Development of a semi-empirical model for radiological assessment of workers involved in operation and maintenance of Oil & Gas plants

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Summary

- Nucleco experience
- NORM in BSS (Basic Safety Standards)
- NORM in Oil & Gas industry
- On-Field operations
- MCNP dose assessment
- Conclusions

Business Overview

Health Physics & Radiological Characterisation

- *Chemical and Radiological Characterization*
- *Radiation Monitoring*
- *Health Physics and Radiation Protection*
- *Environmental impact assessment*

Radioactive Waste & Sources Management

- *Radwaste Treatment and Conditioning*
- *Large Components Dismantling*
- *Temporary Storage*
- *Qualification and Process Development*

Decommisioning & Site Remediation

- *On-Site Dismantling and Decontamination*
- *Work Design and Supervision*
- *Remediation of Contaminated Sites*
- *Emergency planning*

NORM in Basic Safety Standards

Scope of the EURATOM Directive 2013/59

- *"This directive applies in particular to:*

  (c) human activities which involve the presence of natural radiation sources that lead to a significant increase in the exposure of workers or members of the public, in particular:

  (ii) the processing of materials with naturally-occurring radionuclides."

Identification of practices involving Naturally-Occurring Radioactive Material

- *"Member States shall ensure the identification of classes or types of practice involving Naturally–Occurring Radioactive Material […]. Such identification shall be carried out by appropriate means taking into account industrial sectors listed in Annex VI."*

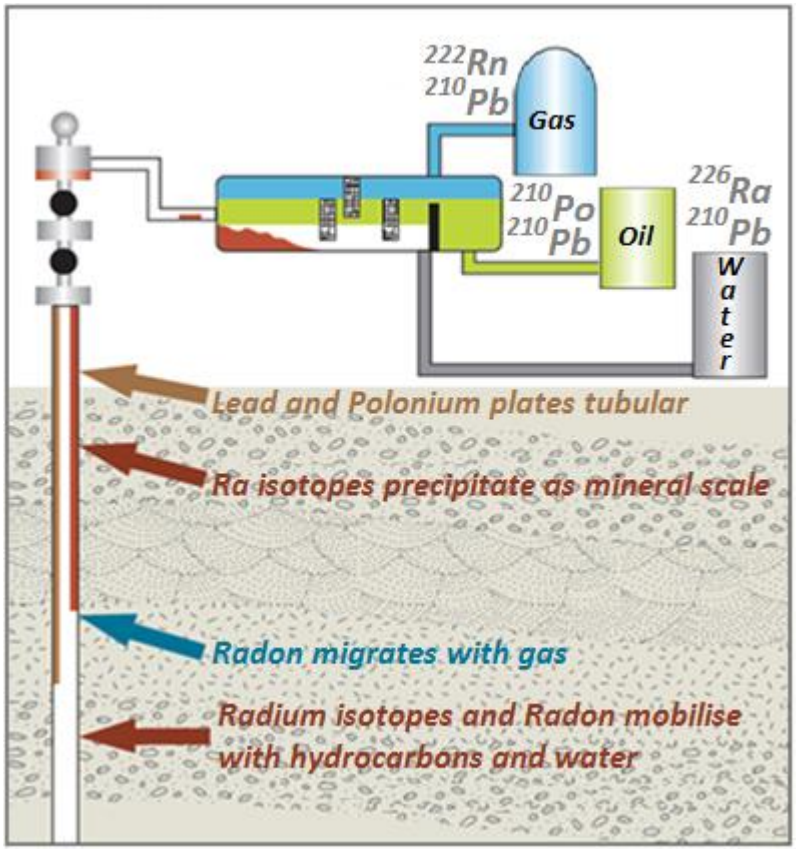
Planned Exposure Situations

- *"Exposure due to natural sources is, in general, considered an Existing Exposure Situation […]. However, the relevant requirements in Sec. 3 for Planned Exposure Situations apply to:*

  (a) Exposure due to material in any practice […] where the activity concentration in the material of any radionuclide in the $^{235}U/^{238}U/^{232}Th$ decay chain is greater than 1 Bq/g […].

