AN APPLICATION OF COST-EFFECTIVENESS ANALYSIS TO RESTRICT THE DAMAGE CAUSED BY AN ACCIDENTAL RELEASE OF RADIOACTIVE MATERIAL TO THE ENVIRONMENT

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When an accidental release of radioactive material occurs, the mitigation of health effects in the exposed population can be achieved only by Remedial Actions (RA) applied to individuals or their environment. RA adoption should be based on a balance of the damage they carry and the reduction in the health effects they can achieve.

In this paper a "cost-effectiveness" analysis is performed by comparing the costs of RA with the monetary value of the collective dose avoided by them. The extent of the resulting damage is partly determined by the Intervention Level (IL) chosen for defining RA time and space features. In a general fashion, the higher the value of IL is, the smaller is the economic damage DCRA caused by RA, but smaller is the health damage DARA avoided by them. If DWRA is the health damage in absence of RA and α is the monetary value of "health damage" ($ per men - Sv), the "total social damage" DT will be equal to αDWRA + DCRA - αDARA.

METHODOLOGY

1) The Effective Dose Equivalent (EDE) received or committed by the Reference Member of the Public (RMP) has been evaluated by accounting a) external exposure from the cloud and from the contaminated ground; b) internal exposure from material inhaled from the passing cloud. Collective EDE for different groups of RMPs has been evaluated on the basis of a commitment time of 30 years for EDE from inhaled material and up to ∞ for exposure to contaminated ground. The RMP is characterized by organ dose conversion factors as in WASH 1400 (1) and organ weighting factors as in ICRP 26 (2).

2) At every distance from the source RA begin at the same time TE after the outset of the accident and all the members of the public in the "Non-Stochastic Effects Area" (NSEA) and in the "Stochastic Effects Area" (SEA) are evacuated. The boundaries of NSEA and SEA are defined by a maximum value RLIM of the distance from the source and the following criteria: a) within NSEA the doses received during or committed for a time span of 30 days by the RMP exceed the following values: Total Body = 5 Sv; GI tract

= 35 Sv; Red Marrow = 5 Sv; Lung = 45 Sv; Thyroid = 250 Sv; b) within SEA the Evacuation Dose (ED) exceeds IL; ED has been defined as the EDE which will be received by RMP from TE to TE + 70 years if RA are lacking; in other words ED is the EDE which could be reduced by RA. After the passage of the cloud a location within NSEA or SEA is interdicted for the Interdiction Time (IT) required for reducing to IL the EDE which will be received by RMP in the 70 years following IT, owing to the exposure to contaminated ground. In SEA, IT cannot be less than the time ITO, required for decontaminating (if needed) and for surveying the area; in NSEA, a larger minimum value IT1 for IT is adopted, because we assume that the evacuees (which suffered NS effects) or other people in their stead cannot return back before IT1.

3) By summarizing, the economic consequences of RA have been evaluated as follows: a) property within NSEA and SEA are expropriated at TE; the economic charge has been computed as the difference between the market values at TE and TE + IT converted at the present worth at time TE; b) the evacuation of SEA is definitive if IT exceeds TEV, the mean time required for evacuees fromSEA to undertake a new work out of the interdicted area. During IT (or up to TEV) the earnings of the evacuees are secured by the community by means of subsides or services ; c) decontamination is equally effective but its cost is a function of land use; d) only a fraction of the goods in the contaminated areas can be removed out of the area for being again utilized after decontamination. A "RA-tree" (Fig. 1) can be built by means of the options ; b) - Interdiction, c) - Decontamination and d) - Goods Removal. The options which minimize the total costs of RA are supposed to be undertaken at every location.

RESULTS

The values of parameters for Reference Cases (RC) are in Table 1. The WASH 1400 accidents PWR2, PWR6 and PWR 7 have been selected as large-extent, mean-extent and contained accidents, which last one approximates a Design Basis Accident. Figg. 2, 3 and 4 show the values of DCRA, α DARA and DCRA-αDARA as function of IL, expressed in a normalized manner as the ratio of total damage to the unitary value of the land around the plant. We could draw the following conclusions:

a) - There is a value ILO of IL which optimizes the balance between DCRA and α DARA: for PWR2 and PWR6 the value of ILO is about 0.1 Sv.

b) For PWR6 there is a value of IL1 of about 0.01 Sv below which DCRA is larger than α DARA. In other words, if IL is less than IL_1, the intervention enlarges, in a broad sense, the social cost of the accident.

c) For a contained accident like PWR7, no value of IL optimizes the balance between health and economic consequences, because DCRA is always larger than αDARA.

The optimization process is scarcely influenced by the values for the parameters of the model. In Fig. 5 the meteorological and the RA scenarios have been modified for PWR2 by changing, one at time, the wind speed, the dispersion coefficients, the deposition velocities and by putting TE = 0.

Also shown are the results for a value of α as low as 10^4 \$/man-Sv and for a "Developed area", whose features are between the RC and an area highly industrializated and with high density of tertiary activity. The strong influence of α on ILO and IL_1 is obvious, but we must notice how DARA is small compared to DWRA.

CONCLUSIONS

1 - The damage related to an accident in a NPP can be classified as follows: a) - Early Damage ($t < TE$); related to health effects from exposures before RA; it could be reduced only by ties on land usage around the plant, and cannot be avoided by RA; b) - Damage which can be controlled by evacuation and interdiction of the land ($t > TE$), related to health effects and to RA costs; it could be minimized by a value of ILO around 0.1 Sv (for PWR2 and PWR6),but the reduction of damage obtained by RA is very small (a few percent); c) - Damage which can be controlled by impoundment of agricultural products, not considered in this paper.

