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CHALLENGES AND SOLUTIONS

Radionuclides and Preliminary Radiological Assessment in the Phosphate Industry of Senegal

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Outline

I. Reserves and phosphate production

II. Content of Phosphate rock in Senegal

III. Production of phosphoric acid in Senegal

IV. Material and methods

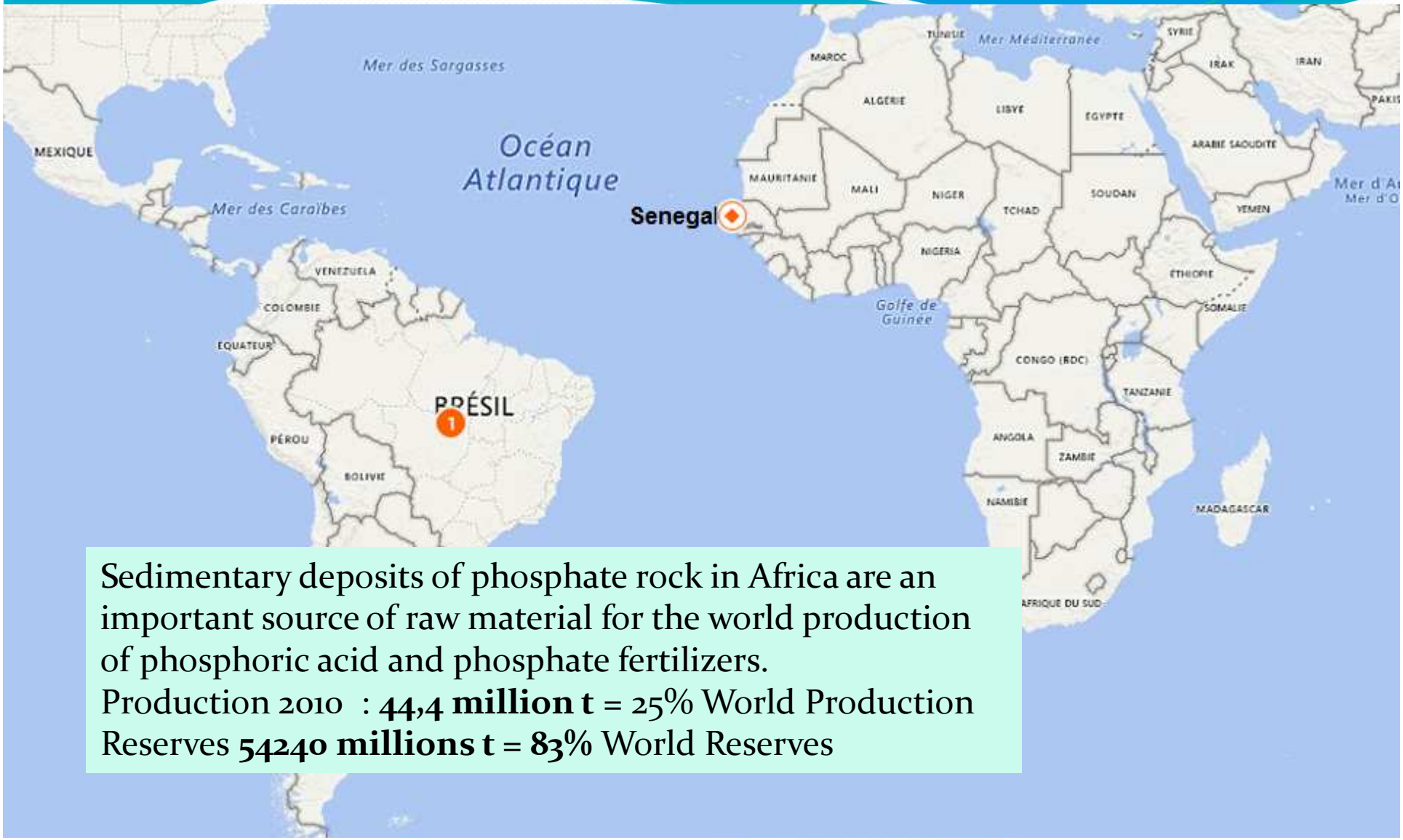
V. Results and discussions

VI. Conclusion





I. Reserves and Production



Sedimentary deposits of phosphate rock in Africa are an important source of raw material for the world production of phosphoric acid and phosphate fertilizers.

Production 2010 : **44,4 million t** = 25% World Production

Reserves **54240 millions t** = **83%** World Reserves

I. Reserves and Production

Several sedimentary deposits occur in Senegal and estimated **mine production 2010 = 0,65 million t**

Matam, calcium phosphates (**Reserves 100 millions t**).

