

Discussion on the Collective Dose in the Application to Radioactive Waste Management

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INTRODUCTION

The collective dose was firstly introduced in ICRP 1958 recommendation [ICRP Publication 1] (1) as a concept of collective exposure, which related to the hereditary effects of radiation. The collective dose was originally used as an expression of the whole risk of the exposed collective. In ICRP 1977 recommendation [ICRP Publication 26] (2), the application of collective dose to the exposed collective was referred more concretely, and the idea of the collective dose was considered to be useful in the application of the justification and optimization.

Actually in the first stage of the nuclear power development, a lot of results were achieved by the utilization of collective dose for the worker as an index for the achievement of optimization and the ALARA concept in the context of occupational exposure. In this meaning, the role of collective dose as the index of detriment of the exposed collective was not small.

On the other hand, when the collective dose for the member of public, such as residents of the nuclear power plant, nuclear fuel cycle facilities and radioactive waste disposal facilities, is considered, the situation is obviously different from that for the worker. Difficult problems are posed by the use of collective dose from very small dose to large population and from dose occurring over very long times. The aggregation of the collective dose over a range of individual doses is legitimate in the case that the linear assumption of dose-effect relationship consists. Therefore, it relates the threshold of the low dose region.

In this paper, the concept of collective dose introduced in ICRP, IAEA and NCRP was firstly summarized, and the discussion points of the application of collective dose to the radioactive waste management were listed and discussed.

CURRENT STATUS OF COLLECTIVE DOSE

1) ICRP

ICRP firstly introduced the concept of collective dose in Publication 1 (1) related to the hereditary effects. After that, ICRP stated in Publication 26 (2) that "The relationship between detriment and the distribution of dose equivalent in an exposed population is not simple, and no single quantity can adequately represent the distribution for the purpose of assessing detriment. Nevertheless, there are many situations in which valuable use can be made of the quantity called collective dose equivalent. [para.22]" and defined the collective dose equivalent as representing the total consequences of the exposure of a population or collective. But, ICRP did not recommend the genetic dose limit because the genetic effects are unlikely to be of overriding importance, and mentioned the collective dose equivalent would be useful for optimization (cost-benefit assessment) of a given practice and justification for particular contributions to population exposures [para.129, 130]. The use of collective quantities should be limited to situations in which the consequences are truly proportional to both the dosimetric quantity and number of people exposed, and in which an appropriate probability coefficient is available. [publication 60, para.34] (3)

Publication 77 (4), which is on "Radiological protection policy for the disposal of radioactive waste," deals with the issue of collective dose, such as a) expanded ranges of time and dose, b) index of radiation effects, c) justification of practice and optimization of protection, and d) summation from small individual dose.

(a) Extended ranges of time and dose

The unlimited aggregation of collective dose over time and space into a single value is unhelpful because it deprives the decision maker of much necessary information (para.20). It would be useful to separate individual dose and time intervals into some block for the expression of collective dose. There may be other, legitimate, grounds for restricting the ranges of space and time over which it is necessary to assess collective dose for the purposes of optimizing protection in waste disposal (para.21). Misunderstandings in the use of collective dose, unrestricted in space and time, sometimes lead to the misapplication of resources. At long distances and periods, the estimates of individual and collective doses are unreliable, partly because of uncertainties in the modeling techniques (para.27). Both the individual doses and the size of the exposed population become increasingly uncertain as the time increases. Furthermore, the current judgments about the relationship between dose and detriment may not be valid for future populations. Therefore, forecasts of collective dose over periods longer than several thousand years and forecasts of health detriment over periods longer than several hundred years should be examined critically (para.58).

(b) Index of radiation effects

Collective dose plays an important role in the application of the Commission's system of protection to waste disposal. Difficult problems are posed by the use of collective dose from very small doses to large

populations and from doses occurring over very long times. These problems are concerned not only with the exemption of sources, but, more generally, with the assessment of the impact of non-exempt sources (para.50).

(c) Justification of practice and optimization of protection

In the justification of a practice, in principle, the total collective dose is needed and should be assessed by summation of the contributions from all doses, however small (para.54). If all the available protection options are likely to deliver similar collective doses beyond some distance or beyond some time in the future, these components of the collective dose will play no part in the choice of option. They need not be estimated.

(d) Summation from small individual dose

The Commission does not recommend that the component of collective dose due to small individual doses should be ignored on the sole ground that the individual doses are small. The Commission has suggested in para.292 of Publication 60 (3) that it may sometimes be possible in optimization to disregard the collective dose from small doses to large numbers of people if the sources are widespread, because it may not be possible to reduce the collective dose with any reasonable deployment of resources (para.56). Societies often take the view that resources should not be applied to reducing risks that are already trivial both to the individual and to society as a whole. However, this principle does not apply the avoidable or controllable risk, even if the risk is small. The small risk does not mean to be neglected but the priority is low.

