Radiological risk assessment to workers of a dicalcium phosphate industry

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EU NORM 2 Symposium, 17-19 June 2014, Prague

OUTLINE

INTRODUCTION

- The phosphate industry and the Dicalcium Phosphate (DCP) production
- The Spanish legal framework concerning NORM

AIMS OF THE STUDY

DEPOSIT OF PHOSPHATE ROCK (PR) IN THE PORT OF TARRAGONA

- Sampling and analytical methods
- Principal results on dose assessment to workers

DCP PRODUCTION PLANT

- Sampling
- Principal results on dose assessment to workers

CONCLUSIONS

INTRODUCTION

European phosphate production

European Phosphate Industry Map

- Located in Flix, North East Spain (South Catalonia)
- 98 km from the Ebro River mouth

INTRODUCTION

The production and storage of dicalcium phosphate

- Extract fluorides
- Rise the mineral concentration
- Increase the biological availability

Phosphate rock (PR)

1000-1500 Bq kg^{-1} of ^{238}U and its decay chain daughters

Wet process (acid leaching)

Thermal process (elemental P by furnancing)

HCl

H_2SO_4

H_3PO_4 Fertilizers Feed supplements

DCP

$$Ca_3(PO_4)_2 + 4HCl \rightarrow Ca(H_2PO_4)_2 + 2CaCl_2$$

$$Ca(H_2PO_4)_2 + CaCO_3 + 3H_2O \rightarrow 2(CaH(PO_4) \cdot H_2O) + CO_2$$

INTRODUCTION

The production and storage of dicalcium phosphate

1000-1500 Bq kg^{-1} of ^{238}U and its decay chain daughters

- Extract fluorides
- Rise the mineral concentration
- Increase the biological availability

- PR imported from Morocco
- Stored in an outdoor deposit of 3000 m^2
- Transported to the DCP plant weekly

INTRODUCTION

Spanish legal framework in NORM

EURATOM 29/96

RD 783/2001

RD 1439/2010

BOLETÍN OFICIAL DEL ESTADO

Núm. 279 Jueves 18 de noviembre de 2010 Sec. I. Pág. 96395

I. DISPOSICIONES GENERALES

MINISTERIO DE LA PRESIDENCIA

17709 *Real Decreto 1439/2010, de 5 de noviembre, por el que se modifica el Reglamento sobre protección sanitaria contra radiaciones ionizantes, aprobado por Real Decreto 783/2001, de 6 de julio.*

El Reglamento sobre protección sanitaria contra radiaciones ionizantes vigente fue aprobado por el Real Decreto 783/2001, de 6 de julio. Mediante este Reglamento, junto

Established for the first time the need of performing studies in workplaces to determine if there exist a significant increment of the exposure to natural radioactivity to the workers and public

INTRODUCTION

Previous studies in DCP production plant

Radiological characterization

- Characterize the raw material, products and by-products (^{226}Ra, ^{210}Pb and ^{210}Po).
- Assess the temporal variability.
- Evaluate the radionuclide fluxes (^{226}Ra, ^{210}Pb and ^{210}Po).

AIMS OF THE STUDY

to establish the radiological risks derived from the external and internal doses received for workers:

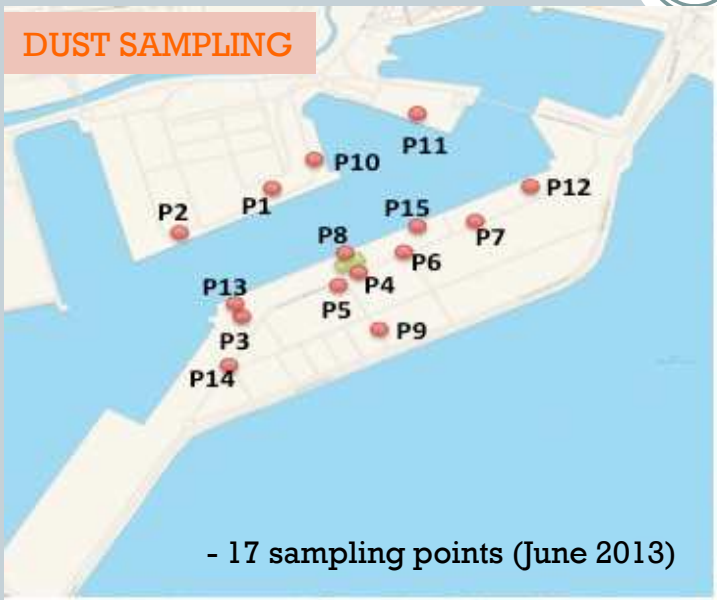
PR deposit in the Port of Tarragona

DCP production plant

OUTDOOR DEPOSIT OF PR IN PORT OF TARRAGONA

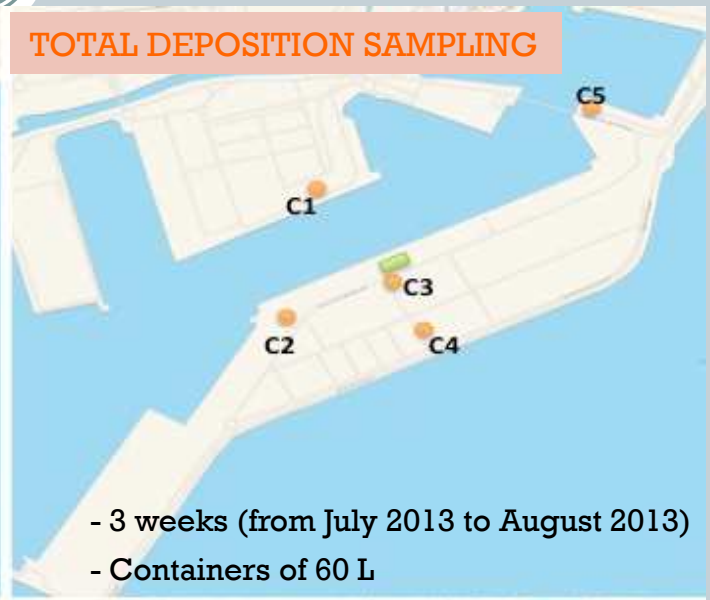
SAMPLING

DUST SAMPLING



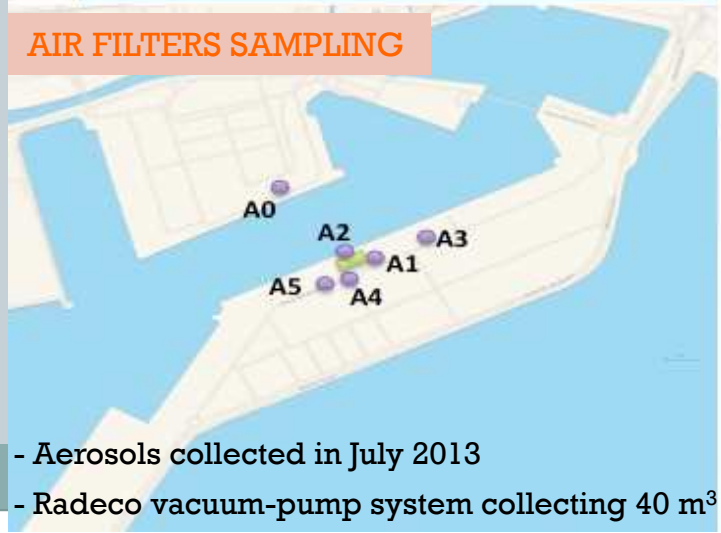
- 17 sampling points (June 2013)

TOTAL DEPOSITION SAMPLING



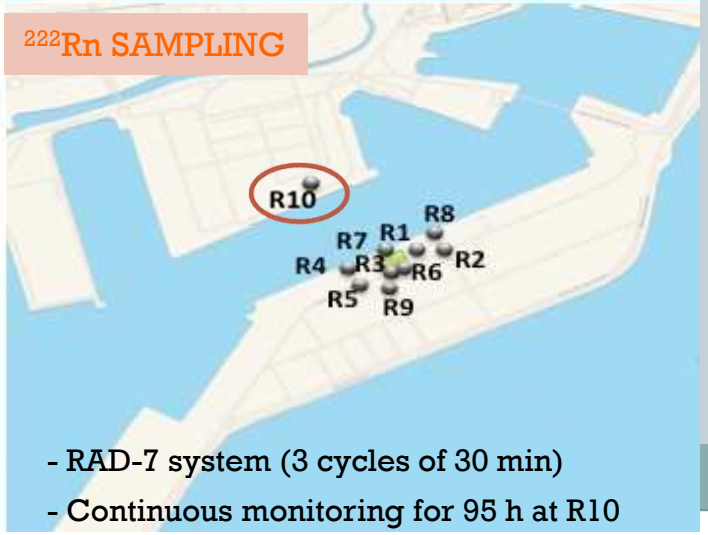
- 3 weeks (from July 2013 to August 2013)
- Containers of 60 L

AIR FILTERS SAMPLING



- Aerosols collected in July 2013
- Radeco vacuum-pump system collecting 40 m^3

^{222}Rn SAMPLING



- RAD-7 system (3 cycles of 30 min)
- Continuous monitoring for 95 h at R10

OUTDOOR DEPOSIT OF PR IN PORT OF TARRAGONA

SAMPLING

- Portable gamma detector (Canberra Inspector 1000)

