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PROBABILISTIC RISK ASSESSMENT FOR PUBLIC (PSA LEVEL-3) FROM POTENTIAL EXPOSURE

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Introduction. The potential exposure is prospectively considered exposure that is not expected to be delivered with certainty but that may result from an anticipated operational occurrence or accident at a source or owing to an event or sequence of events of a probabilistic nature, e.g. equipment failures, operating errors or natural phenomena (such as hurricanes, earthquakes and floods) [1]. To provide a framework of common understanding for potential risk assessment and prepare a guidance to assess the risk of accidental releases, to be used when comparing different alternatives of Innovative Nuclear Systems (INS) this study was made in the framework of the IAEA INPRO Collaborative Project [2] and part of the work was presented in the NATO Advanced Research Workshop and is in preparing for publication [3].

Probabilistic Safety Assessment (PSA) Level-3. The developed methodology is based on the PSA Level-3: assessment of the off-site consequences and estimation of the risks to the public [4]. The phenomena such as atmospheric dispersion, deposition of airborne materials, resuspension, migration through the food chains and other have been considered. For the probabilistic consequence analysis and modeling of the mentioned processes the WinMACCS code version 3.7.0 has been used [5], additionally the JRODOS code has been applied for the deterministic modeling of consequence analysis for the critical meteorological conditions.

WinMACCS code, designed primarily as a probabilistic risk assessment (PRA) tool, accounts for the uncertainty in weather, and so random weather sampling addressed the uncertainty in health effects from accidental releases caused by weather variability. At the same time the code permits evaluate the impact of uncertainty of the model parameters by introducing random sampling distribution for key model parameters [5].

In the beginning of the study an appropriate scenario was chosen with the meteorological data accumulated for at least one year with hourly step interval, the corresponding source term, and other input information and model parameters. Based on this information the iterations for considered weather sampling (8760 sequences) are fulfilled with calculations for each trial of the atmospheric dispersion and deposition; estimation of the doses, health effects. This modeling takes into account the weather uncertainty in correspondent location and in such way the probability of the consequences is estimated. Thereafter the received array of results is subjected to the statistical reprocessing. If uncertainty of the model parameters is taken into account, more cycles of iterated calculations should be made with the same procedure of the consequences estimation.

The above described consequences are evaluated on a grid (r, θ) around the release location. The results are produced on each grid elements for large amount of weather conditions. This produces a distribution of the individual risk at each grid element. For each distribution a mean value of individual risk can be obtained for each grid element. But it has become standard practice to further average them over all directions of the wind rose, rather than presenting these mean values of the individual risk for each grid element. Some studies are based on the approach of maximum doses on fixed distances from the point of release [6, 7]. This study is also centered on the peak doses over all directions of wind rose at each distance and each weather sequences. Peak dose means the maximum dose around the compass under all meteorological sampling options

Risk indicators. One way to consider potential exposures is to use a measure of risk, i.e to estimate the percentiles of doses to evaluate the risk, which estimates the probability that a certain individual is accidentally exposed to ionizing radiations due to a certain category of accident at a plant and results in health effects. As general view the risk can be expressed by such self-explained formula:

$$\textbf{\textit{Risk = Threat Rating x Consequences Values x Vulnerability Rating}} \quad (1)$$

The 'Threat Rating' in our case means probability of the accident occurrence, 'Consequences values' means the doses estimated, 'Vulnerability Rating' is the sensitivity or weakness of the site of plant, which is taken into account through the weather variability, and sensitivity of the adult person to intensity of exposure.

So, the risk from the release occurred at a specific location (with typical meteorological conditions in this location) was calculated as product of 95th percentile of the assessed dose (which itself includes risk concept, as was received based on the weather sampling), the probability of occurrence of the release of considered category and the risk coefficient for stochastic effects (see formula (3)). The nominal risk coefficient for stochastic effects was taken as 0.057 Sv-1 [8]. Probability of occurrence of the release category was considered 1.5 x 10^{-6} [9].

$$Risk = P(RC)^n \cdot D \cdot f(D) \quad (2)$$

Being: $Risk$ - Individual risk; $P(RC)^n$ - Probability of occurrence of the Release category n; D - Effective dose (95th percentile based on weather sampling); $f(D)$ - Nominal risk coefficient for stochastic effects. The results of the dose and risk estimation are presented in the following sections in the exercise description.

Scenario and Results. The source term of the accidental release was taken from the SOARCA project for Surry NPP [8] which is assumed as postulated radionuclide release to the atmosphere. The short-term station blackout (STSBO) with core damage frequency (CDF) to 1.5x10-6 per reactor-year (pry) was assumed for analysis of the environmental impact and doses consequences. Meteorological data were derived from one Spanish meteo station, which describes the weather condition during one year with one hour interval measurements of the wind direction, wind speed, atmospheric stability, and precipitation rate.

Results of Doses estimation. The doses through several pathways including external from cloudshine, groundshine, inhalation, immersion and deposition onto the skin were estimated. Separately the ingestion pathway from contaminated food was analyzed. One of the endpoints in this study is the total effective doses (ICRP60). The age category 'adults' is taken into account and the effective dose is calculated for an integration period of 50 years for inhalation, groundshine and ingestion pathways, and during plume passage for short-term pathways. As it was mentioned before the 'peak doses' were selected and analyzed.

