Monitoring of radioactivity in surface and underground water: From sampling to dose assessment

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ARPA Lombardia – Presentation

www.arpalombardia.it

ARPA Lombardia

- ARPA is a government Agency in charge of **preventing and monitoring environmental pollution**
- It is one of the 21 Italian Agencies operating in the framework of the Network of Italian Environmental Agencies (SNPA), coordinated by the National Environmental Agency (ISPRA) in Rome

ISPRA
Istituto Superiore per la Protezione e la Ricerca Ambientale

ARPA Lombardia - Organization

- Lombardia region: 9 Million people, 15% of Italian population, highest concentration of productive activities
- ARPA Lombardia:
  - 13 offices in the main towns of the region
  - Around 1,000 people employed: chemists, biologists, physicists, engineers, etc.
  - Headquarters: Milano

ARPA Lombardia – Main fields of activity

ARPA LOMBARDIA
Agenzia Regionale per la Protezione dell'Ambiente

- Air
- Surface water
- Groundwater
- Biodiversity

Environmental Monitoring

- Industrial emissions (air, water, wastes)
- Environmental remediation
- Noise
- Non Ionizing Radiation

Controls

- Hydrographic service
- Geological Risk
- Meteorology
- Weather Climatology

Natural Risks

- Radioactivity
- Radon

Radiation Protection

- IPA, As, Ni, Cd, Pb Samples
- Annual and daily bulletins
- Monitoring campaigns

Air Quality

- Environmental impact assessments
- Strategic environmental assessments

Environmental Assessment

Radiation Protection Centre

ARPA LOMBARDIA
Agenzia Regionale per la Protezione dell'Ambiente

- 10 staff members: chemists, biologists and physicists
- 2 measurement labs (Milano and Bergamo), 1 radiochemistry lab accredited under ISO 17025

QUALITY MANAGEMENT SYSTEM
ISO 17025
ACCREDITED
LABORATORY

- Equipment for alfa, beta and gamma measurement, both in field and in lab
- Tools for data evaluation and risk assessment

RESRAD-ONSITE

Radiation Protection Centre

ARPA LOMBARDIA
Agenzia Regionale per la Protezione dell'Ambiente

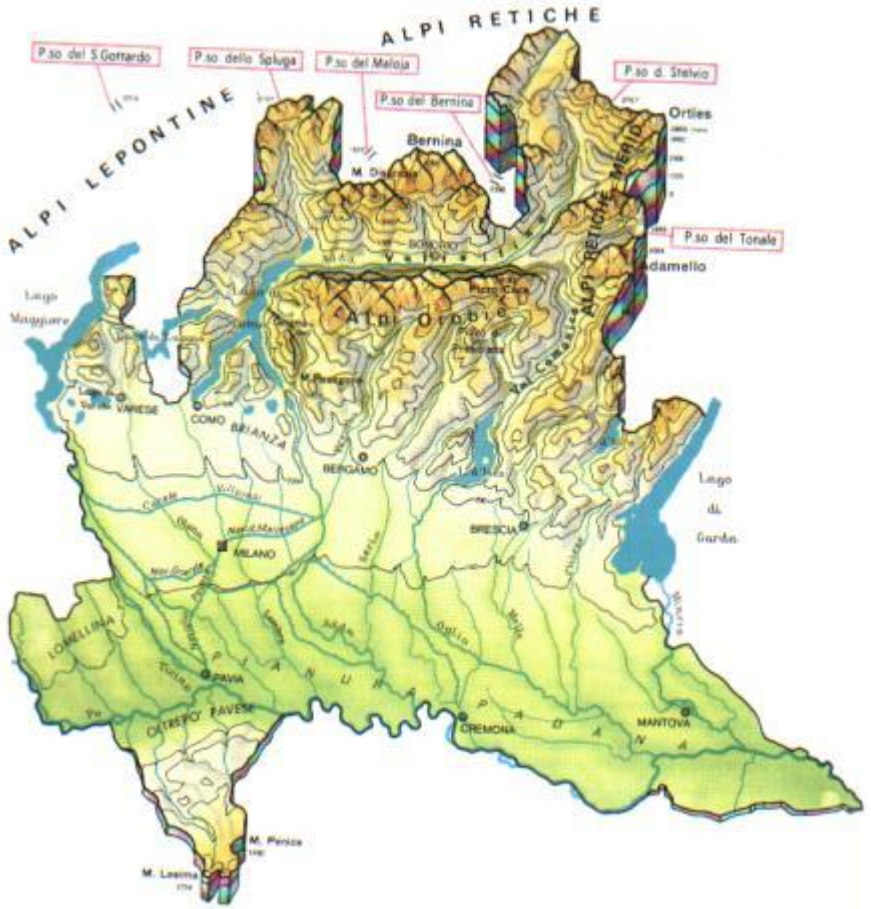
- Member of the National Network for Environmental Radioactivity Monitoring
- Member of IAEA ALMERA Network ALMERA
- Scientific advisors of National and Regional Health Authorities for problems due to radioactive materials

Regione Lombardia

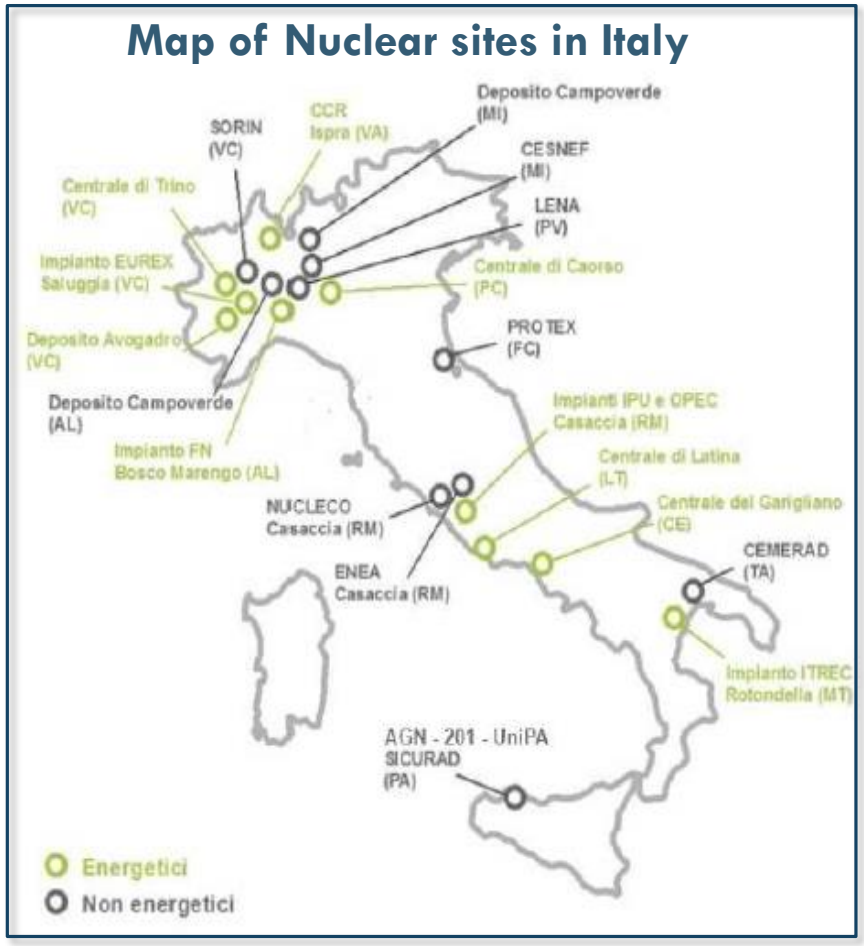
- Since 2000 member of ISO Committees

ISO International Organization for Standardization

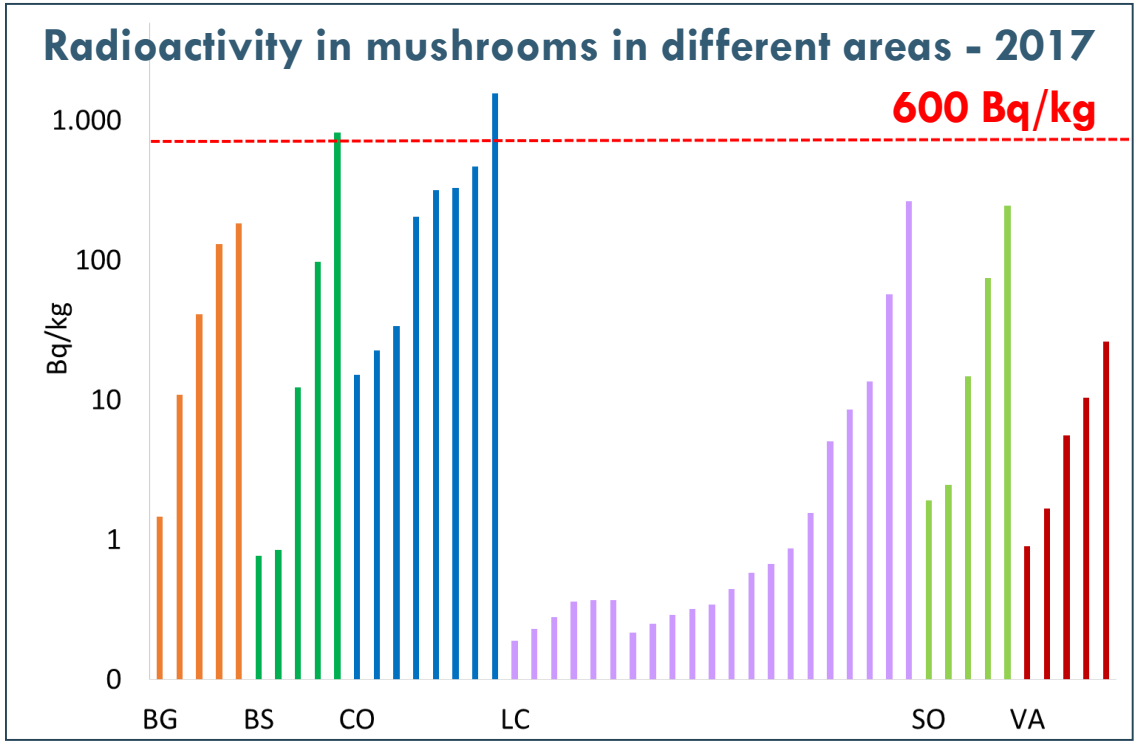
Natural and artificial radioactivity in the environment



Radioactivity in the environment



- Discharges from nuclear sites (**10 NPP under decommissioning**)



- Nuclear accidents (mainly **Chernobyl**)

Radioactivity in the environment

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- **Wastes from medical** use of radioactivity

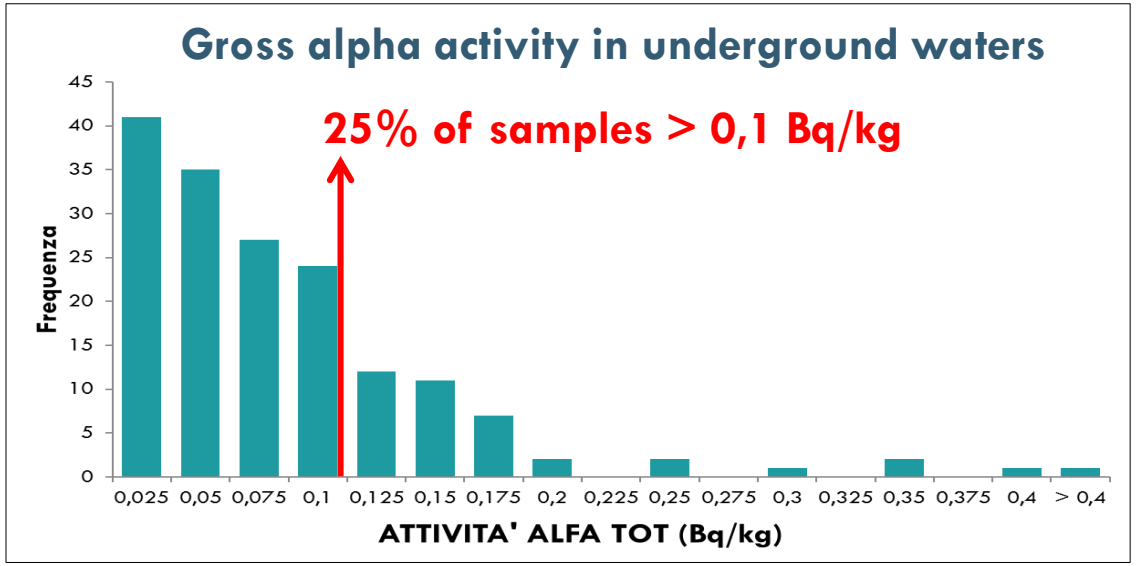
Contaminated wastes in incineration plants

- **Areas contaminated** as a result of past activities:
  - **NORM** industries (phosphogypsum repositories)
  - Waste repositories from accidents occurred in the past (**radioactive source melting** in foundries)

Wastes from radioactive source melting in foundries

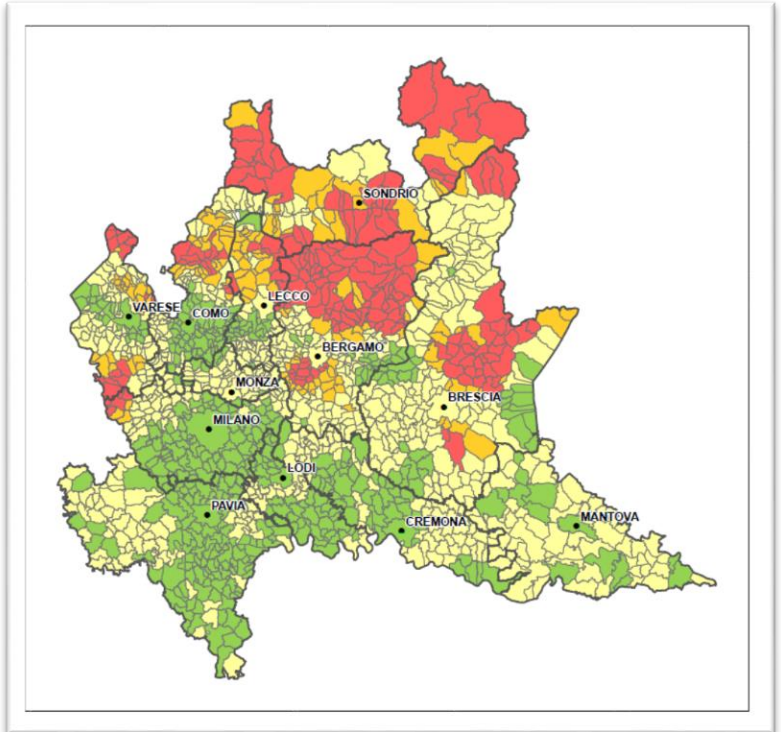
Radioactivity in the environment

- Natural radioactivity
  - Underground waters (radon, radium, uranium, etc.)



