The Dicalcium Phosphate production in the NORM context: study of the radiological characterization and dose assessment to workers

Núria Casacuberta, Dani Mulas, Pere Masqué and Jordi Garcia-Orellana

Institut de Ciència i Tecnologia Ambientals
Universitat Autònoma de Barcelona (Spain)

EU NORM I International Symposium, 5-8 June 2012, Tallinn, Estonia

OUTLINE

INTRODUCTION

The phosphate industry and the Dicalcium Phosphate production

The Spanish legal framework concerning NORM

AIMS OF THE STUDY

SAMPLING AND ANALYTICAL METHODS

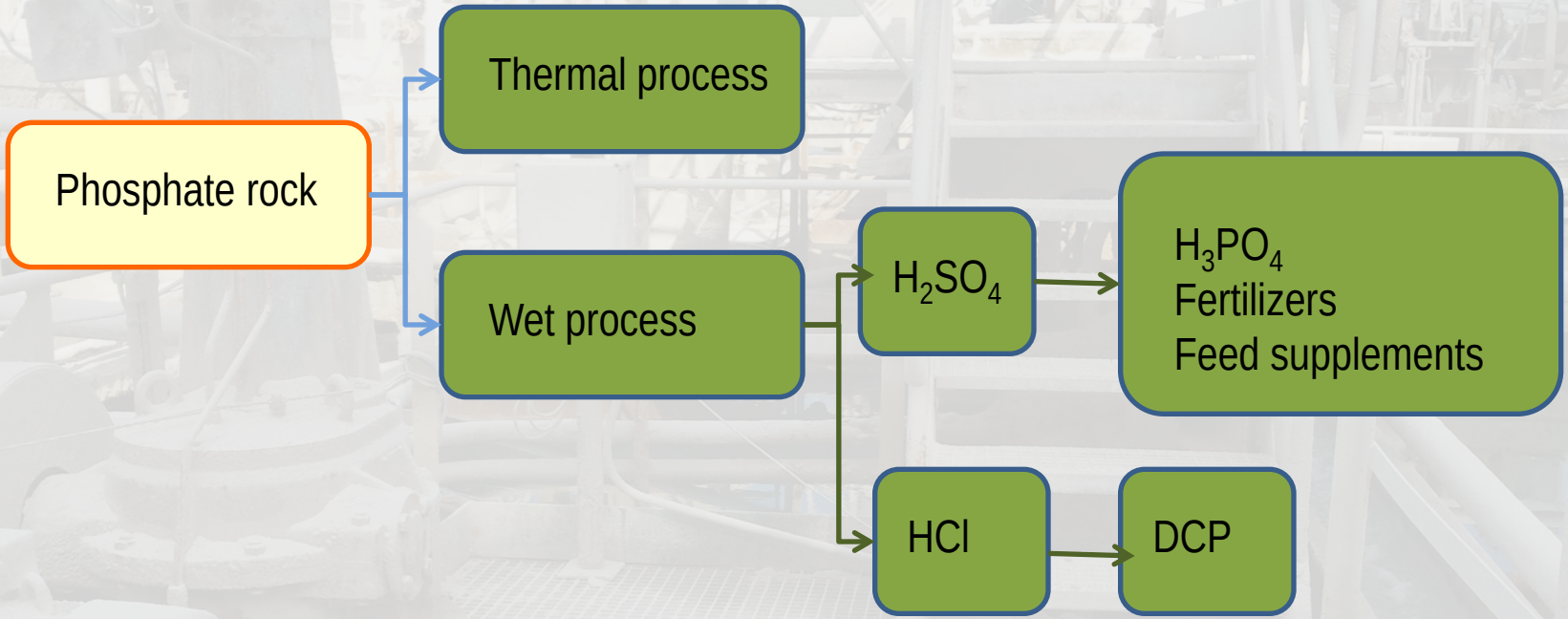
RESULTS on:

RADIOLOGICAL CHARACTERIZATION

DOSE ASSESSMENT TO WORKERS

CONCLUSIONS & FUTURE WORK

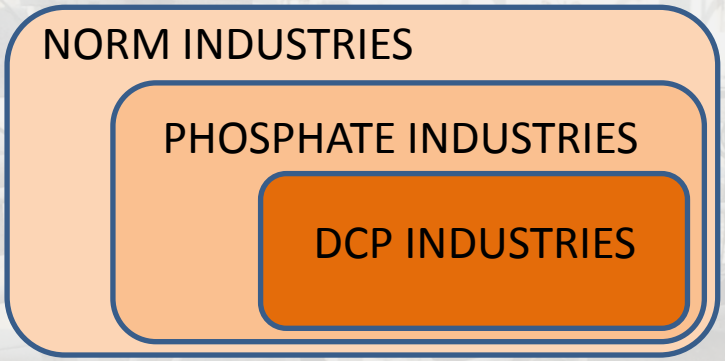
THE PHOSPHATE INDUSTRY



Mineral apatite (francolite or carbonate-fluorapatite). Significant quantities of naturally occurring radionuclides; substitution of Ca^{2+} by U^{4+} :

- Sedimentary phosphate rocks: 1500 $Bq \cdot kg^{-1}$ in average
- Igneous deposits: 70 $Bq \cdot kg^{-1}$.

THE Dicalcium Phosphate PRODUCTION



$Ca(H_2PO_4)_2$

- Inorganic feed supplement
- Classified as feed material by the European Commission Regulation.
- Calcium and phosphorus feed supplement for domestic animals (cattle, poultry, beef, sheep). 18% of P and between 25-30% of Ca.
- High calcium availability (93%).

THE Dicalcium Phosphate INDUSTRY & NORM

NORM industries (IAEA 2006):

- Extraction of REE
- Production and use of thorium and its compounds
- Production of niobium and ferro-niobium
- Mining ores other than uranium ore
- Production of oil and gas
- Titanium dioxide pigments
- Phosphate industry
- Zircon and zirconia
- Production of tin, copper, aluminium, zinc, lead, iron and steel
- Combustion of coal
- Water treatment

Thermal phosphorus production
Phosphate fertilizers
Phosphoric acid production
Dicalcium phosphate production

SPANISH LEGAL FRAMEWORK IN NORM

EURATOM 29/96

RD 783/2001

RD 1439/2010

1- The industry holder MUST perform the studies to show wheter there is an increasing dose to workers and to the public due to the industrial activity.

2- The industry holder MUST declare its industrial activity to the Authorities.

3- This RD is also extended to the wastes storage and handling.


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

Instructions: Nuclear Security Council (CSN)

SPANISH LEGAL FRAMEWORK IN NORM

Instructions: Nuclear Security Council (CSN)

- Effective dose to workers
  - **< 1 mSv·y^{-1}**: no further control is necessary.
  - 1 – 6 mSv·y^{-1}: low-level control is necessary.
  - > 6 mSv·y^{-1}: advanced control is necessary.

- ^{222}Rn measures in working areas.
  - **600 Bq·m^{-3}** average anual concentration.
  - 600 – 1000 Bq·m^{-3}: low-level control is necessary.
  - > 1000 Bq·m^{-3}: advanced control is necessary.

