CONSIDERATIONS CONCERNING THE ALARA PRINCIPLE, THE α VALUE, AND THE CHOICE OF ATTRIBUTES

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Abstract: The paper initially introduces the ALARA principle conceptually through its equations which demand the maximum net benefit, and consecutively demonstrates that it can be interpreted as discriminator between the radiation protection options which are to be avoided and those which are allowed. With respect to the α value, the paper demonstrates that it can be interpreted as an indicator of the velocity decrease of the involved doses. If the entities involved, that which contributes to the protection costs, and that which contributes to the detriment cost are different, substantial inequities could be committed if certain indispensable precautions are not taken. When the quantitative decision-aiding techniques are used in the analysis, these being; the multi-attribute utility analysis, or the multi-criteria outranking analysis, a larger number of attributes are permitted in addition to the two obligatory attributes of protection cost and detriment cost. With this approach it is observed that those attributes which decrease when the annual protection costs increase (or the annual collective dose decreases), tends to increase the α value and vice-versa. This phenomena leads us to various conclusions such as: a) if the quantitative decision-aiding techniques of cost-benefit, differential cost-benefit, and extended cost benefit are employed the α value is explicit, and therefore can be argued between the involved parties. However if the more complex quantitative analyses are used, the selection of the attributes can substantially increase or decrease the α value, committing inequity to one of the parties involved in benefit to the other; b) in order to avoid large distortions provoked by the use of non-obligatory attributes, these should be weighted in such a manner that the decrease provoked by some should be compensated by the increase caused by the use of non-obligatory attributes, these should be weighted in such a manner that the decrease caused by some should be compensated by the increase caused by the others and c) the conclusion reached in "b" also takes into account the relative importance of each attribute, this being the "scaling constant".

KEYWORDS: ALARA Principle, Alfa Value, Quantitative Decision-Aiding Techniques, Radiological Protection Optimization.

Topic 2: Radiological Protection System & Regulation

1. The ALARA principle

The ALARA principle can be interpreted in several manners in addition to that, which aims to render the maximum liquid benefit by the direct application of mathematical equations. We intend to demonstrate this possibility initially with the aim to support us during the final conclusions.

1.1 Application of the ALARA principle with the final objective to decrease the involved doses

The annual limits (AL), for example, worker's whole body dose of 50mSva^{-1}, represent the dividing line between the unacceptable and tolerable regions. That is, doses above the annual limits are unacceptable, and those below are tolerable, but not acceptable. The region for acceptable doses [1] is encountered only below 1/10 of the ALs.

Consequently we can assert that the ALARA principle is applied when it is desired to decrease the dose encountered in the tolerable region to arrive within the acceptable region. For this application, formal techniques are available which lead to a reduction in doses. These are defined as the quantitative decision-aiding techniques.

We can conclude by stating that the ALARA principle is one, which demands that doses be decreased until the acceptable region is attained.

1.2 The ALARA principle as a discriminator between avoided and permitted radiological protection options

For a specific practice to decrease the dose received by those involved, the radiological protection system needs to be improved. To do this the available plausible options need to be verified. It is obvious to suppose that each radiological protection option considered has an associated installed cost to obtain the objective radiation dose to be received by those involved; this foreseen dose is represented by the detriment cost. It is also to be supposed that the higher the cost of the radiological option being considered, the lower will be the dose received, and consequently the detriment cost. In this case we have a confrontation between two opposing parties involving their particular interests. On one side we have the country's competent surveillance authority, and on the other, the responsible for the business activity.

It is in the interest of the surveillance organ that all practices performed in the country attain the region of acceptable doses as rapidly as practicable. Therefore the most expensive radiological protection option, that which decreases the doses received by those involved in the greatest degree, is the most interesting, providing the least preoccupation.

On the other side, for the practice's owner, whose responsibility is to budget an investment to install and implement the radiological protection option, it is more interesting to begin with a radiological protection option less costly, and to postpone for the future those which involve higher costs.

To solve this impasse, the ALARA principle is applied, utilizing quantitative decision-aiding techniques to determine which radiological protection options are unacceptable and those that are to be permitted.

The competent surveillance authority has the power to avoid, through analysis, the implantation those options with forbidden results, and demand of the practice's owner the implementation of the least expensive option that provides acceptable results.

