Occupational exposure assessment in a Titanium Dioxide plant located at the South-West of Spain

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OBJECTIVES

To evaluate the exposures of workers devoted to the production of titanium dioxide pigments through the so called "sulphate method"

Raw material: illmenite (NORM mineral, enriched in radionuclides from the U and Th series).

Routes of exposure considered:

- External radiation and Inhalation

Determinations of ^{222}Rn in the working place performed

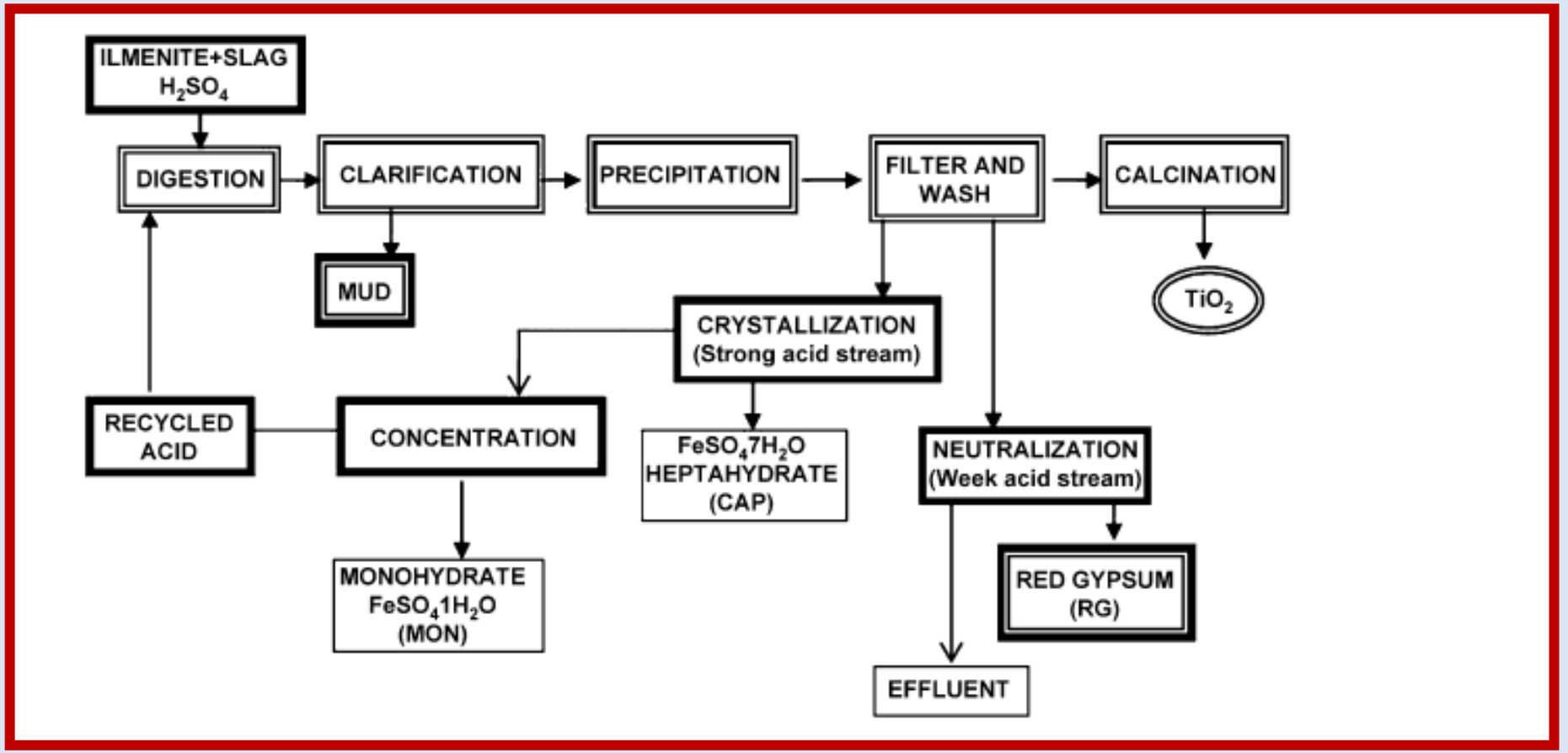
RAW MATERIAL

CHARACTERIZATION

MAJORITARY ELEMENTS (%)			
SiO_2	0.99	MgO	0.55
Al_2O_3	0.94	V_2O_5	0.23
FeO_T	41.81	CaO	0.09
ZrO_2	0.38	TiO_2	50.41
MnO	1.23		

ILLMENITE (Bq/Kg)					
	^{238}U	^{234}U	^{226}Ra	^{228}Ra	^{228}Th
ILM-1	118.5 ± 5.5	135.7 ± 6.4	93 ± 7	296 ± 20	306 ± 21
ILM-2	119.8 ± 5.6	154.9 ± 6.6	69 ± 6	260 ± 21	250 ± 21
ILM-3	108.2 ± 5.5	130.9 ± 6.2	79 ± 6	260 ± 23	252 ± 21
ILM-4	121.8 ± 5.8	146.5 ± 6.5	91± 6	325 ± 22	306 ± 21
ILM-5	123.5 ± 5.0	124. 7 ± 5.0	96 ± 4	365 ± 31	375 ± 30

