ONE OF THE IMPLICATIONS OF THE MONETARY REFERENCE VALUE

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ABSTRACT

In the analysis involving cost-benefit, there is a need to define the monetary value of the reference person-Sievert. The IAEA Safety Series No. 21 suggests that this value can be obtained through the human capital approach, by which the monetary value of one life year lost is given by an economic aggregate, usually the gross domestic product per capita. This approach to determine, the monetary reference value has been widely used in many countries. In this paper, it is showed that if we adhere to this publication 21 of the IAEA Safety Series, all options to protect the example of a small mine used in the publication of ICRP Nº 55, would be eliminated in advance and therefore the publication should be urgently reviewed. Furthermore, it is incorrect to remove in advance all the protection options that have an alpha value greater than that agreed thereby supporting our assertion of an urgent review being necessary.

Key Words: optimization, alpha value, monetary reference value, collective dose, cost-benefit.

1- Introduction

In the analysis of optimization of radiation protection, involving cost-benefit, there is a need to define the monetary reference value of the sievert-person. According to the IAEA Safety Series No. 21[1], this value can be calculated by a human capital approach, by which the monetary value of a life year lost is given by an economic aggregate, usually the gross domestic product per capita. This approach to determine the monetary reference value has been widely used in many countries. When the implicit cost of the person-sievert, associated with an option, is less than the monetary reference value of the person-sievert, the choice of the option is considered to be reasonable from a cost-effectiveness viewpoint. However, if the implicit cost is greater than the monetary reference value of the person-sievert then based solely on cost-effectiveness criterion, the option is judged not to be reasonable, since the cost is greater than that which was agreed to be spent to avoid a unit collective dose.

2 - Material and Methods

This work adopted the approach used in the ICRP publication number 55[2] in which it is used in an example for the design of a ventilation system to protect workers in a small uranium mine. The factors considered were the annual cost of protection, the annual occupational collective dose generated by the external gamma radiation and inhalation of uranium particles from radon and its children, the distribution of individual dose and the discomfort associated with high ventilation rate in the galleries or local residence. The base case or zero option was eliminated due to a group of workers exceeding the dose limit. Five options were considered for radioprotection, comprising seventeen miners divided into three groups, according to their individual occupation in different areas of the mine. The first and second groups each comprised of four miners and a third group of nine miners. Table 1 shows the average individual doses, collective doses and the cost of protection for each option. The monetary reference value agreed upon this publication is USD 20000/ person-Sv

TABLE 1 - Data for the options considered in the case of uranium mine

Options	**0**	**1**	**2**	**3**	**4**	**5**
X Cost (USD)		10400	17200	18500	32200	35500
S Collective Dose (person-Sv)	0.686	0.561	0.357	0.335	0.196	0.178
Average Individual Dose $\overline{\overline{H}}$ (mSva^{-1})						
Group I - (4 workers)	55.2	**40.8**	**28.4**	**26.0**	17.5	15.8
Group II - (4 workers)	41.8	**34.5**	**22.3**	**21.0**	12.6	11.3
Group III - (9 workers)	33.1	**28.9**	17.1	16.3	8.4	7.8

According to the ICRP - 55[2], each option has a value of protection cost and, consequently, as to the collective dose, the set of options is seen as a set of points which are connected linearly. In this reference [2], a first analysis is completed using the cost-effective technique that aims to analyze the reason for the variations in costs and collective doses when we considering each option in turn. Thus, the increased cost of an option to go to the next is ΔX, the corresponding decrease in collective dose is ΔS, and the quotient ΔX/ ΔS is called cost-effectiveness ratio. According to the ICRP – 55 example, and in many other cases, the cost-effectiveness increases progressively when changing the options from 1 to 5. The analysis performed by the Commission is shown in Table 2.

