoops with volumes of 50 l to 500 l or a water sampling rosette (see Figures 1 to 4) and is decanted in appropriate plastic containers.



Fig. 1: 50-l-scoop



Fig. 2: 500-l-scoop

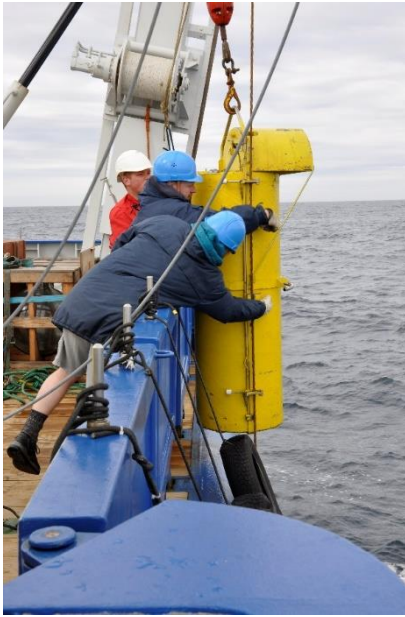


Fig. 3: 270-l-scoop



Fig. 4: Water sampling rosette

3 Analysis

3.1 Principle of the procedure

For the selective enrichment of caesium isotopes from 50 l up to 3000 l of seawater the almost quantitative ion exchange process on potassium hexacyanocobaltate ferrate (KCFC) or potassium-nickel hexacyanoferrate in a polyacrylnitrile binding matrix (KNiFC-PAN) is used [2, 3]. The KCFC, respectively KNiFC-PAN, loaded with caesium is analysed gamma spectrometric for Cs-134 and Cs-137 in a high purity germanium detector.

3.2 Sample preparation

Usually, seawater samples are filtered immediately by a filter cartridge (0,5 µm) during sampling on board.

If volumes up to 150 l are sampled, the seawater is acidified either with 1 ml of nitric acid (approx. 6 mol·l⁻¹) per litre seawater or with 2 ml of hydrochloric acid (approx. 6 mol·l⁻¹) per litre seawater. Acidification with nitric acid is preferred due to the accompanying removal of the seawater's organic components.

The seawater must be acidified with 2 ml of hydrochloric acid (approx. 6 mol·l⁻¹) per litre seawater if the sample volume is greater than 150 l.

3.3 Radiochemical separation

The radiochemical separation described in the following process normally takes place at sea, but may also be carried out onshore because of unfavourable meteorological factors or time restrictions at the end of the survey.

This radiochemical separation consists of an ion exchange process, which can be carried out with one of both tried and tested exchange materials KNiFC-PAN and KCFC. KNiFC-PAN is suitable for radiocaesium enrichment in seawater samples acidified with nitric acid or hydrochloric acid up to 150 l, while KCFC is used only in samples acidified with hydrochloric acid.

The acidified seawater sample is passed with a maximum flow rate of $60 \text{ l}\cdot\text{h}^{-1}$ through an ion exchange column (see figure 5), prepared in accordance with Section 8.3.1 and 8.3.2, respectively. The ion exchange on the exchange material is almost quantitative here.

Note:

The determination of the chemical yield is made regularly with the aid of a Cs-134-free seawater sample which is then contaminated with Cs-134 yield tracer. The average chemical yield calculated from the determinations so far is $0,97 \pm 0,04$.

The volume of the eluate has to be determined by an appropriate measuring device or method. This can be done either by means of a flow meter or by determining the difference between the volume filled and remaining volume. If the activity concentration of strontium-90 (Sr-90) shall be determined additionally in the same sample according to Procedure D-Sr-90-MWASS-01, the eluate has to be collected.

At the end of the ion exchange process, the column must run dry.



Fig. 5: KCFC filled ion exchange column

3.4 Preparation of the counting sources

The ion exchanger is transferred quantitatively with distilled water in an appropriate measuring container and left to stand until it has settled.

If KNiFC-PAN is used, the supernatant solution has to be carefully pipetted off to avoid whirling up the light material. A remaining aqueous supernatant up to 0,7 cm is acceptable. The volume of KNiFC-PAN in the measuring container is usually 50 ml.

Note:

A variation in volume of up to 10 % is tolerable. Larger variations have to be taken into account by a correction factor during analysis; otherwise the counting source is rejected.