  - Radon indoor

(Regional mean value = 116 Bq/m^3)



Emergency Quick Alert

Air monitoring – Gas and particulate

- TSP monitoring: running since 1988
- Gas monitoring: running since 1997

Sampling point and frequency

- Milano city centre
- Particulate: Daily (continuous from 9 a.m. to 9 a.m.)
- Gas: Weekly

Measurement frequency

- Particulate: Daily, Weekly, Monthly
- Gas: Weekly

Monitoring conditions optimized for quick alert of "relevant" air contamination

Air monitoring – Sampling unit

- **Housing:** Commercial

(Air Sampler GMWL-2000 H - General Metal Work Inc. US)

- **Flow counter:** Commercial (Schlumberger; resolution 0,01 m^3)

Uncertainty in flow rate measurement: 5%

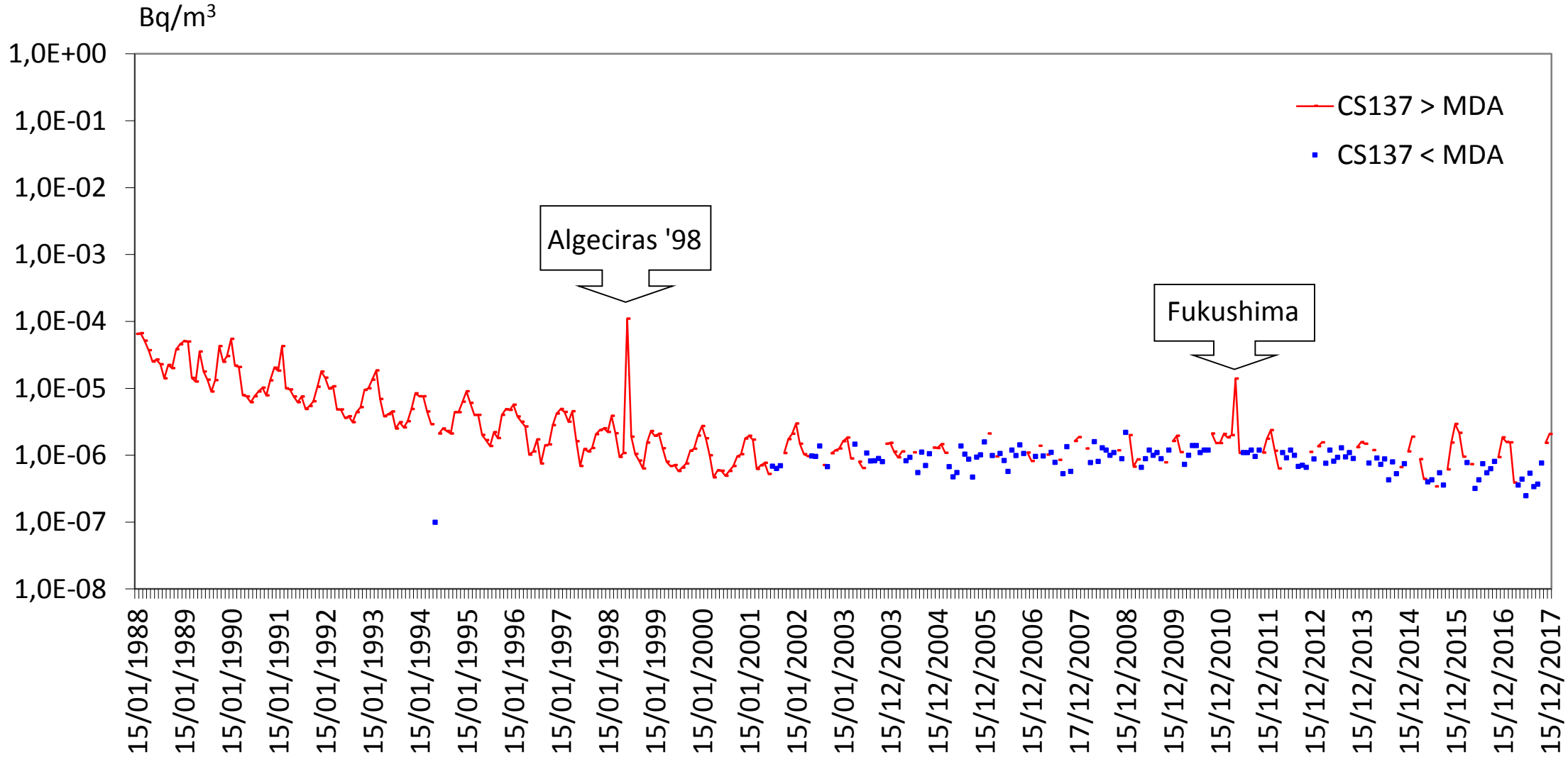
- **Pumping system:**

Flow: ≈ 100 m^3/h (≈ 2400 m^3/d)

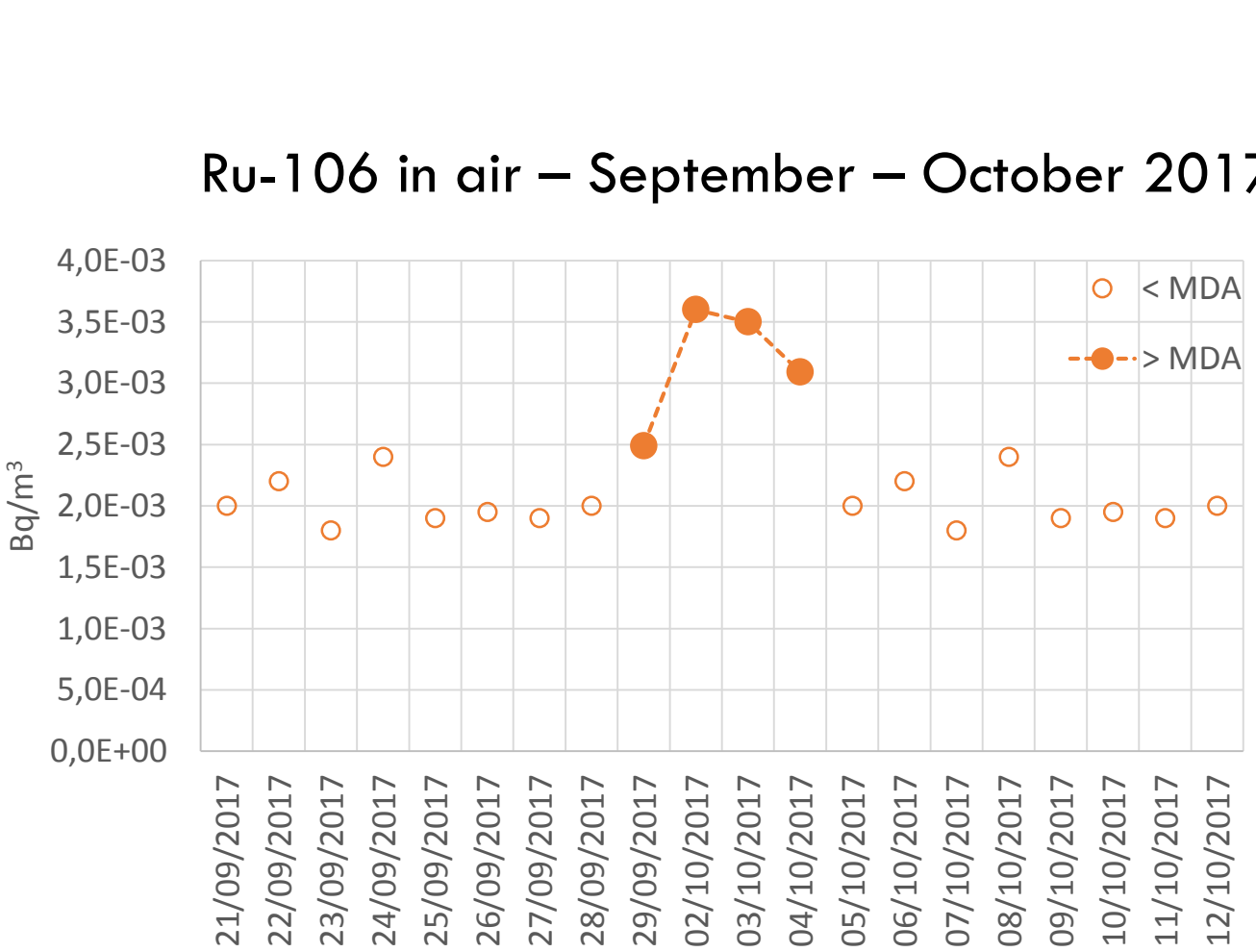
- **Filtering unit:**

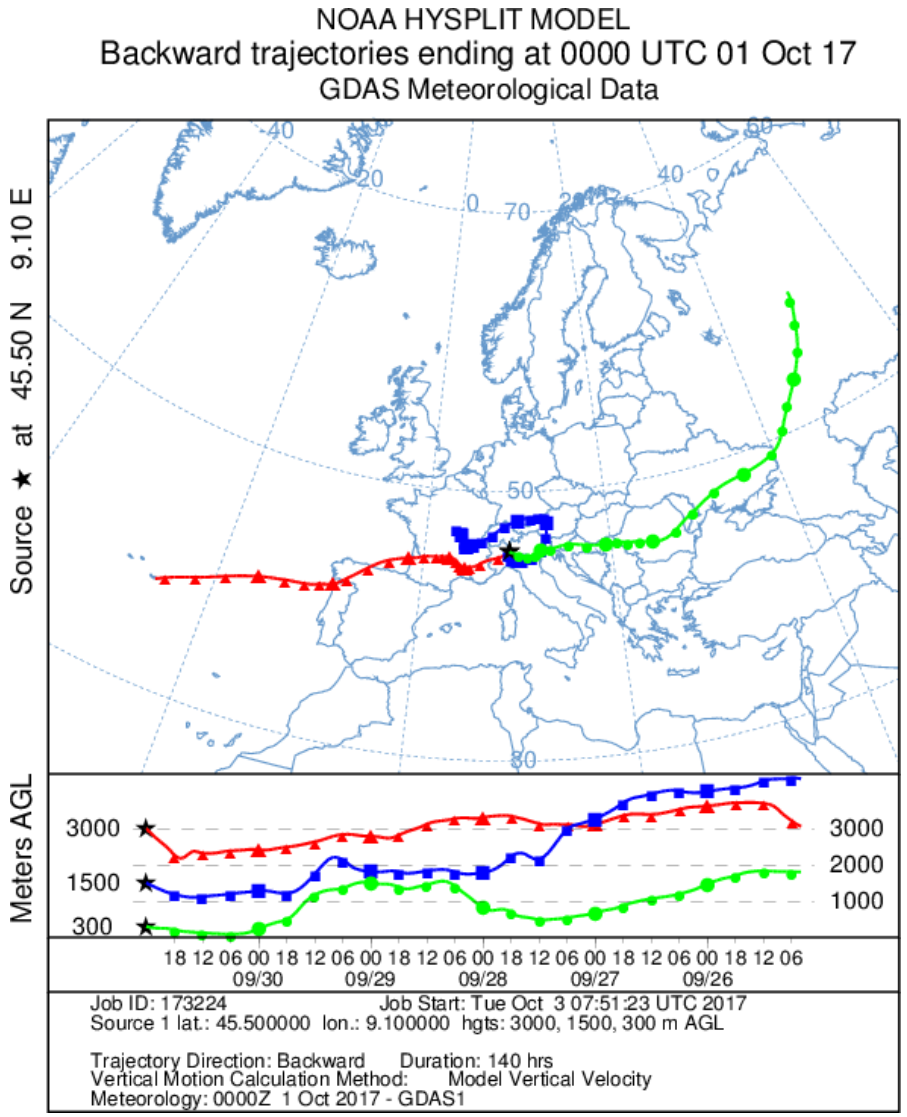
Glass microfiber filter (Whatman GF/A CAT No. 1820-866, 203x254 mm) + **iodine trap**

Air monitoring – Particulate



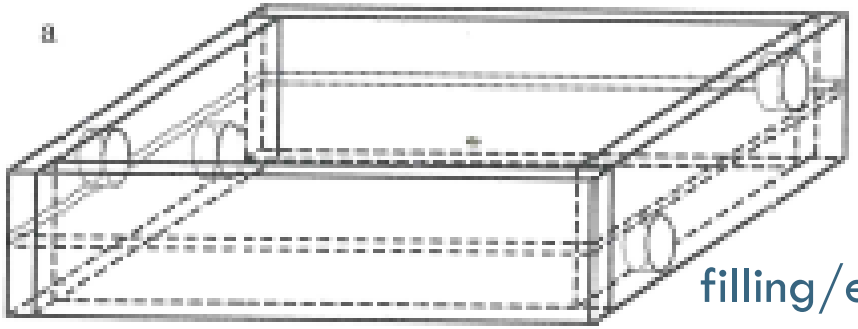
Air monitoring – Early detection of Ru-106





Air monitoring – Iodine trap

Methylmetacrylate box



2 beds, each one:

19 x 24 x **2,4** cm

≈ 500 g RKJ (≈ 1 L) (Marinelli)

filling/empting holes

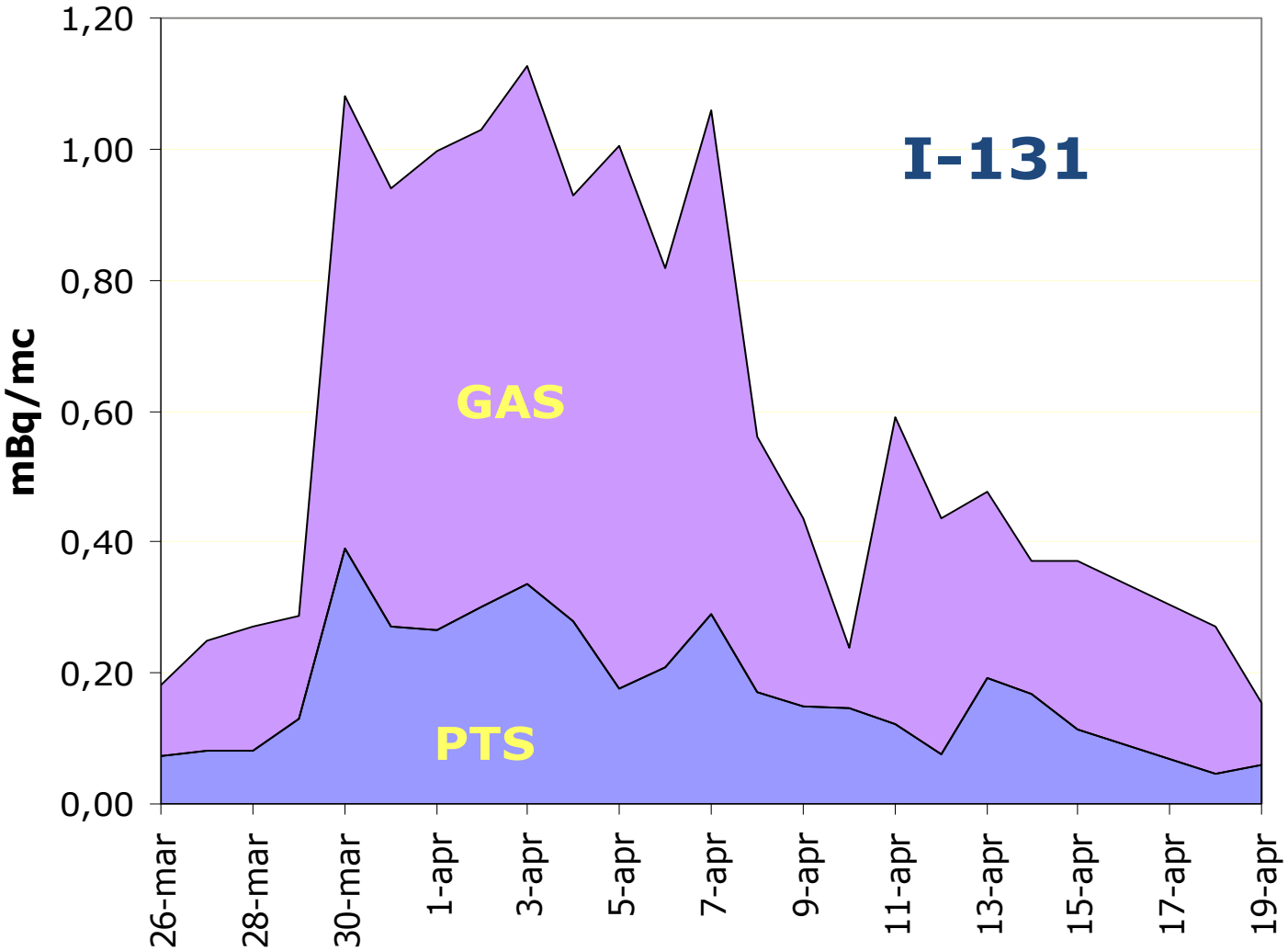
Beds separated by double metal grids

(2 different meshes), silicon sealed

NORIT RKJ

* Granular activated carbon
* Elemental, ionic and organic I retention
* Pellet diameter: 1.3 – 1.5 mm
* BET surface area: 900 – 1000 m2/g

