SPACE-TIME CONCEPT FOR ESTABLISHMENT OF INTERVENTION LEVELS FOR OFF-SITE RADIATION EMERGENCIES

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ABSTRACT

Intervention Levels (ILs) and Derived Intervention Levels (DILs) for initiating countermeasures in public domain following a nuclear accident or radiation emergency are established in advance. Public regime is divided in Domain 1,2 and 3 incorporating space-time concept to meet ICRP-40 recommendations. ILs in dose ranges from 1 mSv to 500 mSv to whole-body and 50 mSv to 2500 mSv to thyroid are proposed. A correlation between gamma dose rate from ground contamination and whole-body dose and inhalation thyroid dose is established to workout DILs. Relationship to obtain period of persistence and completion of countermeasure is also proposed. DILs for important radionuclide concentration in major food items are suggested.

BASES FOR INTERVENTION LEVELS

Accident in a nuclear installation, giving rise to radiological consequences in public domain, may call for implementation of countermeasures (intervention) for protection of public. Thus, there is a need to establish ILs and DILs in advance so that appropriate countermeasures could be undertaken in a planned manner. System of radiological protection for intervention is based on : i) the proposed intervention should do more good than harm; ii) the form, scale and duration of intervention should be optimised. Dose limits used for normal operations do not apply in the case of intervention (1).

The Sets of lower and upper levels of ILs are based on : a) serious nonstochastic (deterministic) effects should be avoided by introduction of countermeasures to limit individual dose to levels below the thresholds for these effects,b)the risk from stochastic effects should be limited by introducing countermeasures which achieve a positive net benefit to the individuals involved and c) the overall incidence of stochastic effects should be limited, as far as reasonably practicable, by reducing the collective dose equivalent (2).

ILs should be so selected that the dose criteria prescribed for Design Basis Accidents (DBA) in nuclear power plants, which dictate the design of engineered safety features, if exceeded only, should pose radiological consequences requiring implementation of disruptive countermeasures such as evacuation. Averting exposure by sheltering, administration of stable iodine or control of food stuffs for a limited period may be acceptable for

SPACE / TIME	NEAR FIELD (A_1)	INTERMEDIATE FIELD (A_2)	FAR FIELD (A_3)
EARLY PHASE (B_1)	A_1-B_1	A_2-B_1	A_3-B_1
INTERMEDIATE PHASE (B_2)	A_1-B_2	A_2-B_2	A_3-B_2
LATE PHASE (B_3)	A_1-B_3	A_2-B_3	A_3-B_3

Figure 1: SPACE-TIME DOMAIN ILLUSTRATION FOR EMERGENCY PREPAREDNESS PLANS

accidents enveloping DBA.

Three Space-Time domains are identified on the basis of these principles for establishing ILs. These are; Domain 1: Near Field - Early Phase (A_1- B_1); Domain 2 : Near Field - Intermediate Phase (A_1-B_2) ; Intermediate Field - Early Phase (A_2-B_1) ; and Intermediate Field - Intermediate Phase (A_2-B_2) and Domain 3: Near Field -Late Phase (A_1-B_3); Intermediate Field - Late Phase (A_2-B_3); Far Field - Early Phase (A_3-B_1); - Far Field - Intermediate Phase (A_3-B_2); and Far Field - Late Phase(A_3-B_3). These are illustrated in figure 1.

Physical boundaries of domains in space and time are dependent on a large number of variable parameters such as, source term; duration of release, atmospheric conditions, etc. Thus, identification of these boundaries in case of an accident leading to atmospheric release of radioactive material would require multiple measurements and evaluations.

INTERVENTION LEVELS

Administration of stable iodine, sheltering, evacuation and control of food stuffs are considered important countermeasures for averting dose in the short term. ILs, suggested for these countermeasures for the three domains are summarised in Table 1 and are given in a range - lower and upper. If assessed release and measurements confirm that lower levels of ILs are not likely to be exceeded, countermeasures need not be initiated. If lower levels are likely to be exceeded, countermeasures should be initiated and completed such that upper levels of ILs are not exceeded. Persons in Domain 1, whose estimated exposures are in excess of upper levels of ILs of dose, may need special attention including medical care. Bases for adopting ILs are : Domain 1: Domain 1 is a low population zone. It is physically nearest to plant. ILs are based on prevention of serious nonstochastic effects. Objective of countermeasures viz., administration of stable iodine, sheltering and/or evacuation is to limit individual doses so as to avoid serious nonstochastic effects. Inhalation route for thyroid exposure would be a major consideration. Domain 2: ILs are chosen to limit stochastic risk to individual member of public. Ingestion route is likely to be the important mode of exposure. Exposure from plume, inhalation and ground contamination are expected. Countermeasures envisaged are administration of stable iodine, sheltering and / or control of food stuffs. Domain 3: ILs are aimed to reduce collective dose. Ingestion route is the predominant mode of exposure. Countermeasure recommended is control