OUTLINE

INTRODUCTION

The phosphate industry and the Dicalcium Phosphate production

The Spanish legal framework concerning NORM

AIMS OF THE STUDY

SAMPLING AND ANALYTICAL METHODS

RESULTS on:

RADIOLOGICAL CHARACTERIZATION

DOSE ASSESSMENT TO WORKERS

CONCLUSIONS & FUTURE WORK

AIMS OF THE STUDY

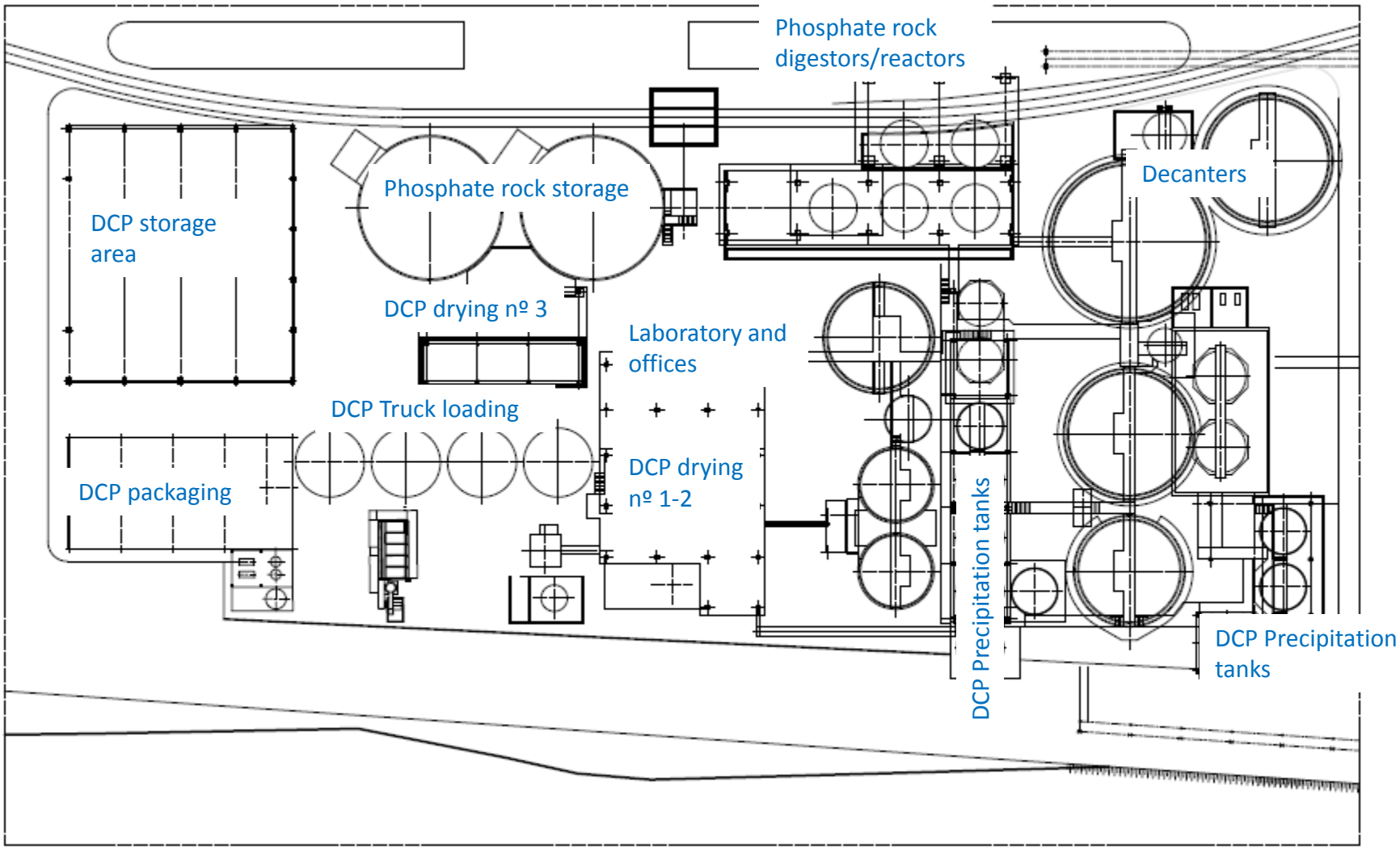
RADIOLOGICAL CHARACTERIZATION:

- 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).

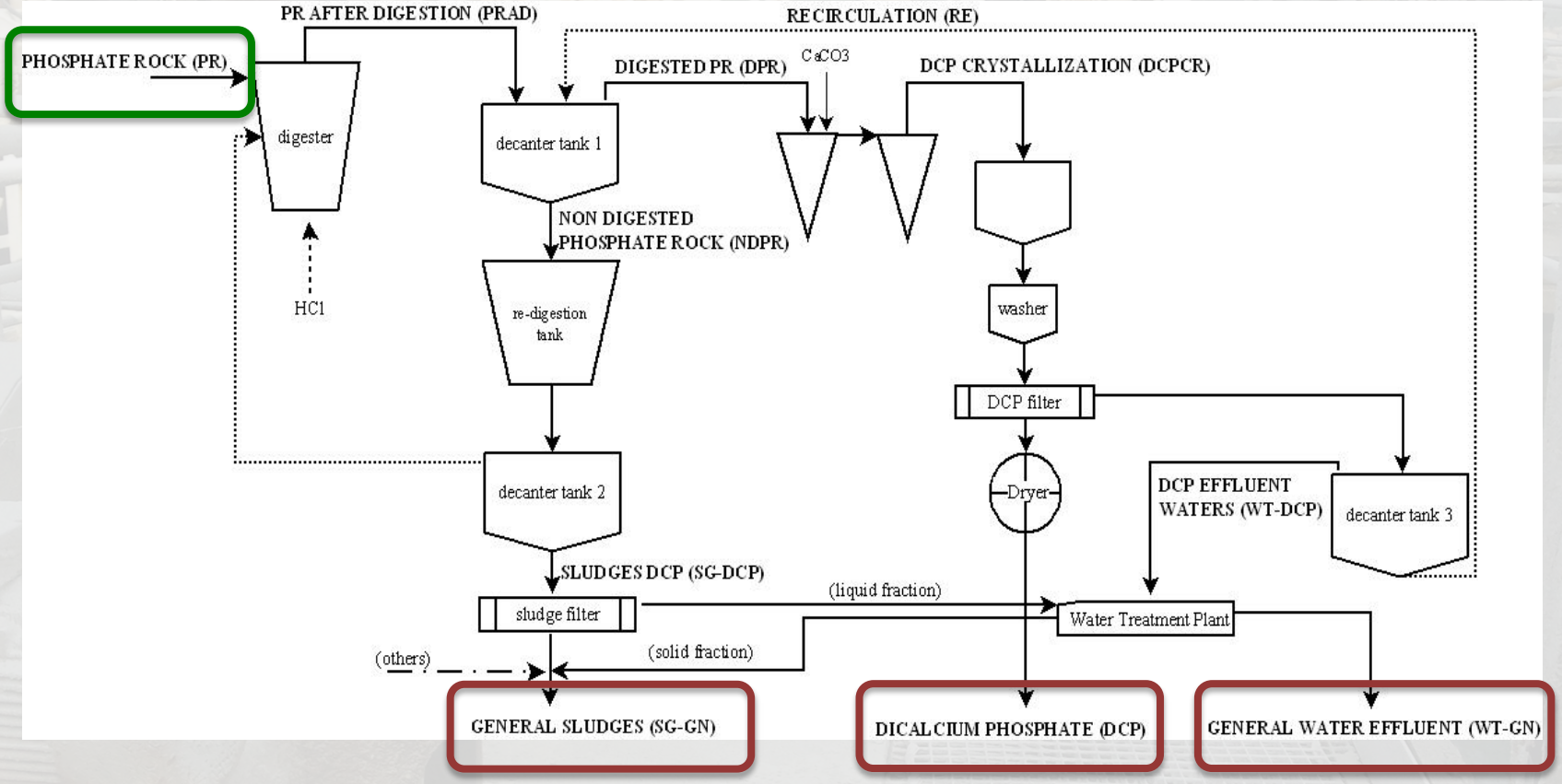
DOSE ASSESSMENT TO WORKERS:

- Study the potential anual dose to workers (1 $mSv \cdot y^{-1}$ ¿?).
- Quantify the doses during the cleaning and maintenance of particular areas in the production process.
- Study the ^{222}Rn concentrations (600 $Bq \cdot m^{-3}$ ¿?).

DCP plant description



RADIONUCLIDE CHARACTERIZATON



RADIOLOGICAL CHARACTERIZATION:

1. Inputs (phosphate rock) and outputs (waters, sludges and DCP).
2. Temporal variability: 1 sample per week during 2 months.

