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From monitoring data to radiation dose assessment for the population

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Outline

- Dose to the average member of the public nationwide
- Dose to the most exposed person near uranium mine sites
- Dose to the most exposed person by the Tejo estuary (radionuclides from nuclear medicine; radionuclides from a nuclear vessel)
- Dose to the representative person by the Lisboa municipal solid waste incinerator
- Exposures to radon

1. Assessment of the Effective Dose to the average member of the public nationwide

Environmental radioactivity monitoring

In previous MENVIPRO project meetings were introduced:

- *The design of environmental monitoring programs*
- *Environmental sampling and radioactivity analysis (methods and instruments)*
- *Data collection*

Types of radiological monitoring programs

- Baseline or pre-operational monitoring
- Operational monitoring
- Compliance monitoring (source control)
- Nation-wide routine monitoring*

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- *Recommended by the IAEA*
- *Mandatory for European Union member states*

Calculation of Effective Dose to the average member of the public nationwide

Makes use of data on environmental radioactivity and radiation from the national monitoring program, such as

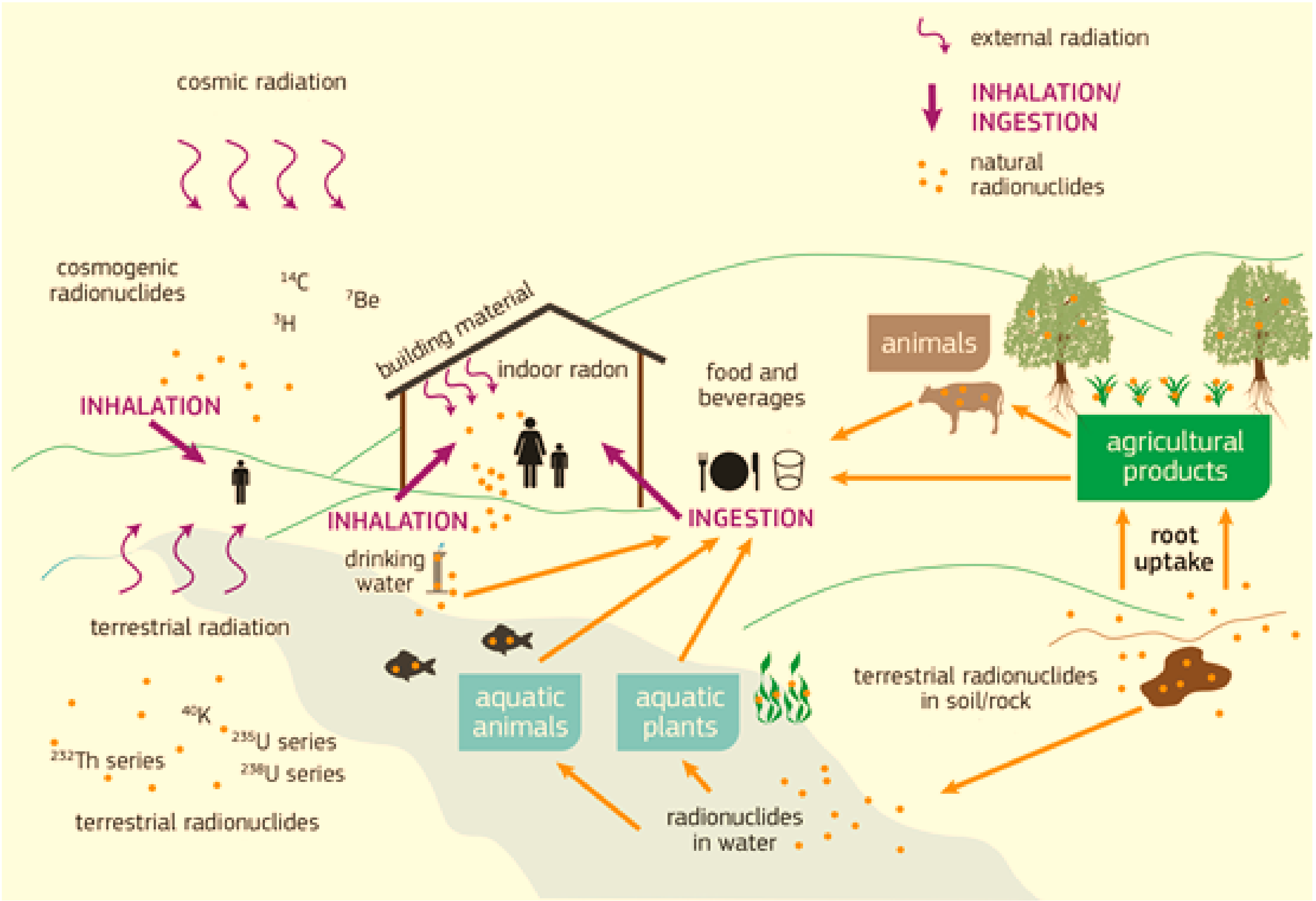
- ambient radiation dose (external radiation; TLDs)
- activity concentration of radionuclides in drinking water and food (ingestion)
- activity concentration of radionuclides in aerosols (inhalation)
- radon indoors and outdoors (inhalation)

