Meracie systémy pre rádiologickú charakterizáciu

Róbert Hinca

Meracia technika pri nakladaní s odpadom

Meraciu techniku s ohľadom na meranú veličinu delíme na:

- Meradlá **aktivity (Bq)** resp. **hmotnostnej aktivity** (Bq/kg) v objeme meraného materiálu, a
- Meradlá **povrchovej kontaminácie (Bq/cm^2)**.

S ohľadom na merací rozsah rozdeľujeme meraciu techniku na:

- Meracie systémy pre **uvoľňovanie materiálov** alebo priestorov **-** meranie nízkych aktivít, MDA by mala byť spravidla desatina od uvoľňovacích úrovní
- Meracie systémy pre **kontrolu akceptačných kritérií pre úložisko** rádioaktívnych odpadov **-** veľmi široký dynamický rozsah, ktorý sa dosahuje zmenou geometrie, použitím kolimátorov. Pre každú meraciu geometriu treba meradlo kalibrovať. Dostávame kalibračnú tabuľku s obsahom množstva kalibračných faktorov:

počet kolimátorov x počet vzdialeností x vektor hmotností x nuklidový vektor

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Meranie povrchovej kontaminácie

- Povrchová kontaminácia **α-emitujúcimi rádionuklidmi** – používajú sa detektory napr. **ZnS** scintilačné detektory, **plynové** proporcionálne detektory, **kremíkové** polovodičové detektory a iónové senzory (nasajú vzduch do ionizačnej komory z povrchu meranej vzorky a detekujú ionizáciu spôsobenú alfa žiaričmi na povrchu meranej vzorky).
- Povrchová kontaminácia **ß-emitujúcimi žiaričmi** sa meria tenkými scintilačnými kryštálmi alebo veľkoplošnými proporcionálnymi plynovými detektormi.
- Meranie povrchovej kontaminácie sa často vykonáva **prenosnými prístrojmi alebo na dopravnom páse**. Pri meraní sudov sa používa otočné zariadenie s výškovo posuvným meradlom.
- Nepriamo je možne stanoviť povrchovú kontamináciu **oterovými skúškami**.

Waste measurements systems Bulk activity measurement

- For repetitive measurements of waste in a particular format (e.g. **200 L drums**) is used a fixed HPGe detector positioned adjacent to a **rotating loading platform** supporting the sample.
- Another method appropriate for large sample volumes is to transfer the (crushed) sample to a hopper and thence to a **conveyor belt** which moves under a detector. This makes it easier to locate 'hot-spots' in the sample.
- A further method is to completely surround the sample with a large-volume detector (usually a plastic scintillator in so called **4π geometry**). Plastic scintillators are sometimes used as a final check on material leaving site for **free release**, or to ensure that material is acceptable for **recycling**.

Main contaminants in decommissioned V1 Jaslovské Bohunice

Alpha nuclides:	**Pu-238, Pu-239/240, Am-241, Cm-244**
Beta nuclides:	**H-3 (liquids), C-14, Ca-41, Ni-59, Ni-63, Sr-90, Tc-99, I-129**
Beta/Gamma nuclides	**Cr-51, Mn-54, Fe-59, Co-58, Co-60, Zn-65, Nb-94, Nb-95, Zr-95, Ru-103, Rh-106^m, Ag-110^m, Sb-125, Cs-134/137, Ce-141, Ce-144, Eu-152/154/155**

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Bulk activity measurement DTM radionuclides

- **Difficult to measure radionuclides:**
  - Bulk monitoring of **α-emitters** is difficult because of the short ranges of the emitted particles. Sometimes, the analyte is **chemically extracted** from a representative sample of the matrix to produce a high-efficiency source which is then measured by α-counting.
  - Bulk monitoring of **β-emitters** can be carried out using a similar approach, although the higher background count-rates of β-detectors mean that the method is only practical for the higher-energy emitters.

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Bulk activity measurement ETM radionuclides

- The assay of β/ γ -emitters in bulk material is a very widely used technique. It can be done using small portable detectors (e.g. a **NaI(Tl)** counter) or trolley-mounted **HPGe** detectors.
- Detection efficiencies for a particular geometry can be determined by comparing the response of the instrument with true activity concentrations determined by γ-spectrometry of a representative sample, but, more often, modelling techniques are used to determine such efficiencies.

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Fingerprint. Scaling factors. Nuclide vectors.

- An important aspect of metrology in decommissioning is the **fingerprint**. This is a **set of ratios** which indicate the **relative proportions** of the radionuclides present in a particular operational area.
- The fingerprint is determined by γ-spectrometry and/or radiochemical analysis of several samples from the area of interest. Often, some of the radionuclides in a fingerprint are not detectable using a given monitor, and one or more of the radionuclides which are detectable will be directly measured and the activities of the others inferred from the ratios.
- The **stability** of the fingerprint is sometimes a concern, and this sometimes requires checking, either by full radiochemical analyses or by more direct methods.

