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VALUATION OF THE HEALTH DETRIMENT COST

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VALUATION OF THE HEALTH DETRIMENT COST

Jacques LOMBARD

SUMMARY

To estimate the efficiency of radiological protection systems we have to compare the cost involved in putting each system into operation (cost of protection) to the collective dose that can thus be avoided. This comparison is facilitated if a man-Sievert monetary value is available.

The man-Sievert value can be estimated from various detriments that can be attributed to this unitary exposure: whether there are lethal or non-lethal somatic effects, genetic effects and psycho-social effects.

ICRP recommends, in its publication 37, to break down the cost of radiological detriment Y into two parts. The first part, $Y1 = \alpha S$, corresponds to the somatic and genetic effects; the second part, $Y2 = \beta \sum N_j f(H_j)$, corresponds to the relevant effects of psycho-social considerations. This breakdown leads to the definition of two man-Sievert value components: α, which reflects somatic and genetic detriments; and β, which reflects the psycho-social effects.

Several different methods can be used to determine α and β. Here, we will analyze the following:

a) The a priori evaluation based on the Value of Human Life (VHL) or the costs of repair (for non-lethal effects).

b) The a priori evaluation based on the loss of life expectancy.

c) The evaluation based on what an individual would agree to give up to reduce the risk associated to a man-Sievert dose.

d) The evaluation based on the expenses effectively incurred in the past to reduce the risk associated to a man-Sievert dose.

* This paper uses the results of a study co-financed by the European Economic Community (EEC) (joint contract NRPB/CEPN, No. BI6-105F).

These points being specified, it is first necessary in order to evaluate the man-Sievert value, to count the damages that should be entered in this evaluation.

Among these damages, the non-stochastic effects due to with very high exposures should first be envisaged. The effects are multiple: from erythema to sudden death, which generally results following exposure of the entire body to over 5 Gray /3/. This set of threshold effects cannot be integrated in the man-Sievert cost evaluation; it is preferable, when necessary, then to directly evaluate the cost of these damages. We will therefore not consider the non-stochastic effects any more and will assume here that the man Sievert value corresponds only to in low exposures (less than the limits for individual doses) with corresponds to the Alara framework.

The stochastic effects resulting from weaker individual exposures make up a family of damages that must be attributed to a man-Sievert. The lethal somatic effect, $1.25\ 10^{-2}$ per man-Sievert, and the serious genetic effect, $0.8\ 10^{-2}$ per man-Sievert, are generally used (see /1/ and /4/) if the risk for all generations is considered.

The non-lethal stochastic effects that can be attributed to the ionizing radiation can also be evaluated. If skin cancers are excluded, the non-lethal stochastic effects that can be estimated are almost as numerous as the others, the total number of cancers being, according to E. Pochin (/5/), 2.06 times the number of lethal cancers.

ICRP, in its Publication 37 /4/, has also recognized the existence of psycho-social effects associated notably to anxiety and to the fact of being close to the individual dose limits.

Three major types of damages attributable to a man-Sievert can therefore be distinguished and introduced in the evaluation : the health-related stochastic effects (lethal and non-lethal) and the psycho-social effects (non-health-related).

3 - THE TWO MAN-SIEVERT VALUE COMPONENTS

Recognition of the "non-health-related" effects has led the ICRP /4/to break down the cost of the detriment Y into two parts. The first part, $Y_1 = \alpha S$, represents the cost of the detriment resulting from the stochastic effects. The second part, $Y_2 = \beta \Sigma N_j f(H_j)$ or $\Sigma \beta_j . N.H_j$ /6/, represents the cost of non-health-related effects. This breakdown introduces several man-Sievert values, α and β ; it facilitates evaluation of the man-Sievert cost, since it clarifies the aspects to be considered in each of them.

To be exhaustive, it should be specified that should integrate the lethal and non-lethal effects. The value is then the sum of the two terms α_1 and α_2, representing the monetary equivalent of the lethal damages (for α_1) and of the non-lethal damages (for α_2) attributable to a man-Sievert.