Calculation of Effective Dose to the average member of the public nationwide

Takes into account:

- The national average diet (Food balance sheet)
- Water consumption
- Other beverages and special food items (if needed)
- External radiation exposure (varies with regions)

Radionuclide sources and pathways



We need to adapt this to local conditions

Calculation of Effective Dose to the member of the public nationwide

Takes in consideration:

- -natural radiation background (natural radionuclides)
- -additional exposures (artificial radionuclides and, in some areas, enhanced concentrations of natural radionuclides)

Effective dose

- The external irradiation is measured directly as ambient radiation dose rate.
- The **total committed effective dose**, H, is computed as

H = Dinh (inhalation)+ Ding (ingestion) + Dext (external irradiation)

H can be reported in mSv/y.

Internal dose from ingested food

Is calculated as

$$D_{ing} = \Sigma\, A_R . DCF_{ingR} . Ing_r .$$

being

- D_{ing} the committed effective dose from radionuclides in the ingested food in one year and expressed in Sv/y,
- A_R the activity concentration of radionuclide R in the ingested food , in Bq/kg,
- $DCF_{inhR,}$ the activity-to-dose conversion factor through ingestion of radionuclide R, in Sv/Bq,
- $Ing_{r,}$ the food ingestion rate in kg/y

Internal dose from aerosol inhalation

Is calculated as

$$D_{inh} = \Sigma\, A_R . DCF_{inhR} . C_d . Inh_r .. T$$

Being

- D_{inh} the committed effective dose from radionuclides in the inhaled dust and expressed in Sv/y,
- A_R the activity concentration of radionuclide R in the inhaled dust, in Bq/kg,
- DCF_{inhR} The activity-to-dose conversion factor through inhalation of radionuclide R, in Sv/Bq,
- $C_{d,}$ the air dust concentration, in kg/m^3,
- $Inh_{r,}$ the breathing rate in m^3/h,
- T the exposure time in hours per year.

Calculation of Annual Effective Dose to the member of the public nationwide

- Usually, over the years radiation doses are mostly due to the natural radioactive background
- Are about 2.4 mSv/y, but vary between regions (geology and radon) and are higher in uranium mining areas
- Small contributions from artificial radionuclides present in the environment (<<10%)
- Larger contributions from artificial radionuclides following nuclear accidents.

Chernobyl nuclear accident (26 April 1986)

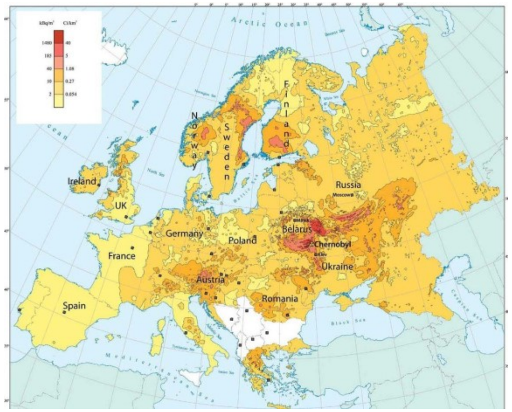
Calculation of Effective Dose to the member of the public nationwide

Routine EMP measurements in the country, and across Europe, allowed local and regional dose assessment.

Dose increased 1-3 mSv/y from fallout.

Advantages of a routine EMP:

- Rapid identification of radionuclides and specific transfer pathways:
  - imported carcasses with high 137Cs content , from East Europe
  - Migratory birds (dove and stournels) from Black Sea region
  - Dry fruits, seeds, and mushrooms from Midle East.
  - Powder milk from central Europe.
- Protection measures approved and implemented timely.



Fukushima nuclear accident (11 March 2011):

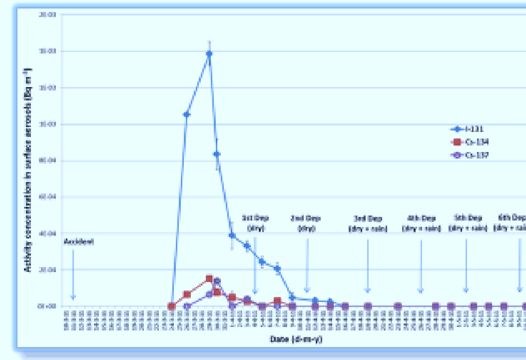
Calculation of Effective Dose to the average member of the public nationwide

Routine EMP provided timely measurements in the country, and across Europe, and allowed local and regional dose assessment.