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Scaling factors standards

- ISO 21238:2007 Nuclear energy — Nuclear fuel technology — Scaling factor method to determine the radioactivity of low- and intermediate-level radioactive waste packages generated at nuclear power plants
- IAEA NUCLEAR ENERGY SERIES No. NW-T-1.18 Determination and use of scaling factors for waste characterization in nuclear power plants. — Vienna : International Atomic Energy Agency, 2009

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SF definition

- **Scaling factor (SF).** A factor or parameter derived from a mathematical relationship used in calculating the radioactivity of a DTM nuclide from that of an ETM key nuclide as determined from sampling and analysis data.

- ISO 21238:2007

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Scale factor application

Generally, the derived activity is function of key nuclide activity:

$$A_{DTM} = F(A_{key})$$

The derived activity A_{DTM} of DTM nuclide is calculated from key nuclide activity A_{key} and scale factor coefficient *SF* for given nuclide according to (linear relationship):

$$A_{DTM} = A_{key} \times SF$$

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Scaling factors basics

- SFs can be calculated from **measurements** of radionuclides obtained through appropriate radiochemical analysis, through **modelling code calculation** or by a combination of both techniques
- Most of nuclear installations provide long-term regular and systematic monitoring of activity inventory and dispose with large database of measurement results (**accumulated sampling**).
- So called **biased sampling** approach is performed, when at first step a **"hot points"** measurement is evaluated and scaling factors calculated and at second step scaling factors **verification** and suitability for free release measurement is considered.

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Scaling factor – Nuclide vectors

- SFs are calculated as a linear regression of measured values, excluding low detection limit values. The only requirement to be met after identification of the outliers is that the regression coefficient should be greater than 0.8.
- However, at the present time in the case of poor correlation, **linear regression of logarithms** supported by statistical tests is used as the applicable calculation method.

Radionuclide vectors & scaling factors comments

Radionuclide vector

- usually **averaged percentage ratio of activity** of radionuclides determined by analysis of waste streams samples
- general term, univocal definition is missing
- it is impossible to use like representative RV calculated without casual correlation analysis if composition of wastes is not **stable**
- often used for counting rate/activity conversion (non spectrometric devices) during free release measurement

Scaling factor

- ratio between gamma emitting key radionuclides and casually related radionuclides
- defined by ISO standard 21238:2007
- based on correlation between fission products and activation radionuclides
- **spectrometric** measurement is necessary (activity of key radionuclides determination)
- **IAEA Nuclear Energy Series MW-T-1.18** „Determination and Use of Scaling Factors for Waste Characterization in NPPs“

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Key nuclide selection

- Basic characteristics:
  - a) nuclide that can be measured by non-destructive means when present in waste packages – gamma emitting;
  - b) having activity levels above the detection limit;
  - c) having a correlation with required difficult-to-measure (DTM) nuclides;
  - d) having a relatively long half-life.
- Additional characteristics:
  - having a nuclide production mechanism similar to that of difficult-to-measure nuclides, and/or
  - having physical properties (particularly solubility) similar to those of difficult-to-measure nuclides.

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Key nuclides

- ^{60}Co is normally used as a key nuclide for corrosion-product nuclides and activation-product nuclides from reactor coolant and
- ^{60}Co and/or ^{137}Cs as key nuclides for fission product nuclides and alpha-emitting nuclides.

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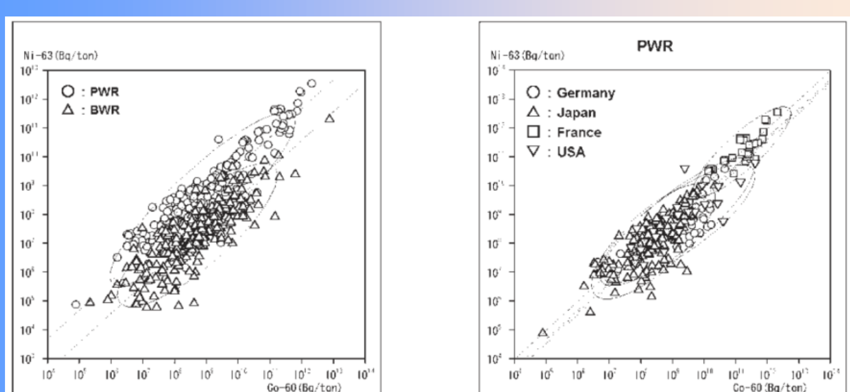
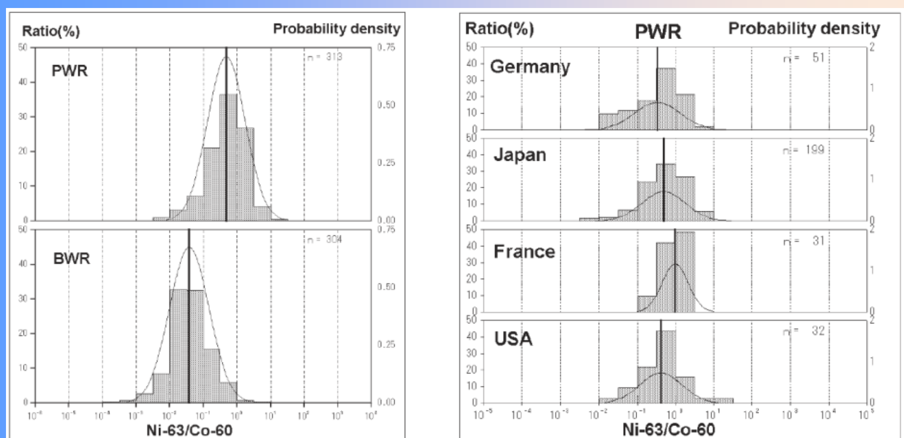
Example: Difficult to measure (DTM) and key nuclides (Slovakia)