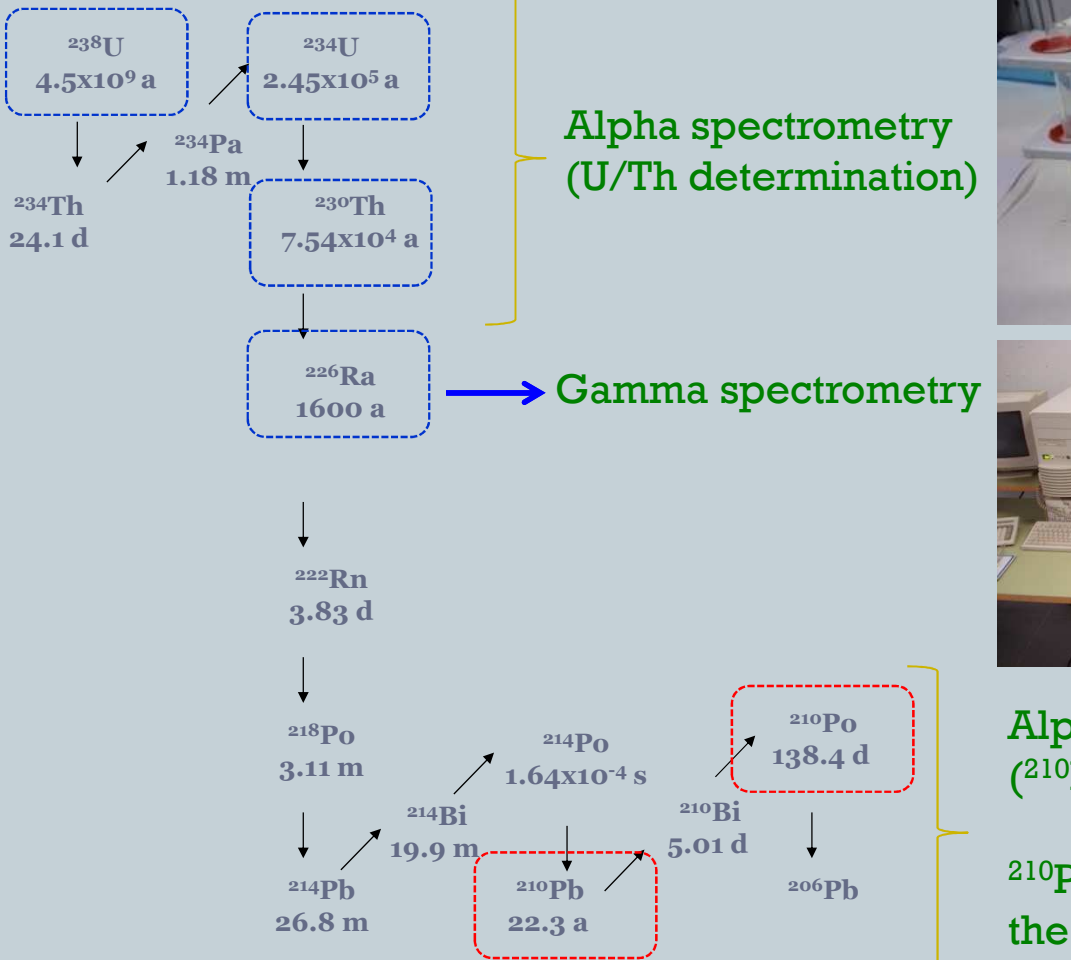
OUTDOOR DEPOSIT OF PR IN PORT OF TARRAGONA

SAMPLING

- Air filters sampling (Radeco vacuum system)
- Personal Dose (Canberra Personal Dosimeters)

OUTDOOR DEPOSIT OF PR IN PORT OF TARRAGONA

RADIOACTIVITY MEASUREMENTS

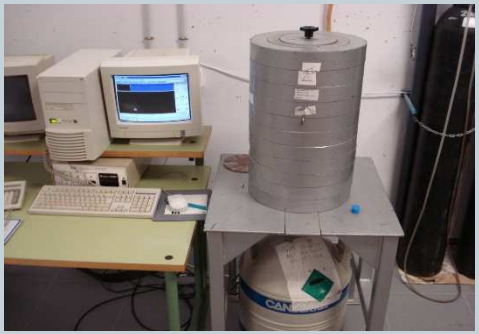


Alpha spectrometry (U/Th determination)

Gamma spectrometry

UTEVA resins

PIPS detectors



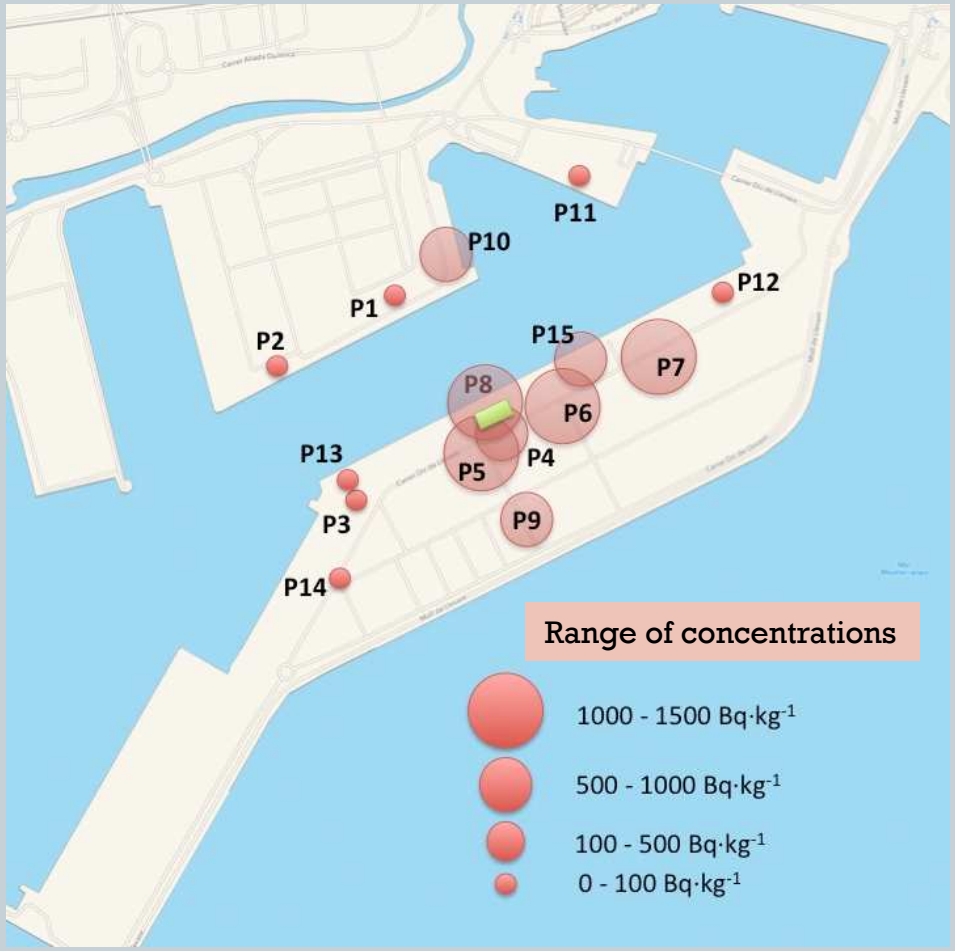
Coaxial HPGe detector

Alpha spectrometry (^{210}Po deposition)

^{210}Pb in a second analysis via ^{210}Po after the first analysis cleaned the original ^{210}Po

OUTDOOR DEPOSIT OF PR IN PORT OF TARRAGONA

RESULTS: DUST ON THE FLOOR



^{238}U in equilibrium with ^{226}Ra and ^{210}Pb (6.6 – 1500 Bq kg^{-1})

↓

Dispersion of the PR from the storage deposit due to the wind

Dust on the ground is low (up to 10 g m^{-2}) → efficient cleaning mechanisms

↓

REDUCE THE RISK FOR WORKERS

OUTDOOR DEPOSIT OF PR IN PORT OF TARRAGONA

RESULTS: ATMOSPHERIC DEPOSITION

The rainfall plays a key role in regulating the atmospheric deposition

Collected 5.8 L m^{-2} of rainfall

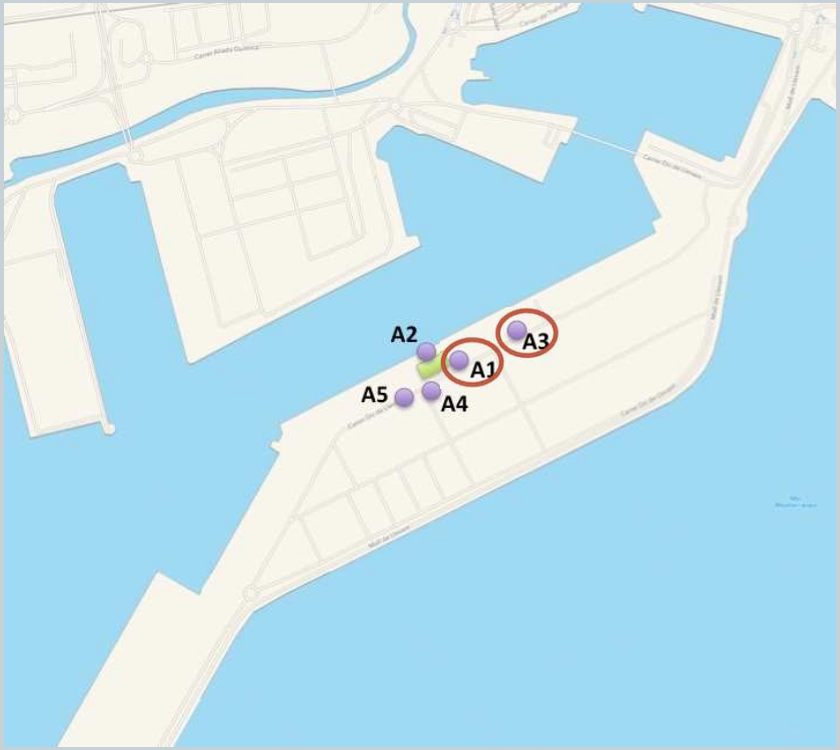
Sample	^{238}U (mBq L^{-1})					
	Dissolved fraction			Particulate fraction		
C-1	N.M	±	N.M	N.M	±	N.M
C-2	N.M	±	N.M	0.25	±	0.12
C-3	2.20	±	0.45	31	±	2
C-4	2.44	±	0.34	19	±	1
C-5	0.40	±	0.11	N.M	±	N.M

PM5 por qué es importante lo de los 5.8 l?