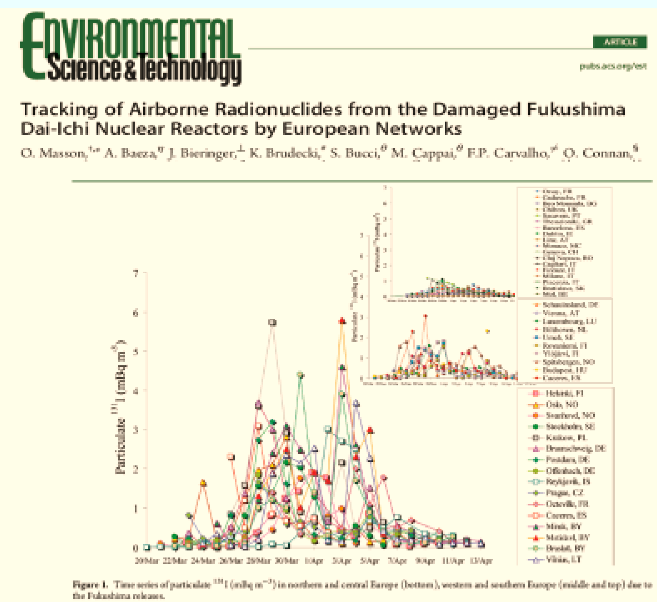
Advantages of EMP:

- A sound basis for decision on radiation protection measures
- Exposure to the public was estimated at 4% of the radiological impact from Chernobyl
- Practically no measures were needed. Approved to keep monitoring commodities imported from Japan.

Radionuclides measured at Lisbon



Radionuclides determined in air filters at Sacavém, Lisbon, following the Fukushima Daiichi nuclear accident. Arrows indicate the collection date of atmospheric deposition samples (Carvalho et al., J. Env. Radioactivity 2012)



Calculation of Effective Dose to the member of the public nationwide

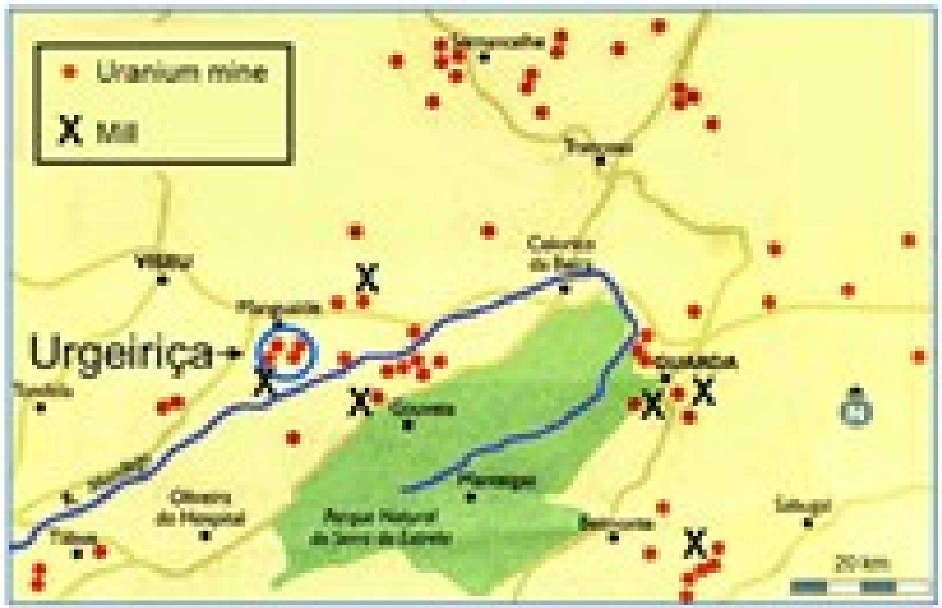
The lesson to learn is:

- Continued monitoring and dose assessment is needed because that are many radioactive sources (nuclear and non-nuclear) with regular discharges into the environment, and accidental releases may occur.
- This is needed to ensure radiation safety of the population.

2. Existing exposures: Dose assessment to the most exposed person from legacy uranium mine sites

Legacy of radium and uranium mining in Portugal

- **Mineralizations of Uranium in the centre-North of Portugal (region of Beiras)**
- **60 deposits exploited (open pits or underground) from 1908-2001**
- **1 Radium Salts Factory and 5 uranium mills**



“MinUrar” Project

- **Assessment of environmental contamination and effects on population health.**

  Requested by the Government following population concerns

Recommendations

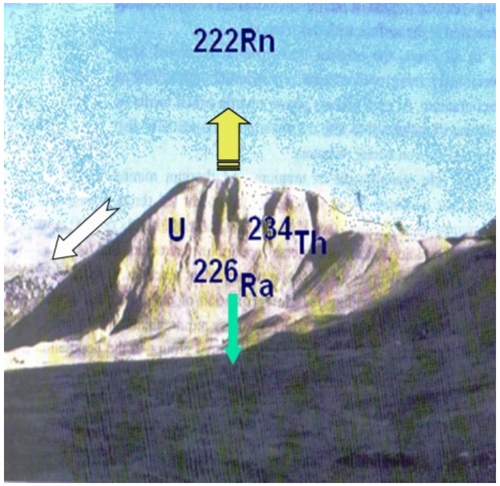
- To undertake environmental remedial action (site dependent)
- Environmental radiological surveillance of old uranium mining and milling sites