DTM nuclide	Key nuclide	DTM nuclide	Key nuclide
C-14	Co-60	Pd-107	Cs-137
Ca-41	Co-60	Sn-126	Cs-137
Ni-59	Co-60	I-129	Cs-137
Ni-63	Co-60	Sm-151	Cs-137
Se-79	Cs-137	Pu-238	Co-60
Sr-90	Cs-137	Pu-239	Co-60
Mo-93	Co-60	Am-241	Co-60
Zr-93	Cs-137	Cs-135	Cs-137
Nb-94	Co-60		

63Ni/60Co nuclides correlation with regard to reactor type



63Ni/60Co nuclides correlation with regard to country



Question about waste streams number

- Number of waste streams is result of **consistency** of measured data .
- In case if **„statistics" is poor, correlation coefficients small, uncertainty high**, is recommended to **split data in more groups = streams** to achieve better „statistics"
- This is also answer if we can combine data from more NPPs.

Waste streams

Derived clearance level for mixture

For mixtures of artificial radionuclides, the weighted sum of nuclide-specific activities or concentrations a_i divided by the corresponding clearance value a_{Li} shall be less than unity. This so called **summation rule** is adopted in national and European standards.

$$\sum_i \frac{a_i}{a_{Li}} = \leq 1$$

$$X_m = \frac{1}{\sum_1^n \frac{f(i)}{X(i)}}$$

IAEA GSR 3 derived clearance level for mixture

f(i) is fraction of activity concentration

X(i) is clearance level

Example for derived clearance level for mixture

f(Co-60)=0,6 *X(Co-60)=100 Bq/kg*

f(Ni-63)=0,4 *X(Ni-63)=100 000 Bq/kg*

$$X_m = \frac{1}{\frac{f(Co)}{X(Co)} + \frac{f(Ni)}{X(Ni)}} = \frac{1}{\frac{0,6}{100} + \frac{0,4}{100000}} = \frac{1}{0,0060004} = 167\,Bq/kg$$

This derived clearance level for mixture is parameter, which we cannot measure directly.

We must calculate aggregate (total) activity for mixture an then compare with derived clearance level .

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Derived level for activity of key nuclide

- From summation rule results another **derived level for activity of key nuclide**

$$\sum_i \frac{a_i}{a_{Li}} = \sum_i \frac{SF_i \cdot a_{key}}{a_{Li}} = \frac{a_{key}}{a_{Lkey}} \cdot \underbrace{\sum_i SF_i \cdot \frac{a_{Lkey}}{a_{Li}}}_{\text{constant for stream}} = \frac{a_{key}}{a_{Lkey}} \cdot C \le 1$$

$$a_{key} \le \frac{a_{Lkey}}{C} = X_{key}$$

a_i , a_{Li} - specific activity and clearance level of nuclide i,
a_{key} , a_{Lkey} - specific activity and clearance level of key nuclide
X_{key} - derived limit for key nuclide.

Example:
C=1,6 for Cs-137 and X= 62 Bq/g
C=1,8 for Co-60 and X=55 Bq/g

This derived limit is more practicable because value a_{key} we can measure directly.
For previous example X_{Co}=99,93 Bq/kg

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Example: Radionuclide vectors

Bulk contamination of buildings material (VVER)					
Radionuclide	H-3	C-14	Fe-55	Ni-63	Cs-137
Abundance	11%	5%	3%	3%	78%
SF(key=Cs-137)	0,14	0,064	0,04	0,04	1
a_{Li} (Slovakia, GO No.345/2006), Bq/g	3000	300	300	3000	0,3
X_m=385 Bq/kg	X_{key}=300/1,000122=299,96 Bq/g				

Bulk aktivation of concrete near reactor (VVER)		
Radionuclide	Fe-55	Co-60
Abundance	88%	12%
SF(key=Co-60)	7,3	1
a_{Li} *(Slovakia, GO No.345/2006), Bq/g*	300	0,3
X_m=2482 Bq/kg	X_{key}=300/1,0073=297,8 Bq/g	