DOSE ASSESSMENT

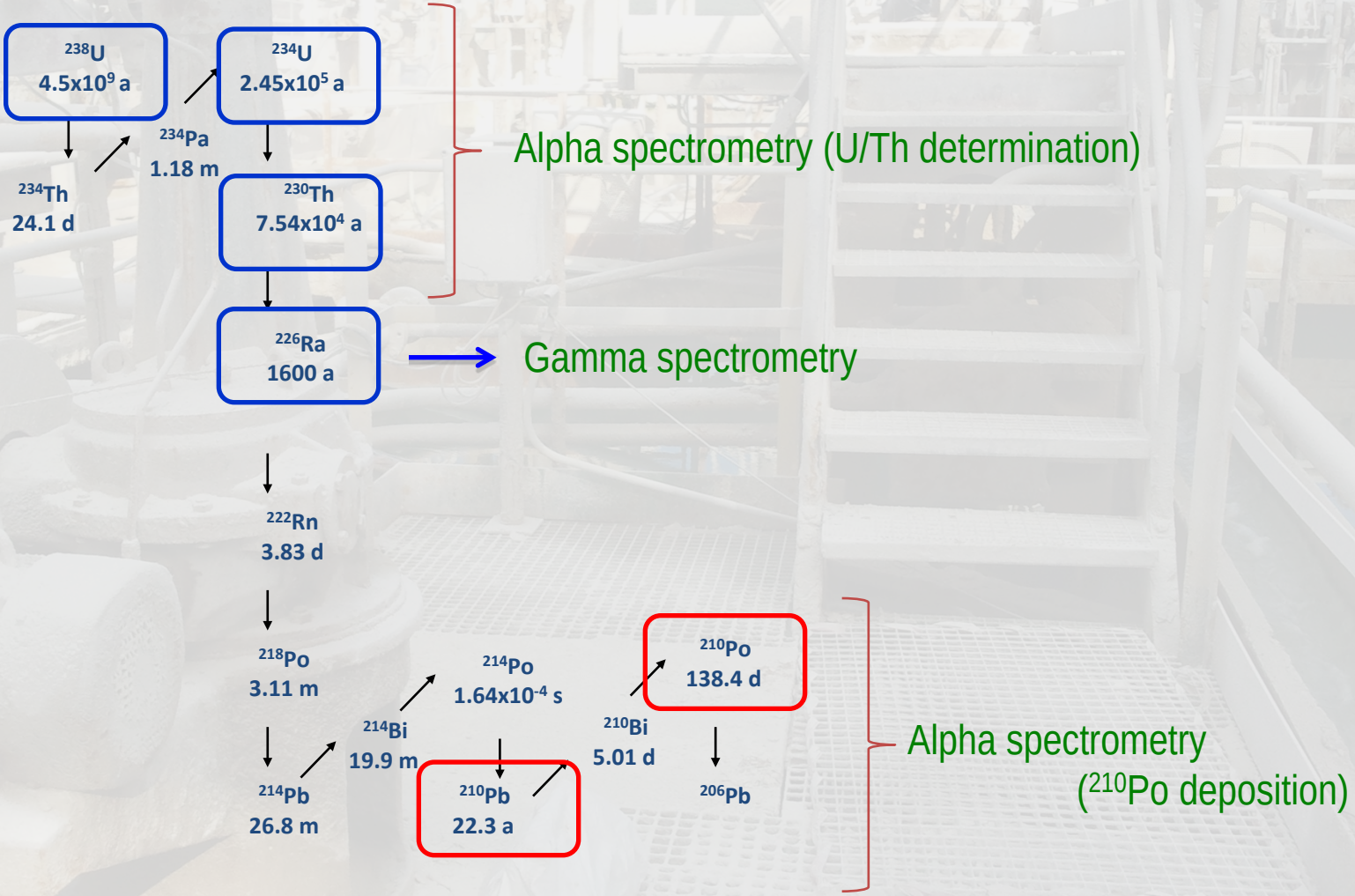
Gamma dose rate:

- Area dosimetry (Eberline, Inspector 1000)
- Maintenance and cleaning of the digestors (Personal dosimeter).

Inhalation dose rate:

- Rn measurements (Rad7)
- Dust assessment (RADECO).

ANALYTICAL METHODS



OUTLINE

INTRODUCTION

The phosphate industry and the Dicalcium Phosphate production

The Spanish legal framework concerning NORM

AIMS OF THE STUDY

SAMPLING AND ANALYTICAL METHODS

RESULTS on:

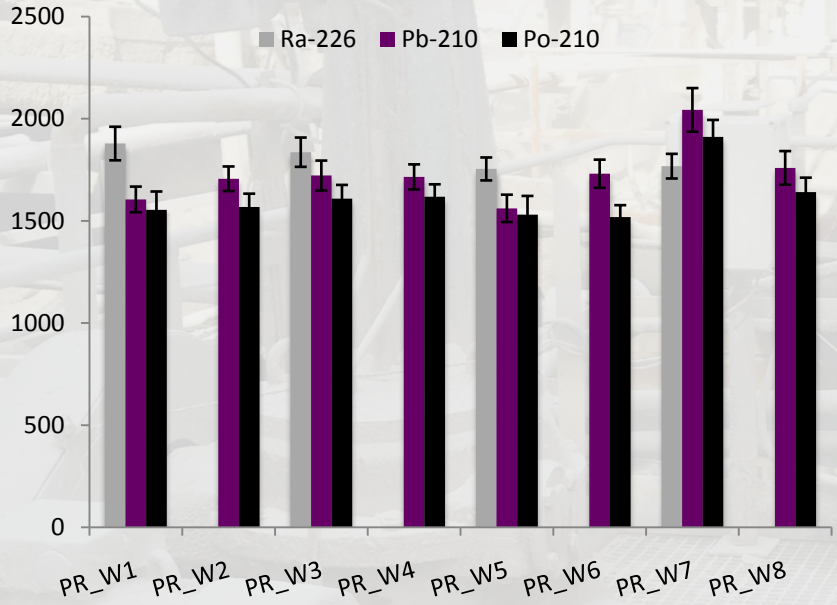
RADIOLOGICAL CHARACTERIZATION

DOSE ASSESSMENT TO WORKERS

CONCLUSIONS AND FUTURE WORK

^{226}Ra, ^{210}Pb & ^{210}Po SPECIFIC CONCENTRATIONS

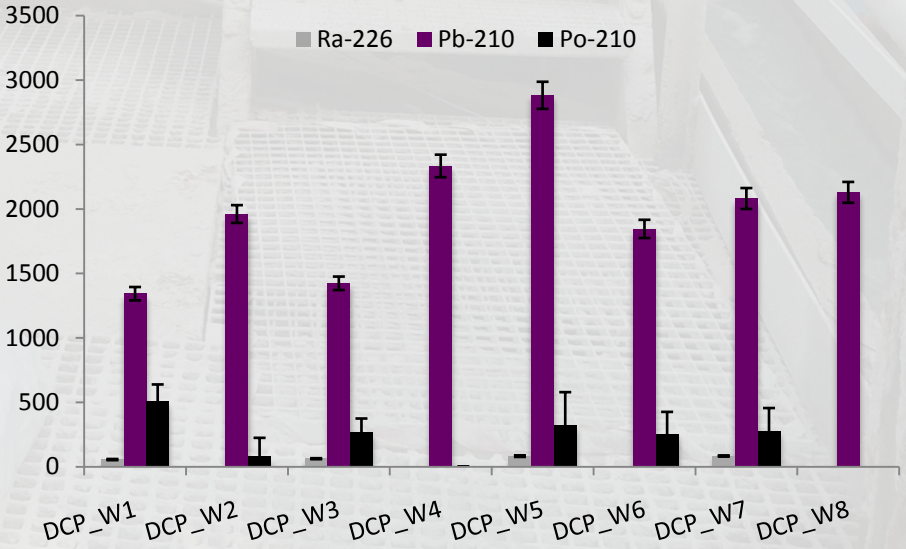
PHOSPHATE ROCK



^{226}Ra: 1809±59 Bq·kg^{-1}
^{210}Pb: 1731±143 Bq·kg^{-1}
^{210}Po: 1620±126 Bq·kg^{-1}