In conformity with the ICRP 37 publications, two components of the man-Sievert cost can therefore be defined: $\alpha = \alpha_1 + \alpha_2$ and β.

4 - METHODS FOR VALUATING THE MAN-SIEVERT COMPONENTS

These components are not evaluated in the same way for a lethal damage, a non-lethal damage and a non-health-related damage. To evaluate the components of the man-Sievert cost, it is consequently necessary to call on different methods; several approaches can be envisaged for each component. We will limit ourselves here to the most conventional approaches for monetizing these various damages.

4.1 - Evaluating the Lethal Damage

The separation of non-health-related damages via term β allows the damages associated to α_1 to be limited to the lethal detriment. One can theoritically start from a generic value for the Value of Human Life (VHL) without taking account of the specific aspects of the nuclear environment, and this value can be transposed to estimate α_1 via the dose-effect relationship.

This value can also be obtained from the value of life-years lost that are attributable to a stochastic man-Sievert (by differentiating the somatic effects using the genetic effects) and determining the value of one year of life lost from an overall indicator such as the (annual gross national product per inhabitant-GNP) when an exposure affects a large number of individuals This better approach has been retained by AIEA for assigning the minimal value of alpha /7/.

4.2 - Evaluating the Non-Lethal Health-Related Damage

This can be evaluated from the cost required to repair these damages (via the medical costs, for example) and by taking into account, if necessary, the loss of production.

4.3 - Evaluating the Non-Health-Related Damage

The simplification of the alpha evaluation linked to introduction of the beta term is in reality only obtained at the price of a transfer of the difficulties of evaluating on the beta term. This term, not always well defined or understood, is in fact difficult to discern, and, consequently, difficult to evaluate.

It is first necessary to acknowledge its existence. This can be done by taking into consideration number of radiological protection problems having dimensions other than the direct cost of lethal or non-lethal health-related effects. For this reason, the willingness to provide more protection against risks having a nuclear origin or the concern for limiting to the maximum degree the number of individuals close to the dose limits are factors which can intervene in the decisions and therefore substantiate the existence of the additional beta term.

The necessity of evaluating the beta term is now recognized; it remains now to explain how to evaluate it. Today, it appears illusory to try to directly determine the value of the beta. To make up for this, the total cost - alpha plus beta - can be reconstituted and the beta value can be determined from this. Two approaches can be used for this:

1) The first consists of asking the persons involved what they would be willing to pay to reduce a man-Sievert (or a fraction of a man-Sievert) risk, the nature of the risk being specified at its best. Beta is then determined from the difference between the proposed overall value and the alpha value calculated from another source.

2) The second consists of looking what has been effectively spent in order to reduce a risk of a man-Sievert (or of a fraction of a man-Sievert) and again determining the beta from the difference from these value and the alpha value. This approach is more concrete since it uses the value actually spent. It is generally referred to as the "a posteriori method", and provides the "implicit" beta values. These implicit values can even come from protection measures not necessarily involving nuclear facilities. It is in this way that the implicit cost of a human life saved in another sector can be defined, as well as by using the dose-effect relationship to transform this value into an equivalent man-Sievert value.

5 - VALUATING ALPHA

This entails valuating the cost of lethal (via a α_1 value) and non-lethal (via a α_2 value) health-related detriment associated to a collective man-Sievert exposure, with the non-health-related components being evaluated in the beta term.

5.1 - Evaluating $\alpha 1$

We will limit ourselves in this term to evaluating the cost that can be attributed to the deaths theoretically associated to a man-Sievert collective dose. The cost of serious genetic effects will also be entered in this evaluation.

