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Management of TENORM in a crude refinery

F. Devecchi[1], G. Colombo[1], R. Fresca Fantoni[1], E. Rizzio[1], E. Di Caprio[2] and S. Macrì[2]

[1] *eni S.p.A. exploration & production division*
[2] *eni S.p.A. refining & marketing division*

Abstract. A multi-step project has been developed by eni r&m to define a TENORM (Technologically Enhanced Naturally Occurring Radioactive Material) management system in refinery plants, compliant with Italian regulations and international guidelines.

The project involves a preliminary survey on refineries to detect, on the basis of the production process, the sections at risk of TENORM accumulation; this analysis is followed by the consequent formation/information to the workers, dose assessment for workers and the public, introduction of radiometric characterization before release of potentially contaminated waste.

1. INTRODUCTION

The accumulation of Naturally Occurring Radioactive Materials, in the form of residuals or waste, has been a well-known phenomenon in the upstream oil sector since a long time. The great quantities of stratum water that enter the production plants together with crude oil and gas may transport natural radionuclides from the reservoir to the surface and favour their deposition inside processing equipment and vessels. The presence of TENORM accounts for a significant radiological hazard for the human health, because it may generate exposures up to such levels that require constant monitoring during both routine and maintenance activities.

In the downstream oil sector however, the volume of stratum water that enters the refineries together with the crude is very small (1–2 % of total product maximum), nevertheless in certain points of the production line it has been observed a deposition of TENORM; the presence of these materials may represent a potential hazard for the workers involved in maintenance activities, because it can expose them to external irradiation and to internal contamination as well.

The first step that has been taken to assess the radiological risk potentially due to TENORM presence in refineries is a on-field survey in a plant, that allowed to determine, together with an in-depth knowledge of the production process, the points subject to potential accumulation of TENORM.

2. MATERIALS AND METHODS

2.1 Radiometric survey in an Italian refinery – case study

In this paragraph the methodology of intervention and the instruments adopted for in situ and laboratory radiometric measurements are detailed.

The survey has been carried out on the basis of the following schedule:

- identification of gamma radiometric anomalies (i.e. dose rate double of environmental background of the area), close to the components where there is circulation of stratum water, by means of NaI(Tl) scintillator (Saphimo-stel);
- determination of environmental dose rate equivalent H*(10) through plastic scintillator dose-meter (Automess GmbH 6150AD5 – beta gamma probe ADb Zynthomat);
- collection of technological matrix samples for the determination of the activity concentration of natural radionuclides via instrumental high resolution gamma ray spectroscopy;
- dose assessment for the workers.

2.1.1 identification and measurement of the radiometric anomalies

Gamma radiometric anomalies were detected only in those sections of the plant where there is circulation or stagnation of stratum water coming from the reservoir together with the crude:

1. stratum water treatment area;
2. desalter area.

Dose rate values reported in the following are comprehensive of natural background (about 60 nSv/h).

2.1.1.1 <u>mud treatment area</u> points of anomaly:.

- along the bottom perimeter of the stratum water desalter tank (Fig. 1);
- along the bottom perimeter of the tank for stratum water storage before treatment (Fig. 2);
- close to the container of the mud removed via centrifugation (Fig. 3).

Figure 1. Desalter tank.

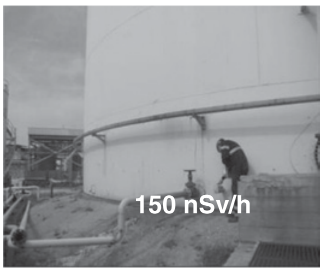

Figure 2. Stratum water storage tank.

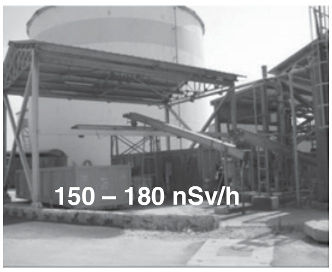

Figure 3. Containers of mud.

2.1.1.2 <u>desalter area</u>: radiometric anomalies detected at the bottom of desalters (Fig. 4).

Figure 4. Desalter area.

2.1.2 spectrometric analyses of technological matrices

Samples were collected from a crude storage tank (Fig. 5), from the container of centrifuged mud (Fig. 3) at the mud treatment plant and from the cocking heating coil area (Fig. 6) while it was out of order because of cleaning/maintenance activities.

The heater shutdown allowed gamma dose rate measurements to be performed inside, close to the heating coil, but no gamma radiometric anomaly was detected. The heating coil was found to be partially coated with carbon coke scales (Fig. 6) from which two samples were collected for the gamma spectrometric analyses. The results of the analyses are summarized in the following table 1 and were performed using a HPGe (Gamma-X) detector (Canberra, USA) coupled to computerized multichannel analyzer (GENIE2000-Canberra, USA).

The activity concentration of ^{226}Ra in the samples is slightly above the Earth crust mean value (40 Bq/kg); the gamma radiometric anomalies detected are not, as a matter of fact, very relevant and do not represent a source of external irradiation hazard for workers (see Par. 2.2).

