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SIMULATION OF FIRE IN A DEPOSIT OF RADIOACTIVE WASTE AND THE RADIOLOGICAL RISK ASSOCIATED TO THIS SCENARIO

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ABSTRACT

A fire at radioactive waste deposit can result in significant damage as well as serious risks to the environment and the health of the general public. The CNEN (National Commission of Nuclear Energy) norms have fire protection regulations criteria and requirements to prevent the occurrence, neutralize the action and minimize the effects of the fire on the radioactive material present on the plant. These norms it is for to avoid or limit to the lowest possible levels the effects of ionizing radiation or toxic substances on humans and the environment. Before a possible fire containing radioactive material is necessary information that can estimate the dose in which the population will be submitted. In this work the proposal is to simulate a fire scenario containing radioactive material using Hotspot Health Physics simulation code and to identify the radiological risk of cancer in the respiratory system associated with this scenario using the BEIR V model.

1. INTRODUCTION

The radioactive waste comes from several activities such as sources used in treatment in the health area and that do not have radioactive activity compatible with the need, materials contaminated in actions with open radioactive sources, radioactive materials derived from research that will not be use again, materials contaminated in the operation nuclear power plants, among other activities.

According to the norm CNEN 8.01 [1], some wastes have conditions that allow their release as conventional waste and these must be strictly obey. Radioactive waste that do not conform to these standard conditions or in other words, they are above the exemption limit, should be stored safely so as not to affect occupationally exposed individuals as well as individuals of the public and the environment.

In Brazilian legislation there are three types of deposit for radioactive waste, initial, intermediate and final deposit. The norm CNEN 8.01 [1] also provides the classification of

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radioactive waste according to its level of radiation and its half-life. The deposit considered in this study is a inicial deposit of low and medium level of radiation, on the licensing of this type of deposit the norm CNEN 8.02 [2] establishes general criteria, requirements of security, and radiological protection. About these safety requirements for obtaining authorization and operation of the deposit it is mandatory to submit a Final Safety Analysis Report (RFAS) containing some information, characterization of radioactive waste and disused sources that make up the deposit, description of the tank and its components, equipment and systems important for safety, radiation protection plan, protection against fire, among others.

The purpose of this study is to simulate the fire in a radioactive waste deposit, to provide estimates of the dose in which people will be submitted, to assist in making decisions and minimize the possible consequences.

2. MATERIALS AND METHODS

Fire modeling and the effective equivalent dose were perform in Hotspot Health Physics Codes 3.0.3 software [3]. This software uses a Gaussian semi-empirical model to calculate the dispersion of the radioactive material as it moves with the winds in the impacted area, depending mainly on the climatic conditions. The Hotspot was created to provide a quick and safe calculation tool to evaluate accidents involving radioactive materials, its 4 general programs are plume (continuous or instantaneous release), explosion, fire and resuspension. Fig. 1 shows the program screen corresponding to the tab with the general program options, among others. The Hotspot codes are a first-order approximation of the radiation effects associated with the atmospheric release of radioactive materials.

