GOBIERNO DE ESPAÑA
MINISTERIO DE CIENCIA E INNOVACIÓN
Ciemat
Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas

# PRELIMINARY TEST OF GAMP ON GELA SITE

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EMRAS II - Meeting in Limoges

# GAMP


Identification of the problem
1
Stakeholder
Decision maker
Site investigation and characterisation
2
Define objectives
3
Decision maker
Establish screening criteria
4
Stakeholder
Screening assessment
5
Screening criteria met?
6
yes
Stakeholder
Decision maker
no
More realistic assessment
7
Screening criteria met?
8
yes
no
Decision maker
Establish cleanup criteria
9
Stakeholder
Detailed assessment
10
X
Remediation work
Cleanup criteria met?
no
yes
Decision maker
Stakeholder
Actions to be taken
See expanded diagrams in subsequent figures
Measurements
General steps
Decisions (not necessarily radiological)
Communication

# 1 - IDENTIFICATION OF THE PROBLEM

- Phosphogypsum (PG) stacks in Sicily

Problem:

Quantify the radiological hazard to the public

Preliminar information:

- Discharges to the stack: 1981-1992
- Discharges of slurry with 10-20% of PG contents

# 2 - SITE INVESTIGATION AND CHARACTERIZATION

- Information provided by Leandro Magro and Cristina Nuccetelli

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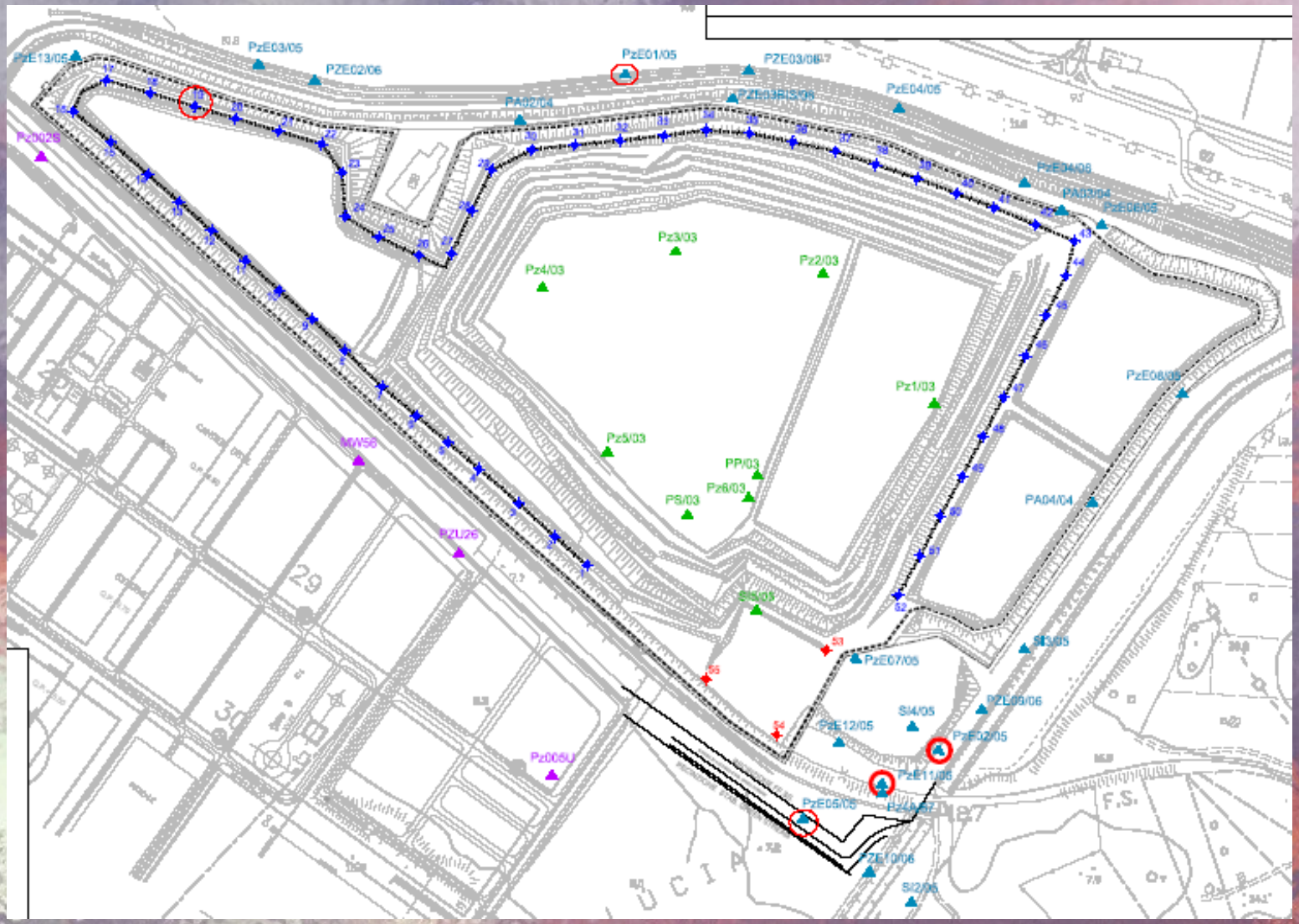

