Assessment of the Exposure Dose During Removal of TENORM Sludge from Crude Oil Storage Tanks

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ABSTRACT

Recently, many studies have been conducted on the effect of radiation hazards in non-nuclear industries. Petroleum industry (production and refining) is a main source of TENORM in the environment. This paper describes a simulation that was performed using a developed model based on Mont Carol calculations in order to evaluate the occupational dose rate for workers during the activity of removal and maintenance of crude oil storage tanks in refining facility. The information obtained is an important part of the baseline data, helping the Regulatory Body in establishing the guidelines for the protection of workers and the public from the hazardous effects of ionizing radiation in non-nuclear activities.

Key Words: Refining industry, Exposure dose, Gamma spectrometry

INTRODUCTION

The presence of naturally occurring radioactive material (NORM) has been recognized since the early 1930s in petroleum reservoirs, in oil and gas production and in processing facilities. Oil scaling as a waste problem occurs either when production equipment is taken for cleaning or as a part of the final waste handling during decommissioning of oil installations (1). Measurements of natural radionuclides in crude oil and other materials have been reported in a number of publications worldwide(2-4). The radioactivity contribution due to oil refining process in Egypt was comprehensively studied previously(5).

The aim of this study is to establish a developed mathematical model for dose calculation. This developmental model could be used for evaluating the radiological risk for the workers during the cleaning and maintenance processes of crude oil storage tanks petroleum refining industry.

SIMULATION PARAMETERS

Computer simulation was pioneered as a scientific tool in meteorology and nuclear physics in the period directly following World War II, and since then it has become indispensable in a growing number of disciplines. The list of sciences that make extensive use of computer simulation has grown to include radiation protection physics.

The suggested simulation model is based on the following assumptions:-

1- The selected activity concentration of $^{226}$Ra and $^{232}$Th in the sludge samples is presented in table (1). These concentrations are taken from a previous work of the second author(5)where samples were taken from two tanks.

2- The sludge density is 1.2 g/cm$^3$.

3- Sludge compositions: 90% C, 9.5% H, 0.15% N, and 0.2% O

4- The operations that are necessary to extract the sludge from the two tanks modeled as

a- Opening door in the tank

A circular shape door with diameter 0.6 m is on the side of the tank, and at a distance 0.3 m from the bottom of the tank from which the oil sludge can be extracted, figure (1). Only external exposure is considered in this case.
b- Manual shoveling of the sludge
The sludge is assumed to be of a cylindrical shape. The first tank is 25m diameter and 1.5 m height. The second tank is 30m diameter and of smaller height than the first tank. 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 precautionary values of 150 h and 250 h, respectively, have been used for calculations. The operator is assumed to stand, at the center of the tank, and dose rate is calculated at two positions from the tank bottom: I) center of the tank (point A), II) at the door (point B) as shown in figure 1.

**Fig. (1):** The tank model shapes.

### CALCULATION METHODS

For a uniformly distributed gamma-emitting isotope, the dose rate at any point p due to the isotope radioactivity in an infinitesimal volume \(dV\) at any other point at a distance \(R\) from point p with media thickness \(r_i\) and \(\mu_i\) total attenuation coefficient with coherent scattering in \(m^{-1}\) where \(i\) donate the media no, is calculated as:

\[
dD(r, E) = A \Gamma \frac{e^{-\sum \mu_i r_i}}{R^2} dV \quad (1)
\]

Where \(D(r, E)\) is the absorbed dose rate in Gy/sec, \(A\) is the activity concentration of the isotope in \(\text{MBq/m}^3\), \(\Gamma\) is the specific gamma-ray emission in \((\text{C/kg}) \text{ m}^2/\text{MBq.hr}\).

