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

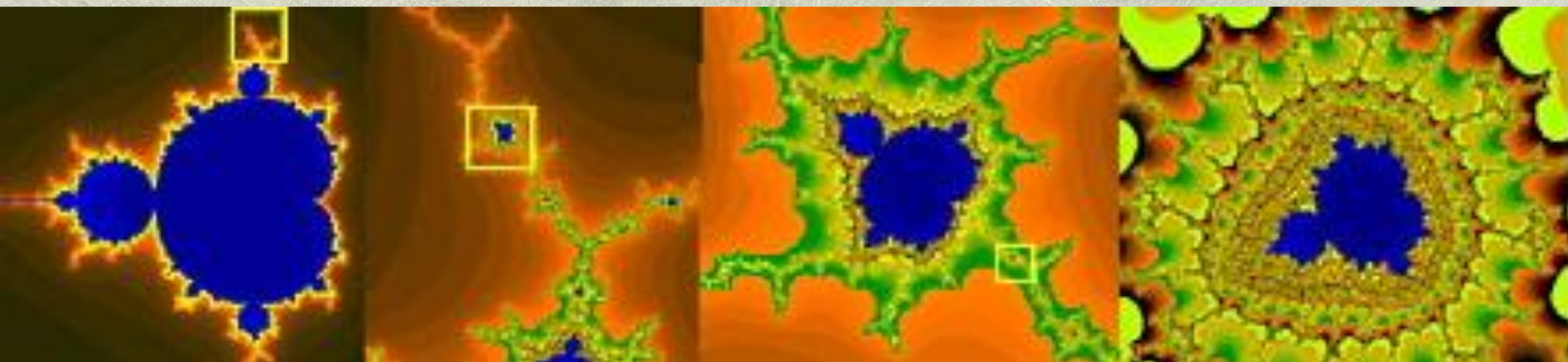
CONSIDERATIONS ON BACKGROUND SUBTRACTION IN MODELLING:

NORM

EMRAS II – 4-7 oct 2011

Juan C. Mora

Fractal behaviour of the natural background



"ALL MODELS ARE WRONG BUT SOME ARE USEFUL"

Box, GEP.
Science and statistics J. Am. Stat. Assoc. 71(356). 791-799 (1976)

A couple of measurements and a discussion made me reflect:

Should the background in modelled values be considered?

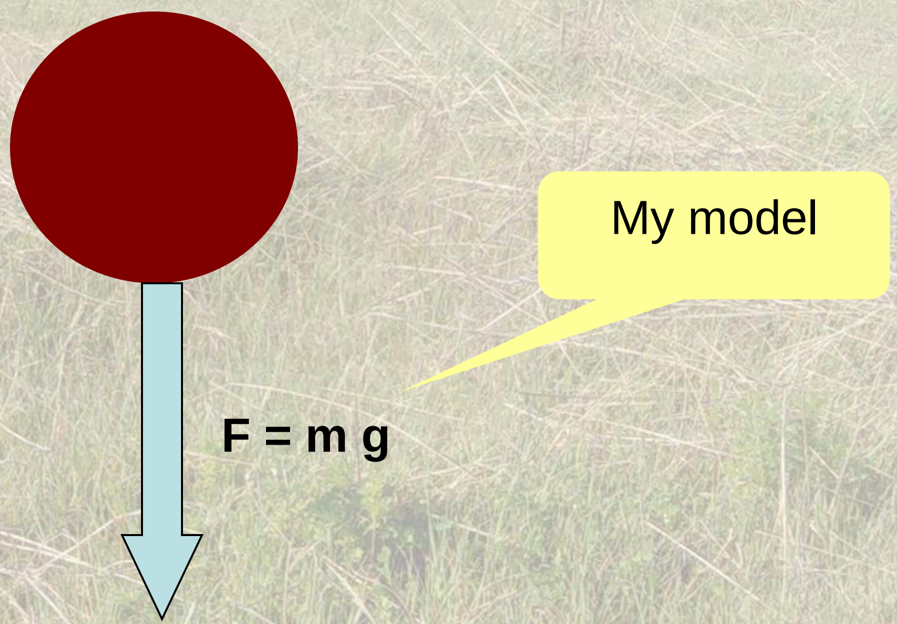
….or should it not?

I have more questions than answers (Désolé)

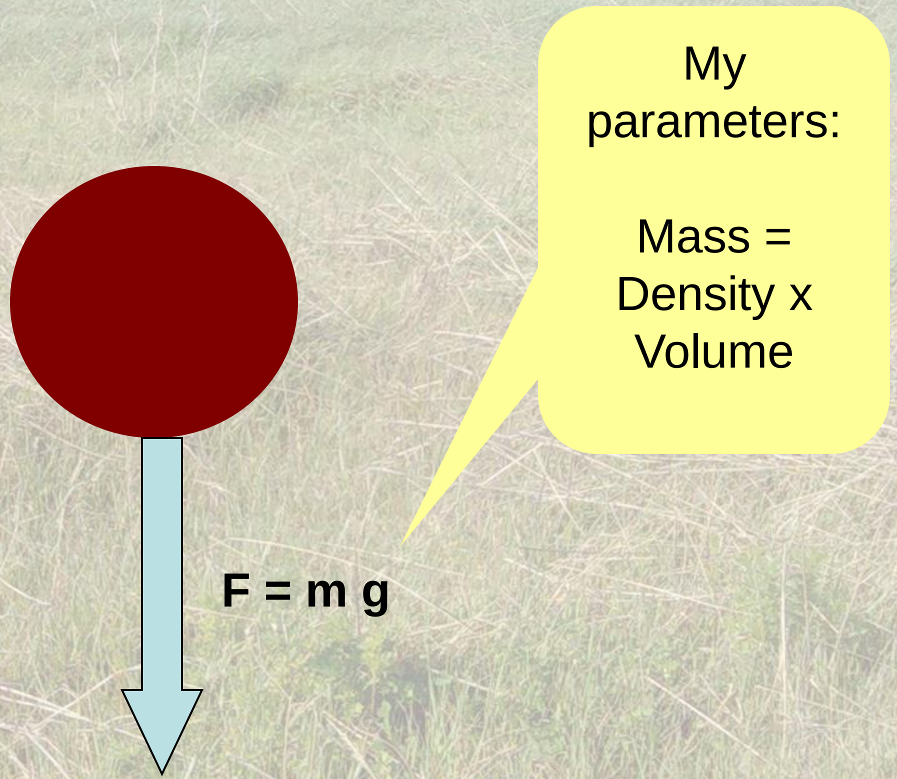
Basic idea: Is background important in my model?

an example: gravity

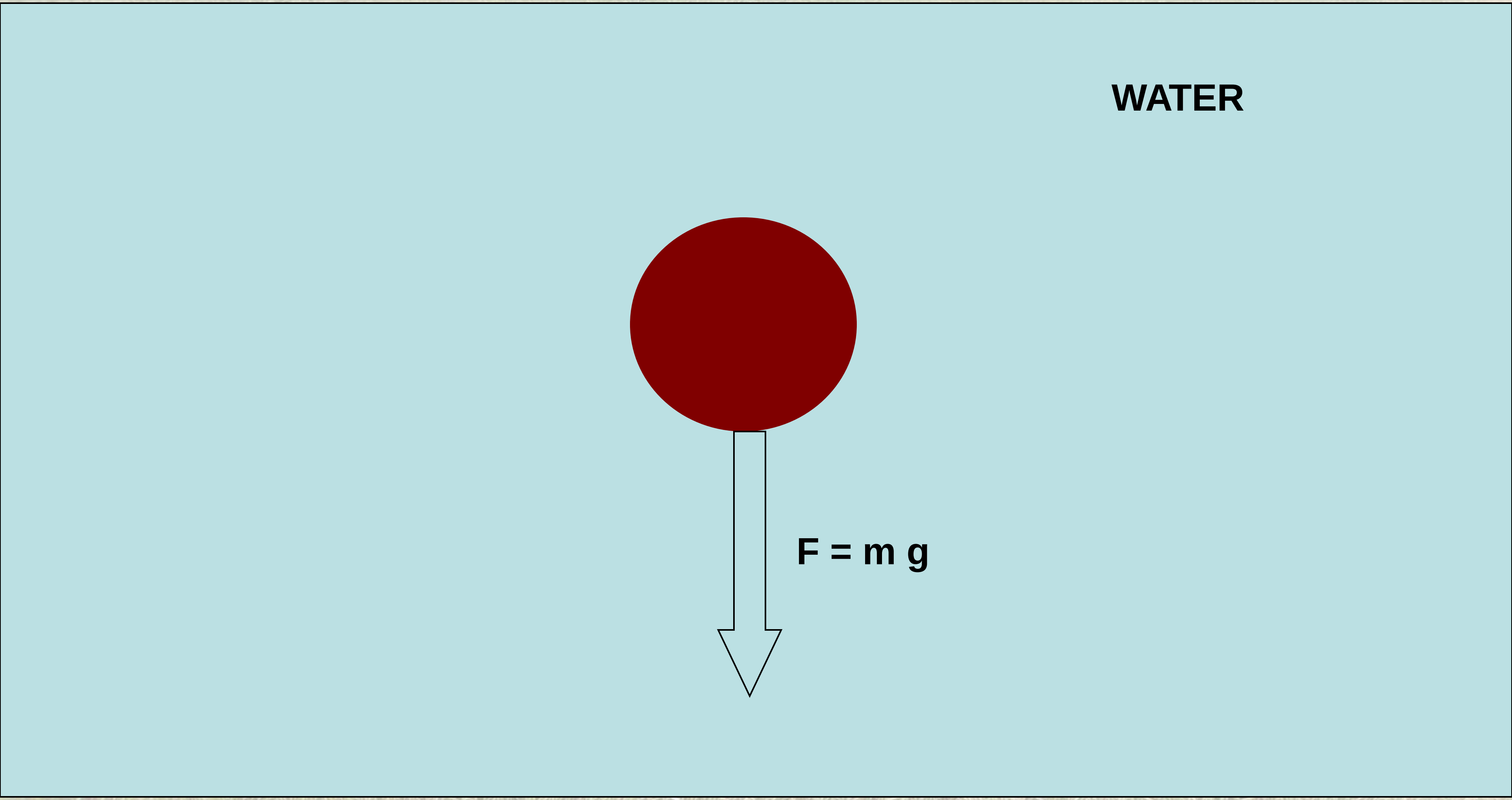
(an example: gravity)