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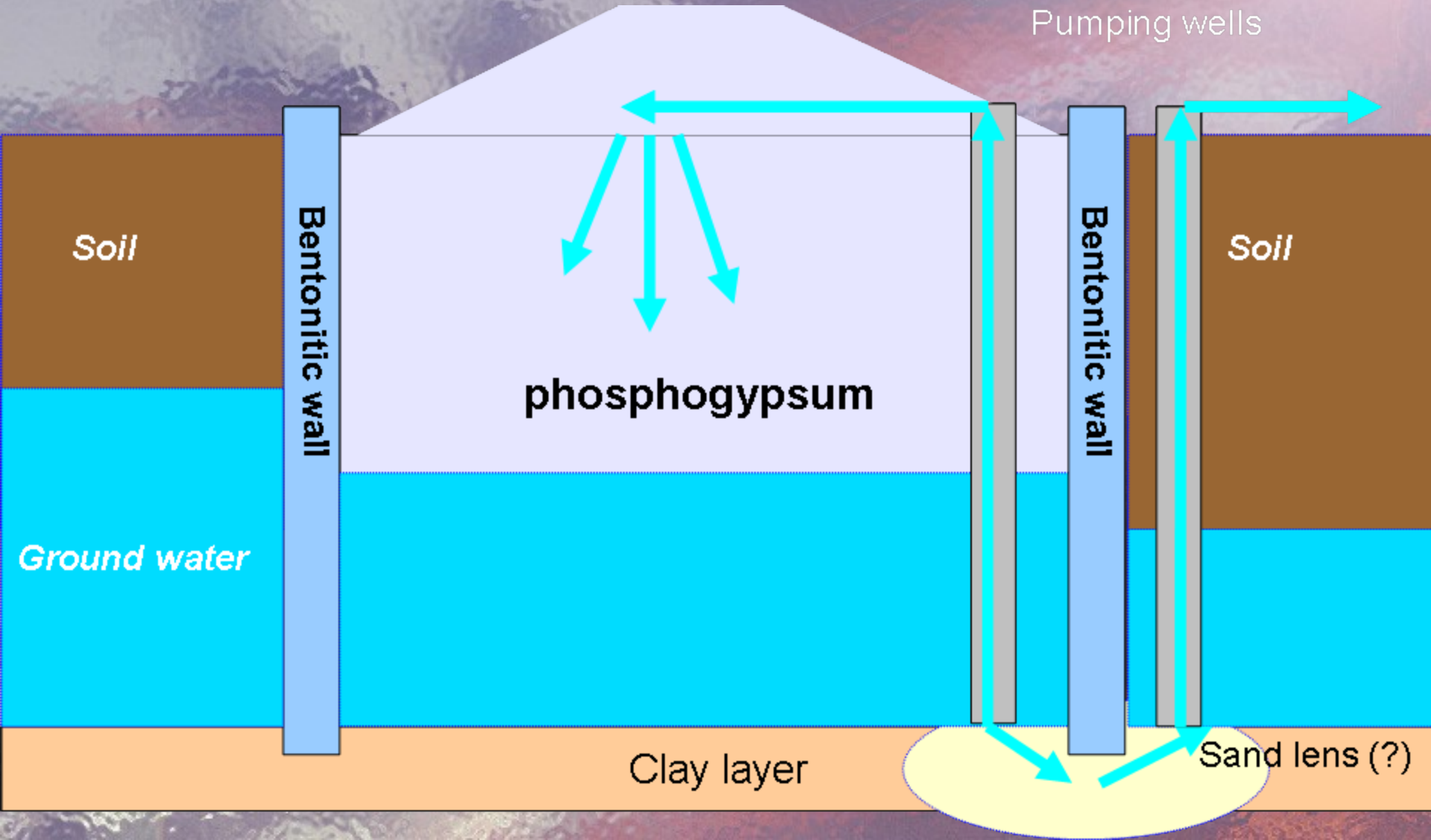


# 2 - SITE INVESTIGATION AND CHARACTERIZATION

- Information provided by Leandro Magro and Cristina Nuccetelli

Characteristics PG:

- Total Area = 55Ha
- Average depth of PG = 14.5 m
- Hidraulic conductivity = 5E-6 m $s^{-1}$

Characteristics clay:

- Total Area = hundreds of Ha
- Depth = 20-30 m
- Hidraulic conductivity = 10-12 10E-11 m $s^{-1}$

# 2 - SITE INVESTIGATION AND CHARACTERIZATION

- Information provided by Leandro Magro and Cristina Nuccetelli

Characteristics sand lens:

- Darcy vel. = 5 m $a^{-1}$
- Hidraulic conductivity = 10-12 10E-11 m $s^{-1}$

Groundwater direction: NW → SE

- Future use of the site after installing a cover (2 plastic lines and 2 m soil): Solar power plant.

# 2 - SITE INVESTIGATION AND CHARACTERIZATION

Table I. Measured concentrations of radionuclides in phosphogypsum and phosphorites.

| PHOSPHOGYPSUM | Nuclide | Bq $kg^{-1}$ |
|---|---|---|
| *High Purity Germanium 38% spectrometer* | $^{226}Ra$ | 418 ± 27 |
| | $^{214}Pb$ | 313 ± 15 |
| | $^{214}Bi$ | 272 ± 12 |
| | $^{212}Pb$ | 19 ± 1 |
| | $^{212}Bi$ | 19 ± 2 |
| | $^{234m}Pa$ | 25 ± 4 |
| *High Purity Germanium 94% spectrometer* | $^{226}Ra$ | 410 ± 35 |
| | $^{214}Pb$ | 293 ± 27 |
| | $^{214}Bi$ | 248 ± 18 |
| | $^{212}Pb$ | 18 ± 1 |
| | $^{212}Bi$ | 19 ± 2 |
| | $^{234m}Pa$ | <10 |

# 2 - SITE INVESTIGATION AND CHARACTERIZATION

## OTHER STEPS

- Identify the hazards:
  - Chemical agresives and radioisotopes

- Radiological survey - it was made a preliminar radiological characterization of the PG

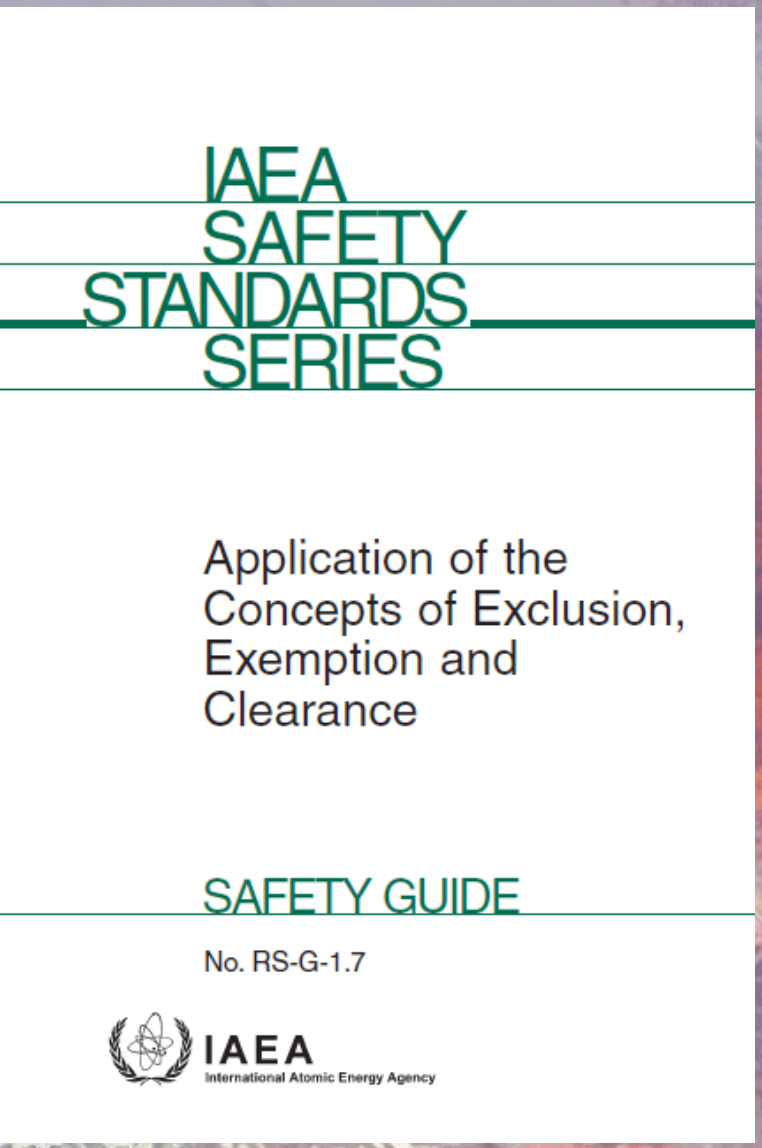
# 2 - SITE INVESTIGATION AND CHARACTERIZATION