The dose rate at point \(p\) due to the entire isotope in the soil is computed from all the infinitesimal volume elements:

\[
D(r, E) = C \Gamma \int_0^V \frac{e^{-\sum \mu_i r_i}}{R^2} dV \quad (2)
\]

Eq. (1) can be rewritten as:

\[
D(r, E) = C \Gamma g \quad (3)
\]

Where the geometry factor \(g\) is defined as,
\[ g = \int_{0}^{V} \frac{e^{-\sum_{j=1}^{\infty} \mu_j}}{R^2} dV \quad (4) \]

The total mass attenuation coefficients with coherent scattering (cm\(^2\)/g) were calculated using XCOM program: Photon Cross Sections Database (NIST). This software has a database that can be used to calculate photon cross sections for scattering, photoelectric absorption and pair production, as well as total attenuation coefficients, for any element, compound or mixture (Z\(\leq\)100), at energies from 1 keV to 100 GeV \(^7,^8,^9\).

RESULTS AND DISCUSSION

Table(2) shows the computed effective dose to workers in different working places. It is shown that, in both cases and for all workers the most relevant contribution is due to external irradiation. For workers at the opening door, the calculated doses are below the specific action level of 300 \(\mu\)Sv/a indicated by the international specific action level of 300 \(\mu\)Sv/a. In this case, workers are not considered occupationally exposed to hazardous ionizing radiation.

For workers manually shoveling the sludge, three calculated effective doses are found to be above the international specific action level (in bold) for maximum activity concentration calculations.

Nevertheless, the total doses to the worker shoveling the sludge from tanks are sometimes far from the prescribed action level. However, it must be emphasized that all the calculations have been made under conservative assumptions. The working hours for which doses have been calculated in the working phases are more than the real estimated ones. During the manual shoveling operations, the operator is assumed to stay continuous 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 decrease, while doses are estimated assuming a continuous exposure to the activity of the initial volume of the sludge. Lastly, the protective factors of the face masks used by the operators are lower than those of masks used in reality.

CONCLUSIONS

This paper describes a simulation performed using our model for dose calculation to the workers in oil refining industry, especially for those in direct contact with the sludge through maintenance and cleaning processes. Although some radiation dose is bigger than the international permissible limits and, in a precautionary approach, some operative indications have been suggested, in order to reduce the total dose to the workers. The radon has the highest share in the dose\(^{10}\) so, it is recommended that, during shoveling operations, the two tanks must be ventilated at a rate not less than 250 circulations per hour. Continuous monitoring of the Radon and air particulate concentration will be carried out during the working operations.

Table (1): The minimum, maximum activity and average concentrations of \(^{226}\)Ra and \(^{232}\)Th (Bq/kg) in the collected sludge samples

<table>
<thead>
<tr>
<th>Activity (Bq/kg)</th>
<th>(^{226})Ra</th>
<th>(^{232})Th</th>
</tr>
</thead>
<tbody>
<tr>
<td>Min.</td>
<td>55.1 ± 8.6</td>
<td>17.1 ± 8.0</td>
</tr>
<tr>
<td>Max.</td>
<td>1785.8 ± 285.7</td>
<td>885.0 ± 24.7</td>
</tr>
<tr>
<td>Average</td>
<td>701.5</td>
<td>249.7</td>
</tr>
</tbody>
</table>
Table (2): The calculated effective dose for the workers (two removal times).

<table>
<thead>
<tr>
<th>Models</th>
<th>External Dose per removal time (µSv)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>150h</td>
</tr>
<tr>
<td></td>
<td>Min</td>
</tr>
<tr>
<td>Opening door at the tank</td>
<td></td>
</tr>
<tr>
<td>First Tank (25m)</td>
<td>2.79</td>
</tr>
<tr>
<td>Second Tank (30m)</td>
<td>3.34</td>
</tr>
<tr>
<td>Manual shoveling of the sludge</td>
<td></td>
</tr>
<tr>
<td>First Tank (25m)</td>
<td>6.55</td>
</tr>
<tr>
<td>Second Tank (30m)</td>
<td>10.1</td>
</tr>
</tbody>
</table>

REFERENCES


(4) L.E. Matta, J.M. Godoy, and M.C. Reis, 2002, $^{226}$Ra, $^{228}$Ra, and $^{232}$Th in scale and sludge samples from the Campos basin oil field E&P activities. Radiat. Prot. Dosim. 102, 175–178.