Ambient dose rate at several uranium legacy sites

Dose equivalent, mSv per year

	Counties	Dose
GE	**Canas Senhorim** county (outside mining area)	**2.4**
	Mill tailings Barragem Velha	**8.8**
	Sludge Barragem Nova	**3.2**
	Low grade ore Escomb Sta Barbara	**16.2**
	Low grade ore Descarga minério	**32.0**
	Shaft area Zona do Poço nº 5	**4.5**
GN 1	Old mine area Moreira de Rei	**2.2**
	Old mine area Rio de Mel	**2.3**
GN 2	Reference Sátão	**1.2**

Environmental remediation



- Approved by the Government
- Implemented by the mining company holding EDM- started in 2006

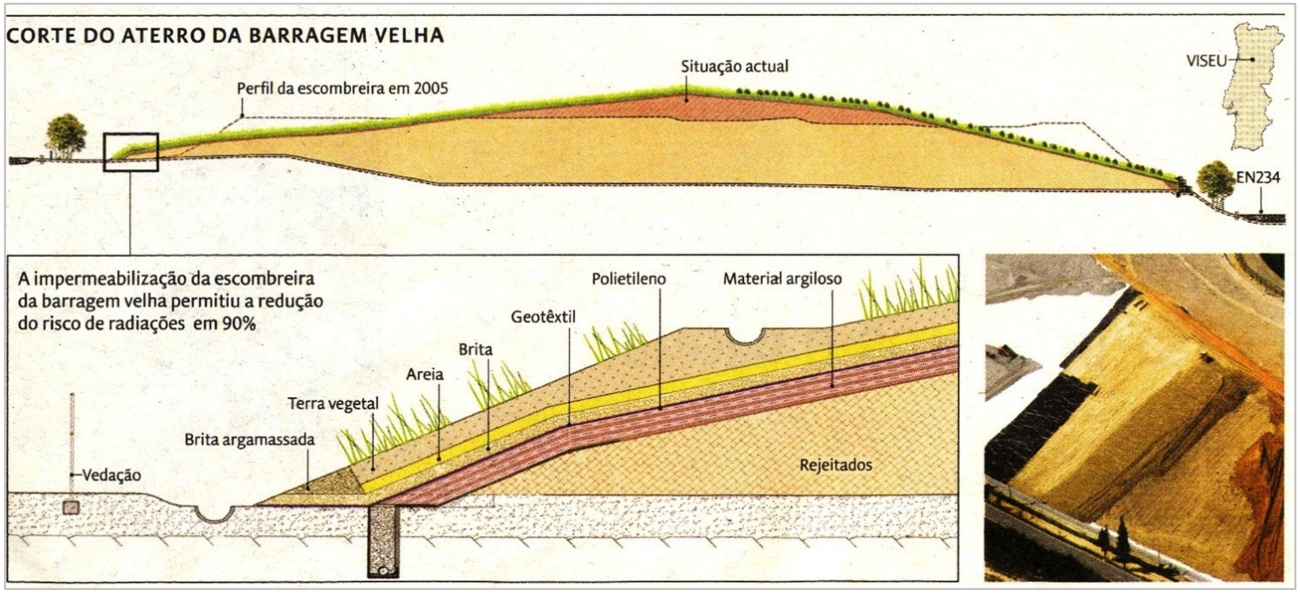
- Goals:
  - Confine the milling tailings
  - Concentrate mining waste in 4 disposal sites
  - Treat the acid mine waters

Aerial view of Urgeiriça (early 2008)

Tailings cover

Aerial view of Urgeiriça (early 2008)

Multi layer cap



Decontamination of facilities

Industrial areas of uranium milling were cleaned:

- Removal of contaminated pipes, sewers and soil,
- Dust control during operations
- Radiation protection measures.

After decontamination, several buildings were allocated to other industrial activities.

Mining and milling waste recover

Removal of waste at Prado Velho

Waste disposal in a former uranium mine pit

- There were many small mines
- Mining and milling waste were concentrated in a few places, disposed in duly prepared pits, and confined with multi-layer covers.

Clean sites released for public use

Several former mine sites (open pits) were monitored, cleaned, and re-shaped.