INDUSTRIAL PROCESS SCHEME



MAGNITUDE OF THE INDUSTRIAL PROCESS

AMOUNTS PER YEAR

142 000 METRIC TONNES OF ILLMENITE

70 000 METRIC TONNES OF RED GYPSUM

140 000 METRIC TONNES OF COOPERAS

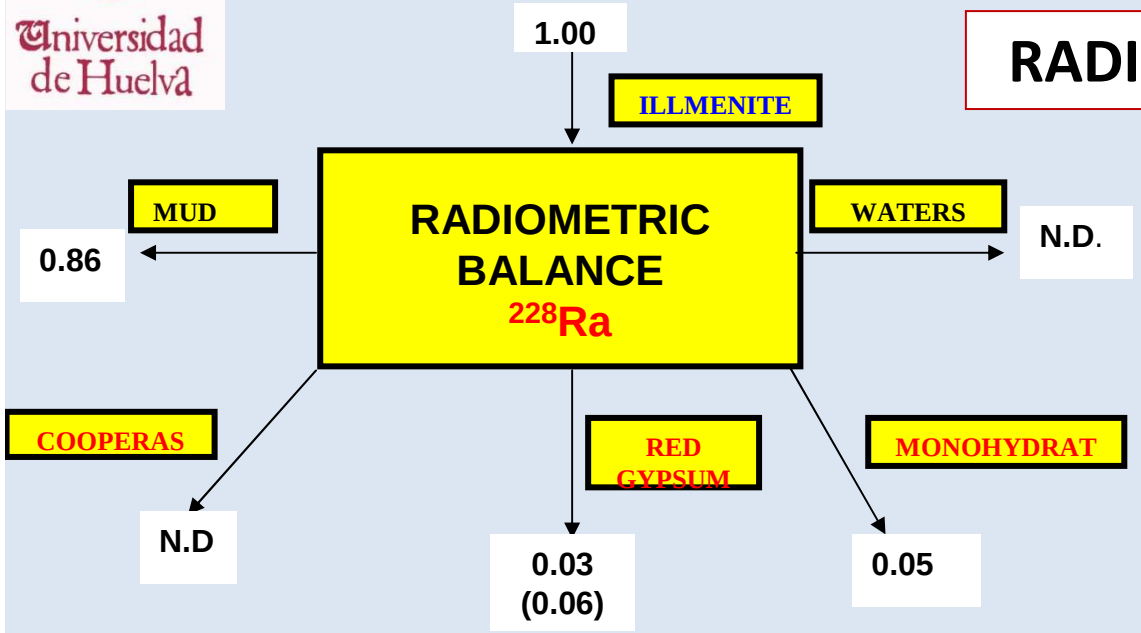
125 000 METRIC TONNES OF MONOHYDRATE

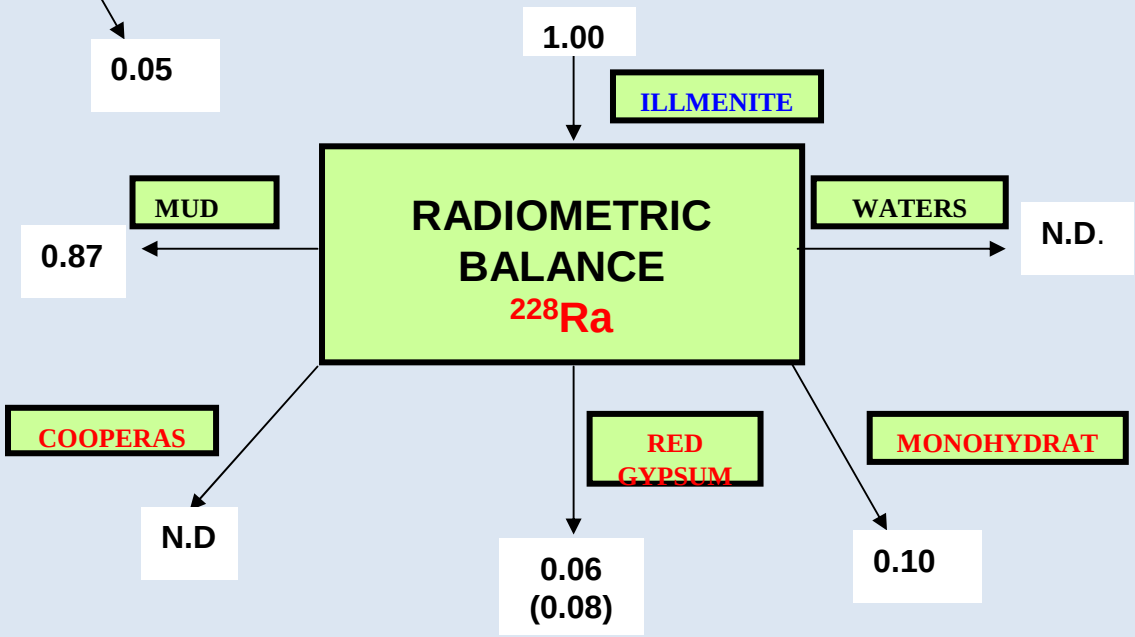
25 000 METRIC TONNES OF WET MUDS

WET MUDS (Bq/Kg)						
M		^{238}U (Bq/kg)	^{226}Ra (Bq/kg)	^{232}Th (Bq/kg)	^{228}Ra (Bq/kg)	^{228}Th (Bq/kg)
M	COOPERAS	0.9 ± 0.1	N.D*	8.0 ± 0.2	N.D*	9.1 ± 0.4
M	MONOHYDR.	53 ± 1	11 ± 1	365 ± 6	44 ± 2	411 ± 12
M	RED GYPSUM	19.4 ± 0.4	14 ± 1	115 ± 2	88 ± 3	122 ± 3
M	TiO_2 PULP	3 ± 1	6 ± 1	5 ± 1	25 ± 1	8 ± 1
MUD-5	238 ± 10	252 ± 11	744 ± 44	299 ± 27	2472 ± 150	656 ± 34