- Identify pathways and scenarios
  - In a preliminary experts discussion inhalation of resuspended material and ingestion of foods cultivated in the area are identified as the possible main pathways.
  - The more restrictive scenario in this preliminar phase is the residential on site.
  - This scenario defines also the “Representative Individual” (human)

# 3 - OBJECTIVES

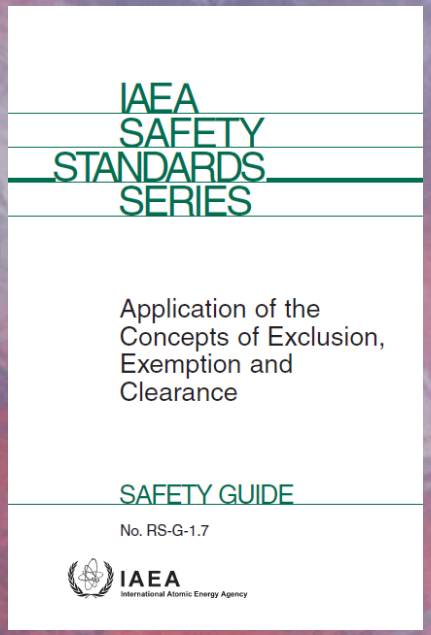
- To determine the radiological impact of the situation, in absence of any physical barrier, in order to evaluate the necessity of a remediation
  - Secondary: evaluate if the remediation proposed for chemical hazards is still valid for radioactive hazards.

# 4 - SCREENING CRITERIA



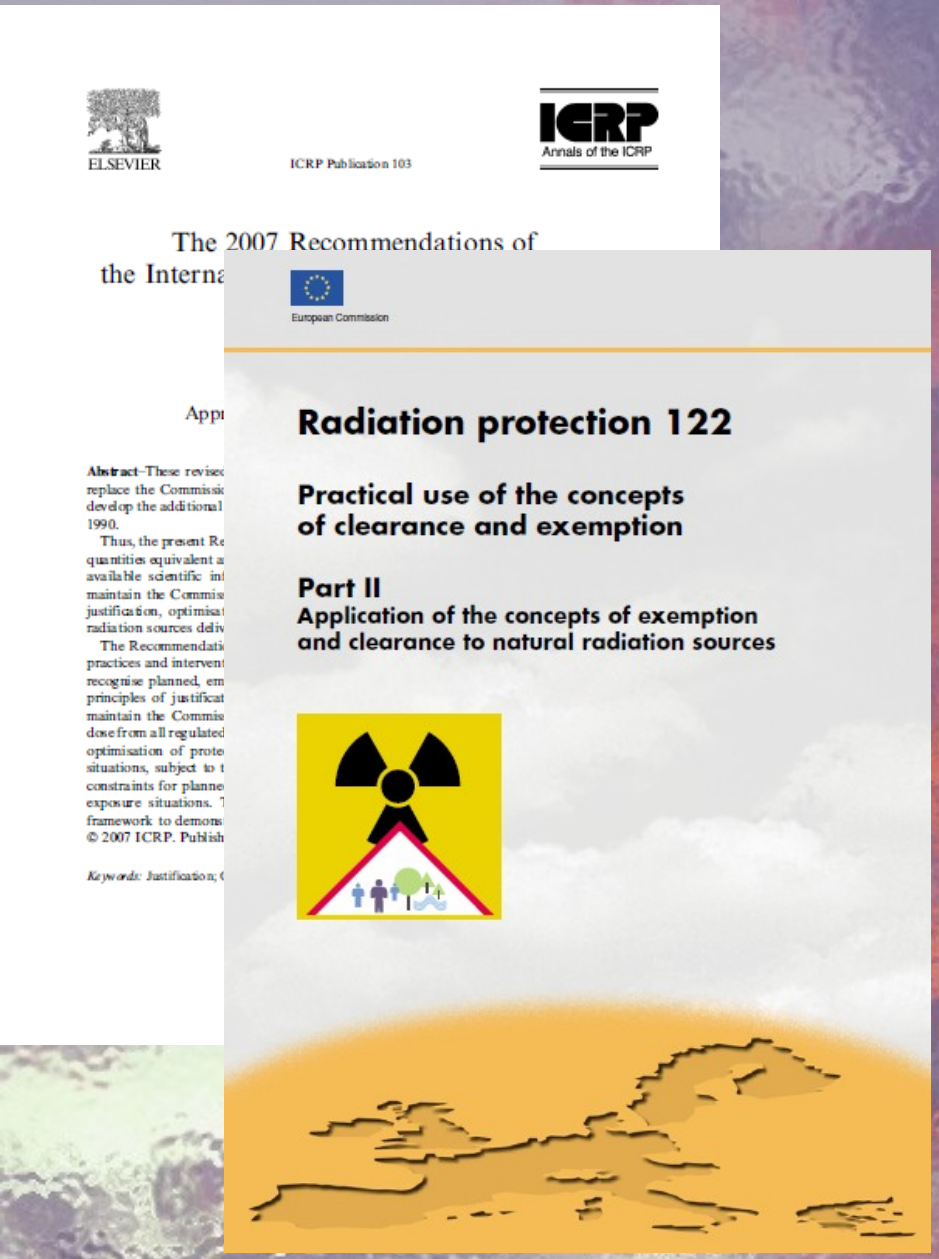

- The screening criteria can be established in terms of activity concentration.
- For natural decay chains (daughters and subchains):
  - 1 000 Bq $kg^{-1}$
- For $^{40}K$
  - 10 000 Bq $kg^{-1}$