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Current measurement systems overview

- **Free release measurement:**
  - solid radioactive waste clearance levels verification
- **Repository acceptance criteria measurement:**
  - acceptance criteria verification for waste packages containing solid low and intermediate level radioactive wastes
- **In-situ measurement:**
  - Portable instruments used for in-situ measurement

Free release measurement

- **Non-spectrometric devices** are widely used for waste release from nuclear facilities into the environment, and activities of individual radionuclides are estimated from the **total count-rate**
- **Uncertainties:**
  - **tens to hundreds of per cent** when radionuclide is correctly identified;
  - **infinite** when radionuclide is incorrectly identified

Free release measurement

- **Spectrometric devices** are rarely used with long integration times and hence have insufficient sensitivity; also, there are problems with the software used.

Repository acceptance criteria measurement:

- Spectrometric devices used to quantify wastes destined for the repository have **problems** with the measurement of activities of radionuclides across a **wide dynamic range**.
- Uncertainties:
  - tens to hundreds of per cent for high activities of radionuclides.

In-situ measurement:

- Portable instruments used for in-situ measurement do not form a single integrated unit for the direct measurement of α-, β- and X-ray emitting radionuclides (**DTM**)
- **Sampling**, transport of radioactive material and measurement in off-site laboratories are necessary, which is lengthy and impractical
- High resolution gamma spectrometry (**ISOCS**) is possible to use with scaling factors to DTM activities calculations

Dose rate and surface contamination measurement devices

- Hand held survey instruments are used to measure **dose rate** and **surface contamination** to be compared with clearance levels in such cases when the surface measurement is suitable.
- Handheld instrument used:
  - **Contamat FHT 111 M** (Thermo company) - portable hand-held surface contamination by alpha, beta and gamma emitting radionuclides measurements.
  - **PAM series meters (PAM - 100, 300, 350)** (VF company) - portable hand-held surface contamination by alpha, beta and gamma emitting radionuclides measurements.
  - **DJ-2000E** (VF company) - detection unit is intended for alpha/beta (gamma) surface contamination measurements using a large-surface sealed proportional detector.

Contamat FHT 111 M

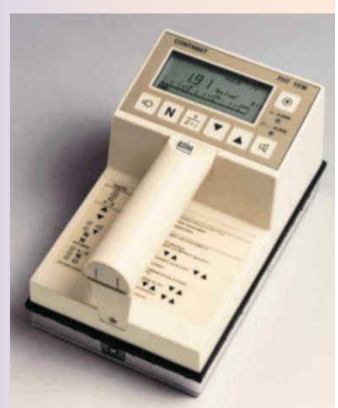
Surface contamination measurement

Counter tubes for alpha, beta, gamma;
100 or 166 cm^2 window area

Contamat with ten fixed nuclides per counter tube (standard)

Xenon counter-tube with permanent gas filling: C-14, P-32, S-35, Co-60, SR-90/Y-90, Tc-99m, I-123, I-125, I-131, Cs-137

Butane flow-type counter tubes with refillable gas reservoir: C-14, P-32, S-35, Co-60, Ni-63, Sr-90/Y-90, I-131, Cs-137, Tl-204, Am-241



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Bulk activity measuring systems used in Slovakia.

WM2110 Low Level Waste Assay System (Canberra company)

RTM 640 Rados Waste measurement system (Mirion Technologies Company)

CM1110 Soil Measuring and Segregation System with belt conveyer (Canberra)

VMP Capacious Low Level Waste Measuring System (VUJE company)

TK-159 Waste Bag Monitor (VF company)

FRM-02 Free release monitor (VF company), related FRM-06 and FRM-24

SGS Standard Segmented Gamma Scanner (Canberra)

IPROL-1 LaBr Probe with InSpector 1000 analyzer (Canberra company) in-situ waste measurements

ISOCS - In Situ Object Counting System (Canberra company)

WM2110 Series Q2 Low Level Waste Assay Systems

Provides **qualitative** and **quantitative** gamma assays for waste in 208 L drums

Sensitivity better than **370 Bq** for drum

Three uncollimated germanium detectors mounted in five-day multi-attitude cryostats with manual LN2 fill system (optional Cryo-Pulse)

Factory calibrated for **turnkey** operation, and includes QA check source and holder

Low background 10 cm (optional 15 cm) low background **steel shield**

Automatic weighing system for matrix **attenuation corrections** due to sample density

