Evaluation of radiological risk during the activity of removal of sludge with tenorm from crude oil storage tanks and its transport to the treatment/disposal plant

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INTRODUCTION

This paper describes a simulation performed using the MICROSHIELD model in order to evaluate the radiological risk for workers during the activity of removal of sludge with TENORM from crude oil storage tanks and its transport to the treatment plant. While the external dose, computed with the Microshield model, is the most relevant, internal doses have also been evaluated. The study is a part of a wider project of the ENI international oil and natural gas company, in collaboration with ARPA-Veneto (Regional Agency for Environmental Protection of Veneto), which aims at defining a procedure for the periodic removal of sludge with TENORM from crude oil storage tanks: this procedure must ensure compliance with the threshold dose rates to which workers and the population are exposed, due to the presence of TENORM in the crude residue, in accordance with the national regulations.

MATERIALS AND METHODS

Modelling phase

MicroShield [1] is a software calculating external gamma doses at selected receptor points, given a specific source geometry, composition and activity. In this study, doses are computed in two different actual scenarios describing extraction and transport of oil sludge. The input data required by the model are the following:

- exposure geometry
- distance from the radiating source
- radionuclides present in the source and their activity
- shielding materials;
- shield geometry;
- build up factor

Doses due to air particulate inhalation have been computed following the methodology described in the TSD-DOSE code [2], with the dose coefficients given by the Legislative Decree 241/2001[3].In order to compute doses due to Rn inhalation, the methodology described by RP 122 has been used [4].

The radioactive source consists of sludge characterised by the following chemical-physical features:

- Sludge Density: 0.9 g/cm^3.
- Sludge Composition: 90% C, 9.5% H, 0.15% S, 0.15% N, 0.2% O.

- Ra-226 activity is 1767 Bq/Kg for tank no.1 and 2226 Bq/kg for tank no. 2, which represent precautionary values. These values are based on measurements by gamma spectrometry on source samples taken in situ. Secular equilibrium is assumed, so that the activity measured for Ra-226 has been assigned to its daughters, including Po-210 and Pb-210. For Th-234, Pa-234, Ra-228, Th-228 and K-40 the value 40 Bq/Kg has been used, which corresponds to the average concentration in the earth's crust

Working phases
The operations necessary to extract the sludge from the two tanks are modelled as indicated below.

Opening a door in the tank
A door 2 m high and 4 m large is cut on the side of the tank, from which the oil sludge can be extracted. Only external exposure is considered. As the external dose measured on site is very low, this phase has not been modelled with Microshield.

Manual shovelling of the sludge
Stratiform cylindrical distribution of the source is assumed below the operator. Average height of residues is 0.3 m for tank no.1 and 0.8 m for tank no. 2, while the diameter is 15.25 m in the first tank and 13.72 m in the second. There are no shields between sources and operators. The estimated time for manual removal of sludge is 120 working hours for tank no. 1 and 200 hours for tank no. 2, but the precautionary values of 150 h and 250 h, respectively, have been used for calculations. The operator is assumed to stand, at the centre of the tank, and dose rate is calculated at 0.5 m, 1 m and 1.5 m from the tank bottom. Exposure of the workers in this case is due to:

- external radiation (modelled with Microshield)
- air particulate inhalation (a reduction factor of 50 is adopted)
- radon inhalation. Radon concentrations are calculated in the hypothesis of tank ventilation rate of 250 changes per hour.

Removal of material using a bobcat
As far as external radiation is concerned, the individual operating the vehicle is exposed to a dose deriving both from the sludge deposited in the bucket and from sludge deposits in the tank. As to air particulate inhalation internal radiation, the assumption that workers use a face mask, with protection factor 10, as been made. There is no exposure to radon, as the operator works outdoors.
Also in this phase, the working hours have been set 150 h for tank no.1 and 250 h for tank no.2, with a precautionary assumption.

Sludge transport
The sludge is transported by track, whose driver is exposed to external radiation only, emanated by the load carried. Every trip lasts 20 hours. 20 trips are necessary for the transport of the sludge of tank no. 1, and 25 for tank no.2
The truck is represented by a box with the following dimensions:10 m length, 2 m height, 1 m width. During the travel, the driver stays 0.5 m above the truck floor, at a 0.5 m distance from sludge.
Any shielding effect, due to the metal of the container and the driver's cabin is ignored.

RESULTS AND CONCLUSIONS

Tables 1 and 2 show the computed dose to workers in the different working phases. Different contributions from external radiation, air particulate inhalation and radon inhalation, as well as their sum, is shown. The two tables refer to tanks n. 1 and n. 2, respectively. In both cases and for all workers the most relevant contribution comes from external irradiation. In general, doses are below the specific action level of 300 μSv/a indicated by the Italian normative for the public[3]: in fact, in this case, workers are not considered occupationally exposed to ionising radiation.

Nevertheless, the total dose to the worker shovelling the sludge from tank n.2 is not so far from the prescribed action level. However, it must be emphasised that all the calculations have been made under conservative assumptions. In fact, the input activity, for the several radionuclides, is higher than the average measured values. The working hours for which doses have been calculated in the second and third working phases are more than the real estimated ones. During the manual shovelling operations the operator is assumed to stay continuatively above the radioactive source, while a part of the sludge can be pumped out mechanically. Furthermore, as the sludge is removed from the tank, its volume, and consequently the associated activity, gradually decreases, while doses are estimated assuming a continuous exposure to the activity of the initial volume of the sludge. Lastly, the protection factors of the face masks used by the operators are lower than those of masks used in reality.
Anyway, in a precautionary approach, some operative indications have been suggested, in order to reduce the total dose to the workers, the most important of which are the following. It is worth to use two different groups of workers, shovelling the sludge in the two tanks, as well as two different bobcat operators. During shovelling operations, the two tanks must be ventilated at a rate not lower than 250 changes per hour. Continuous monitoring of the Radon and air particulate concentration will be carried out during the working operations.

Table 1. Individual doses (μSv) to the different workers involved in the operations of removal of oil sludge from tank no. 1. Contributions of the different exposure pathways and their sum are shown.

Worker	***External radiation***	***Air particulate inhalation***	***Radon inhalation***	***TOTAL DOSE (μSv)***
Shoveller	***124.7***	***---***	***0.6***	***125.3***
Worker opening the door in the tank	***2.6***	***---***	***---***	***2.6***
Bobcat operator	***50 .4***	***1.7***	***---***	***52.1***
Truck driver	***96.0***	***---***	***---***	***96.0***

Table 2. As in table 1, but for tank no.2.

Worker	*External radiation*	*Aair particulate inhalation*	*Radon inhalation*	*TOTAL DOSE (μSv)*
Shoveller	***292.5***	***---***	***3.0***	***295.5***
Worker opening the door in the tank	***4.6***	***---***	***---***	***4.6***
Bobcat operator	***107.0***	***3.6***	***---***	***110.6***
Truck driver	***200.0***	***---***	***---***	***200.0***

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