5.1.1 - Evaluating from the Value of Human Life (VH)

a) Principle

It is estimated that in general the probability of inducing a lethal somatic effect is $1.25\ 10^{-2}$ per man-Sievert and that the probability of inducing a serious genetic effect is $0.8\ 10^{-2}$ per man-Sievert for all future generations. According to this estimation it can be assumed that one man-Sievert is equivalent to a probability of approximately 0.02 to obtain a lethal health-related effect or a serious genetic effect. The man-Sievert value can then be evaluated as being equivalent to 0.02 times the value of a human life (VH):

$$\alpha 1 = 0.02\ VH$$

b) Value of Human Life

In this section, we only intend dealing with what can be called the "a priori" value of human life, otherwise said, the general estimates, which do not take into consideration the nature and the specificities of the risk. If the price-fixing for slaves is excepted, it can be estimated that the first studies that tried to find the value of a person date from 1930 and were carried out to try to determine the cost of life insurance. Several works appear each year on the subject; we will therefore limit ourselves here to citing the work of Reynolds /8/, who was the first to apply this concept to a public health problem (road accidents), that of Abraham and Thedie /9/, and in particular that of M.W. Jones Lee /10,11/. These works are generally based on the theory of human capital, which establishes the price of a human life from the resources that he will produce up to the time of his death, which is generally increased by his future consumption. The value provided depends on the age and socio-professional category of the individual concerned. The results vary from one country to another, from one year to another, and according to the hypothesis held.

This method, which is fairly general in fact, was used in some relatively long studies carried out during the fifties and seventies; the advantage of this type of study has greatly diminished since then. The major results were the following:

- 2,000 pounds 1952, according to Reynolds /8/
- 110,000 French francs 1957, according to Abraham and Thedie /9/
- 8,920 pounds 1963, according a first study by Dawson /12/
- 19,000 pounds 1970, according to Dawson's second study /13/.

A common unit (pound, franc, dollar, etc.) and a reference year must be found in order to compare these values. Here, we will use the 1985 dollar to make it easier to understand the results:

- 30,000 dollars 1985, according to Reynolds /8/
- 140,000 dollars 1985, according to Abraham and Thedie /9/
- 84,000 dollars 1985, according to Dawson /12/
- 135,000 dollars 1985, according to Dawson /13/.

Although all these studies were not based on the same hypothesis, the results are relatively homogenous and estimate the Value of Human Life (VH) at between 30,000 and 140,000 dollars 1985.

c) Value of $\alpha 1$

If we assume that $\alpha_1 = 0.02$ VH and that VH is between 30,000 and 140,000 dollars (1985), we obtain:

$$\alpha_1 = 600 \text{ to } 2{,}800 \text{ dollars } 1985$$

Before making any interpretation of these values, it should be recalled that they are based on rather old Values of Human Life (1952 to 1970). Since the standard of living has increased since this time, the results provided here are less than they should be, despite the correction made to take into account inflation.

Today, major studies fixing the Value of Human Life according to multiple criteria are no longer carried out because they are judged to be too burdensome and to no longer correspond to requirements. Nevertheless, they are still used to make general estimates or for comparative purposes.

If we wish to bring the range of Values of Human Life back up-to-date, the values between 50,000 and 500,000 dollars can be used as a basis and consequently the following is obtained:

$$\alpha_1 = 1{,}000 \text{ to } 10{,}000 \text{ dollars } 1985$$

5.1.2 - Evaluating from the years of life lost

a) Principle

The Value of Human Life discussed above provides the monetary equivalent of a given individual's life at a given moment. This value takes sex, age, socio-professional and often other parameters into consideration.

With regard to ionizing radiation, the latency time for stochastic effects is a factor which may be advantageous to take into account. It should then consist of basing the man-Sievert value estimate <u>not</u> on an overall Value of Human Life but rather on the years of life lost which can be associated to it. To do this, it is necessary to know the loss of life expectancy associated to a somatic and genetic effect.

In ICRP publication 27 /14/ it is estimated that the loss of life expectancy associated to a somatic effect is on the order of 15 years. UNSCEAR /16/estimated the loss of life expectancy associated to a genetic effect at around 30 years.

