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Whole body dose due to Station Blackout at Angra 2 Nuclear Power Plant.

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1. Introduction

Under normal operating conditions, nuclear power plants release small amounts of radioactive effluent over their useful life. [1]. In the unlikely event of a severe accident, followed by successive failures of physical barriers and problems in the reactor control and protection systems, the release of radioactive material can become significant. The problems generated from these catastrophic events can result in an increase of the levels of radioactivity near the plant, representing a threat to human beings, society and local life. Therefore, the dispersion study can generate results with impacts on the occupation and design of the site. It is important to remember that the severity of a possible accident associated with nuclear facilities, in general, is strongly linked to the population density of the regions around the facilities, as well as the evacuation policy, medical treatment and other public health measures to mitigate its radiological consequences [2].

2. Methodology

Naturally, proper operation of systems, devices and equipment in a nuclear power plant requires a stable electric power supply. In normal condition it puts into operation the refrigeration systems, monitoring and control systems, lighting and other routine services; whereas in emergency conditions, it activates safety systems and several devices which are called CLASSE IE to ensure a safe and successful shutdown of the reactor if necessary. If or when a reactor is shutdown, the residual heat generated from the decay of the fission products must be removed from the core to prevent the melting of fuel rod claddings, which in turn, ultimately avoids the release of radioactive materials into the atmosphere. However, when station blackout takes place, the reactor coolant pumps (RCPs) are shutdown as a result, and that makes the core temperature rise, which leads to a severe accident in the reactor.

Furthermore, the chimney venting system may possibly release radioactive material to the atmosphere out of control, becoming dependent only on the butterfly type isolation valves of the containment purge system, which open by pressure difference between the valves after reaching a containment pressure of 6.2 bar. It is assumed that the time needed to release all radioactive material from inside the containment is 72 hours and the valves open hourly. Another assumption is that the radionuclides pass through a filtration system before they are released to the atmosphere. The filters used for Iodine and particulates such as Cesium are activated carbon and high-efficiency particulate absorber (HEPA), respectively, and the design retention factor of both filter is 99,99% for the respective type of radionuclides. All the noble gases are to escape the containment since both filters are unable to retain them.

The source term used in present work is obtained by means of proportionality between Angra 1 and Angra 2. That is, the source term of Angra 2 is calculated based on its activity estimated from numbers of fuel pellets of both power plants and the already known activity of Angra 1. This calculation resulted in total activity of Angra 2 equivalent to 146.18% of activity of Angra 1.

The use of mathematical models facilitates the simulation process of transport mechanisms and pollutants deposition. These models provide a conservative theoretical estimate of the concentration levels of pollutants in the air, making it possible to evaluate the spatial and temporal evolution of these pollutants in the atmosphere.

The choice of the WRF model configuration, as well as the domains, spatial resolution, and grid nesting, were made to obtain necessary meteorological data for the INPUT of the CALMET model. The initial and boundary conditions assimilated by the WRF are derived from the GFS (Global Forecasting System Model) of the National Centers for Environment Prediction (NCEP), whose spatial resolution is 0.5 ° (~ 55 km) and a time resolution of 3 hours.
To compose the GFS domain, both horizontally and vertically, a model for interpolation of the data is used. More details about this model can be found in KALNAY et al. [3]. The GFS data can be obtained for free from the electronic address. Link: https://www.ncdc.noaa.gov/data-access/model-data/model-datasets.
The meteorological data of the January month of 2009 was used for the simulation with the WRF. The January month data was chosen, due to being the most recent data obtained from Eletronuclear for the four Angra towers. The grid used by CALMET has a domain of 80 km and a cell number of 229 x 229. In the region of the NPP, the wind field data of the Eletronuclear Towers was used, which radius of influence is 5 km.

3. Results and Discussion

The simulation was initiated on 5 January 2009, at 6:00 AM and it was conducted during 72 hours. For this, it was assumed that the movement of all the radionuclides, once in the atmosphere, is strictly in accordance with the wind field of the region of analysis during the whole simulation time. Fig. 1 shows both the wind field of the region and the radionuclides transport.