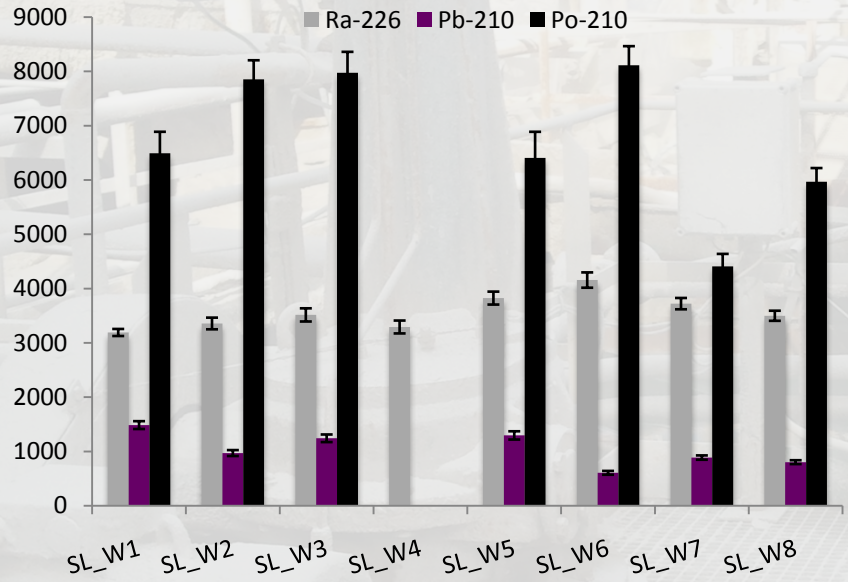
^{226}Ra: 56 – 84 Bq·kg^{-1}
^{210}Pb: 1343 - 2882 Bq·kg^{-1}
^{210}Po: 79 - 507 Bq·kg^{-1}

DICALCIUM PHOSPHATE



^{226}Ra, ^{210}Pb & ^{210}Po SPECIFIC CONCENTRATIONS

INDUSTRIAL SLUDGES



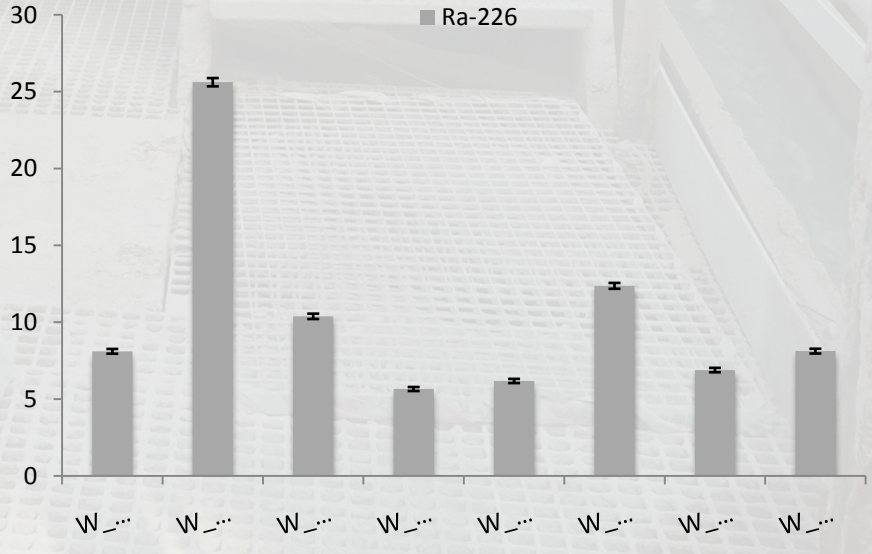
^{226}Ra: 3191 - 4156 $Bq \cdot kg^{-1}$