NORM in Oil & Gas Industry

Mobilization from Reservoir Rock



Radionuclide	Scale [Bq/g]	Sludge [Bq/g]	Nat. Gas [Bq/m³]
^{238}U	0.001 - 0.5	0.005 - 0.01	-
^{226}Ra	0.1 - 15 000	0.05 - 800	-
^{210}Po	0.02 - 1.5	0.004 - 160	0.002 - 0.08
^{210}Pb	0.02 - 75	0.1 - 1 300	0.005 - 0.02
^{222}Rn	-	-	5 - 200 000
^{232}Th	0.001-0.002	0.002 - 0.01	-

Oil & Water - Scale Prediction

Mixing of incompatible waters

Water	*mg/l*	*Ba^{2+}*	*Ca^{2+}*	*Sr^{2+}*	*Ra^{2+}*	*SO_4^{2-}*
Formation water	*Min*	*20*	*700*	*170*	*5.4E-11*	*15*
	Max	*1 200*	*9 000*	*650*	*3.2E-5*	*140*
Seawater	*Min*	*-*	*200*	*-*	*-*	*2 700*
	Max	*<0.2*	*450*	*10*	*-*	*3 400*

Drop in temperature and pressure → Supersaturation → Precipitation

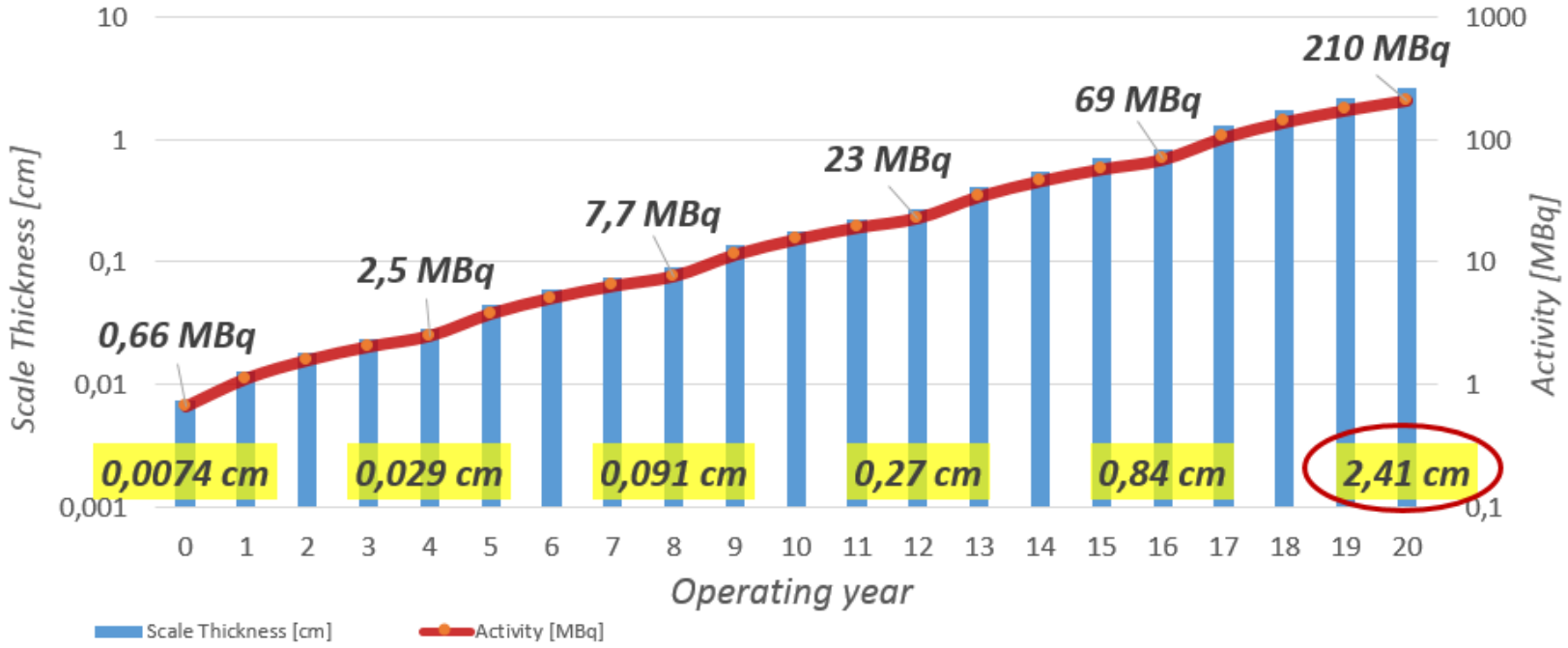
- ***Crystal growth rate***
- ***Supersaturation degree***
- ***Volumetric flow rate***
- ***Water fraction trend***