Using these hypotheses, the loss of life expectancy associated to a man-Sievert can be evaluated as being the probability of having a somatic or genetic effect multiplied by the loss of life expectancy associated to each of these effects:

$$(1.25\ 10^{-2} \times 15) + (0.8\ 10^{-2} \times 30) \simeq 0.43 \text{ year}$$

Next, it is necessary to find a monetary equivalent for a year of life lost. If the "statistical" nature of the damage we are considering is given and the person affected is not determined, the simplest method of using this is to retain a synthetic indicator, such as the annual gross national product (GNP) per inhabitant, for the standard of living of a country. It should be recalled that this indicator is equal to the value of all goods and services coming out of the national production network that are in a final state and ready to be consumed, stored or invested.

It can therefore be assumed that during the course of the year each individual contributed to an increase in his country's wealth having a value equal to the annual GNP per inhabitant and that the cost of a year of life lost is equivalent to the annual GNP per inhabitant. The implicit hypothesis held here is that all individuals in a country contribute to the make-up of the GNP and that, since the statistical nature of the effects that one wishes to evaluate is given, it is not necessary to go into details with regard to the respective contributions of individuals. If the individuals are thus assumed to be equal in this respect, the loss of one individual is equal to the loss of the annual GNP per inhabitant.

Following these hypotheses, it can be deduced that the man-Sievert value α_1 is equal to the loss of life expectancy that it causes, multiplied by the annual GNP per inhabitant:

$$\alpha_1 = 0.43 \text{ (annual GNP per inhabitant)}$$

b) Value of α_1

The annual GNP per inhabitant in France was approximately 11,000 dollars in 1985. The following is therefore obtained:

$$\alpha_1 = 0.43 \times 11{,}000 \simeq 4{,}700 \text{ dollars 1985}$$

This estimate only requires knowledge of the GNP for each country; the values for α_1 can easily be set for different countries.

If the various GNP values per inhabitant for the year 1983 /16/ are taken, the following results are obtained:

TABLE I

COUNTRY	GNP/inh. (dollars 1983)	α_1 (dollars 1983)
Germany (Federal Republic)	11 420	4 900
Austria	9 210	3 900
France	10 390	4 400
United-Kingdom	9 050	3 900
Italy	6 350	2 700
Sweden	12 400	5 300
Switzerland	16 390	7 000
Argentina	2 030	900
United States	14 090	6 000
United Arab Erimates	21 340	9 100
India	260	100
Japan	10 100	4 300

5.2 - Evaluating α_2

5.2.1 - Principle

a) Hospital Expenses

It can be estimated that in addition to the lethal somatic effet of $1.25\ 10^{-2}$, a man-Sievert is also capable of causing a non-lethal somatic effect of approximately $1.3\ 10^{-2}$. To be exhaustive, the alpha evaluation should take account these effects in the α_2 factor. In general, the cost of these non-lethal effects is evaluated using the hospital expenses. It should be noted that this cost also involves lethal effects, and that the hospital expenses associated to all effects are approximately $2.5\ 10^{-2}$ effect per man-Sievert and are entered in this α_2 term - which in fact includes the non-lethal somatic costs.

α_2 is therefore obtained by multiplying the hospital expense for a cancer by $2.5\ 10^{-2}$.

b) Miscellaneous Costs

Non-lethal health effects can also lead to losses in production ; therefore, to be as exhaustive as possible, but at the same time keeping it simple, this work stoppage can be accounted for. If it is assumed that such as cancer leads to a work stoppage of three months, this overcost can be evaluated as being one-quarter the GNP per inhabitant.

In total, the following is obtained for α_2:

$$\alpha_2 = (2.5\ 10^{-2} \times \text{hospital expenses for one cancer}) + (1.3\ 10^{-2} \times \frac{\text{GNP/inhab})}{4}$$

5.2.2 - Value of α_2

An American study /17/ evaluated the cost of 139,000 cancers detected in 1980 in the United States. In 1985 dollars, this gives 6,900 million dollars, i.e. an average of approximately 50,000 dollars per cancer. If we look at this in the context of the French GNP per inhabitant of 11,000 dollars 1985, we obtain the following:

$$\alpha_2 = (2.5\ 10^{-2} \times 50{,}000) + (1.3\ 10^{-2} \times \frac{11{,}000}{4}) = 1{,}250 + 36 \simeq 1{,}300 \text{ dollars}$$

This value is not negligible with regard to α_1 values; for the most part, it depends on the hospital expenses.

