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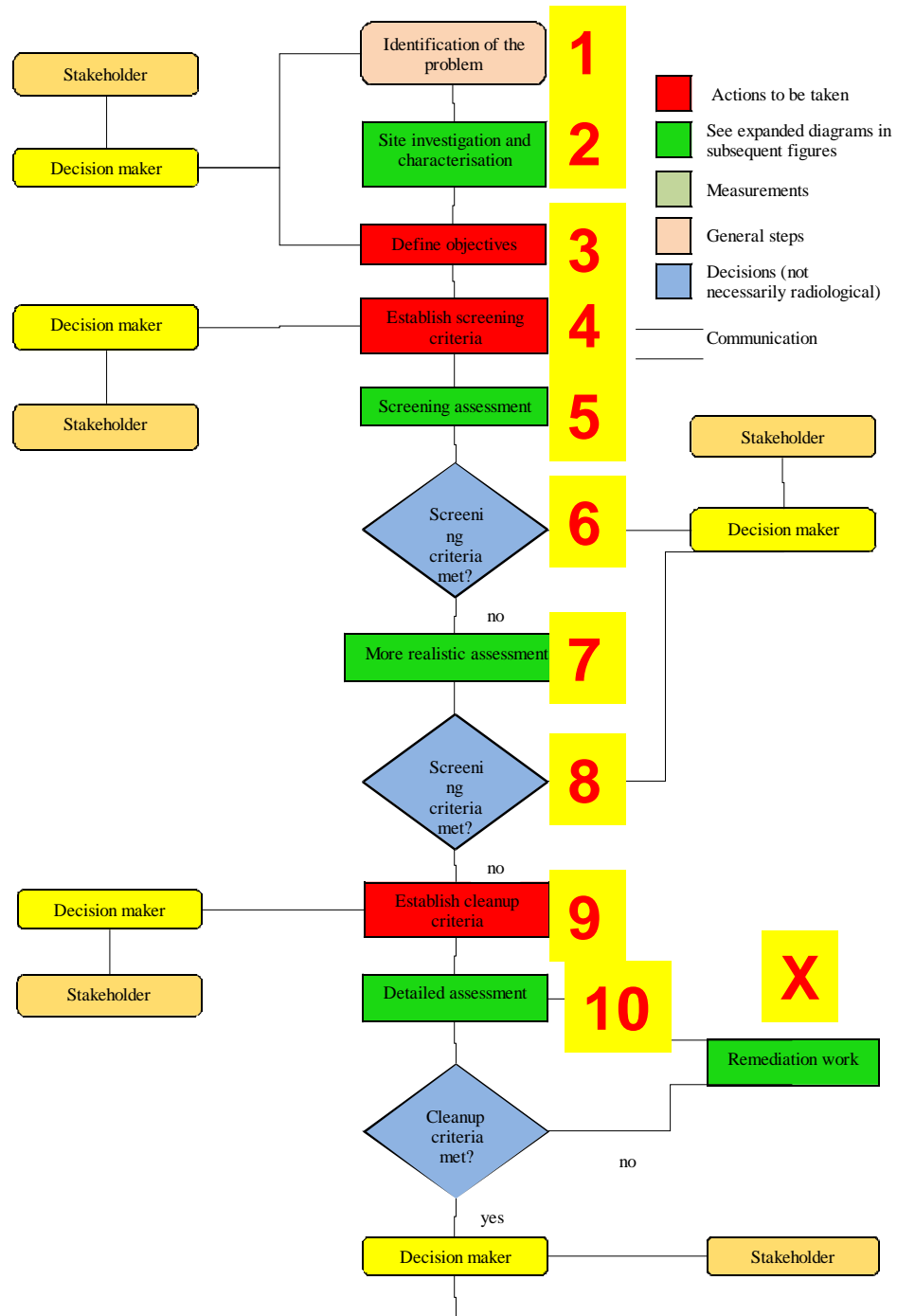
PRELIMINARY TEST OF GAMP ON GELA SITE

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29th sept 2010

EMRAS II - Meeting in Limoges

GAMP



1 - IDENTIFICATION OF THE PROBLEM

- Phosphogypsum (PG) stacks in Sicily

Problem:

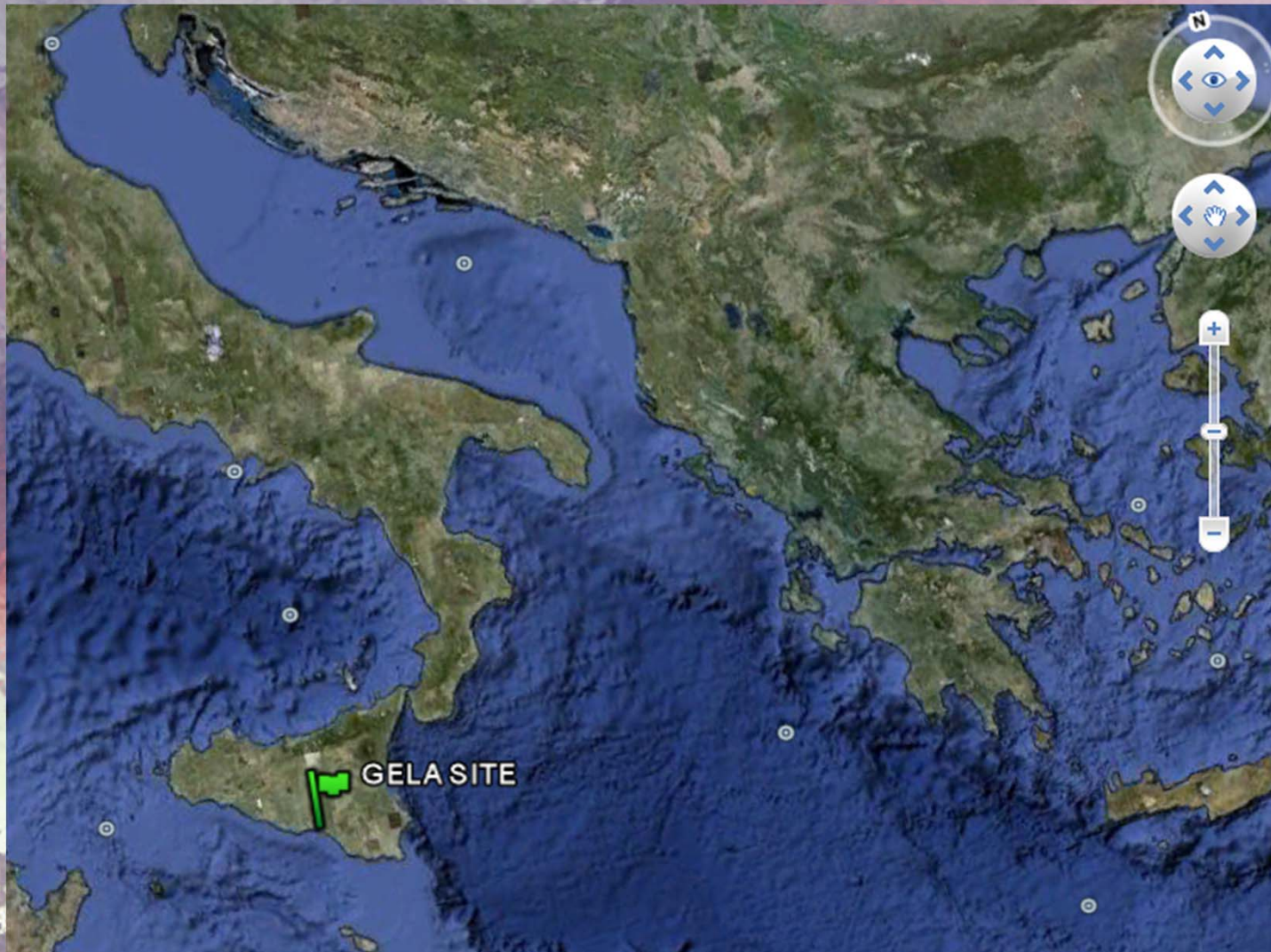
Quantify the radiological hazard to the public