Pere Masqué; 16.6.2014

OUTDOOR DEPOSIT OF PR IN PORT OF TARRAGONA

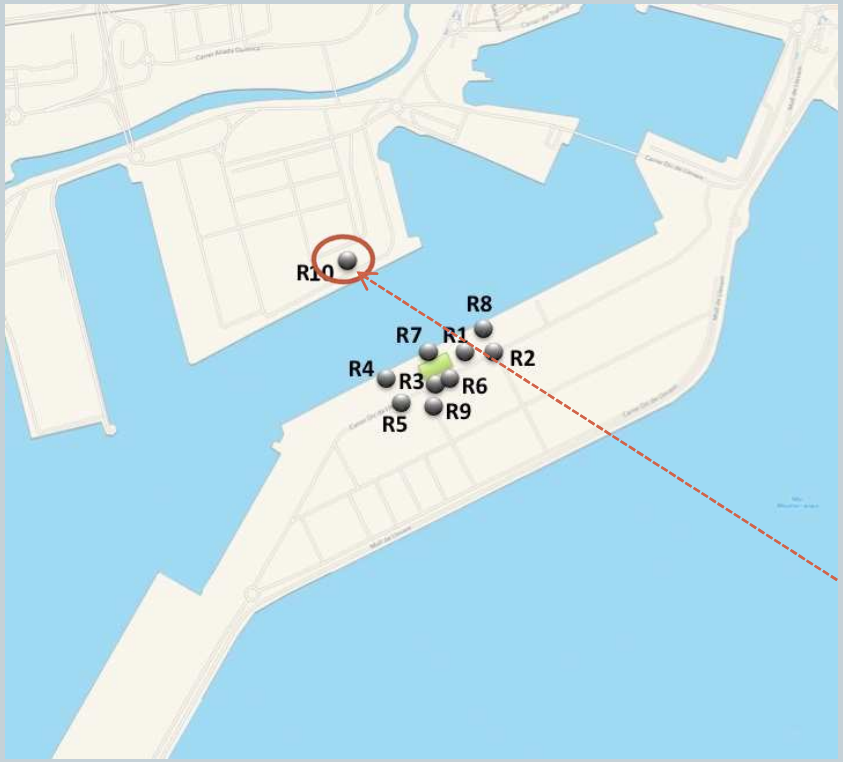
RESULTS: AEROSOLS PARTICLES



Sample	^{238}U (mBq m^{-3})		
A-0	0.15	±	0.01
A-1	0.38	±	0.02
A-2	0.10	±	0.01
A-3	0.32	±	0.02
A-4	0.15	±	0.01
A-5	0.12	±	0.01

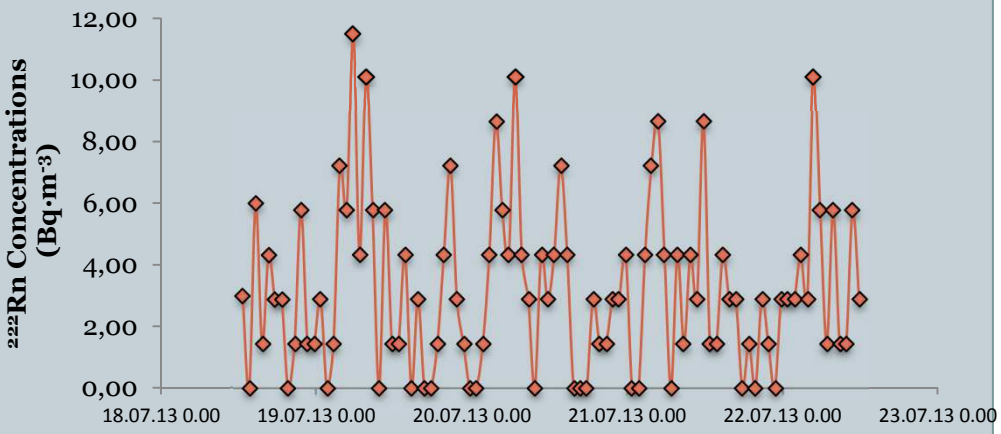
OUTDOOR DEPOSIT OF PR IN PORT OF TARRAGONA

RESULTS: ^{222}Rn IN THE AIR



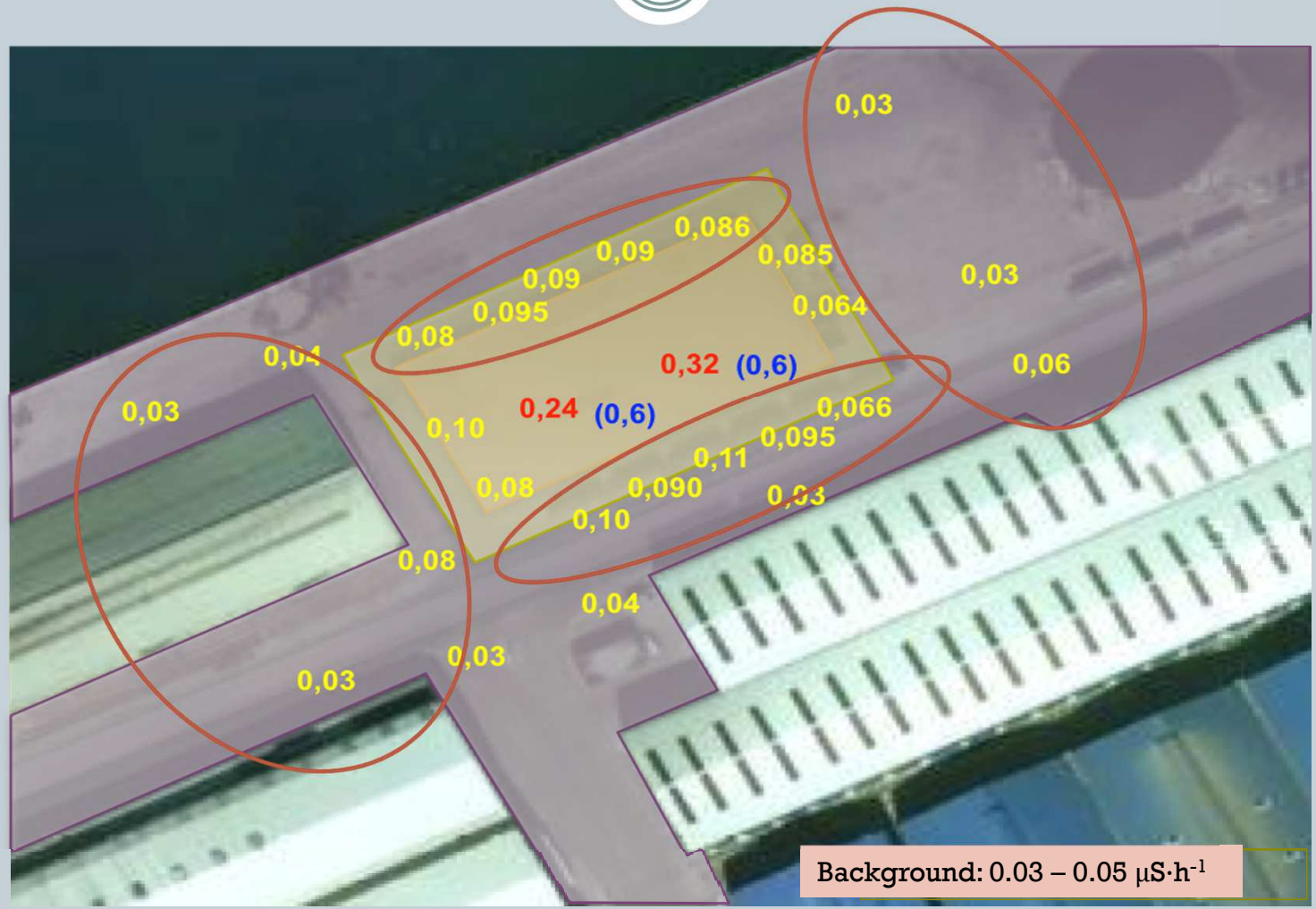
0 – 6 Bq·m^{-3}

< 10 Bq·m^{-3} (UNSCEAR, 2000)