No significant contamination remained, and sites were considered adequate for public use as:

- Recreational areas
- Mine museum
- Water reservoir for fire-fighting

Mine water: chemical treatment

Mine water drainage:

- Generally acid
- Contains stable metals (Ar, Bi, Y, Cu, Pb, …)
- Often in high concentrations
- Contains dissolved and particulate radionuclides (U, Th, Ra, Rn, Pb, Bi,…)

Chemical treatment:

- Addition of BaCl2,
- addition of hydroxide to raise pH to 8-9,
- Co-precipitate stable metals and radionuclides
- Before releasing treated water

Treated water

Automated treatment and control:

- physico-chemical measurements
- Addition of chemicals
- Transfer by pumps into a sequence of decantation ponds
- Release into surface streams
- Mud (precipitate) accumulated in ponds
- periodically removed and disposed

Mine water: treatment by plants

Mine drainage:

- Pumped into a sequence of ponds with plants (Typha) growing
- Growing plant biomass accumulates metals and radionuclides
- Water parameters checked before release of treatedwater into streams
- Plant biomass incinerated and disposed as rad waste

Watercourses decontamination

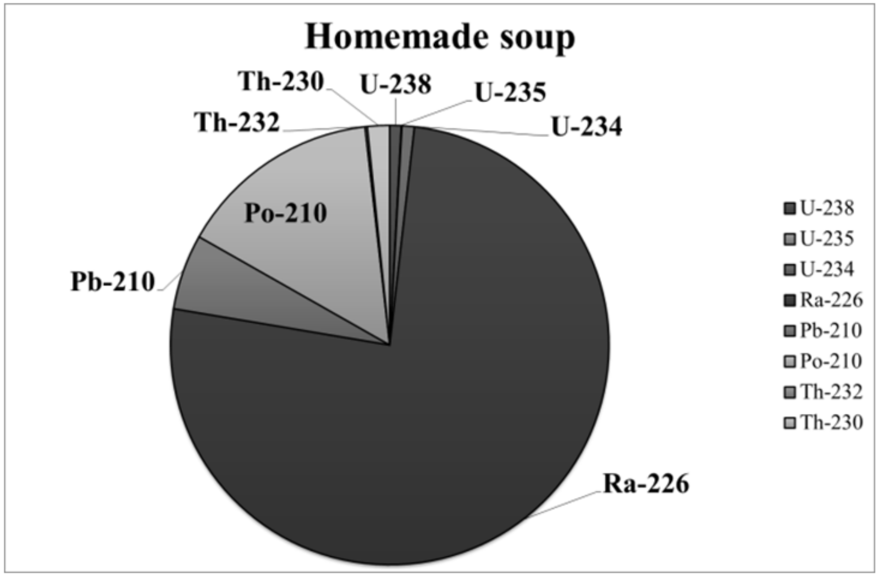
Near uranium milling facilities and tailings:

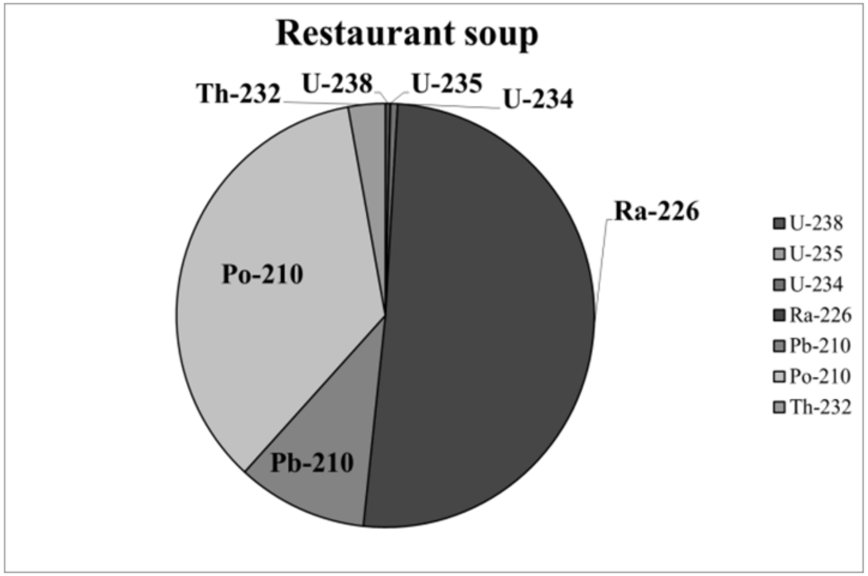
- In the past the process water was released directly into streams,
- Bottom sediments and soils accumulated radionuclides and chemicals
- Streams were cleaned (sediment and biomass removal), re-shaped, bed and banks stabilized with limestone.

Radioactivity in the food chain

.Effective radiation dose extrapolated to annual basis (mSv/year) for members of the public computed on the basis of the comparison meal made with non-local products (restaurant).