Preliminary 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



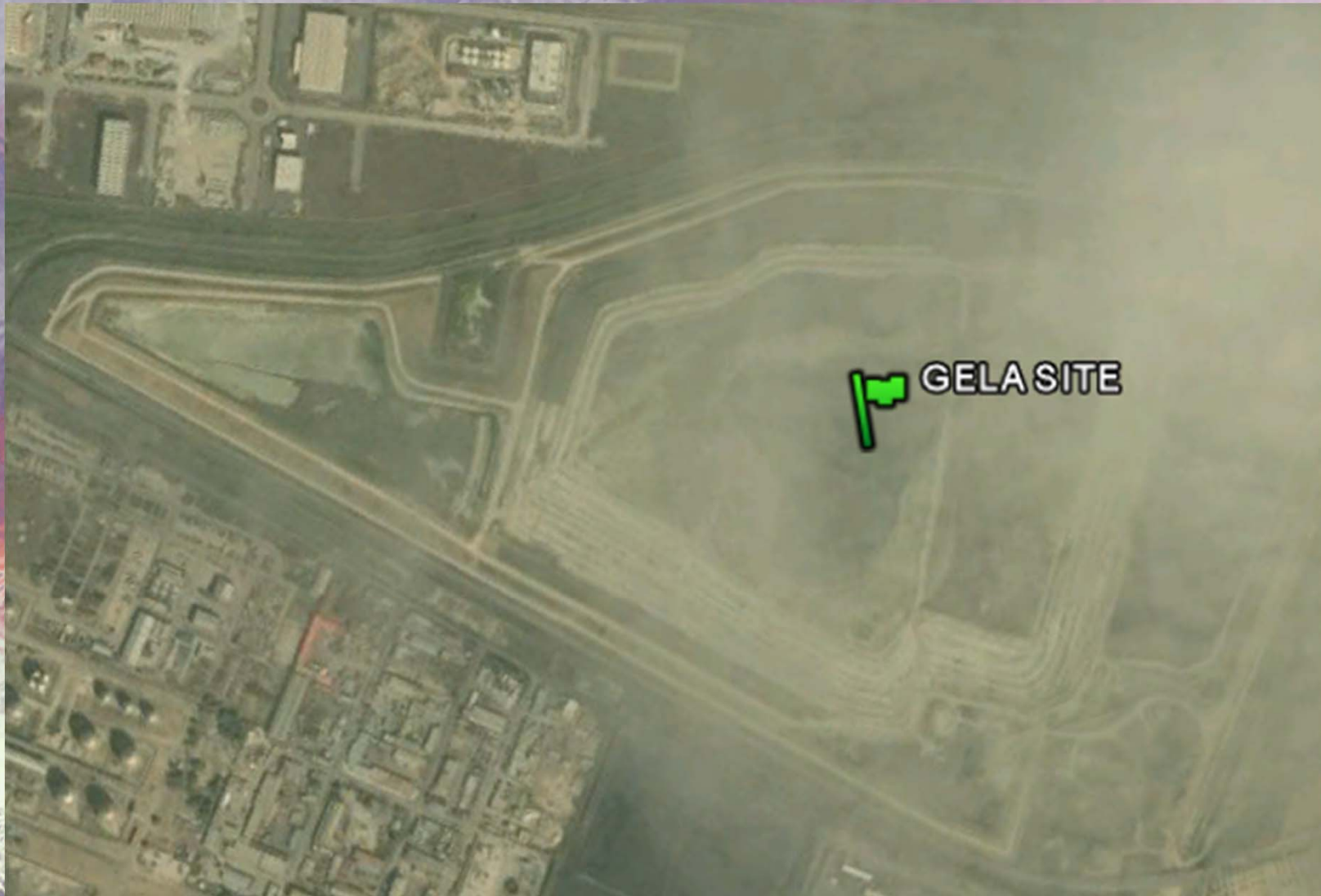
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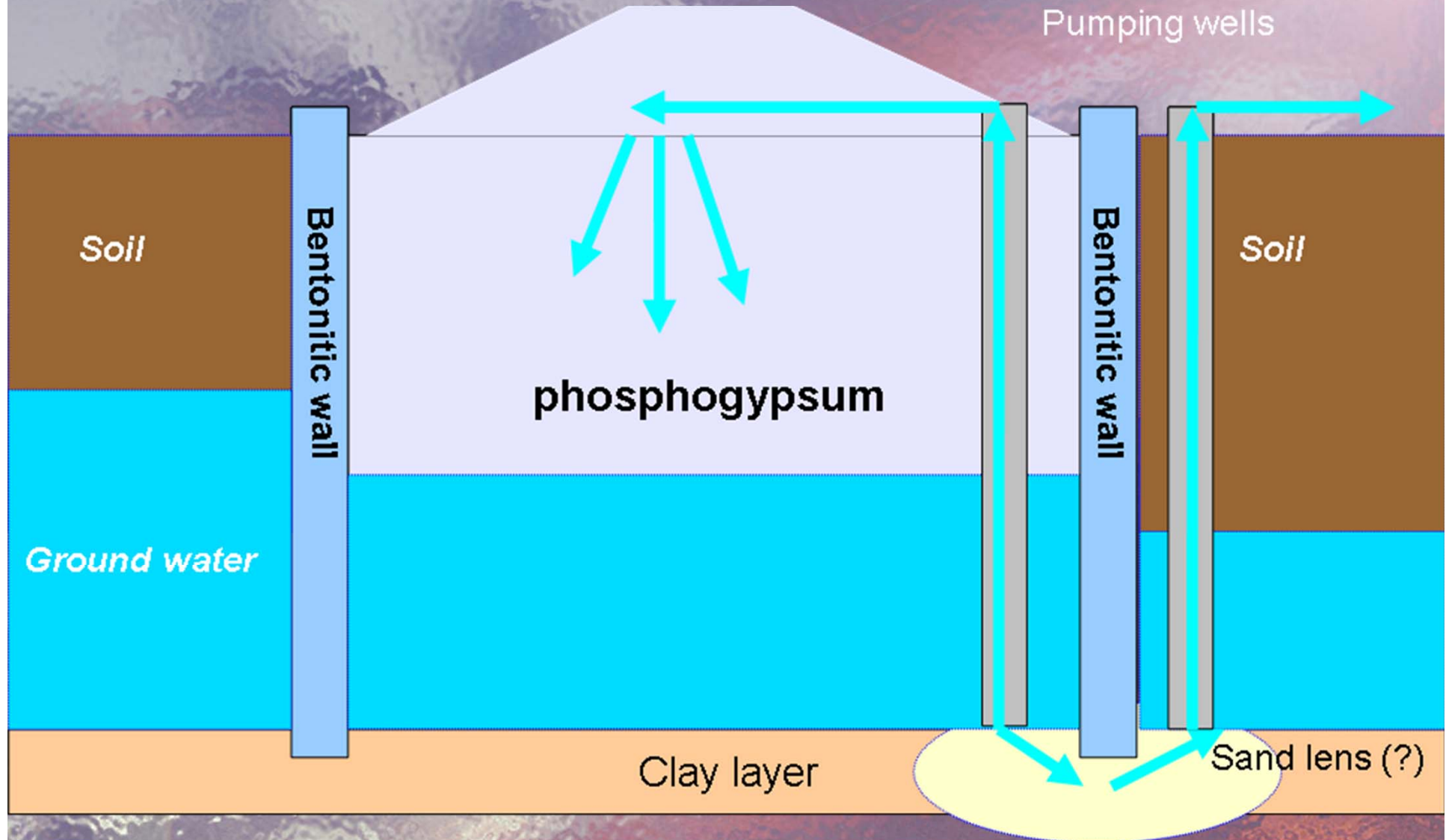
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Characteristics PG:

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

Characteristics clay:

