RADIOLOGICAL RISK EVALUATION FOR DECOMMISSIONING OF AN INTERIM STORAGE OF RADIOACTIVE LIGHTNING RODS

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Intro

Radiological risks evaluation is attempted, acknowledging the hazards in each procedure of dismantling, storage and transport of radioactive lightning rods. Failure Modes and Effects Analysis method (FMEA) is exploited as a tool for the risk evaluation, in order to classify each associated risk. Appropriate measures are suggested for the emergency preparedness and response which reduce the Risk Priority Number (RPN) of the FMEA method

FMEA

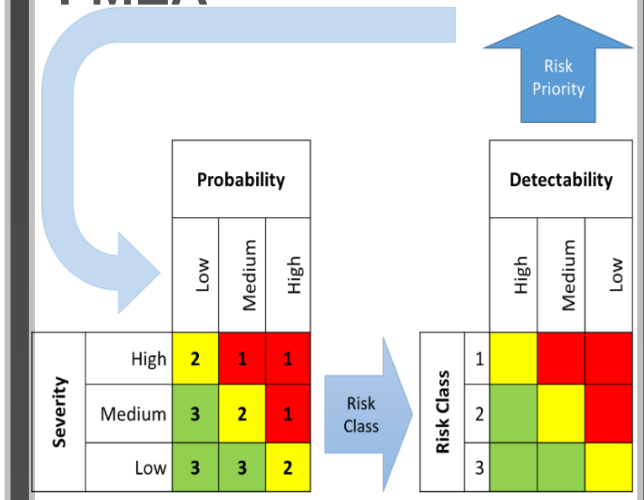

Chart flow of the evaluation of the risk priority, using two products: the severity of the hazard by the probability of occurrence (i.e. risk class) and the risk class by the detectability. After the application of measures and precautions the severity, the probability and the detectability will be improved, therefore new round of evaluation can be run

Gauss Plume Model

The Gauss Plume Model [3] assumes that the release follows a Gaussian distribution into the radioactive plume. Specifically, the concentration $C^i(x)$ (Bq/m) for every i airborne radioisotope composing the plume, at x distance from the point of the release, along the central line of the plume as it follows the direction of the wind, is given by:

$$C^i(x) = Q^i DF^i(x),$$

where Q^i is the release rate (Bq/s) of the ith isotope and DFi(x) is its diffusion factor, given by:

$$DF^i(x) = \frac{1}{\pi\sigma_y\sigma_z u}\exp\left(-\frac{H_e^2}{2\sigma_z^2}\right) f_{decay} f_{deposition}$$

where H_e is the height of the point of release, u is the wind speed at this height, σ_x and σ_y are the diffusion parameters which are functions of the distance from the release point and the stability category of the atmosphere [7].

Based on Gauss Plume Model, Matlab code was developed to evaluate the effective doses to the 1st responders and the members of the public, for the scenario of fire on radioactive lightning rods.
The effective dose is anticipated by:

— inhalation of the plume (internal exposure);
— cloud shine (external exposure);
— ground shine (external exposure).

The factors combined to set the different meteorological conditions are:

— Air speed
— Rain density
— Stability of the atmosphere (Pasquill stability classes).

The scenario of fire considers a fire encompassing the entire stored inventory. For the dispersion of the radioactive plume typical meteorological conditions of Greece are considered, i.e.: Stability condition in Pasquill class, D ; Wind speed, 1m/s; Precipitation: Dry conditions (blue line in Figs. 1 & 2); Moderate rain of 3 mm/h (red line in Figs. 1 & 2).

Figures and Tables

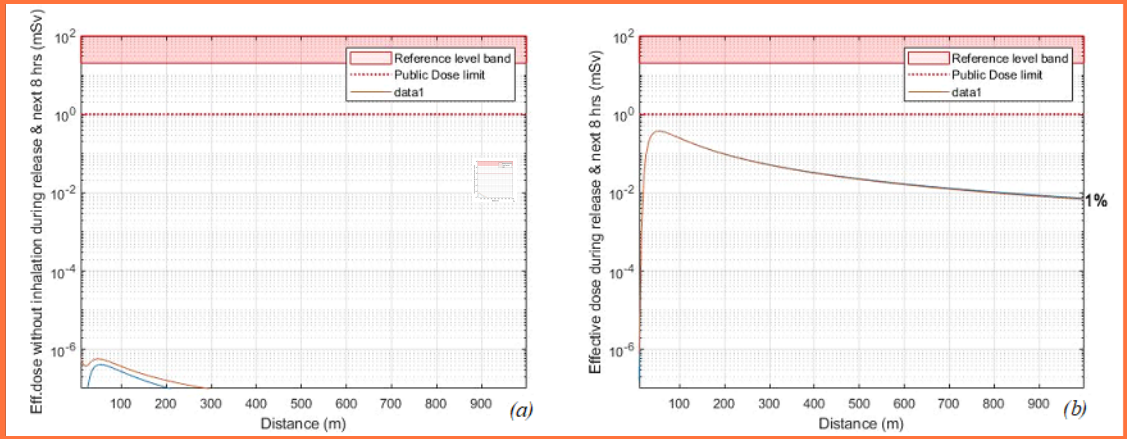

FIG. 1. The dose to the first responders: (a) using a breathing apparatus or filter, (b) without using breathing apparatus or filter. Pasquill stability class: D; Wind speed: 1 m/s. Red line indicates moderate rain (3mm/h) and blue line indicates dry weather conditions