2 - If RA were managed only on the basis of the "cost-effectiveness" analysis as carried out in this paper (but we are aware that this cannot be true, mainly owing to the psychological factors which could enhance the reduction of the health effects), an Intervention Plan for reducing the "social damage" would be justified only for large and mean extent accidents. For large accidents the time and space features of RA could be so large that also the probability of the accident should be accounted for in planning the intervention.

REFERENCES

1 - WASH 1400 - Reactor Safety Study - 1975

2 - ICRP Publication 26 - 1977

Table 1 Values of the parameters for the Reference Case

TE(evacuation time) = 6 hours = 6 hours ITO (Interdiction Tima for SEA) = 60 days IT1 (Interdiction Time foe SEA) = 1 year TEV (for SEA) = 1 year Decontamination Factor DF = 99 % Accidents categories PWR2, PWR6, PWR7 (as in WASH 1400)	RLIM = 250 km Pasquill categorie D Wind speed u = 5 m/sec Deposition Velocity: Noble gases = 0; Particulates = 0.1 cm/sec; Halogenes = 1 cm/sec $\alpha = 10^5$ \$/men-Sv	
	Reference Case	Developed area
Value of property (M\$/km^2)	0.75	50
Population Density (km^{-2})	10	500
Perishable goods	10%	10%
Real Estate	70%	70%
Chattel	20%	20%

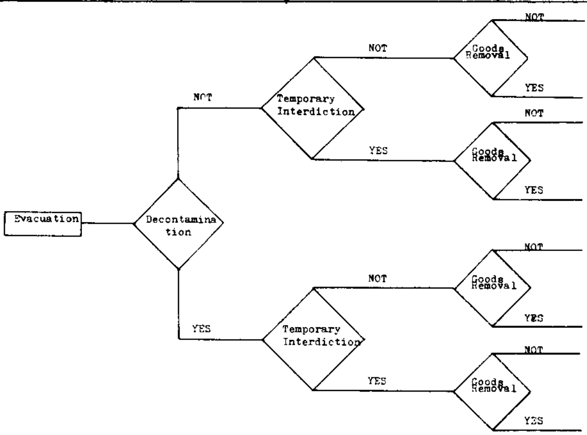

Figure 1 - Remedial Actions Tree. At every location are adopted the RA which minimize the total costs.

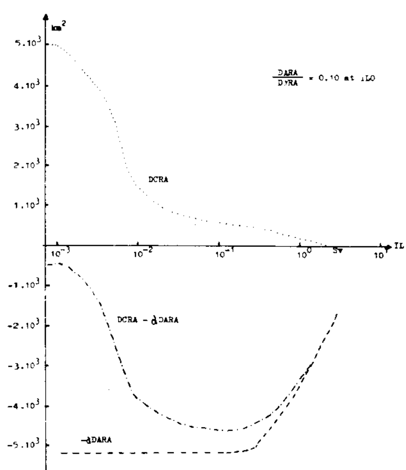

Figure 2 - Results for PWR2 - Reference Case

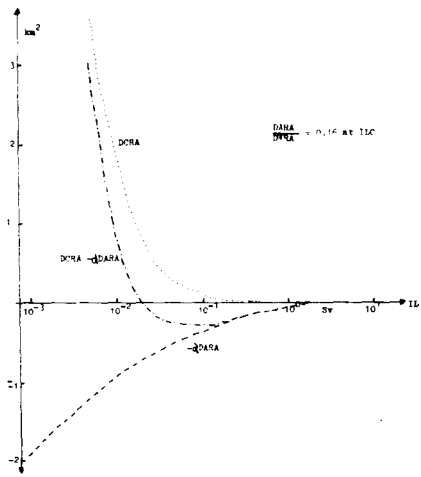

Figure 3 - Results for PWR6 - Reference Case

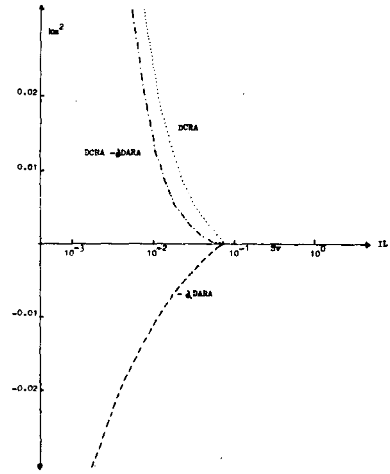

Figure 4 - Results for PWR7 - Reference Case

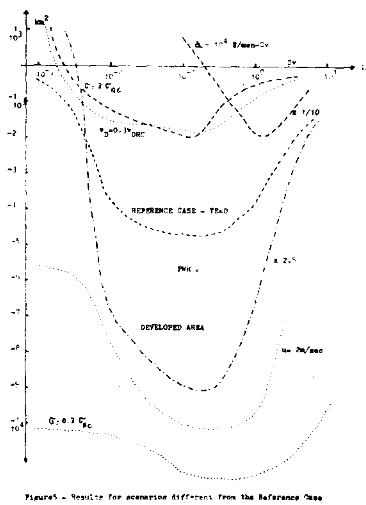

Figure5 - Results for scenarios different from the Reference Case