Air monitoring – Iodine 131

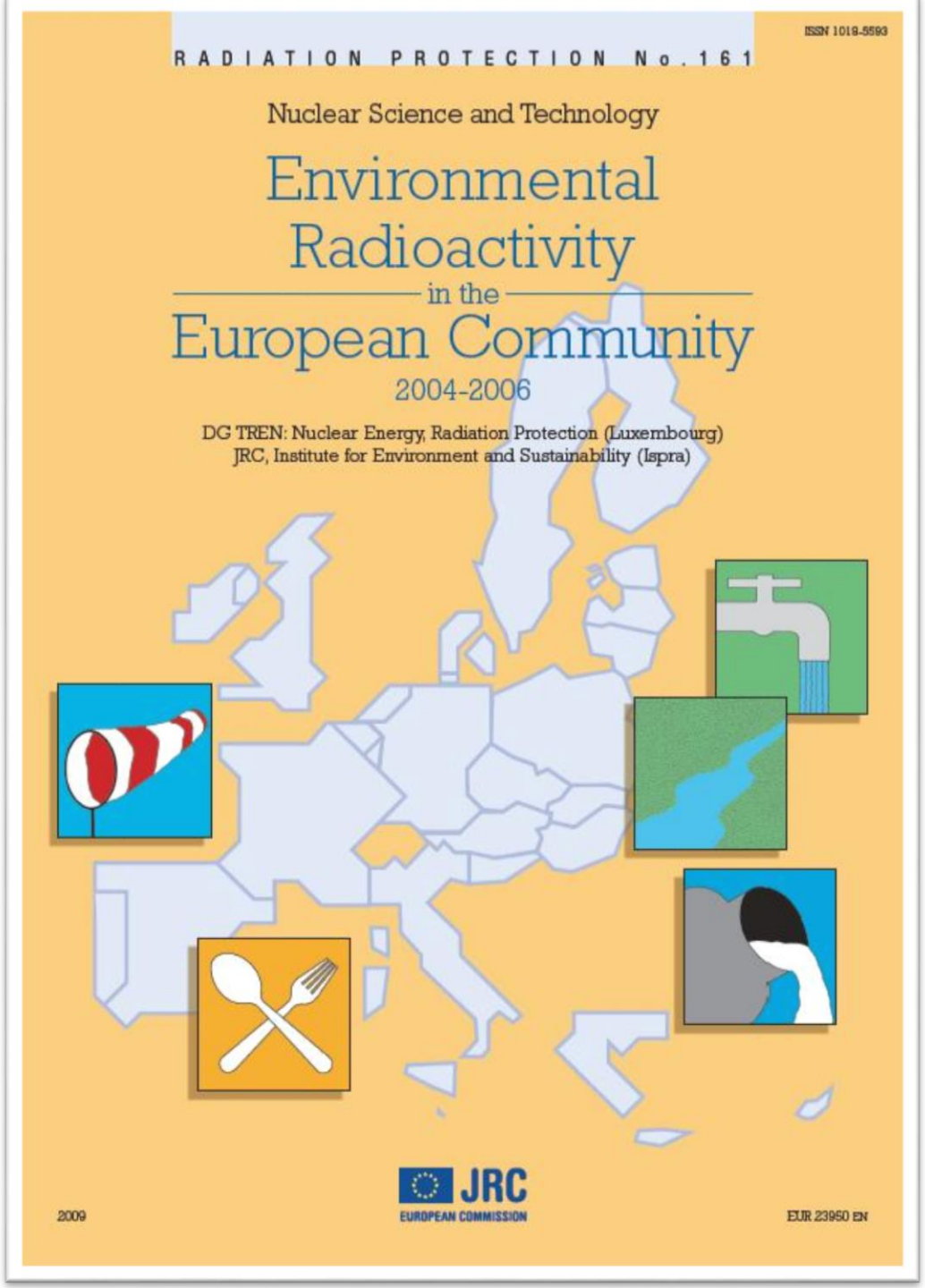


FUKUSHIMA 2011

Radioactivity in Air (particulate)

Avg $I_{gas}/I_{particulate}$ = 80 %

Results comparable to those obtained by other EU laboratories (Masson et al, 2011)



ARPA LOMBARDIA
Agenzia Regionale per la Protezione dell'Ambiente

European and National Environmental Radioactivity Network

Monitoring Network

ARPA is part of the **National Environmental Radioactivity Network,** fulfilling requirements of European Union:

- European Commission Recommendation 2000/473
- European Council Directives (2013/51/EURATOM)

Environment Monitoring

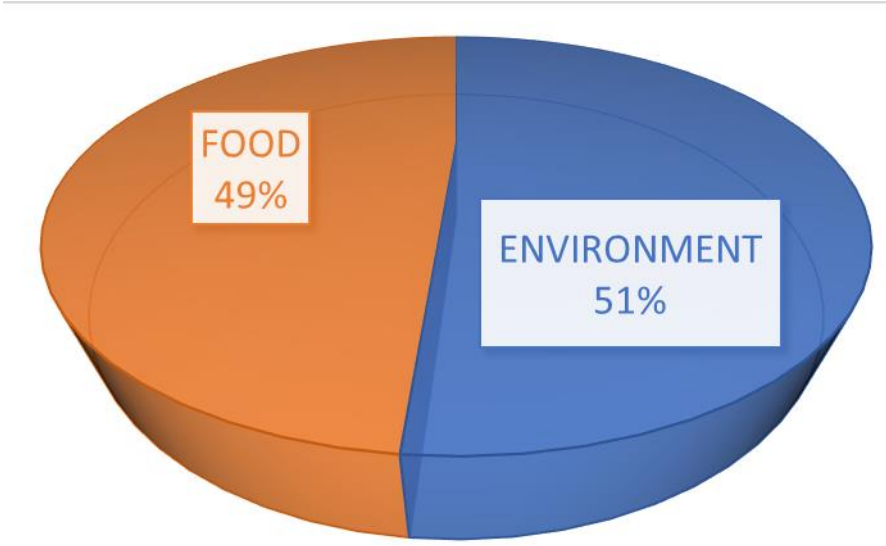
Source Related Monitoring

No. of samples analyzed

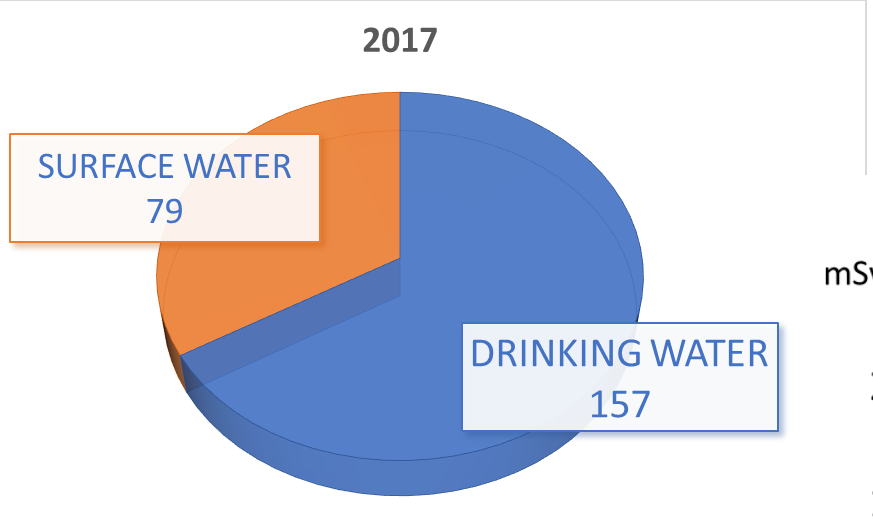
- Food and environmental samples, about 1000 samples per year

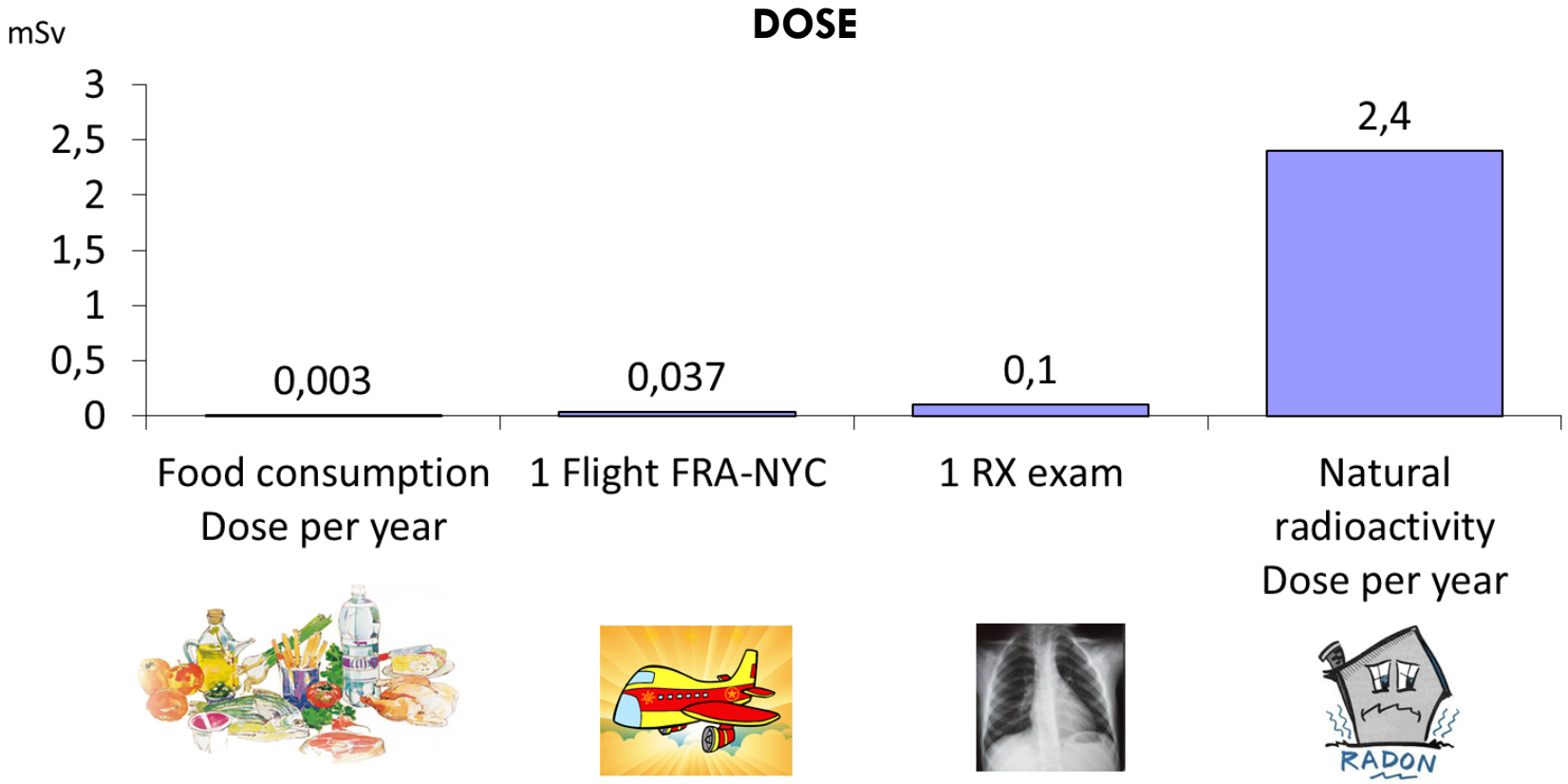
Sample	Radionuclide	Minimum Detectable Activity
AIR	GROSS BETA Cs-137	0,005 BQ/M^3 0,03 BQ/M^3
SURFACE WATER	GROSS BETA Cs-137	0,6 BQ/L 1 BQ/L
DRINKING WATER	H-3 Sr-90 Cs-137 NATURAL RADIONUCLIDES	100 BQ/L 0,06 BQ/L 0,1 BQ/L NOT SPECIFIED
MILK	Sr-90 Cs-137	0,2 BQ/L 0,5 BQ/L
MIX DIET	Sr-90 Cs-137	0,1 BQ/DAY PER PERSON 0,2 BQ/DAY PER PERSON

as required by European Commission Recommendation 2000/473



Monitoring Network





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Water Monitoring

Drinking water

- According to European Council Directive 2013/51:
  - monitoring of major ground or surface water supplies and water distribution networks

Parameter	Parameter value	Derived concentration	Limit of detection required by UE Directive
RADON	100 Bq/L		10 Bq/L
TRITIUM	100 Bq/L		10 Bq/L
INDICATIVE DOSE	0,1 mSv/y		
Gross Alpha		0,1 Bq/L	0,04 Bq/L
Gross Beta		1 Bq/L	0,4 Bq/L
U-238		3 Bq/L	0,02 Bq/L
Ra-226		0,5 Bq/L	0,04 Bq/L
Cs-137		11 Bq/L	0,5 Bq/L

Indicative Dose < 0,1 mSv/y

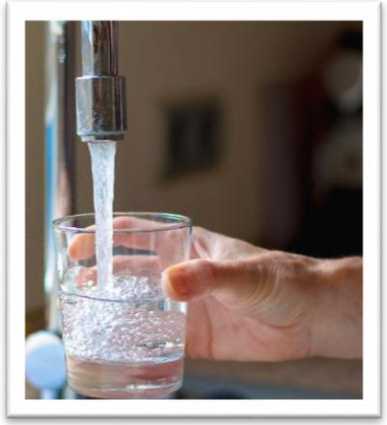
Gross alpha and beta as *screening parameters*

IF EXCEEDED

Single nuclides

Drinking water: Monitoring network

- Extensive monitoring of Gross Alpha and Beta (Gross Beta including possible contribution of Cs-137):
  - Sampling about 0,5 L of water from tap
  - Measurement by Liquid Scintillation Counting with ISO 11704:2010



20 mL Teflon Coated Polyethilene Vials

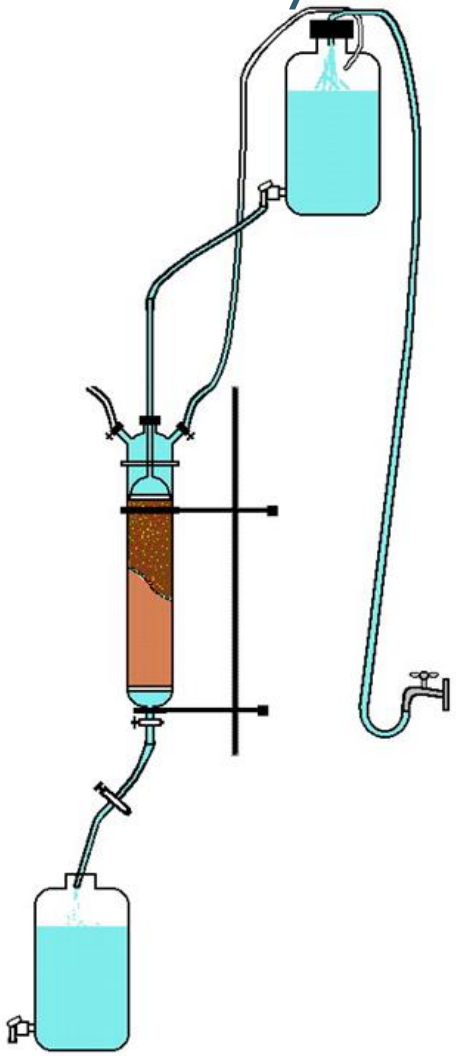
MEASUREMENT METHOD

100 mL of sample concentrated 1:10 by evaporation
pH adjusted to 2,5
8 mL sample + 12 mL liquid scintillation cocktail
1000 min counting with alpha/beta discrimination

Parameter	Screening value	Limit of detection Required by Law	Limit of detection in our Lab
Gross Alpha	0,1 Bq/L	0,04 Bq/L	0,008 Bq/L
Gross Beta	1 Bq/L	**0,4 Bq/L**	**0,08 Bq/L**

Drinking water: Monitoring network

- In selected points, continuous sampling for high sensitivity monitoring by Gamma Spectrometry



METHOD

- Continuous elution, over 1 month, on a colum (1 kg) of ionic exchange resin
- Measurement by Gamma Spec. for 4000 minutes

HPGe Detectors, 30% relative efficiency:

Parameter	Amount of sample	Counting Time	Limit of detection *
Cs-137	1 L	1000 min	0,1 Bq/L
	200 L	4000 min	0,0005 Bq/L

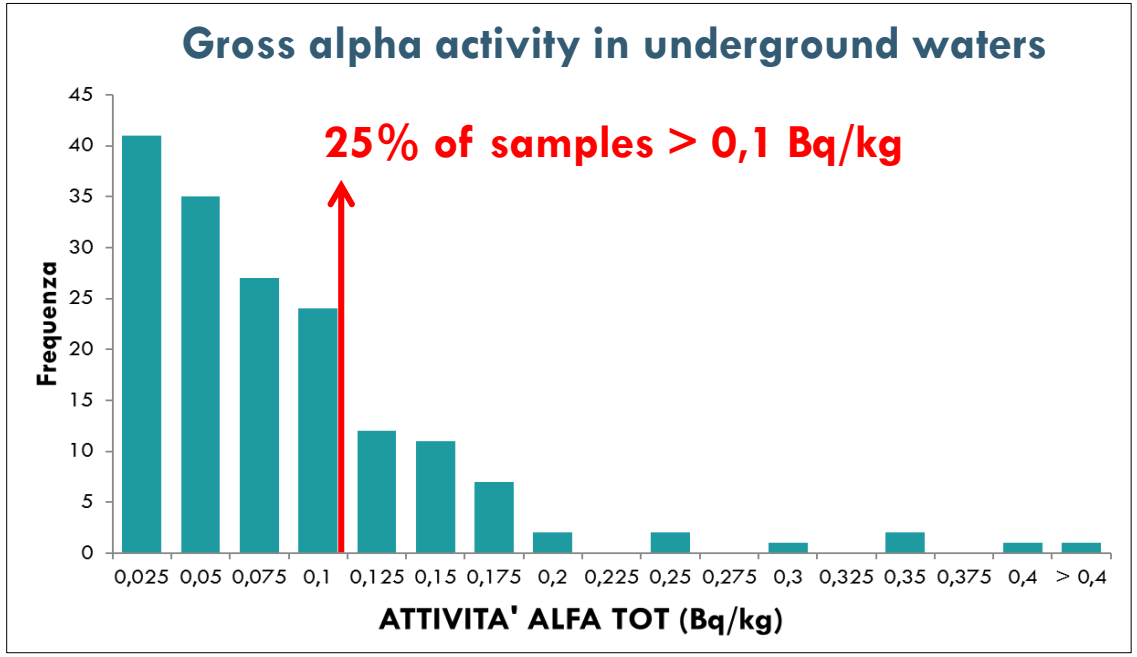
* Limit of detection required by EU: 0,5 Bq/L