Sample	Origin	Absorbed radiation dose from ingestion (mSv/year)	
		Age group: 2-7 years	Age group: > 17 years
Soup	Cunha Baixa	1.7	0.7
Soup	Restaurant	0.09	0.04





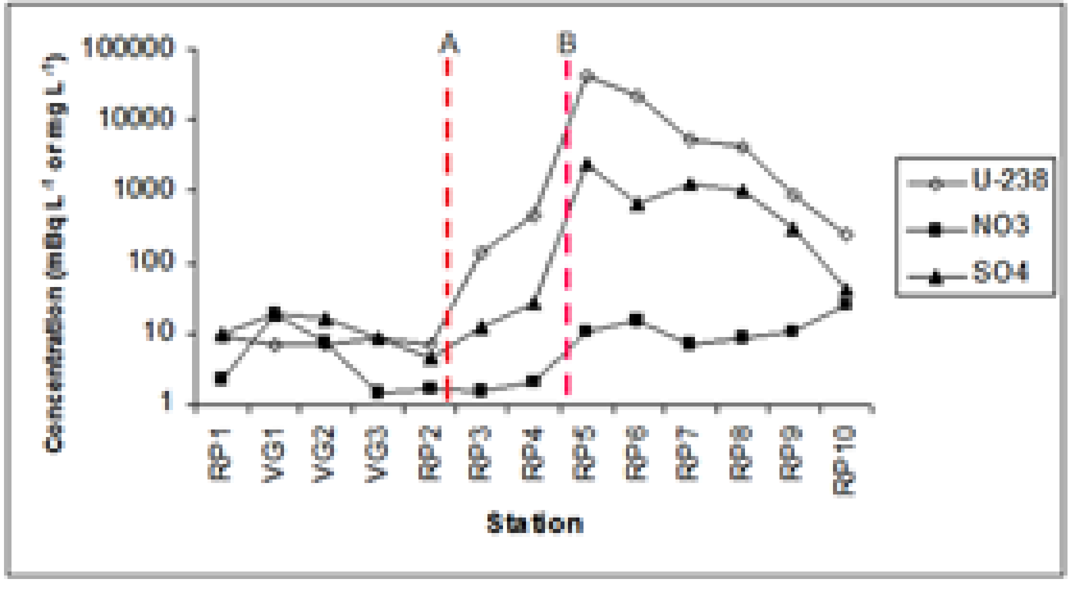
Alternative water supply

In a valley near Cunha Baixa mine:

- Uranium mine was on hills' slope above village and agriculture valley
- Aquifer was contaminted by acid from in situ leaching in the mine
- In the valley, water from wells became acide and contaminated with radionuclides (226Ra)
- Wells were sealed.
- Surface water reservoir built on top of the hills to provide clean water for irrigation in the valley.

Water courses cleaning

Milling tailings with the cover in place, at Urgeiriça. In the first plane, the stream Ribeira da Pantanha after clean up and reconstruction of the stream bed.



Contamination of Ribeira da Pantanha water before remediation.

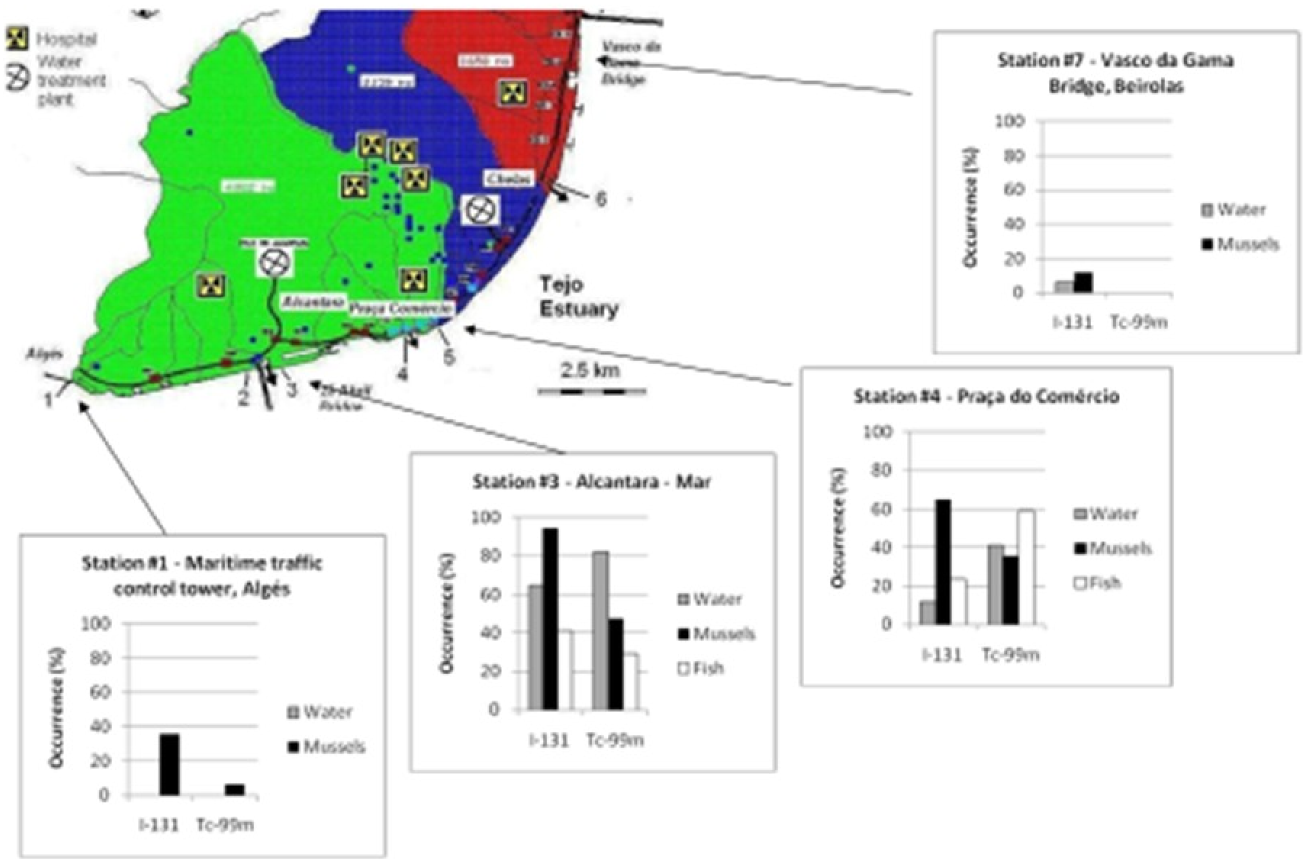
3.Dose to the most exposed person by the Tejo estuary:

A) radionuclides from nuclear medicine discharges;

B) radionuclides from a nuclear vessel discharge

A)Radionuclides from nuclear medicine discharges

Radionucléides dans l'estuaire



Monitoring of the food chain: fish, shrimp, molluscs and its consumption by the inhabitants

Dose to the representative person by the Tejo estuary (radionuclides from nuclear medicine)

- Monitoring food chain
- Low dose
- But discharges not acceptable. Pressure on source control and reduced discharges

B) Radionuclides from a nuclear vessel discharge

Specific monitoring plan during visits of nuclear powered vessels

- Fission products, water, sediments, and mussels as bioindicators
- Cesium 137 discharge from a nuclear submarine in distress at the mouth of estuary (cesium 137 levels were enhanced

B) Radionuclides from a nuclear vessel discharge

- Regular visits of nuclear powered vessels to Lisbon harbour
- Possible scenario of a nuclear accident/incident with release of radioactivity into the environment
- A specific monitoring plan is implemented during visits of nuclear powered vessels focusing fission products

The nuclear powered aircraft carrier USS Enterprise in the Tagus Estuary, 2002

Radiological surveillance programme

- Continuous monitoring of the atmosphere
  - gamma radiation (dose rate)
  - particle borne radioactivity (aerossols)
  - radioactive iodine
- Monitoring of radioactivity in the water, sediment and aquatic bio-indicators (mussels) during the entire stay
- Automatic record of radiological data and local weather data up and downwind

Visit of a nuclear submarine

- The *HMS Trenchant* entered the Lisbon harbour, 9th October 1998 and reported a malfunction in the nuclear reactor.
- Similar case with the submarine HMS Tireless, in Gibraltar

Risk of a nuclear accident

- If the accident could not be effectively contained there would be a significant radiation risk to the general public
- In a worst case scenario, risk assessment indicated that doses could be of 5 mSv in a radius of 2 km
- Potential radioactive contamination in a radious of 30 km.
- The HMS Trenchant sailed to base (Davenport dockyards) for repair

Survey of the Tagus estuary

- Collaboration between the Portuguese Navy and ITN/DPRSN
- Implementation of detailed radioactivity survey of the Lisbon area and estuarine ecosystem
- Aiming at identifying and mapping any radioactive contamination

