Radiological Impact to the Public of the Incineration of Oil Sludge of an Italian Oil Company

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INTRODUCTION

In this study a simulation with the PC-CREAM suite of models has been performed in order to estimate the radiological impact on the population due to the incineration process of oil sludge and the following emission of fly ash into the atmosphere. The study is a part of an ampler 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 management of oil bottom sludge from storage tanks: this procedure must guarantee compliance with the thresholds of radiation dose to the population, due to the presence of NORM in the oil residue, established by the national normative. The study is theoretical, and assumes that the incinerator is located in the plan of northern Italy and has the average technical characteristics of such plants.

MATERIALS AND METHODS

Model
The PC-CREAM suite of models is made up of six interfaced modules, describing the transfer of radionuclides within and between the several environmental compartments, the pathways determining the exposure of the population to ionizing radiation and the following risk (Simmonds, 1995).
In the present study the emission of natural nuclides into the atmosphere has been considered and their dispersion due to atmospheric motions is described with a gaussian model. The evaluation of individual and collective doses is based on suitable dosimetric models (ICRP, 1991) and on data on the population life style. Doses are calculated in the form of annual average values in the fiftieth year of a continuous discharge. Different types of data have been collected and elaborated in order to provide the necessary input to the model.
A continuous release of fly ash due to the incineration of 230 m^3 oil sludge per year is assumed: this quantity corresponds to the decommissioning of a tipical ENI storage plant. The associated activity concentration has been measured by gamma spectrometry. The total activity contained in the oil-sludge is then 4.56E+08 Bq for ^{226}Ra and 8.82E+06 Bq for ^{228}Ra. Secular equilibrium is assumed, so that all the following nuclides of the two decay chains have the same concentration of the parents.
The program allows to specify meteorological informations typical of the site where the incineration plant is located. The frequency with which the wind blows in the different angular sectors around the stack, as a function of the atmospheric stability class (Pasquill's classification is adopted (Pasquill, 1961)) has been computed, on the basis of wind speed, precipitation and atmospheric stability data. Wind and precipitation have been retrieved from the meteorological station closer to the incineration plant. Atmospheric stability has been computed on the basis of the data of the Global Data Assimilation System using the

algorithms of the HYSPLIT transport and dispersion model (Rolph, 2003). All data refer to the whole year 2006. Wind prevailingly blows in sector 210°N (15.5%) and with F (moderately stable) atmospheric stability class (46.5%).
The plant has only one stack, with a dropping system efficiency of 99.99%. The surrounding area is agricultural, and the corresponding roughness length has been set 0.3 m. The effective stack height has been calculated on the basis of the meteorological data (daily mean environmental temperature, mean wind and atmospheric stability) and of the plant data (flux, density and temperature of the effluent) and is 73.34 meters.The absence of "building wake" effect has been verified.
In order to compute collective doses, the distribution of population and of agricultural production in the area surrounding the incineration plant has been specified. Individual doses are computed for three age groups, characterized by different diet, breath rate, dose coefficients, habits relating to external exposure: infants, children and adults. Ingestion rates of various food refer to regional statistical data (Turrini, 1999). The precautionary assumption that all the ingested food is produced near the incineration plant has been made.
The following exposure pathways have been selected in the present study: consumption of cow's and sheep's meat, cow's milk and milk products, green and root vegetables, grain and fruit, inhalation of radionuclides in the plume and of resuspended radionuclides, external gamma and beta radiation from airborne and deposited radionuclides.

Simulations
Two main simulations have been performed, named DS ("Dropping System") and NDS ("No Dropping System"), which differ only for the dropping system efficiency, that is 99.99% in the first case (for all the radionuclides but ^{222}Rn that totally escapes into the atmosphere, being a gas), and 0 in the second, where the dropping system is not active. The real situation will be an intermediate one between those described by the two simulations. In fact, enrichment in some nuclides (such as 210Pb and 210Po) may occur in the thinner fraction of dust for which dropping system efficiency might be less than 99.99%.
More simulations have been carried out for sensitivity studies. To test the dependence of dose from the wet deposition processes, represented by the code only in the atmospheric stability classes C (slightly unstable) and D (neutral), simulations in which absence of precipitation is assumed have been performed. To test the dependence of the dose from the effective stack height, simulations in which this parameter corresponds to the geometric stack height (40 meters) or to a value (80 meters) slightly higher than that computed on the basis of the specific data for the incineration plant have been performed.