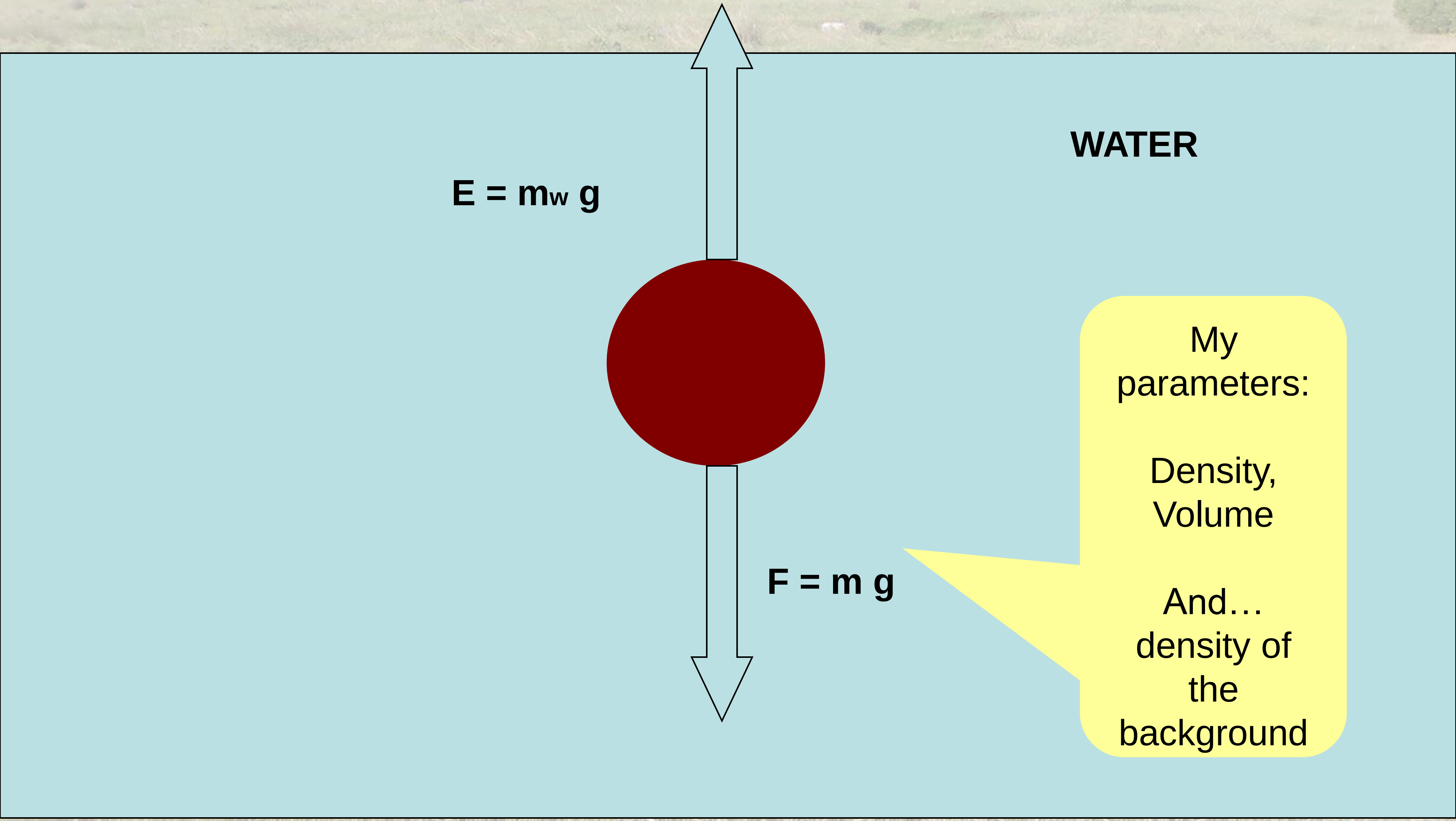
(an example: gravity)



(an example: gravity)



(an example: gravity)



$$E = \sum_T w_T \sum_R w_R \cdot D_{T,R}$$

ICRP [103]

Effective dose

$D_{T,R}$ Averaged absorbed dose in the tissue T due to the radiation R

w_R Radiation weighting factor

w_T Tissue weighting factor

Total effective dose

IAEA [OLD BSS]

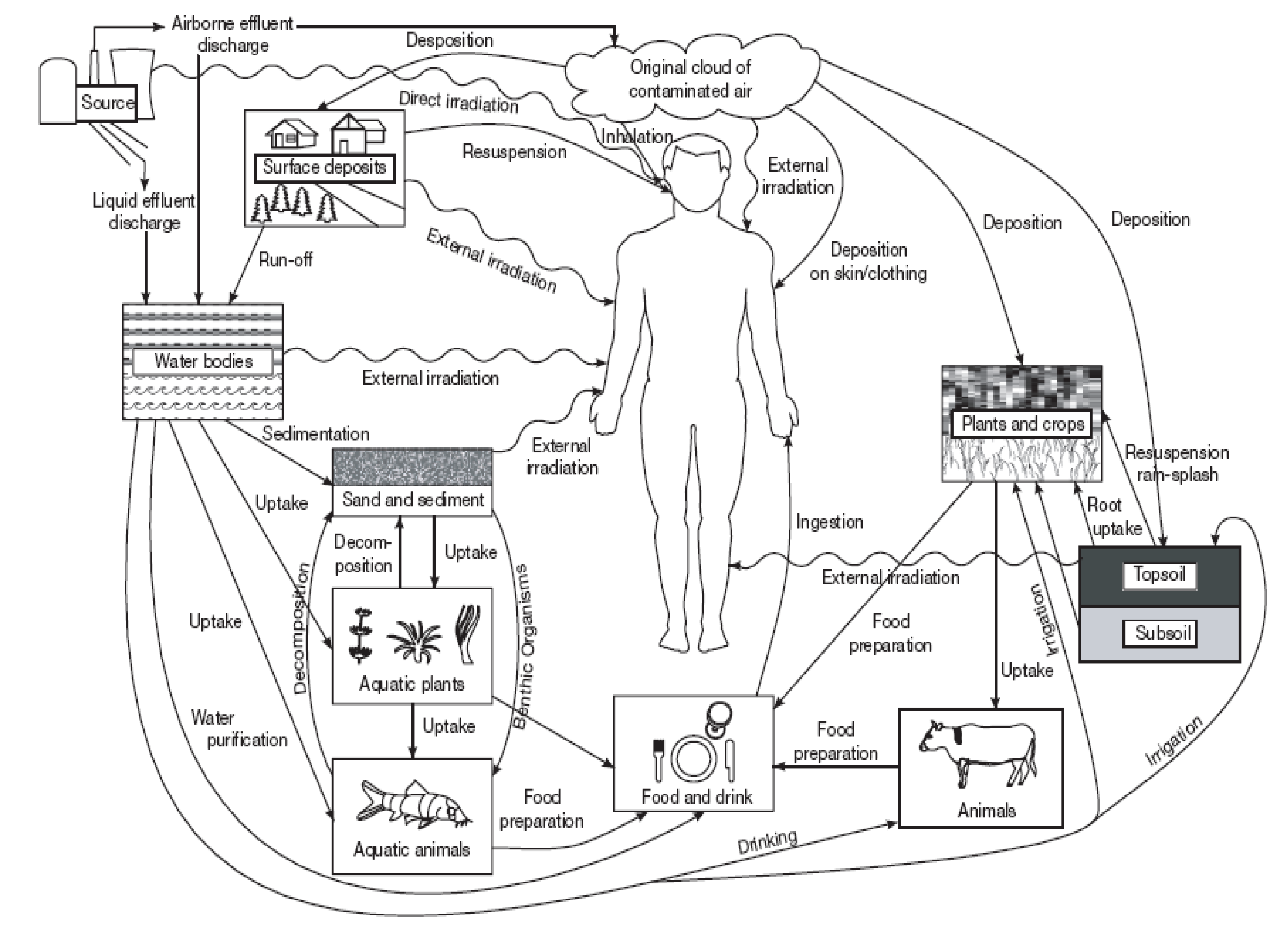
$$E_T = H_p(d) + \sum_j e(g)_{j,ing} \cdot I_{j,ing} + \sum_j e(g)_{j,inh} \cdot I_{j,inh}$$