^{210}Pb: 606 - 1485 $Bq \cdot kg^{-1}$

^{210}Po: 4407 - 8111 $Bq \cdot kg^{-1}$

INDUSTRIAL WATERS

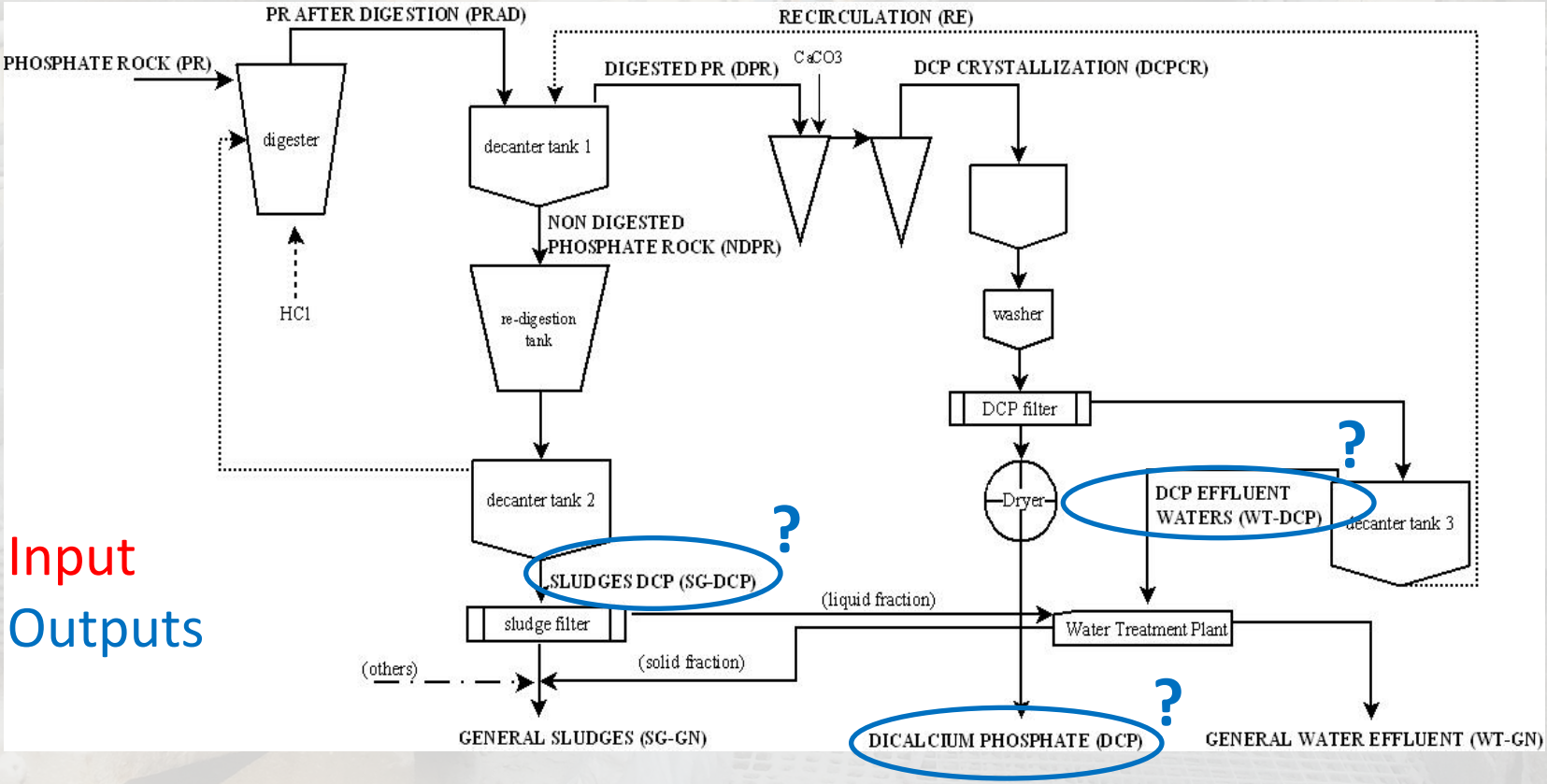
^{226}Ra: 6 – 25 $Bq \cdot L^{-1}$



FLUXES OF RADIONUCLIDES

100% $kBq \cdot h^{-1}$

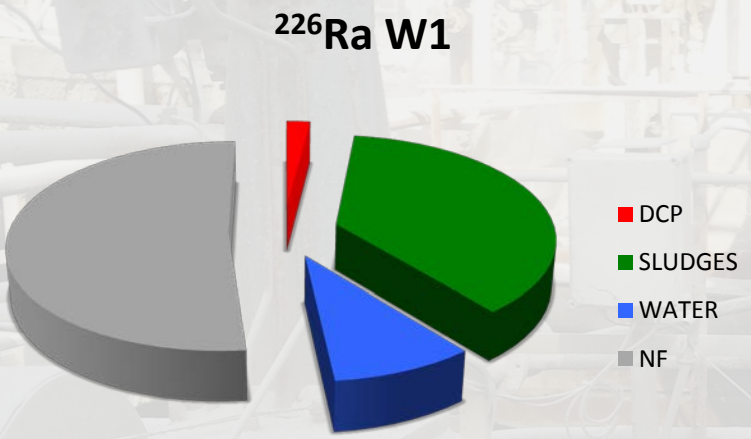
^{238}U and daughters

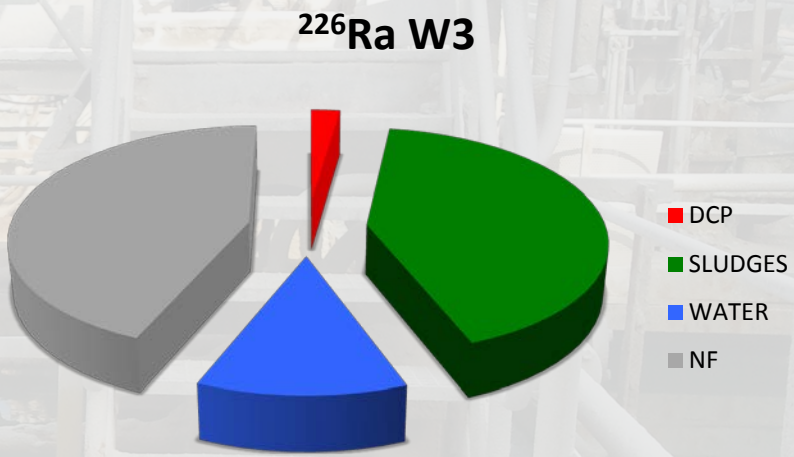


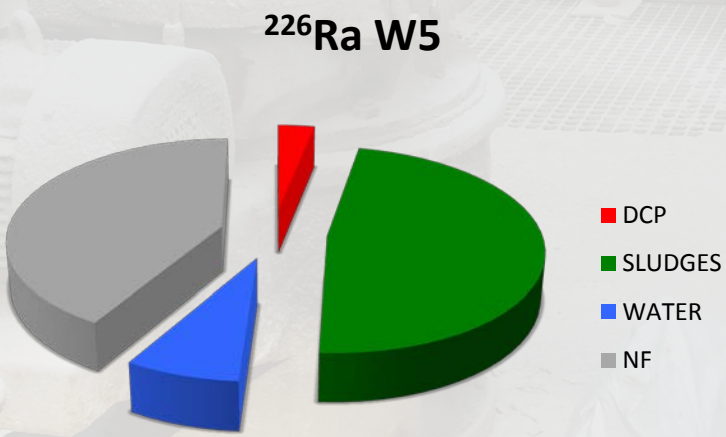
Input

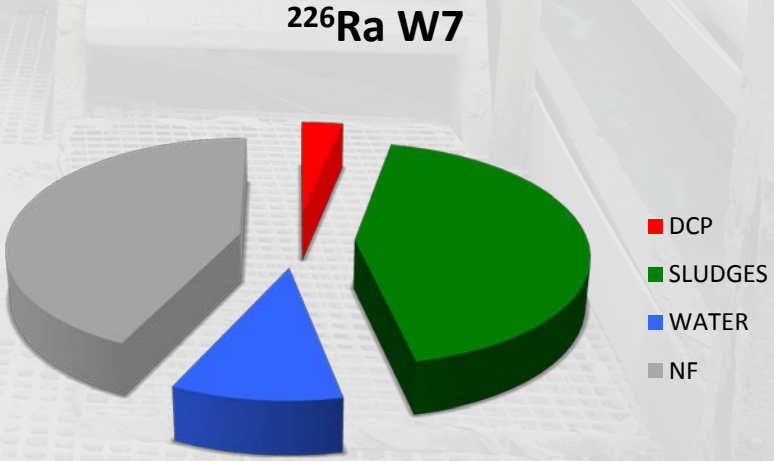
Outputs

OUTPUT FLUXES OF ^{226}Ra

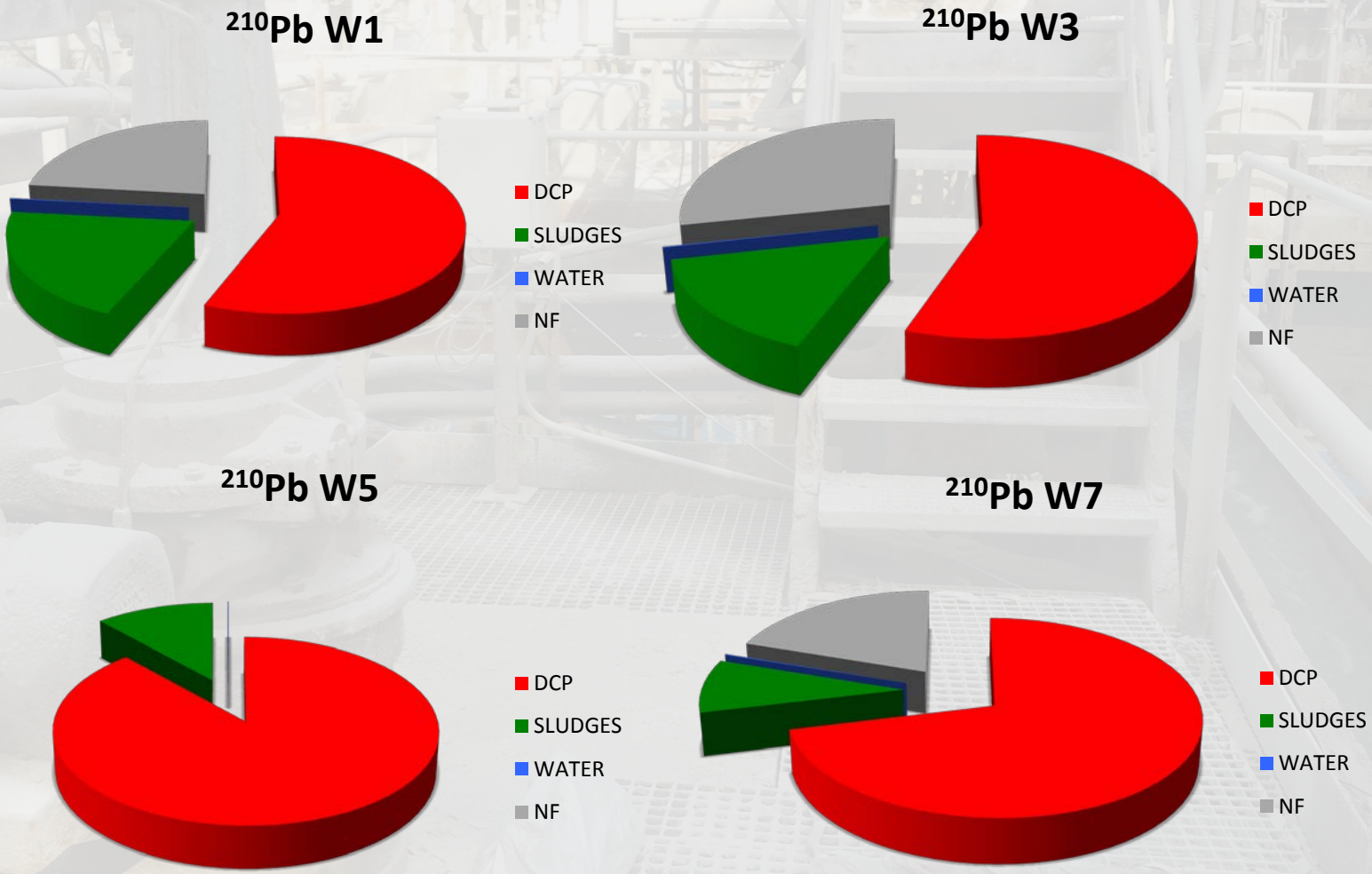






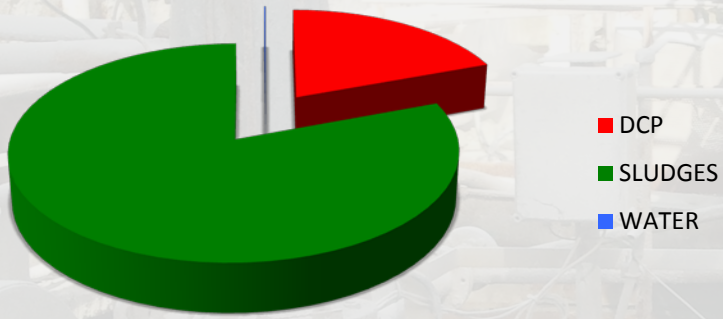


