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

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

- Sedimentary phosphate rocks: 1500 Bq·kg\(^{-1}\) in average
- Igneous deposits: 70 Bq·kg\(^{-1}\).
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
1- The industry holder MUST perform the studies to show whether 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.

Instructions: Nuclear Security Council (CSN)
SPANISH LEGAL FRAMEWORK IN NORM

Instructions: Nuclear Security Council (CSN)

- Effective dose to workers
  - $< 1 \text{ mSv} \cdot \text{y}^{-1}$: no further control is necessary.
  - $1 - 6 \text{ mSv} \cdot \text{y}^{-1}$: low-level control is necessary.
  - $> 6 \text{ mSv} \cdot \text{y}^{-1}$: advanced control is necessary.

- $^{222}\text{Rn}$ measures in working areas.
  - $600 \text{ Bq} \cdot \text{m}^{-3}$ average annual concentration.
  - $600 - 1000 \text{ Bq} \cdot \text{m}^{-3}$: low-level control is necessary.
  - $> 1000 \text{ Bq} \cdot \text{m}^{-3}$: advanced control is necessary.
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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 annual dose to workers (1 mSv·y$^{-1}$ ?).
- Quantify the doses during the cleaning and maintenance of particular areas in the production process.
- Study the $^{222}$Rn concentrations (600 Bq·m$^{-3}$ ?).
DCP plant description

- Phosphate rock storage
- DCP drying nº 3
- Phosphate rock digestors/reactors
- Decanters
- DCP Precipitation tanks
- DCP Precipitation tanks
- DCP drying nº 1-2
- Laboratory and offices
- DCP Truck loading
- DCP packaging
- DCP storage area
- DCP Truck loading
- DCP Precipitation tanks
RADIONUCLIDE 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

Alpha spectrometry (U/Th determination)

Gamma spectrometry

Alpha spectrometry (210Po deposition)
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226Ra, 210Pb & 210Po SPECIFIC CONCENTRATIONS

PHOSPHATE ROCK

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

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

DICALCIUM PHOSPHATE

226Ra: 1809±59 Bq·kg⁻¹
210Pb: 1731±143 Bq·kg⁻¹
210Po: 1620±126 Bq·kg⁻¹
226Ra, 210Pb & 210Po SPECIFIC CONCENTRATIONS

INDUSTRIAL SLUDGES

- 226Ra: 3191 - 4156 Bq·kg⁻¹
- 210Pb: 606 - 1485 Bq·kg⁻¹
- 210Po: 4407 - 8111 Bq·kg⁻¹

INDUSTRIAL WATERS

- 226Ra: 6 – 25 Bq·L⁻¹
100% kBq·h⁻¹
²³⁸U and daughters
OUTPUT FLUXES OF $^{226}\text{Ra}$
OUTPUT FLUXES OF $^{210}\text{Po}$
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.
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: $^{222}\text{Rn}$ 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

²¹⁰Po in mBq·m⁻³

Phosphate rock arrival and storage to the plant

DCP package and truck loading
$^{210}\text{Po} \text{ Inhalation dose rate (preliminary results)}$

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

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

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

RADIOLOGICAL CHARACTERIZATION:
- Products and by-products: $< 1000 \text{ Bq} \cdot \text{kg}^{-1}$ $^{226}\text{Ra}$, $^{210}\text{Pb}$, $^{210}\text{Po}$.
- 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 $^{226}\text{Ra}$ is enhanced within the production process.

DOSE ASSESSMENT TO WORKERS:
- In general $< 0.5 \text{ uSv} \cdot \text{h}^{-1}$ except specific areas (reactors and pipes: up to 50 uSv·h⁻¹).
- Clearance and maintenance of reactors/digestors does not suppose a radiological risk due to low time of exposure.
- Low $^{222}\text{Rn}$ concentrations ($< 600 \text{ Bq} \cdot \text{m}^{-3}$).
- Potential high dose of inhalation ($^{210}\text{Po}$) in two specific areas.
- With proper formation to workers and simple security measures $< 1\text{ mSv} \cdot \text{y}^{-1}$. 
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!

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