Drinking water: Monitoring network

Results at a glance:

➡ Gross Alpha:

- 25% of samples > 0,1 Bq/L
- Mainly due to Uranium isotopes (natural origin)



➡ Gross Beta:

- < Limit of Detection (0,08 Bq/L)

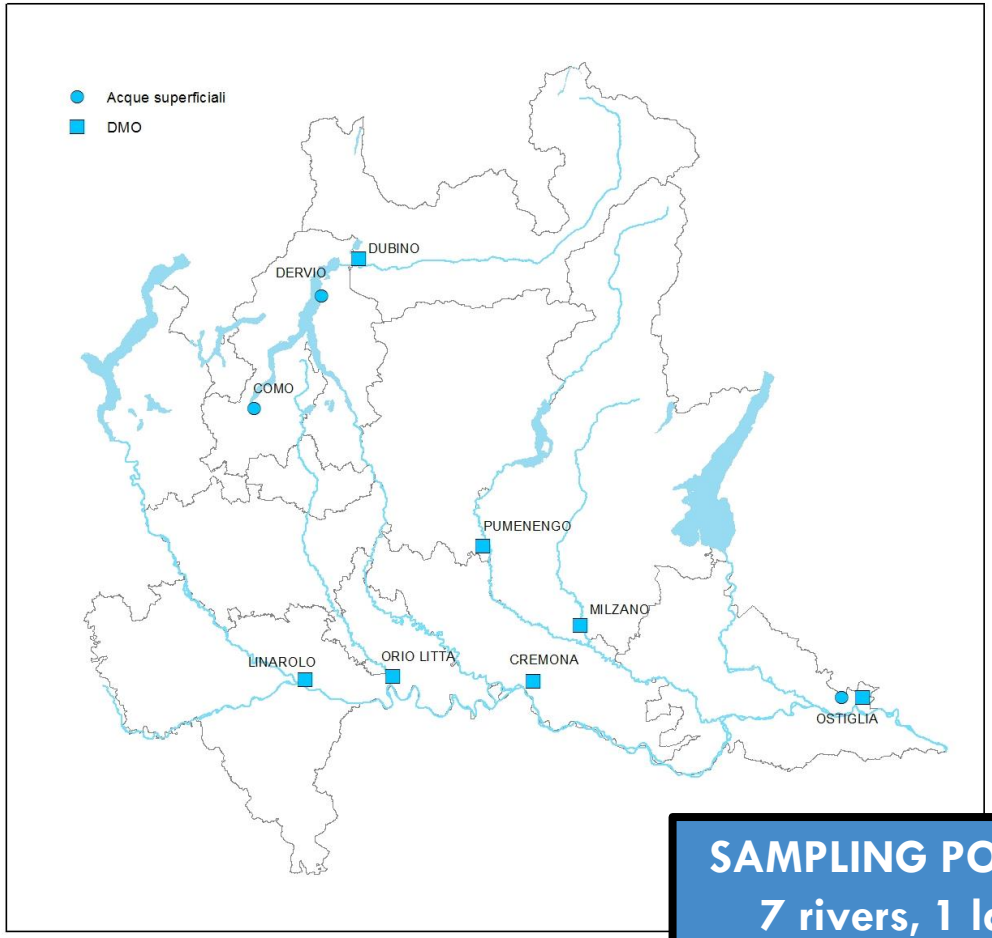
➡ Artificial nuclides (Gamma Spec.) < L.D. (0,0005 Bq/L for Cs-137)

Surface water

Surface water

- According to European Recommendation 2000/473:
  - monitoring of major inland waters for *Residual beta* and *Cs-137*

SAMPLING POINTS:
36 rivers, 17 lakes



SAMPLING POINTS:
7 rivers, 1 lake

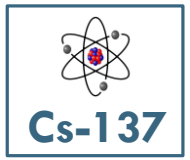
Surface water

- For surface water samples:

  Reporting Level as required by EU Commission (>= Detection limit):

  - Residual beta: 0,6 Bq/L
  - Cs-137: 1 Bq/L

  In few cases more parameters are required (Pu isotopes, Sr-90)

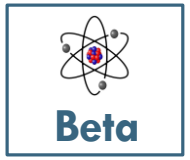


Direct sampling (1 liter) and measurement by Gamma Spec.:

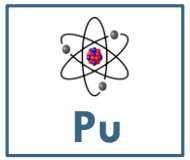
1 L, Marinelli Beaker, 1000 min counting time, HPGe 30%

L.D. = 0,1 Bq/L

Radiochemistry:



- ISO 11704 Gross beta (L.D. = 0,08 Bq/L)



- ISO 13167 Pu isotopes

- ISO 13160 Sr-90

Surface water: results at a glance

- Sampling point: Dervio (Como lake)
- Sampling depth: 5 mt
- 2 samples per year (spring + autumn)

	Gross alpha Bq/kg	Gross beta Bq/kg	Pu-239/40 Bq/kg	Pu-238 Bq/kg	Sr-90 Bq/kg	Cs-137 Bq/kg
Autumn	0,0212 ± *0,0087*	< 0,091	< 0,000047	< 0,000042	< 0,0057	< 0,10
Spring	0,0238 ± *0,0092*	< 0,085	< 0,00019	< 0,00016	< 0,0050	< 0,10
*L.D.**		*0,6 Bq/L*				*1 Bq/L*

** L.D.: Limit of Detection as required by EU Commission Recommendation 2000/473*

Surface water

- In few cases lower limits of detection (Gamma emitters, Cs-137) are required

Cs-137

Direct sampling of 5 liters followed by sample concentration:

- Absorption on ion exchange resins
- Sample evaporation with SiO2

Absorption on ion exchange resins

- Resin: Amberlite MB6113 (mixed bed) with saturation indicator
- Resin capacity: ~ 35 ml resin / g dry residue (depending on dissolved salts)
- Resin amount: ~ 0,1 L
- Sample amount: ~ 5 L
- Elution rate: ~ 40 mL/min
- Contact time: ~ 2,5 min
- Resin uptake: tested by atomic adsorption analysis on eluate (stable Ca) – 100%

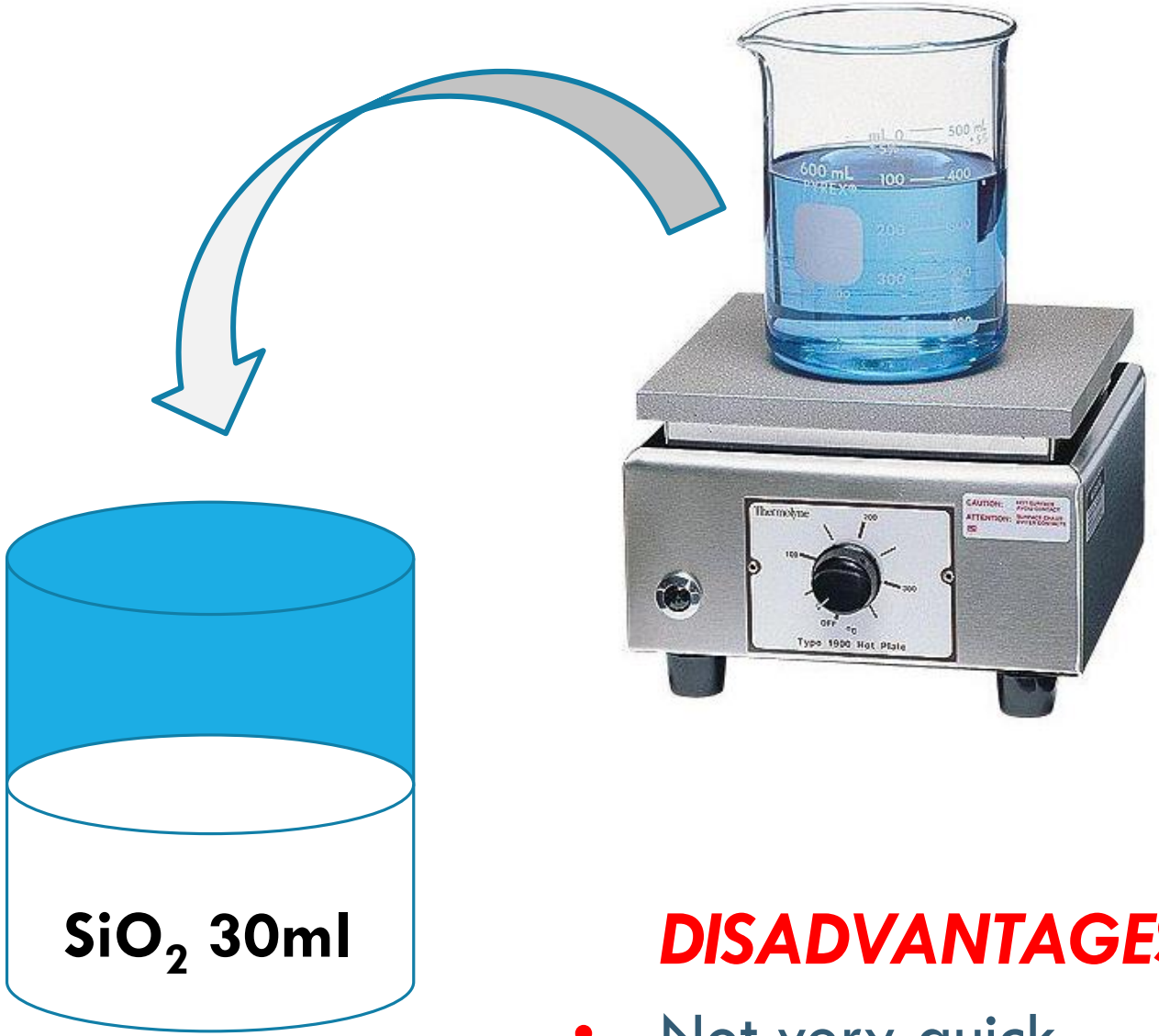
Sample evaporation with SiO_2

- Sample evaporated on a hot plate
- Water samples is acidified (nitric acid, pH 2 c.a.) to avoid salts precipitations and adhesion on beaker walls
- Inert material (silica-gel – SiO_2) is added (~ 25 g)
- Sample is evaporated to dryness, silica gel is transferred in a beaker and measured
- No filtration required
- Up to 10 liters can be easily treated (3-7 days)

METHOD TESTED BY SPIKED SAMPLES, YIELD = 100%

ADVANTAGES

- Works well independent on the amount of dissolved salts
- Once dried is still dusty (no crusty scales, no residues left on beaker)
- The residue recovery (powder) is easy and complete
- Very easy to attain correct geometry and density
- Silica gel is easily available and in high purity
- Relatively cheap: ~ 0,1 €/g of SiO_2



DISADVANTAGES

- Not very quick

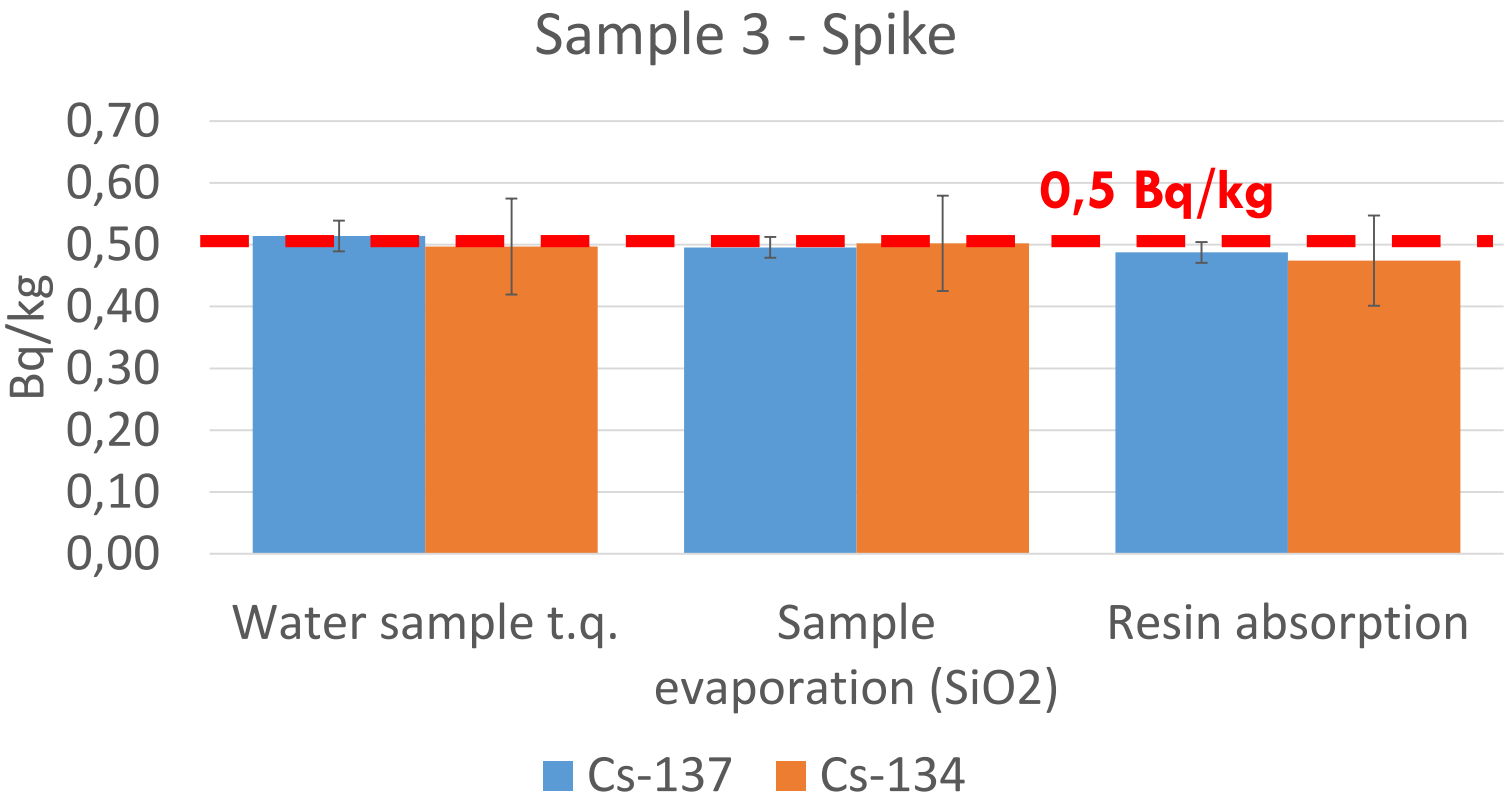
Limit of Detection of different methods for Cs-137

HPGe detector, 30% relative efficiency

	Water as is	Sample evaporation (SiO_2) Resin absorption	Resin absorption
Amount of sample	1 L	5 L	200 L
Geometry	Marinelli 1 L	Beaker 30 cc	Marinelli 1 L
Counting time	1000 min	1000 min	4000 min
MDA Cs-137	0,1 Bq/L	0,01Bq/L	0,0005 Bq/L