Parametre meradla typu Q2

Q2 Low-Level Waste Assay System Performance

			Typical MDA				Worst Case MDA			
			pCi/g		Bq/g		pCi/g		Bq/g	
Nuclide	Daughter Measured	Energy (keV)	Density (g/cc) 0.1	0.8	Density (g/cc) 0.1	0.8	Density (g/cc) 0.1	0.8	Density (g/cc) 0.1	0.8
^{137}Cs	^{137m}Ba	662	0.18	0.05	.0067	.0019	0.26	0.15	.0096	.0056
^{134}Cs		800	0.15	0.04	.0056	.0015	0.21	0.11	.0078	.0041
^{60}Co		1173	0.15	0.04	.0056	.0015	0.2	0.09	.0074	.0033
^{58}Co		810	0.15	0.04	.0056	.0015	0.21	0.11	.0078	.0041
^{232}Th	^{228}Ac	908	0.55	0.15	.0204	.0056	0.73	0.38	.0270	.0141
^{228}Th	^{208}Tl	583	0.47	0.14	.0174	.0052	0.64	0.42	.0237	.0156
^{228}Th	^{208}Tl	2614	0.22	0.04	.0081	.0015	0.29	0.09	.0107	.0033
^{238}U	^{234}Th	93	6.2	2.3	.2296	.0852	9.1	19.2	.3370	.7111
^{238}U	^{234m}Pa	1001	26.7	6.9	.9889	.2556	36	17.3	1.333	.6407
^{238}U	^{214}Bi	609	0.32	0.09	.0119	.0033	0.47	0.27	.0174	.0100
^{235}U		185	0.32	0.11	.0119	.0041	0.46	0.64	.0170	.0237
Transuranics										
^{241}Am		60	1.1	0.6	.0407	.0222	1.8	10.2	.0667	.3778
^{239}Pu		414	1.2E+04	3.8E+03	4.3E+02	1.4E+02	1.7E+04	1.4E+04	6.2E+02	5.2E+02
^{238}Pu		152	1.5E+04	5.1E+03	5.5E+02	1.9E+02	2.0E+04	2.9E+04	7.4E+02	1.1E+03

CONDITIONS: uniform source calibration; Three 20% Ge detectors; 10 minute count time; 95% fill height for 200 liter drum

MDA (minimum detectable activity): 5% Type 1 error, 5% Type II error.

WORST CASE LLD: Maximum activity present if all activity is in a 1 cm sphere at the worst location

Segmented Gamma Scanner (SGS)

Canberra

MDA for ^{137}Cs **3,7 kBq** for standard conditions and 60 kg/drum or **60 Bq/kg**

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Parametre meradla typu SGS

WM-2200 Series Performance

Nuclide	Daughter Measured	Energy keV	MDA µCi	MDA kBq	
^{137}Cs	^{137m}Ba	662	0.1	3.7	**CONDITIONS:** 200 liter drum with < 0.3 g/cc matrix density, 30 minute assay time, Background < 0.02 mR/h, no other significant nuclides present.
^{134}Cs		800	0.1	3.7	
^{60}Co		1173	0.1	3.7	
^{133}Ba		356	0.2	7.4	
^{152}Eu		1408	0.4	14.8	
^{235}U		185	0.2	7.4	
^{238}U	^{234}Pa	1001	20	740	
^{239}Pu		414	1.20E+04	4.40E+05	

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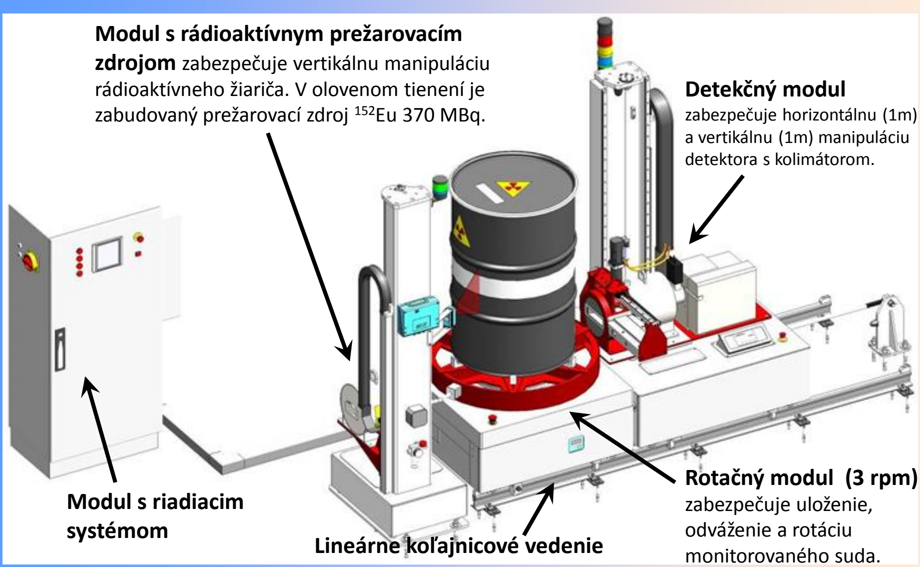
Segmentový gamaskener sudov WS 1100 na A1, (CP Žilina + MicroStep IQM Hriňová)



Segmentový gamaskener sudov WS 1100 na A1, (CP Žilina + MicroStep IQM Hriňová)

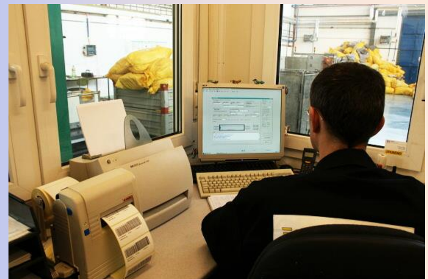
Detekčný modul zabezpečuje horizontálnu (1m) a vertikálnu (1m) manipuláciu detektora s kolimátorom.