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

2 - SITE INVESTIGATION AND CHARACTERIZATION

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Characteristics sand lens:

- Darcy vel. = 5 m a^{-1}
- Hydraulic conductivity = $10^{-12} \text{ to } 10^{-11} \text{ m s}^{-1}$

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
<i>High Purity Germanium 38% spectrometer</i>	²²⁶ Ra	418 ± 27
	²¹⁴ Pb	313 ± 15
	²¹⁴ Bi	272 ± 12
	²¹² Pb	19 ± 1
	²¹² Bi	19 ± 2
	^{234m} Pa	25 ± 4
<i>High Purity Germanium 94% spectrometer</i>	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 preliminary 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

IAEA SAFETY STANDARDS SERIES

Application of the
Concepts of Exclusion,
Exemption and
Clearance

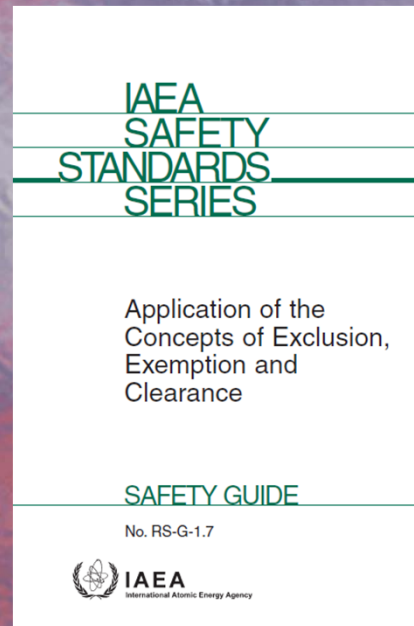
SAFETY GUIDE

No. RS-G-1.7



- The screening criteria can be established in terms of activity concentration.
- For natural decay chains (daughters and subchains):
 - 1 000 Bq kg⁻¹
- For ⁴⁰K
 - 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 strengthen the screening criteria

4 - SCREENING CRITERIA



ICRP Publication 103



The 2007 Recommendations of
the International Commission on Radiological Protection



App

Abstract—These revised Recommendations replace the Commission's Recommendations developed in 1990.

Thus, the present Recommendations maintain the Commission's principles of justification, optimisation and protection of the public.

The Recommendations recognise planned, emergency and exceptional situations, subject to the constraints for planned exposure situations. The framework to demonstrate compliance with the Recommendations is provided.

Keywords: Justification, C

Radiation protection 122

Practical use of the concepts of clearance and exemption

Part II Application of the concepts of exemption and clearance to natural radiation sources