Radium co-precipitates with Barium Sulfate

Oil & Water - Scale Activity

Key assumptions for scale thickness and activity deposited

- *12 months of continuous operation starting each year from no thickness*
- *1 meter height section of the 3 km depth extraction duct – worst situation*
- *Constant flow rate and supersaturation degree*
- *Only $BaSO_4$ accumulates and causes radioactive scale – 6350 Bq/g*



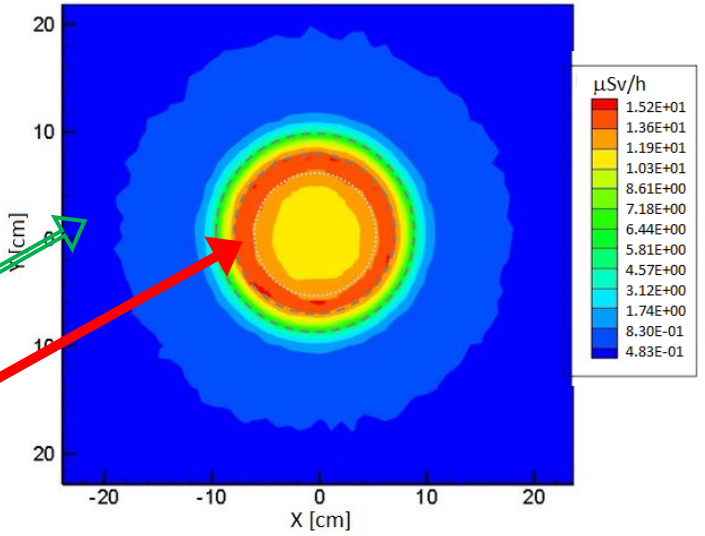
Oil & Water - Effective Dose from Scale

Oil and Production Water flow

- *1 m^2 square area around the pipe*
- *Air surrounds external surface*
- *50% water and 50% oil - last year of operation*
- *2.4 cm thickness of radioactive $BaSO_4$*

External dose: 0.48 µSv/h

Hot spot: 15.2 µSv/h

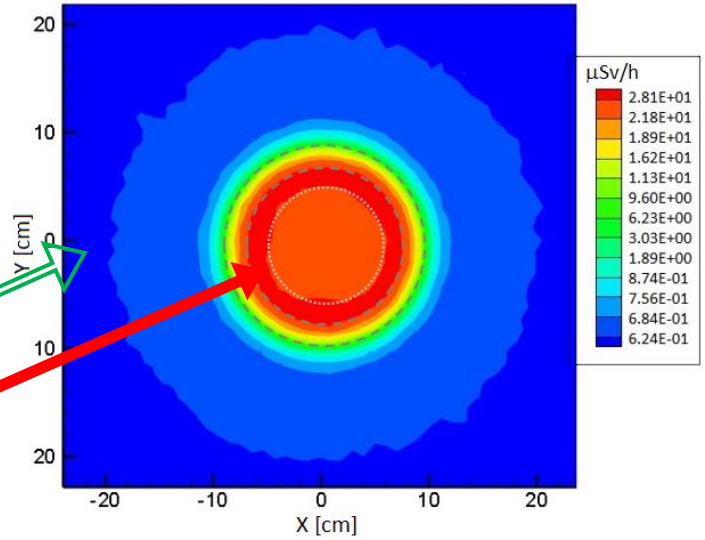


Pipe cleaning

- *Empty pipe (air)*
- *External irradiation modeled*
- *No inhalation nor ingestion considered*