OUTPUT FLUXES OF ^{210}Pb

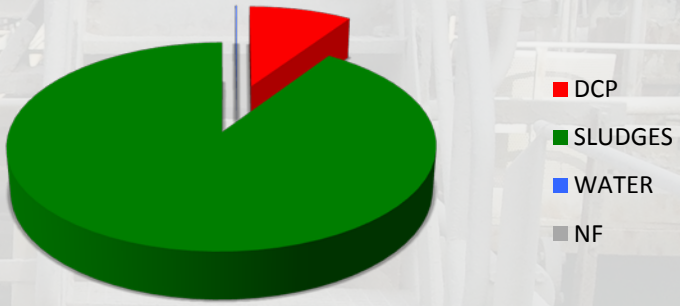


OUTPUT FLUXES OF ^{210}Po

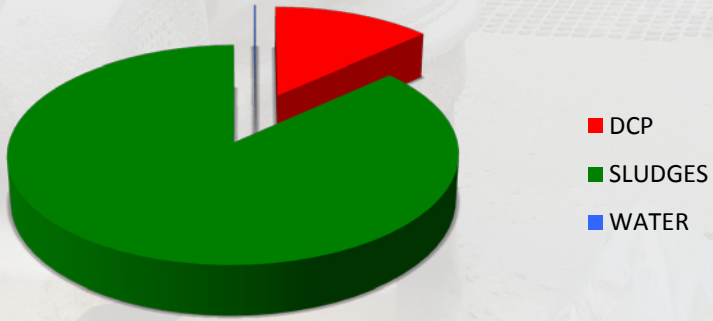
^{210}Po W1



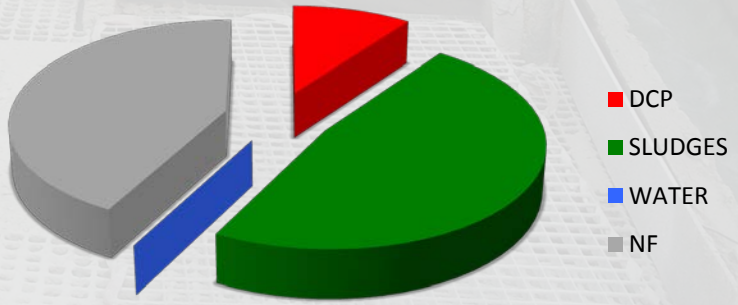
^{210}Po W3



^{210}Po W5



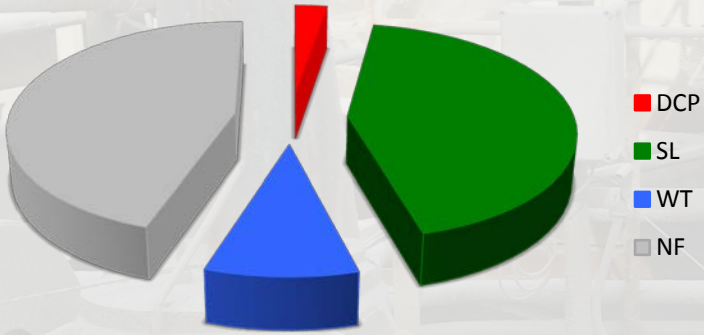
^{210}Po W7



AVERAGE OUTPUT FLUXES (weeks 1, 3, 5 & 7)

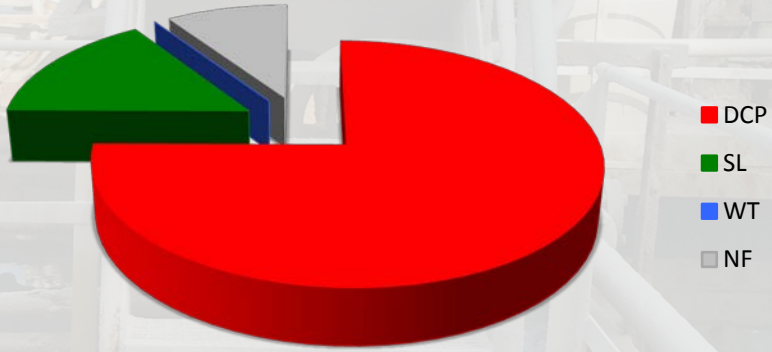
Output to Input Ratio (OIR)

Ra-226



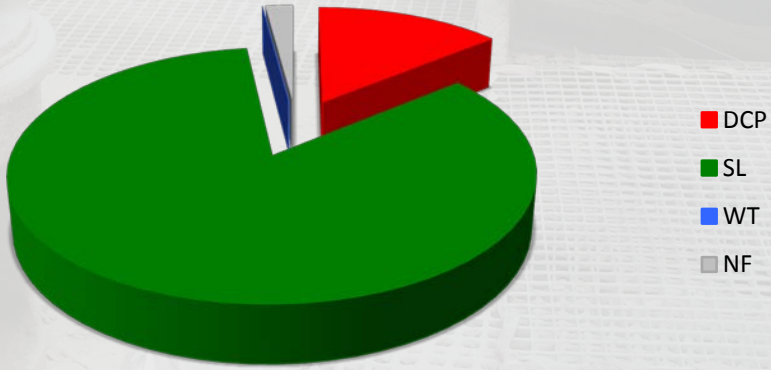
0,55±0,04

Pb-210



0,91±0,21

Po-210



0,98±0,25

RADIOLOGICAL CHARACTERIZATION: things to take into account….