RADIONUCLIDE FLUXES

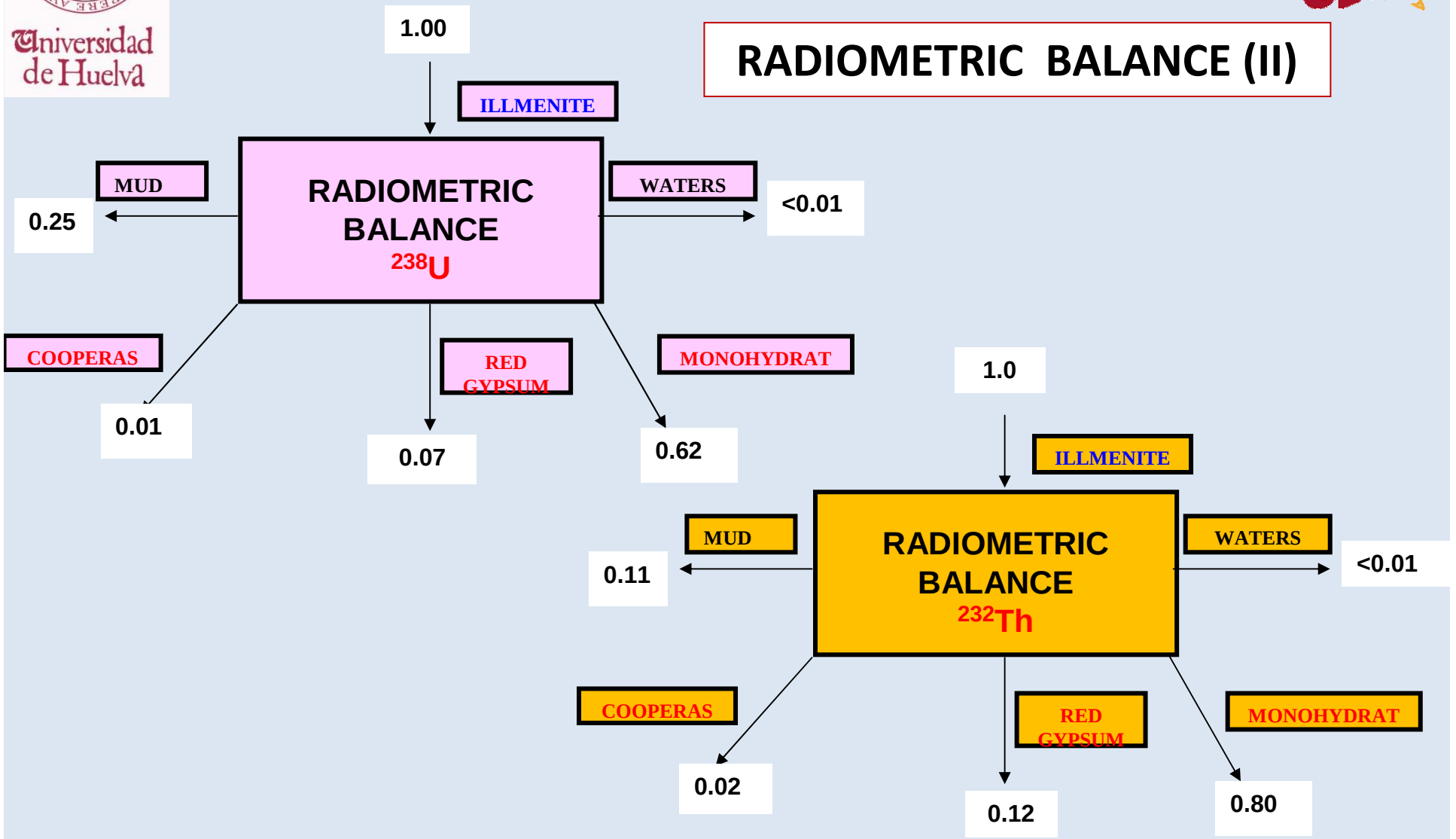
RADIOMETRIC BALANCE (I)





RADIONUCLIDE FLUXES

RADIOMETRIC BALANCE (II)



EXTERNAL RADIATION

WAREHOUSES

Instantaneous external gamma dose rates (μSv/h) determined at several storage areas in the analyzed TiO_2 plant.