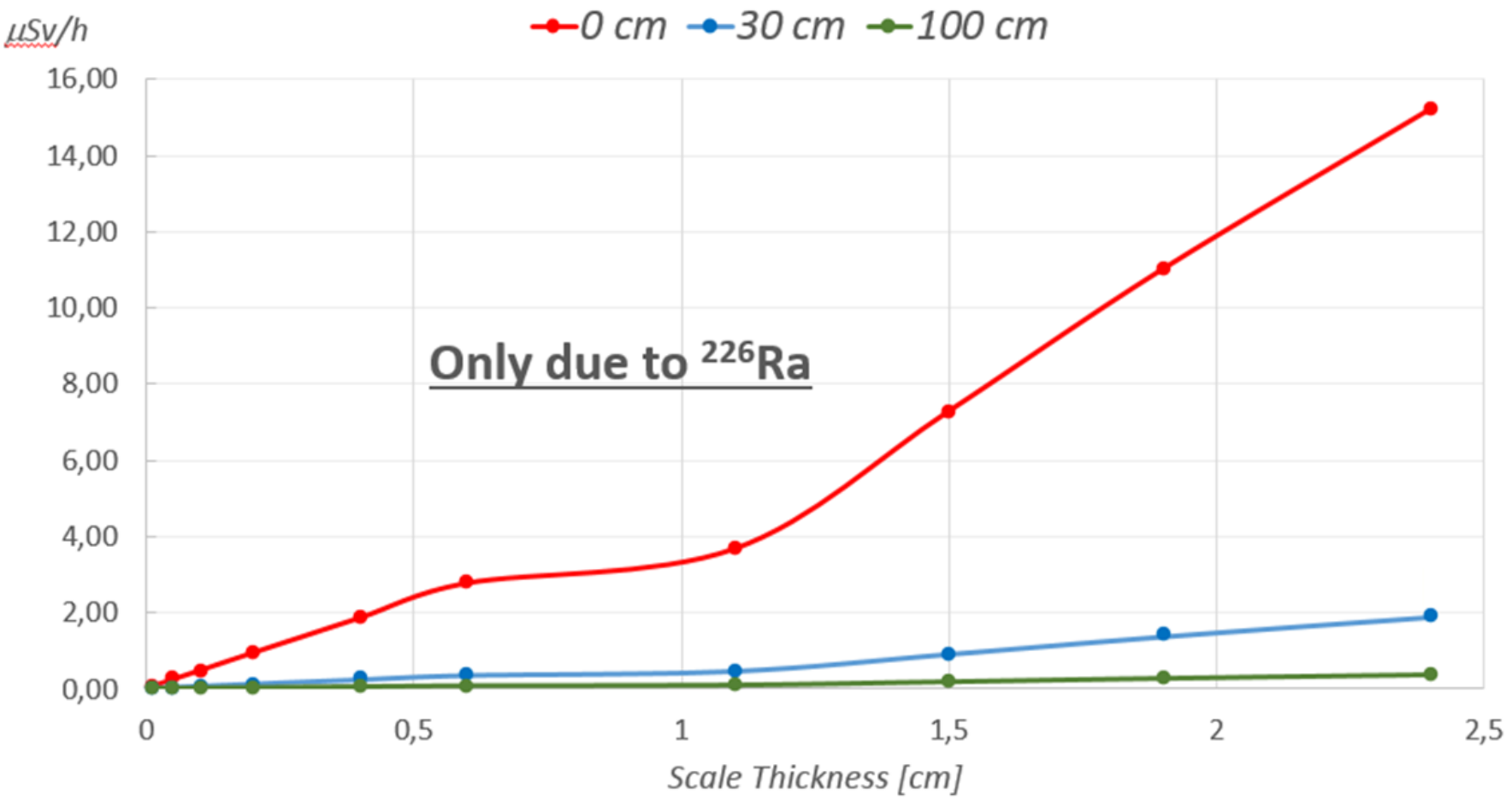
External dose: 0.62 µSv/h

Hot spot: 28.1 µSv/h



Oil & Water - Effective Dose Trend

Intermediate values Oil-Water mixture



Gas Production – Storage Tanks

Storage conditions

- *Two 30x3 m cylindrical storage tanks*
- *16 bar pressurised liquid CO_2*
- *Phase-equilibrium temperature*
- *Semi-static flow*

