

Recent international regulations: Low dose - low rate radiation protection and the demise of reason

Abstract

The radiation protection measures suggested by the International Committee for Radiation Protection (ICRP), national regulating bodies and experts, have been becoming ever more strict despite the decrease of any information supporting the existence of the Linear no Threshold model (LNT) and of any adverse effects of Low Dose Low Rate (LDLR) irradiation. This tendency arises from the disproportionate response of human society to hazards that are currently in fashion and is unreasonable. The 1 mSv/year dose limit for the public suggested by the ICRP corresponds to a 1/18,181 detriment-adjusted cancer risk and is much lower than other hazards that are faced by modern societies such as e.g. driving and smoking which carry corresponding rate risks of 1/2,100 and 1/2,000. Even worldwide deadly work accidents rate is higher at 1/ 8,065. Such excessive safety measures against minimal risks from man made radiation sources divert resources from very real and much greater hazards. In addition they undermine research and development of radiation technology and tend to subjugate science and the quest for understanding nature to phobic practices.

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Introduction

Although exposure to high dose-high rate (HDHR) ionizing radiation, such as the radiation produced by nuclear power plants and weapons or in radiotherapy, is unquestionably detrimental to human health, it is far from conclusive whether the same is true about low dose-low rate (LDLR) exposures, such as environmental and medical irradiation, which comprise most of the everyday situations requiring radiation protection measures. Such situations are widely considered to be low, if any, risk situations and dealing with them should include other factors such as social and economic. The as low as reasonably achievable (ALARA) principle [1, 2] has been admittedly, the basis for all LDLR radiation protection standards in any area of ionizing radiation and is re-stated in the recent ICRP document: "... *The principle of optimisation of protection: the likelihood of incurring exposures, the number of people exposed, and the magnitude of their individual doses should all be kept as low as reasonably achievable, taking into account economic and societal factors*" [3a]. Dose and exposure to radiation are both taken to refer to effective dose throughout this paper unless stated otherwise.

However, in recent years there is a growing tendency to ignore the R in the acronym when suggesting protection measures. This tendency is evident in the everyday dealings of experts and radiation protection advisers (RPAs) as well as in the assessment of shielding and the exposure limits set by advisory committees and legislative bodies. Despite the careful formulation of the ICRP's recommendation for dose *optimization* in radiation protection situations: "... *Optimisation of protection is not minimisation of dose. Optimised protection is the result of an evaluation, which carefully balances the detriment from the exposure and the resources available for the protection of individuals. Thus the best option is not necessarily the one with the lowest dose*" [3b], optimization is being increasingly interpreted as dose minimization.

It is my intention to present the contradictions that arise from such a treatment and to demonstrate that human psychology has gradually emerged as the major criterion in proposing and assessing safety. It is also my intention to show that negative psychology has been gradually diminishing social approval of all uses of radiation. This tendency has already undermined research and development of new techniques in radiation applications and may evolve into a major obstacle in advancing basic research in areas such as radiation physics, radiological and atomic engineering, radiation biology and radiopharmacy as well as any other area, even those involving only LDLR exposure of humans to radiation.

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The basis for the ICRP radiation protection paradigm

The current radiation protection paradigm as offered by the ICRP is based on the fact that HDHR radiation is harmful to all biological tissues. However, the possibility and extent of the damage to humans caused by LDLR irradiation depends on the existence or not of a threshold in radiation effects and despite this being inconclusive, the ICRP goes on to assume the validity of a linear, no-threshold model (LNT): "...*The probabilistic nature of stochastic effects and the properties of the LNT model make it impossible to derive a clear distinction between 'safe' and 'dangerous',...some finite risk, however small, must be assumed*" [3c] and "...*Use of this so-called LNT model is considered by the Commission to be the best practical approach to managing risk from radiation exposure...*" [3d]. The ICRP admits that there are widespread opposing opinions: "...*a report from the French Academies (2005) argues in support of a practical threshold for radiation cancer risk*" [4, 3e], and that, not only there is insufficient evidence for the LNT model, but it is unlikely that any such evidence will ever be available: "...*the Commission emphasises that whilst the LNT model remains a scientifically plausible element in its practical system of radiological protection, biological / epidemiological information that would unambiguously verify the hypothesis that underpins the model is unlikely to be forthcoming (see also UNSCEAR, 2000, NCRP 2001)*" [5, 3f]. In addition, in other aspects of irradiation: "...*There continues to be no direct evidence that exposure of parents to radiation leads to excess heritable disease in offspring*" [3g]. And taking into account that even in the case of high dose – high rate (HDHR) exposures non-cancer effects were overestimated in the past: "...*The Commission also notes reports (reviewed in UNSCEAR, 2001) which argue, on the basis of A-bomb survivor and mouse genetic data, that the risk of heritable diseases tended to be overestimated in the past*" [3h], it seems that there should not be much to worry about LDLR exposures. So if, by their admission, this is the case about biological / epidemiological information, then where were ICRP's suggestions based on? The answer is provided in a different section of the ICRP document, where "prudent" and "precaution" are the key words: "...*this so-called LNT model is considered by the Commission to be the best practical approach to managing risk from radiation exposure and commensurate with the 'precautionary principle' (PP)*" [6]. *The Commission considers that the LNT model remains a prudent basis for radiological protection at low doses and low dose rates (ICRP, 2005d)*" [3d].