MAIN LIMITING MAGNITUDE

1 mSv / y → public

20 mSv / y → workers

NORM


Airborne effluent discharge
Desposition
Original cloud of contaminated air
Source
Direct irradiation
Inhalation
Surface deposits
Resuspension
External irradiation
Liquid effluent discharge
Deposition
Deposition
Deposition on skin/clothing
Run-off
External irradiation
Water bodies
External irradiation
Sedimentation
External irradiation
Plants and crops
Resuspension rain-splash
Sand and sediment
Uptake
Decom-position
Uptake
Ingestion
Root uptake
Topsoil
Subsoil
External irradiation
Uptake
Decomposition
Aquatic plants
Benthic Organisms
Food preparation
Irrigation
Uptake
Water purification
Uptake
Food preparation
Aquatic animals
Food preparation
Food and drink
Animals
Irrigation
Drinking

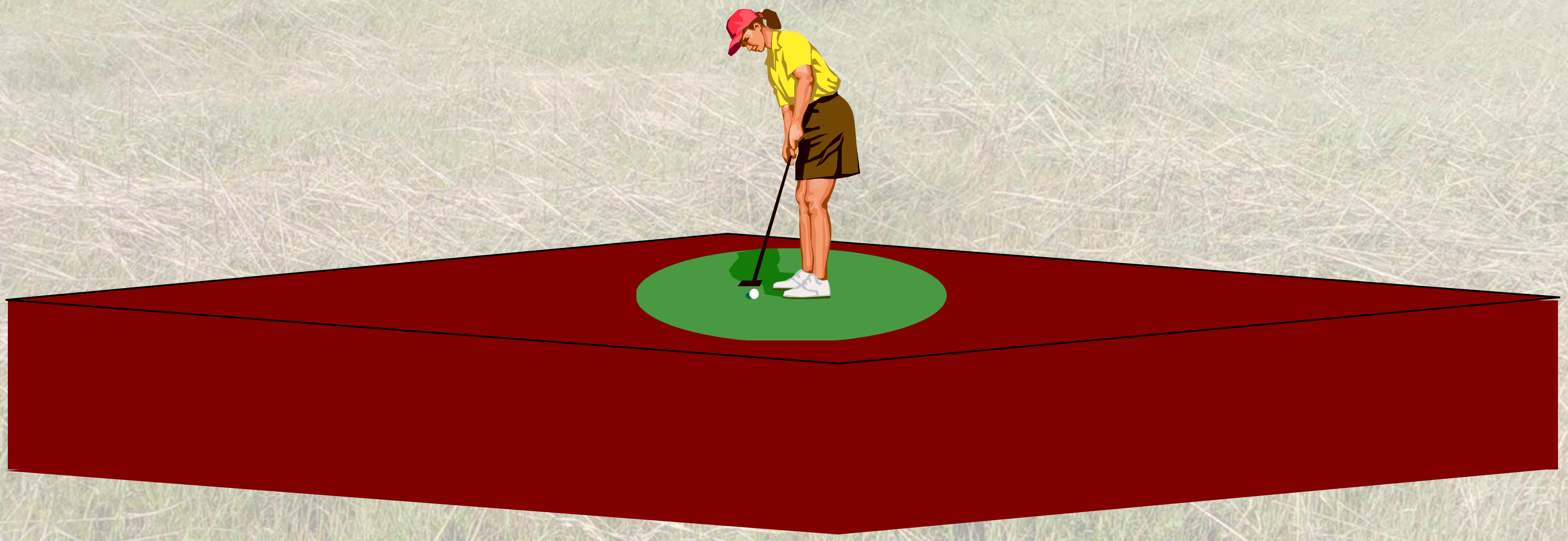
1st NORM problem:

Situation **WITH** NORM contamination

1st NORM problem:

Situation **WITHOUT** NORM contamination

What is the result if we retire the NORM?



All the exposure pathways remain

1st NORM problem:

Usually raw data are used for modelling and then the results are compared with a dose limit/constraint that is defined as an increase of the background

Is this process consistent???

2nd NORM problem:

Indoor Radon

Discussion with a colleague (a customer in fact):

1. My position: radon must be included in the dose asessments of NORM
2. His position: It must be considered apart…

2nd NORM problem:

Indoor Radon

New IAEA BSS:
3.4. Exposure due to natural sources is in general considered an existing exposure situation and is subject to the requirements stated in Section 5. However, the relevant requirements in Section 3 for planned exposure situations apply to:
a)Exposure due to material in any practice specified in para. 3.1 where the activity concentration in the material of any radionuclide in the uranium or thorium decay chains is greater than 1 Bq/g or the activity concentration of 40K is greater than 10 Bq/g;
b)Public exposure delivered by discharges or in the management of radioactive waste arising from a practice involving material as specified in para. 3.4(a);
c) Exposure due to 222Rn and its progeny and 220Rn and its progeny in workplaces in which occupational exposure due to other radionuclides in the uranium or thorium decay chains is controlled as a planned exposure situation;
d) Exposure due to 222Rn and 222Rn progeny where the annual average activity concentration of 222Rn in air in the workplace remains above the reference level established in accordance with para. 5.27 after the fulfilment of the requirement stated in para. 5.28.

Requirement 50: **Public exposure due to radon indoors**
annual average activity concentration due to 222Rn of 300 Bq m-3 dwellings
reference level not exceeding an annual average activity concentration of 222Rn of1000 Bq m-3 in workplaces

2nd NORM problem:

Indoor Radon

5. EXISTING EXPOSURE SITUATIONS

5.1. The requirements for existing exposure situations in Section 5 apply to:

(c) Exposure due to natural sources, including:
(i) 222Rn, 220Rn and their progeny, in workplaces other than those for which exposure due to other radionuclides in the uranium or thorium decay chains is controlled as a planned exposure situation, in dwellings and in other buildings with high occupancy factors for members of the public;
(ii) Radionuclides of natural origin, regardless of activity concentration, in commodities, including food, feed, drinking water, agricultural fertilizer and soil amendments, and construction material, and existing residues in the environment;
(iii) Materials, other than those stated in para. 5.1(c)(ii), in which the activity concentration of no radionuclide in either the uranium or thorium decay chains exceeds 1 Bq/g or the activity concentration of 40K does not exceed 10 Bq/g;
(iv) Exposure of aircrew and space crew to cosmic radiation.

2nd NORM problem:

Indoor Radon

Radon concentration indoors is considered as an absolute value: background+any other contribution.