OUTDOOR DEPOSIT OF PR IN PORT OF TARRAGONA

RESULTS: EXTERNAL DOSE



OUTDOOR DEPOSIT OF PR IN PORT OF TARRAGONA

RESULTS: TOTAL DOSE

o

$$E = E_{external} + \sum_i \left(h(g)_{i,inh} \cdot j_{i,inh}\right) + \sum_i \left(h(g)_{j,ing} \cdot j_{j,ing}\right) < 1\ mSv \cdot y^{-1}$$

$$E = f \cdot \dot{H}^{*}(10) \cdot t_A + \sum_i \left(h(g)_{i,inh} \cdot j_{i,inh}\right)$$

^{226}Ra
(In equilibrium with daugthers)

^{238}U decay serie
(In equilibrium with daugthers)

OUTDOOR DEPOSIT OF PR IN PORT OF TARRAGONA

RESULTS: TOTAL DOSE

$$E_{external} = f \cdot \dot{H}^{*}(10) \cdot t_A$$

Effective external dose rate

< 0.130 mSv·y^{-1}

f = 1 (Dose equivalente factor)

$\dot{H}^{*}(10)$ = 0.30 µSv·h^{-1}

t_A = 9 h·week^{-1}

$$E_{inh} = V \cdot t_A \cdot \sum_i \left(DCC_{i,inh} \cdot c_{i,inh} \right)$$

$C_{i(inh)}$= Concentration of ^{238}U decay serie in air (Bq·m^{-3}) at each sampling point (secular equilibrium with its daughters)

V= Breathed rate at working place (1.2 m^3·h^{-1})

t= Residence time of employees at the workplace (9 h·week^{-1})

$DCC_{i(inh)}$= Dose conversion factor for each radionuclide (AMAD of 5µm) (^{238}U, ^{234}U, ^{230}Th, ^{226}Ra, ^{210}Po, ^{210}Pb)

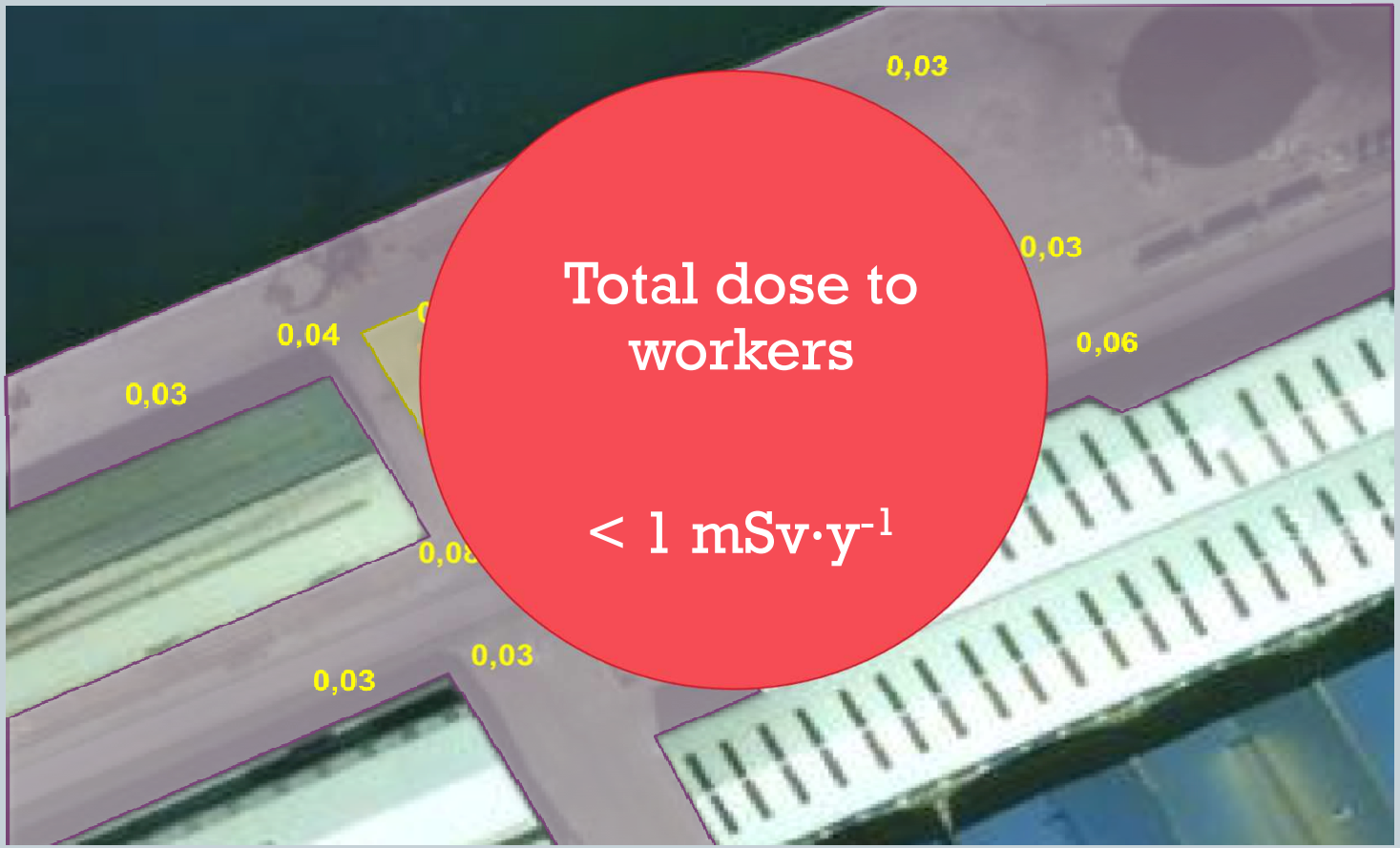
Internal dose by inhalation

< 0.01 mSv·y^{-1}

OUTDOOR DEPOSIT OF PR IN PORT OF TARRAGONA

RESULTS: TOTAL DOSE

$$E = E_{external} + E_{inhalació}$$



RESULTS: PR LOAD IN TRAIN WAGONS

Dosis received by workers

0 μSv in 3 hours

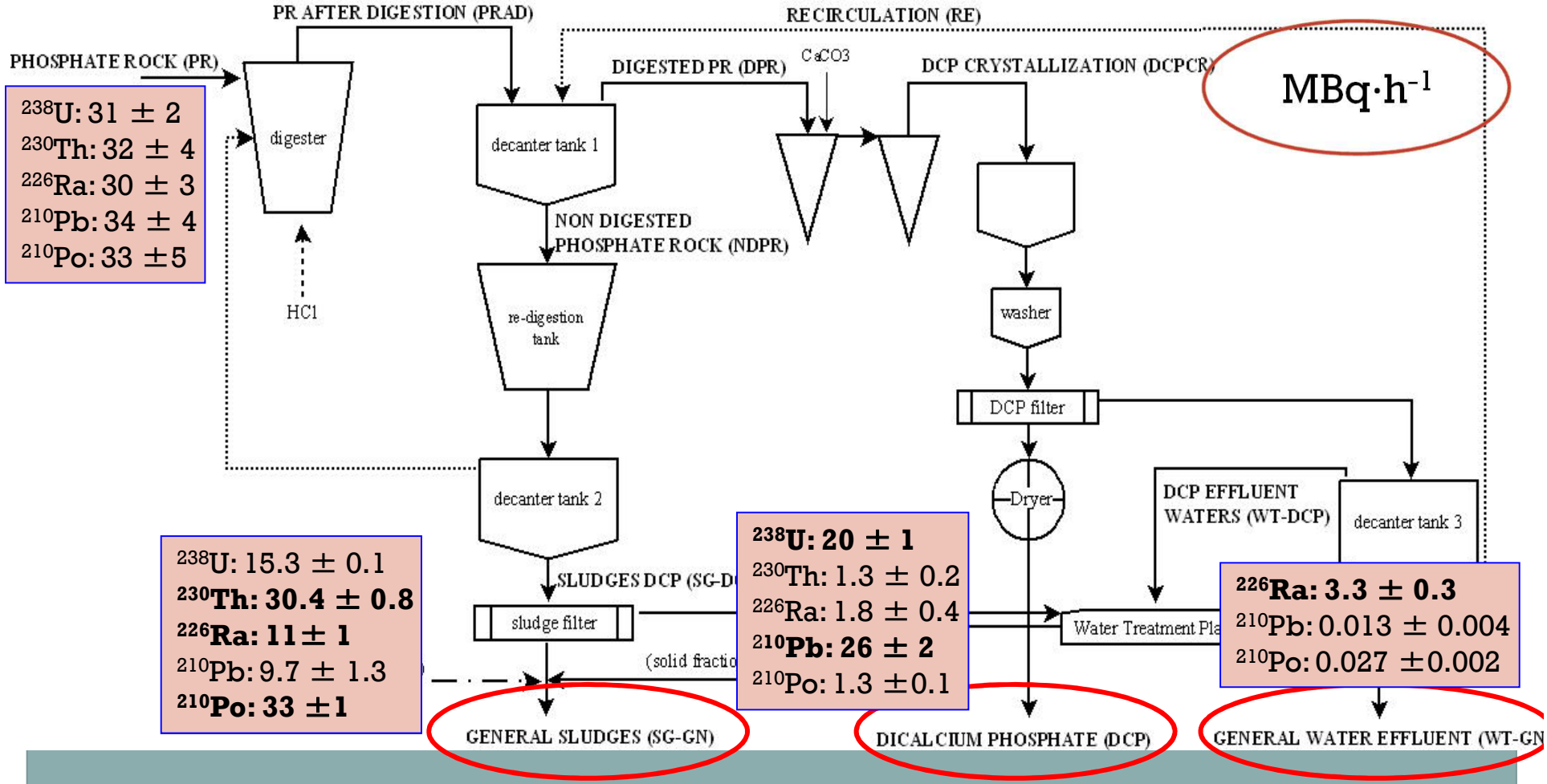
PR LOAD IN TRAIN WAGONS

Sample	Internal dose by inhalation (mSv y^{-1})
DP-0	0.0072
DP-1	0.179
DP-2	N.M.
DP-3	0.984
DP-4	0.0171
DP-5	0.0586
DP-6	0.261
DP-7	0.261