Thiès-Lam Lam, alumino calcium phosphates (**Reserves 80 millions t**) (**mining actvities since in 1960 in Taïba**)





I. Reserves and Production

ICS phosphate mine in TAÏBA (100 km from DAKAR)

phosphoric acid plants loc DAROU plant, near the min

fertilizers in a plant located in MBAO (18 km of DAKAR)

The phosphoric acid produced is temporarily stocked in open ponds and later pumped in wagons to be transported by railways to Dakar harbor for export.

II. Content of Phosphate rock in Senegal

Phosphate rock in Senegal, besides phosphor and calcium, content also many other elements.

Main chemical constituents of phosphate ores. Concentration (%)							
P_2O_5	CaO	SiO_2	MgO	Al_2O_3	Fe_2O_3	F	CO_2
15–39	8–47	12–45	0.8–5.2	0.5–32	0.5–10		Ref.1

Main chemical constituents in the phosphate rock. Concentration (%) Ref.1 Ref.2									
P_2O_5	CaO	SiO_2	MgO	Al_2O_3	Fe_2O_3	F	CO_2	Na_2O	K_2O
32–37	50	5	0.1	1.1	0.9	3.7	1.8	0.3	0.1

Heavy metal in phosphate rock. Concentration (ppm)					
Cd	Hg	Cu	Pb	As	Cr
<5–115	0.2	Ref.1 Ref.2	5	18	6

Radionuclides in phosphate rock. Activity concentration (Bq/g)			
Ref.2 Ref.3 Ref.4 ^{238}U	^{230}Th	^{226}Ra	^{210}Pb
0.7–1.3		1–1.1	1

VAN STRAATEN, P., Rocks for Crops: Agrominerals of Sub-Saharan Africa, International Centre for Research in Agroforestry, Nairobi (2002), http://www.uoguelph.ca/~geology/rocks for crops/ Ref.1

VAN DER WESTHUIZEN, A.J., Foskor Limited, Phalaborwa, South Africa, personal communication, 2002. Ref.3

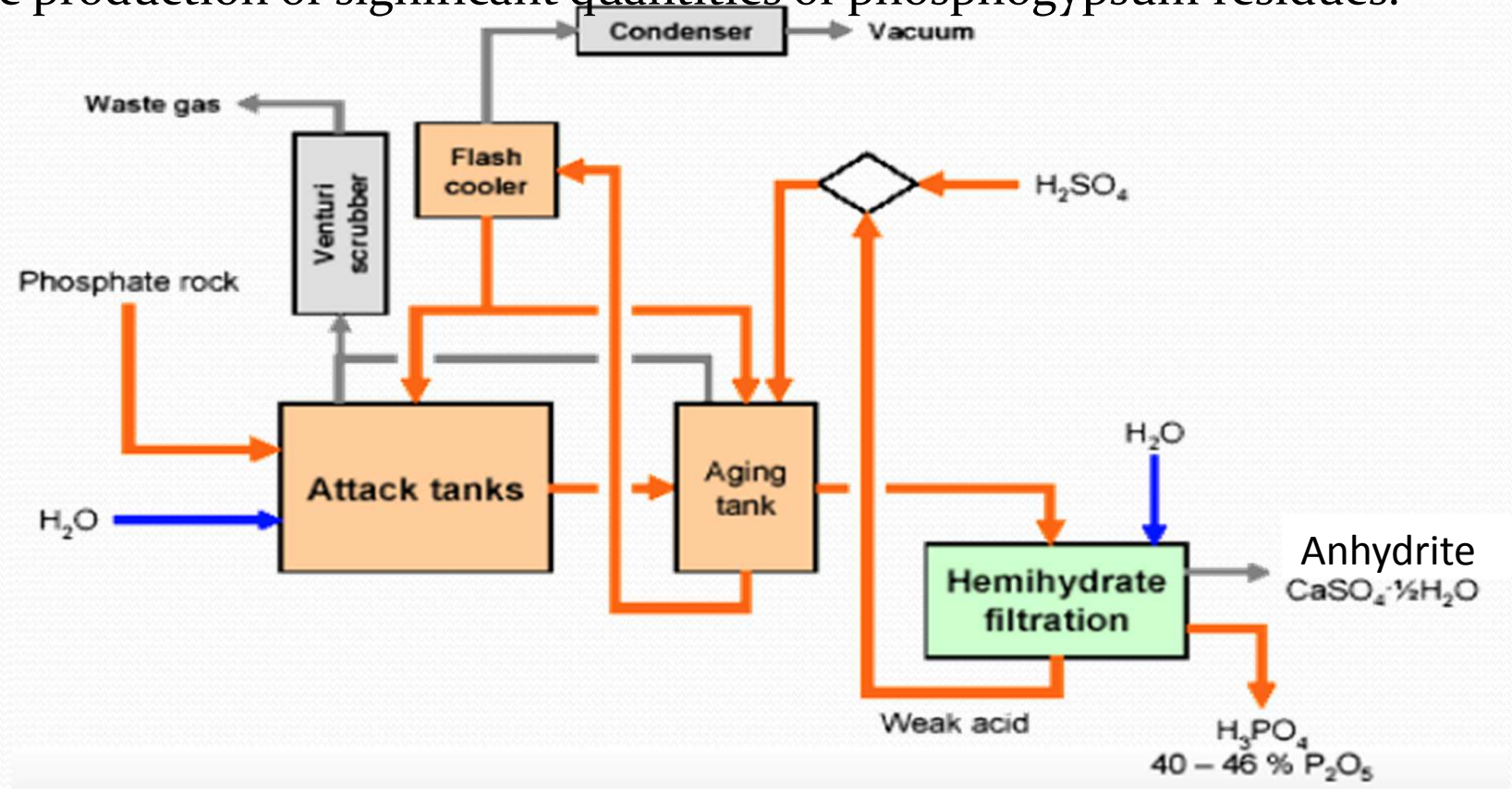
EUROPEAN FERTILIZER MANUFACTURERS' ASSCOCIATION, Best Available Techniques for Pollution Prevention and Control in the European Fertilizer Industry, Booklet No. 4 of 8: Production of Phosphoric Acid, EFMA, Brussels (2000). Ref.2