In the case of KCFC, the supernatant solution is decanted first. Afterwards, the measurement container is placed open in a fume hood for a period sufficient to evaporate the supernatant solution. A complete drying has to be avoided, though, to prevent a loss of KCFC and a change of measurement geometry due to disturbance, respectively. Then, the filling level of KCFC in the measuring container is determined by a ruler from the bottom of the measuring container and it is documented in cm. With the table created according to Section 4.2 within the filling level dependent calibration, the recovered volume of the ion exchanger can be determined. This should be between 27 ml and 33 ml in case of the small columns; in case of the large columns it should be between 70 ml and 90 ml.

The measuring container together with the relevant ion exchanger represents the counting source and is measured by gamma spectrometry.

4 Measuring the activity

4.1 General

To determine the activity of caesium isotopes, the counting source is measured with a gamma spectrometric measuring system with a high purity germanium detector. The duration of measurement is selected in such a way that the relative standard uncertainty of the net count numbers of Cs-137 is approximately one percent.

4.2 Calibration

The calibration of the measuring device is carried out either filling level specific or filling level dependent with an aqueous solution of a traceable standard containing a mixture of radionuclides. No ion exchanger is added here.

For the later measurement of counting sources containing the ion exchanger KNiFC-PAN a filling level specific calibration with a volume of 50 ml of the mixed nuclide solution is carried out.

For the measurement of counting sources containing the ion exchanger KCFC in contrast, the calibration is made filling level dependent. For this purpose, mixed nuclide solutions of appropriate volumes, in case of the small columns between 20 ml and 35 ml, are used. The number and distance of the calibration points have to be adjusted to the measurement purpose. Further, the filling levels of the mixed nuclide solution are determined by a ruler from the bottom of the measuring container and are documented in cm in a table.

For periodic verification of the energy calibration a europium-152-activity standard is used.

Basic information on calibration is to be found in the General Chapter γ -SPEKT/GRUNDL of this Procedures Manual.

4.3 Background

Background is checked regularly, whereby a monthly verification is proved appropriate. By recording background spectra for every single detector on a regular basis, spurious lines in the pulse height spectrum resulting in the surroundings and the detector itself, respectively, can be taken into account (see General Chapter γ -SPEKT/GRUNDL of this Procedures Manual).

4.4 Measurement

The counting source obtained after section 3.4 is centred on the detector, possibly by means of a centring ring.

5 Calculation of the results

5.1 Equations

The activity concentrations of caesium isotopes are determined with following equations.

For calculating the activity concentration of Cs-134, which shows various gamma lines in the pulse height spectrum, corrections have to be taken into account in principle (see Annex B of the General Chapter γ -SPEKT/GRUNDL of this Procedures Manual). In the present case, results of round robin tests have shown these corrections to be negligible. However, a slight underestimation of the Cs-134 activity concentration thereby is accepted.

5.1.1 Output quantity

The activity concentration of the radionuclide r at the time of sampling is calculated according to Equation (1):

$$c_r = R_{n,r} \cdot \varphi = R_{n,r} \cdot \frac{f_{A,r}}{\varepsilon_r \cdot \eta \cdot p_{\gamma,r} \cdot V} = R_{n,r} \cdot \frac{e^{\lambda_r \cdot t_A}}{\varepsilon_r \cdot \eta \cdot p_{\gamma,r} \cdot V} \quad (1)$$

The net count rate of the line of the radionuclide r in accordance with Equation (2):

$$R_{n,r} = R_{b,r} - R_{T,r} - R_{0,r} \quad (2)$$

Herein are:

- c_r activity concentration of the radionuclide r , in $\text{Bq}\cdot\text{m}^{-3}$;
- $f_{A,r}$ correction factor for the decay of the radionuclide r while measuring;
- $p_{\gamma,r}$ emission intensity of the gamma line of the radionuclide r ;
- $R_{b,r}$ gross count rate of the line of the radionuclide r , in s^{-1} ;
- $R_{n,r}$ net count rate of the line of the radionuclide r , in s^{-1} ;
- $R_{T,r}$ background count rate underneath the line of the radionuclide r , e. g. as count rate of a trapezoidal background, in s^{-1} ;
- $R_{0,r}$ net count rate at the line of the radionuclide r in a background spectrum, in s^{-1} ;
- t_A time period between sampling and start of measurement, in s ;
- V volume of the water sample, in m^3 ;
- ε_r detection efficiency for the radionuclide r , in $\text{Bq}^{-1}\cdot\text{s}^{-1}$;
- η chemical yield of caesium (see note of Section 3.3);
- λ_r decay constant of the radionuclide r , in s^{-1} ;
- φ procedural calibration factor, in $\text{Bq}\cdot\text{s}\cdot\text{m}^{-3}$.

