Using free license codes to simulate the diffusion of contaminants in case of radiological release

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Introduction

The radiological risk is inherent to a wide range of activities: military, medical, industrial and research involving nuclear fusion.

An explosion in a nuclear fusion plant could result from a LOCA (Loss Of Coolant Accident) or from a LOCA (Loss Of Water Accident) which lead to air ingress, the dust, which is finally produced during the life of the reactor and accumulates into the Vacuum Vessel (VV) can be mobilized and form an explosive dust-air cloud which can be ignited by the energy hydrodynamics following hydrogen ignition by a weak spark [2].

- A valid tool to predict the consequences of accidents and reduce their risk exists: in computing systems that allow modeling the evolution of a possible release of radioactive materials in different kind of scenario.
- Being able to predict the consequences of a radiological or nuclear accident for the population and the environment is essential to:
  - **EMERGENCY PLANNING**
  - **EMERGENCY MANAGEMENT**

The first action needs a great number of data to create sufficiently detailed scenarios to implement the planning process; the second requires a fast, field portable tool that can be used to predict the immediate consequences of an accident to support the decision making process.

Free license codes, such as the HotSpot code, can be used with this aim, contributing collecting useful preliminary data.

The HotSpot code

HotSpot evaluates the radiation effects associated with the atmospheric release of radioactive materials based on a Gaussian dispersion model. This tool is used to evaluate the short-term (10 km) and long-term (100 km) effects of a nuclear accident.

The model was developed for general releases of radionuclides and for nuclear events, and allows the user to simulate the releases of any radionuclide which is included in the ICRP 30 and in the ICRP 74 thanks to the "general model".

- **general dispersion**
- **general population**
- **general emergency planning**

(3.) Simulation of an explosion at the ITER facility

An explosion in a nuclear fusion plant such as ITER could cause the atmospheric dispersion of radioactive isotopes of Tungsten, Beryllium and Hydrogen (Trimix) [15-27].

To estimate the hypothetical distribution of radioactivity as a function of distance, and its impact on health workers and the environment we evaluate scenarios according to the boundary conditions (diffusion model, meteorology, sampling time, etc.), validated with the calculation.

About 1000 kg of dust can be present in the VV, as a result of the normal activity of the plant. According to the material characteristics and the processes in the plant, the radioactivity of the dust would be:

- 36% Beryllium
- 30% Tungsten.
- 25% Hydrogen.

Two different scenarios have been simulated:

- **Explosion Model** for the release of the total amount of dust as an explosion from ground level.
- **Combined Model** for the release of 65% of the total amount of dust as an explosion from ground level and 35% as a general release with an height of 24m from ground level.

Chapter of the work

The aim of this work is to demonstrate the capability of free license codes to model the radiological diffusion in case of real or hypothetical accidents to collect data which are useful to guarantee the safety of people and operators, and the security of nuclear power plants.

Both these aspects are critical issues for the development of nuclear fusion plants like ITER (International Thermonuclear Experimental Reactor).

**Workflow**

1. Benchmark of the code: with data from a real accident involving the explosion and subsequent release of radioactive material from a spent nuclear fuel reprocessing facility [3] to evaluate the confidence of the results.
2. Validation of the model: results from the simulation and experimental data were compared to evaluate the best model and settings of the code to simulate an explosion at the ITER facility.
3. Simulation of an explosion at the ITER facility: simulation of a worst case scenario for the explosion of the plant and the release of 100% of the radioactive dust and Hydrogen was simulated. Results have been discussed and presented here.

(1.) Benchmark and (2.) Validation

Characteristics of the accident

The accident involved the explosion of a stainless steel tank containing spent nuclear fuel, organic and inorganic compounds used in the reprocessing process. The explosion was caused by an uncontrolled release of the internal pressure, which gave rise to a shock wave in the atmosphere and to a column of dust and gas, including radioactive material, that was dispersed in the atmosphere.

Results of the simulation and the experimental data were compared to evaluate the best model and settings of the code to simulate an explosion at the ITER facility.

In Table 1, we give a more detailed description of the combination of boundary conditions and output settings which were used in the experiment.

![Figure 1](image1.png)

A good agreement of data is evident for distances under the 10 km from the point of the release of radionuclides

Conclusions

- **Numerical results from the simulations suggest that an incident in ITER facility with release of activated dusts would be significant.**
  - For the two simulation models, TEDE values of 1.0E4 Sv would be reached in the proximity of the plant.
  - These values decrease, with increasing of the distance of about two orders of magnitude at 4.5 km from the source, reaching the value of the order of 1.0E-1 Sv for distances between 10 and 20 km. (an error of about 10% is associated to the values within a distance of 10 km).
  - According to these results, external doses of 50 mSv (the lower threshold limit for evacuation) and 500 mSv (the upper threshold limit for sheltering) would occur within the area surrounding the facility, representing an elevated hazard for workers and people by its proximity.
  - Despite the code is conservative and estimate tend to be greater than real values, it has to be understood that this code needs very little time for calculations (less than 1 minute) and very few, and raw, input data are needed to obtain conservative mapping of the area surrounding the facility involved in the accident using the HotSpot code as BSS (Decision Support System) in the phase of emergency planning and management also for nuclear fusion facilities such as ITER.

References