STORAGE AREA	μSv/h
Open area for storage of Illmenite (7 measurements)	0.22 – 0.39
Open area for storage of Muds (6 measurements)	0.56 – 0.63
Storage area of Cooperas (3 measurements)	0.08
Storage area of Iron Sulphate Monohydrate	0.14
Storage area of Red Gypsum	0.12
Background value (outside the factory)	0.08 – 0.09

Muds transported in wet form to an inertising plant for treatment and safe disposal

EXTERNAL RADIATION

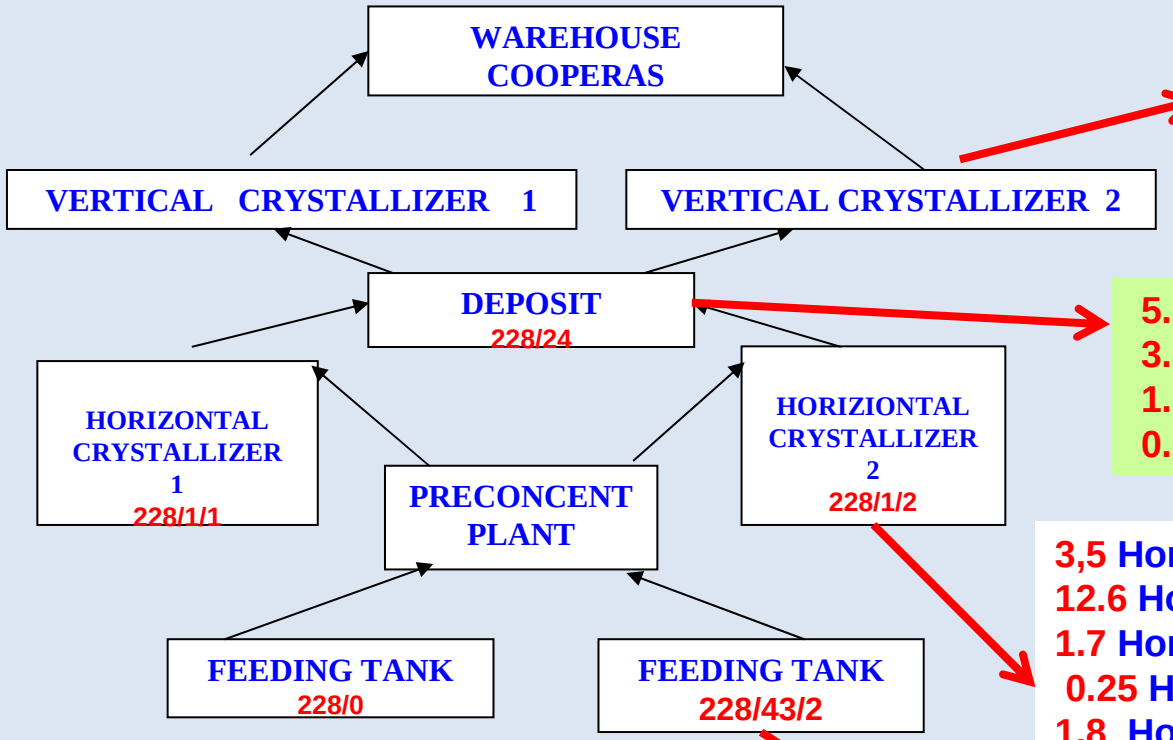
INDUSTRIAL PROCESS

Instantaneous external gamma dose rates (μSv/h) determined at several areas inside the analyzed TiO_2 plant.