Temporal variability in:

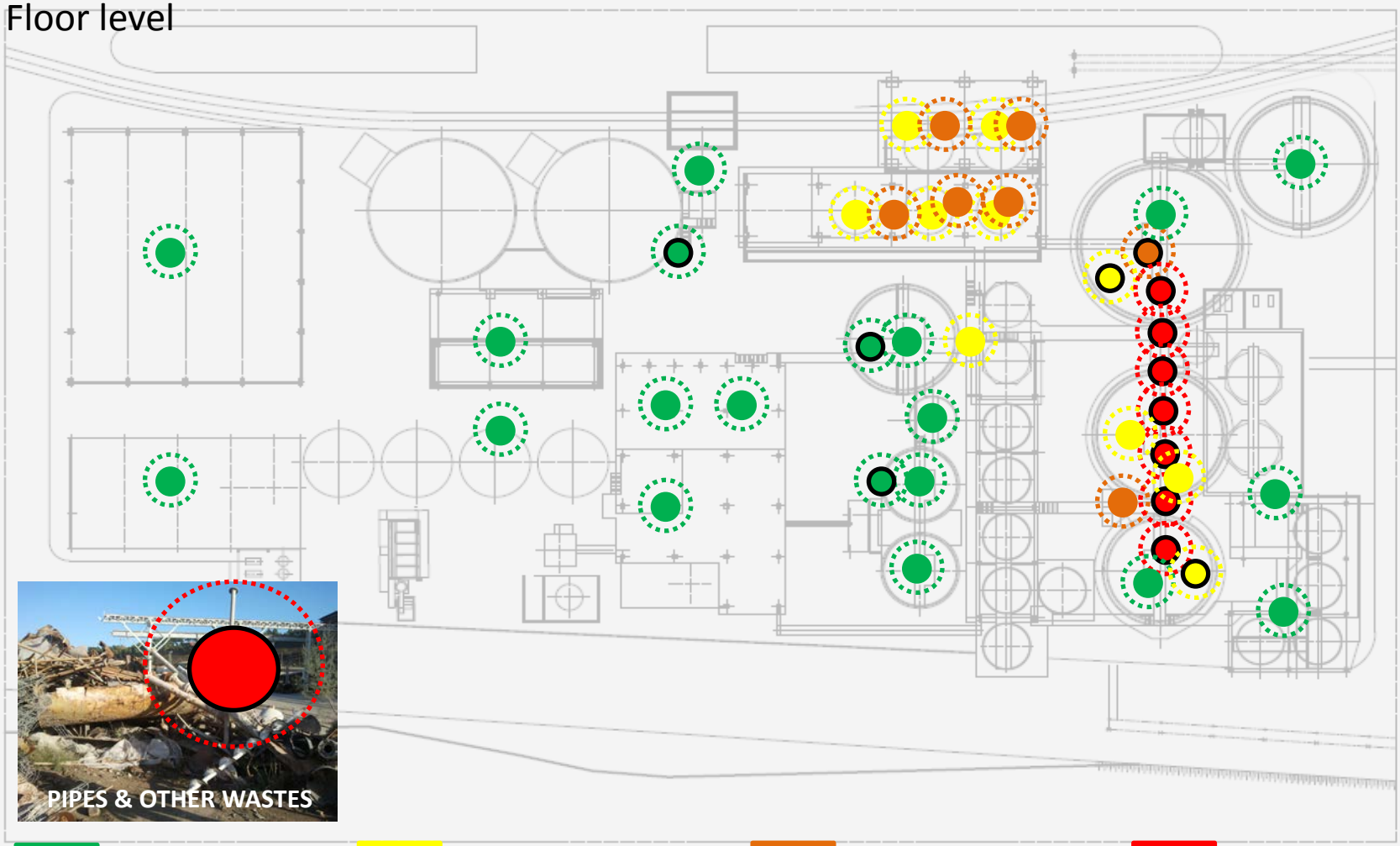
- Industrial production.
- Radionuclide concentration in products and sub-products.
- General fluxes of radionuclides.

Necessary to:

- Know the radionuclide behaviour within the industrial process.
- Estimate the amount of radioactivity in inputs and outputs.
- See the potential accumulation of radionuclides in the plant.

Gamma dose rates: AREA DOSIMETRY

Floor level



< 0.5 uSv·h^{-1}

0.5 – 3 uSv·h^{-1}

3 - 10 uSv·h^{-1}

> 10 uSv·h^{-1}

Gamma dose rates: HIGH EXPOSURE AREAS

Identification of two areas with HIGH GAMMA EXPOSURE:

- Reactors

- Pipes

CLEANING AND MAINTENANCE?

Gamma dose rates: CLEANING & MAINTENANCE

Gamma dose rates: CLEANING & MAINTENANCE

1st PERSONAL DOSIMETER: < 0,1 mSv

2nd PERSONAL DOSIMETER: < 0,1 mSv

3rd PERSONAL DOSIMETER: < 0,1 mSv

4th PERSONAL DOSIMETER: < 0,1 mSv

5th PERSONAL DOSIMETER: < 0,1 mSv

CLEANING AND MAINTENANCE OF REACTORS/DIGESTORS DOES NOT SUPPOSE A RADIOLOGICAL RISK TO THESE WORKERS:

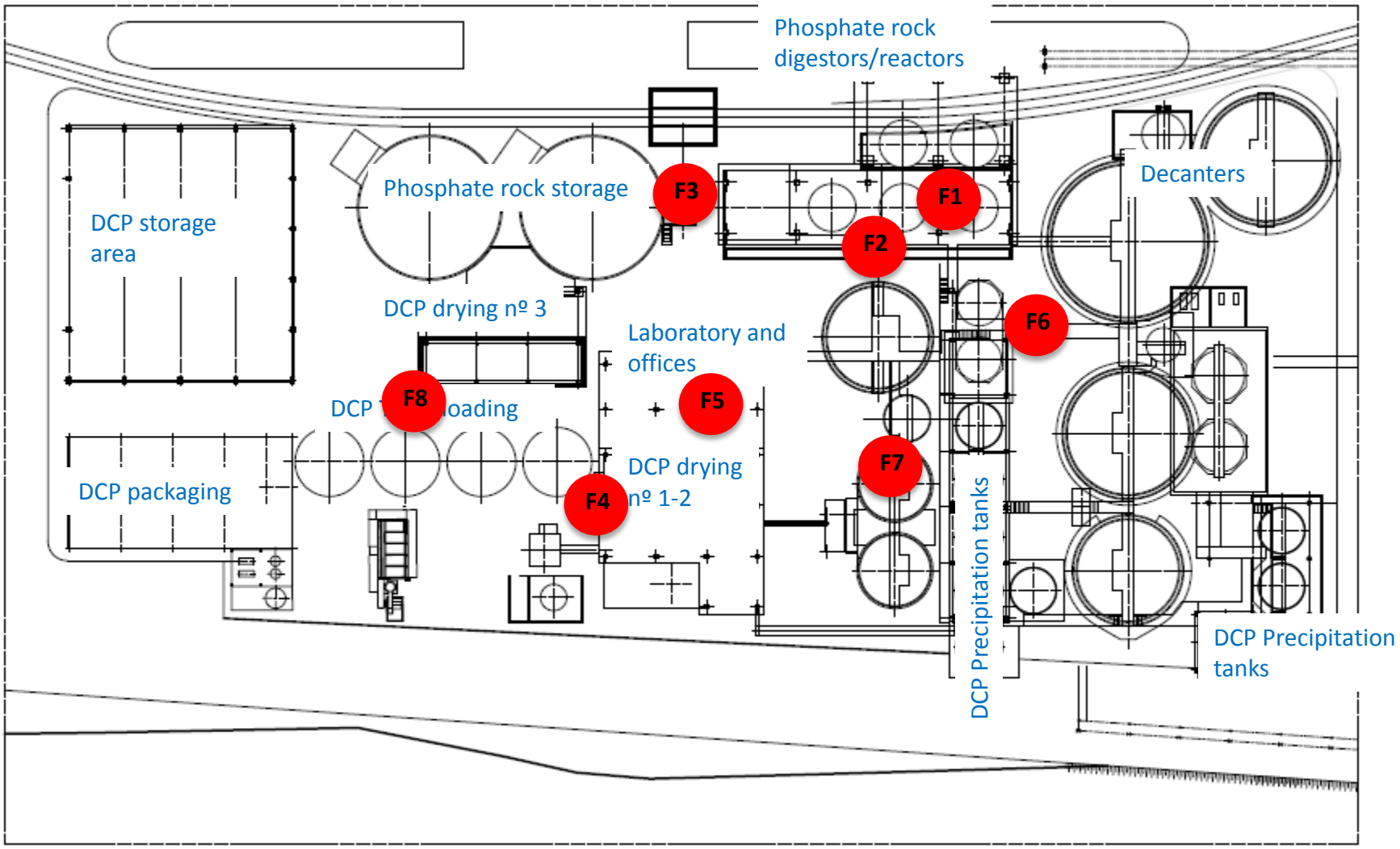
- Short time of exposure.
- High detection limit (0,1 mSv).