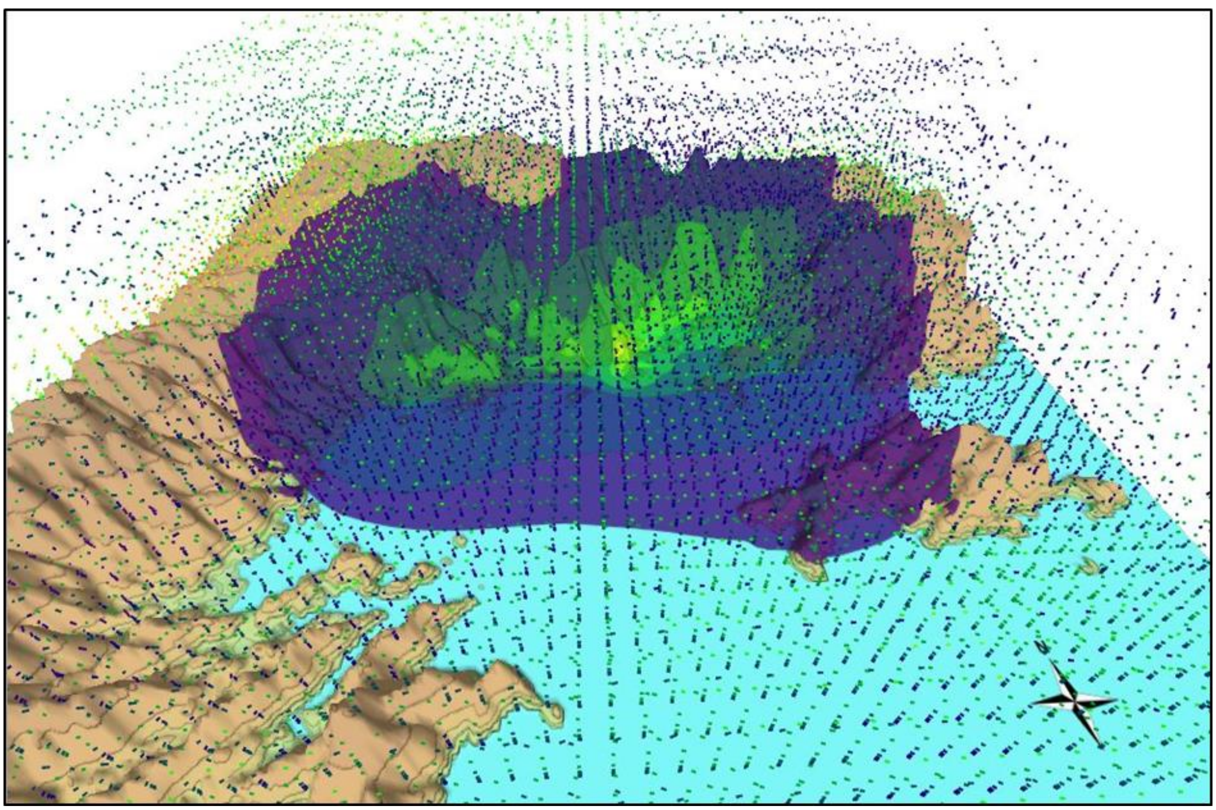

Figure 1: Concentration of the radionuclides and the wind field around Angra 2 NPP

An illustration of the simulated plume dispersion in the atmosphere of Angra dos Reis is available at the following link: https://www.youtube.com/watch?v=uws8etaIcE8.

The analysis of radionuclide concentration was made at specific areas which were selected regarding the respective population. The selected areas and their distances from the Angra 2 NPP are listed in Table 1.

Table I: Relevant areas for the radionuclides concentration and dose analyses.

Area	Distance from the Angra 2
Praia Brava	2 km
Ilha Grande	25 km
Paraty	35 km

The whole body dose of the radionuclides in each area in the Table 1, are shown in Table 2. In these calculations, the plume exposure was considered to be 100%, namely, the public individuals were assumed not to be provided with any mean of radiation protection.

Table II: Whole body doses calculated (72h of exposure)

Area	WHOLE BODY DOSE(mSv)
Praia Brava	1,87E+02
Ilha Grande	6,86E+01
Paraty	3,11E+01

4. Conclusions

According to the PEE/RJ [4], the preventive evacuation of the population constitutes an effective protection measure up to the distance of 5 km around the plant. From this distance, no additional benefit will be obtained with the preventive evacuation. Thus, to the EPZ 10km and EPZ 15km, it is preferable to recommend, in the short term, that the population remains sheltered.

According to a CNEN study [5], the protection measures for CNAAA can be divided as follows:

- <u>Area Emergency</u>: EPZ 3 km and EPZ 5 km (notification to the population to remain in residences or workplace, awaiting instructions) and EPZ 10 km and EPZ 15 km (notification to the population to keep on the alert for further instructions, keeping their normal activities); and

- General Emergency: EPZ 3 km (population evacuation), EPZ 5 km (keep population sheltered) and EPZ 10 km and EPZ 15 km (notification to the population to remain in the residences or workplace, awaiting instructions).

Based on the dose values for sheltered and evacuation of Regulatory Position CNEN 3.01 / 006: 2011 [6], whose values are 10 mSv for sheltered and 50 mSv for evacuation, will be recommended the protection measures for each area of the Table I.
In summary, it is possible to conclude that:

- The period chosen for the simulation presents greater displacement of the wind field to the West region. Due to this fact, the most affected area is Praia Brava;
- The most advisable protective measure for the regions of Praia Brava and Ilha Grande is Evacuation;
- For the region of Paraty, in the first hours, shelter was considered the most adequate protective measure. However, within 72 hours, the most adequate protective measure is the notification of a possible evacuation; and
- In the event of a Severe Accident, this accident will be characterized as a General Emergency.

Advance planning is essential to identify potential problems that may occur in an evacuation. The NRC case study cites the following aspects of planning as contributing to efficiency and effectiveness of evacuation [7]:

- High level of cooperation among agencies;
- Use of multiple forms of emergency communications;
- Community familiarity with alerting methods, the nature of the hazard and evacuation procedures;
- Community communication; and
- Well-trained emergency responders.

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