AREA	μSv/h
Open Area for storage of Illmenite	0.22 – 0.39
Milling Area	0.12 – 0.25
Digestion Area	0.11 – 0.23
Area separation sludges	0.10 – 0.23
Hydrolisis Area	0.10 – 1.10
Crystallization Area	0.15 – 12.60
Maduration area (monohydrate)	0.10 – 0.55
Washing Area	0.15 -0.28
Neutralization Area (Red Gypsum)	0.10 – 0.15
Area finishing TiO_2 pigment	0.10 – 0.12

EXTERNAL RADIATION

CRYSTALLIZATION AREA



0.54 Vertical Crystallizer 1. Lower part
0.18 Vertical Crystallizer 1. Upper part
0.62 Vertical Crystallizer 2. Lower part
0.16 Vertical Crystallizer 2. Upper part

5.1 Deposit 228/24 lower part east side
3.3 Deposit 228/24 lower part west side
1.0 Deposit 228/24 upper part est side
0.6 Tanque 228/24 upper part west side

3,5 Horizontal Crystallizer 1. Separator
12.6 Horizontal Crystallizer 2. Separator
1.7 Horizontal Crystallizer 1. Initial zone
0.25 Horizontal Crystallizer 1. Final zone
1.8 Horizontal Crystallizer 2. Initial zone
0.55 Horizontal Crystallizer. Intermediate zone
0.27 Horizontal Crystallizer. Final zone

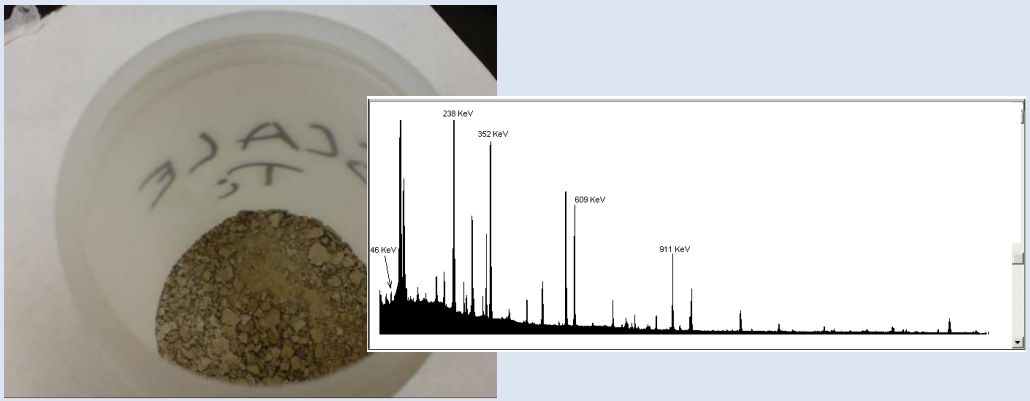
μSv/h

0.35 Deposit 228/0

EXTERNAL RADIATION

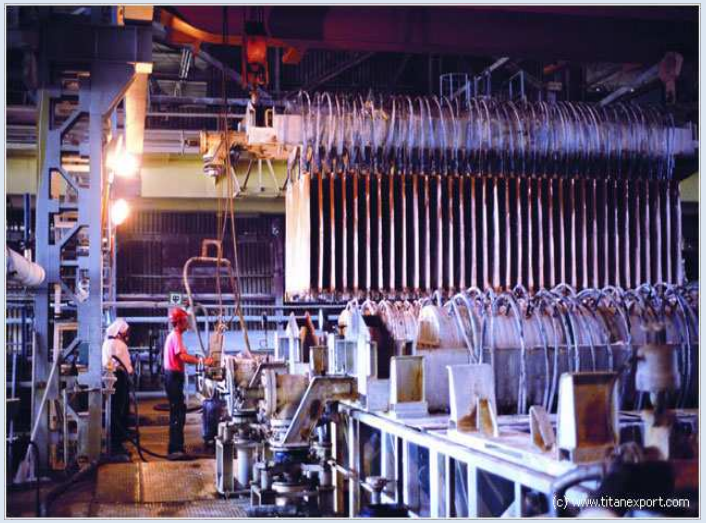
HOT POINTS

SCALES



	Bq/g
^{228}Ra	180
^{224}Ra	165
^{226}Ra	105
^{210}Pb	25
^{40}K	15

MOORE FILTERS



- Pb-210 : 520 Bq/m^2
- Ra-226: 1400 Bq/m^2
- Ra-228: 5600 Bq/m^2
- Ra-224: 1600 Bq/m^2

EXTERNAL RADIATION

Higher instantaneous external dose rates at places with very low occupancy factor.