# 5-6 – SCREENING CRITERIA MET?



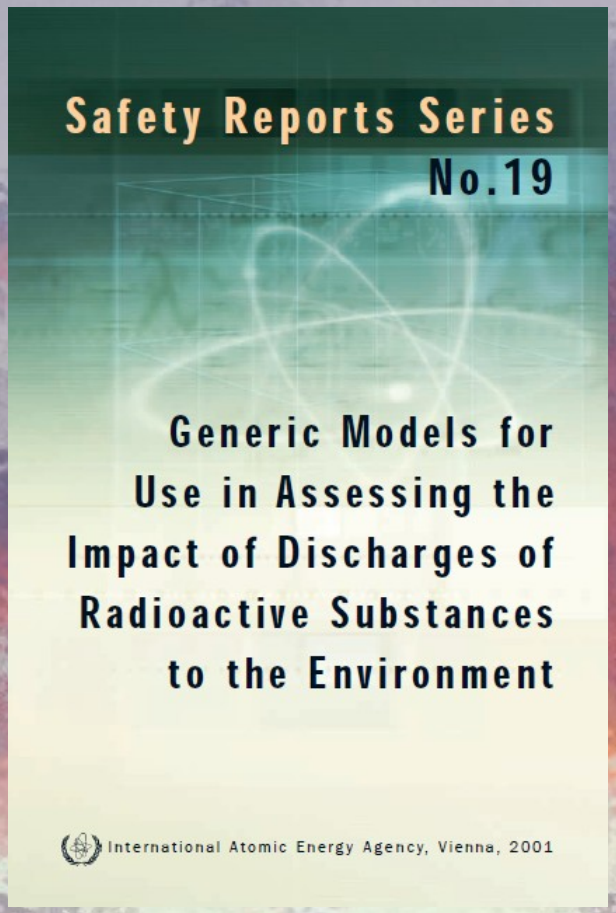

- **MODELLER RECOMMENDATION:** The screening criteria is met for all the radionuclides. The material can be used in any application. No more studies or intervention is needed.
- Consulted the Decision Maker (DM), and after the dialogue with stakeholders, DM decides to strength the screening criteria

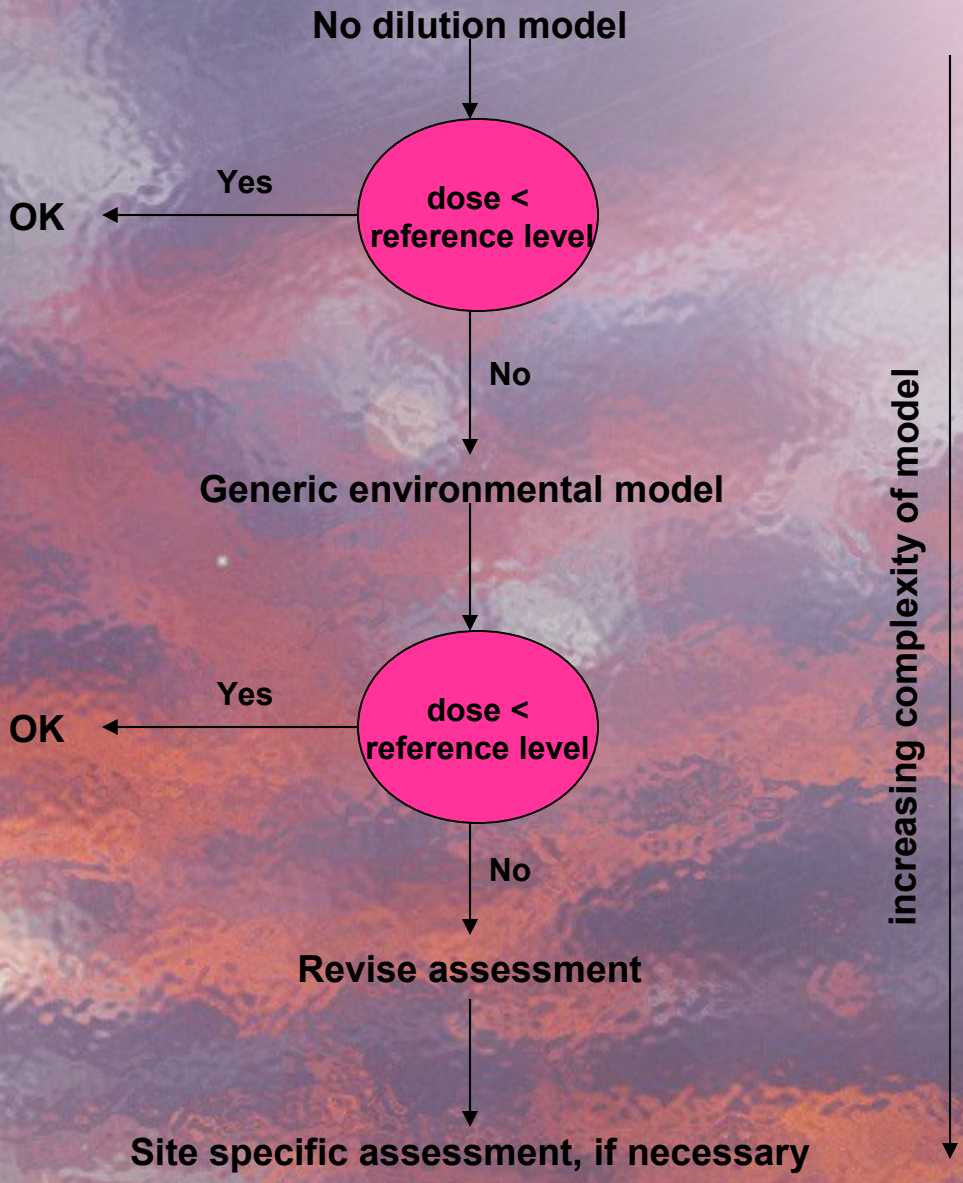
# 4 - SCREENING CRITERIA



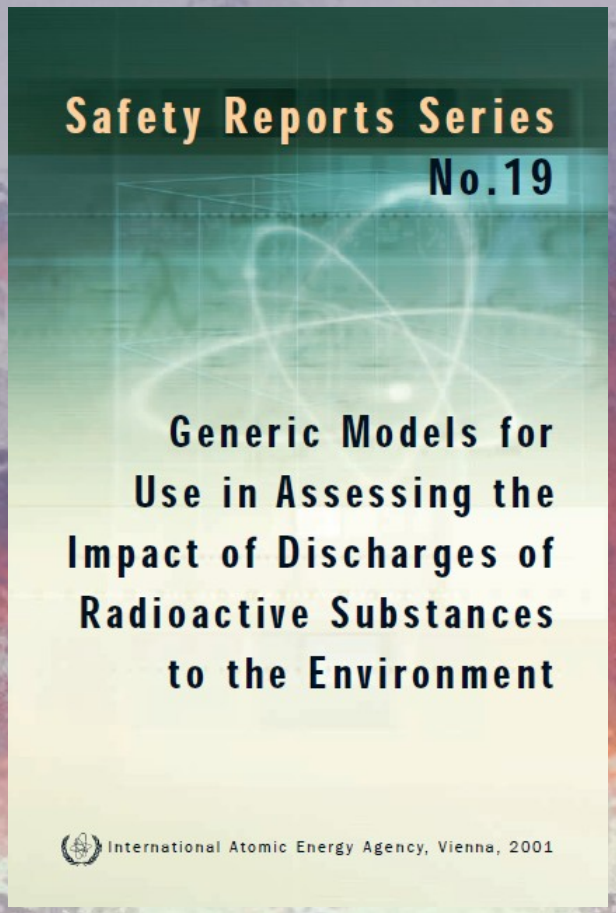

- DECISSION: New screening criteria in terms of effective dose established by the DM:
- ICRP 103
  - NORM (table 8, page 117) - 1 - 20 mSv $a^{-1}$
  - Existing situation: OPTIMIZE
- RP-122 part 2
  - Reference level:
  - 0.3 mSv $a^{-1}$

# 5 - SCREENING ASSESSMENT



# 5 - SCREENING ASSESSMENT




- The more conservative screening model is choose for the first step:

NO DILUTION (INGESTION)

- CONSERVATIVE Default values used for this model. Compare with Ref. Lvl.
- Data needed:
  - Activity Concentrations.

