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Investigation on Radiation Doses Distribution after an Accident at a Nuclear Fuel Cycle Facility

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I. Introduction: Emergency Planning Zones (EPZ) are designated areas where immediate protective actions are required to protect the public during a nuclear emergency exposure situation. A nuclear emergency can arise due to the release to the environment of radioactive material that may cause severe health effects (deterministic and stochastic) to warrant consideration for application of protective actions. The protective actions in a nuclear emergency cover measures to limit the exposure to radiation of the members of the public and facilities workers (1, 2, 3).

The goals of protective actions are to mitigate the duration of exposure to ionizing radiation by moving people to a safe distance (evacuation), using shielding (shelter in place), thyroid blocking when appropriate and restrictions on food and water. Evacuation and shelter in place are two common protective actions measures during events that involve the release of radioactive materials. These actions are complex and require advanced planning to reduce health risks. Such planning is a component of emergency preparedness and response (EPR)(4).

Emergency Planning Zones are an integral part of EPR, and are estimated considering environmental releases of radioactive materials, meteorology, spectrum of accidents and radiological doses from different exposure pathways and enable individuals and authorities to organize prompt and effective emergency response. The emergency planning zones include Precautionary Action Zone (PAZ) with the objective to avoid or to minimize severe deterministic health effects, and the Urgent Protective Action Zone (UPZ) where the risks of stochastic effects is sufficiently high to perform environmental monitoring and implement protective actions based on results. The exact size and shape of each EPZ is a result of detailed planning which includes consideration of the specific conditions at each site, geographical features of the area, and demographic distribution.

The zones as well as the required actions are based on the consequences due to possible accidents which should be determined from a hazard assessment or risk analysis. To perform accident risk analysis methodology there are various computer codes designed to be used and among them there is the USNRC (United States Nuclear Regulatory Commission) RASCAL (**R**adiological **A**ssessment **S**ystem for **C**onsequence **A**na**L**ysis) computer code for making dose projections for atmospheric releases during nuclear emergencies.

II. Metodology: In this study, the EPZ around a fuel cycle facility was determined using US NRC RASCAL computer code, considering a criticality accident in a solution containing enriched uranium, in a fuel cycle facility. RASCAL (5) is a computer code that evaluates releases from nuclear power plants, fuel cycles facilities, spent fuel storage pools and casks and radioactive material handling facilities and is designed to be used in the independent assessment of dose projections during response to radiological emergencies. The dose calculations were assessed by running two scenarios involving an airborne release of radioactive material, since the accident scenario has a deep impact on the size of emergency planning zones. The first scenario considers an initial spike of $5.3x10^{16}$ fissions followed by 47 bursts of $1.0x10^{16}$ fissions at 10 minute intervals resulting in a total fission yield of $1.0x10^{18}$ fissions, with bursts lasting for 8 hours. The second scenario considers criticality excursion with a single spike of $1.0x10^{18}$

fissions in a volume solution containing enriched uranium with the radioactive material being release to atmosphere during 1h. From the fission yield, RASCAL determines the fission product release to the atmosphere, the atmospheric dispersion of those fission products, and the doses from the plume. RASCAL also calculates the direct gamma and neutron shine dose. The results will provide the basis for protective action decisions.

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The airborne relative fractions were considered as 100% for noble gases, 25% for iodine and 0.5% for others isotopes. The building wake effect was considered in both cases and the possible consequences to estimate the doses. The meteorological conditions were also considered in this studied since it plays a fundamental role in the dispersion of the radioactive plume. For this study, the classes F and G of atmospheric stability were adopted as predominant. After the criticality accident, the volatile radioactive materials of main radiological significance are cesium and iodine and the main exposure pathways are cloud shine, inhalation and ground shine. Therefore, the surface concentration (Bq/m^2) and the deposition rate ($Bq/m^2/s$) of these radioisotopes were determined for the scenarios studied in this work.

III. Results: The results show that the major contribution to the total dose is due to the direct doses (gamma + neutron). The values obtained in the case of an accident with a single peak and also with multiple peaks, result in a direct dose of 100mSv at 100m and 11mSv at 300m. In the case of a single peak, the direct dose is received immediately following the accident, and therefore, it is impossible to avoid, taking any mitigating action of the radiological protection. Considering a scenario with multiple peaks, it is possible to manage the direct doses and the containment of radioactive materials to the environment. The dose resulted from the plume (immersion + inhalation) is negligible when compared to the direct dose, studied for both scenarios.

IV. Conclusion: The arrangement for emergency preparedness and response plays an important role for the safety of nuclear power programs and it is useful to estimate the emergency planning zones around a nuclear fuel cycle facility.

Urgent protective actions that must be taken before or immediately after the radioactive material release to be effective, such as evacuation, storage and administration of iodine, would not be effective, as the scenario considers a single peak of $1.0x10^{18}$ fissions in a short interval of time, so there would be no time for any mitigating action. The mitigation actions would be related to soil contamination and would require environmental analysis, food sampling and monitoring of the affected area by the radioactive plume.

When considering a multi-peak scenario, protective measures are needed to minimize doses to workers to individuals from the public are minimized. In this case, criticality is continuous and protective measures such as evacuation and sheltering should be considered around the facility.

References:

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