TABLE 2 - Data for the options considering the example of the mine

Options	S (person-Sv)	X (USD)	ΔX $\left(X_i - X_{(i-1)}\right)$	ΔS $\left(S_{(i-1)} - S_i\right)$	ΔX/ΔS USD (person-Sv)$^{-1}$
1	0.561	10400.00			
2	0.357	17200.00	6800.00	0.204	33333.33
3	0.335	18500.00	1300.00	0.022	59090.91
4	0.196	32200.00	13700.00	0.139	98561.15
5	0.178	35500.00	3300.00	0.018	183333.33

Source: ICRP-55 Table 2

It is observed that ΔX/ ΔS is expressed in USD/person-Sv. If this function were continuous, this result would be interpreted as the coefficient of variation of the function in a given interval. If this continuous function derived, we could obtain the rate of change of the function at any point, known as the alpha value in any point of interest of the function. To obtain this information, it is assumed the mathematical function that best fitted the costs of radiological protection options depending on the collective dose, i.e $X = f(S)$, determining the alpha value for each option by the derivative at the point. Therefore, this function is determined:

$$X = f(S) \qquad (1)$$

to derive it, then, at each point that defines the option of radiological protection, i.e:

$$-\frac{dX}{dS} = f'(S) \qquad (2)$$

and determining their values, $x_1,.....,x_n$, which represent the different options.

Using Microsoft Excel, it was observed that the function that best fitted the points was the potential function; so it was assumed that the annual cost of protection function, (X_A), is a potential function whose formula is given by:

$$X_A = 5693S^{-1.0648} \qquad (3)$$

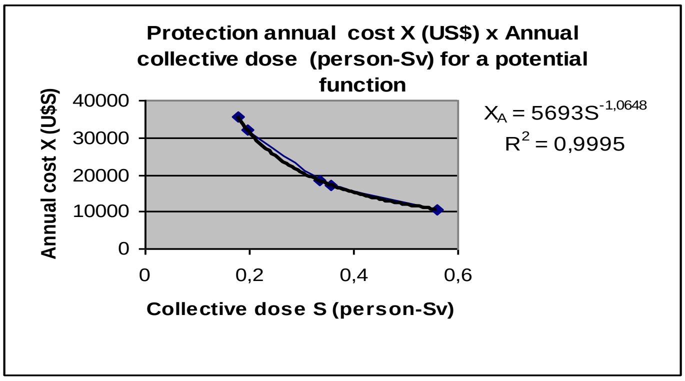
where,

X_A= Protection Annual Cost in USD

S = Annual Collective Dose in Person-Sievert

A graphical representation of the formula and its coefficient of determination is shown in Figure 1.

Figure 1 - Approximation of points for the potential function



Then, the derivative of the protection annual cost, $-\frac{dX_A}{dS}$, is given by:

$$-\frac{dX_A}{dS} = 6061.9064S^{-2.0648} \qquad (4)$$

Table 3 shows the values of the cost of the options provided by the ICRP, the values of the cost of the options set by a potential function X_A and the derivative function $-\frac{dX_A}{dS}$ of the available options.

TABLE 3 - Values of the cost of options for the power function X_A and the values of the derivative function $-\frac{dX_A}{dS}$ to the available options.

Option	S (person-Sv)	X (USD)	X_A (USD)	$-\frac{dX_A}{dS}$ USD/(person-Sv)
1	0.561	10400.00	10535.27	**19996.35**
2	0.357	17200.00	17047.48	**50846.36**
3	0.335	18500.00	18242.04	**57982.47**
4	0.196	32200.00	32281.00	**175371.45**
5	0.178	35500.00	35767.94	**213964.64**

ICRP - 55[2], also suggests the technique of Integral Cost-Benefit Analysis as a way to obtain the optimal choice of radiological protection. In this study it was considered the protection annual costs shown in Table 1 plus the cost of detriment, Y, which is the product of the collective dose for each option by the monetary reference value, alpha, where $\alpha = 20.000$ USD (person-Sv)$^{-1}$. The optimal solution is the one with $(X+Y)_{min}$. Table 4 presents the results found in ICRP - 55[2].