Anmerkung:

If the volume of the KNiFC-PAN counting source differs by more than 10 % in terms of the volume of the calibration source, this needs to be taken into account by an additional correction factor in the analysis.

5.1.2 Standard uncertainty of the output quantity

The standard uncertainty of the activity concentration $u(c_r)$ is calculated according to Equations (3) and (4) after transformation of the equations of Annex A of the General Chapter γ -SPEKT/GRUNDL of this Procedures Manual and on condition that no contribution of the considered radionuclide is present in the background spectrum:

$$u(c_r) = \sqrt{c_r^2 \cdot u_{\text{rel}}^2(\varphi) + \varphi^2 \cdot \left[\frac{R_{n,r}}{t_m} + \frac{R_{T,r}}{t_m} \cdot \left(1 + \frac{b}{2 \cdot L} \right) \right]} \quad (3)$$

with

$$u_{\text{rel}}^2(\varphi) = u_{\text{rel}}^2(f_{A,r}) + u_{\text{rel}}^2(\varepsilon_r) + u_{\text{rel}}^2(\eta) + u_{\text{rel}}^2(p_{\gamma,r}) + u_{\text{rel}}^2(V) \quad (4)$$

In the Equations (3) and (4) are:

- b line width of the gamma line, in keV;
- L number of channels used for determination of the trapezoidal background count rate to the left and to the right of the gamma line, in keV;
- t_m duration of measurement of the counting source, in s;
- $u(c_r)$ standard uncertainty of the activity concentration, in Bq·m⁻³;
- $u_{\text{rel}}(f_{A,r})$ relative standard uncertainty of the correction factor for the decay;
- $u_{\text{rel}}(p_{\gamma,r})$ relative standard uncertainty of the emission intensity of the gamma line;
- $u_{\text{rel}}(V)$ relative standard uncertainty of the volume;
- $u_{\text{rel}}(\varepsilon_r)$ relative standard uncertainty of the detection efficiency;
- $u_{\text{rel}}(\eta)$ relative standard uncertainty of the chemical yield;
- $u_{\text{rel}}(\varphi)$ relative standard uncertainty of the procedural calibration factor.

5.2 Worked example

In the worked examples of the Sections 5.2 and 6.2, the interim results and the result are given with four significant digits. Deviations from the calculated values are possible when using another number of significant digits.

In the following, the Cs-137 activity concentration is calculated according to the numerical values listed below. The relative standard uncertainty of the correction factor for the decay $u_{\text{rel}}(f_{A,r})$ is neglected.

$R_{g,\text{Cs-137}} = 0,06 \text{ s}^{-1};$	$t_{A,\text{Cs-137}} = 15,8 \cdot 10^6 \text{ s};$
$R_{T,\text{Cs-137}} = 0,01 \text{ s}^{-1};$	$t_m = 86\,400 \text{ s};$
$R_{n,\text{Cs-137}} = 0,05 \text{ s}^{-1};$	$b = 2,363 \text{ keV};$
$\lambda_{\text{Cs-137}} = 0,73 \cdot 10^{-9} \text{ s}^{-1};$	$L = 1,182 \text{ keV};$
$\varphi = 85,999 \text{ Bq} \cdot \text{s} \cdot \text{m}^{-3};$	
$p_{\gamma,\text{Cs-137}} = 0,851;$	$u_{\text{rel}}(p_{\gamma,\text{Cs-137}}) = 0,002;$
$V = 0,570 \text{ m}^3;$	$u_{\text{rel}}(V) = 0,02;$

$$\begin{aligned} \varepsilon_{\text{Cs-137}} &= 0,025 \text{ Bq}^{-1} \cdot \text{s}^{-1}; & u_{\text{rel}}(\varepsilon_{\text{Cs-137}}) &= 0,05; \\ \eta &= 0,97; & u_{\text{rel}}(\eta) &= 0,05. \end{aligned}$$

The activity concentration $c_{\text{Cs-137}}$ is calculated according to Equations (1) and (2):

$$c_{\text{Cs-137}} = 0,05 \text{ s}^{-1} \cdot \frac{e^{0,73 \cdot 10^{-9} \text{ s}^{-1} \cdot 15,8 \cdot 10^6 \text{ s}}}{0,025 \text{ Bq}^{-1} \cdot \text{s}^{-1} \cdot 0,97 \cdot 0,851 \cdot 0,57 \text{ m}^3} = 4,300 \text{ Bq} \cdot \text{m}^{-3}$$