# 5 - SCREENING ASSESSMENT

Background not considered

Adults

Only transfer from soil to vegetables

## INGESTION

From soil uptake:

$$\mathbf{C_{v,i,2} = F_v \times C_{s,i}}$$

Where soil concentration is:

$$C_{s,i} = 418 Bq \cdot kg^{-1}$$

# 5 - SCREENING ASSESSMENT

## INGESTION

$$E_{ing,p} = C_{p,i} H_p DF_{ing}$$

Considering only the contribution of $^{226}Ra$ and ingestion of vegetables for the Effective dose

$F_v = 0.04$

$H_p = M_{veg} = 410$ kg $a^{-1}$ (Europe)

DCF = 2.8 $10^{-7}$ Sv $Bq^{-1}$

**E = 1.92 mSv $a^{-1}$**

# 6 - SCREENING CRITERIA MET?

## INGESTION

- The result of the model is > 1.9 mSv $a^{-1}$
- The established screening criteria was 0.3 mSv $a^{-1}$

**SCREENING CRITERIA NOT MET**

- MODELLER RECOMMENDATION: Perform an assessment less conservative.

# 7 - MORE REALISTIC ASSESSMENT

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- The use of the field, without any soil cover, for the cultivation of all the vegetables that the representative individual can consum was too conservative.

- A more realistic assessment for the present situation can include a different use of the stack, for example:
  - recreational uses or
  - cultivation of forage for animals, that consume a 50% of all their food from this place.

# 7 - MORE REALISTIC ASSESSMENT

## RECREATIONAL USES

- No cover
- 1 h per day spent over the stack
- mass loading 10 mg $m^{-3}$
- Dose conversion factors (CROM or SRS 19). For Ra-226:
  - Inhalation - 9.5E-6 Sv $Bq^{-1}$
  - Ext. Exp. surfaces - 5.7E-8 Sv $m^2$ $Bq^{-1}$ $y^{-1}$
  - Immersion in the material - 1E-8 Sv m3 $Bq^{-1}$ $y^{-1}$

# 7 - MORE REALISTIC ASSESSMENT

## RECREATIONAL USES

- For Ra-226:
  - Inhalation - 13.8 μSv $y^{-1}$
  - Ext. Exp. surfaces - 130 μSv $y^{-1}$
  - Immersion in the resuspended material - 1.7E-6 μSv $y^{-1}$

- The main contribution in this case is the external exposure from the soil.

# 7 - MORE REALISTIC ASSESSMENT

## RECREATIONAL USES

- Considering only the reported radioisotopes of greatest activity:
  - Pb-214 and Bi-214, with DCFs for external exposure from surface contamination of 5.7E-8 and 4.9E-8 Sv m2 $Bq^{-1}$ $y^{-1}$ respectively
- The effective dose, only for those 3 radioisotopes and only for external exposure would be

$$299\ \mu Sv\ y^{-1}$$

- Aditionally considering the inhalation of Ra-226 the dose screening criteria of 300 Sv $y^{-1}$ is exceeded. (Even not considering Rn exhalation)

# 7 - MORE REALISTIC ASSESSMENT

## AGRICULTURAL NON HUMAN CONSUMPTION

- Again, considering no cover and only Ra-226
- Considering that all the meat consumed by the representative individual is produced in the site.
- That 50% of the food of the catle is produced in the stack (the concentration of the rest of the food is considered negligible)

# 7 - MORE REALISTIC ASSESSMENT

## AGRICULTURAL NON HUMAN CONSUMPTION

- The dose for consumption of the meat will result in

$$304 \ \mu Sv \ y^{-1}$$

- Again the dose screening criteria of 300 Sv $y^{-1}$ is exceeded.

# 8 – SCREENING CRITERIA MET?

**SCREENING CRITERIA NOT MET**

- **RECOMMENDATION: Remediation of the site is recommended.**

# 9 – ESTABLISH CLEANUP CRITERIA

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- After a dialogue with the stakeholders, the decision maker establish the same effective dose criteria than was established as screening criteria:

$300\ \mu Sv\ y^{-1}$

- The established remediation works (for no radiological purposes) include the use of a cover that will avoid Rn exhalation and the external radiation in a factor that should be at least 1000 ($< 0.3\ \mu Sv\ y^{-1}$).

# X - REMEDIATION

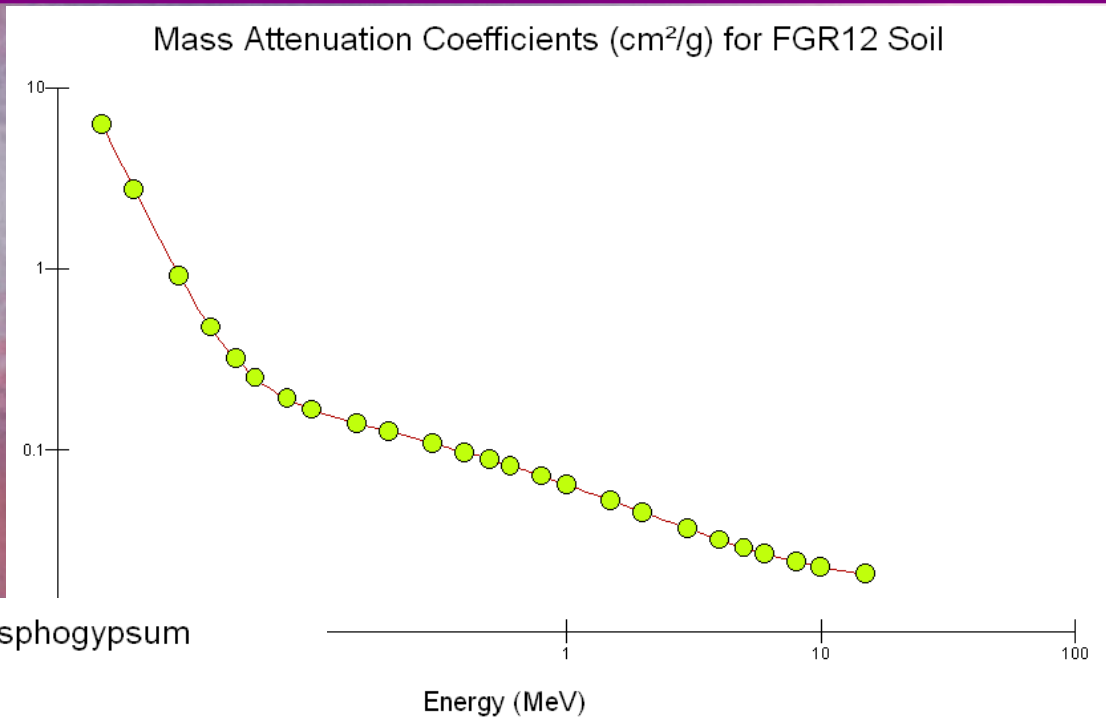
- The projected plastic liner will avoid practically in a 100% the Rn exhalation, but human or animal intrusions (accidental or not) should be considered in assessments of future scenarios.
- A cover of soil will be installed. In order to calculate the necessary thickness for RP purposes, Microshield is used.
- Phosphogypsum considered as pure $CaSO_4$, soil composition taken from FGR12. Density of PG = 1.3 g $cm^{-3}$, density of soil = 1.6 g $cm^{-3}$.
- The radioisotopes are now considered in secular equilibrium (no radon exhalation).