This PP has been best presented in the Rio Declaration of the UN in 1992 and it is based on the premises that : a) "...*lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation*". In addition it is also stressed that: b) "...*the PP applies when there exist considerable scientific uncertainties about causality, magnitude, probability and nature of harm*" [6]. In an effort to clarify the above, UNESCO [2005] provides the following peculiar statement: "...*we are*

not saying that the plausible hypothesis (for a future event) is more probable than the implausible, although we are saying the plausible hypothesis is more of a serious possibility than the other" where the perplexing concept "serious possibility" as opposed to "more probable" does not really make any sense. This, instead of improving, results in an even more obscure definition of PP. So without any alternative evidence and, by admission of the ICRP, not expecting any, it seems that the entire, LDLR radiation protection strategy of the ICRP is a negative action strategy based on the loose idea of the Precautionary Principle or on just playing safe.

Contradictions in the current radiation protection paradigm

Nevertheless, without any explanation, specific dose limit values are assigned by the ICRP in Table 6, "*Recommended dose limits in planned exposure situations*", which are chosen in order to limit the risk involved to an acceptable level. So, the limit for occupational exposures is set to an effective dose of 20 mSv/year, averaged over defined periods of 5 years and the limit for public exposures is set to 1 mSv in a year, also averaged over periods of 5 years if necessary [3i].

Strangely enough, the ICRP later on, suggests a higher than public dose limit regarding the exposure of the fetus: "...*the methods of protection at work for women who are pregnant should provide a level of protection for the embryo/fetus broadly similar to that provided for members of the public...ensure that the additional dose to the embryo/fetus would not exceed about 1 mSv during the remainder of the pregnancy*" [3j], resulting to about 1.33 mSv/year, i.e. considerably higher than the general public. However, on this matter there are other opinions also. Although it is claimed that: "...*International organisations and national authorities responsible for radiological protection, as well as the users, have taken the recommendations and principles issued by the Commission as a key basis for their protective actions. As such, virtually all international standards and national regulations addressing radiological protection are based on the Commission's recommendations*" [3k], the US National Council for Radiation Protection (NCRP) recommends a much higher dose limit: a monthly dose to the embryo or fetus of up to 0.5 mSv, resulting to a total of 4.5 mSv for the duration of the pregnancy [7].

It is also admitted that even at doses far greater than those expected in LDLR radiation protection situations: "...*Termination of pregnancy owing to radiation exposure is an individual decision affected by many factors. Absorbed doses below 100 mGy to the embryo/fetus should not be considered a reason for terminating a pregnancy*" [3l], implying that no adverse effects are expected.

The ICRP's position on risk assessment is the following: "...*The Recommendations are based on scientific knowledge and on experts' judgement. Scientific data, such as those concerning health risks attributable to radiation exposure, are a necessary prerequisite, it is confirmed that but societal and*

economic aspects of protection have also to be considered. All of those concerned with radiological protection have to make value judgements about the relative importance of different kinds of risk and about the balancing of risks and benefits. In this, radiological protection is not different from other fields concerned with the control of hazards. The Commission believes that the basis for, and distinction between, scientific estimations and value judgements should be made clear whenever possible, so as to increase the transparency, and thus the understanding, of how decisions have been reached” [3m]. But, despite the statement that “*radiological protection is not different from other fields concerned with the control of hazards*” the dose limits suggested above correspond to risks that definitely do not compare with other accepted risks in human societies. If section 192 in the UNSCEAR 2000 report is taken into account: “... *Worldwide annual exposures to natural radiation sources would generally be expected to be in the range 1-10 mSv, with 2.4 mSv being the present estimate of the central value.*” and “... *Exposures to natural radiation sources are more significant for the world's population than most exposures to man-made sources...*” [5], then, from the data contained in the same report, it can be calculated that 18.6% of the world's population receives more than 2.5 mSv/year. A smaller fraction, 5.17% receives more than 4 mSv/year and about 1.1% receives more than 5.5 mSv/year. In addition, wide variations of the population exposures are observed in various parts of the world, with the maxima ranging locally from a staggering 260 mGy/year in Ramsar (Iran) through 35 mGy/year in Guarapari (Brazil) and Kerala (India) while the respective country average annual dose values are 10.2, 5.5, 3.8 mGy/year. Even in Europe, and despite relatively low country averages of 0.63 mGy/year in Norway, 0.5 mGy/year in Italy and 0.48 mGy/year in Germany, in some regions of the same countries exposures of 10.5 mGy/year, 4.38 mGy/year and 3.8 mGy/year have respectively been observed [8]. These values can be compared to the published background radiation levels around all Russian nuclear power plants which vary around 0.1 μ Sv/hr or about 0.88 mSv/year [9].