Methods comparison – IAEA PT 2016

1. Water analysis (as is)
2. Sample evaporation (SiO_2)
3. Absorption on ion exchange resins – low volume



QC SAMPLE

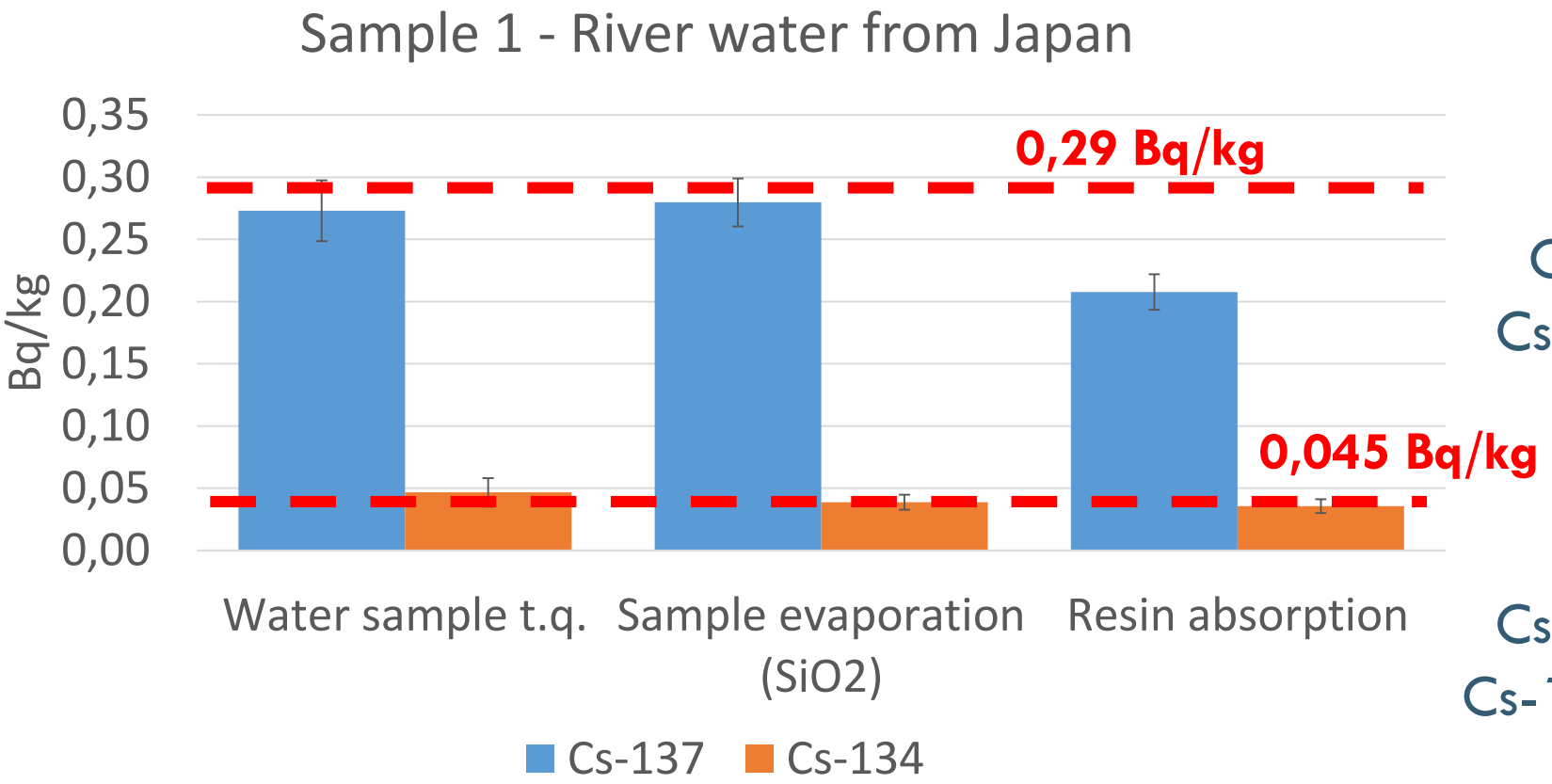
Expected value:
0,5 Bq/kg

Measured value:
Cs-137: 0,495 ± 0,017 Bq/kg
Cs-134: 0,502 ± 0,078 Bq/kg

Methods comparison – IAEA PT 2016

1. Water analysis (as is)
2. Sample evaporation (SiO_2)
3. Absorption on ion exchange resins – low volume

JAPAN RIVER



Expected value:

Cs-137: 0,29 ± 0,02 Bq/kg

Cs-134: 0,045 ± 0,005 Bq/kg

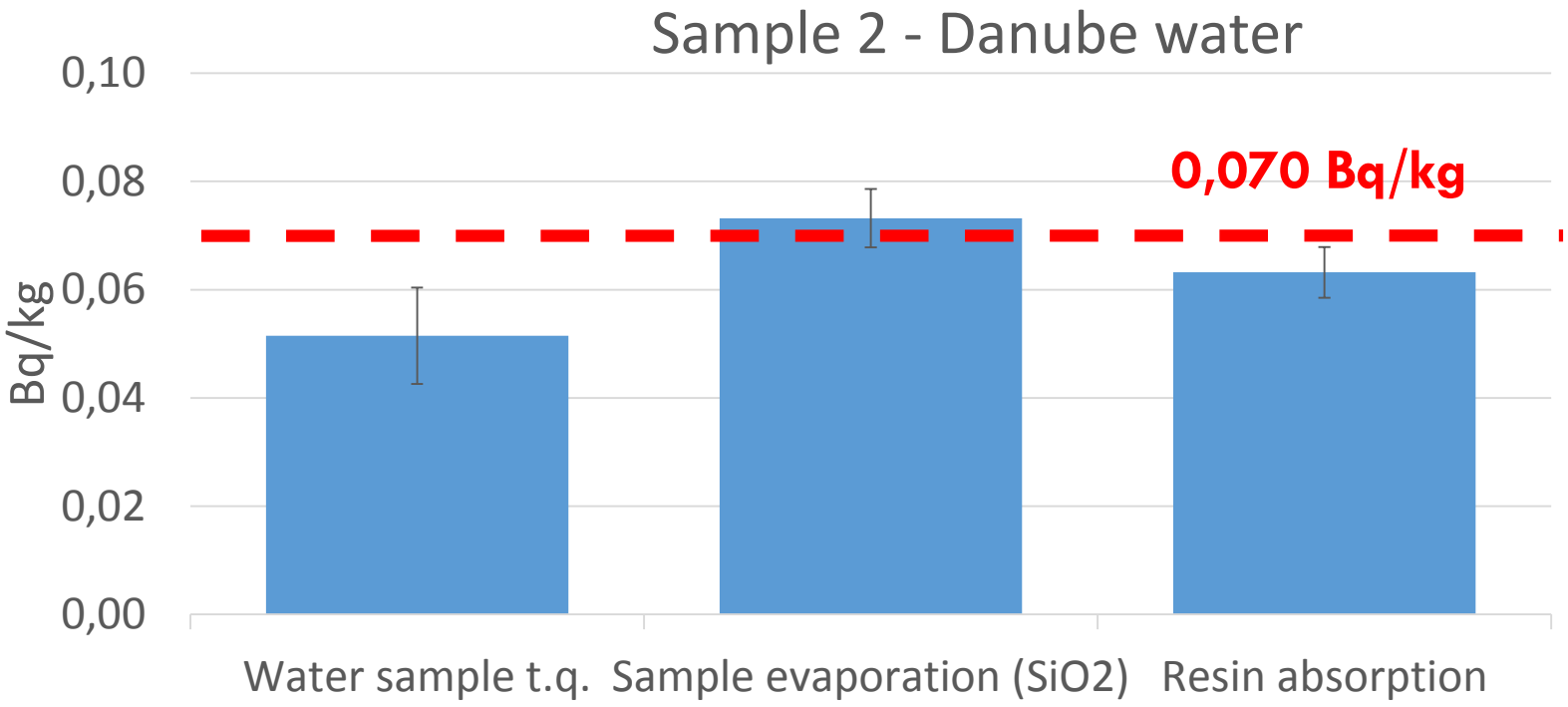
Measured value:

Cs-137: 0,279 ± 0,019 Bq/kg

Cs-134: 0,0387 ± 0,0062 Bq/kg

Methods comparison – IAEA PT 2016

1. Water analysis (as is)
2. Sample evaporation (SiO_2)
3. Absorption on ion exchange resins – low volume



DANUBE WATER

Expected value:
Cs-137: 0,070 ± 0,005 Bq/kg

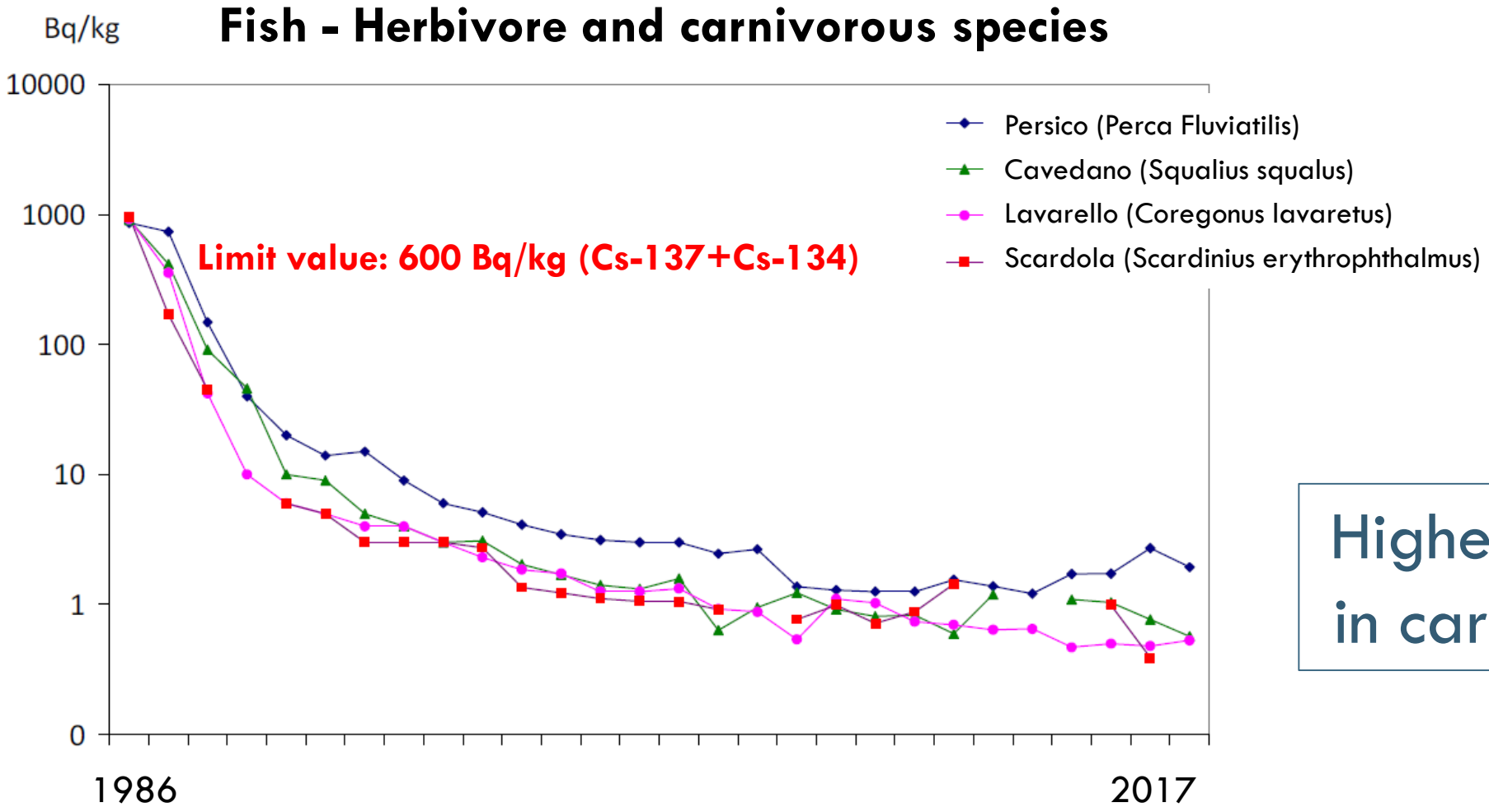
Measured value:
Cs-137: 0,0732 ± 0,0054 Bq/kg