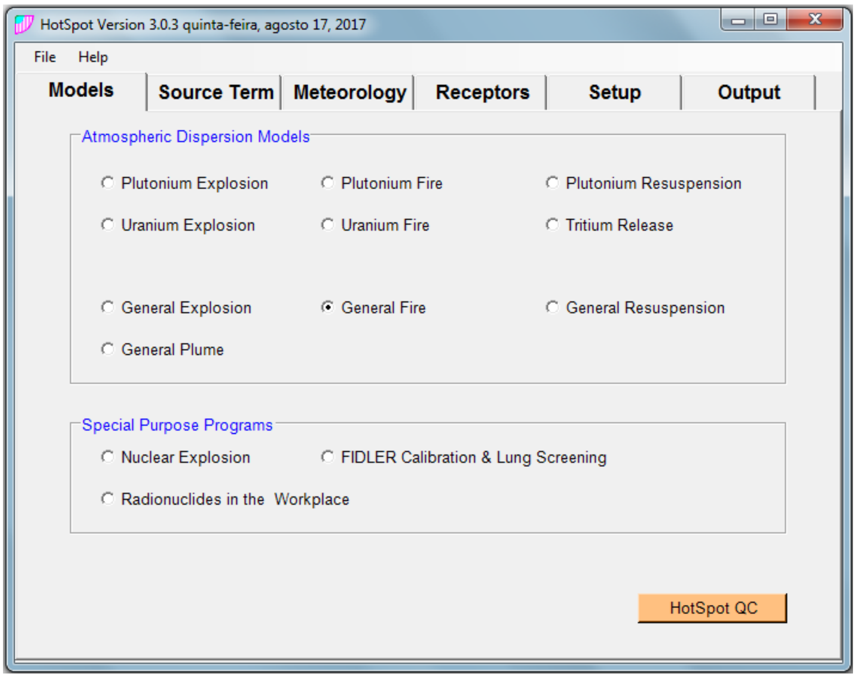

Figure 1: Hotspot code screen with the options of atmospheric models.

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The fire model in the hotspot considers the physical height of the explosion, the radius of release, which in the present study were admitted values of 2 and 1 meters, respectively, and also considers the height of the cloud generated by the explosion, for which it was adopted a height of 10 meters. The parameters adopted in this simulation, among others, were: general fire atmospheric dispersion model; Mixture containing several radionuclides, as shown in Table 1. The location chosen for the deposit was in a standard region of the software that adopts more conservative options of geometry, the class of atmospheric stability was adopted as very unstable.

Table 1: Radionuclide and the activity involved.

Radionuclide	Activity (Bq)
^{241}Am	1.9×10^{12}
^{59} Fe	3.7×10^{10}
^{60} Co	1.9×10^{12}
^{95} Zr	1.5×10^{10}
^{54} Mn	3.7×10^{10}
^{63} Ni	2.0×10^{10}
^{65} Zn	3.7×10^{10}
^{90} Sr	4.5×10^{8}
^{137} Cs	5.1×10^{10}

The Hotspot provides an estimate of the total effective equivalent dose (TEDE) for the population involved in the scenario of release of radioactive material, in which case the maximum reached 0.029 Sv. The use of TEDE allows comparisons of exposures to different types and levels of radiation. The simulation output data in the Hotspot were use as input data for analysis of the risk of solid cancer in the respiratory system. This analysis was perform using the BEIR V (Biological Effects of Ionizing Radiations) model [4], a linear relative risk model obtained by adjustments of the LSS (Life Span Study) as presented in the IAEA TECDOC-870 [5], man and woman respectively:

$$RR = 1 + \alpha_1 D \exp\left(\beta_{1\ \log e}\left(\frac{T}{20}\right)\right) \tag{1}$$

$$RR = 1 + \alpha_1 D \exp\left(\beta_{1\ \log e}\left(\frac{T}{20}\right) + \beta_2\right) \tag{2}$$

Where, α_1 = 0.636, β_1 = 0.711 and T = years after exposure. According to the committee responsible for BEIR V the relative risk of this site decreases with the exposure time, with exposure coefficient β_1 being -1.437.

The BEIR V considers the following three main sources of epidemiologic data on the induction of human lung cancer by radiation:

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I. the survivors of atomic-bomb explosions in Hiroshima and Nagasaki;
II. patients who were treated with X rays for ankylosing spondylitis;
III. uranium miners and other underground miners exposed chronically to high-LET (alpha) radiation from inhaled ^{222}Rn and its progeny.

Each of these populations has received detailed long-term follow-up to ascertain the health risks associated with these diverse types of exposure.

3. RESULTS AND DISCUSSION

In the data output of the fire scenario modeling the hotspot provides the TEDE data in relation to the distance, as can be seen in the plume graph, Fig. 2. Hostpot also provides dose estimates of each organ. To calculate the radiological risk in the respiratory system, the doses received by the lung were estimated in relation to the distance of the source event, ranging from 10 m to 2 km, as can be seen in Table 2. From the lung dose, the following results were found for the relative risk of radiation-induced cancer according to the BEIR V model at 20, 30, 40 and 50 years after exposure, where the relative risk for men and Fig. 3, the relative risk for woman, Fig. 4.