↓

Occupational effective doses due to external radiation are under normal running conditions lower than 1 mSv/y.

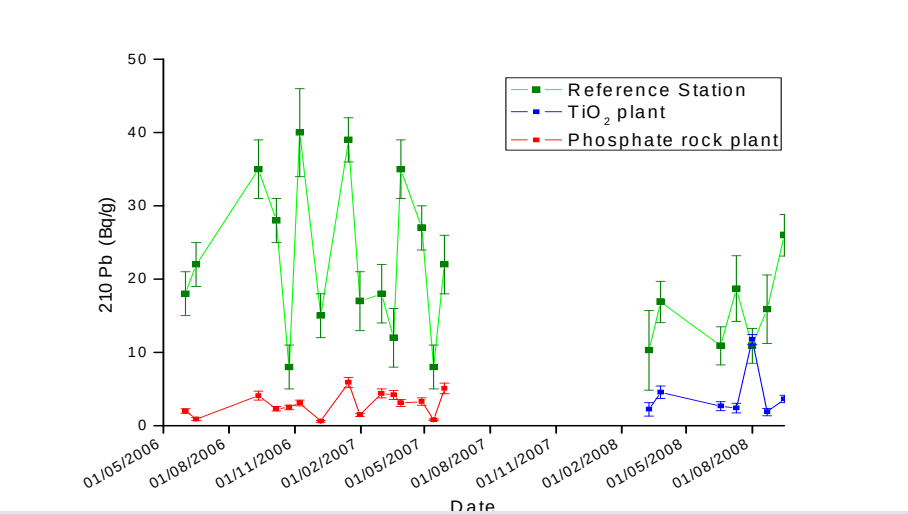
Workers in the crystallizer area:

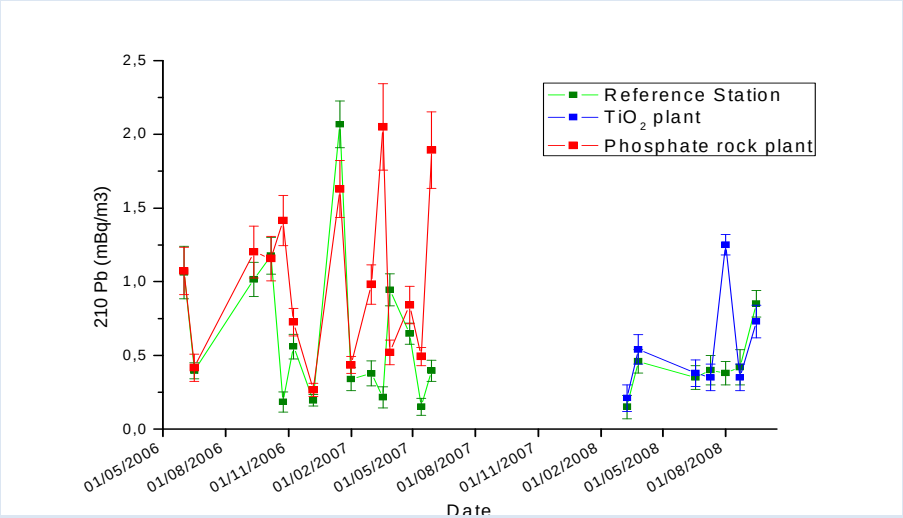
. Conseravtive instantaneous dose rate	10 μSv/h
. Occupational factor	50 h/year
- Effective dose rate external radiation	0.5 mSv/y

INHALATION (I)