After being analyzed, the owner has the right to install and implement any of the radiological protection options that have not been avoided. It is evident that the higher the costs of implementation of the radiological protection option chosen, the region of acceptable radiation doses will be attained more rapidly. Conversely, the cheaper the option chose, the more time will be necessary to reach the acceptable dose region due to the necessity to elaborate more optimizations.

The optimization principle considered with this feature can be defined as that which determines the speed of dose decrease during a period of time of successive optimizations. The optimization principle, interpreted in this manner, demands a more accurate analysis with respect to the alfa value.

2. The α value

The α value, i.e., the detriment cost associated with the unit collective dose, supplies us with the velocity with which we desire to arrive within the acceptable dose region. The application of the ALARA principle establishes that the lower the α value, the higher will be the number of optimizations to reach the acceptable region and vice-versa. If we suppose a constant time interval between the execution of one ALARA principle and the following; this interval being the implantation and the implementation of the optimum option, verification of the expected results, and the introduction of the next optimization, we see that the number of optimizations will be proportional to the time spent for their execution and therefore proportional to the speed of the decrease in the obtained doses. If we double the α value, evidently we reduce by one-half the time spent to reach the acceptable region, even though the final radiological protection cost for the different time intervals can be the same. This obliges the practice's owner to have at disposition the entire budget to cover the expense of all optimizations and optimum options more rapidly then for the case of lower α values. This fact takes on major importance in those countries, as in the case of Brazil, where the protection cost and the detriment costs are under the authority of different competent organs. While the inferred cost to the practice's owner to improve the radiological protection conditions is realized in a short time interval and the value is determined by the actual socio-economic conditions, the same does not occur for the detriment cost since this investment obeys an entirely different system, detailed as follows:

In the first place this cost is not a direct expense of the practice's owner since it is funded by the federal government through the "unified health system" (Sistema Único de Saúde – SUS).

Secondly, the detriment, being by nature stochastic cancers, has an incubation period of decades, thus the allocation of funds will follow in the same frequency as the appearance of the sickness.

Thirdly, as the doses become lower with successive optimizations and therefore the detriment cost follows in the same rhythm, a lower final cost is encountered than that stipulated a the initiation of the optimizations, and higher than that stipulated for the option which arrives at the acceptable region.

Finally, with the advance of medicine, treatment techniques, and cure discoveries, nothing guarantees the actual costs. Probably they will be less and the treatment more effective.

In this case an increase in the α value benefits the competent organ for the detriment cost, obliging the practice's owner to lay out more funds for the unit collective dose defined by the organ who has responsibility for the detriment.

Within this panorama, when other attributes are introduced in addition to those of simple costs of radiological protection and that of the detriment, the α value can increase enormously if the selection is not realized correctly, consequently increasing the speed of reaching the acceptable region, and demanding an application of funds by the owner in a much shorter time interval, without being noticed.

In this case the entity responsible for the detriment cost receives a still greater advantage due to the fact that the involved cumulative dose will be less. This is exactly what we subsequently intend to show.

3. Choice of attibutes

To better understand what we intend to demonstrate and conclude, we will use the example presented as follows to make our argument much more clearly. To do this we refer to the case of the small uranium mine examined in publication no. 55 of the ICRP [2].

The data for this small mine are encountered in table 1 referred to in item 81, which we reproduce here.

Table 1 - Data for the options considered in uranium mine example

Protection Option	1	2	3	4	5
Annual protection cost, $	10400	17200	18500	32200	35500
Annual collective dose, man Sv	0,561	0,357	0,335	0,196	0,178
Annual average individual doses to workers in group, mSv					
I	40,8	28,4	26,0	17,5	15,8
II	34,5	22,3	21,0	12,6	11,3
III	28,9	17,1	16,3	8,4	7,8
Discomfort from ventilation	No problems	slight	slight	severe	Difficult to work

From the ICRP no. 55 publication, it can be verified that any one of the five options could be considered as optimum, depending on which of the attributes are considered in addition to those of annual costs for radiological protection and detriment, and on the different criteria applied.

What we demonstrate here is the interval for the α value for which each one of the five options remain optimum when only the mandatory attributes of annual radiological protection and detriment costs are considered, and subsequently show the variations that occur introducing two additional variables, these being the discomfort due to the ventilation system and the average annual dose.