The standard uncertainty of the activity concentration $u(c_{\text{Cs-137}})$ is determined in accordance with Equations (4) and (3):

$$u_{\text{rel}}^2(\varphi) = 0,05^2 + 0,05^2 + 0,002^2 + 0,02^2 = 0,005404$$

$$\begin{aligned} u(c_{\text{Cs-137}}) &= \sqrt{4,300^2 \cdot 0,005404 + 85,999^2 \cdot \left[\frac{0,05}{86400} + \frac{0,01}{86400} \cdot \left(1 + \frac{2,363}{2 \cdot 1,182} \right) \right]} \text{ Bq} \\ &\cdot \text{m}^{-3} = \\ &= 0,3254 \text{ Bq} \cdot \text{m}^{-3} \end{aligned}$$

Thus, the activity concentration of Cs-137 is:

$$c_{\text{Cs-137}} = (4,300 \pm 0,3254) \text{ Bq} \cdot \text{m}^{-3}$$

5.3 Consideration of the uncertainties

Uncertainty contributions arising from sampling are not taken into account in the framework of this Procedures Manual, as these can depend on many different and often not quantifiable factors.

The standard uncertainty of the analysis contains the standard uncertainties of the statistical counting, of the calibration, of the chemical yield, of the emission intensity and of the volume of the sample.

The standard uncertainties for the duration of measurement, for the decay constant, for the position of the line maximum and for the peak's full width at half-height h are neglected.

For correction factors which are neglected during calculation of the analysis result, no further standard uncertainty is taken into account.

6 Characteristic limits of the procedure

The calculation of the characteristic limits follows the standard series ISO 11929 [4].

An Excel spreadsheet (see Section 7.1) as well as a project file for the software Uncert-Radio (see Section 7.2) are available on the website of this Procedures Manual.

Further considerations concerning the characteristic limits are to be found in the General Chapters ERK/NACHWEISGR-ISO-01 and ERK/NACHWEISGR-ISO-02 of this Procedures Manual.

6.1 Equations

6.1.1 Decision threshold

The calculation of the decision threshold of the radionuclide r , c_r^* , is made according to Equation (5):

$$c_r^* = k_{1-\alpha} \cdot \varphi \cdot \sqrt{\frac{R_{T,r}}{t_m} \cdot \left(1 + \frac{b}{2 \cdot L}\right)} \quad (5)$$

with $k_{1-\alpha}$ as quantile of the normal distribution for $\alpha = 0,0014$.

6.1.2 Detection limit

By implementation of the auxiliary quantities Ψ and θ , the detection limit of the radionuclide r , $c_r^\#$, is calculated according to Equations (6) to (8):

$$c_r^\# = \frac{c_r^* \cdot \Psi}{\theta} \cdot \left[1 + \sqrt{1 - \frac{\theta}{\Psi^2} \cdot \left(1 - \frac{k_{1-\beta}^2}{k_{1-\alpha}^2}\right)} \right] \quad (6)$$

with

$$\theta = 1 - k_{1-\beta}^2 \cdot u_{\text{rel}}^2(\varphi) \quad (7)$$

$$\Psi = 1 + \frac{k_{1-\beta}^2}{2 \cdot c_r^*} \cdot \varphi \cdot \frac{1}{t_m} \quad (8)$$

where $k_{1-\beta}$ as quantile of the normal distribution for $\beta = 0,05$.

6.1.3 Limits of the coverage interval

The calculation of limits of the coverage interval is not required.

6.2 Worked examples

Together with the numeric values of Section 5.2 and the values for the quantiles of the normal distribution for $k_{1-\alpha} = 3,000$ and $k_{1-\beta} = 1,645$ the decision threshold $c_{\text{Cs-137}}^*$ is determined according to Equation (5).

$$c_{\text{Cs-137}}^* = 3 \cdot 85,999 \text{ Bq} \cdot \text{s} \cdot \text{m}^{-3} \cdot \sqrt{\frac{0,01 \text{ s}^{-1}}{86400 \text{ s}} \cdot \left(1 + \frac{2,363 \text{ keV}}{2 \cdot 1,182 \text{ keV}}\right)} = 0,1241 \text{ Bq} \cdot \text{m}^{-3}$$