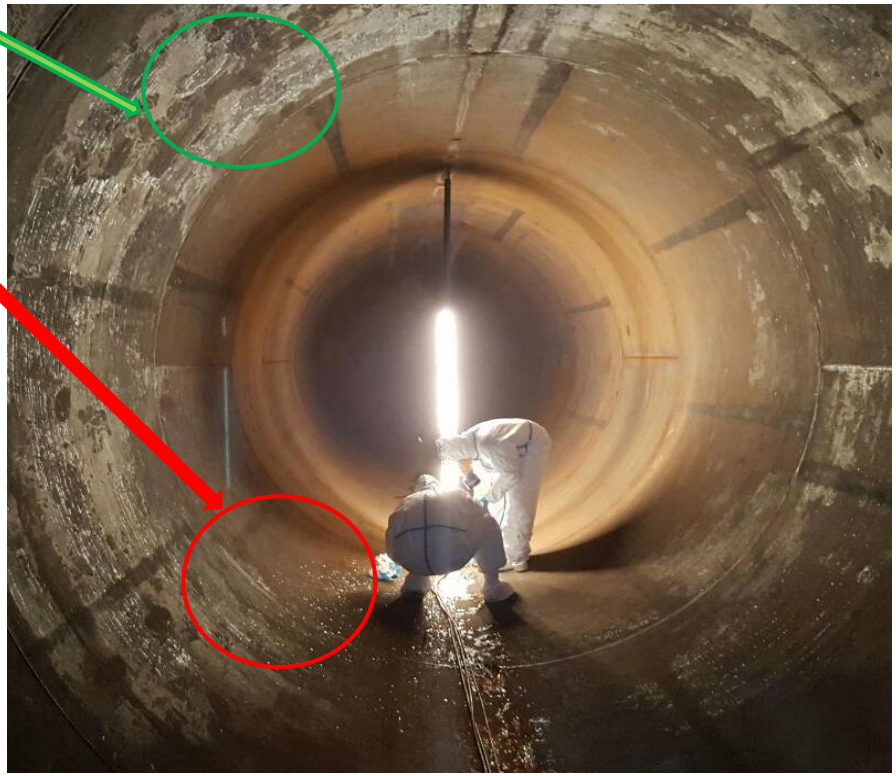
Physics parameters

- *Particle size*
- *Particle and fluid density and velocity*
- *Drag force*
- *Turbulent diffusivity*

Gas Production - Nucleco On-Field

Internal surface inspection

- *0.7 mm solid deposition on inner surface*
- *Sludge at the bottom of the tank*



Radiation measurements

- *^{210}Pb contamination within thin film deposition – 2540 Bq/g*
- *^{210}Pb contamination in bottom tank sludge – 196 Bq/g*

Radiation protection & decontamination

- *Radon and dose rate monitoring*
- *Mobile working station set up*
- *Inner surface scraping and clean up*

Gas Production – MCNP Model

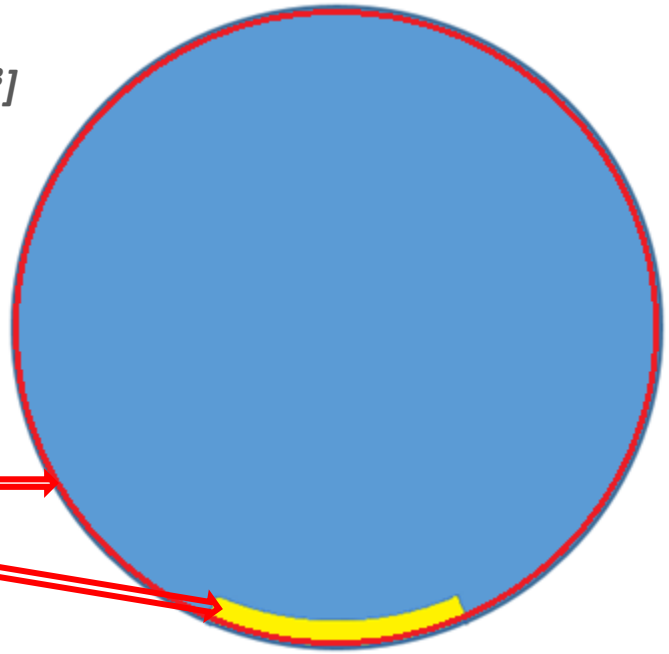
Nucleco Input Data

- *Sludge activity concentration [Bq/g]*
- *Average matrix density [kg/m^3]*
- *Volumetric source distribution based on On-Field data [m^3] (contaminated volume)*