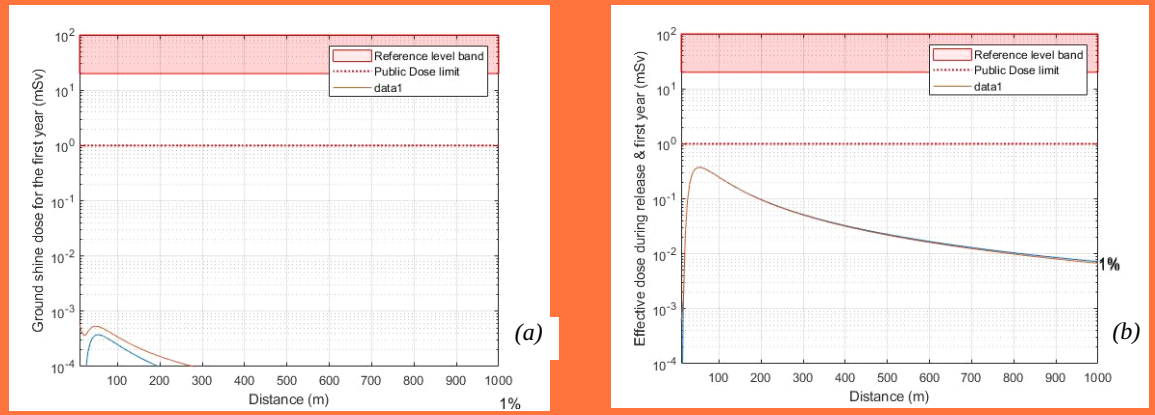

FIG. 2. The dose to the public over the first year, in case of: (a) evacuation of the area during release, (b) no evacuation of the area during release. Stability condition: D. Wind speed: 1m/s. The blue line indicates dry conditions and the red line indicates moderate rain (3 mm/h).

TABLE 1. An example of factors affecting the risk evaluation and the risk priority number for three generic processes of the decommissioning phase of an interim storage of lightning rods

Process:			Storage	Transshipment	Transportation
Severity	Failures	to next process (%)	100	100	100
	Workers	eff. dose (% of 100mSv)	0.30	0.30	0.30
		# persons exposed	20	24	22
	Public	eff. dose (% of 1mSv)	0.10	0.01	0.05
		# persons exposed	80	80	90
		Severity (%)	29	30	32
Likelihood of Occurrence (%)			60	40	60
Likelihood of Detection (%)			50	10	15
Risk Priority Number			86000	11848	28361
Precautions to reduce Severity, Occurrence of Failure or increase Detectability			Fire Detectors Extinguishers Controlled Access Removal of flammable materials Breathing mask / Evacuation	Fire Detectors Extinguishers Employee training Rehearsal of the transshipment with dummy materials Breathing mask / Evacuation	Fire Detectors Extinguishers ADR compliance Breathing mask / Evacuation
Severity	Failures	to next process (%)	100	100	100
	Workers	exposure (% of 100mSv)	0.00	0.00	0.00
		# persons exposed	20	24	22
	Public	exposure (% of 1mSv)	0.00	0.00	0.00
		# persons exposed	80	80	90
		Severity (%)	29	30	31
Likelihood of Occurrence (%)			4	5	4
Likelihood of Detection (%)			6	3	4
Risk Priority Number			670	369	442

CONCLUSIONS

FMEA method along with the estimation of the effective dose to the workers and the public can be used by the radiation protection experts to classify the risks of the decommissioning of a facility with radioactive materials. Therefore, the priority for precautions and protective measures can be given with a graded approach.

Breathing with protective apparatus or filters reduces the dose to the firemen by almost six orders of magnitude;
The radioisotopes of Ra-226 and Am-241 contribute significantly to inhalation dose, as the organ receiving the highest dose is the lungs and the bone surface;
Even if the radius of the safety perimeter sets closer than 100 m, the annual dose constrain level for the public (0.3 mSv) will be satisfied;
The high contribution of the inhalation dose to the total dose, indicates that evacuation of the surroundings during release of the plume is an efficient measure for the reduction of dose to the public to levels less than the natural background;
The radiological hazard for 1st responders and members of the public is readily manageable, based on comparison of the calculated doses with the public dose limit. It is important to highlight the compatibility of the above analysis with the approved national plan for radiological or nuclear emergency response in category III facilities.

REFERENCES

[1] IAEA, Criteria for Use in Preparedness and Response for a Nuclear or Radiological Emergency, IAEA Safety Standards Series No. GSG-2, IAEA, Vienna (2011).
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[3] Hanna, S., Briggs, G.A., Jr. Hosker, R.P., Handbook on Atmospheric Diffusion of Energy. US Department of Energy, DOE/TIC-11223 (DE92002045), 10.2172/5591108 (1982).
[4] National plan for radiological or nuclear emergency response in category III facility, ΑΔΑ: 9Ε1Ο46ΝΠΙΘ-ΒΔ0, (2021).