To determine these intervals we will utilize the cost-benefit equation: X + αS. The limiting α values between the options 1 and 2, 2 and3, 3and 4, and 4 and 5, will be those encountered by the following equations, where the subscript indicates the option number.

$$X_1 + \alpha S_1 = X_2 - \alpha S_2$$
$$X_2 + \alpha S_2 = X_3 - \alpha S_3$$
$$X_3 + \alpha S_3 = X_4 - \alpha S_4$$
$$X_4 + \alpha S_4 = X_5 - \alpha S_5$$

We can isolate the α value from these equations and transform them into the following:

$$\alpha(S_1 - S_2) = X_2 - X_1 \quad \text{ou} \quad \alpha = \frac{X_2 - X_1}{S_1 - S_2}$$

$$\alpha(S_2 - S_3) = X_3 - X_2 \quad \text{ou} \quad \alpha = \frac{X_3 - X_2}{S_2 - S_3}$$

$$\alpha(S_3 - S_4) = X_4 - X_3 \quad \text{ou} \quad \alpha = \frac{X_4 - X_3}{S_3 - S_4}$$

$$\alpha(S_4 - S_5) = X_5 - X_4 \quad \text{ou} \quad \alpha = \frac{X_5 - X_4}{S_4 - S_5}$$

Substituting into these equations the values for the radiological protection and detriment costs supplied from table 1, we obtain:

between option 1 & 2 : α = 33,333
between option 2 & 3 : α = 59,090
between option 3 & 4 : α = 98,561
between option 4 & 5 : α = 183,333

This indicates that up to a α value of US$ 33,333 protection option no. 1 is the optimum. Above this value, and up to US$ 59,090, protection option no. 2 is the optimum. Following from US$ 59,090 up to US$ 98,561 option no. 3 is the optimum, from US$ 98,561 up to US$ 183,33 option no. 4 is the optimum, and for values above this last number, option no. 5 will be the optimum. Thus we obtain a difference in the α value of approximately one order of magnitude between US$ 20,000 used in the ICRP publication 55, and that used at the beginning of the interval for option no. 5
Introducing the additional attributes we can note the following:

The attribute of average annual individual doses that decrease with the increase of the cost of radiological protection tends to increase the α value due to the fact that its qualitative consideration can move the optimum option from no. 2 over to no. 4, as demonstrated in item no. 90 of the ICRP publication 55.

On the other hand the attribute of discomfort due to ventilation which increases with the increase of the protection cost, tends to diminish the α value due to the fact that its qualitative consideration does not cause preoccupation for the options nos. 1, 2 and 3, being the best option 1 as shown in item no. 91

of the same publication, but provides a moderate indication against option no. 4, and a significant indication against option no. 5.

Summarizing we can state that those attributes which decrease as the costs of radiological protection increases, and consequently are decreasing in the same direction as the annual collective dose, tend to increase the α value, and vice-versa.

4. Conclusions

From that which has been demonstrated we can conclude:

a) Where it remains possible to use the quantitative decision-aiding techniques of “cost-benefit analysis” and “differential cost-benefit analysis”, that is the singular use of the two obligatory attributes of annual costs for radiological protection and for detriment; the determined α value is explicit and clear. Even using the “extended cost-benefit analysis” in which one or two more attributes can be included, the α value increases, but it still remains visible and therefore can be argued between the parties involved.

b) When more complex techniques such as “multiple attribute utility analysis” or “multi-criteria outranking analysis”, which accept any number of attributes, and for which an explicit α value is not obtained, are applied, the choice of these attributes can substantially elevate or diminish the α value, raising disadvantage to some of the parties involved, while favoring the others.

c) To avoid this unwanted distortion, it is necessary to give relative weights to the chosen attributes in a manner which compensates between those which decrease in the same direction as the annual protection cost increases, therefore increasing the α value, and those which increase with increasing annual protection costs and thus tend to decrease the α value.

d) The previous conclusion can be aggravated by the possible distortion caused by the relative importance assigned to each of the chosen attributes represented by the “scaling constants” used by the multi-attribute utility analysis and the multi-criteria outranking analysis techniques. In this case in addition to the weight assigned to the chosen attributes, it is necessary to define the relative importance of each in order to avoid exaggerated decreases or increases in the α value established by the country’s competent authority.

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