Assess and mitigate the Early Offsite Consequences of Accident for Nuclear Power Plants

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Introduction

A severe accident could release radionuclides to the environment. This study has been carried for calculating early offsite consequences resulting from a hypothetical nuclear power plant accident such as LOCA accident. This study is important to evaluate the exclusion boundary and the boundary of low population zone. The early dose and health effect for the public is calculated via three pathways: cloudshine, short-term groundshine, and inhalation. During Fukushima accident the mitigation actions play a good role to decrease the consequences of accident. So this study is important for management the emergency plan before constructing such plants. The mitigation actions are the actions should be taken after the occurrence of nuclear accident to protect the public against the associated risk. This study has been defined these actions.

Methodology

A **S**implified **M**odel for calculating **A**tmospheric **R**adionuclide **T**ransport (**SMART**) and health effect code has been developed using an integral approach for calculating early offsite consequences resulting from nuclear power plant accidents.

Dose Calculation and Health Effect:

The data base for PWR core inventory for 54 nuclides are provided as inputs with reference power equal 3412 Mwth . This model predicts time-integrated air concentration of each radionuclide at any location from release as a function of time-integrated source strength using the Gaussian plume model. Dispersion parameters are calculated from exponential fits to the Pasqual-Gifford curves for six atmospheric Stability classes designated A to F. They include dry and wet deposition, radioactive decay and daughter buildup, reactor building wake effects on plume mixing, the inversion lid effect, and the effect of plume rise. The early dose and health effect for the public is calculated via three pathways: cloudshine, short-term groundshine, and inhalation.

Cloudshine: The biological dose (rem) to organ j due to cloud shine is calculated from:

$$D_c^j = \sum_{i=1}^{N} \chi_i \; (F_c / F_{c\infty})_i^j \; SF_c$$

Where χ_i is the integrated air concentration (Ci-s/m^3) of nuclide i at the reference location, and $(F_{c\infty})_i^j$ is the cloud–dose conversion factor for nuclide i (rem-m^3/Ci-s). The dose is further reduced by multiplying by an appropriate shielding factor (SF_C) for cloud exposure, which depends on the emergency response action.

Groundshine: The biological dose (rem) to organ j from external exposure to gamma radiation emitted by deposited radionuclides is:

$$D_g^j = \sum_{i=1}^{N} \chi_{Di} \; (F_g)_i^j \; SF_g$$

Where D_g^j is the total groundshine dose (rem) to organ j, χ_{Di} is the ground concentration of radionuclide i (Ci/m^3), $(Fg)_i^j$ is the integral ground-dose conversion factor for nuclide i and organ j (rem-m^2/Ci), SF_g is a shielding factor to account for ground roughness, structures vehicles, etc., and depends on the emergency actions.

Inhalation: The dose due to inhaled radionuclides is calculated from:

$$D_i^j = \sum_{i=1}^{N} \chi_i \; (F_{in})_i^j \; Br$$

Where D_i^j is the total inhalation dose (rem) to organ j, Br is the breathing rate of the receptor (m^3/s), and $(F_{in})_i^j$ is the dose conversion factor (rem/Ci inhaled).

Health Effect: These effects are early deaths and injuries modeled for organ specific doses from the three pathways. First, the cumulative hazard is calculated as:

$$H = \ln(2) \left(\frac{D}{D_{50}} \right)^v$$

Where D is the dose and D_{50} is the dose for producing an effect in 50% of the exposed individuals, and v determines the steepness of the dose effect curve.

Evaluation the exclusion area EA and low population zone LPZ:

The EA and LPZ are determined according to CFR (2002) .

Define the mitigation actions: Early effects are more significant for determining the necessary emergency response actions. These actions may represented by sheltering, evacuation, distribution of stable iodine tablets and/or relocation. This study defines these actions.

Results and Discussion

The calculations of short individual dose represents the mean short-term individual dose for different organs at different distances. In addition, the absorbed doses of skin and thyroid have the highest dose values than other organs.

Table 1 The mean short-term individual dose verses distances for different organs

Distance(Km)	0.5	1.5	2.5	3.5	4.5
Effective	6.141E+00	1.515E+00	6.948E-01	8.192E-01	2.429E-01
Thyroid	3.498E+01	5.732E+00	2.149E-00	2.009E+00	8.923E-01
Eye lens	1.462E+00	3.571E-01	1.577E-01	2.071E-01	9.188E-02
Ovaries	1.775E+00	4.510E-01	2.033E-01	2.447E-01	9.100E-02
Skin	1.602E+02	2.774E+01	8.790E+00	5.959E+00	1.800E+00
Lung	1.815E+01	5.319E+00	2.612E+00	2.921E+00	7.397E-01
B marrow	1.911E+00	4.883E-01	2.213E-01	2.685E-01	1.002E-01
GI-tract	7.330E+00	2.107E+00	1.025E+00	1.160E+00	3.116E-01