Sample	Internal dose by inhalation (mSv y^{-1})
A-0	0.00301
A-1	0.00763
A-2	0.00201
A-3	0.00643
A-4	0.00301
A-5	0.00241

DCP PRODUCTION PLANT

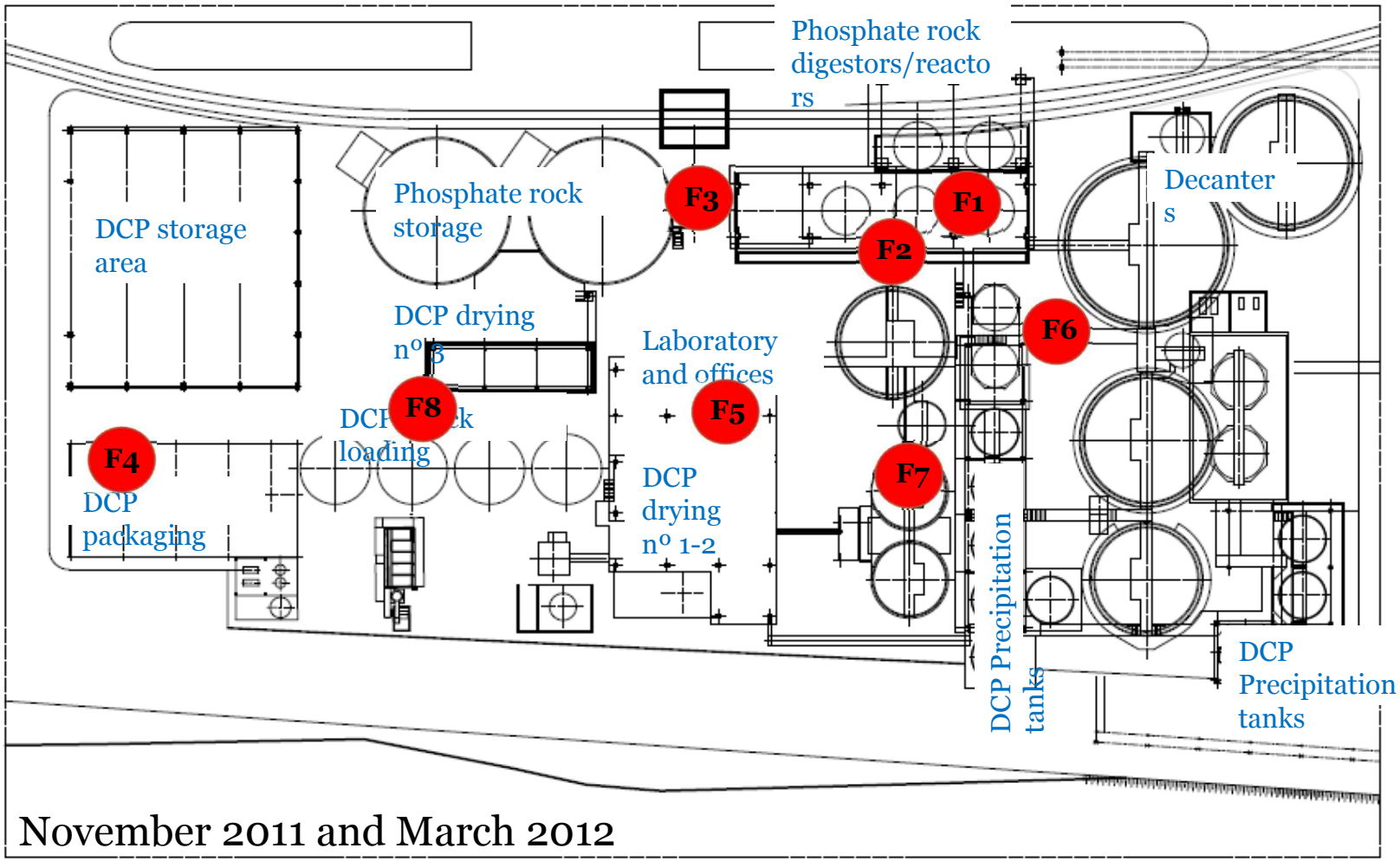
FLUXES OF RADIONUCLIDES



Casacuberta et al. 2011

DCP PRODUCTION PLANT

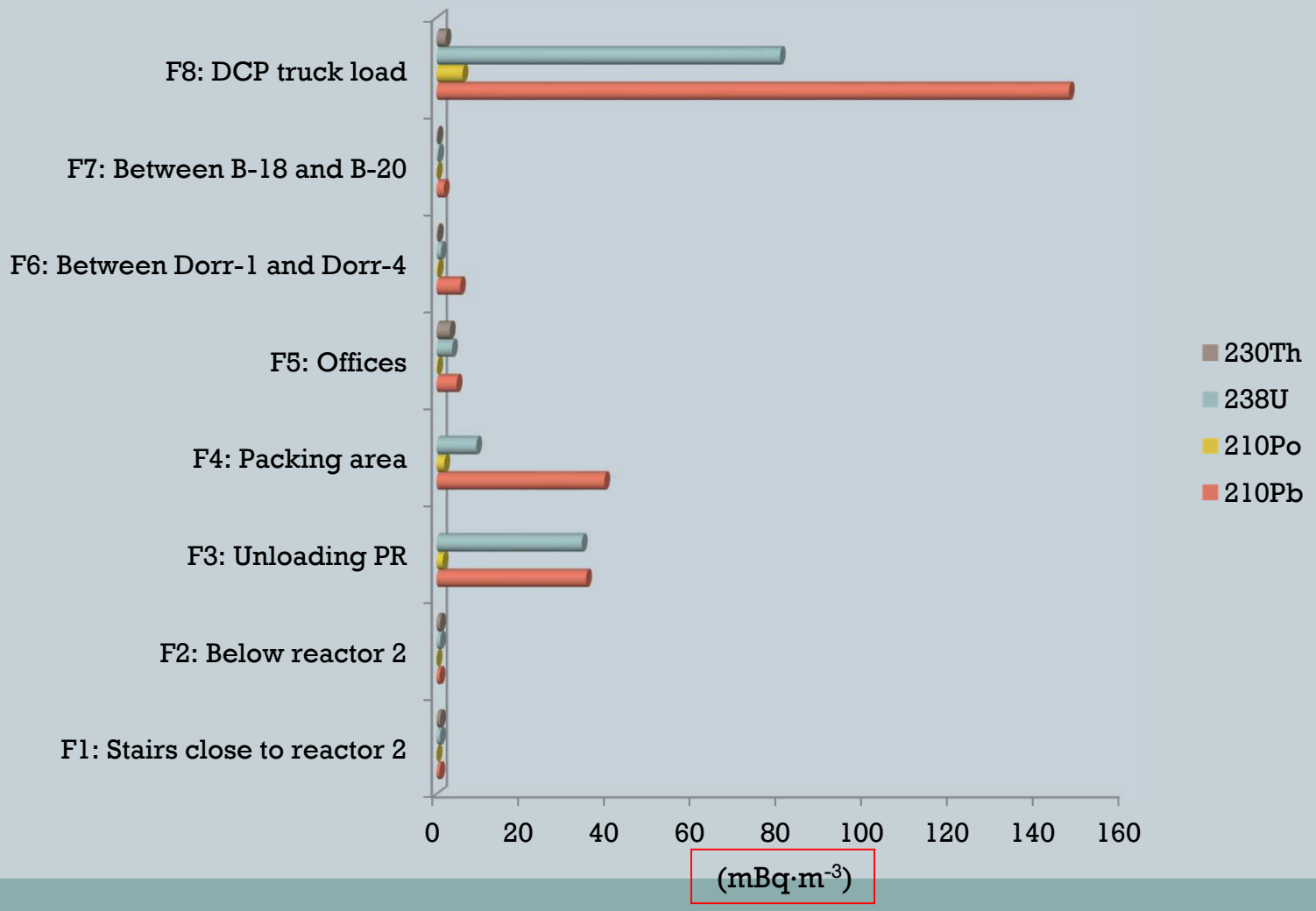
AIR FILTERS SAMPLING



November 2011 and March 2012

DCP PRODUCTION PLANT