- **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

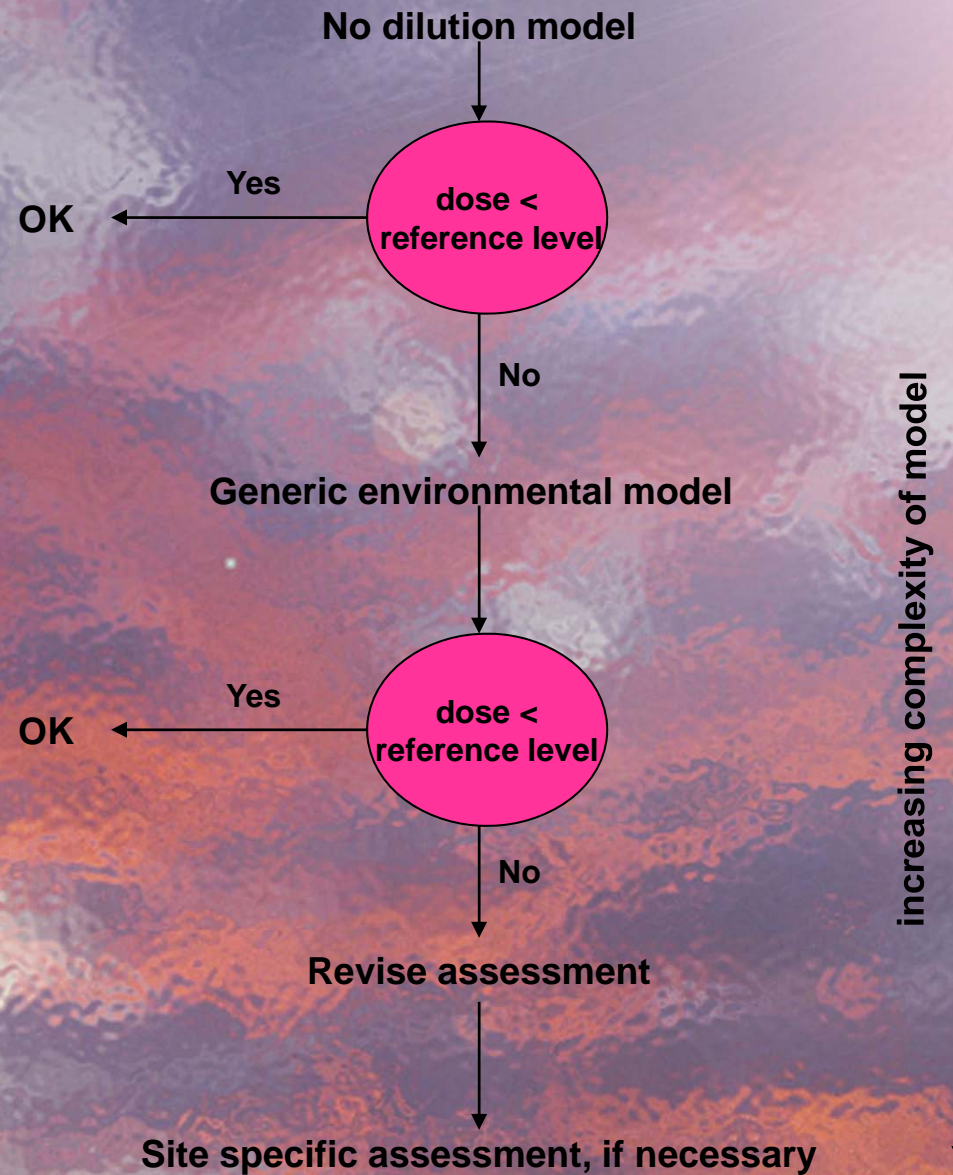
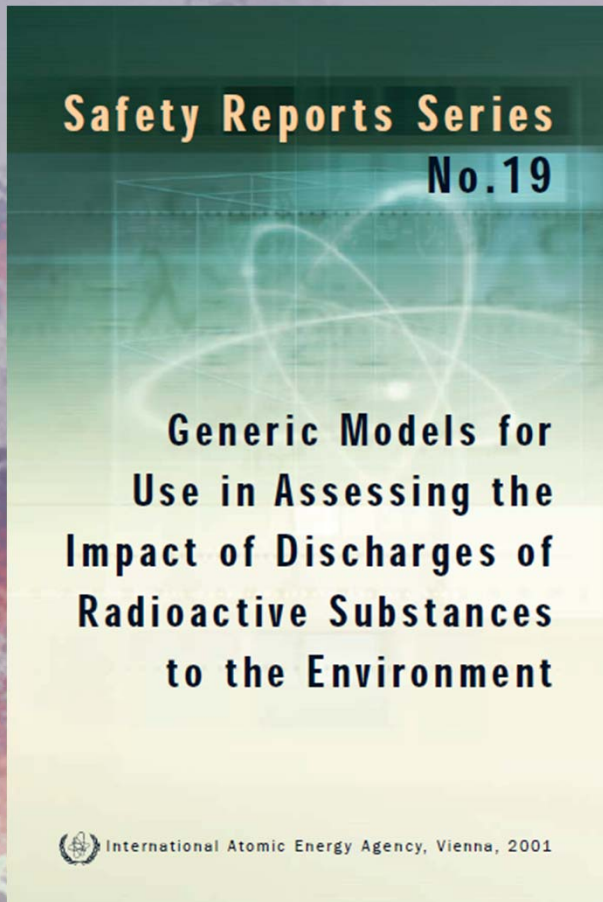
- Existing situation: OPTIMIZE

- RP-122 part 2

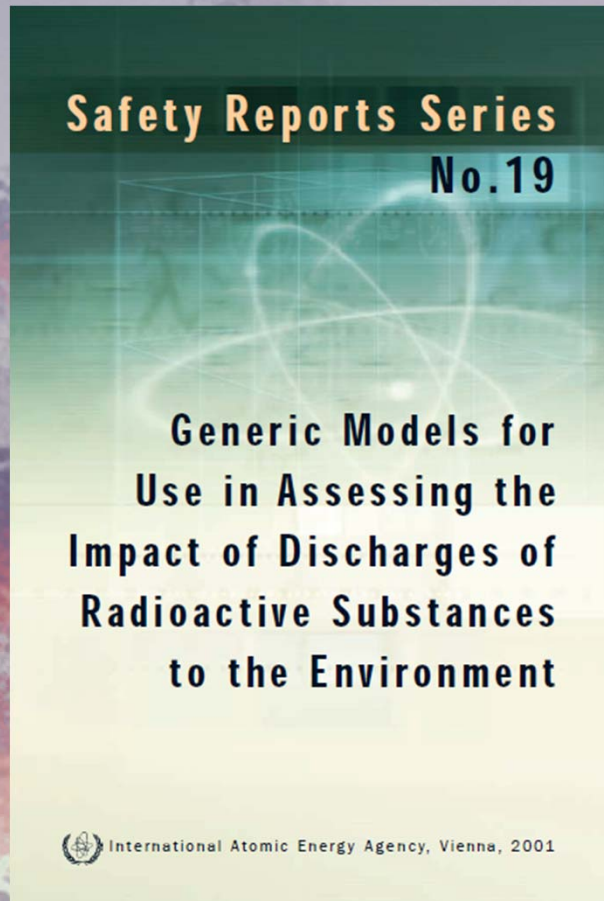
- Reference level:

- 0.3 mSv a⁻¹

5 - SCREENING ASSESSMENT



5 - SCREENING ASSESSMENT



- The more conservative screening model is chosen 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

5 - SCREENING ASSESSMENT

INGESTION

From soil uptake:

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

Where soil concentration is:

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

5 - SCREENING ASSESSMENT

INGESTION

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

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

$$F_v = 0.04$$

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

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

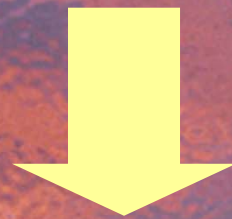
$$E = 1.92 \text{ mSv a}^{-1}$$

6 - SCREENING CRITERIA MET?