Inhalation dose rate: ^{222}Rn measurements

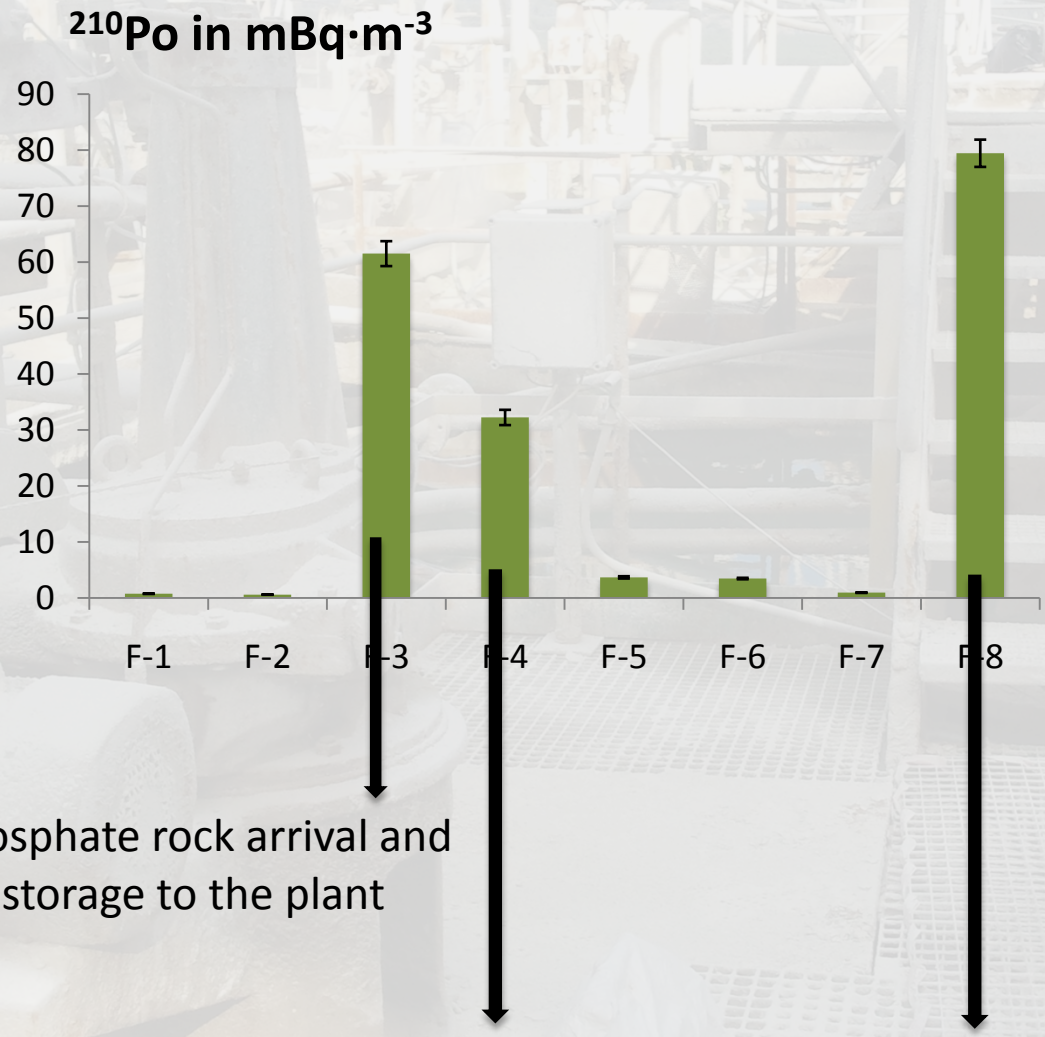
0 - 100 Bq·m^{-3} 100 - 200 Bq·m^{-3} 200 – 400 Bq·m^{-3}

< 600 Bq·m^{-3}

Inhalation dose rate: DUST CHARACTERIZATION



Inhalation dose rate: DUST CHARACTERIZATION



^{210}Po Inhalation dose rate (preliminary results)

$$E\ (mSv \cdot y^{-1}) = C_i \cdot V \cdot t \cdot DCC_{i(inh)}$$

C_i= Concentration of ^{210}Po in air (Bq·m^{-3})
V= Breathing rate (1,2 m^3·h^{-1})
t= Residence time of employees at the workplace (2000/year)
$DCC_{i(inh)}$= Dose conversion factor for ^{210}Po (if inhaled) (Sv·Bq^{-1})

Filter number	Description	mSv·y^{-1}		
F-1	Close to digestors	0,0040	±	0,0002
F-2	Digestors cleaning (floor 0)	0,0032	±	0,0002
F-3	PR arrival and storage	0,32	±	0,01
F-4	DCP packaging	0,170	±	0,007
F-5	Offices	0,019	±	0,001
F-6	On production line	0,018	±	0,001
F-7	On sludges line	0,0050	±	0,0003
F-8	DCP truck loading	0,42	±	0,01

DOSE ASSESSMENT TO WORKERS: things to take into account….

Residence time at each area within the plant.

Temporal variability in:

- Industrial production.
- Radionuclide concentration in products and sub-products.
- General fluxes of radionuclides.

Security measures: reduce the dose considerably.

Formation to workers.

ANUAL DOSE: < 1 $mSv \cdot y^{-1}$

OUTLINE

INTRODUCTION

The phosphate industry and the Dicalcium Phosphate production

The Spanish legal framework concerning NORM

AIMS OF THE STUDY

SAMPLING AND ANALYTICAL METHODS

RESULTS on:

RADIOLOGICAL CHARACTERIZATION

DOSE ASSESSMENT TO WORKERS

CONCLUSIONS & FUTURE WORK

CONCLUSIONS

RADIOLOGICAL CHARACTERIZATION:

- Products and by-products: < 1000 $Bq \cdot kg^{-1}$ ^{226}Ra, ^{210}Pb, ^{210}Po.
- Temporal variability of radionuclide concentration (depending upon production volume).
- Variability within fluxes of radionuclides but good Output to Input Ratio when averaging the 8 sampling weeks.
- About 40% of ^{226}Ra is enhanced within the production process.

DOSE ASSESSMENT TO WORKERS:

- In general < 0,5 $uSv \cdot h^{-1}$ except specific areas (reactors and pipes: up to 50 $uSv \cdot h^{-1}$).
- Clearence and maintenance of reactors/digestors does not suppose a radiological risk due to low time of exposure.
- Low ^{222}Rn concentrations (< 600 $Bq \cdot m^{-3}$).
- Potential high dose of inhalation (^{210}Po) in two specific areas.
- With proper formation to workers and simple security measures **< 1mSv·y^{-1}**.

FUTURE WORK

FINAL DOSE ASSESSMENT, considering:

- ^{226}Ra, ^{210}Pb and ^{210}Po in dust.
- Residence time of each employee at each area.
- Cleaning and maintenance of decanters and tubing.

WASTES MANAGEMENT:

1. Pipes and tubing

2. Press filters

Thank you!

Núria Casacuberta, Dani Mulas, Pere Masqué and Jordi Garcia-Orellana

Nuria.Casacuberta@uab.es

Institut de Ciència i Tecnologia Ambientals
Universitat Autònoma de Barcelona (Spain)

EU NORM I International Symposium, 5-8 June 2012, Tallinn, Estonia