Modul s rádioaktívnym prežarovacím zdrojom zabezpečuje vertikálnu manipuláciu rádioaktívneho žiariča. V olovenom tienení je zabudovaný prežarovací zdroj ^{152}Eu 370 MBq.

Segmentový gamaskener sudov WS 1100 na A1, (CP Žilina + MicroStep IQM Hriňová)

Meraná veličina:	aktivita, jednotka Bq, hmotnostná aktivita, jednotka Bq/kg
Merací rozsah:	aktivita od 3,7 kBq pre rádionuklidy ^{137}Cs, ^{134}Cs, ^{60}Co pre dobu merania 30 min, hustota materiálu do 300 kg/m^3, pozadie do 200 nSv/hod.
	hmotnostná aktivita od 60 Bq/kg pre ^{137}Cs, ^{134}Cs, ^{60}Co pre dobu merania 30 min, hustota materiálu do 300 kg/m^3, pozadie do 200 nSv/hod.
Maximálna relatívna chyba merania:	$\pm$ 20% pre sudy s hustotou do 1000 kg/m^3.

Measuring system MERLIN (Envinet) is used for measurement of materials and objects released to the environment from NPP Dukovany and NPP Temelin.



- Shielded measurement chamber (10 cm Pb, 1 cm Fe). Insufficiency: shielding from lead (high price, non-ecological material).
- Measuring boxes: plastic walls and stainless steel frame, dimensions 40 cm x 40 cm x 120 cm, maximum load 300 kg, measured in three positions. Insufficiency: small dimensions and maximum load.
- **Measurement range for mass activity: 10^1 to 10^4 Bq/kg.**
- **Three HPGe coaxial detectors** (resolution 1.9 keV and relative efficiency 30 % for Co-60) situated under and from the both sides of measurement box and conveyor for the container movement.

Free release measurement facility in Řež

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SUPERFOUR DETECTOR ASSEMBLY

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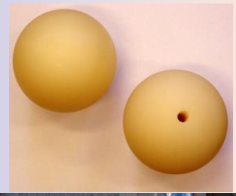
Calibration phantom container

Geometry of the container:
(0.4 m x 0.8 m x 1.2 m)
Volume: 384L
loading capacity 500 kg
(maximum 750 kg)

Containers for
radioactive material
and
phantom with rods for reference activity

Calibration standards for steel



Material for Phantoms
1100 hollow steel petanque balls and
1100 plastic balls with drillings

Diameter of one ball:	74 mm
Steel thickness:	5.5 mm

1100 steel balls and 1100 plastic balls with **drillings** for Eu-152 and Co-60 point sources
10 more Eu-152 point sources for the "phantom container"

Active material for calibration standards:

<u>Metal</u>:
- 12 steel tubes (half-filled container)
- Tube diameter 20 cm, length 40 cm, mass 20 kg
- with Co-60 (80 kBq), Ag-110^m (800 kBq) in 250 kg Iron
- additional disks and shavings for laboratory measurements

PHANTOM CONCRETE

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PHANTOM METAL

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Free release monitor FRM02

Calibration phantom crate and drum

32 scintillation type detectors in 4π geometry,
MDA for Cs-137 < 280 Bq for material density 300 kg/m^3

The monitor implements **radionuclide vectors** (fingerprints) technique, or optionally, can be calibrated for a variety of single radionuclides.

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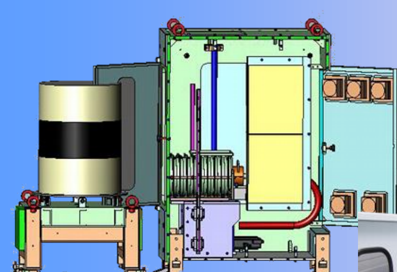
GAMS 02 Measuring system (ENVINET/ORTEC)

Repository acceptance criteria measurement in CR



Mass activities of identified radionuclides are calculated in the measurement range **10^3 to 10^8 Bq/kg.**

Energy range:
50 keV to 2000 keV.