Although such environmental exposures are well above the world average they have not been shown to correlate to any significant increase in spontaneous cancer incidence or other health detriments. Hence, it is unreasonable to shield man made sources to a universal dose limit of 1 mSv/year as suggested by the ICRP. Such a limit for non-benefit exposures of the general public seems excessive and unjustified if both the lack of evidence for radiation effects and the unavoidability of exposure of large groups of human population to much higher environmental radiation levels are taken into account. It also seems pointless, if some parts of the public receive much more radiation at home or at work than from man made sources in a hospital or near a nuclear power plant.

On this, ICRP avoids the issue by stating that: “... *The Recommendations can apply in their entirety only to situations in which either the source of exposure or the pathways leading to the doses received by individuals can be controlled by some reasonable means*” [3n].

Despite the obscurity or lack of relevant evidence for LDLR effects, the Commission goes on to propose quantitative, detriment-adjusted radiation induced, cancer risks and risks for radiation induced heritable effects: “... On the basis of these calculations the Commission proposes nominal probability coefficients for detriment-adjusted cancer risk as 5.5 10^{-2} /Sv for the whole population and 4.1 10^{-2} /Sv for adult workers. For heritable effects, the detriment-adjusted nominal risk in the whole population is estimated as 0.2 10^{-2} /Sv and in adult workers as 0.1 10^{-2} /Sv. The most significant change from Publication 60 is the 6–8 fold reduction in the nominal risk coefficient for heritable effects” [3o] and “... The Commission considers that it is prudent to assume that life-time cancer risk following in-utero exposure will be similar to that following irradiation in early childhood, i.e., at most, about three times that of the population as a whole: 0.165/Sv” [3p] which, presumably apply, both, to HDHR and LDLR exposure. These values proposed by the ICRP together with the 1 mSv/year dose limit, lead to risk values of 1/18,181 and 1/24,390 for inducing cancer to the whole population and to adult workers respectively. For heritable effects, the respective risks are 1/500,000 and 1/1,000,000. Strangely enough, as mentioned earlier, it can be calculated that the risk for irradiated fetuses to develop cancer sometime later on during their life is 1/4,662, i.e. considerable higher than the rest of the human population. No explanation can be found in the recommendations for this.

And as if such low dose limits were not enough, additional “*constraints*” are imposed for the exposure of the public. Even though a “*constraint*” has not been proposed as a limit, the ICRP admits that: “... *the word ‘constraint’ is interpreted in many languages as a rigorous limit. Such a meaning was never the Commission’s intention*” [3q] but nevertheless, this additional constraint is quantified, further reducing the maximum permissible radiation risk: “... *For potential exposures of the public, the Commission continues to recommend a risk constraint of 10^{-5} per year (corresponding to a risk of 1/100,000)*” [3r]. No explanation is given for the choice of the particular value. Presumably, it is, once again, based on the Precautionary Principle. The problems arising from environmental exposures are dismissed: “... *(ii) the exemption from some or all radiological protection regulatory requirements for situations where such controls are regarded as unwarranted, often on the basis that the effort to control is judged to be excessive compared to the associated risk (need not be regulated)*” [3s]. So, the general idea that originated in the ICRP and seems to be currently held by most RPAs and regulating bodies is that the public should be shielded down to unrealistic levels corresponding to 0.18 mSv/year whenever possible. When not possible, as in hundredfold environmental exposures, the matter will just be ignored.

Radiation risks are treated differently than other types of risks

Despite ICRP’s statement that: “Radiological protection is not different from other fields concerned with the control of haz-

ards” and that: a) “... no planned exposure situation should be introduced unless it produces sufficient net benefit to the exposed individuals or to society to offset the radiation detriment it causes” [3t], b) “... In both approaches, the responsibility for judging the justification usually falls on governments or national authorities to ensure an overall benefit in the broadest sense to society and thus not necessarily to each individual” [3u] and c) “The first band, 1 mSv or less, applies to exposure situations where individuals receive exposures-usually planned-that may be of no direct benefit to them but the exposure situation may be of benefit to society” [3v], it seems that, none of the authorities mentioned, the ICRP itself included, is prepared to bear the responsibility and the implications of the use of radiation and obtain this overall benefit to society even against the benefit of individuals. The 1 mSv dose limit is set so low that actually defeats its purpose if this is the well being of the public. All that is being achieved is that society spends disproportionately high resources for LDLR radiation protection, while the coping with quite real and often much greater hazards will be left underfunded. Radiation risks recently in fashion, such as exposure to sunlight and the alleged risk of exposure to low frequency electromagnetic radiation fields (EMF) and to microwave frequencies produce a response from society which is disproportionate to the extent of any actual risks involved, while other, much greater risks are ignored.