LARDINOYE, M.H., WETERINGS, K., VAN DE BERG, W.B., Unexpected ^{226}Ra build-up in wet process phosphoric-acid plants, Health Phys. **42** 4 (1982) 503–514 Ref.4

One amongst such elements is uranium (in the order of a few Bq/g) and its radioactive progeny which, altogether, may cause occupational exposure to ionizing radiation in phosphate processing facilities.

III. Production of phosphoric acid in Senegal

The industrial process used in Senegal for dissolving phosphate rock is the attack with sulfuric acid which is the basis for the production of phosphoric acid and leads to the production of significant quantities of phosphogypsum residues.



$Ca_{10}(PO_4)_6F_2 + 10\ H_2SO_4 + 10x H_2O = 6\ H_3PO_4 + 10\ CaSO_4,\ xH_2O + 2\ HF$

x = 0,5 ⇒ hemi-hydrate method **x = 2** ⇒ dihydrate method.

(Solution of **phosphoric acid** H_3PO_4) and (**calcium sulfat** in solid form named phosphogypsum).

III. Production of phosphoric acid in Senegal

Figure 1. Left: phosphate rock mining; Right: phosphoric acid plant and phosphogypsum piles at Taïba.

A pit of about 30 m depth to reach the phosphate rich layer often immerged in the water table, which prevents dust release during excavation

IV. Matérial and methods

- Measurements external radiation (ambient dose rates) were performed at 1 m above the ground with portable spectrometer Identifinder from FLIR, duly calibrated in a SSDL with a standard cesium-137 and cobalt-60 sources.
- Representative samples of materials were collected with a stainless steel large spoon and sealed in identified plastic bags. and the GPS coordinates duly recorded
- In the laboratory samples (aliquots of about 100g) were analyzed by gamma spectrometry in sealed boxes with the same geometry as customized multisource calibration sources from Eckert&Ziegler, using a large volume Broad Energy Germanium (BEGe) detectors.
- Gamma spectra were analyzed with Genie 2000 software
- The QA/QC was ensured through regular participation in the IAEA analytical inter-laboratory comparison programme and analysis of certified reference materials.

V. Results and discussions

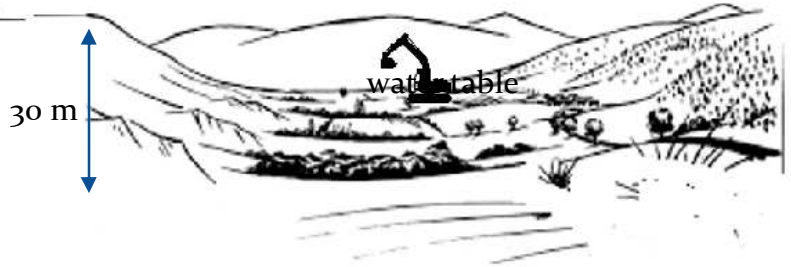
Ambient radiation exposure.