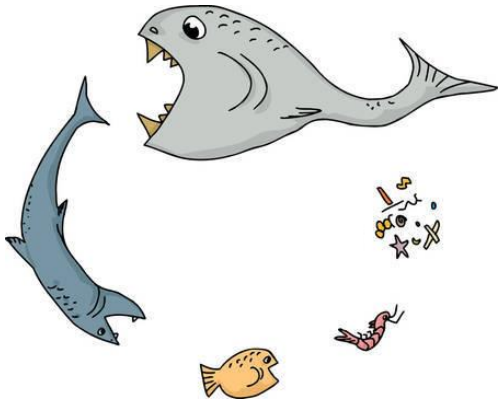
Surface water – Environmental markers

Fish and Suspended Particles

Surface water - Fish

- Fish monitoring provides direct data of food contamination

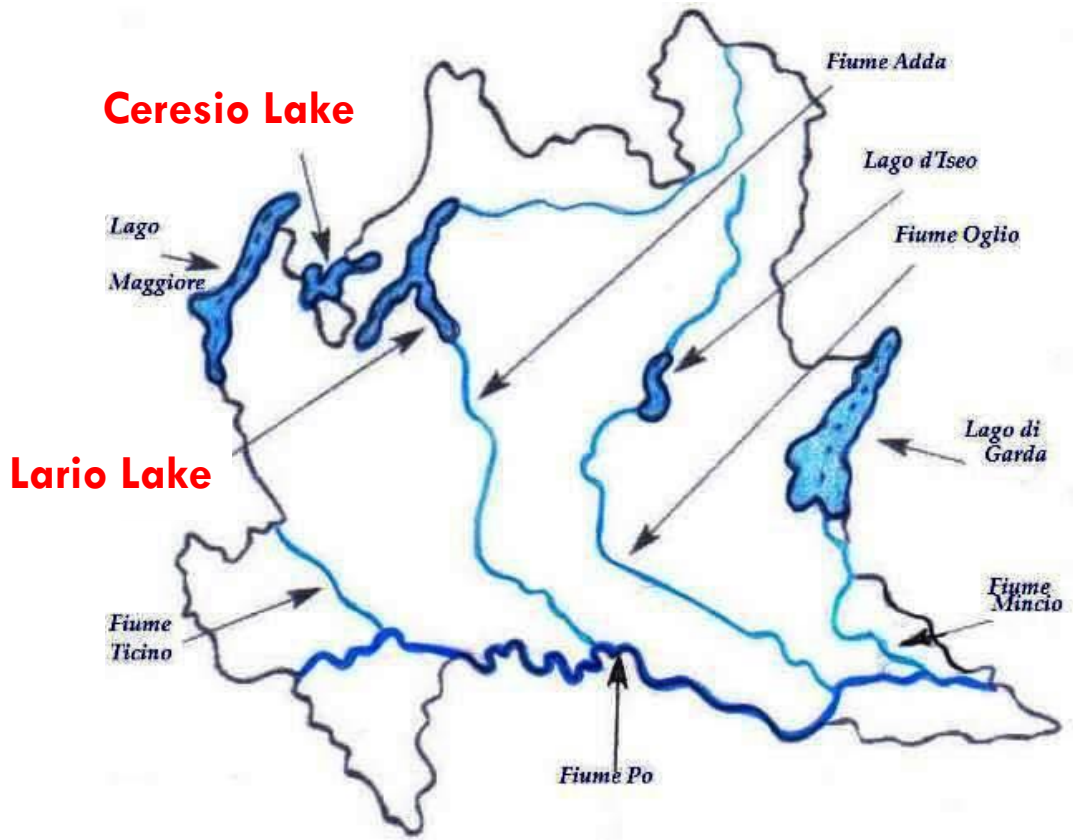


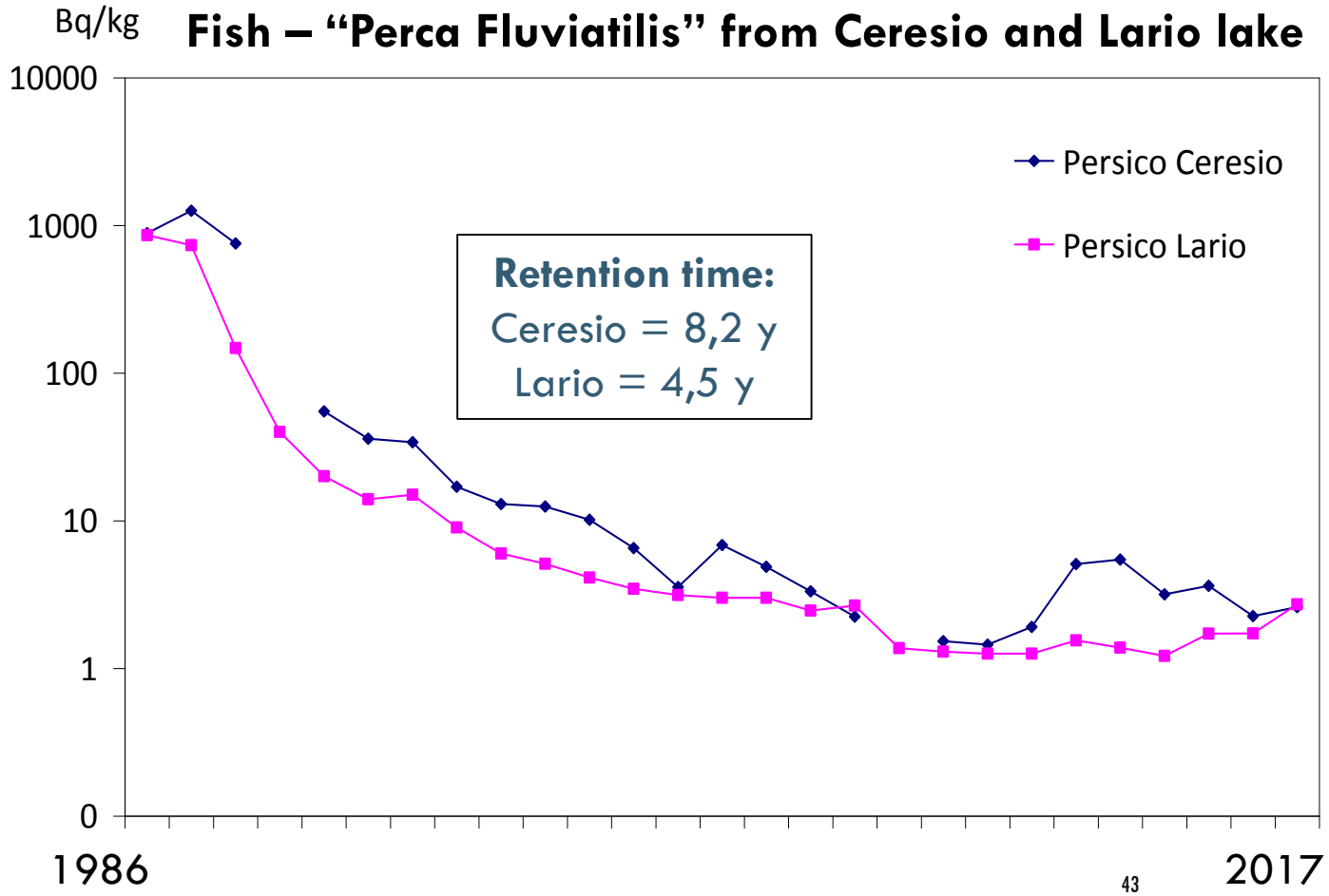


Higher Cs-137 values in carnivorous species

Surface water - Fish

- Source of information about environmental dynamics of different water basins





Surface water – Suspended particles

"Cartene shells" time-integrating method:

- Point and time integrating system
- Sampling period: from 5 to 7 days

ADVANTAGES: easy and cheap

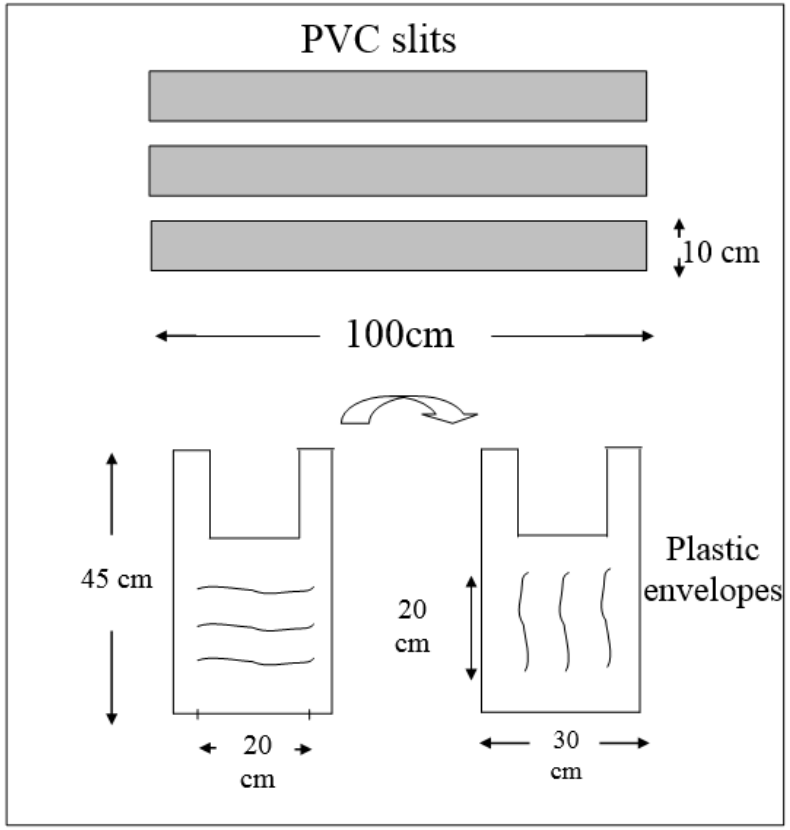
DISADVANTAGES: can't be referred to a specific volume of water, just a relative marker

Successfully tested during the "Intercomparison of freshwater and suspended particles sampling" held in 1999

Surface water – Suspended particles

"Cartene shells" time-integrating method:

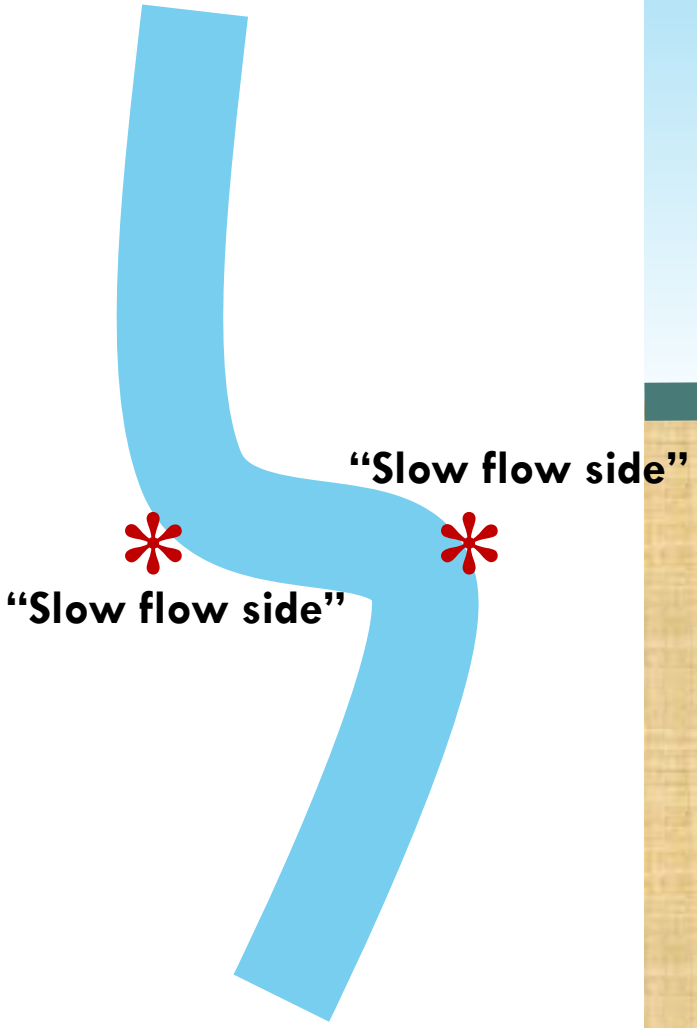
- Consist of a cartene envelope inserted in a second one. A grid is made on these plastic bags to trap the particulate matter in suspension. Inside these 2 envelopes at least 3 PVC strips are inserted, after being balled up to effectively collect the suspended particles.



- In these 2 envelopes, secured by tying together the handles, are inserted some stones as ballast

“Cartene shells”

Possible sampling points



7 days sampling

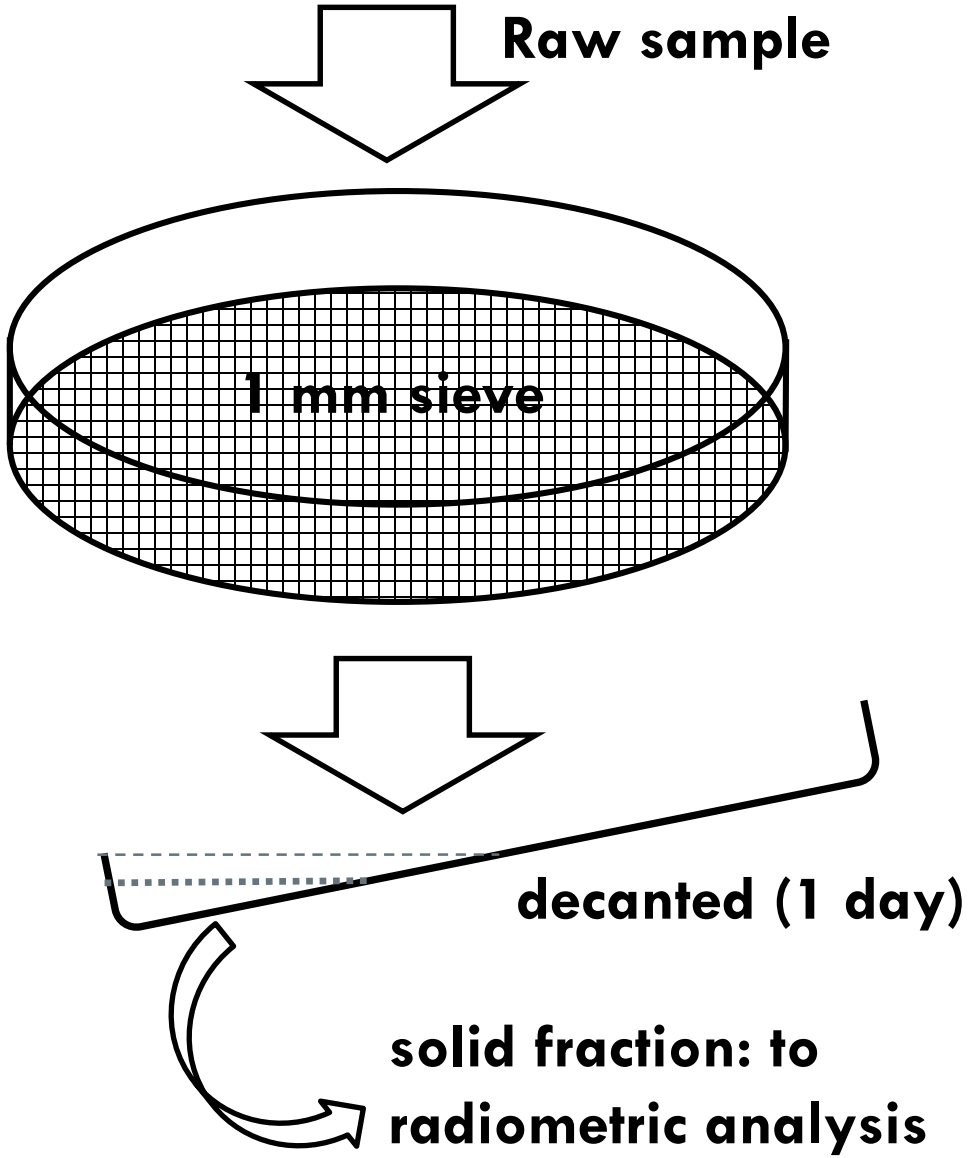
Cartene sampler

≈ 3 - 4 m

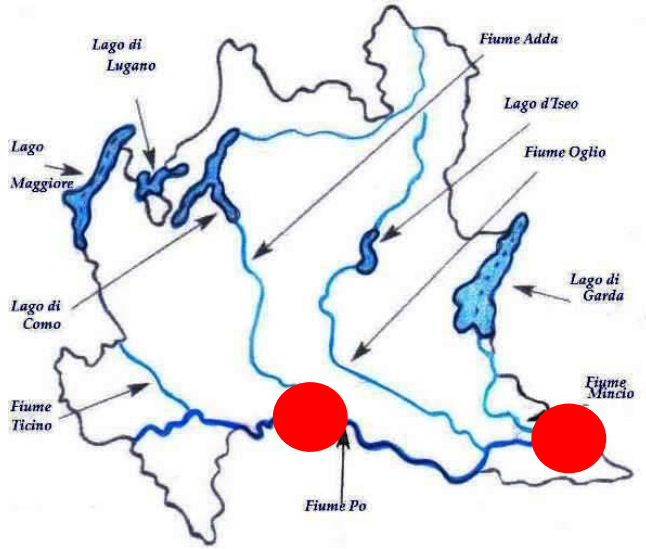
≈ 0,5 - 1 m

“Cartene shells”

- At the end of the sampling time the systems are pulled out and brought to the laboratory
- The particles collected are sieved at 1 mm and left to settle during one night
- The supernatant water is removed and the sample homogenized
- The solid fraction is analysed by gamma spectrometry
- The activity concentration is referred to the dry weight, determined on 40 g aliquot, 1 night at 105° C