The "action levels" or "reference levels" were derived in an effective dose basis:

6-10 mSv y-1

…that is in the order of magnitude of the background

ICRP 103: 200 Bq m-3 // 1000 Bq m-3

while

ICRP 65: 600 Bq m-3 // 1500 Bq m-3

2nd NORM problem:

Indoor Radon

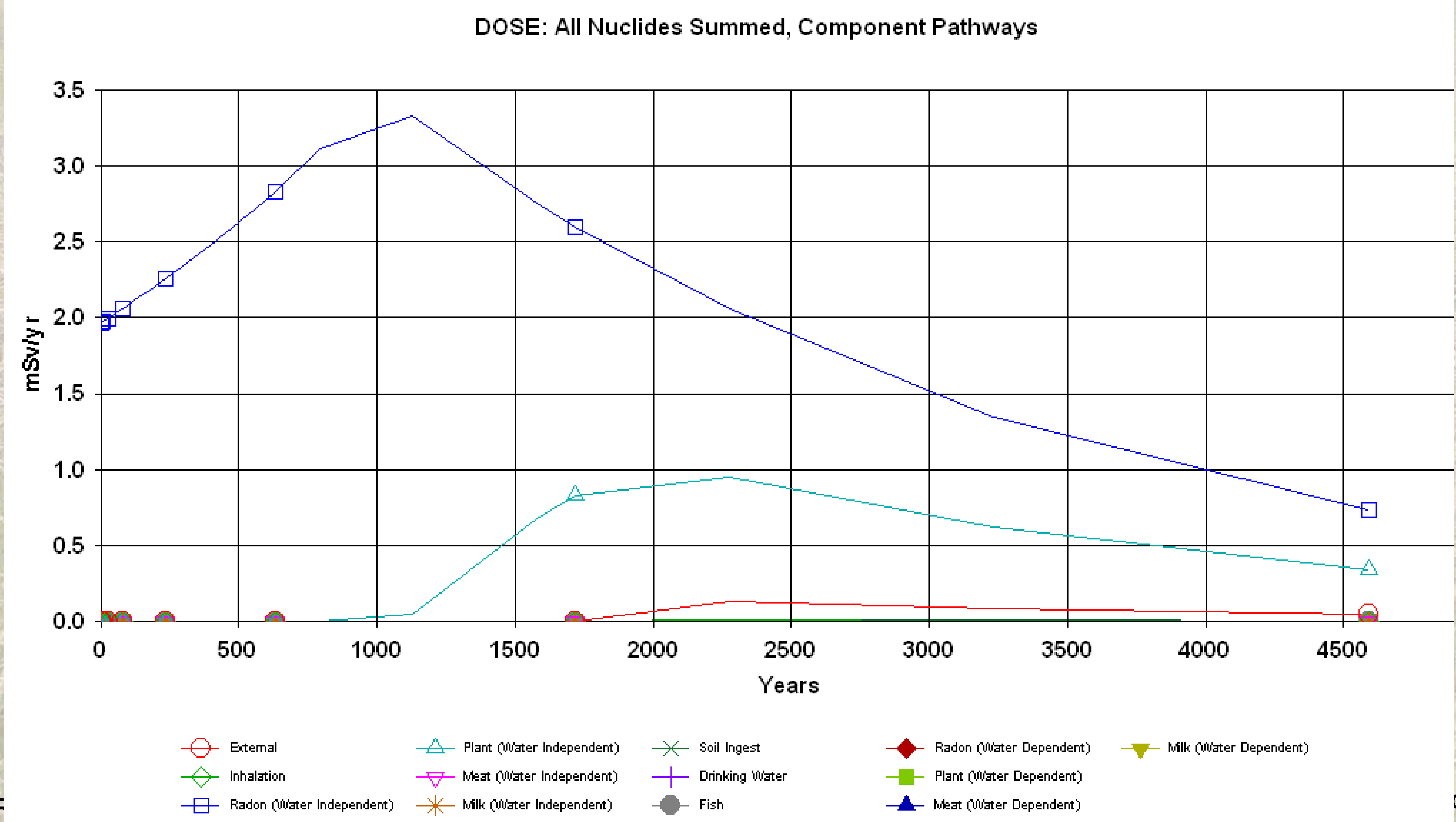
Table 5. Framework for source-related dose constraints and reference levels with examples of constraints for workers and the public from single dominant sources for all exposure situations that can be controlled.

Bands of constraints and reference levels[a] (mSv)	Characteristics of the exposure situation	Radiological protection requirements	Examples
Greater than 1 to 20	Individuals will usually receive benefit from the exposure situation but not necessarily from the exposure itself. Exposures may be controlled at source or, alternatively, by action in the exposure pathways.	Where possible, general information should be made available to enable individuals to reduce their doses. For planned situations, individual assessment of exposure and training should take place.	Constraints set for occupational exposure in planned situations. Constraints set for comforters and carers of patients treated with radiopharmaceuticals. Reference level for the highest planned residual dose from radon in dwellings.

2nd NORM problem:

Indoor Radon

Gela case: Indoor dose



2nd NORM problem:

Indoor Radon

3rd NORM problem:

Adjustment of parameters

We all adjust the parameters in the models using real measured data in order to reproduce them…without considering the influence of background

After that, we will treat the results as an increase of the effective dose over the natural background

It seems to me that something is wrong…

Are those the only examples???

Which pathways may present this problem?:

- External exposure due to deposits (shielding to nat. back.)
- Radon (consider it apart?)
- Foodstuff concentration (due to transfer from soil)?
- Transport of resuspended material?
- …

Obviously, the difference is small if background is negligible, but

… is this always the case?

Of course, it is the case with artificial radionuclides

Radon in spanish dwellings

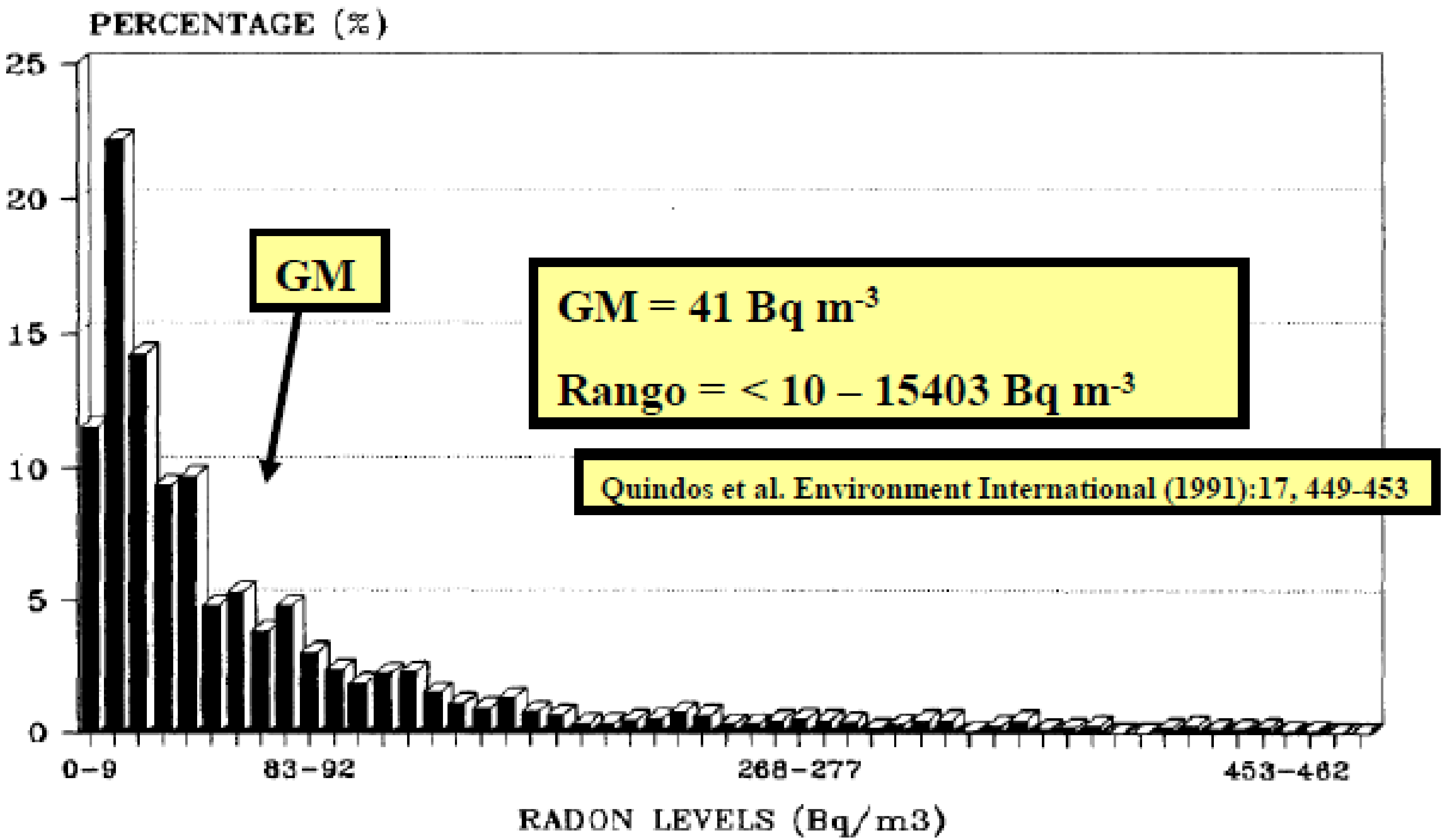


Fig. 2. Log-normal distribution of indoor-radon measurements.