INGESTION

- The result of the model is $> 1.9 \text{ mSv a}^{-1}$
- 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

7 - MORE REALISTIC ASSESSMENT

- The use of the field, without any soil cover, for the cultivation of all the vegetables that the representative individual can consume 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 - $9.5\text{E-}6 \text{ Sv Bq}^{-1}$
 - Ext. Exp. surfaces - $5.7\text{E-}8 \text{ Sv m}^2 \text{ Bq}^{-1} \text{ y}^{-1}$
 - Immersion in the material - $1\text{E-}8 \text{ Sv m}^3 \text{ Bq}^{-1} \text{ y}^{-1}$

7 - MORE REALISTIC ASSESSMENT

RECREATIONAL USES

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

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

- Additionally 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 cattle 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

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

- 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:

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

- 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 ($< 0.3 \mu\text{Sv y}^{-1}$).

X - REMEDIATION

- The projecter 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

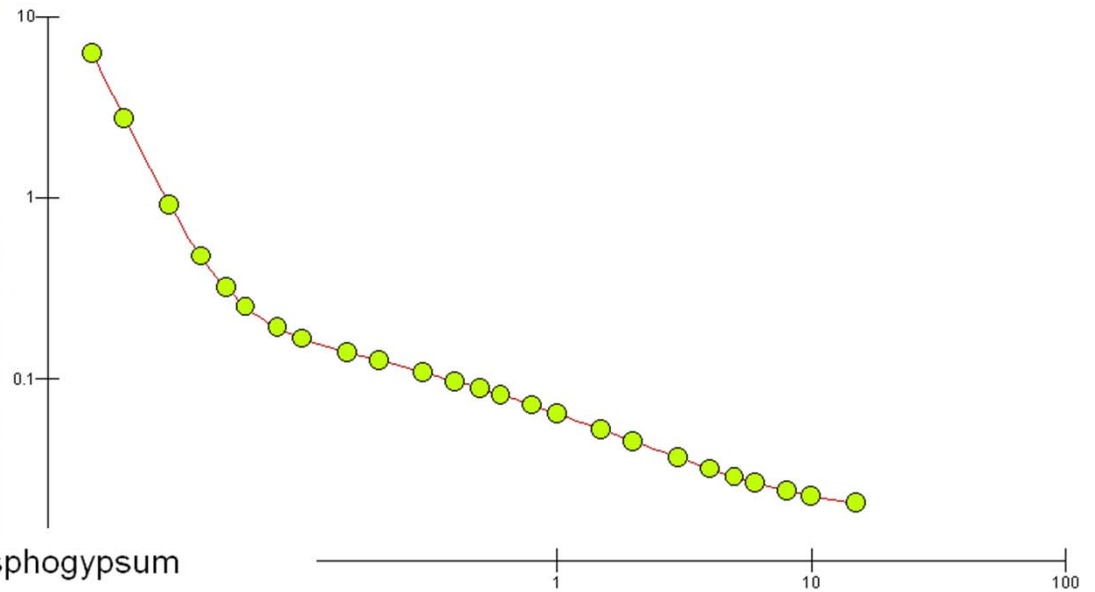
Table II.3. Soil Composition

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

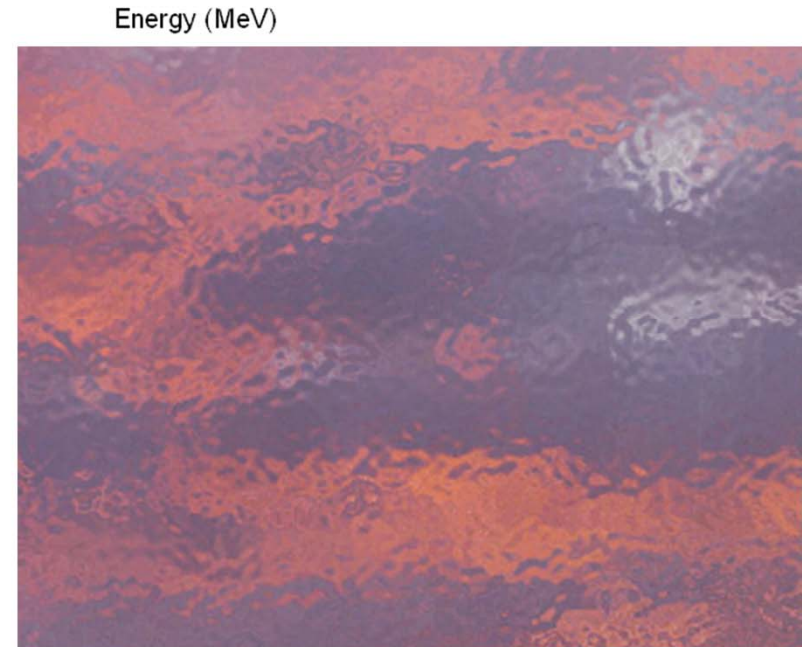
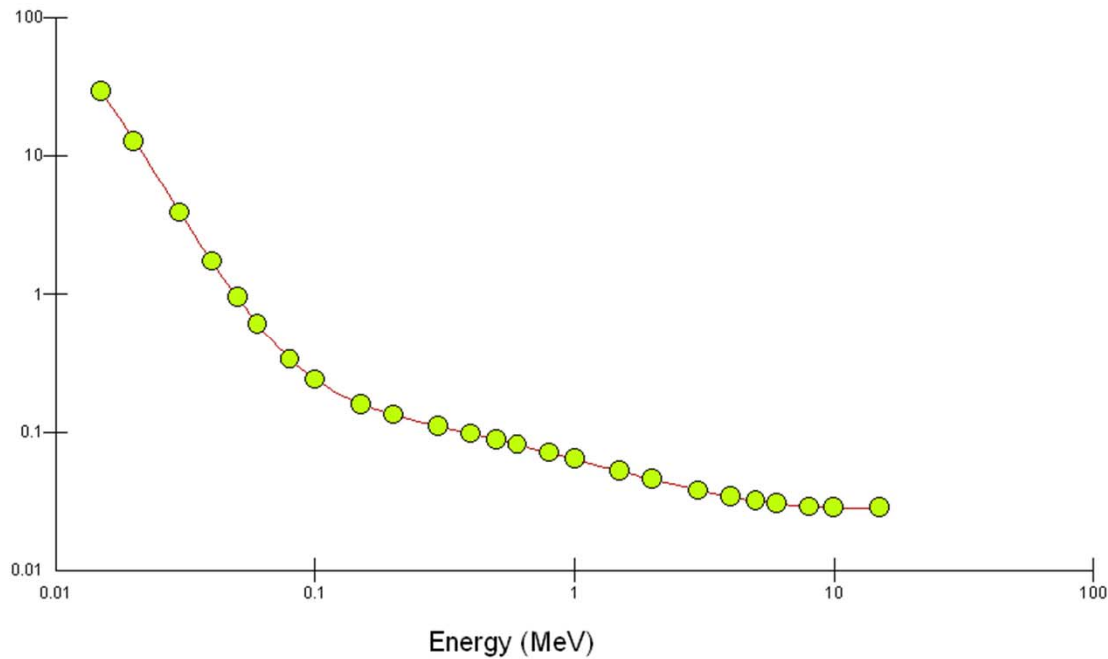
X - REMEDIATION



