Calculation of scale thickness in oil pipelines using MCNP-X

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Incrustations of barium, strontium and calcium, for example, are usually formed by the mixture of formation water and injection water. The high concentration of sulfate anions presents in the injection water when interacting with high concentrations of divalent cations (Ba^{2+}, Sr^{2+} e Ca^{2+}) present in the formation water under favorable thermodynamic conditions may result in the formation of sulfate salt precipitates. Over time, these scales gradually deposit on the walls of the pipes and equipment used in the extraction and transport of oil, contributing to reduce the internal diameter of the pipes and may even obstruct passages and damage equipment, necessitating periodic maintenance actions, such as cleaning or even pipe replacement [1].
The present progress is related to the study of the gamma transmission method with the Monte Carlo N-particle code (MCNP-X) for the evaluation thickness of concentric incrustations of Barium Sulphate ($BaSO_4$) in iron pipe containing oil from through the elaboration of analytical equations, a gamma radiation source of ^{137}Césio (662 keV) with divergent beam of 5.73° and as NaI(Tl) 2x2" scintillation detector, according Figure 1.

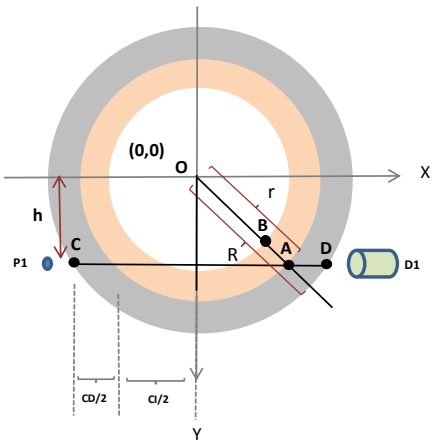

Figure 1. Simulated system.

These equations were obtained for calculating the incrustation thickness. The path traveled by the radiation in the fouling is provided by Eq. 1 and 2, to obtain the fouling thickness, Eq. 3.

$$WINC = \frac{\ln K + \mu D * wD + \mu F * wI}{-\mu INC + \mu F} \quad (1)$$

$$wI = wINC + wF \quad (2)$$

$$X = \sqrt{(Xa - Xb)^2} + \sqrt{(Ya - Yb)^2} \quad (3)$$

Where:

$k = I/I_0$;
μ_i: transmission coefficient for material (cm^{-1});
Wi: radiation path to the material (cm);
X: scale thickness (cm);
Xa, Xb, Ya and Yb: coordinates of the line segment to get scale thickness (x).

The model developed in the MCNP-X code was validated by means of the analytical equations developed using three different scale thicknesses, 2 cm, 4 cm and 6 cm. The methodology predicts a possible misalignment between source-detector (h) and could predict the thickness of the fouling in these different thicknesses, according to Table 1.

Table 1 - Thickness scale (X_n) and relative percentage error (E).

	2 cm		4 cm		6 cm	
h (cm)	X_2 (cm)	E	X_4 (cm)	E	X_6 (cm)	E
3	1.99	-0.71	3.98	-0.56	5.96	-0.65
3.5	1.99	-0.73	3.98	-0.60	5.97	-0.55
4	1.99	-0.64	3.98	-0.51	5.97	-0.57
4.5	1.99	-0.56	3.99	-0.36	5.97	-0.48
5	1.99	-0.57	3.99	-0.24	5.98	-0.26
5.5	1.99	-0.44	4.00	0.10	6.01	0.09
6	1.99	-0.47	4.00	0.06	6.04	0.70
6.5	1.99	-0.49	4.00	0.06	6.09	1.46

All as thicknesses showed deviations below 1.46%, demonstrating that the technique can be used satisfactorily for this purpose.

References

[1] MARTIN, A.; MEAD, S.; WADE, B. O. **Materials, containing natural radionuclides in enhanced concentrations**. Brussels: European Commission, 1997.