Radon exposure in Spain

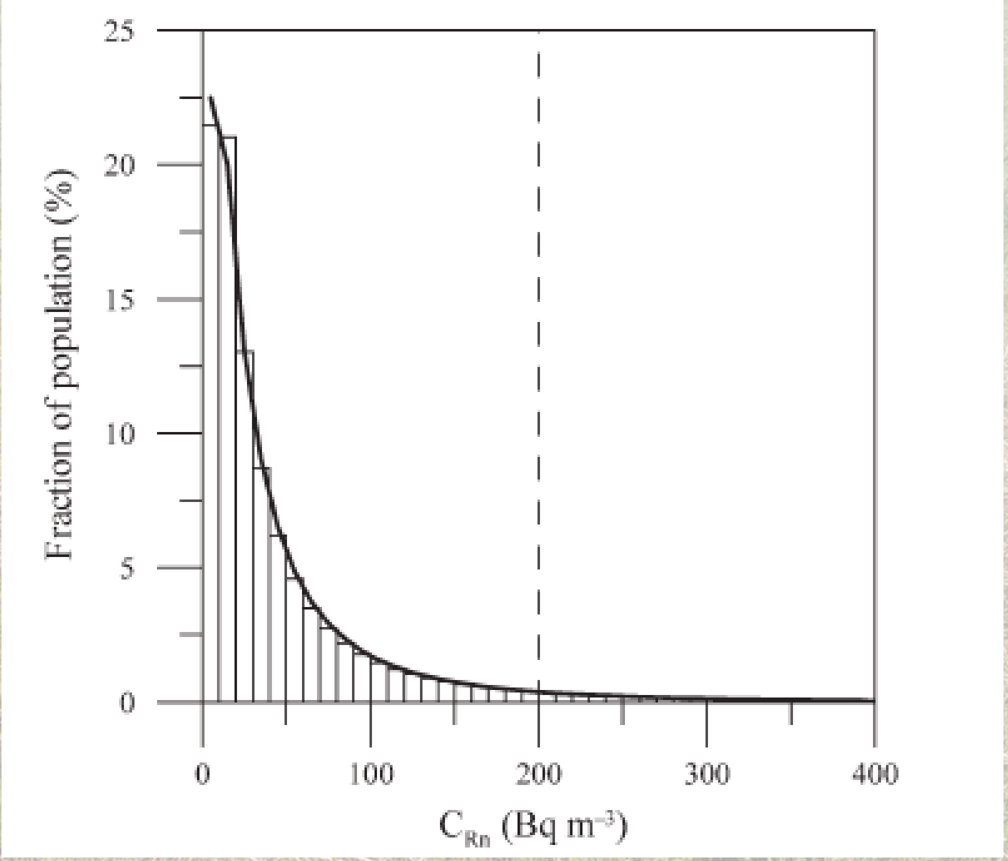


Figure 3. Distribution of population with respect to radon exposure (a) in Spain and, (b) in two Autonomous

NATURAL IONIZING RADIATION EXPOSURE OF THE SPANISH POPULATION
M. Garcı´a-Talavera et. al. Radiation Protection Dosimetry (2007), Vol. 124, No. 4, pp. 353–359

Radon variations indoor

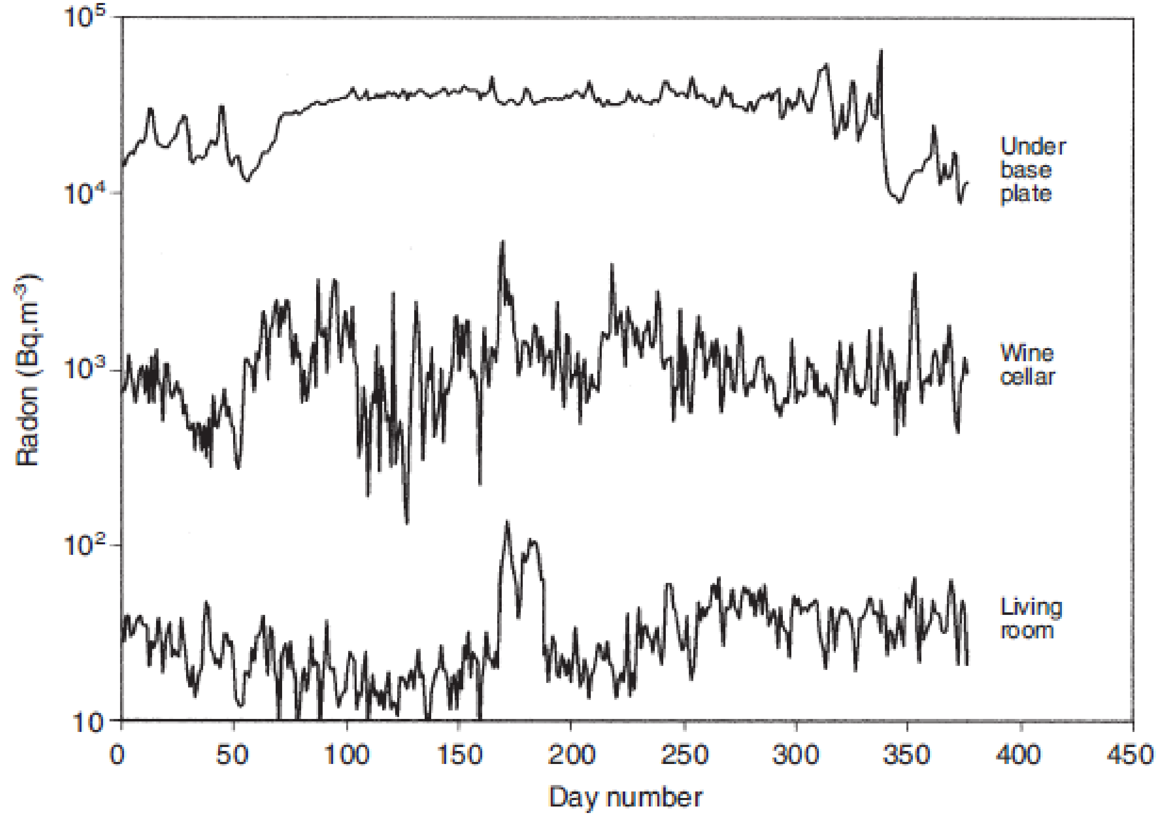


Figure 2. Radon concentration at three indoor locations, data set 1.

TEMPORAL VARIATION OF RADON LEVELS IN HOUSES AND IMPLICATIONS FOR RADON MEASUREMENT STRATEGIES
J. C. H. Miles Radiation Protection Dosimetry Vol. 93, No. 4, pp. 369–375 (2001)

Radon variations indoor: living room

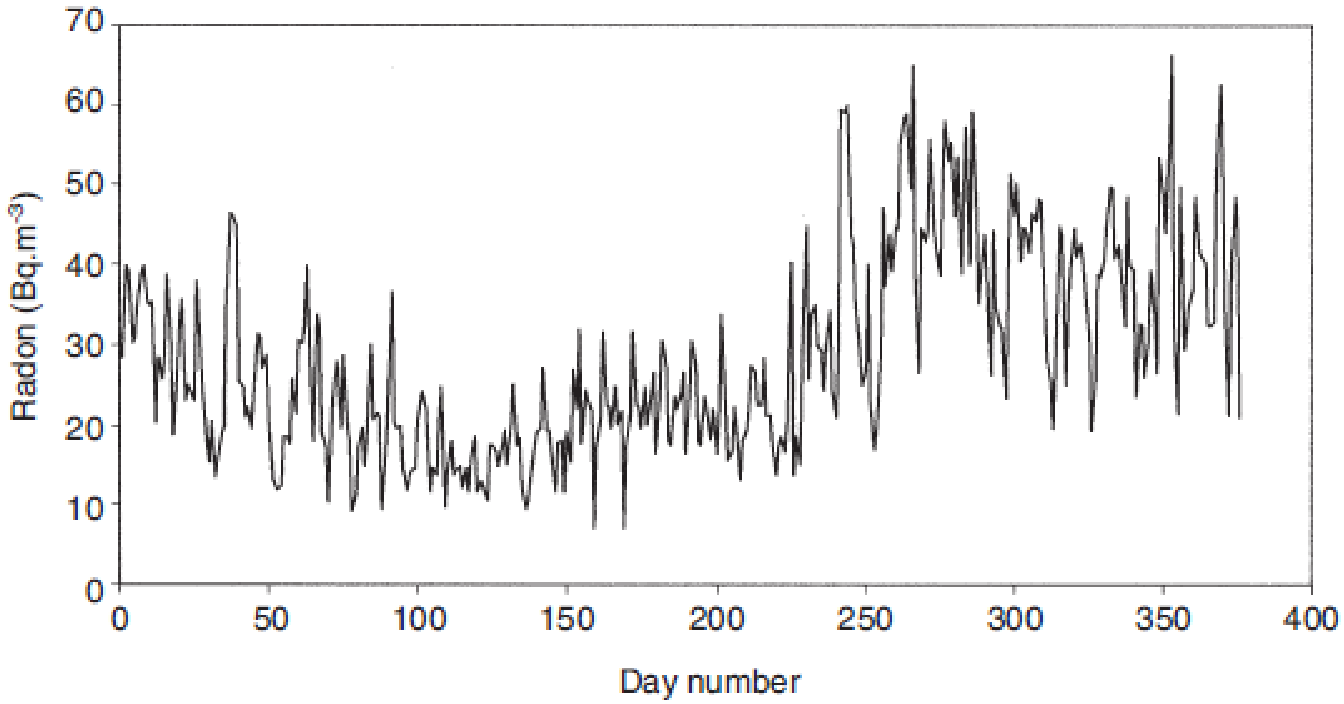


Figure 3. Radon concentration in living room, data set 1, modified data.