On the other hand, a potential risk of internal contamination occurs during maintenance activities of contaminated equipment, because the activity concentration of ^{210}Pb is not negligible and even if the emitted radiation is weakly penetrating and doesn't therefore lead to external irradiation, contaminated particulate may be inhaled or ingested by workers. (see Par. 2.2).

2.2 Dose assessment for the workers

Table 2 reports the assessed annual doses, due to external irradiation, for operators working in areas in which gamma radiometric anomalies were detected (see Par. 2.1.1).

The evaluation was performed cautionary assuming the worker in contact with the point of highest dose rate for 440 hours. Radiation background is subtracted.

In heating coil maintenance it was taken into account also the possibility of internal contamination for the operators, that was assessed under the following hypothesis:

- workers use respiratory PPE such as FFP3 half-face mask (protection factor: 30). [1]
- dust concentration set to 2 mg/m^3 (dusty indoor working procedures). [2]
- activity concentration for ^{210}Pb equal to the maximum value found in samples; ^{210}Po in equilibrium with ^{210}Pb.
- Committed dose factor for introduced Bq: [3]
  ^{210}Pb: $1.1 \cdot 10^{-6}$Sv/Bq
  ^{210}Po: $2.2 \cdot 10^{-6}$Sv/Bq

In this scenario, the committed dose for 100 worked hours is 0.2 microSv, to be compared with the Italian Legislation limit of 1 mSv/a.

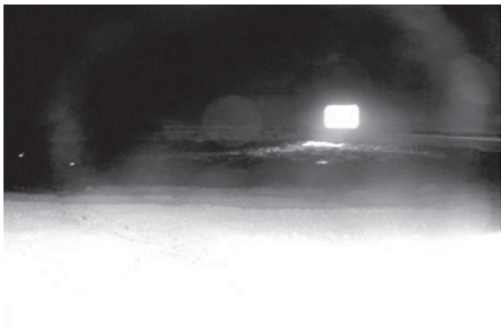

Figure 5. Bottom sludge.

Figure 6. Cocking heating coils.

Table 1. Results of spectrometric analyses.

Sample	^{210}Pb (Bq/kg)	^{226}Ra (Bq/kg)	^{228}Th (Bq/kg)	^{228}Ra (Bq/kg)	^{40}K (Bq/kg)
Mud from mud treatment plant	577 ± 59	184 ± 19	23.6 ± 4.4	48.3 ± 4.5	< 30.6
Sludge from crude storage tank	367 ± 33	153 ± 15	< 18.5	20.7 ± 2.3	< 25.8
Sludge from crude storage tank	517 ± 50	113 ± 11	11.6 ± 2.5	11.0 ± 1.7	37.9 ± 5.8
Heating coil scale	3414 ± 320	117 ± 22	86.4 ± 10.2	< 22.2	< 39.6
Heating coil scale	14445±1271	< 218	160.4 ± 19.2	< 44.3	< 121

2.3 Preliminary information/formation of the workers

As demonstrated in the previous paragraphs, the presence of TENORM in a refinery represents an additional source of risk that must be identified and declared. As for other sources of risk (hazardous atmosphere, high voltage, H_2S etc.) workers must receive a correct information about the nature of the risk itself and a proper formation about its management during the daily activities on the plants.

The induction course shall involve workers at every level: Management, senior staff, junior staff, contractors, and should cover:

– base concepts of Radiation Protection
– natural radioactivity
– TENORM and safety of workers and public
– Legal aspects.

Table 2. External irradiation dose values.

Operative Area	Max value of dose rate, radiation background subtracted (nSv/h)	Hours per day in contact with the radiometric anomaly (h)	Annual dose (220 working days) (mSv)
Desalter tank	270	2	0,12
Stratum water storage tank	100	2	0,04
Mud container	130	2	0,06
Desalter	275	2	0,12

2.4 Waste management

All kinds of waste (i.e. sludge, iron components, etc.) that come from an area in which there is possibility of TENORM contamination due to the industrial process taking place, should be subject to the proper radiometric checks before disposal. For instance, in case of sludge or scale waste, a sample shall be sent to a laboratory to determine activity concentration of radionuclides and thus define the best disposal option. In case of scrap materials, a superficial contamination measurement should be performed.

3. RESULTS AND CONCLUSIONS

As for upstream activities, also in downstream the possibility of TENORM accumulation is to be taken into account when preparing safety/environmental procedures. Despite the fact that gamma-emitters (Ra-226 mainly) concentrations seem to be lower than in extraction plants, there is a relatively increased concentration of beta and low-gamma emitters such as Pb-210. This fact partly modifies on-field survey procedures and highlights the importance of radiometric characterization of residues and waste, in view of a correct management of maintenance and decommissioning activities and waste disposal. As far as workers exposure is concerned, it is well below legislation dose limits for standard activities and can be reduced even further by the application of simple safety procedures.

References

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[3] Italian Radiation-Protection Regulations (D. Lgs. 230/95 e s.m.i. All. IV para. 14.1)

[1] Ente Nazionale Italiano di Unificazione.