RADOS RTM640lnc (Mirion Technologies) radioactive waste contamination monitor

Shielding of monitoring chamber: lead, min. 50 mm, max. 80 mm

Electric-powered chamber door

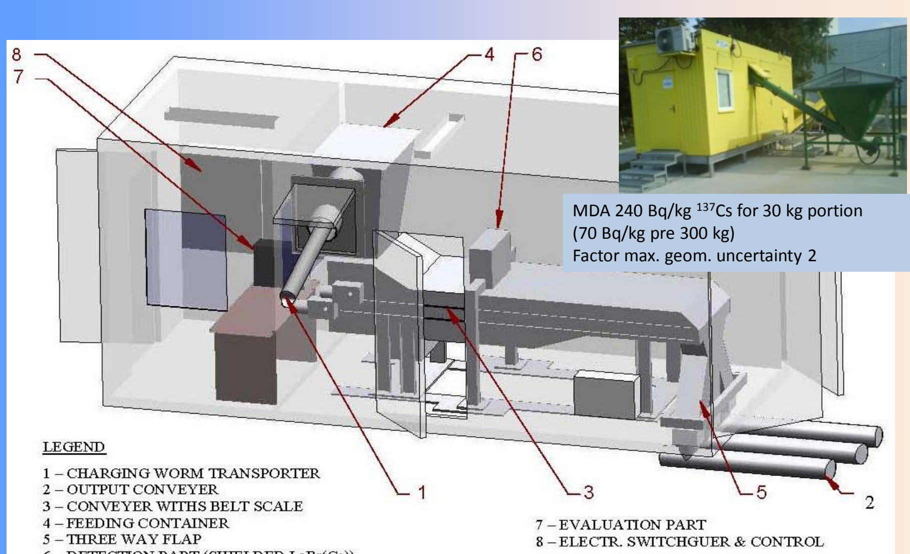
Container transport chain conveyor

Measurements are made by using **10 large volume plastic scintillators** dimension 500 mm x 500 mm x 50 mm in a 4π chamber.

Activity-calibration and evaluation: Leading nuclide vector correlation, homegenity test-procedure

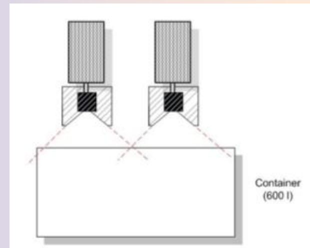
Calculation of total gamma activity is based on nuclide fingerprint method named 'leading nuclide correlation' (lnc) which can be specific to the measurement sessions.

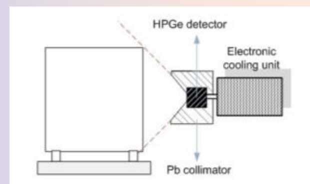
CM1110 - Soil Measuring and Segregation System with belt conveyer (Canberra)



MDA 240 Bq/kg ^{137}Cs for 30 kg portion
(70 Bq/kg pre 300 kg)
Factor max. geom. uncertainty 2

VMP - Capacious Low Level Waste Measuring System (VUJE company)





MDA =10 Bq/kg ^{137}Cs
t=2 x 10 min
PDE = 0.3 µSv/h

Modular Gamma Box and Container Counter (Canberra)

The system is being used to assay several kinds of containers, from which the most common is known as CMD (clearance and measurement container), a metallic box with a capacity of about 2 m^3. Bags of 1 m^3 as well as 220 l drums are also measured with this system.

IPROL-1 LaBr Probe with InSpector 1000 analyzer (Canberra company)

in-situ waste measurements:

MDA= 60 Bqkg (^{137}Cs)
distance 5 cm,
doserate 0.1 µSv/h
measuring time 5 min.
optional: collimator

Uncertainties till 50%

Cronos-4 and Cronos-11

Gamma Object / Tool Monitors

6x50 mm thick large surface area plastic scintillator detectors
Radiation Detected:
Gamma photons with energy over 50 keV: ^{241}Am, ^{133}Ba, ^{137}Cs, ^{60}Co, etc.

Built-in 100 kg range, 0.1 kg resolution, **weigh scale**.
Used to detect gamma radiation in/on articles such as waste bags, tools, briefcases, hard hats, and other miscellaneous objects.

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TGS Tomographic Gamma Scanner WM2900 (Canberra)

System performance will depend on actual measurement conditions.

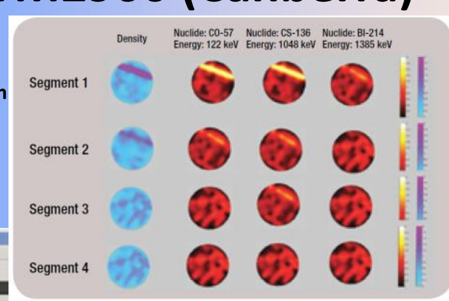
Under the following conditions the standard WM2900 waste assay system has an MDA of approximately 25 Bq/kg for 137Cs or 0.4 g for 239Pu:

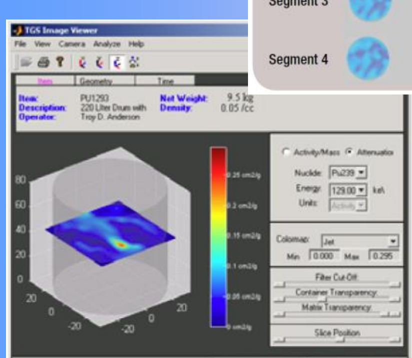
- ✓ *Standard 200 L drum.*
- ✓ *Density less than 0.3 g/cc.*
- ✓ *Background less than 200 nSv/hr.*
- ✓ *No other significant nuclides present.*
- ✓ *60 minute total assay time.*