TEMPORAL VARIATION OF RADON LEVELS IN HOUSES AND IMPLICATIONS FOR RADON MEASUREMENT STRATEGIES
J. C. H. Miles Radiation Protection Dosimetry Vol. 93, No. 4, pp. 369–375 (2001)

Radon variations indoor: classroom

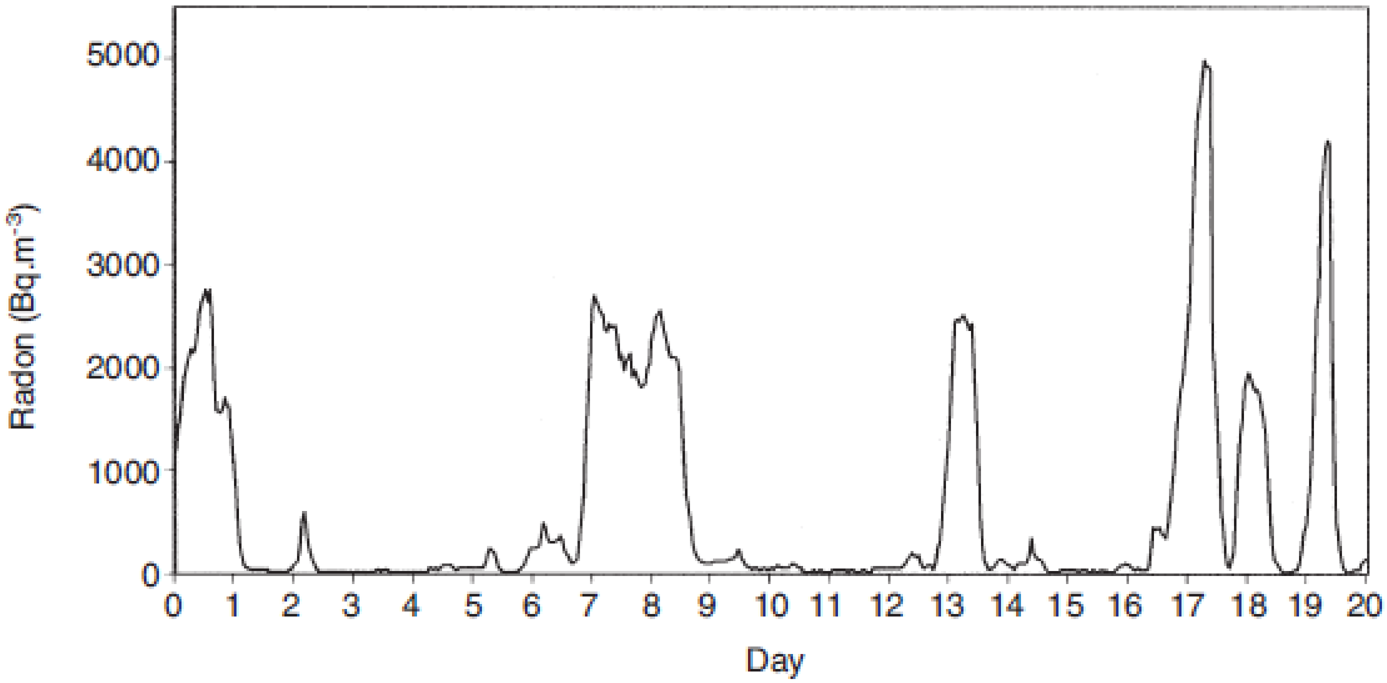


Figure 7. Variation in radon levels in a classroom of a small village school, data set 3.

TEMPORAL VARIATION OF RADON LEVELS IN HOUSES AND IMPLICATIONS FOR RADON MEASUREMENT STRATEGIES
J. C. H. Miles Radiation Protection Dosimetry Vol. 93, No. 4, pp. 369–375 (2001)

Natural "external" background

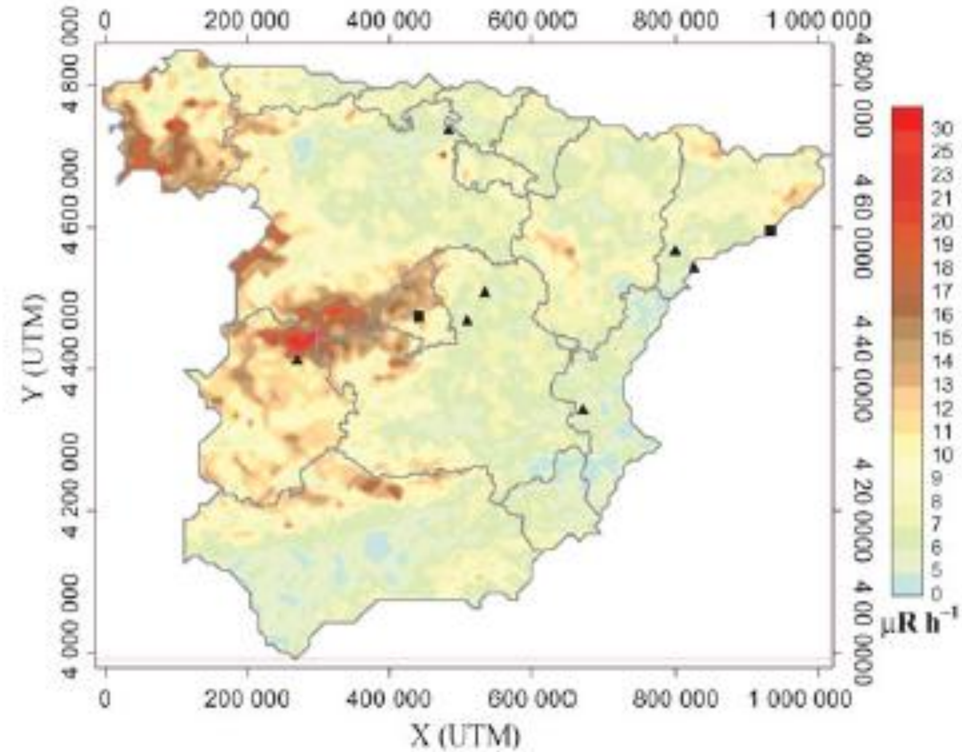


Figure 1. Exposure to gamma radiation outdoors measured at 1 m above the ground. The gray division lines correspond to Autonomous Communities borders. Symbols show the location of Madrid and Barcelona (■) and the nuclear power plants (▲).

NATURAL IONIZING RADIATION EXPOSURE OF THE SPANISH POPULATION
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Effective dose due to natural background in Spain:

The nationwide average effective dose from natural radiation sources has estimated to be 1.6 mSv y^{-1} and the variation range (0.6, 19.1) mSv y^{-1}. On average, cosmic radiation represents 18%, terrestrial gamma radiation 30%, radon and thoron inhalation 34% and ingestion 18%. These doses are significantly lower than the worldwide average value proposed in UNSCEAR[(1)] but are in good agreement with values reported for other European countries.