Estimated total activity: 180 MBq

MCNP Model

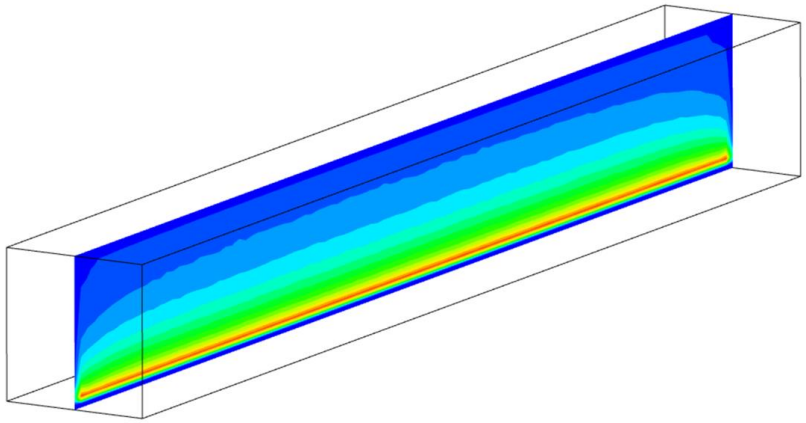
- *Thin film contamination – 3000 kg/m^3*
- *Water and rust with ^{210}Pb on the bottom – 2000 kg/m^3*
- *Spherical configuration approximated to vertical walls*



Gas Production – Estimated effective dose

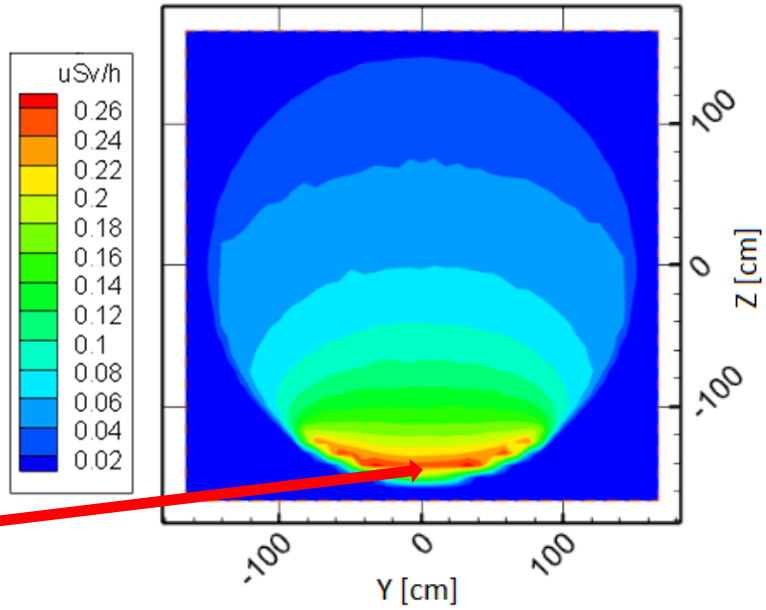
MCNP Output - Key Assumptions

- *10 years of continuous operation*
- *3 months stop before decontamination*
- *Air inside the tank during Nucleco operations*
- *No inhalation nor ingestion considered*



MCNP Output - Comparison

- *Vertical and horizontal dose range*
- *Effective dose to workers undetectable by adopted instruments*
- *Calculated dose comparable with environmental background ≈ 0.2 µSv/h*



Hot spot: 0.26 µSv/h

Conclusions

On-Field data verification

- *Data collected during On-Field operations are in agreement with bibliographical ones in terms of:*
  - ✓ *Activity concentration[1]*
  - ✓ *Effective dose[2]*

Data consistency → Radiation protection

- *In Oil-Water case study the activity concentration as well as the effective dose calculated are at least an order of magnitude higher than the environmental background, resulting in a radiation protection issue*
- *In Gas Production the computed values are comparable with background and not negligible*

1) "IAEA SRS N° 34, "Radiation protection and the management of radioactive waste in oil and gas industry"- 2003"

2) Hamlat, Djeffal, Kadi "Assessment of radiation exposure from naturally occurring radioactive materials in the oil and gas industry"- 2001

NUCLECO

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www.nucleco.it/en

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