2) IAEA

IAEA gives two role to collective dose, a) index of the effect of practice and source and b) index for optimum option in the optimization of protection.

a) Index of the effect of practice and source

The necessity for the index of the effect would occur in the application of exemption principle. Basic Safety Standard, Safety Series No.115 (5) says as follows:

“I-2. The general principles for exemption are that:

- (a) the radiation risks to individuals caused by the exempted practice or source be sufficiently low as to be of no regulatory concern;
- (b) the collective radiological impact of the exempted practice or source be sufficiently low as not to warrant regulatory control under the prevailing circumstances; and
- (c) the exempted practices and sources be inherently safe, with no appreciable likelihood of scenarios that could lead to a failure to meet the criteria in (a) and (b).”

Although it is not stated clearly what is adopted as an index of collective radiological impact in this description, it is described that the collective dose should be taken into account in IAEA TECDOC-401 (6). It is necessary to pay an attention to the point that IAEA would not set a limit value for a collective dose and regulate the collective radiological impact by that directly.

b) Index for optimum option in the optimization of protection

On the other hand, about a collective dose as an index of optimization, the following descriptions can be found in Schedule I-3 of BSS (5): “A practice or a source within a practice may be exempted without further consideration provided that the following criteria are met in all feasible situations:

- (a) the effective dose expected to be incurred by any member of the public due to the exempted practice or source is of the order of $10 \mu\text{Sv}$ or less in a year, and
- (b) either the collective dose committed by one year of performance the practice is no more than about $1 \text{ man}\cdot\text{Sv}$ or an assessment for the optimization of protection shows that exemption is the optimum option.”

In addition, BSS (5) said in Appendix III “public exposure” as follows: “III.4. Should a practice or source within a practice discharge radioactive substances to the environment that could cause public exposure in a country other than the country where the practice or source is located, and where a monetary value of unit collective dose is required by the Regulatory Authority to be used for the optimization of the control of discharges, registrants and licensees shall be responsible for ensuring that the monetary value applied to the collective dose incurred outside the country where the practice or source is located is not less than the value prescribed within it.”

3) NCRP

NCRP published its report No.121 “Principles and application of collective dose in radiation protection” (7) and added limitation for the application of a collective dose within it. It is said that following three conditions are necessary for the collective dose to be a rigorous concept:

- 1) the risk of the biological effect of interest must be proportional to dose over the range of interest,
- 2) the biological response to a given dose must be independent of the temporal pattern over which the dose is delivered, and
- 3) the doses involved must be so high that cell killing and /or deterministic effects complicated the outcome.

NCRP discussed and developed a basic concept of collective dose, and made following recommendations in the report of No. 121(7).

- 1) The concept of collective dose should be considered as one of the means for assessing the acceptability of a facility or practice. However, because collective dose depends upon demographic variables as well as radiation doses, it is recommended that regulatory limits not be set in terms of collective dose.
- 2) Collective dose is most useful when applied to populations with known characteristics such as size, age, sex, etc. Where population characteristics are poorly defined or highly uncertain or subject to significant temporal change, collective dose should be applied with appropriate caution.
- 3) When the uncertainty in the number of individuals summed in the population component of collective dose is large (e.g., one or more orders of magnitude), collective dose should not be used as a surrogate for risk even at relatively high levels of individual radiation doses.
- 4) Application of collective dose should be limited to stochastic effects (deterministic effects are not included) and to the dose range in which risk is assumed to be proportional to dose and independent of dose rate.
- 5) Assessing risk from collective exposures in medicine must reflect the great uncertainty in applying population based risk estimates to patients due to specific age distributions, health status and, possibly, shorter life expectancy.
- 6) All doses should be included in calculations of collective dose; there is no conceptual basis for excluding any individual doses, however small, from the collective dose calculation. There may, however, be practical limitations (see recommendations 2), 3) and 4)).
- 7) When the range of individual doses spans several orders of magnitude, the distribution should be characterized by dividing it into several ranges of individual doses, each covering no more than two to three orders of magnitude, with the population size, mean individual dose, collective dose and uncertainty being considered separately for each range.
- 8) Projection of collective committed doses to future populations and situations should be done with care and situations must recognize the large uncertainties introduced by unpredictable changes in relevant parameters, e.g., less than about 10 percent.
- 9) When the collective dose is smaller than the reciprocal of the relevant risk coefficient, the risk assessment should note that the most likely number of excess cancer deaths is zero.

DISCUSSION AND PROBLEM

In this chapter, the role of a collective dose in the radiological protection, especially in the safety management of radioactive waste, is discussed.

