THE ROLE OF PROBABILISTIC EVENTS IN THE APPLICATION OF THE JUSTIFICATION CRITERION

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Probabilistic events (potential accidents) at large installations -specifially nuclear power plants- play a major role in the public debate. According to the ICRP criteria an installation is only justified if it results in a net benefit for society. It is logical and in accord with the importance assigned by public opinion that probabilistic events be included in an evaluation of its justification.

This entails an assessment of the probability of occurrence and the consequences of such events. However, even a crude evaluation of such events shows that if only casualties are considered and evaluated using a realistic monetary equivalent (e.g. 2 million DM per fatality), the resulting damage per unit of time is extremely low compared to the benefit of such an installation.

If one does not resort to the simple argument that the public debate is irrational, the only other explanation is that social effects play a larger role in such an evaluation than the effects on individuals.

We have attempted to evaluate these social effects by dividing the environs of a nuclear installation situated in a densely populated area into social units. Within 10 km of the plant, each community was considered to be a unit. Between 10 and 120 km counties were generally used as units. Therefore, the size of one unit varied from 1 000 to 75 000 inhabitants (communities) and from 90 000 to 1 400 000 (counties).

Impact on these social units is investigated on the basis of the following:

a) fraction of early fatalities

b) fraction of late fatalities

c) fraction of land to be evacuated (ground contamination)

d) fraction of land with long term consumption restrictions

e) fraction of land with short term consumption restrictions (contamination of leaves).

In pathway "a" the following function was used to calculate the probability of early death P_a for a person receiving a dose D (in Sv):

$$P_a = 1 - 0.5^{\left(\frac{D}{4}\right)^{6.6} + \left(\frac{D}{9.5}\right)^{4} + \left(\frac{D}{15}\right)^{10}}$$

The dose D was calculated for a given event (with a specific weather situation) for each location within the social unit and the resulting probability P_a was then multiplied by the number of poeple living at that location.

By summing up over all locations within that social unit, the fraction of population suffering early death as a consequence of the assumed event could thus be evaluated.

The probability of delayed death (pathway b) was calculated with the following equation: $P_b = 0.01\ D$

For the remaining three pathways limit values have been used to determine if a given location is considered inhabitable after an event or if restrictions on the consumption of foodstuff produced at that location have to be imposed.

A location was considered inhabitable if the dose accumulated within one year due to ground contamination would exceed 0.25 Sv. It is realized that the public opinion in Germany may possibly tend to use a more restrictive limit.

For the pathways d and e if was assumed, that foodstuff exceeding 2000 Bq/kg would not be allowed to be consumed.

In this way the fraction of the population and the fraction of land within one social unit being harmed by a specific event was obtained.

The corresponding social damage was evaluated as follows for each pathway:

A sigmoidal damage function was selected with such parameters that social damage is close to zero if only a small fraction of the inhabitants of a social unit is harmed. It approaches 1 if the fraction approaches 1. The time needed for a society to regenerate after a disaster follows a curve of similar shape. The function which we selected is shown in Figure 1.

For one event (assumed to happen in a specific weather situation) the social damage caused by each pathway was calculated for each social unit. It was then multiplied by an factor representing relative importance; namely, 1 for pathway a, 0.1 for pathway b, c and d and 0.01 for pathway e and added up for all 5 pathways to obtain the relative social harm for a given event.

In order to add up the societal harm of social units with a different number of inhabitants, this relative value was multiplied by a weighting factor equal to the population of the respective social unit.

This calculation was then performed for all weather conditions which had occurred in the past in one calendar year. Thus we obtained the probability distribution of the social harm as a consequence of a specific event and additionally the average social harm per event for each social unit.

Finally this avarage social harm was summed up over all social units to obtain the total social harm caused by the event.

This calculation was repeated for different release situations by variing the percentage of core inventory released to the atmosphere, the emission height and the duration of the release.

The results show that the societal harm usually increases if the release of a given percentage of core inventory is distributed over a longer period of time as compared to a release lasting about 1 hour only. This is explained by the fact, that changing wind directions result in more social units being harmed by the emission. This is only partly compensated by the diluting effect caused by a distrubition over a larger area specifically if the contamination of land stays above the set limit in both cases.

In order to test the applicability of such a probabilistic societal harm factor one has to attribute a monetary equivalent. The order of magnitude can be evaluated by applying this methodology to systems recently ordered in some countries for the mitigation of the consequences of a core melt accident acompanied by containment failure. Evidently such installations are considered "reasonable" in the eyes of the authorities.

The impact of such an installation on the individual and societal harm can be shown by comparing different release cases as shown in Figure 2. The results (Figure 3) have been tentatively evaluated using the same monetary equivalent for societal harm as for individual harm (2 million DM per unit of harm). It turns out that an installation with an annual cost (capital + operating cost) of 1 million DM is justified if it reduces the release of iodine and aerosols by a factor of 100 or more for events with a probability of occurence of more than 1.6×10^{-5} per year.

According to probabilistic risk assessment studies this is the order of magnitude expected for such events.

Therefore the inherent monetary equivalent for societal harm reflected by these requirements was in the order of 2 million DM per unit of harm. The individual harm alone caused by such events would not justify these additional installations.

The remaining social and individual costs of probabilistic events will then have to be included in a justification evaluation of the modified installation.

Monetary equivalents of much more than 2 million DM per unit of societal harm would have to be used if one wanted to argue that the impact of probabilistic events makes a nuclear installation of the evaluated design unjustified.

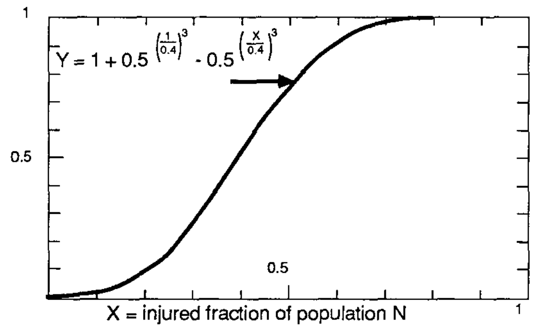

fig.1 **Societal Hazard = Y * N * I**

Case	Emission Height (m)	Duration (h)	% of Core Inventory released: Noble Gases	Iodine	Cesium...
A	40	1, 8, 48	100	100	100
B	160	1, 8, 48	100	100	100
C	160	1, 8, 48	100	0.3	0.03
D	160	1, 8, 48	100	0.3	0.0003
E	160	1, 8, 48	100	0.003	0.0003

fig.2 **Analysed Release Events**

Case	Duration	Early Death	Delayed Death	Societal Damage
A	1	193 000	4 300	802 000
	8	337 000	13 400	1 357 000
	48	308 000	30 000	1 864 000
C	1	5	149	18 000
	8	0	149	37 000
	48	0	150	71 000
E	1	0	34	6 500
	8	0	34	8 300
	48	0	34	9 600

fig 3. Average Consequence per Event