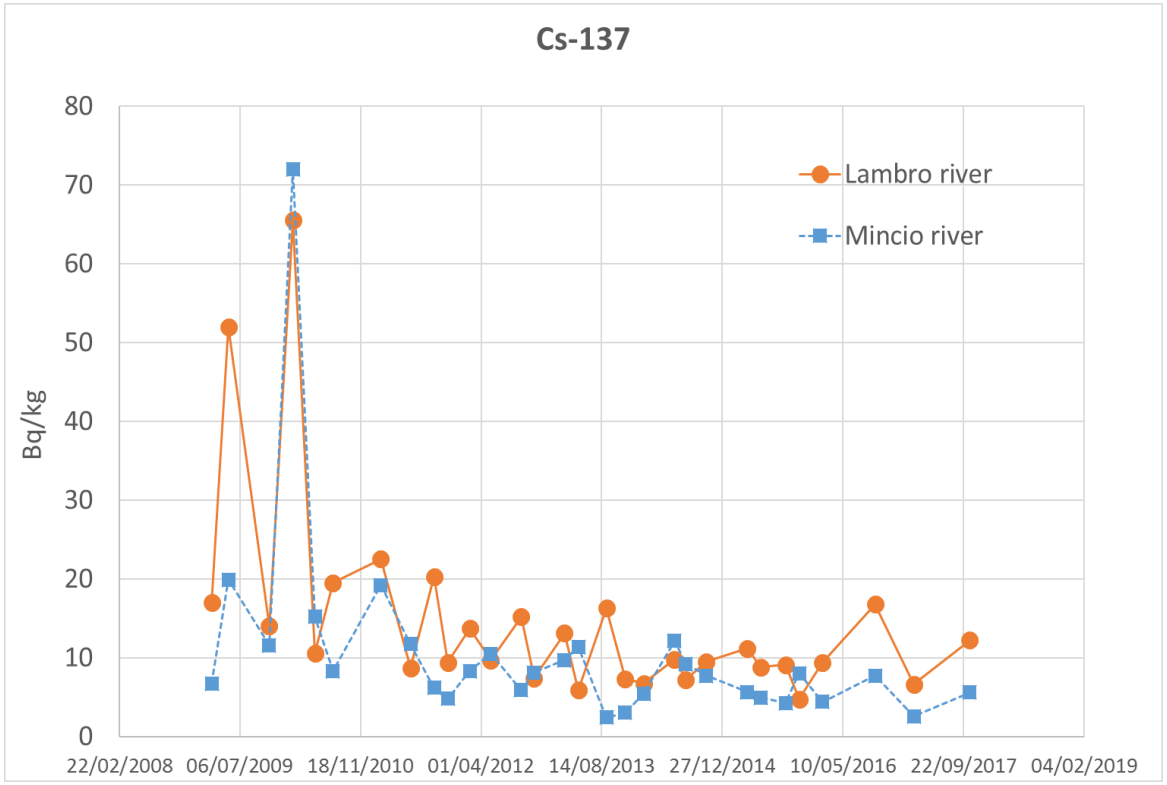


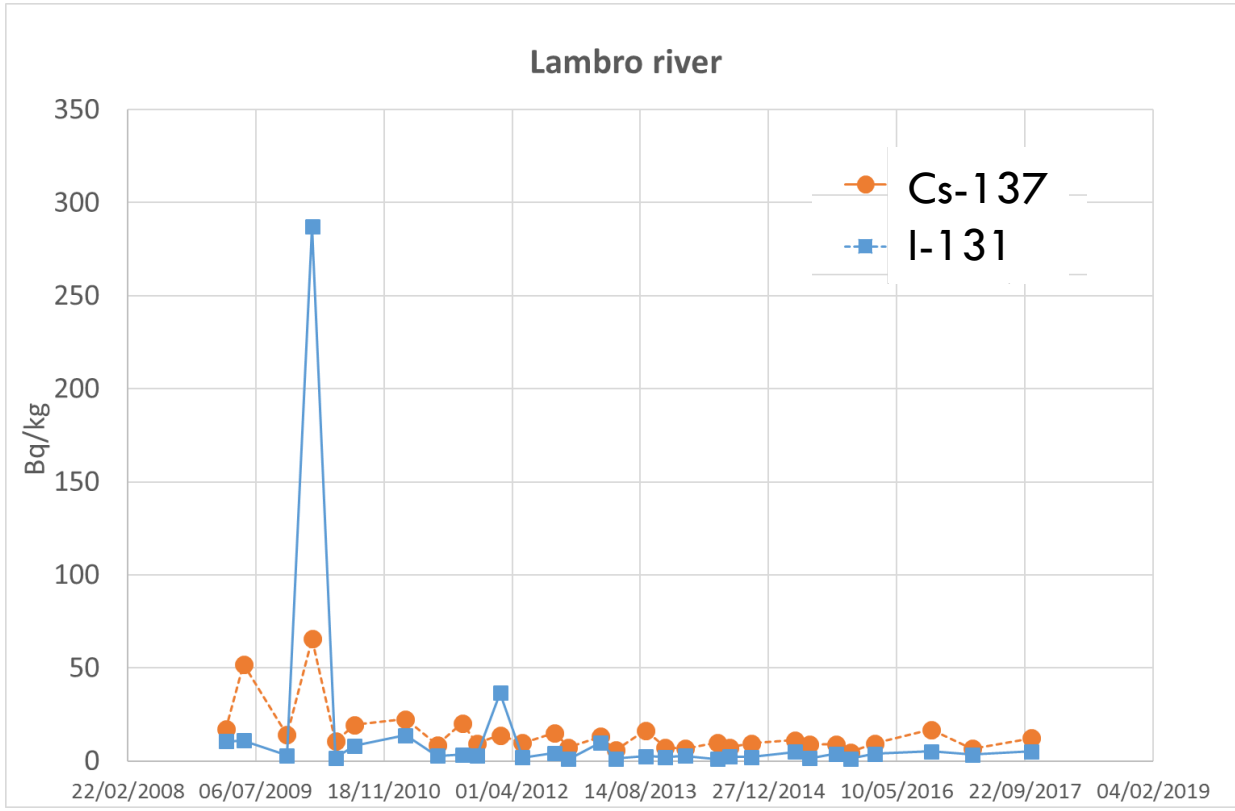
Suspended particles: results at a glance



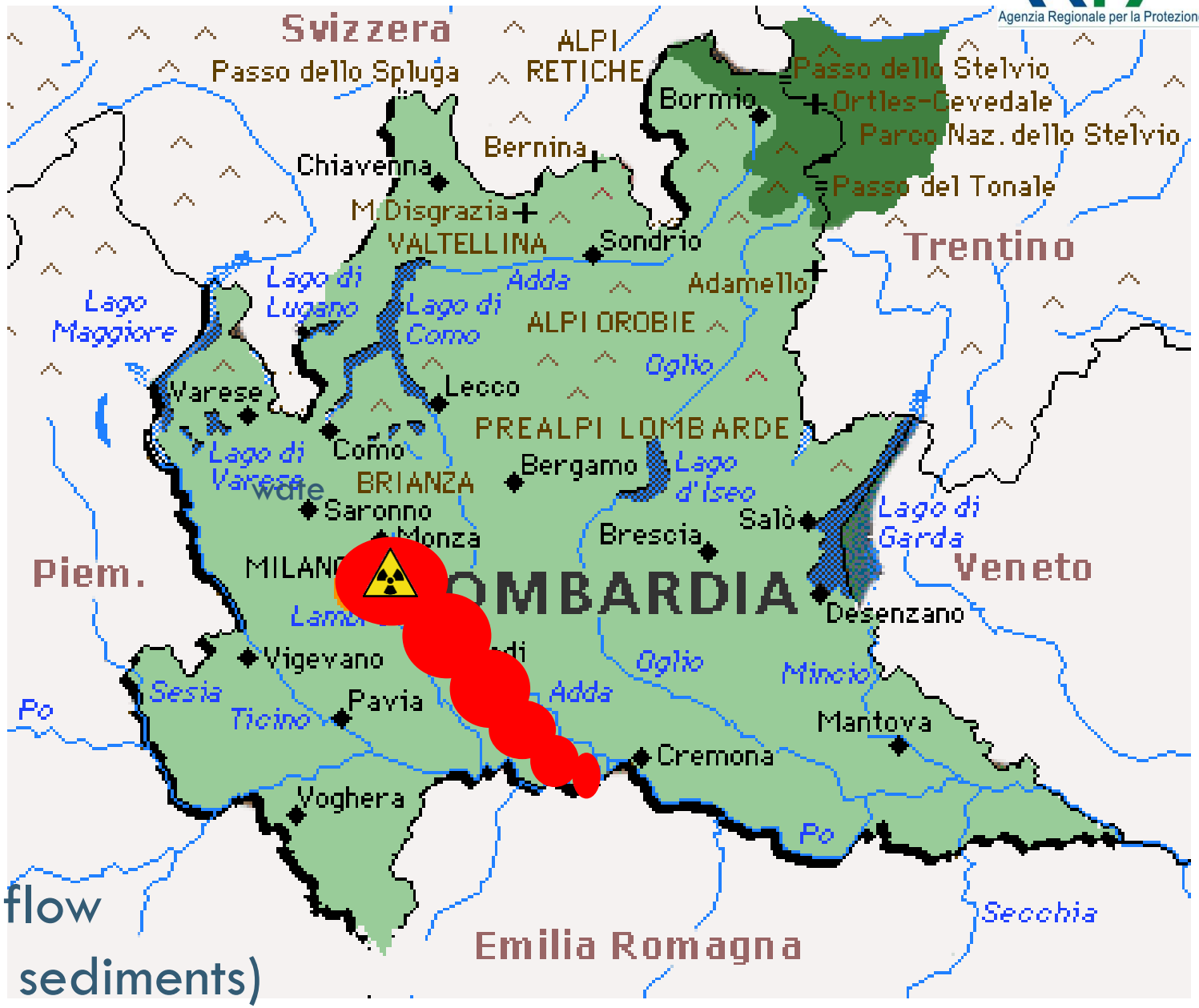
Sampling points:

- Lambro river, south of Milano
- Mincio river, south of Cremona





Suspended particles «allowed» to detect a serious accident in an aluminum foundry that melted contaminated scraps and discharged into a river contaminated waste waters



«Excess» Cs-137 in river flow (suspended particles and sediments)

ARPA LOMBARDIA
Agenzia Regionale per la Protezione dell'Ambiente

STEP BY STEP

Activity

Dose

Limit of detection

Which method? Which Detection Limit?

STEPS:

- Define the exposure scenario
- Define the “Target Dose” (T.D.)
- Define the relationship between dose and Cs-137 concentration (C)
- Calculate the Cs-137 concentration ($C_{T.D.}$) corresponding to the target dose
- Assume as Detection Limit a fraction (e.g. 1/10) of $C_{T.D.}$
- Select the measurement method

1. Exposure scenario: Drinking water

- Target Dose: 0,1 mSv/y according to EU Directive 51/2013

- Relationship between dose (D) and Cs-137 concentration (C):

$$\mathbf{D}\ (Sv/a) = \mathbf{C}\ (Bq/kg)\ \times\ \mathbf{I}\ (kg/y)\ \times\ \mathbf{h(g)}\ (Sv/Bq)$$

$$\mathbf{C}\ (Bq/kg) = \mathbf{D}\ (Sv/a)\ /\left[\mathbf{I}\ (kg/y)\ \times\ \mathbf{h(g)}\ (Sv/Bq)\right]$$

Where:

I (kg/y) = Water consumption rate – Adults: **730 kg/y**

h(g) = Dose coefficient for ingestion – **Cs-137**, adults: 1,3E-08 Sv/Bq

1. Exposure scenario: Drinking water

- Cs-137 concentration ($C_{T.D.}$) corresponding to the target dose of 0,1 mSv/y:

$$\mathbf{C_{T.D.}}\ (Bq/kg) = \mathbf{D}\ (Sv/a)\ /\ \left[\mathbf{I}\ (kg/y)\ \times\ \mathbf{h(g)}\ (Sv/Bq)\right] =$$

$$= 1E\text{-}04\ (Sv/a)\ /\ \left[730\ (kg/y)\ \times\ 1{,}3E\text{-}08\ (Sv/Bq)\right] = 10{,}5\ Bq/kg$$

- Desired Detection Limit: 1/10 of $C_{T.D.}$ = 10,5 / 10 = 1 Bq/kg

- Measurement method: direct Gamma Spec. on 1 L (typical L.D. = 0,1 Bq/L)

2. Exposure scenario: Fishing

- Target Dose: 1 mSv/y

- Relationship between dose (D) and Cs-137 concentration (C):

$$\mathbf{D}\ (Sv/a) = \mathbf{C}\ (Bq/kg)\ \times\ \mathbf{I}\ (kg/y)\ \times\ \mathbf{h(g)}\ (Sv/Bq)$$

$$\mathbf{C}\ (Bq/kg) = \mathbf{D}\ (Sv/a)\ /\left[\mathbf{I}\ (kg/y)\ \times\ \mathbf{h(g)}\ (Sv/Bq)\right]$$

Where:

I (kg/y) = Fish consumption rate – Adults: **16 kg/y** (Italian Diet)

h(g) = Dose coefficient for ingestion – **Cs-137**, adults: 1,3E-08 Sv/Bq

2. Exposure scenario: Fishing

- Cs-137 concentration in Fish (C_F) corresponding to the target dose of 1 mSv/y:

$$C_F\ (Bq/kg) = D\ (Sv/a) \,/\, \left[I\ (kg/y) \ \text{x}\ h(g)\ (Sv/Bq) \right] =$$

$$= 1E\text{-}03\ (Sv/a) \,/\, \left[16\ (kg/y) \ \text{x}\ 1{,}3E\text{-}08\ (Sv/Bq) \right] = 4800\ Bq/kg$$

Relationship between Dose and Fish contamination

2. Exposure scenario: Fishing

Relationship between Fish and Water contamination?

- Cs-137 concentration in water (C_W) corresponding to C_F (4800 Bq/kg):

Hypothetical* relationship between Cs-137 in surface water (C_W) and in fish (C_F):

C_F (Bq/kg) = C_W (Bq/m^3)* B_p (Bq/kg per Bq/L) / 1000

where B_p = **Bioaccumulation factor** = 30 ÷ 10000 Bq/kg per Bq/L

C_W (Bq/m^3) = C_F (Bq/kg) *1000 / B_p (Bq/kg per Bq/L) =

= *4800* (Bq/kg) *1000 / 10000 (Bq/kg per Bq/L) = 480 Bq/m^3 = 0,48 Bq/L

* IAEA Safety Reports Series No.19 - Generic Models for Use in Assessing the Impact of Discharges of Radioactive Substances to the Environment.
* IAEA Technical Reports SeriEs No. **472 -** Handbook of Parameter. Values for the Prediction of Radionuclide Transfer in Terrestrial and Freshwater Environments.

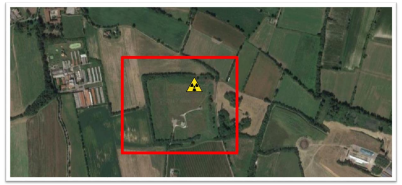
2. Exposure scenario: Fishing

Desired Detection Limit: 1/10 of C_W = 0,48 / 10 = 0,05 Bq/kg

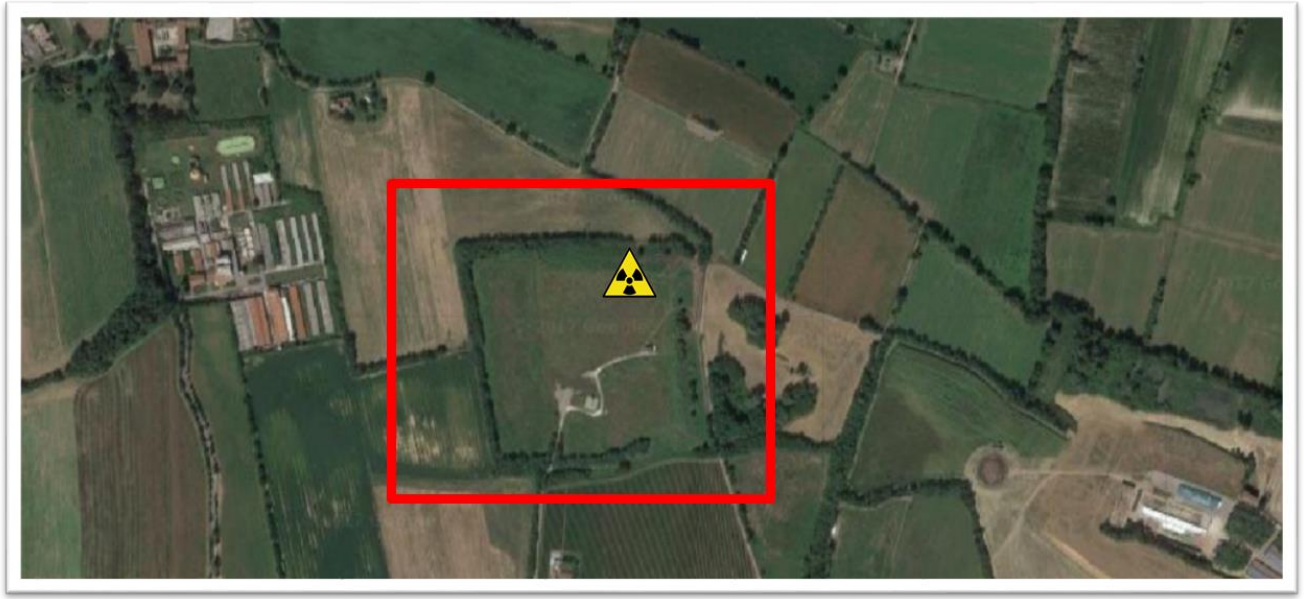
HPGe detector, 30% relative efficiency

	Water as is	Sample evaporation (SiO_2) Resin absorption	Resin absorption
Amount of sample	1 L	5 L	200 L
Geometry	Marinelli 1 L	Beaker 30 cc	Marinelli 1 L
Counting time	1000 min	1000 min	4000 min
MDA Cs-137	0,1 Bq/L	0,01Bq/L	0,0005 Bq/L
	NO		

3. Exposure scenario: Waste waters from waste repository

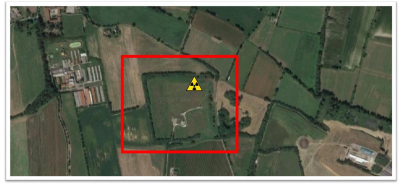


- Surveillance around contaminated sites
  - Phosphogypsum repositories: gross activity, Uranium, Radium, Po-210 and Pb-210
  - Foundry slag repositories contaminated by artificial nuclides: Cs-137, Am-241