Mass Attenuation Coefficients (cm²/g) for FGR12 Soil



Mass Attenuation Coefficients (cm²/g) for Phosphogypsum



X - REMEDIATION

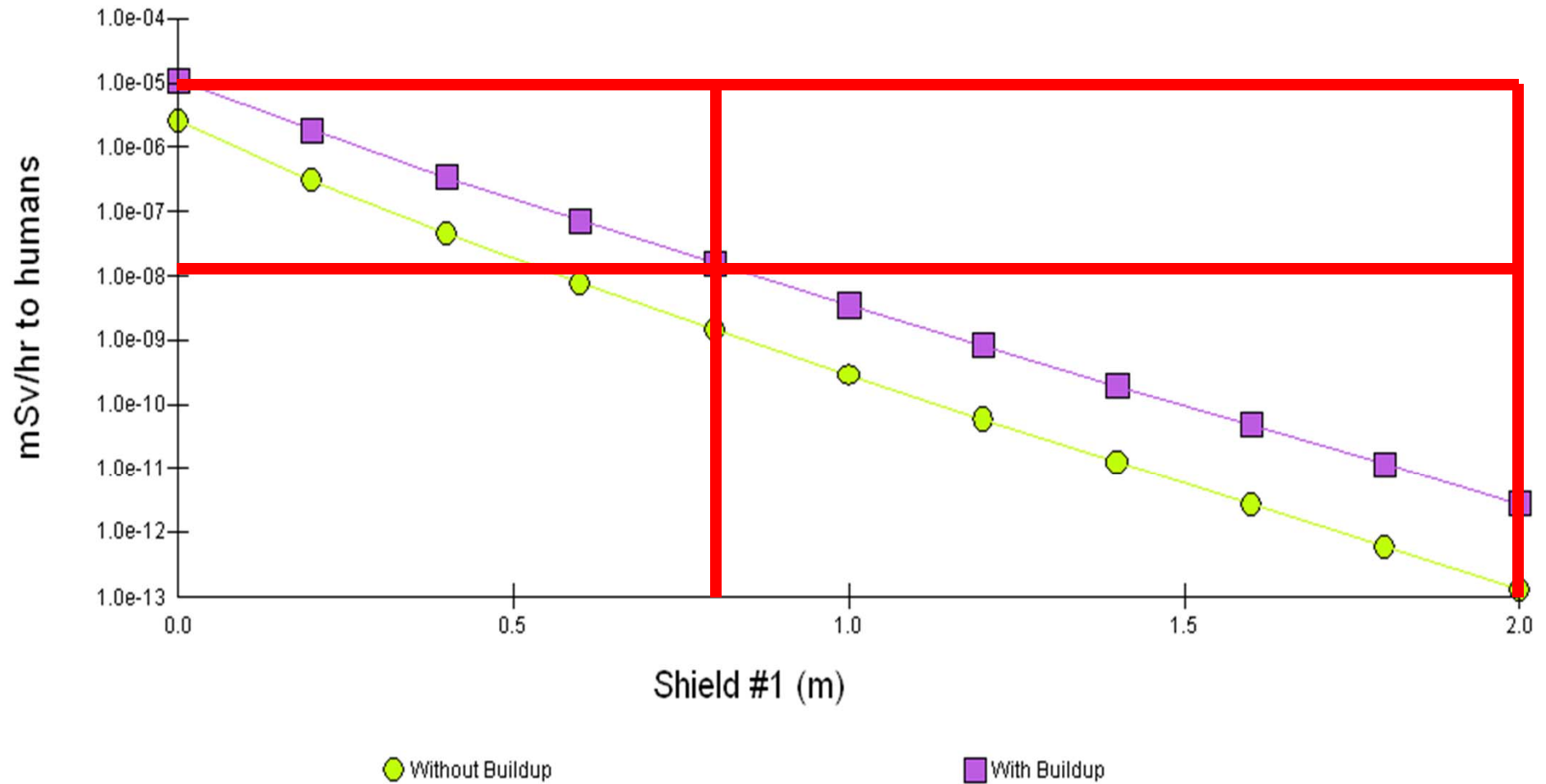
Decay of 30 years

Nuclide	curies	becquerels	$\mu\text{Ci}/\text{cm}^3$	Bq/cm^3
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

GELA

Dose Point 1 - (17.5,27.5,27.5) m