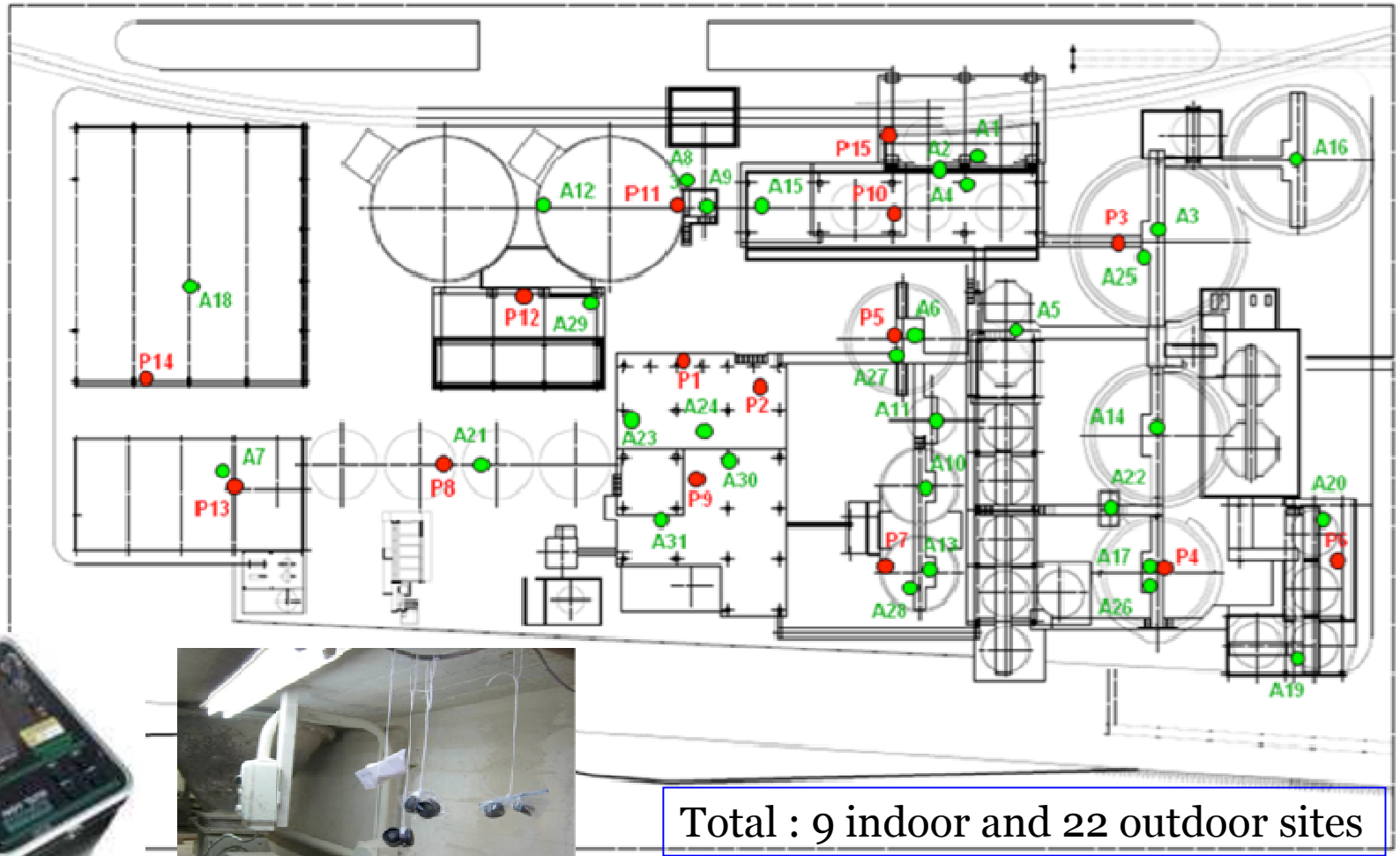
RESULTS: AIR FILTERS SAMPLING



DCP PRODUCTION PLANT

^{222}Rn SAMPLING

- P: Passive detector (Makrofols)
- A: Active detector (Rad-7 and AlphaGUARD)

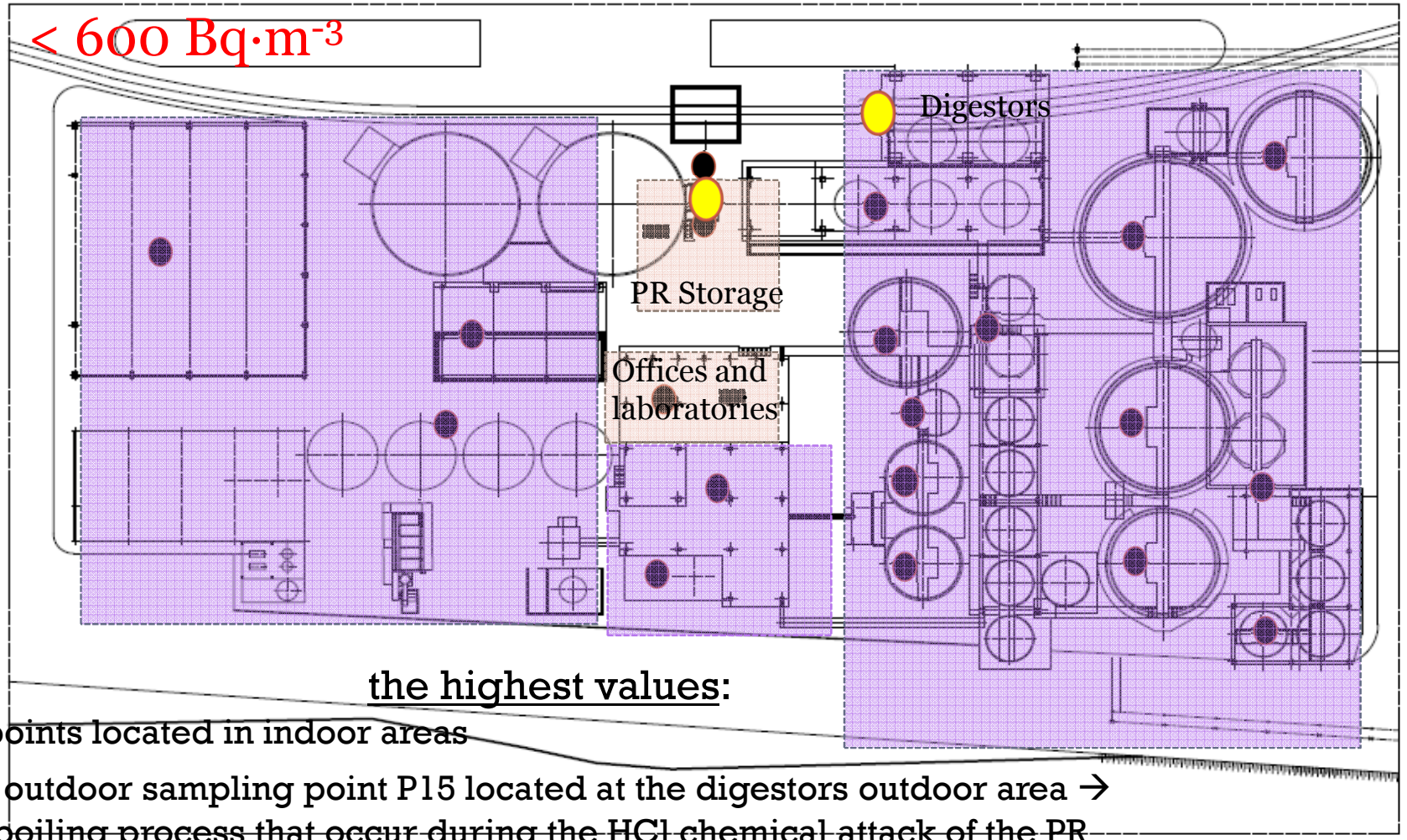


Total : 9 indoor and 22 outdoor sites

DCP PRODUCTION PLANT

RESULTS: ^{222}Rn MEASUREMENTS

0 - 100 Bq·m^{-3} 100 - 200 Bq·m^{-3} 200 – 400 Bq·m^{-3}



the highest values:

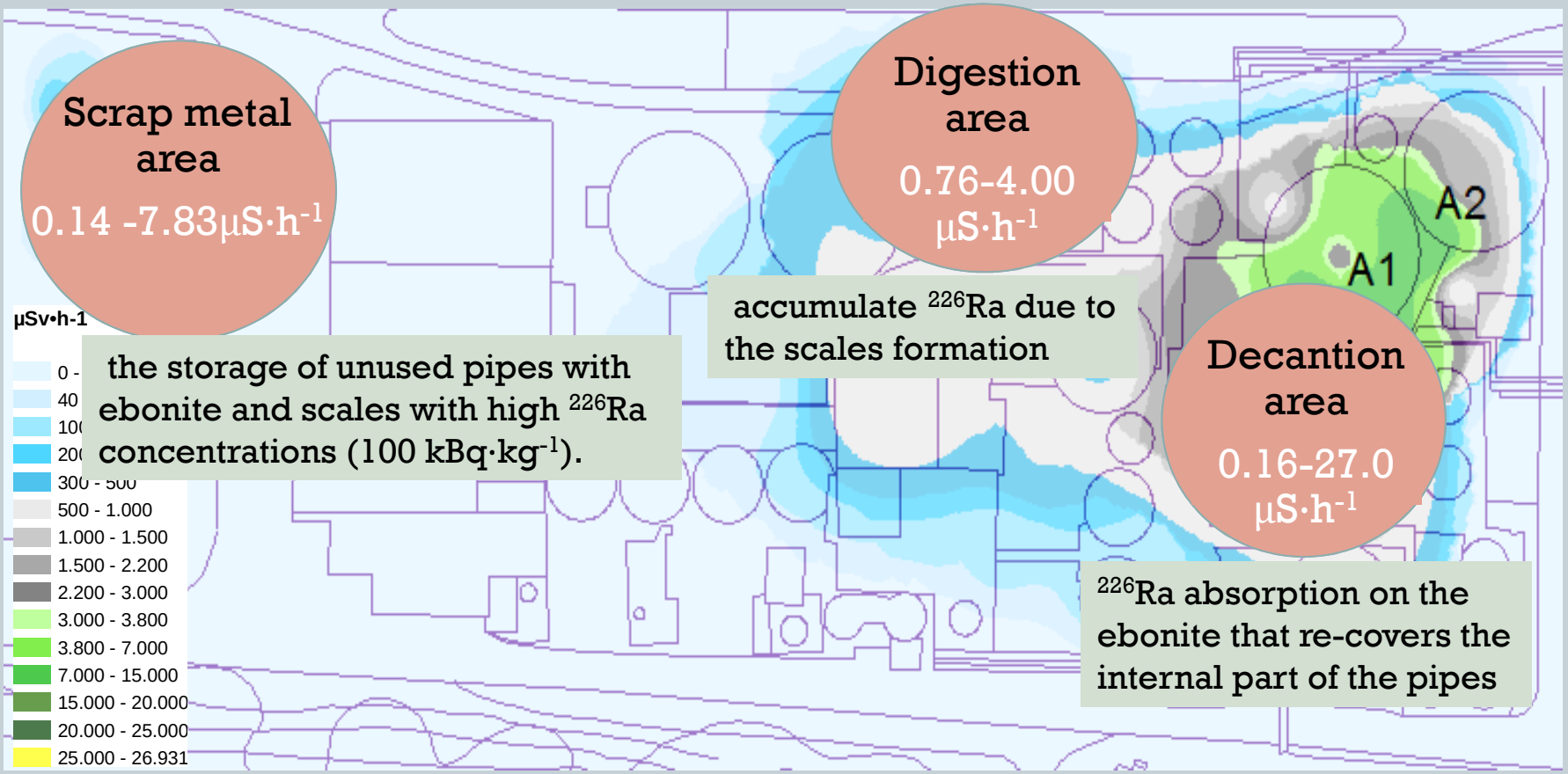
-at points located in indoor areas

-the outdoor sampling point P15 located at the digestors outdoor area → the boiling process that occur during the HCl chemical attack of the PR

DCP PRODUCTION PLANT

RESULTS: EXTERNAL DOSE

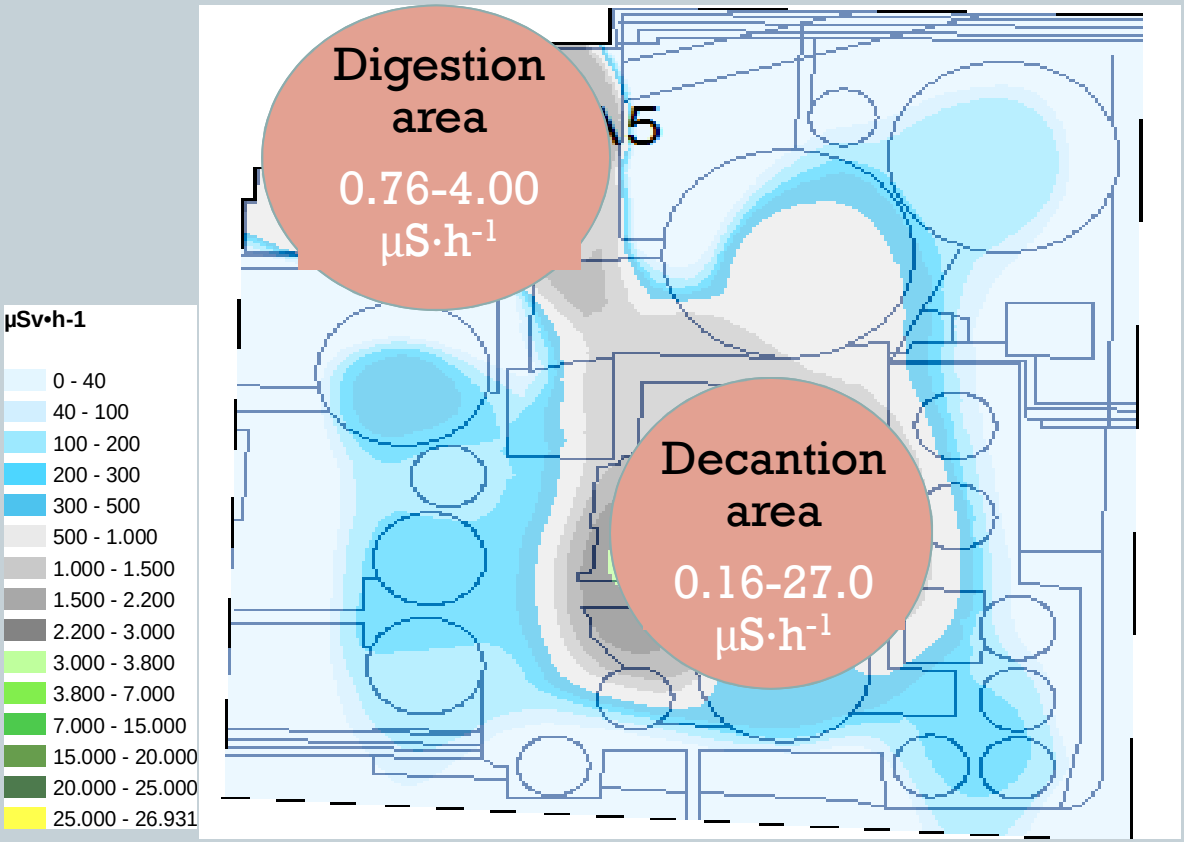
Ground floor



DCP PRODUCTION PLANT

RESULTS: EXTERNAL DOSE

1st floor

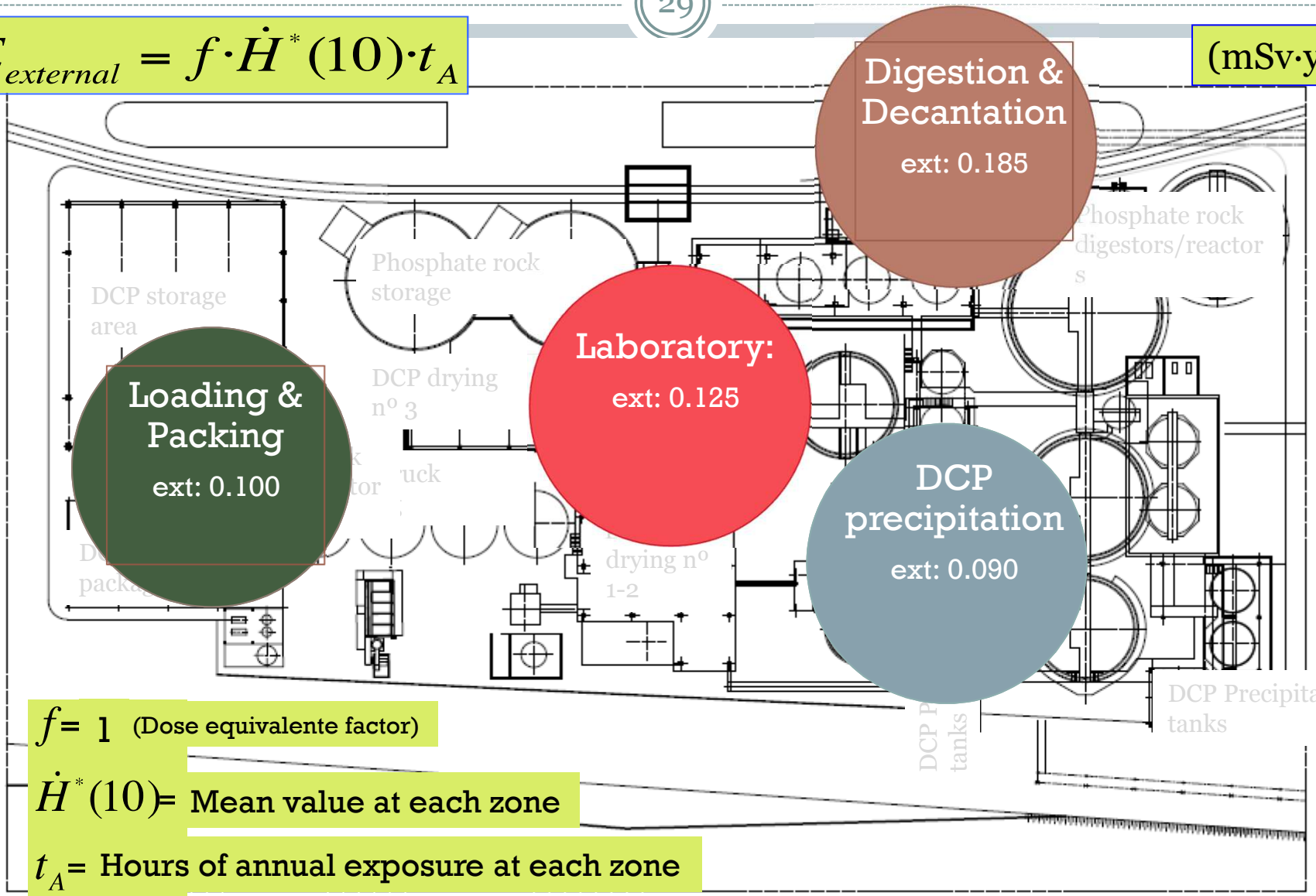


DCP PRODUCTION PLANT

RESULTS: TOTAL DOSE (EXTERNAL DOSE)

$$E_{external} = f \cdot \dot{H}^{*}(10) \cdot t_A$$

(mSv·y^{-1})



f = 1 (Dose equivalente factor)