5.3 - Alpha Value

If the values α_1 and α_2 are used again, the following results - applicable in France - are obtained for the cost of a man-Sievert, expressed in 1985 dollars.

a) If α I is estimated using recent values for the Value of Human Life (α_1 = 1,000 to 10,000 dollars):

$$\alpha = 2{,}300 \text{ to } 11{,}300 \text{ dollars}$$

b) If α_1 is estimated using the life-years lost (α_1 = 4,700 dollars):

$$\alpha = 6{,}000 \text{ dollars}$$

It may be interesting to compare these values to those which exist in the literature as well as to the alpha value rather than to the sum of alpha and beta:

a) Values Cited by ICRP in its publication 22 /18/

In its 22nd publication, ICRP provides man-rad values between 10 and 250 dollars 1970. These values correspond to man-Sievert values of 2,500 to 60,000 dollars 1985.

b) Values Cited by CPIR in its publication 37 /4/

In its 37th publication, which is of course more recent, the man-Sievert values are between 1,000 and 100,000 dollars (year not specified); the values used in the numeric examples are between 10,000 and 20,000 dollars.

c) International Regulations

Various international regulations have set alpha values. Among these values are the 200 dollars per man-rem used by the Swedish in 1981 /19/, i.e. 20,000 dollars per man-Sievert in 1981 or 1985, with the value being brought up-to-date.

d) In Reference to Social Costs of Cancers

Voilleque and Pavlick /20/ evaluated the overall cost of a cancer (grouping together the lost potentialities reflected in α_1, as well as the medical costs reflected in α_2). The values obtained were between 27,600 and 100,000 dollars 1975, i.e. approximately 45,000 to 160,000 dollars 1985.

If the equivalent of one man-Sievert is taken as 0.02 cancers, the alpha values obtained are between 900 and 3,200 dollars 1985.

All these values are given in the following table.

TABLE II

Method or source	Alpha value (dollars 1985)
Value of human life	2300-11300
Year of life lost	6000
ICPR Publication 22 /18/	2500-60000
ICPR Publication 37 /4/	1000-100000
Examples ICPR Publication 37 /4/	10000-20000
Sweden /19/	20000
Voilleque, Pavlick /20/	900-3200

The relative homogeneity of these alpha values should be noted, with the figure of 100 000 dollars per man-Sievert, cited in ICRP Publication 37, more likely reflecting the alpha + beta sum than the single alpha value.

These results obviously depend on the country for which they have been proposed as well as on the year used as reference; they cannot be directly transferred to another situation.

It is for this reason that research has now taken a new direction. Studies are on a smaller scale, and involve a well-defined risk and reflect the particular aspects required to manage this risk.

These new studies more often involve the alpha + beta term (the former studies dealt with alpha); they hold the following hypothesis: the Value of Human Life does not in itself exist, but decisions have been taken or would be desirable in order to reduce the risk of mortality, considering expense. The decisions effectively taken or the desires of the persons involved can then be used to determine a Value of Human Life by dividing the expenses for protection by the expected reduction in mortality. The value found is only applicable for the decision studied; whether this value can be transferred is a matter to be looked into.

These studies offer the advantage of being as close as possible to reality, with the disadvantage and inconvenience of not being easily used in other domains. Moreover, they have a tendency to perpetuate former values.

All this indicates that there is no longer one unique Value of Human Life, but several. To put in another way, a unique alpha value can be defined for a given country, but not a unique beta value. This is not really surprising, since if one examines the factors substantiating the entry of this beta term - anxiety, for example - the latter is not necessarily identical for a single exposure; it is dependent on whether the exposure resulted from a reactor or from a radiographic exposure. Likewise, if one wishes to take into account the individual dose level, a single exposure will not be judged in the same manner; it will be judged according to who it concerns - an individual from the public or a worker, and possibly a uranium miner or a nuclear plant employee.