Analysis and results

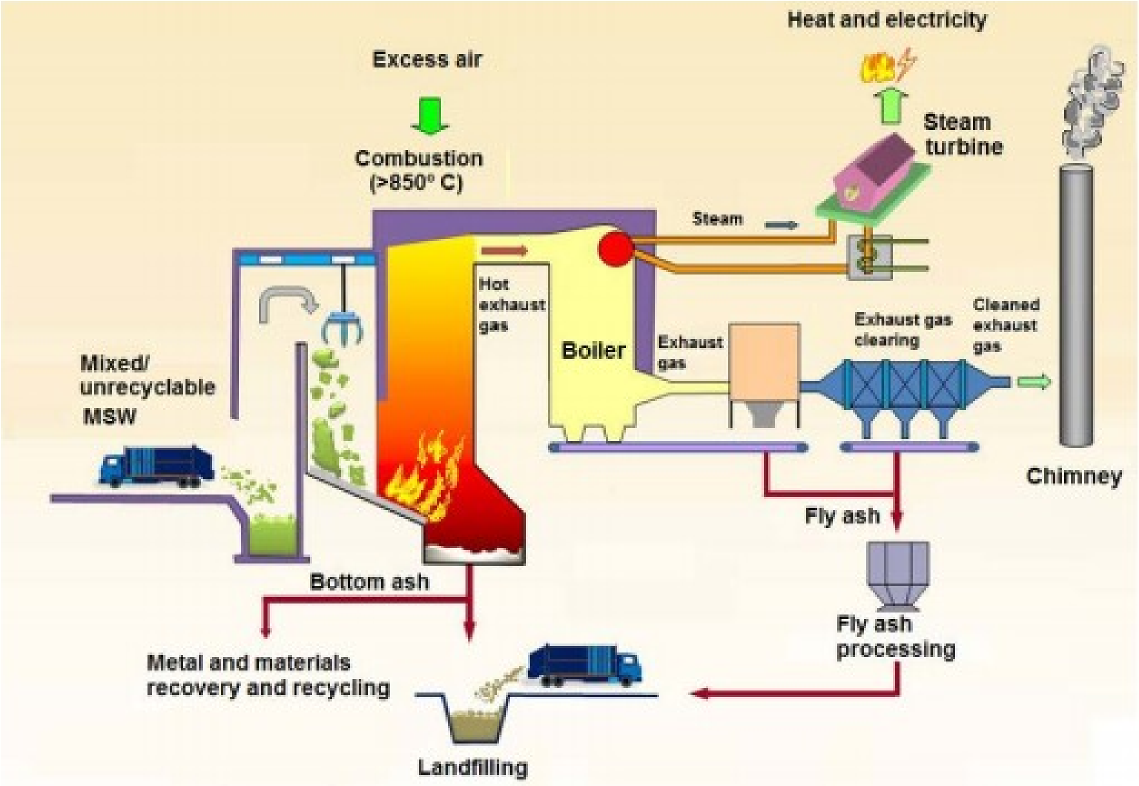
- *In some spots,* sediment samples contained ^{137}Cs in concentrations above values from global radioactive fallout
- Release of contaminated coolant into the estuary likely took place
- Concentrations were low. Light contamination of biota (clams) with 137Cs.
- No significant radiological risk to the population and to the environment.
- Communication to the press: no significant radiological accident. Dose to representative person <0.1 mSv/y

4. Dose to the representative person by the Lisboa municipal solid waste incinerator

Dose to the representative person by the Lisboa municipal solid waste incinerator

- Risk of presence of radioactive sources in the municipal solid waste to be incinerated (sealed sources in metal containers were separated by metal detectors)
- Open sources and contaminated materials from hospitals are frequent (detected by the portals)
- Dose from natural radionuclides volatilized (210Po, 226Ra) measured in aerossols.
- Dose from artificial radionuclides in cinerated calculated using models

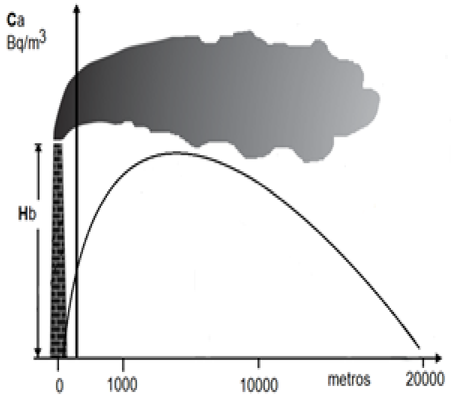
Incinerators



Temperatures of 800 – 1300 °C and above

Radiological risk of incinerated radioactive waste

Hypothetical (serious) cases of volatilization of radioactive sources (CROM model vs. 8)



Radionuclido	Emissão para atmosfera	Concentração no ar (Bq/m³)	Dose por inalação (mSv/dia)	Dose anual mSv
^{137}Cs (100 mCi)	$3{,}7x10^9$ Bq	$6{,}35x10^3$	0,64	234
^{131}I (100 mCi)	$3{,}7x10^9$ Bq	$6{,}35x10^3$	1,03	376
^{99m}Mo-^{99m}Tc (100 mCi)	$3{,}7x10^9$ Bq	$6{,}35x10^3$	$1{,}67x10^{-3}$	0,61

Remark:
Iodine-131 has the greatest impact (dose) for members of the public
Technetium-99m has a much lower radiological impact (dose).

Dose limit = 1 mSv/ano

5. Radon in dwellings



Exposures to radon

- Radon mapping indoors made in 1980s. Radon prone areas identified. Part of the European Radon map.
- Since then, monitoring of public buildings (schools, hospitals, banks, shopping centers) and workplaces -mandatory under 1996 EU BSS and controlled.
- No Gov action/measure for dwellings. Campaigns made to measure radon in residencial buildings and adopt simple countermeasures.
- Missing: legal decisions about building preventive measures. Radon national action plan needed. A more detailed radon mapping is foreseen.

CONCLUSION:

Why a continuous Environmental Monitoring Programme (EMP) ?

To keep and continuously improve the ability to

- Detect and identify any nuclear or radiological emergency
- Identify and quantify radionuclides present in the environment
- **Assess the radiation dose to humans**
- Make sound decisions
- Act with radiation protection measures.

If there is no EMP…

- What risk assessment can we make ?
- What advice to the population? Decision? Measures ?

Thank you for your kind attention.