$\dot{H}^{*}(10)$ = Mean value at each zone

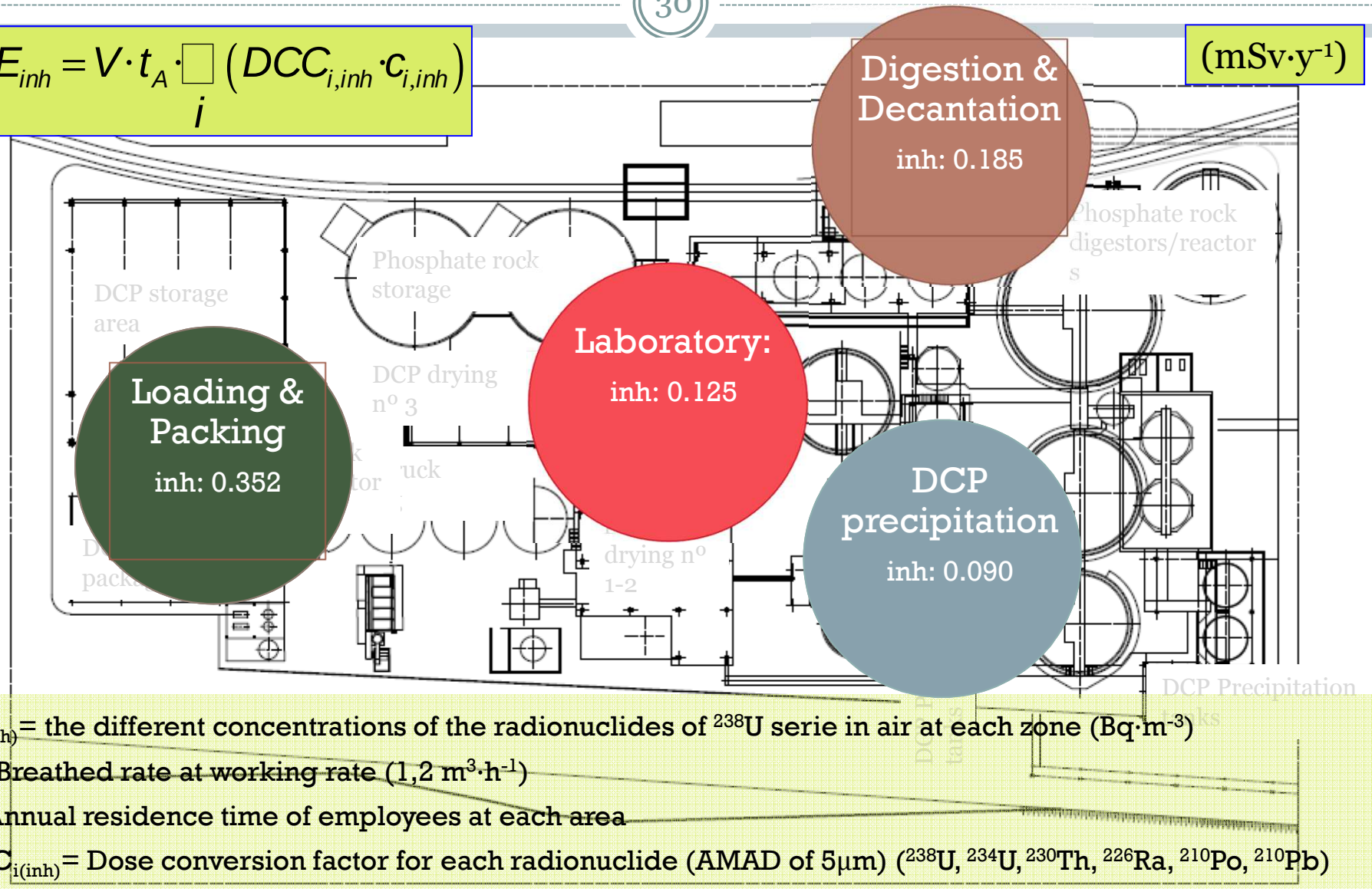
t_A = Hours of annual exposure at each zone

DCP PRODUCTION PLANT

RESULTS: TOTAL DOSE (INTERNAL DOSE)

$$E_{inh} = V \cdot t_A \cdot \sum_i \left(DCC_{i,inh} \cdot c_{i,inh} \right)$$

(mSv·y^{-1})



$C_{i(inh)}$= the different concentrations of the radionuclides of ^{238}U serie in air at each zone (Bq·m^{-3})

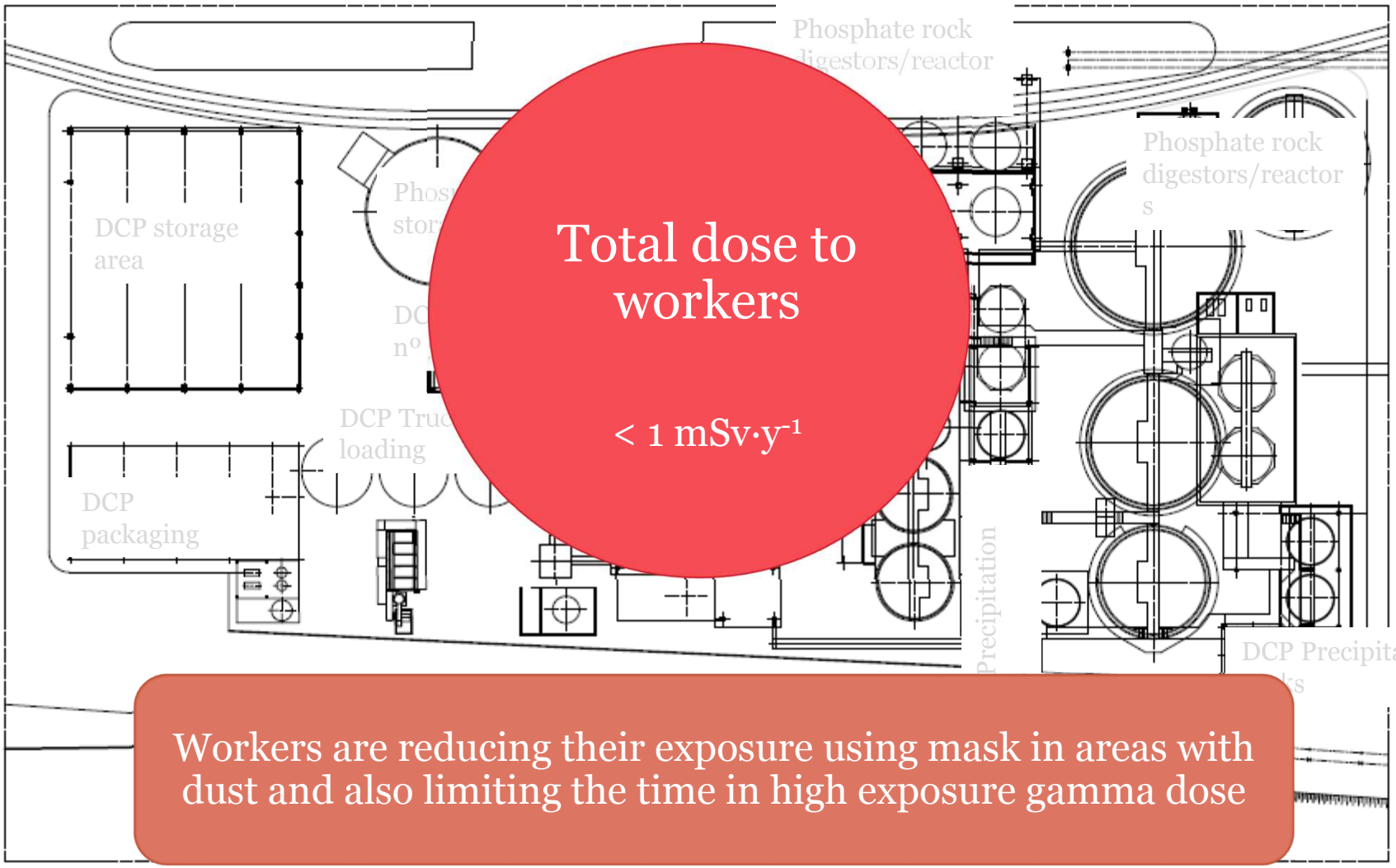
V= Breathed rate at working rate (1,2 m^3·h^{-1})

t= Annual residence time of employees at each area

$DCC_{i(inh)}$= Dose conversion factor for each radionuclide (AMAD of 5μm) (^{238}U, ^{234}U, ^{230}Th, ^{226}Ra, ^{210}Po, ^{210}Pb)

DCP PRODUCTION PLANT

RESULTS: TOTAL DOSE



CONCLUSIONS

PORT OF TARRAGONA

1.There is a dispersion of the PR around the deposit that can be measured in the dust accumulated in some parts of the port. Dust accumulation is less important proportionally to the distance to the storage deposit.

2.Maintenance practices carried out in the Port, where the load of PR and the floor cleaning are done with cab loaders, are generally effective and reduce significantly the impact of the PR derived doses to workers.

DCP PRODUCTION PLANT

1.The dose assessment in the DCP production plant has revealed that the highest contribution to the total dose is due to the external dose produced by the ^{226}Ra accumulated in pipes where doses can reach values up to 30 $\mu Sv \cdot h^{-1}$.

2.The locations where these higher values were obtained are characterized by low occupancy factors of workers in the plant.

CONCLUSIONS

Although the doses are lower than the limits of 1 $mSv \cdot y^{-1}$, the concentrations of ^{238}U chain are not negligible and several radioprotection norms are necessary to maintain the dose as low as possible.

Thank you for your attention

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