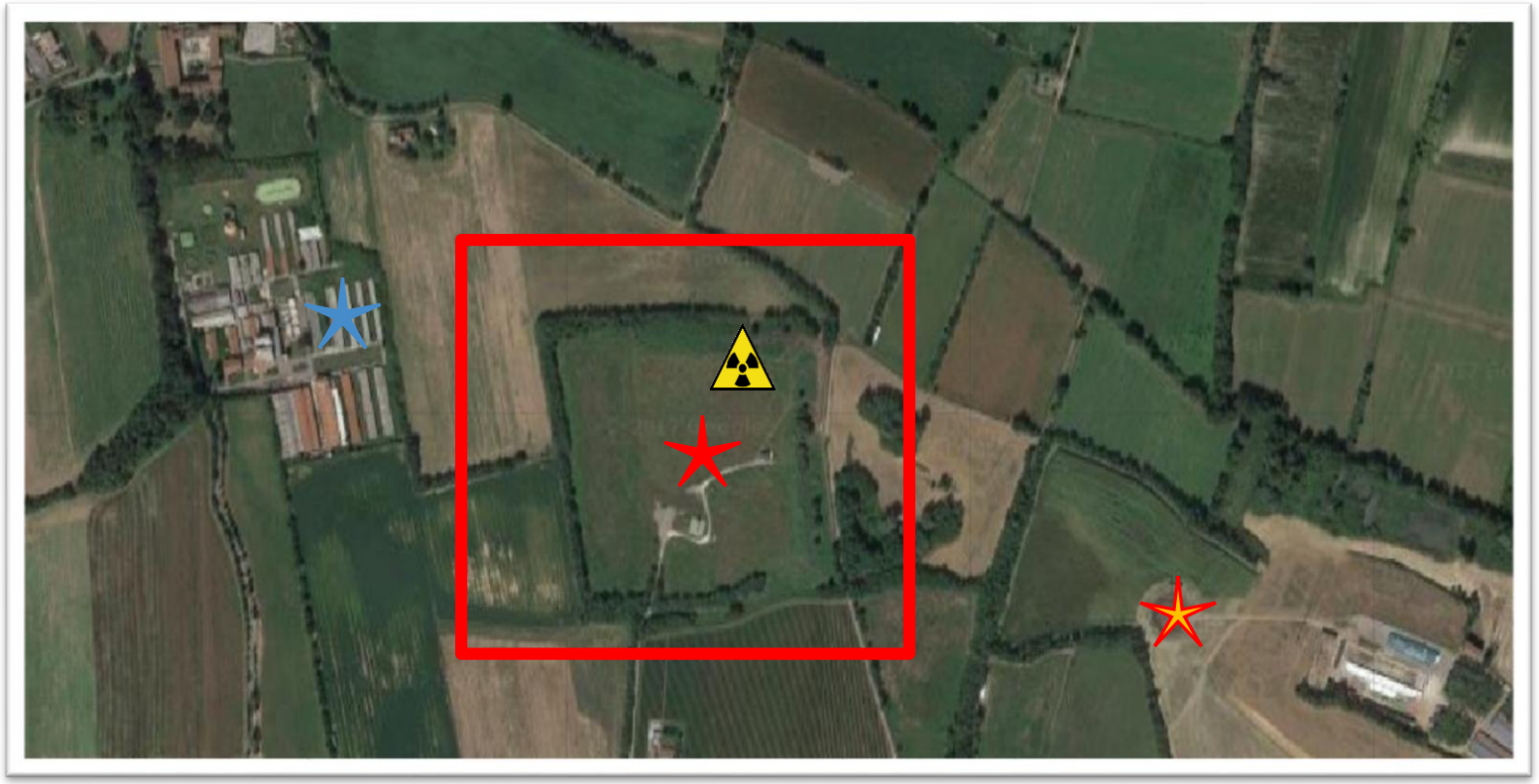
Foundry slag repository contaminated by Cs-137

3. Exposure scenario: Waste waters from waste repository



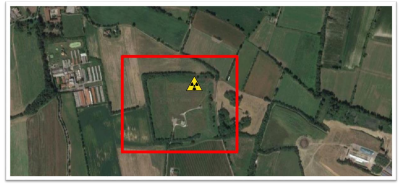
Which monitoring plan?

- Well providing drinking water to animals and human ★
- Groundwater below the repository ★
- Pond water outside the repository, potentially contaminated by groundwater ★



Sampling every 9 month

3. Exposure scenario: Waste waters from waste repository



Which Limit of Detection?

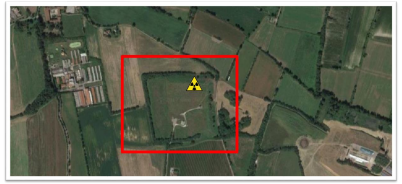
Well providing drinking water to animals and human

- Drinking water (EU Directive 51/2013): 0,1 mSv/y
- Corresponding derived concentration for Cs-137: 10,5 Bq/L
- Dose constraint put to 10 microSv/y (radiological non relevance)
- Corresponding derived concentration for Cs-137: 1,0 Bq/L

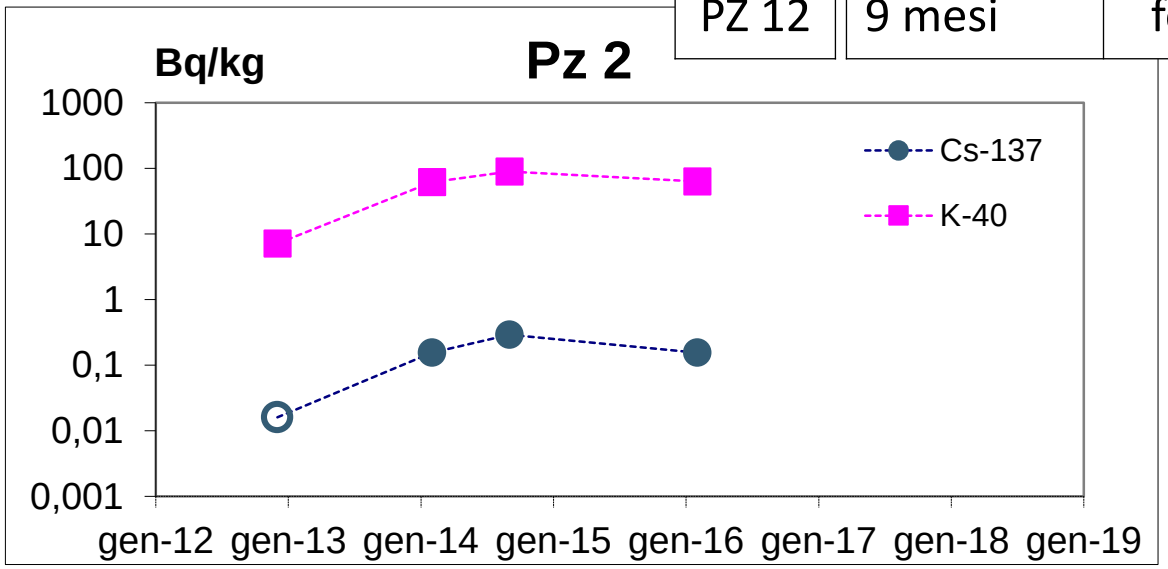
Required sensitivity:

- For radioprotection purposes: 0,1 Bq/L (1/10 of 1,0 Bq/L)
- To assure early detection of contamination release: 0,01 Bq/L

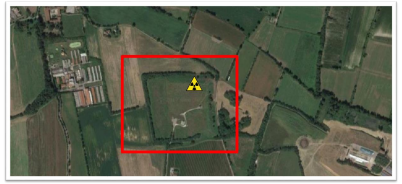
3. Exposure scenario: Waste waters from waste repository



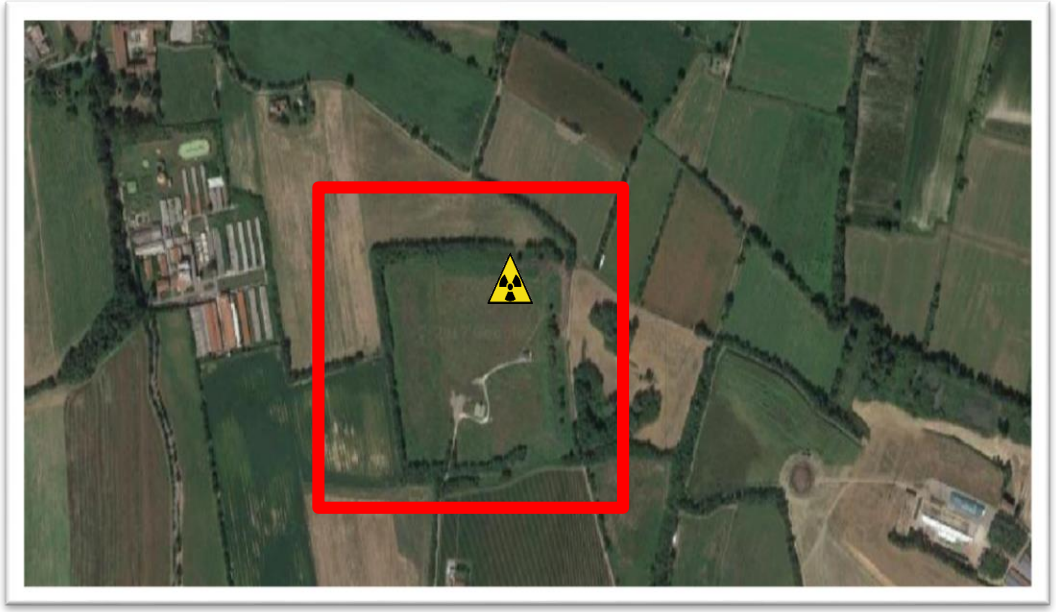
ID	Frequency	Last sampling	Next sampling	Amount	Treatment	MDA (Bq/kg)
PZ 1	9 mesi	feb-16	nov-16	6 L	5 liters silica gel	0,01
PZ 2	9 mesi	feb-16	nov-16	6 L	5 liters silica gel	0,01
PZ 4	9 mesi	feb-16	nov-16	6 L	5 liters silica gel	0,01
PZ 10	9 mesi	feb-16	nov-16	6 L	5 liters silica gel	0,01
PZ 11	9 mesi	feb-16	nov-16	6 L	5 liters silica gel	0,01
PZ 12	9 mesi	feb-16	nov-16	6 L	5 liters silica gel	0,01



3. Exposure scenario: Waste waters from waste repository



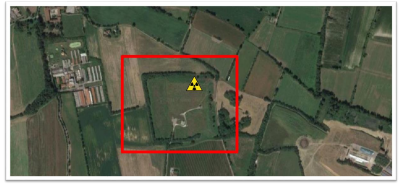
Further problem: production of big amounts of waste water contaminated by Cs-137



Definition of exposure scenario:

- waste collected by tanks
- sent for waste processing to an ordinary sewage
- sludge (which concentrate Cs) used in agriculture

3. Exposure scenario: Waste waters from waste repository



Cs-137: 100 Bq/kg

Contaminated waste water
1000 ton/year

10^2 Bq/kg * 10^6 kg/y
= 10^8 Bq/y

10^8 Bq/y

«Clean» Waste water

Sewage treatment plant

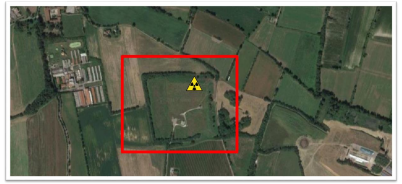
Clean water → River

Sludge → Agriculture

2000 ton/y

10^8 Bq/y / 2*10^6 kg/y
= 500 Bq/kg

3. Exposure scenario: Waste waters from waste repository



Sludge (500 Bq/kg Cs-137) in agriculture:

- Max amount per area: 0,75 kg/m^2 of agricultural land (National Regulation)
- Cs-137 (Bq/m^2) = 500 Bq/kg * 0,75 kg/m^2 = 375 Bq/m^2
- Sludge mixed with soil (10 cm depth -1500 kg/m^3) :

  375 Bq / (1m^2 * 0,1m * 1500kg/m^3) = 2,5 Bq/kg

10 cm of soil contaminated by Cs-137 – 2,5 Bq/kg

1 µSv/y, mainly due to external irradiation (97%)

RESRAD - Argonne National Laboratory - http://resrad.evs.anl.gov/

Exposure pathways: external irradiation, food ingestion, etc.

RESRAD ONSITE GRAPHICS

File Edit Options View

Plot Type
- Dose
- Concentration
- Dose/Source Ratio
- Soil Guidelines
- Risk

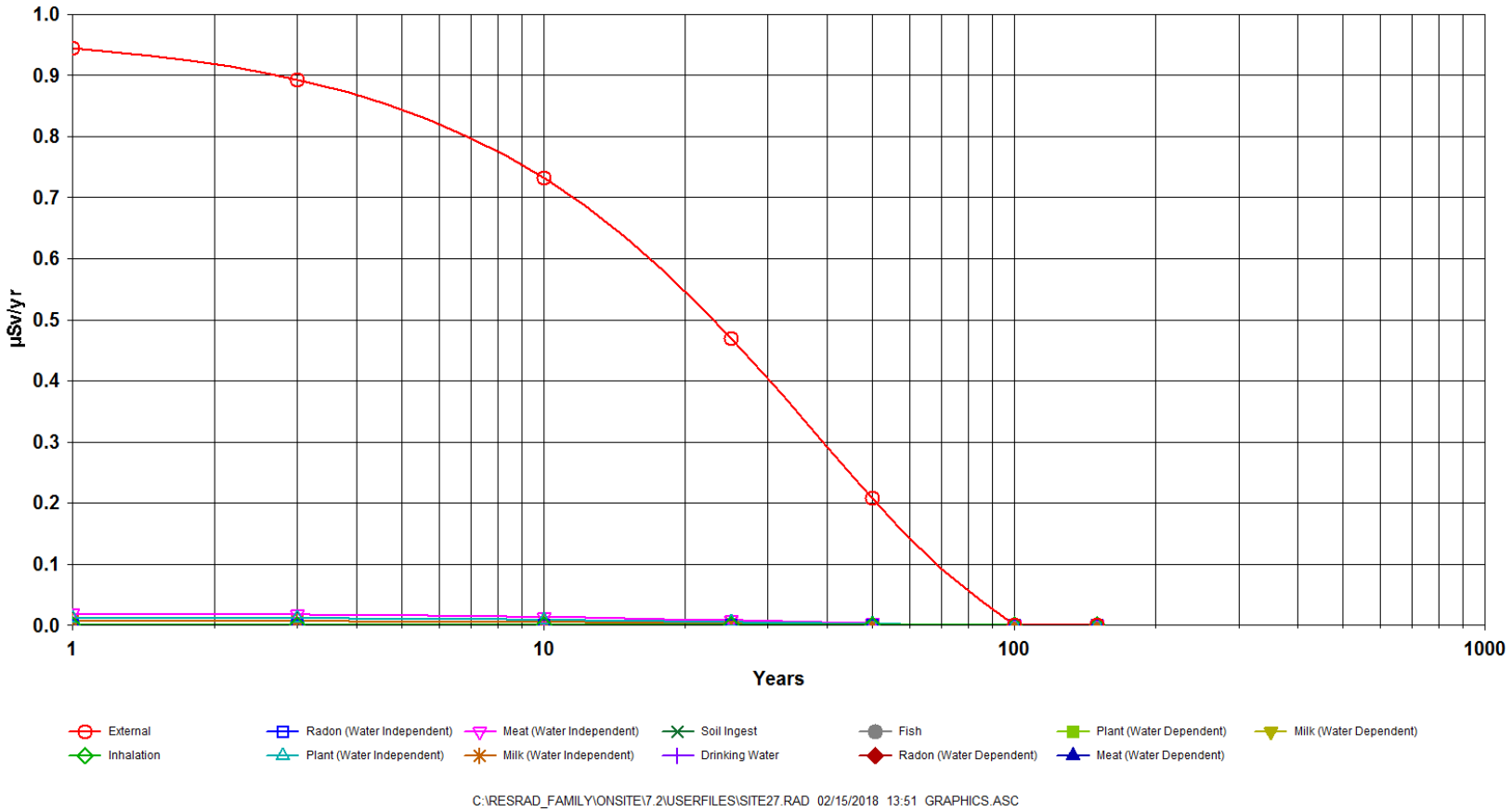
Radionuclide
- Summed
- Individual
- Individual and Progeny
- Individual and Threads

Cs-137

Pathways
- Summed
- Components
- Water Indep./Dependent
- Individual

External

DOSE: All Nuclides Summed, Component Pathways



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RESRAD - Argonne National Laboratory - http://resrad.evs.anl.gov/

3. Exposure scenario: Waste waters from waste repository

To resume:

Exposure scenario: use in agriculture of slags contaminated by water contaminated by Cs-137

Waste water: 100 Bq/kg of Cs-137 ⇔ 1 µSv/y to the most exposed group

"Specific clearance level" for waste water corresponding to 10 µSv/y:

1000 Bq/kg of Cs-137

Required sensitivity: 1/10 of 1000 Bq/kg = 100 Bq/kg

Conclusions

Conclusions

- The choice of the method to be used for the measurement of Cs-137 in water depends on the desired Limit of Detection
- The Limit of Detection can be fixed by law (especially for drinking water)
- In most cases, the Limit of Detection must be evaluated taking into account the specific exposure scenario and dose limit

Limit of Detection	Drinking water	Surface water	Waste water
EU Legislation	0,1 - 0,5 Bq/L	1 Bq/L	--
Specific exposure scenarios	1 Bq/L	0,05 Bq/L	100 Bq/L

- In surface water monitoring the use of “contamination markers” provides reliable and useful data