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 $10^{-7} \rightarrow 1.3E-5 \mu\text{Sv y}^{-1}$ 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

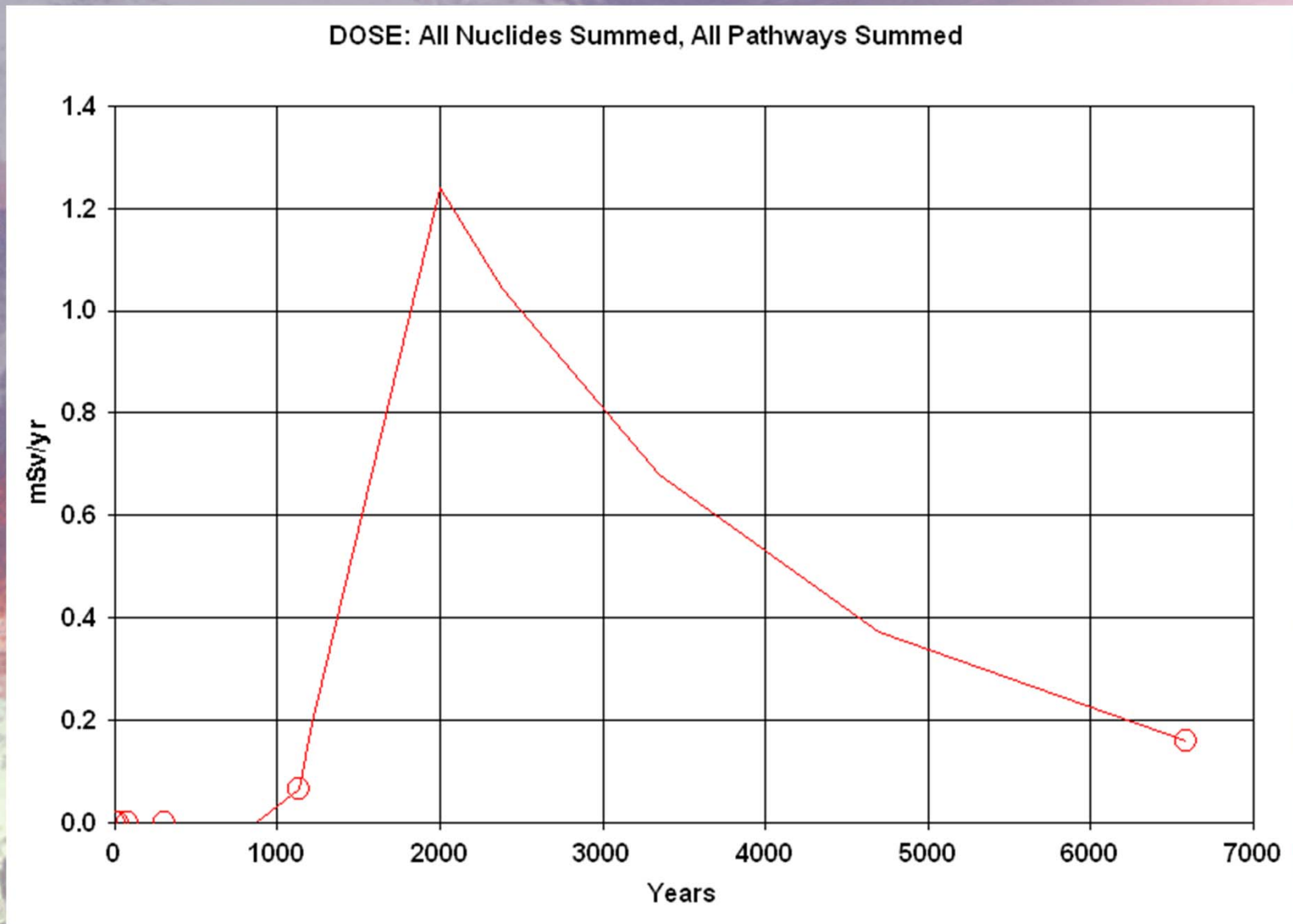
CAUTION!

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 RECOMMENDED IF DETAILED, NOT CONSERVATIVE MODELS, ARE USED.

10 - DETAILED ASSESSMENT

ANYWAY



10 - DETAILED ASSESSMENT

ANYWAY

DOSE: All Nuclides Summed, Component Pathways