TABLE 4 - Results of cost benefit analysis, according to the ICRP 55[2]

Option	S (person-Sv)	X (USD)	Y (USD)	X +Y (USD)
1	0.561	10400.00	11220.00	**21620.00**
2	0.357	17200.00	7140.00	24340.00
3	0.335	18500.00	6.700.00	25200.00
4	0.196	32200.00	3920.00	36120.00
5	0.178	35500.00	3560.00	39060.00

Source: ICRP-55 Table 3

The analytical solution is the option number one in bold and underlined in the table.

3- Results and discussion

A significant option obtained by the ICRP - 55[2], as shown in Table 4, is an option whose cost is USD $21,620.00. According to the result of the derivative, the corresponding alpha value is USD $19,996.35 / person-Sv, as shown in Table 3.This alpha value, is substantially equal to the agreed value of USD $20000/ person-Sv. Thus, the optimal option has been identified since other values at any other point of the function would exceed the agreed value, see Table 3.

Alternatively, at the results in Table 1, demonstrate that for option 1, considered optimal, all groups receive an Average Individual Dose that far exceeds the value recommended by the ICRP - 60[3], where it is advocated that although the limit of the annual dose is $50mSva^{-1}$ the dose over a period of 5 years may not exceed 100mSv; it is recommended to maintain an average $20mSva^{-1}$. This observation is also valid for groups I and II of options 2 and 3.

Considering the recommendations of ICRP - 60[3]and the results shown in Table 1, we conclude to recommend option 4, where the group I, which is receiving higher doses, would receive Average Individual Dose of 17.5 $mSva^{-1}$ and groups II and III would receive 12.6 $mSva^{-1}$and 8.4 $mSva^{-1}$, respectively.

However the alpha value at this point for option number 4, would be USD$ 175,371.45 / person-Sv, according to Table 3, which is much higher than the agreed value of USD $20000/ person-Sv[2].

IAEA safety report number 21[1] includes ways to take into account the distribution of individual doses. In this report, it is referenced a model in which proposes that for a certain basic value of individual dose it is appropriate to assume a single monetary value for the unit collective dose, but starting from this basic value of individual dose, the monetary value of person-Sv should increase taking into account the degree of aversion for higher individual doses.

It was also observed in IAEA safety report number 21[1] that regulators from several countries recommend very different values for person-Sv and many companies operating in these countries adopt different monetary values for person-Sv, considering the annual individual dose distribution in their studies.

4. Conclusion

It is concluded that there is an impasse in that option one is valid because it is the only one that meets the agreed value of USD 20000/person-Sv and meets the ICRP - 55[2]; however this same option is not used because it is not in accordance with the recommendations in the ICRP - 60[3]. This example clearly shows that it is not possible to optimize thinking by only considering the collective dose and that it is necessary to consider the distribution of individual doses in this process.

Nonetheless we should keep in mind that, although the monetary reference values of the person-Sievert and, consequently, the value given to the annual individual dose distribution may be different for each country, the risks associated with activities involving ionizing radiation and the ultimate goal of decreasing doses to permissible levels, are the same all over the world.

Considering the existence of information systems, as contained in IAEA safety report number 21[1], such as the Information System for Regulatory Authorities (RAIS), the Information System on Occupational Exposure (ISOE) and Scientific Committee of the United Nations Study of the Effects of Atomic radiation UNSCEAR, there is a large amount of data available regarding the distribution of individual doses in various sectors, including ionizing radiation in the member countries of the International Atomic Energy Agency (IAEA).

Hence, it would be possible and appropriate to conduct a study based on this information in order to find curves of global monetary benchmarks that apply to the different segments involving the use of ionizing radiation that exist in the Member States of the IAEA. Such curves should not depend primarily on the Gross Domestic Product per capita of the countries, but they would be built to take into account the maximum individual dose distribution and, consequently, the collective dose in these different countries.

Due to the economic disparities among countries, it might be interesting that these curves were based on a given index, like the purchasing power parity (PPP). Of course, this discussion would be supervised by the IAEA on the basis of a consensus among its member states.

5. References

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