DOMAIN	Counter-measure	Intervention Level mSv			
		Whole Body		Thyroid	
		Lower	Upper	Lower	Upper
	Administration of stable I	-	-	500	2500
1	Sheltering	20	100	-	-
	Evacuation	100	500	-	-
	Administration of stable I	-	-	50	500
2	Sheltering	5	20	-	-
	Control on food stuffs	5	20	50	500
3	Control on food stuffs	1	5	not anticipated	

Table 1:INTERVENTION LEVELS FOR DOMAINS 1,2 & 3.

of food stuffs.

DERIVED INTERVENTION LEVELS

ILs are translated into DILs in quantities which are easily, reliably and accurately measurable. The time required for these measurements is important for initiation of countermeasures in Domain 1 & 2. Measurement of radiation field at 1 m above ground is a simple, fast and accurate parameter. A relationship is, therefore, derived to correlate gamma dose rate at 1 m from ground contamination to projected dose received by individual member of public following an accident resulting in atmospheric release. Dose rate from ground contamination DR_g is given by :

$$DR_g = \chi . V_d . DCF_i \qquad \text{-----} \quad (1)$$

Where, χ is time integrated airborne concentration, V_d is deposition velocity ($0.01 ms^{-1}$) for iodines and DCF_i is dose conversion factor ($2.9E\text{-}12$ Svh^{-1}/Bqm^{-2}). Intake of 6.76E05 Bq of iodines gives thyroid dose of 0.5 Sv, hence for a breathing rate of $1.7E\text{-}4\ m^3 s^{-1}$, χ is 2E09 $Bqsm^{-3}$. Using these values, DR_g calculates to $5.8E\text{-}05\ Svh^{-1}$ for inhalation dose of 0.5 Sv. Thus 0.1 $mSvh^{-1}$ dose rate from ground contamination would be equivalent to > 0.5 Sv thyroid dose from inhalation.

DR_g should be reliably available before initiating sheltering and/or evacuation. Thus, there is need to confirm these measurements over a period of time, and, if, radiation field persists, appropriate countermeasures can be initiated and completed. Total dose D_t to the whole body consists of plume dose D_p, inhalation dose D_i and ground contamination dose D_g. D_g is a

Countermeasure	Sheltering		Evacuation		
DR_g(mSv/h)	P_h(h)	P_c(h)	DR_g(mSv/h)	P_h(h)	P_c(h)
0.1 - 0.5	4	56	2.0 - 2.5	10	50
0.5 - 1.0	4	26	2.5 - 3.0	10	40
1.0 - 1.5	4	16	3.0 - 3.5	10	32
1.5 - 2.0	4	11	3.5 - 4.0	10	27

Table: DILs IN DOMAIN 1 FOR SHELTERING & EVACUATION

fraction f = .3 (4). Hours of persistence P_h, hours of completion of countermeasures P_c, ILs and DILs are related as follows:

$$(P_h+P_c) = ILxf/DIL \qquad \text{---- (2)}$$

Thus, for given DILs in terms of DR_g, IL and P_h, P_c can be calculated.

Relationships (1) and (2) are used for arriving at DILs for Domains 1 and 2. Accordingly, administration of stable iodine should be completed as soon as DR_g is more than 0.1 mSv/h and 0.01 mSv/h in Domain 1 and 2 respectively. DILs for evacuation and sheltering are given in Table 2. DILs for control of food stuffs in concentration of radionuclides, are calculated based on reference (3)

CONCLUSIONS

The ICRP-40 concept of recommending ILs for phases has been extended to incorporate space dimension. DILs are established in terms of radiation field at 1 m above contaminated ground, which is easily, reliably and accurately measurable. Proposed relationship between IL, DIL, P_h and P_c helps to adjust P_h and P_c to suit typical site conditions. Also, selective implementation of sheltering and evacuation can be undertaken depending on radiological conditions.

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