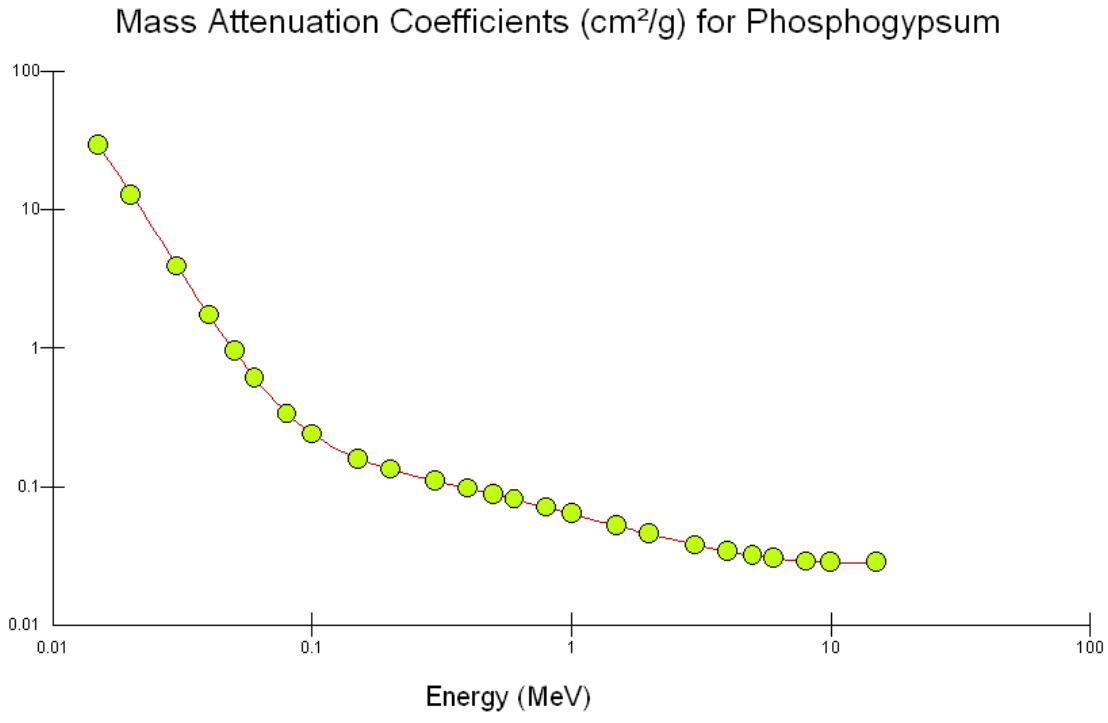
# X - REMEDIATION

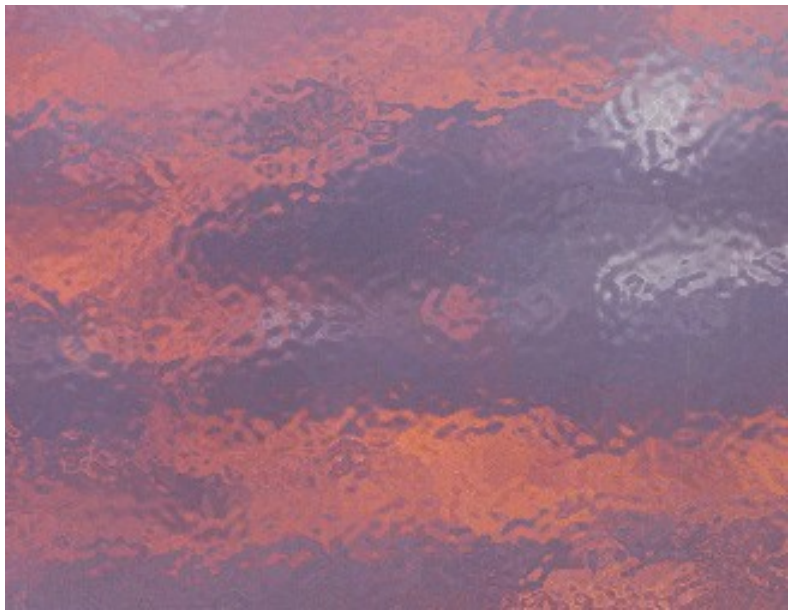
Table II.3. Soil Composition

| Element | Mass Fraction |
|---|---|
| H | 0.021 |
| C | 0.016 |
| O | 0.577 |
| Al | 0.050 |
| Si | 0.271 |
| K | 0.013 |
| Ca | 0.041 |
| Fe | 0.011 |
| Total | 1.000 |

