RADIATION PROTECTION PRINCIPLES APPLIED TO CONVENTIONAL INDUSTRIES PRODUCING DELETERIOUS ENVIRONMENTAL EFFECTS

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Comparison of the radiation protection standards for the population-at-large with the ambient standards for conventional pollutants, reveals differences in the principles upon which the standards are based.

The most important factors considered in establishing the radiation protection standards for populations-at-large (as well as for specific sections of the population) are as follows:

1. Somatic effects, influencing the exposed person himself
2. Genetic effects, influencing the descendants
3. Effects on specific tissues and organs of the human body (leading to the concept of critical organ)
4. Additivity of effects, considering the simultaneous effects on several tissues and/or the whole body, and the total risk to all irradiated tissues
5. Sensitivity of exposed person, e.g. children
6. Stochastic health effects, i.e. the probability of the occurrence of an effect, as a function of dose
7. Non-stochastic health effects, i.e. the severity of an effect, as a function of dose
8. Quantitative acceptable risk (e.g., expressed as deaths per person per year) based on risks experienced or acceptable in other human activities
9. Size of population exposed, expressed as the product of the exposure dose and the number of persons exposed, assuming a linear dose-effect relationship
10. Cost-benefit and ALARA (as low as reasonably achievable) considerations, taking into account technical, economic and social factors in limiting the exposure.

With the exception of the non-stochastic health effects, none of the other factors considered in establishing the radiation protection standards, are taken into account (certainly not explicitly) in spelling out the ambient standards for conventional pollutants, such as SO_2 and NO_x.

These and other differences result in more relaxed ambient standards for conventional pollutants, in comparison with the radiation standards, as illustrated by the ratios between the standards and the natural, medically perceivable and lethal levels (Table 1). The differences are in the range of orders of magnitude. The consequence of the severity of the limitation of exposure to radiation, as compared with conventional pollutants, is the penalization of the nuclear industry due to the increased cost of its safety measures.

TABLE 1. Comparison of different levels of exposure to radiation, SO_2, and NO_2

	SO_2* (ppm)	NO_2* (ppm)	Radiation (mR/day)
Level			
Background	0.0002	0.01	0.35 (130mR/y)
Maximum permissible exposure	0.03	0.05	0.03 (8mR/y)
Medically perceivable effect**	0.02	2	2×10^4 (20R)
Lethal**	0.5	500	5×10^5 (500R)
Ratios of levels			
Maximum permissible/background	150	5	~ 0.1
Medically perceivable effect/ maximum permissible	0.6	40	$\sim 6 \times 10^5$
Lethal/maximum permissible	17	10^4	$\sim 10^7$

* with particulates
**one-day level

The fact that deleterious exposures are not restricted to the same extent in different human activities, appears to cause a misuse of public resources. Considering that there is a limit to the public economic means available, societal expenditures for reducing risks should be spread, as much as possible, over all human activities to get the maximum return from investments. Indeed, the law of diminishing returns indicates that the return on investments to decrease the marginal hazards of an activity is insignificant as compared with the return on initial expenditures which diminish the hazards substantially. The nuclear industry is already at the stage where additional expenditure brings only marginal returns, while many conventional industries are at the initial stage of safety expenditures.

The greater safety cost imposed on nuclear power plants, as compared with conventional power plants, may result in the substitution of a hazard worse than the radiation hazard due to the release of SO_2 and other harmful pollutants from conventional power plants.

It is proposed that, to diminish the hazards to the public uniformly and effectively and also to get an optimum return on the safety investments made by the public, radiation protection principles should be used as prototypes for pollutants having harmful environmental effects. It is also proposed that radiation health physicists should be active in the application of these principles of population protection.

The application of one of the principles of radiation protection, that of limiting the integrated population exposure (expressed as person x rem), is illustrated here for a conventional pollutant, such as SO_2. A study of the atmospheric release of SO_2 under different conditions is analyzed, to emphasize the importance of considering the size of the exposed population.

Assume that the only requirement concerning the release of SO_2 from any installation is to keep the ambient air concentration at the fence of the installation below the half-hour standard of 0.3 ppm, adopted in Israel. Assume also that the density of the population, uniformly distributed around the installation is 400 persons/km^2.

With these assumptions, the ambient SO_2 concentration (ppm) and the total integrated population concentration (person x ppm) were calculated for a distance up to 80 km from the source for two release cases: a) ground-level release (Table 2) and b) release from a height of 200 m (Table 3).

TABLE 2. Integrated SO_2 population concentration for a ground level release. Assumptions: 1) concentration of SO_2 at the fence of the plant (1 km from the source) = 0.3 ppm, 2) deposition velocity of SO_2 = 1 cm/sec, 3) population density = 400 persons/km^2, 4) average atmospheric conditions

Distance (km)	Population	Concentration (ppm)	Integrated concentration (person x ppm)
0-2	$4x10^3$	$1.2x10^{-1}$	500
2-3	$8x10^3$	$5x10^{-2}$	400
3-5	$1.8x10^4$	$2x10^{-2}$	300
5-8	$3.3x10^4$	$7x10^{-3}$	200
8-16	$3x10^5$	$5x10^{-3}$	1,500
16-30	$7x10^5$	$5x10^{-4}$	350
30-50	$1.5x10^6$	$2.5x10^{-4}$	400
50-65	$2x10^6$	$2x10^{-4}$	400
65-80	$2.5x10^6$	10^{-4}	200
			∿4,000

The classical Gaussian plume formula (1) was used in these calculations, assuming average atmospheric conditions, and the integrated population concentration was calculated by multiplying the number of persons in concentric rings at various distances around the installation by the concentration calculated for the middle of the ring.

Assuming that the ambient concentration at the fence of the installation is at the level of the half-hour ambient standard, it was found, as expected, that the ambient concentration at any distance further from the source is below this concentration, for both the ground-level and 200 m height releases.

However, there is a very significant difference between the integrated population concentrations in the two aforementioned release cases. Assuming a deposition velocity of 1 cm/sec, the integrated population concentration for a ground-level release is about 4,000 person x ppm, while for a release at a height of 200 m, it is about 138,000 person x ppm.

It should be stressed again that in both release cases, the ambient cocentrations are below the standard. However, the difference by a factor of up to about 35 in the integrated population concentrations indicates that the integrated population concentration for conventional pollutants should also be limited as in the case of radiation protection, in addition to the limitation of the ambient concentration.

TABLE 3. Integrated SO_2 population concentration for an elevated release. Assumptions same as in Table 1, except for height of release which is assumed to be 200 m.

Distance (km)	Population	Concentration (ppm)	Integrated concentration (person x ppm)
0-2	$4x10^3$	0.3	1,200
2-3	$8x10^3$	0.3	2,400
3-5	$1.8x10^4$	0.25	4,500
5-8	$3.3x10^4$	0.25	8,200
8-16	$3x10^5$	0.07	21,000
16-30	$7x10^5$	0.04	28,000
30-50	$1.5x10^6$	0.02	30,000
50-65	$2x10^6$	0.01	20,000
65-80	$2.5x10^6$	$7x10^{-3}$	17,500
			$\sim$132,800

The importance of applying to conventional pollutants, the other principles and factors considered in establishing the radiation protection standards, could be similarly demonstrated.

REFERENCES

1. Gifford, F.A. Jr., (1960): Nuclear Safety, 2 (2), 56.