In accordance to TECDOC-1575, vol. 8 (2008) [9], "Safety of Reactor", UR1.5 "A major release of radioactivity from an installation of an Innovative Nuclear System (INS) should be prevented for all practical purposes, so that INS installations would not need relocation or evacuation measures outside the plant site, apart from those generic emergency measures for any industrial facility used for similar purpose." So, following investigation is based on the analysis of these criteria as need of relocation and evacuation countermeasures. The lifetime overall doses and doses integrated for 7 days were analyzed. The ingestion doses are not presented here and were calculated apart for possibility to consider scenario that uncontaminated food and water can be supplied and that the public would not eat radioactively contaminated food. In accordance to Spanish legislation evacuation countermeasure is based on the criteria 50 mSv of 7 days integrated dose [11], so estimation of such doses was fulfilled to check if evacuation is necessary.

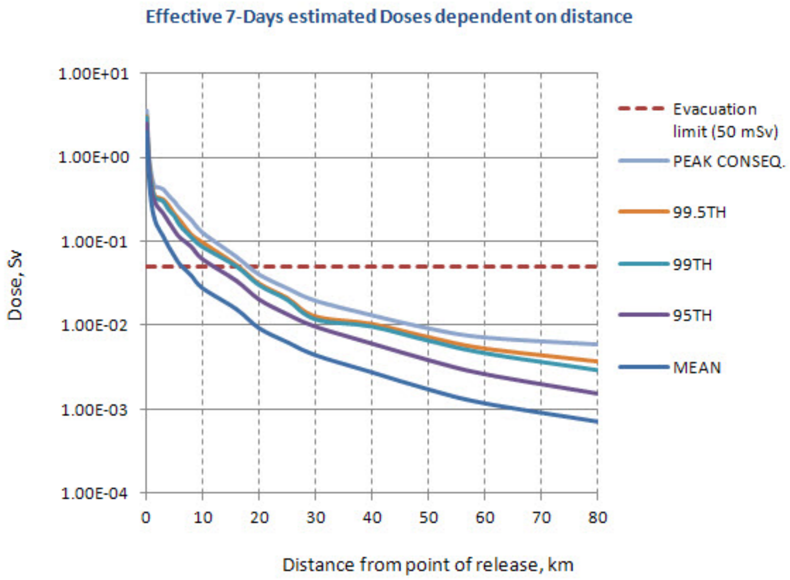

Figure 1. Effective 7-Days estimated doses dependent on distance from point of releas

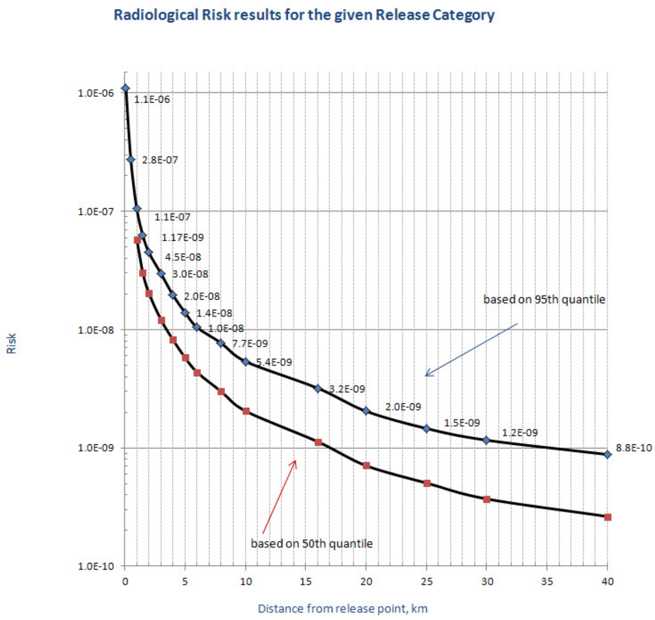

Figure 2. Risk curve based on the 95th and 50th lifetime dose percentiles

Graph of dose percentiles together with dose limit curve see in the Fig.1. Such family curves can help in understanding the results and facilitate in the making decisions. There is shown for percentile 99th the distance where the dose exceeds the limit is 16 km, what means that only for 1 % of the cases this distance can be exceeded. On the other hand for 50th percentile the distance of exceeding the dose criterion is 6 km, which is high frequency and large distance, so evacuation on off-site area, out of a fence of a site will be necessary. So, in accordance to this scenario INS should be not acceptable.

Risk estimation. The risk was calculated as product of lifetime effective dose (95th percentile), the nominal risk coefficient for stochastic effects, and the probability of occurrence of the release category (see formula (1)). The results of the estimated risk are presented on the Fig. 2. The risk curve constructed for 50th percentile of doses is also presented for comparison. So, in this graph the risk, as function of distance from point of release, is shown. This methodology can be proposed as a risk-informed approach to analyze the acceptability of a new installation. Also a risk can be calculated and compared with the risk curve acceptability criteria, which consider in coordinate system of the effective doses and the annual probability of accidental sequences [12].

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