It is therefore more complex to set the values for beta than to evaluate alpha. Two paths of analysis may be followed to attempt to provide values:

a) The decisions that decision makers would like to make. The willingness to pay would then be considered.

b) The decisions which have been effectively taken. The a posteriori (after-the-fact) method would then be considered.

6.2 - Willingness to Pay

6.2.1 - Principle

This method is simple, which in part justifies the interest paid it since the seventies. It should be emphasized nevertheless that this method is today losing ground; a good number of experts judge the concept of Value of Human Life to be impertinent and prefer instead to base decisions on multicriteria methods or on discussions among experts.

After having determined what should be examined, this method is based on a questionnaire which establishes more or less directly what each person would be willing to pay to reduce a given risk. Thus, for example, to evaluate the beta term, one begins with a reference situation leading to a collective risk R0, and for this risk, the selected persons are asked what appears normal to them to give up in order to reduce the collective risk from level R0 to level R1. To test the sensitivity to the responses, the situation, the risk and the values R0 and R1 are then changed - and not necessarily in a coherent fashion - to form a group of responses to which a procedure more or less complex is applied to determine the average cost that person that these persons would be willing to pay to reduce a man-Sievert collective dose.

The advantage of this approach is that it puts the persons questioned in face of choices which are as close as possible to the problem that one wishes to resolve. This approach is inconvenient in the sense that it provides answers that may vary according to the persons questioned, the questionnaire, the situations, the values R0 and R1, the interrogator, and the time at which the questionnaire was administered (external events may possibly influence it).

6.2.2 - Values of Alpha + Beta ($\alpha + \beta$)

It is not possible to use all the values obtained using this method. The advantage is moreover limited since, by definition, it is not easy to transfer a value from one domain to another since the the questionnaire is usually very specific. M.W. Jones Lee /11/ has nevertheless pooled some of these results and cites Values of Human Life obtained using this method as being from 75,000 dollars to 10,000,000 dollars (1985), i.e. values derived from $\alpha + \beta$ of :

$$\alpha + \beta = 1{,}500 \text{ to } 200{,}000 \text{ dollars}$$

From among these results, one study involves the risk attributed to a nuclear plant. This study, made in 1977 by Mulligan /23/, estimated the Value of Human Life using sums that would be agreed upon to reduce an annual theoretical individual risk of 10^{-3}, 10^{-4} and 10^{-5}.

The Values of Human Life obtained are between 74,000 and 4,320,000 dollars 1983, i.e. the following values derived from $\alpha + \beta$:

$$\alpha + \beta = \text{approximately } 1{,}500 \text{ to } 90{,}000 \text{ dollars 1985}$$

This study is dated and involves accidental risk; it can only translate the general fear of nuclear exposure and the particular fear of accidents. The risk levels used as reference do not appear to be very realistic; the values provided are to be used with extreme precaution. To be able to determine the values of beta in a more exact manner, it would be necessary to await results from more realistic studies.

6.3 - Implicit Values

6.3.1 - General Studies

Rather than question persons sure to be interested in the decision but who will not generally finance it, this latter method is based on decisions of protection effectively made to evaluate what expense has been actually agreed upon to reduce a risk. Even protective measures that have been refused can be analyzed so as to have an overcost for the Value of Human Life. This approach has already provided numerous Values of Human Life; these values have been gathered by M. Jones Lee /11/, and J. Graham and J Vaupel /24/ for a set of decisions.

According to Jones Lee, the values vary between 170,000 and 5,960,000 dollars per human life, i.e. between 3,500 and 120,000 dollars approximately for alpha + beta; none of these values corresponds to a radiological or carcinogenic risk. Graham and Vaupel put the values at varying from 0 to 7,500,000 dollars 1978 per human life, i.e. approximately 0 to 275,000 dollars 1985 for alpha + beta. Some of these values involve carcinogenics: saccharine, nitrile acrylic, arsenic and vinyl chloride. The Values of Human Life corresponding to these substances vary from 136,000 to 7,500,000 dollars 1978, i.e. approximately 5,000 to 275,000 dollars 1985 for alpha + beta. This large spread of values is difficult to interpret; the higher values correspond to very strict norms (1 ppm vinyl chloride) which have not perhaps been enacted for health reasons only.