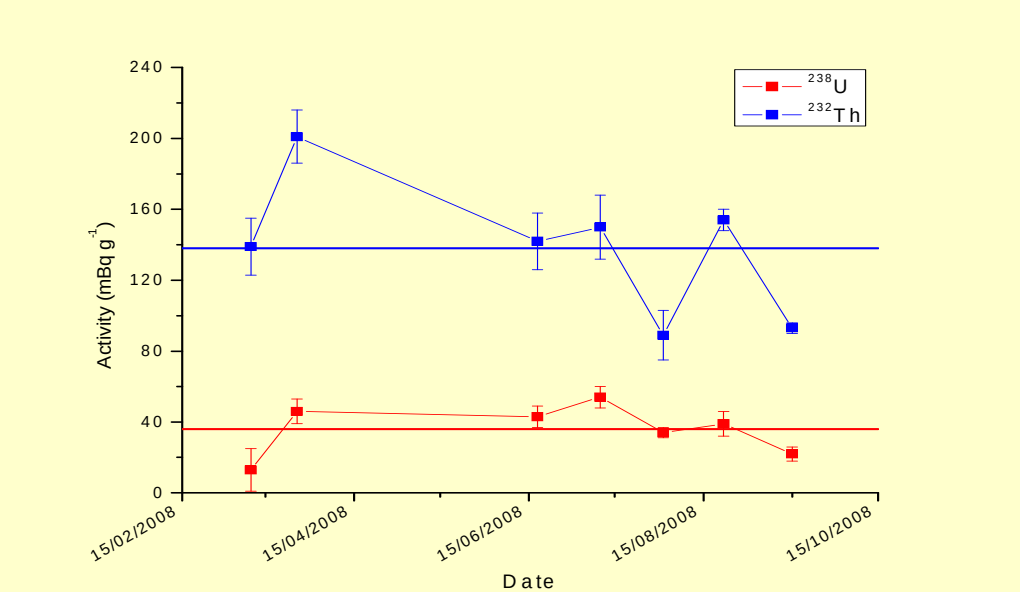
Samplings were performed at different locations of the factory with high volume samplers (68 m^3 h^{-1}, and PM10 inlets), using QF20 Schleicher and Schuell quartz fibre filters and taken one sample every fifteen days with an air collection time of 48 hours.

The average particulate matter concentration in the TiO_2 plant was 140 ± 30 μg m^{-3} , one order of magnitude higher than the determined one in a reference station (26 ± 3 μg m^{-3}).





INHALATION (II)



Ra-isotopes in secular equilibrium with their progenitor in both series.
U/Th ratios similar to the found ones in the raw material

Main origin of the aerosols:
milled illemenite, diluted with material depleted in natural radionuclides

Committed efective doses due to inhalation evaluated as few µSv/y

^{222}Rn DETERMINATIONS

Determinations performed with passive detectors during several months at different locations of the factory.

In all the cases, the concentrations of ^{222}Rn were lower than 100 Bq/m^3

Concentrations not unexpected because the factory is very good ventilated

DUE TO ^{222}Rn, NO REMEDIATION ACTIONS ARE NEEDED

CONCLUSIONS

The TiO_2 industry working by the "sulphate method" is a typical example of NORM industry. Raw material contains around 100Bq/kg of radionuclides from the Uranium series and 300 Bq/*Kg* of radionuclides from the Th series.

Along the industrial process the secular equilibrium between the radionuclides from the same series is disrupted, following different routes according to their chemical behaviour.

Under normal running conditions, the occupational exposures by external radiation are quite moderate and lower than 1 mSv/y.

The inhalation route has clearly less influence that the external irradiation route in the occupational exposure increments.

^{222}Rn levels inside the TiO_2 factory are of non concern.

From the radiological point of view, only some precautions need to be taken in specific points of the factory during maintenance operations: cleaning of crystallizers, changes of Moore filters, etc.

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