NATURAL IONIZING RADIATION EXPOSURE OF THE SPANISH POPULATION
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Effective dose due to natural background in Spain:

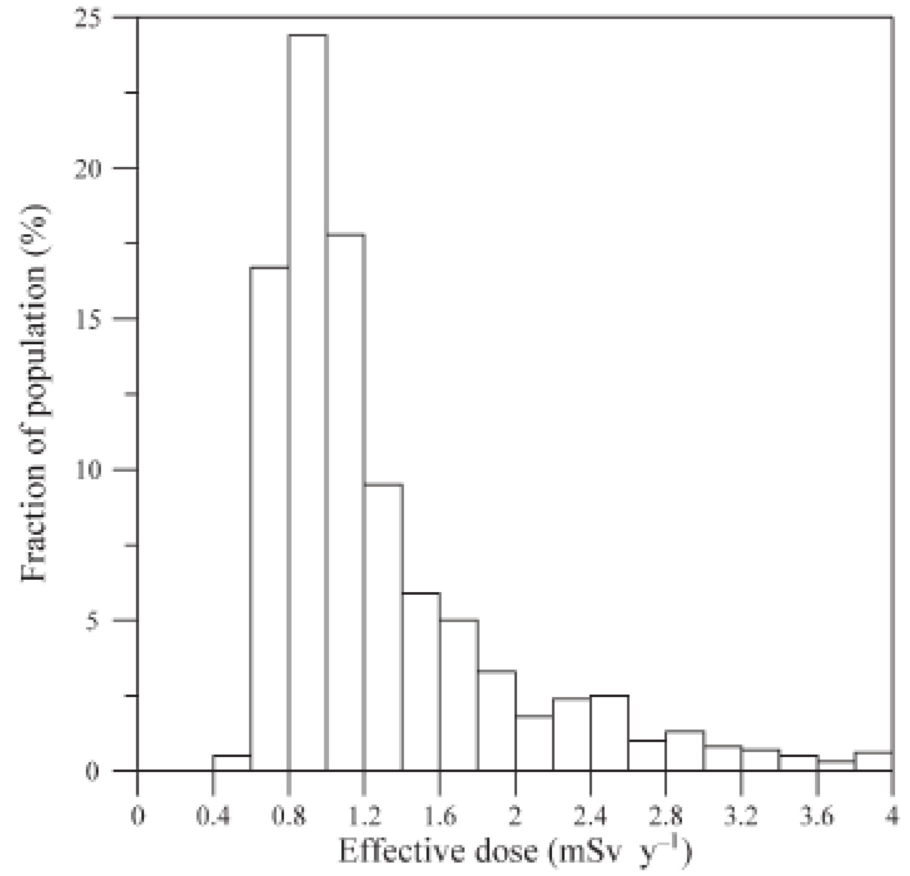

Figure 4. Distribution of population with respect to effective dose from natural radiation sources in Spain.

NATURAL IONIZING RADIATION EXPOSURE OF THE SPANISH POPULATION
M. Garcı´a-Talavera et. al. Radiation Protection Dosimetry (2007), Vol. 124, No. 4, pp. 353–359

Effective dose due to natural background worldwide:

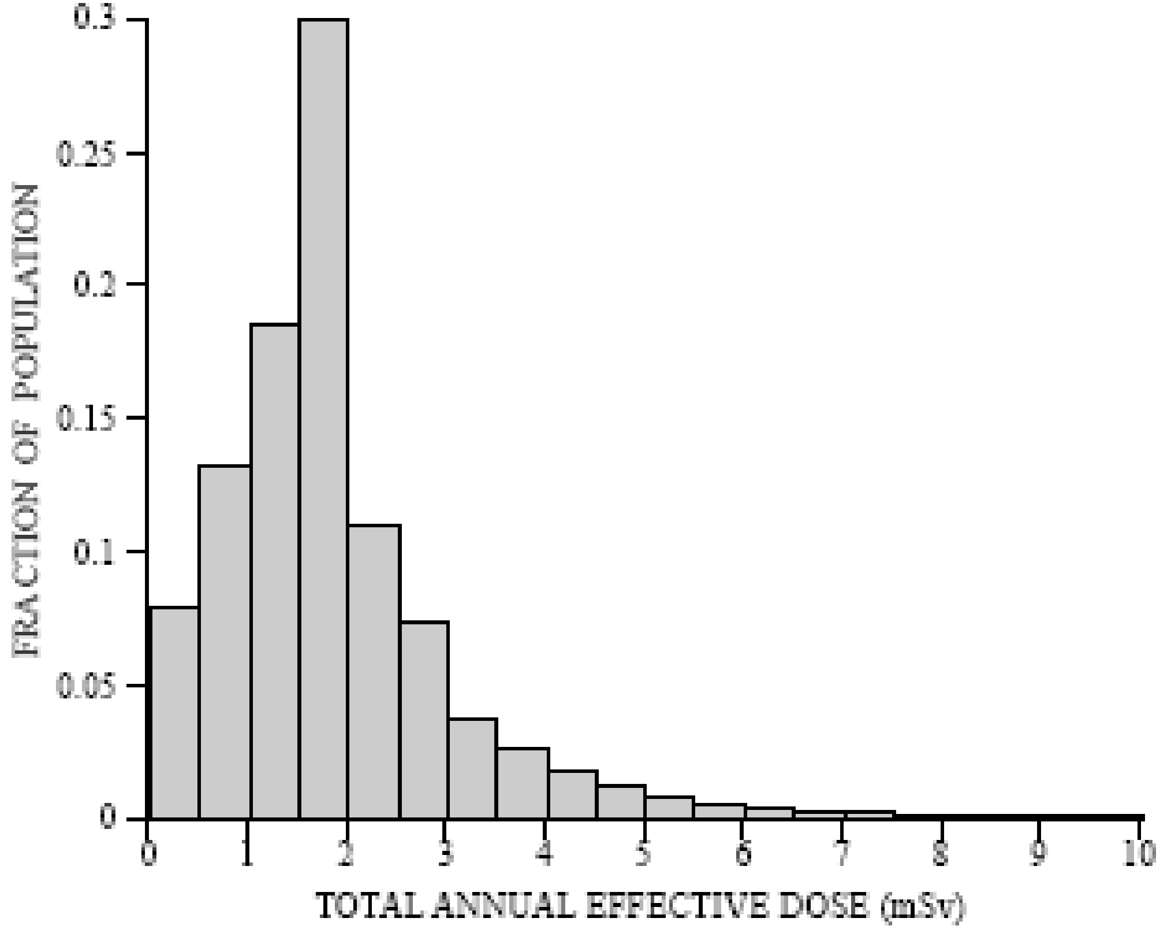

Figure XV. Distribution of population of fifteen countries with respect to total annual effective dose.

UNSCEAR 2000

Natural radioactivity in foodstuff:

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Concentrations of naturally occurring radionuclides in foods vary widely because of the differing background levels, climate, and agricultural conditions that prevail.

NORM

Table 15
Concentrations of uranium and thorium series radionuclides in foods and drinking water

Region / country	*Concentration (mBq kg⁻¹)*									*Ref.*
	^{238}U	^{230}Th	^{226}Ra	^{210}Pb	^{210}Po	^{232}Th	^{228}Ra	^{228}Th	^{235}U	
Grain products										
North America										
United States	3–23	0.9–10	7–100	33–81		0.1–2.8			0.1–1.3	[F3,M16]
Asia										
China	9.8		17	34	42	13	38		0.5	[Z1]
India	7.4–67				15–120					[D6, K6]
Japan	1.2		14			1.2				[S22]
Europe										
Germany	20–400		20-2 900	40-4 000	37–1 900					[B3, G5]
Poland	4.7–11	1.4–17	80–110	110–160	90–140	2.0–21				[P3, P7]
Romania	6.1–85		30–90	49–59	20–360	1.6–33				[B20,R20]
U.K.	6.2–35		0.7-5 200	56–120	27–260	12		180-2300		[B2]
Reference value	20	10	80	50 (100)	60 (100)	3	60	3	1	
Leafy vegetables										
North America										
United States	24	20	56	41		18			1.2	[F3,M16]
Asia										
China	16		75	360	430	23	220		0.7	[Z1]
India	61–72				320					[D6, K6]

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NORM

Table 15
Concentrations of uranium and thorium series radionuclides in foods and drinking water

Region / country	*Concentration (mBq kg^{-1})*									*Ref.*
	^{238}U	^{230}Th	^{226}Ra	^{210}Pb	^{210}Po	^{232}Th	^{228}Ra	^{228}Th	^{235}U	
Root vegetables and fruits										
North America										
United States	0.9–7.7	0.2–1.1	7–47	8–150		0.08–1.4			0.1	[F3,M16]
Asia										
China	13		63	27	29	4.7	110		0.6	[Z1]
India	0.4–77				16–140					[D6, K6]
Japan	26		11			2.3				[S22]
Europe										
Germany	10-2 900		5–9 400	20-4 900	22–5 200					[B3, G5,M18]
Italy			14–25							[D9]
Poland	0.9–10	0.7–7.5	11–215	24–93	28–210	0.7–7.1				[P3, P7]
Romania	6–120		9–190	19–44	12–140	0.4–2.1		22		[B20,R20]
U.K.	6		9.0–41	18–76						[B2]
Reference value	3	0.5	30	30 (25)	40 (30)	0.5	20	0.5	0.1	

UNSCEAR 2000

Natural radioactivity in foodstuff:

Table 2. Comparison of the average activity concentrations of ^{232}Th, ^{226}Ra, and ^{40}K in vegetables determined in the present study and from different studies