The detection limit $c_{\text{Cs-137}}^\#$ is calculated in accordance with Equation (6):

$$\begin{aligned} c_{\text{Cs-137}}^\# &= \frac{0,1241 \text{ Bq} \cdot \text{m}^{-3} \cdot 1,011}{0,9854} \cdot \left[1 + \sqrt{1 - \frac{0,9854}{1,011^2} \cdot \left(1 - \frac{1,645^2}{3^2}\right)}\right] \\ &= 0,2000 \text{ Bq} \cdot \text{m}^{-3} \end{aligned}$$

with

$$\theta = 1 - 1,645^2 \cdot 0,0054 = 0,9854$$

$$\psi = 1 + \frac{1,645^2}{2 \cdot 0,1241 \text{ Bq} \cdot \text{m}^{-3}} \cdot 85,999 \text{ Bq} \cdot \text{s} \cdot \text{m}^{-3} \cdot \frac{1}{86400 \text{ s}} = 1,011$$

7 Software supported calculation

7.1 View of the Excel spreadsheet

Procedure for determining the activity concentrations of caesium isotopes in sea water by gamma spectrometry
 D-Cs-MWASS-01 Version November 2017 / verified February 2022
 Procedures manual for monitoring of radioactive substances in the environment and of external radiation (ISSN 1865-8725)

SAMPLE IDENTIFICATION: seawater

#Number of parameters p	10
k_alpha	3
k_beta	1,645
gamma	0,05

Create Excel variables!

User-Input: Input of values
 Definition Excel variables

Excel-VBA: #Keywords
 Values from Vbasic

Data input:	variable names:	Input values	StdDev	partial derivatives	uncertainty budget:	budget in %
#Values of parameters p						
#Number of gross counts Ng	Ng	5,184E+03	7,200E+01	9,954E-04	7,167E-02	4,849E+00
trapezoidal BG count rate	RT	1,000E-02	3,401E-04	-8,600E+01	2,925E-02	8,079E-01
b/2L	b2L	9,996E-01		0,000E+00	0,000E+00	0,000E+00
detection efficiency	eps	2,500E-02	1,250E-03	-1,720E+02	2,150E-01	4,364E+01
emission intensity, 661,7 keV	p_gamm	8,510E-01	1,702E-03	-5,053E+00	8,600E-03	6,983E-02
volume of the sea water sample	V	5,700E-01	1,140E-02	-7,544E+00	8,600E-02	6,983E+00
time elapsed sampling --> startns	tA	1,580E+07		3,139E-09	0,000E+00	0,000E+00
half-live of Cs-137	lambdaCs137	7,300E-10		6,794E+07	0,000E+00	0,000E+00
chemical yield for Cs	etaCs	9,700E-01	4,850E-02	-4,433E+00	2,150E-01	4,364E+01
duration of measurement	tm	8,640E+04		-5,972E-05	0,000E+00	0,000E+00

(List can be continued here)

Model section $c = \text{phix} \cdot \text{Rn}$

Auxiliary equations h (Formulae)

#Gross count rate Rg	1/s	Rg	6,000E-02
decay correction sampling --> st		_fA	1,012E+00

(List can be continued here)

#Net count rate Rn	1/s	Rn	5,000E-02
#Calibration factor, proc.dep.	Bq*s/m³	phix	8,600E+01
#Value output quantity	Bq/m³	Result	4,300
#Combined standard uncertain	Bq/m³	uResult	0,325

0,1999785 <-- output value modifiable by VBA

#Decision threshold	Bq/m³	0,124
#Detection limit	Bq/m³	0,200

further derived values

Auxiliary quantity Omega	Omega	1,000
Best estimate	BestEst	4,300
Uncertainty best estimate		0,325
Lower confidence limit		3,662
Upper confidence limit		4,938

Calculate!

The corresponding Excel spreadsheet is available on the website of this Procedures Manual.

7.2 View of the UncertRadio result page

UR UncertRadio: Calculation of uncertainty budget and detection limits - D-Cs-MWASS-01_V2017-11_gp2022-02_EN.bxp

File Edit Options Help

Procedure Equations Values, Uncertainties Uncertainty budget Results Text Editor

Final measurement result for c_Cs137:

Value output quantity: 4,2999	Bq/m³
extendend (Std.-)uncertainty: 0,32987	Bq/m³
relative ext.(Std.-)uncertainty: 7,6714	%

Best Bayesian Estimates: min. Coverage-Intervall

Value output quantity: 4,2999	Bq/m³
extendend (Std.-)uncertainty: 0,32987	Bq/m³
lower range limit: 3,6534	Bq/m³
upper range limit: 4,9465	Bq/m³