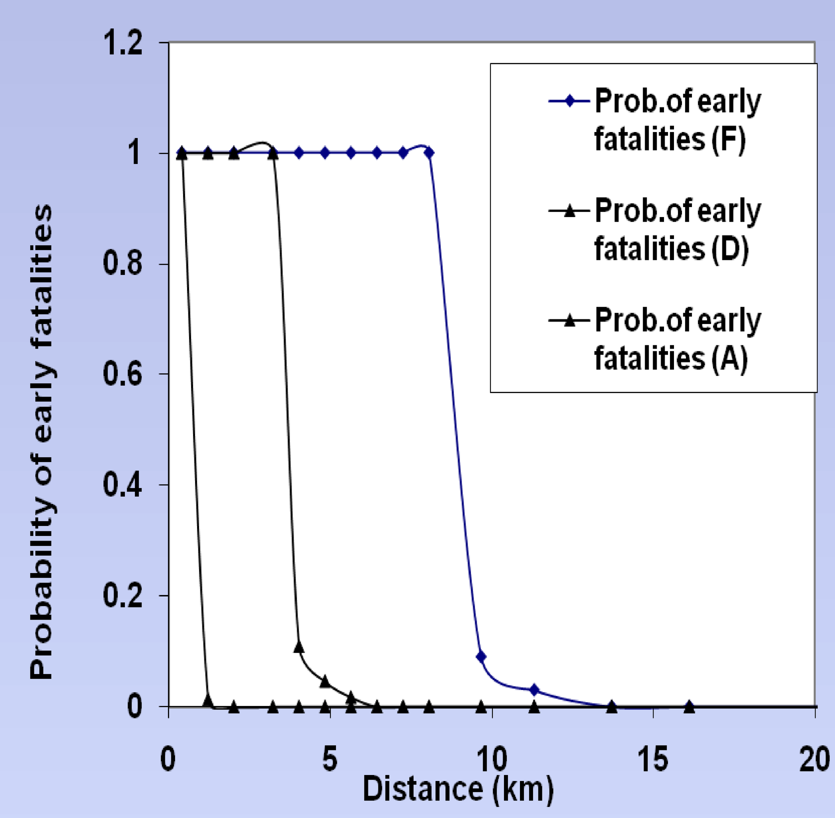

Fig (١)The probability of early fatalities as a function of distance at different stability class

The effect of atmospheric stability classes are investigated. Fig (1) shows the relation between the probability of early fatalities and distance for three stability classes. It is noticed that the probability decease rapidly as the stability of the atmosphere is decreased. Also, the observed results show that the value of probability begin to be less than one at distance equals about 1 km in case of stability class A. While in case of stability class F this distance equals 8 km, this results shows how the effect of the weak dispersion condition of the site on safety condition.

The results of evaluation the EA and LPZ are equal to 2km and 5km . Tables (2a) and (2b) show that, the number of mitigation actions which should take place after the accident at exclusion area and around the plant at public area for 16 sectors . From the Table (2a) it is noticed that the action of sheltering and evacuation automatically takes place at the downwind sectors after the accident for workers and public. While this action takes place only in regions close to the site (workers area or exclusion area) in the other sectors.

It is noticed from Table (2b), which represent the pattern of iodine distribution, that this action takes place automatically along the distances up to 2.5 Km (workers area) in all sectors. While the same action takes place at a distance equals 3.5 Km in downwind sector based on dose level equals 0.02 Sv.

Table 2 The number of action for 16 sectors at different distances

(2-a): Sheltering + Evacuation

1 → Sheltering +evacuation automatically

Sector	Distance (km)				
	0.5	1.5	2.5	3.5	4.5
1	1	1	1	0	0
2	1	1	1	0	0
3	1	1	1	0	0
4	1	1	1	0	0
5	1	1	1	0	0
6	1	1	1	0	0
7	1	1	1	0	0
8	1	1	1	1	1
9	1	1	1	1	1
10	1	1	1	1	1
11	1	1	1	0	0
12	1	1	1	0	0
13	1	1	1	0	0
14	1	1	1	0	0
15	1	1	1	0	0
16	1	1	1	0	0

(2-b): Iodine distribution

1 → Stable iodine automatically
2 → Stable iodine based on dose =0.02Sv

Sector	Distance (km)				
	0.5	1.5	2.5	3.5	4.5
1	1	1	1	0	0
2	1	1	1	0	0
3	1	1	1	0	0
4	1	1	1	0	0
5	1	1	1	0	0
6	1	1	1	0	0
7	1	1	1	0	0
8	1	1	1	2	2
9	1	1	1	2	2
10	1	1	1	0	0
11	1	1	1	0	0
12	1	1	1	0	0
13	1	1	1	0	0
14	1	1	1	0	0
15	1	1	1	0	0
16	1	1	1	0	0

CONCLUSIONS

It should be assess the early offsite consequences of severe accident for NPP for many purposes such as site evaluation of NPP, emergency plan and for the evaluation of the exclusion area and low population zone. The mitigation actions should be take place after the nuclear accident especially in the down wind sectors. . For different organs, the skin and thyroid received the highest dose values than the other organs.

Meanwhile the more stable condition of type F gives the worst dilution process and highest receiving dose. The physical parameters of the plants are very dominating factor, in the dispersion process of pollutants and on its behavior in the surrounding environmental. The probability of early fatalities is highly effect by the stability conditions of the atmosphere.