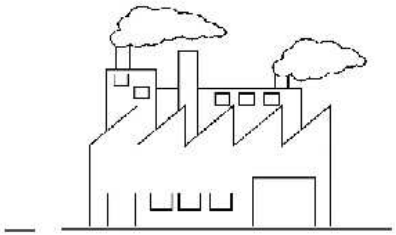
A preliminary assessment of **radiation doses at workplaces** in the **phosphate industry** was carried out in Senegal encompassing all phases, from the phosphate mine to the phosphoric acid production plant.

Background dose rate
0.02 to 0.04 µSv/h

15º 07′ 46” N, 016º 53′ 20” W

Open pit of a phosphate mine,
dose rate : 0,39 to 0.65 µSv/h





Chimical plant
near the ore piles
0.62-0.64 µSv/h.

V. Results and discussions

Occupational radiation exposure is assessed.

In the **chemical plant**, the ambient radiation doses near the ore piles were of **0.62-0.64 µSv/h.**

The phosphogypsum is to **waste piles** where radiation dose rate reached **5 µSv/h**.

dose rates increased to **6-8 µSv/h by the filtration unit**

For 2000 h work per year and assuming full time exposure at worplaces, **radiation exposure to these external sources in the facilities** may give rise to annual doses :

of **2-4 mSv/y at several work posts**,

of **16 mSv/y in the filtration unit**,

a **maximum of 24 mSv/y at the surface of iron pipes**.

V. Results and discussions

Partitioning of radionuclides in phosphate materials during industrial processing

Table 1. Radionuclide concentrations (Bq/kg) in soil and phosphate materials from the region of Taïba.

Samples	K-40	Ra-226	Ra-228	U-235
#1 Top soil from the mining area	13±6	16±1	10±1	<3,1
#2 Taïba city, surface soil	18±5	10±1	8±1	<3,1
#3 Unprocessed phosphate rock	<22	1230±50	14±1	85±10
#4 Wet phosphate raw material	<19	1080±80	8±1	65±12
#5 Phosphogypsum	<19	600±20	3±1	14±6

Radionuclides of U series are represented by 226Ra, and of Th series by 228Ra, and actinium series by the 235U.

- **Top soil** (city and mining area) : similar concentrations of **^{226}Ra** and **^{228}Ra**
- **Phosphate ore** : concentrations of uranium series radionuclides were much higher than those of thorium series radionuclides.The elevated uranium concentration and thus 226Ra concentration is related to the marine origin of phosphate rock deposit. This phosphate rock was likely produced by biogenic processes in an upwelling planktonic area, and its radioelement composition reflects the much higher abundance of uranium in sea water compared to thorium.
- The concentration of 40K in soils and in phosphate rock were all low.