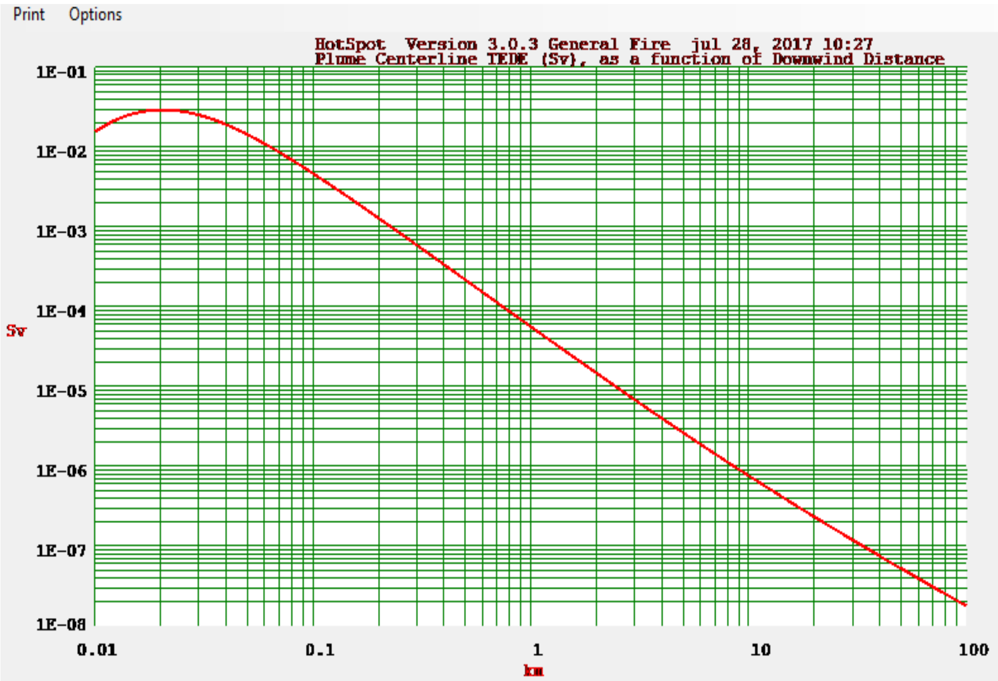

Figure 2: Plume centerline TEDE (Sv), as function of downwind distance. Source: Hotspot health Physics Codes 3.0.3.

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Table 2: Distance x Dose Equivalent on lung.

Distance from source (Km)	Dose Equivalent - Lung (Sv)
0.01	2.40×10^{-3}
0.02	4.50×10^{-3}
0.03	3.90×10^{-3}
0.04	2.90×10^{-3}
0.05	2.20×10^{-3}
0.1	7.20×10^{-4}
0.2	2.00×10^{-4}
0.3	9.10×10^{-5}
0.4	5.20×10^{-5}
0.5	3.30×10^{-5}
1.0	8.60×10^{-6}
2.0	2.30×10^{-6}