# X - REMEDIATION



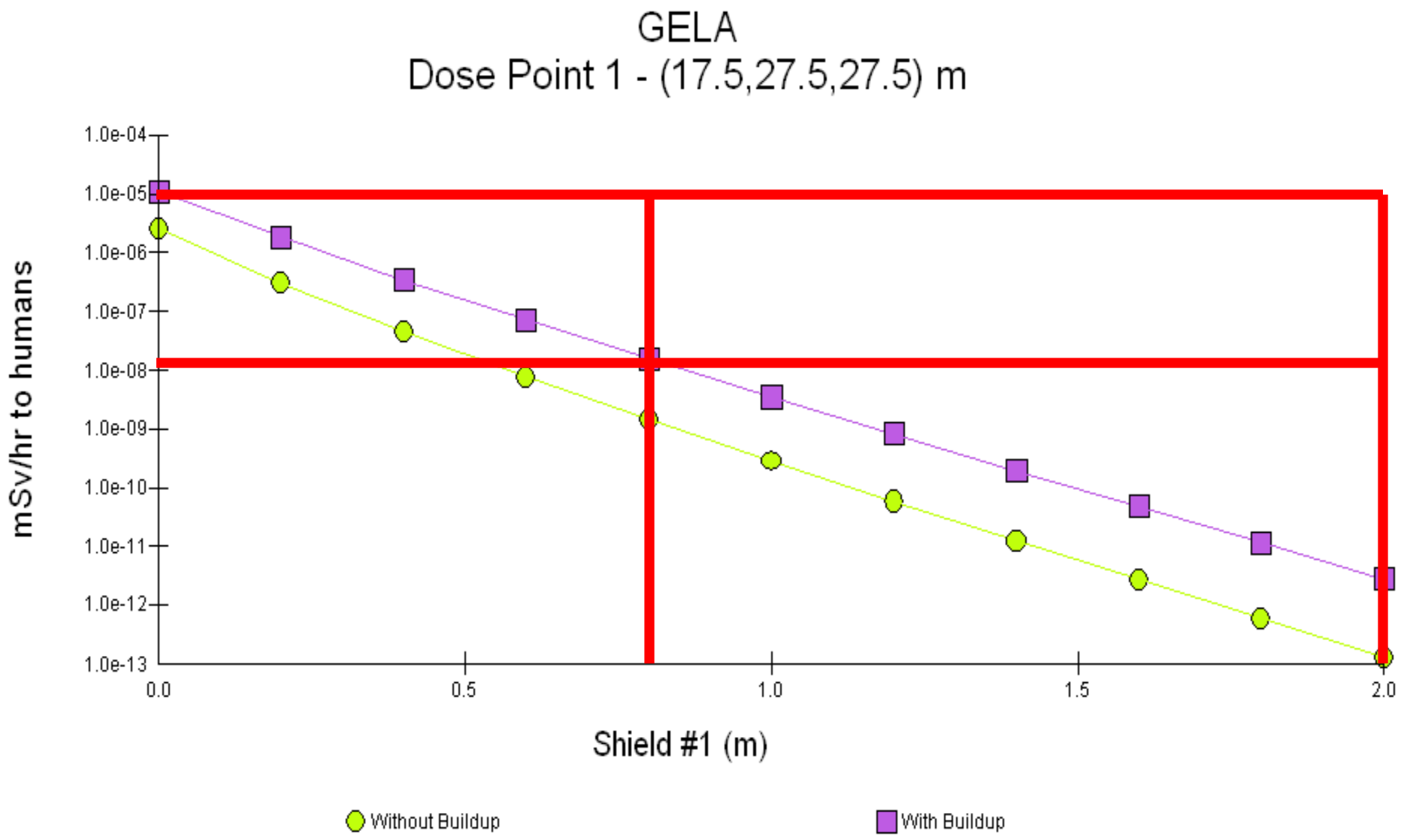



# X - REMEDIATION

## Decay of 30 years

| Nuclide | curies | becquerels | µCi/cm³ | Bq/cm³ |
|---|---|---|---|---|
| Bi-210 | 4.7663e-002 | 1.7635e+009 | 1.0867e-006 | 4.0206e-002 |
| Bi-214 | 7.8152e-002 | 2.8916e+009 | 1.7817e-006 | 6.5925e-002 |
| Pb-210 | 4.7682e-002 | 1.7642e+009 | 1.0871e-006 | 4.0222e-002 |
| Pb-214 | 7.8152e-002 | 2.8916e+009 | 1.7817e-006 | 6.5925e-002 |
| Po-210 | 4.7135e-002 | 1.7440e+009 | 1.0746e-006 | 3.9761e-002 |
| Po-214 | 7.8136e-002 | 2.8910e+009 | 1.7814e-006 | 6.5911e-002 |
| Po-218 | 7.8168e-002 | 2.8922e+009 | 1.7821e-006 | 6.5938e-002 |
| Ra-226 | 7.8167e-002 | 2.8922e+009 | 1.7821e-006 | 6.5937e-002 |
| Rn-222 | 7.8168e-002 | 2.8922e+009 | 1.7821e-006 | 6.5938e-002 |

# X - REMEDIATION



# X - REMEDIATION

- The remediation considered for the correction of chemical hazards included the addition of 2 m of clean soil.
- For a factor of 1000 reduction in gamma exposure, less than 1 m is needed.
- A soil of 2 m will produce a reduction in gamma exposure of a factor of $10^{-7}$ → 1.3E-5 μSv $y^{-1}$ in the case of external exposure in the recreational scenario.
- The second pathway for that scenario was the inhalation of resuspended material, which is also cancelled with this remediation.

# 10 - DETAILED ASSESSMENT

- Design possible scenarios (present and future):
  - Occupancy times
  - Respiration rates
  - …
- Measurement of background levels
- More local parameters should be used
  - distance of cultivation
  - real consumption rates
  - real irrigation rates
  - density and composition of soils and materials
  - …

# 10 - DETAILED ASSESSMENT

- Intrusion scenarios must be considered.
- Use of dispersion models for calculation of the concentration of leached water
  - porosity (PG and soils)
  - Volume of saturated zone PG
  - rainfall rate
  - pumping flow rate

# 10 – DETAILED ASSESSMENT

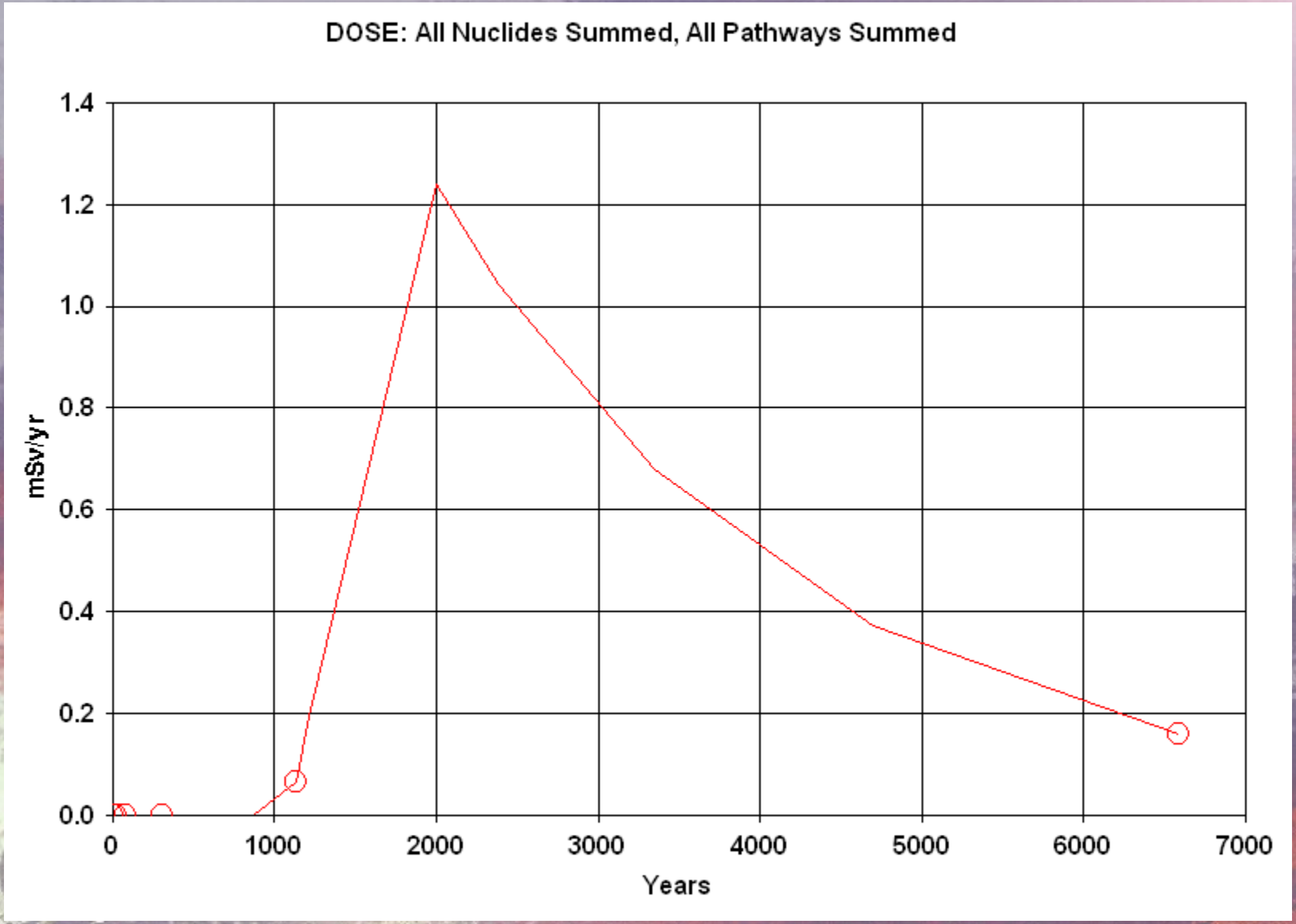
CAUTION!