6.3.2 - Studies in the Nuclear Field

Studies have also been done in the nuclear field; their analysis is often simpler. A European seminar was held in 1983 to determine a position on the ALARA studies. Several alpha + beta values /25/ can be drawn from this seminar; they are between 2,000 and 750,000 dollars per man-Sievert, and correspond to a wide range of decisions taking into consideration the public, the workers, the hospital environment and the electro-nuclear cycle. Again, these values differ too much to be easily interpreted; it is for this reason that we think it beneficial that some of the studies made at the CEPN be repeated so even more information can be drawn from them.

6.3.3 - CEPN Studies

These studies look at various case studies and risks involving the public or the workers /22/. They provided the following results:

TABLE III

Case Study	Risk		VH (10^6 $ 85)
Road	Accident	Public	0.2
PVC plant	Carcinogen	"	420-5000
MVC Plant	"	"	330-4000
Old PVC Plant	"	"	0.5-6.3
PWR	Ionising Radiation	"	92
PWR	"	Occupational	11
Uranium Mine	"	"	1.8
Hospital	"	"	1.3
Asbestos (F)	Carcinogen	"	0.5-1.3
Asbestos (UK)	"	"	5-13

Insofar as concerns vinyl chloride and asbestos, the values are provided in intervals, since there has not been a sufficient consensus on the dose-effect relationships for these two substances.

So as to understand the differences between the Values of Human Life obtained and to be able to draw some information from them to set beta values, it is first necessary to count the factors that are likely to influence a decision maker's decision to spend more or less to reduce a risk. These various factors have been broken down into three classes, according to whether they are of a decisional, psycho-social or technico-economic nature. The major factors (having intervened in the decision) were then determined for each of these studies. The existence of each of these factors will have a tendency to justify - in the eyes of the decision maker - an increase (+) or a decrease (-) in expenses likely to be allocated for reduction of a health-related risk.

Among the "decisional" factors can be noted the following:

- the fact that the risk involves the public (+).

- the existence of a high individual risk level (+); close to individual limits, if they exist.

Among the "psycho-social" factors are the following:

- the existence of groups of expressions or the fact that the risk is focalized (+)

- the familiarity of the risk (-)

- the fact that the person exposed to the risk was voluntarily exposed (-)

- the fact that this person draws a direct benefit from the generative activity of the risk in the form of a beneficiary (-).

Among the "technico-economic" factors are the following:

- the fact that the technology is recent and that the protection has been built-in from the time the plant was designed (+)

- the financial capability of the activity involved (+).

When reviewing the ten case studies, the following factors are found.

TABLE IV

Case Study	Decisional	Psycho-social	Technico-economic
Road	Public (+) High ind. risk (+)	Beneficiary (-) Volontary (-) Familiar (-)	
PVC	Public (+)	Focalisation (+)	Financial cap.(+) New techn. (+)
MVC	Public (+)	Focalisation (+)	Financial cap.(+) New Techn. (+)
Old PVC	Public (+)	Focalisation (+)	Financial cap.(+)
PWR public	Public (+)	Focalisation (+)	Financial cap.(+) New. Techn. (+)
PWR occup.		Focalisation (+) Familiar (-)	Financial cap. (+) New Techn. (+)
U. Mine	Hish ind. risk (+)	Familiar (-)	Financial cap.(+)
Hospital	High ind. risk (+)	Familiar (-)	
Asbestos (F.)	High ind. risk (+)	Familiar (-)	
Asbestos (UK) GB	High ind. risk (+)	Familiar (-) Focalisation (+)	

In order to be able to determine the robe of these various factors it is assumed that each plays an equally important part and that they can simply be pooled to obtain a synthetic indicator. If this algabraic sum of the factors is then compared to the implicit Values of Human Life corresponding to the various case studies, to following results are obtained :