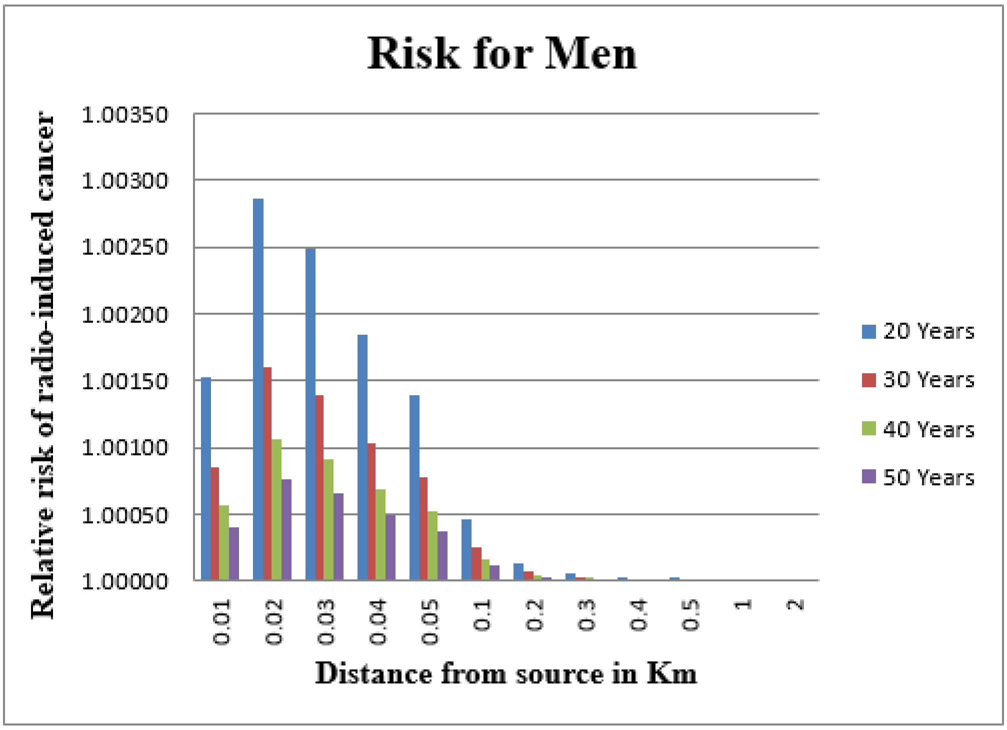

Figure 3: Relative risk of cancer induced by ionizing radiation for men.

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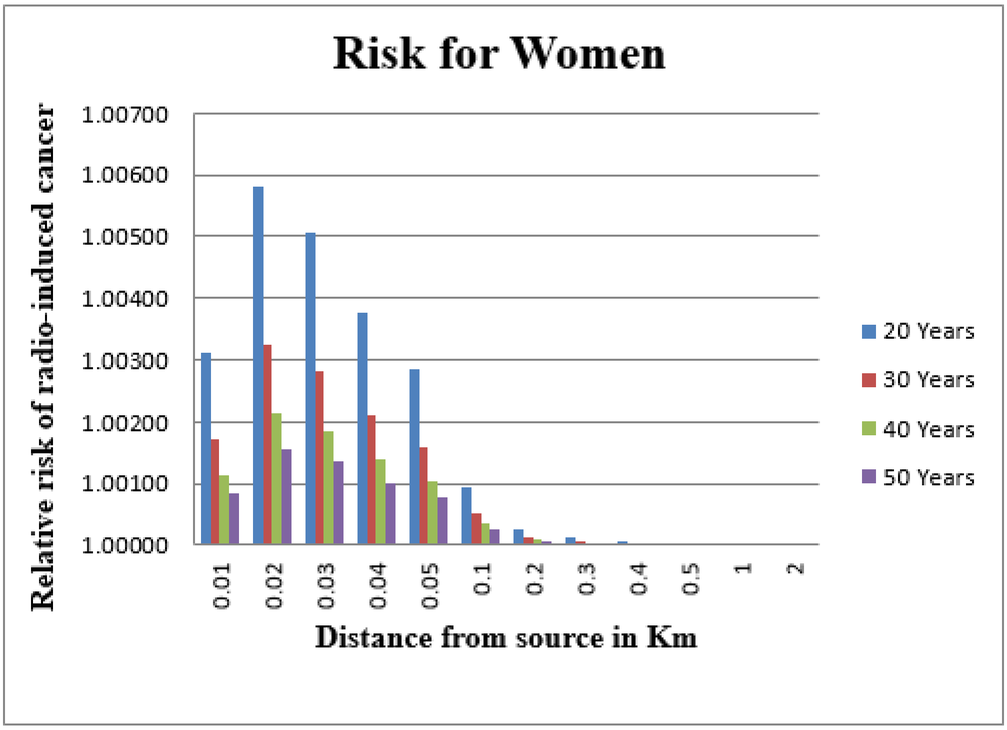

Figure 4: Relative risk of cancer induced by ionizing radiation for women.

4. CONCLUSIONS

According to the BEIR V model the relative risk is higher among women because of their large numbers of lower basal rates than men. You may also notice decreased risk with the passage of years after exposure. But the committee responsible for the BEIR V model [4] acknowledges that its risk estimates become more uncertain when applied at very low doses. Starting from a linear model at low doses, however, it can increase or decrease the risk per unit dose. In this case, the mean dose associated with the lung before the simulated scenario was 1.42 mSv.

In future work the intention is to associate the variation of the duration of the fire with the radiological risk presented in the scenario, with the intention of providing data estimates to be used in measures of protection for the people involved in a case of radiological emergency.

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