USE OF DETAILED MODELS WITH DEFAULT PARAMETERS, USUALLY VALID FOR NORTHERN EUROPE OR USA, COULD NOT GIVE RESULTS VALID FOR THE PROBLEM.

UNCERTAINTIES CALCULATION, OR AT LEAST A DISCUSSION, IS STRONGLY RECOMENDED IF DETAILED, NOT CONSERVATIVE MODELS, ARE USED.

# 10 - DETAILED ASSESSMENT

## ANYWAY



# 10 - DETAILED ASSESSMENT

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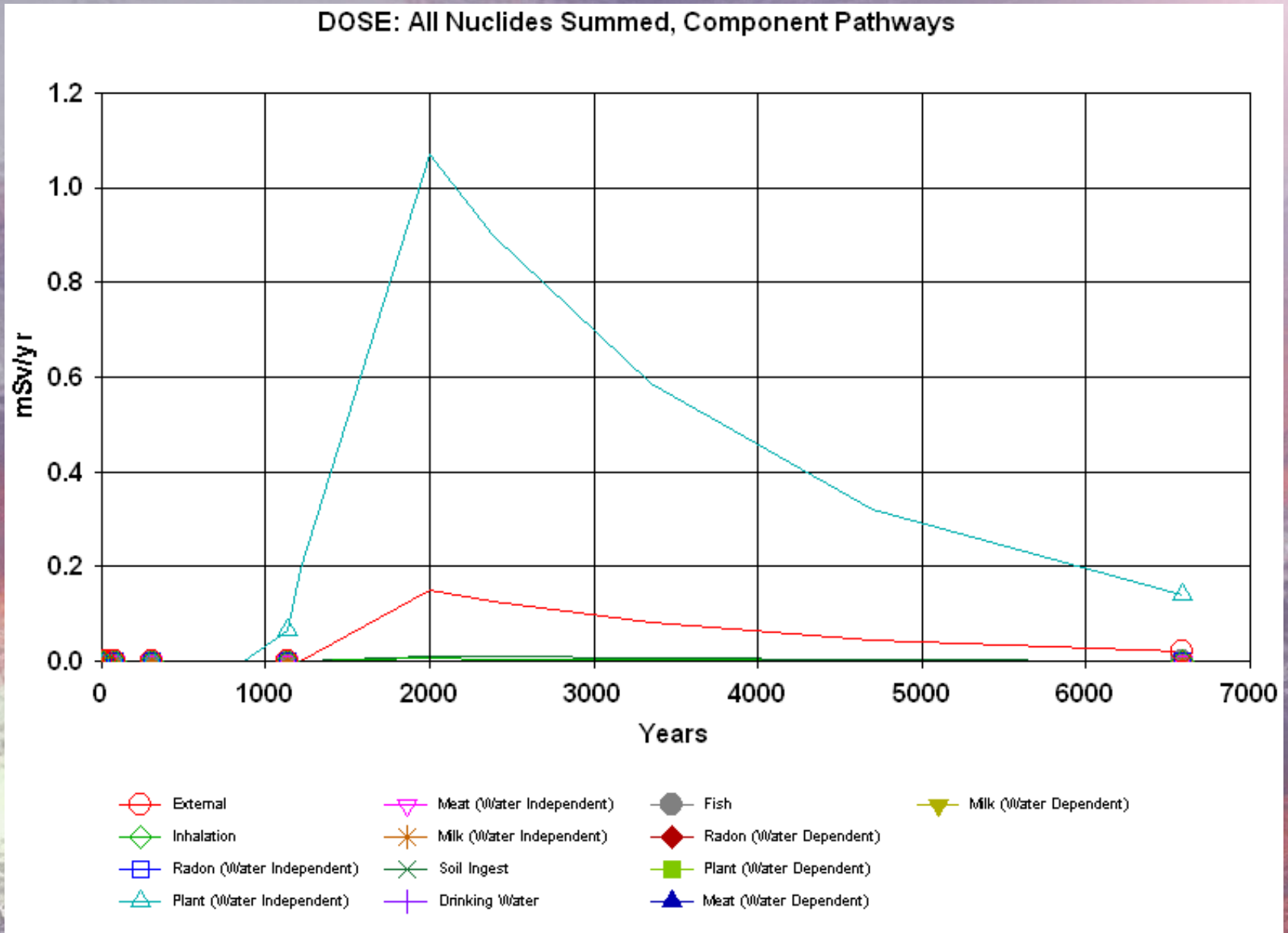

# 10 - DETAILED ASSESSMENT

## ADITTIONS DUE TO JANUARY MEETING

- Rn pathway was not used due to the assumption that plastic line will avoid Rn exhalation 100%
- Lieve data: Life of plastic (outside?) is around 20-30 years, so may be the assumption is not conservative.
- Instead, no plastic liner was considered as adittional scenario where a 100% Rn exhalation is produced.
- Resrad onsite is used, including the default values for those parameters not included in the description of the scenario

# 10 - DETAILED ASSESSMENT

## ADITTIONS DUE TO JANUARY MEETING