V. Results and discussions

Activity concentrations, Bq/kg

K-40	Ra-226	Ra-228	U-238
13 ±6	16 ±1	10 ±1	< 3,1

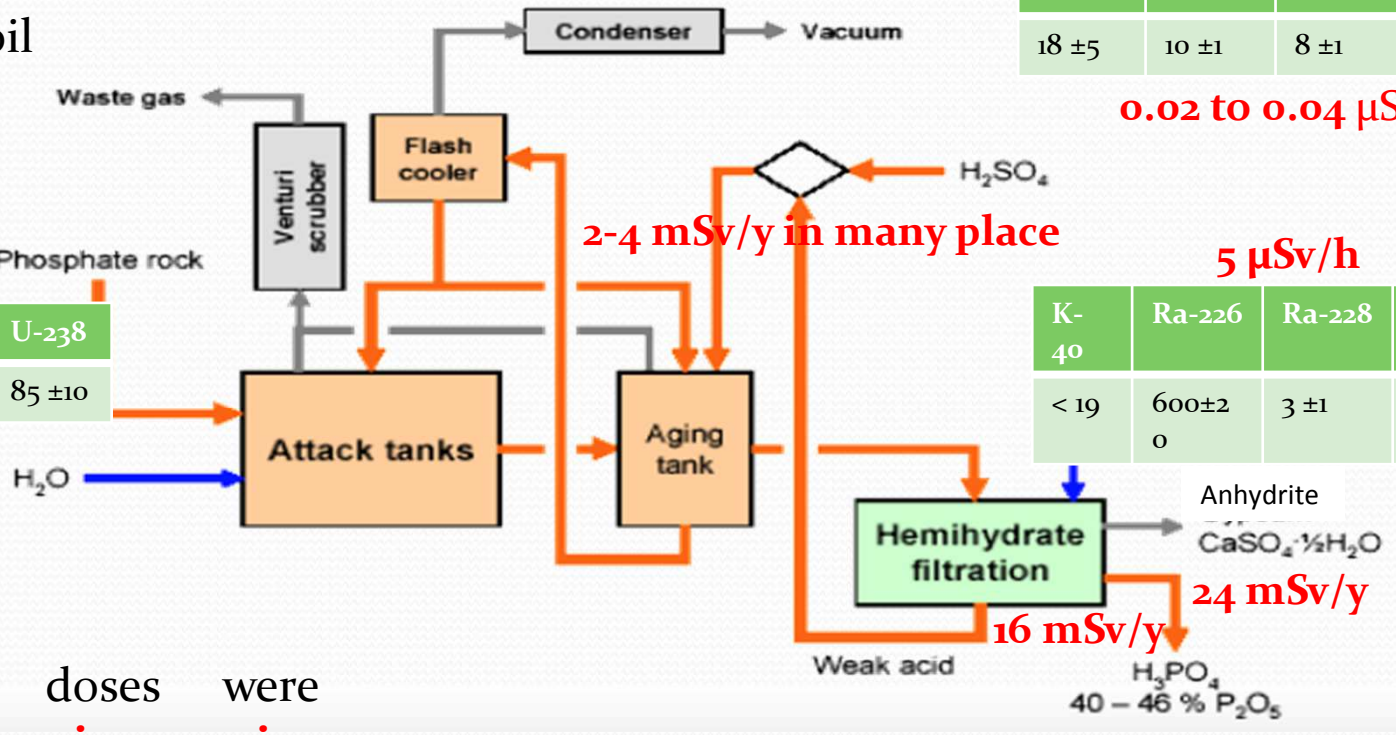
Mining area, top soil

0,78 to 1.3 mSv/y

Taïba City soil

K-40	Ra-226	Ra-228	U-238
18 ±5	10 ±1	8 ±1	< 3,1

0.02 to 0.04 µSv/h



K-40	Ra-226	Ra-228	U-238
< 22	1230 ±50	14 ±1	85 ±10

5 µSv/h

K-40	Ra-226	Ra-228	U-238
< 19	600±20	3 ±1	14 ±6

These radiation doses were **mostly due to uranium series radionuclides**

Wet phosphate raw material

K-40	Ra-226	Ra-228	U-238
< 19	1080 ±80	8 ±1	65 ±12

V. Results and discussions

In the mine trench and in the facilities of the chemical plant, besides exposure to external radiation :

- the **inhalation of dust** containing radionuclides needs to be assessed as a pathway of radiation exposure, although inhalation of acid vapors might even be an higher occupational health risk;
- Due to the elevated concentrations of uranium series radionuclides (226Ra), the **radon (222Rn)** may be also a relevant stressor and the radiological risk of radon inhalation must be assessed;
- **Phosphogypum** content of 226Ra is 600±20 Bq/kg give interest in the concentration of other uranium series radionuclides, such as 210Po and 210Pb, which are expected to be present in phosphogypsum in much higher concentrations because of their low solubility;
- The **final destination of phosphogypsum** piles, and eventually its confinement is open to assessment and decision.

VI. Conclusion

This survey of phosphate rock mining and phosphoric acid production in Taïba, allowed identifying :

- **enhanced radiation dose rates** especially in the **chemical plant**. A more detailed **radiation protection study** shall be carried out in order to advise radiation protection measures that shall be implemented by the company.
- the **cleaning of pipes and disposal of scales**, which may have very high radium content, need specific attention.
- **Radon exposure in the facilities should be investigated** also in order to adopt suitable radioprotection measures for workers, besides protection against inhalation of acid fumes.
- the **large volume of phosphogypsum stacks** sticking out of landscape and its dispersal in the environment by famers, rain and wind **needs assessment** due to the close distance to the city of Taïba.
- It is also pertinent to **assess the radiological risk** of use of uranium rich phosphate fertilizers which may eventually advocate for the relevance of extracting uranium from phosphoric acid.
- A more **completed radiation protection study** shall be carried out in order to increase the **regulatory awareness** and advise radiation protection measures that shall be implemented in these industries in Senegal.





THANK YOU FOR ATTENTION