Coverage factor k: 1.0
 Probability (1-gamma): 0,950

Decision threshold and detection limit for c_Cs137:

Decision threshold (DT): 0,1241	Bq/m³	Iterations: 1
Detection limit (DL): 0,2001	Bq/m³	Iterations: 5

k_alpha=3,000, k_beta=1,645 Method: ISO 11929:2019, by iteration

Monte Carlo Simulation:

Number of simul. measurements: 100000 Values <0 included
 Number of runs: 1 min. Coverage interval

primary estimate: 4,3226	Bq/m³	0,024
uncertainty primary estimate: 0,33360	Bq/m³	0,224
Value output quantity: 4,3226	Bq/m³	0,024
extendend uncertainty: 0,33360	Bq/m³	0,224
relative extd.(Std.-)uncertainty: 7,7177	%	
lower range limit: 3,7175	Bq/m³	0,076
upper range limit: 5,0271	Bq/m³	0,056
Decision threshold (DT): 0,12589	Bq/m³	0,873
Detection limit (DL): 0,20028	Bq/m³	0,570

active run: 1 IT: 6 Start MC

The corresponding UncertRadio project file is available on the website of this Procedures Manual.

8 Catalogue of the chemicals und equipment

8.1 Chemicals

The chemicals used should be of analytically pure quality.

- hydrochloric acid, HCl: approx. 6 mol·l⁻¹;
- nitric acid, HNO₃: approx. 6 mol·l⁻¹;
- potassium hexacyanocobaltate ferrate, K₂[CoFe(CN)₆]: grain size range 170 µm to 500 µm;
- potassium-nickel hexacyanoferrate, K₂[NiFe(CN)₆]: grain size range 100 µm to 700 µm
potassium-nickel hexacyanoferrate in a polyacrylonitrile binding matrix in distilled water with a content of powdery potassium-nickel hexacyanoferrate of 80 % with regard to dry residue.

8.2 Equipment

The following equipment is used for the procedure:

- water sampling rosette or special scoop with volumes of 50 l to 500 l;
- plastic containers with volume scale, at least 50 l;
- filter cartridge, 0,5 µm;
- columns:
 - for volumes up to 270 l (small column): Ø 4,5 cm, length 6 cm
 - for volumes as of 270 l (large column): Ø 6 cm, length 10 cm, respectively:

On both column ends, caps with olives for fixing a hose are screwed. Between cap and column body made of acrylic glass perforated plates are placed which are covered with a large-pored fibre fleece to keep the exchange material back.
- optionally, flow meter (accuracy less than 1 %) for determining the volume of the eluate;
- pump (for onshore processing);
- measuring site for gamma spectrometry;
- usual equipment of a radiochemical laboratory.

8.3 Preparatory works

8.3.1 Preparation of the ion exchange column with KNiFC-PAN

Without any pretreatment, 50 ml of KNiFC-PAN are transferred into a small column. The column is filled with distilled water to the top of the upper olive's end and stored until use.

8.3.2 Preparation of the ion exchange column with KCFC

Depending on the volume of the seawater sample different sized columns are used. For seawater samples of 50 l to 270 l, 20 g of KCFC are suspended in distilled water and transferred into a small column, as volumes of more than 270 l of seawater 60 g of KCFC are suspended and transferred into a large column. Afterwards, the KCFC is rinsed with distilled water until the passing wash water is clear. The column is filled with distilled water to the top of the upper olive's end and stored until use.

References

- [1] *Allgemeine Verwaltungsvorschrift zum integrierten Mess- und Informationssystem zur Überwachung der Radioaktivität in der Umwelt (IMIS) nach dem Strahlenschutzvorsorgegesetz (AVV-IMIS)*. Bundesanzeiger, 2006, Nr. 244a, S. 4-80.
- [2] Boni, A. L.: *Rapid Ion Exchange Analysis of Radiocesium in Milk, Urine, Seawater, and Environmental Samples*. Analytical Chemistry, 1966, Vol. 38 (1), S. 89-92.
- [3] Schmied, S., Meyer, A., Bendler, I., Šebesta, F.: *Offshore concentration of caesium radioisotopes from large volume seawater samples using KNiFC-PAN*. Applied Radiation and Isotopes, 2019, Vol. 147.
- [4] Standard series ISO 11929:2019, *Determination of the characteristic limits (decision threshold, detection limit and limits of the coverage interval) for measurements of ionizing radiation — Fundamentals and application (Parts 1 to 3)*.