1) Role of collective dose as an index

When a collective dose is used for radiological protection, the collective dose has two meanings, that is 1) the standard value, and 2) an index of optimization.

a) A collective dose as a standard value

When a collective dose was used as the quantity that represented an actual situation or a prediction of exposure, "What is the value of a collective dose?" has important meaning. A genetically significant dose and population dose are the examples. A collective dose is considered to be useful as an index to show general influence and social risk objectively. However, it is assumed that it is not suitable that numerical value is given to this index and a collective dose has a restrictive meaning for regulation by using that value.

b) A collective dose as an index of optimization

A collective dose is used as an index of optimization in the case of the evaluation of optimization, especially cost-benefit analysis. It seems that there is no objection in assumption that the collective dose is a useful tool which optimization evaluation is useful for.

The clause "not to exceed 1manSv" which prescribed by a principle of exemption and clearance, seems to be "a limit". But a value of collective dose to come out as a result of evaluation is only a variable of calculation process, and the value does not have a restrictive meaning itself. Therefore, it is saying that the further detailed optimization analysis does not need, if a calculation value of 1manSv came out in a process of optimization calculation. In ICRP Publ.46 (8) and IAEA Safety Series No.89 (9), the reference values for exemption are 1) $10 \mu\text{Sv/y}$ for an individual dose and 1manSv for a committed collective dose. These values show that the exemption could be done without further optimization consideration. Therefore, a higher dose might be adopted if the result of optimization showed that an exemption is most suitable alternative. However, the values of $10 \mu\text{Sv}$ and 1manSv are apt to be treated as standard values in the present situation. It is important to be considered as an index.

2) An application to an exemption of radioactive waste

Only "An individual dose is very small." is not enough for exemption of radioactive waste, it is necessary to consider the collective dose from a viewpoint of the total amount restriction. It is an idea of guaranteeing that the damage does not grow as total summation of extremely small individual doses by reducing the collective dose.

a) Scale of a group/population

As for $10 \mu\text{Sv/y}$ and 1manSv, there is criticism to be too small as the value that does not need to

consider optimization as standard values. When thinking the exposure of 100,000 people, $10 \mu\text{Sv/y}$ and 1manSv are balanced as the same level. But, if the population of the world is assumed to be 5,000,000,000 people, the collective dose by the natural background radiation becomes $12,000,000\text{manSv}$. In this case, the individual dose will be ridiculously small to achieve 1manSv of collective dose. Even if based on the discussion "this principle does not apply the avoidable or controllable risk, even if the risk is small. The small risk does not mean to be neglected but the priority is low.", 1manSv would be too small or cause the doubt whether it is necessary to add a very small dose. Therefore, the scale of the group/population is one of the important parameters when the collective dose is considered, and it is necessary to use the collective dose for an appropriate scale.

b) Summation of collective dose from extremely small individual dose

ICRP does not accept that it need not to add a small dose to a collective dose for the reason that the dose is merely small. The reason of this is that a present radiological protection system bases on the linear non-threshold hypothesis and the integral of dose is used everywhere.

The idea that the dose below the recording level treats as a zero about individual monitoring for the worker has been presented. Of course, the concept and application of those doses are different: A collective dose is used in case of justification or optimization as a source-related quantity, and an individual dose is used for individual monitoring for the individual-related quantity. Because the concept to consider a value not more than a given value to be a zero has been adopted, if the condition of application is clear, the concept could be applied for an extremely low individual dose in the evaluation of collective dose.

c) Consideration of spatial extension

A cut-off by a spatial extension is assumed, relating to both the scale of group and small individual dose. If the place far from the waste disposal site is considered, the scale of population to be added the individual dose becomes enormously big. For example, U.S.A. EPA calculated a collective dose for the people of less than 50 miles a radius from the exhaust point of a facility for unlimited recycling of very low level of radioactive metal scrap (10). It is thought that it is appropriate to consider the range in which a numerical value has a realistic and reasonable meaning.

3) Summation of collective dose over long periods of term

The uncertainty of the collective dose becomes big with expansion of time. ICRP said in Publication 77, "Forecasts of collective dose over periods longer than several thousand years and forecasts of health detriment over periods longer than several hundred years should be examined critically." The introduction of time cut-off would be lead to the reduction of the uncertainty. The point of time cut-off could be determined by the concept that identification between alternatives becomes difficult because of the increased uncertainty.

CONCLUSION

An application of collective dose is divided into the occupational exposure and the public exposure, and, is different in each concept. For the worker, an estimation of collective dose was comparatively easy because the exposure style and target group were clear. The collective dose was used for the reduction of exposure and the optimization of working procedure, and utilized as the index of an optimization process. Here, the present concept of collective dose in ICRP, IAEA and NCRP were summarized and discussed on the some point in case of application of the collective dose to public exposure related to radioactive waste management.

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P-9-116

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