References	^{232}Th (Bq kg^{-1})	^{226}Ra (Bq kg^{-1})	^{40}K (Bq kg^{-1})	^{210}Po (Bq kg^{-1})
UNSCEAR (2000) (Leafy products-fresh weight)	15×10^{-3}	5×10^{-2}	—	10×10^{-2}
Reference values				
UNSCEAR (2000) (Root vegetables and fruits fresh weight) Reference values	5×10^{-4}	3×10^{-2}	—	4×10^{-2}
Yen-Chuan Kuo et al. (1997) (fresh weight)	—	3×10^{-2}	—	—
Badran et al. (2003) (fresh weight)	—	—	106.3	—
[8] and [9] (dry weight)	17.38	10.14	4374.88	3.11
This study (dry weight)	10.17	27.74	1497.88	14.99

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Radioactivity in soils and various foodstuffs from the Gediz River Basin of Turkey

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Natural radioactivity in soil:

Median worldwide values:
K40 = 400, U238 = 35, and Th232 = 30 Bq kg-1

Population weighted values:
K40 = 420, U238 = 33, and Th232 = 45 Bq kg-1

UNSCEAR 2000

Natural radioactivity in soil:

Table 5
Natural radionuclide content in soil
Data not referenced are from UNSCEAR Survey of Natural Radiation Exposures

Region / country	*Population in 1996 (10^6)*	*Concentration in soil (Bq kg^{-1})*							
		^{40}K		*^{238}U*		*^{226}Ra*		*^{232}Th*	
		Mean	*Range*	*Mean*	*Range*	*Mean*	*Range*	*Mean*	*Range*
Africa									
Algeria	28.78	370	66−1 150	30	2−110	50	5−180	25	2−140
Egypt	63.27	320	29−650	37	6−120	17	5−64	18	2−96
North America									
Costa Rica	3.50	140	6−380	46	11−130	46	11−130	11	1−42
United States [M7]	269.4	370	100−700	35	4−140	40	8−160	35	4−130
South America									
Argentina	35.22	650	540−750						
East Asia									
Bangladesh	120.1	350	130−610			34	21−43		
China [P16, Z5]	1232	440	9−1 800	33	2−690	32	2−440	41	1−360
– Hong Kong SAR [W12]	6.19	530	80−1 100	84	25−130	59	20−110	95	16−200
India	944.6	400	38−760	29	7−81	29	7−81	64	14−160
Japan [M5]	125.4	310	15−990	29	2−59	33	6−98	28	2−88
Kazakstan	16.82	300	100−1 200	37	12−120	35	12−120	60	10−220
Korea, Rep. of	45.31	670	17−1 500						
Malaysia	20.58	310	170−430	66	49−86	67	38−94	82	63−110
Thailand	58.70	230	7−712	114	3−370	48	11−78	51	7−120
West Asia									
Armenia	3.64	360	310−420	46	20−78	51	32−77	30	29−60
Iran (Islamic Rep. of)	69.98	640	250−980			28	8−55	22	5−42
Syrian Arab Republic	14.57	270	87−780	23	10−64	20	13−32	20	10−32

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Natural radioactivity in soil:

Region / country	Population in 1996 (10^6)	Concentration in soil (Bq kg^{-1}) ^{40}K Mean	^{40}K Range	^{238}U Mean	^{238}U Range	^{226}Ra Mean	^{226}Ra Range	^{232}Th Mean	^{232}Th Range
North Europe									
Denmark [N5]	5.24	460	240–610			17	9–29	19	8–30
Estonia	1.47	510	140–1 120			35	6–310	27	5–59
Lithuania	3.73	600	350–850	16	3–30			25	9–46
Norway	4.35	850		50		50		45	
Sweden	8.82	780	560–1 150			42	12–170	42	14–94
West Europe									
Belgium	10.16	380	70–900			26	5–50	27	5–50
Germany	81.92		40–1 340		11–330		5–200		7–134
Ireland [M6]	3.55	350	40–800	37	8–120	60	10–200	26	3–60
Luxembourg	0.41	620	80–1 800			35	6–52	50	7–70
Netherlands [K2]	15.58		120–730		5–53	23	6–63		8–77
Switzerland	7.22	370	40–1 000	40	10–150	40	10–900	25	4–70
United Kingdom [B2]	58.14		0–3 200		2–330	37			1–180
East Europe									
Bulgaria	8.47	400	40–800	40	8–190	45	12–210	30	7–160
Hungary	10.05	370	79–570	29	12–66	33	14–76	28	12–45
Poland [J7]	38.60	410	110–970	26	5–120	26	5–120	21	4–77
Romania [I12]	22.66	490	250–1 100	32	8–60	32	8–60	38	11–75
Russian Federation	148.1	520	100–1 400	19	0–67	27	1–76	30	2–79
Slovakia	5.35	520	200–1 380	32	15–130	32	12–120	38	12–80
South Europe									
Albania	3.40	360	15–1 150	23	6–96			24	4–160
Croatia	4.50	490	140–710	110	83–180	54	21–77	45	12–65
Cyprus	0.76	140	0–670			17	0–120		
Greece	10.49	360	12–1 570	25	1–240	25	1–240	21	1–190
Portugal	9.81	840	220–1 230	49	26–82	44	8–65	51	22–100
Slovenia	1.92	370	15–1 410			41	2–210	35	2–90
Spain	39.67	470	25–1 650			32	6–250	33	2–210
Median		400	140–850	35	16–110	35	17–60	30	11–64
Population-weighted average		420		33		32		45	

UNSCEAR 2000

Natural radioactivity in soil:

Table 8
Outdoor absorbed dose rates in air inferred from concentrations of radionuclides in soil compared with direct measurements

Country	*Absorbed dose rate in air (nGy h⁻¹)*		
	From soil concentrations	*From direct measurements*	*Ratio soil/measurements*
Luxembourg	72	49	1.5
Ireland	58	42	1.4
Sweden	77	56	1.4
India	69	56	1.2
China (Hong Kong SAR)	107	87	1.2
Norway	86	73	1.2
United States	55	47	1.2
Switzerland	49	45	1.1
Kazakstan	65	63	1.0
Belgium	44	43	1.0
Portugal	86	84	1.0
Malaysia	93	92	1.0
Egypt	32	32	1.0
Slovenia	56	56	1.0
Romania	58	59	1.0
China	58	62	0.9
Poland	42	45	0.9
Estonia	54	59	0.9
Slovakia	60	67	0.9
Japan	45	53	0.8
Lithuania	48	58	0.8
Thailand	62	77	0.8
Russian Federation	52	65	0.8
Bulgaria	56	70	0.8
Hungary	48	61	0.8
Algeria	54	70	0.8
Iran (Islamic Rep. of)	53	71	0.7
Denmark	39	52	0.7
Spain	54	76	0.7
Greece	39	56	0.7
Albania	40	71	0.6
Syrian Arab Republic	33	59	0.6

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Juan C. Mora

Natural radioactivity in soil:

Table 11
Areas of high natural radiation background

Country	*Area*	*Characteristics of area*	*Approximate population*	*Absorbed dose rate in air [a] (nGy h⁻¹)*	*Ref.*
Brazil	Guarapari Mineas Gerais and Goias Pocos de Caldas Araxá	Monazite sands; coastal areas Volcanic intrusives	73 000 350	90-170 (streets) 90-90 000 (beaches) 110-1 300 340 average 2 800 average	[P4, V5] [A17, P4] [V5]
China	Yangjiang Quangdong	Monazite particles	80 000	370 average	[W14]
Egypt	Nile delta	Monazite sands		20-400	[E3]
France	Central region Southwest	Granitic, schistous, sandstone area Uranium minerals	7 000 000	20-400 10-10 000	[J3] [D10]
India	Kerala and Madras Ganges delta	Monazite sands, coastal areas 200 km long, 0.5 km wide	100 000	200-4 000 1 800 average 260-440	[S19, S20] [M13]
Iran (Islamic Rep. of)	Ramsar Mahallat	Spring waters	2 000	70-17 000 800-4 000	[S21] [S58]
Italy	Lazio Campania Orvieto town South Toscana	Volcanic soil	5 100 000 5 600 000 21 000 ~100 000	180 average 200 average 560 average 150-200	[C12] [C12] [C20] [B21]
Niue Island	Pacific	Volcanic soil	4 500	1 100 maximum	[M14]
Switzerland	Tessin, Alps, Jura	Gneiss, verucano, ^{226}Ra in karst soils	300 000	100-200	[S51]

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Possible solutions:

1.- Obtain and Substract the background measurements…even better if data and background are distributions

2.- Model the situation without considering the background, after model the situation without considering the contaminated material and finally substract both results.

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Thank you for your attention