TABLE V

Case Study	Sum of factors	VH (10^6 \$)	($\alpha + \beta$) (10^6 \$)
PVC	+ 4	420 - 5000	8.4 - 100
MVC	+ 4	330 - 4000	6.6 - 80
PWR Public	+ 4	92	1.84
Old PVC	+ 3	0.5 - 6.3	0.01 - 0.13
PWR occup.	+ 2	11	0.22
U. Mine	+ 1	1.8	0.04
Asbestos (UK)	+ 1	5 - 13	0.1 - 0.26
Hospital	0	1.3	0.03
Asbestos (F)	0	0.5 - 1.3	0.01 - 0.03
Road	- 1	0.2	0.004

Despite the rough nature of the evaluation of the overall role of the factors, a relatively good correlation is obtained between the sum of the factors and the implicit Value of Human Life associated to each case study.

This constant is used to prove the important part that these factors play, and, consequently, the importance of the beta term. Although very rough, these results illustrate that a typology of decisions can be envisaged, using a global indicator that takes into account the pertinent factors, and that for each of these typologies, a "coherent" Value of Human Life can be assigned, and, consequently, a "guide" value for alpha + beta ($\alpha + \beta$).

Looking again at the preceding values, the following results -entirely provisional - can be obtained:

TABLE VI

Sum of factors	VH (10^6 \$ 1985)	($\alpha + \beta$) (10^6 \$ 85)
+ 4	100 - 1000	2 - 20
+ 3 ; + 2	10 - 100	0.2 - 2
+ 1 ; 0	1 - 10	0.02 - 0.2
- 1	0 - 1	0 - 0.02

These results lead to beta values that are larger than previously obtained. Obviously, one may wish to obtain more coherency among the values obtained. This is done through again questioning either the economic models underlying the interpretations of the Values of Human Life or by questioning the former decisions. It would be premature to try to draw more information from such a provisional type result; more in-depth studies would be required to be able to draw information that is really reliable.

6.4 - An other proposal

The idea of classifying the man-Sievert or the Human Life values according to the type of risk is not a new one. One such proposal by T. Schneider /26/ can be cited; this proposal breaks down the risks into four categories, according to the implied risk level of the individual subjected to the risk. Thus, category 1 groups the quasi-total implied (voluntary risk) risks, such as mountain climbing, while category 4 groups the risks sustained (totally involuntary risk), such as the nearness of a power plant. It therefore takes into account the various Values of Human Life for these four categories - values that can be translated in equivalent man-Sievert values ($\alpha + \beta = 0.02$ VH).

TABLE VII

Risk	VH (Swiss France)	($\alpha + \beta$) \$ 1985
1. Volontary	10^5	1000
2. Quasi-volontary	10^5 - $5\ 10^5$	1000 - 5000
3. Quasi-involontary	$5\ 10^5$ - $2\ 10^6$	5000 - 20000
4. Involontary	$0.2\ 10^7$ - 10^7	20000 - 100000

These values vary by a factor of 100 and are not very far from the previous results for a sum of factors from -1 to 1.

7 - CONCLUSION

The optimization of radiological protection, based on a typical cost benefit or cost effectiveness analysis, requires that the values for the man-Sievert be set. Any other method would also compare - when planning a comparison of preventive actions - a cost and a collective risk and must be based more or less explicitly on an indicator near the cost of the man-Sievert. The setting of this or these parameter(s) is therefore primordial for any ALARA-type study.

The breakdown of the man-Sievert cost into two values, alpha (α) and beta (β), allows the aspects that each country concerned wishes to enter into the cost to be more clearly defined.

Insofar as concerns the alpha term, the methods considered lead to relatively coherent values (from 1,000 to 10,000 dollars approximately per man-Sievert).

The beta values vary more however, since they correspond to very different situations. The classification of the risks appears to be a satisfactory answer to the problem of fixing these values. It is in this way that the various values were defined according to the decisional, psycho-social, technical or economic factors, or according to the level of willingness on the part of the individual sustaining the risk.

These considerations illustrate the difficulties that can be encountered with regard to setting the price of the man-Sievert, as well as the prudence with which recommendations in this field must be made.

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