RESULTS AND CONCLUSIONS

In both DS and NDS simulations infants represent the most critical group, being generally characterised by higher dose coefficients: the highest individual effective doses are $6.6 \cdot 10^{-5}$ μSv/y in the first case and $2.8 \cdot 10^{-1}$ μSv/y in the second. Collective effective doses are $1.1 \cdot 10^{-4}$ μSv/y and $1.1 \cdot 10^{-1}$ μSv/y, respectively. Doses are higher in the NDS simulation, which is coherent with the higher fly ash release due to the inactivity of the dropping system. In both cases individual doses are much lower than the action level of 300 μSv/y indicated by the normative.
In the DS simulation, inhalation of ^{222}Rn, which is not dampened by the dropping system, is most important (Fig. 1, left panel): its contribution increases with the age of the considered individuals, as their breathing rate is higher. The role of ^{210}Po is second by importance, and is stronger for younger individuals, who mainly absorb it from green vegetables, grain and fruit,

because of their higher dose coefficients. In simulation NDS (Fig.1, right panel), the highest contribution is from ^{210}Po, which is mainly ingested. In second instance, the contribution of ^{210}Pb and ^{226}Ra come. ^{226}Ra is mainly inhaled, and is more significant for adults.
As to collective doses, the role of inhalation becomes even more important, because of the lower assumption of contaminated food, grown up near the stack, by individuals living far from it: in simulation DS the role of ^{222}Rn thereby becomes more important, as well as that of ^{226}Ra and ^{210}Pb in the NDS case (Fig. 2).
The spatial pattern of individual doses strongly depends on the position of the receptor point, due to both the wind direction and the predominance of different atmospheric stability classes in the several directions, which determine different trends of individual dose as a function of distance. The maximum value is reached at 210°N and 6 km distance in simulation DS, while in NDS it is at 300°N and 1 km distance, as well as within the first 500 meters from the stack. Further from the stack individual doses decrease. The higher amount of fly ash released in the NDS simulation and, consequently, the stronger intensity of the deposition processes might explain the position of the maximum, closer to the stack.

Sensitivity to the description of the wet deposition processes is strong, especially near the stack: when this process is described, individual doses are higher. The process is described only in atmospheric stability classes C and D: it would be interesting to analyse its importance also in other stability classes, but this can not be performed with the current version of PC-CREAM. Sensitivity of the individual effective dose to the effective stack height is also higher near the stack. Results show that individual doses increase when the effective stack height decreases.
According to the results shown, the most precautionary case is that obtained assuming the dropping system is not active and the stack height is equal to the geometric stack height . The highest value is reached at 210°N, 3 km far from the stack, and is 1.7 μSv/y: also in this case it is much lower than the action level of 300 μSv/y indicated in the Italian law.
It is interesting to compare PC-CREAM collective doses with those obtained with a simplified model described in the UNSCEAR report 1982, which computes the dose due to direct inhalation during the passage of the cloud, ingestion of contaminated food , external irradiation and inhalation of resuspended material after deposition. Results of the different models, for the two scenarios in which the dropping system is active or not (simulations DS and NDS), show that in the first case collective doses are very similar, while in the second the dose computed with PC-CREAM is lower than that computed with the UNSCEAR model, even if of the same order of magnitude.The environmental pathways breakdown of the models is different: for the UNSCEAR model inhalation of resuspended material is most relevant, followed by inhalation of the plume, but a considerable contribution is also due to ingestion of Polonium; instead, according to PC-CREAM, inhalation of the plume is dominant.

In summary, on the basis of the dose estimates given by the PC-CREAM model, it can be assessed that the impact to the public of dust emissions from the considered oil sludge incineration process is substantially negligible.

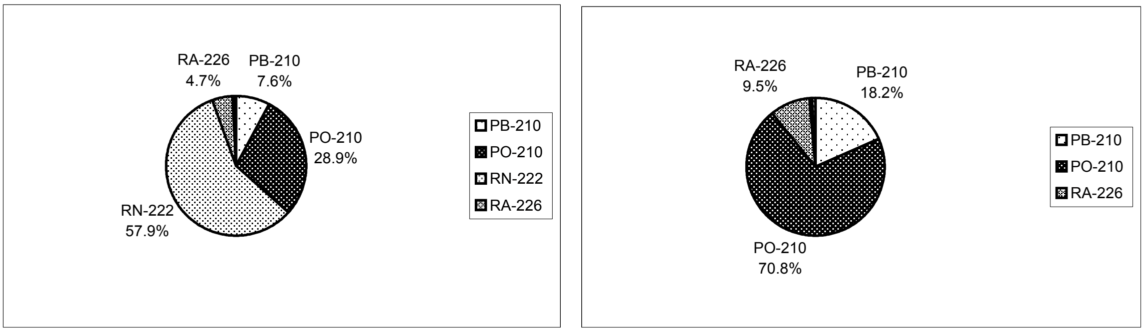

Figure 1. Radionuclide breakdown of annual average individual effective dose at the fiftieth year of continuous release, for simulations DS (left pannel) and NDS (right pannel), in the receptor point where the dose is highest.

Figure 2. As in Fig.1 but for collective effective dose.

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