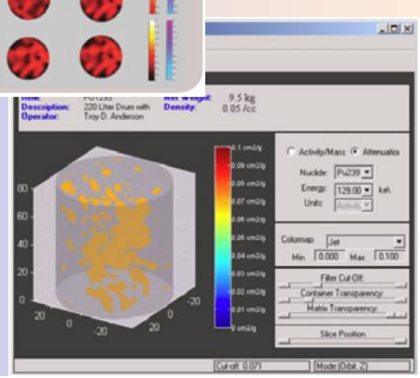
Complete quantitative gamma analysis for fission/activation products or TRU (alpha) radionuclides

TGS Tomographic Gamma Scanner WM2900 (Canberra)

A comprehensive graphics package allows the attenuation map and emission image to be visualized from different perspectives.

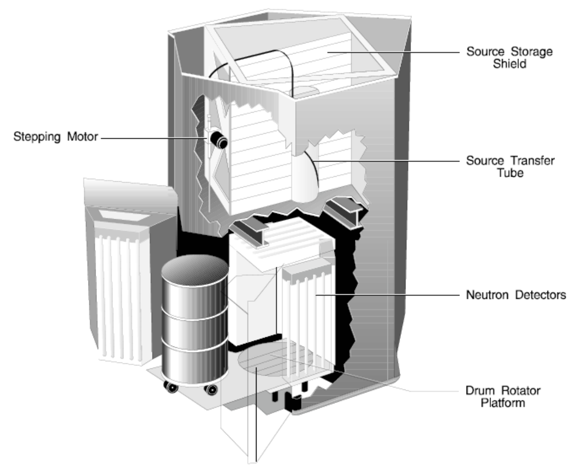






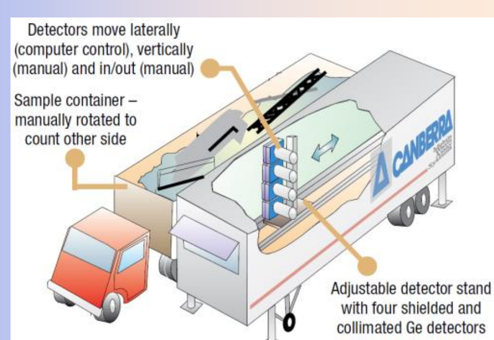
Model WM3210 Passive/Active Neutron Cf-252 Shuffler System

Unique 252Cf Shuffler mechanism for both Active and Passive neutron coincidence counting of 200 L drums
Active mode sensitivity, 1000 second count time:
Fast neutrons: 300 mg 235U
Thermal neutrons: 3 mg 235U
Passive mode sensitivity,
1000 second count time:
4 mg 240Pu
Fast Teleflex source shuffling mechanism with 400 ms transfer time. Three rpm turntable for barrel rotation.
Sixty-four 3He tubes.
Accuracy – 15% for waste barrels.



Modular Gamma Box and Container Counter

Energy calibration is performed by measuring a number of sources of different energies (typically ^{60}Co, ^{133}Ba and ^{137}Cs) placed in a centered position in the platform. A FWHM characterization is also been made for each detector.
Efficiency calibration is a complex process that is carried out basically by a mathematical process, although it also involves test measurements. It is accomplished through the ISOCS software.



For a box counter operating with 4 detectors and counting times of 300 s, MDA's of approximately **2 Bq.kg^{-1} , 3 Bq.kg^{-1} and 10 Bq.kg^{-1}** are obtained for the nuclides **^{60}Co, ^{137}Cs and ^{152}Eu** respectively. This is, at least, one order of magnitude higher than the clearance levels.

Cartogam – charakterizácia priestorov

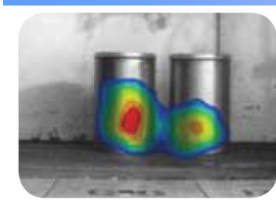
When planning for maintenance or decommissioning operations, it can be used to provide radiation intensity maps of areas during normal operations, to evaluate radiological hot spot locations, and to quickly locate positions of contaminated areas in order to define the dismantling scenario.

Two dimensional gamma mapping and dose range.

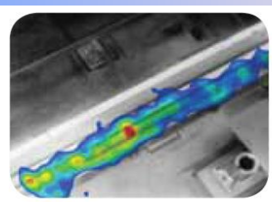
Superposition of gamma and visible images.

Detection range: better than 300 nGy/h in 30 min up to 10 Gy/h

Cartogam can be coupled with ISOCS, to quantify radioactivity



Drum measurements



Contamination on a waste-transport rail