Hazards to the public excluding radiation

Apart from the environmental exposure to radiation, there are other examples of human activities which involve much greater risks than those dealt with by ICRP. Most conspicuous of these, which affect all members of society, are smoking, perinatal risks such as Down syndrome and everyday activities which may lead to traffic accidents and work related accidents. The following are some examples of the risks involved to compared to LDLR radiation risks and are presented in Table 1.

In Greece during the 1994-2006 period, traffic accidents involving death correspond to a risk of 1/5,747 per year.

Those that involve both death and serious injury correspond to a risk of 1/2,100 per year [10]. Of course, it may argued that Greece is an extreme example for driving accidents, but although there are countries in which driving involves a much lower risk, it must be stressed that there are also other countries with much higher risk rates. In the so-called entertainment area, smoking is killing world-wide, three million people each year and this figure is increasing [11]. This rate corresponds to a yearly death risk rate of roughly 1/2,000. Both traffic accidents and smoking risks are much higher than the 1/18,181 and 1/24,390 risk that corresponds to the 1 mSv/year radiation dose limit set by the ICRP for inducing detriment-adjusted cancer to whole population and to adult workers respectively. If the dose constraints suggested are used, then the Greek Committee for Atomic Energy’s maximum permissible risk becomes 1/36,362 [12] and the ICRP’s universal risk constraint is set to 1/100,000.

Regarding hereditary dangers, the Down syndrome spontaneous incidence risk is actually quite high, about 1/900 for women under 30 years of age and about 1/230 for women under 37 years [13, 14], which nevertheless has not become yet an obstacle to pregnancy. This may be contrasted to the maximum permissible risk for heritable effects set by the ICRP, corresponding to the 1 mSv/year radiation dose limit, which amounts to an unrealistic 1/500,000.

Of course, some risks, such as driving accidents which are related to the number of cars available in a country, although close, may not always be directly comparable to radiation risk. A woman can risk a Down syndrome birth only once in every time she gives birth while the lifetime hereditary defects risk from radiation must include the total lifetime exposure of the same woman. However, first, no woman can have offspring with hereditary defects after reproductive age so, for this, it does not matter if she is exposed afterwards. Second, the radiation exposure dose limit both for the public and working population has to be averaged for 5 years. So, in both cases the total lifetime dose that is relevant to hereditary effects can be calculated to be between perhaps 15 and 5 mSv. This leads

Table 1. Risks attributed to human activities as compared to risks because of LDLR environmental exposure and LDLR exposure to man made sources. All risk rates are presented as the ratio of 1 event per number appearing in the Table, per year.

Risk rate/year due to: (1/number)			Man made LDLR exposures				Other hazards			
			ICRP 103 recommendations (1 mSv/year dose limit combined with the nominal probability coefficients) ^[3]	ICRP 103 constraints ^[3]	Traffic accidents (Greece) ^[10]	Smoking ^[11]	Work accidents	Environmental LDLR exposure combined with ICRP’s nominal probability coefficients 1% of global population ^[5]	Ramsar ^[8]	Down syndrome (example: 27 year old woman, 3 births) ^[13,14]
Death & serious injury	World	Public	18,181	100,000		2,000	8,065 ^[15]	3,306	70	
		Adult workers	24,390				1,282 ^[15]	4,435	94	
		Europe			2,100		16,667 ^[16]			
Heritable defects		Public	500,000					90,909	1,923	300
		Adult workers	1,000,000					181,818	3,846	

to a slightly higher LDLR radiation risk of <0001 ($15.0.2 \cdot 10^{-2}/\text{Sv}$) $1/33,333$ which is still much smaller than the *lifetime risk* for a Down syndrome birth which is e.g. $1/300$ for a woman of 27 years, who has given birth three times. Nevertheless, all hospital RPAs involved with X-ray can testify about the difficulty in dealing with modern prospective mothers who smoke, drink, drive cars and are well above 30 years of age and at same time are seriously concerned with unintentional diagnostic fetus exposures which usually correspond to risks of the order of $1/100,000$. And it is not rarely that they have already had their gynaecologist's opinion in favor of pregnancy termination against all reason and despite even ICRP's recommendation of the 100 mSv limit. This corresponds to a risk no greater than $1/5,000$ for possible hereditary defects and $1/60$ for detriment adjusted lifetime cancer for the offspring.

In another area, accidents and work related risks are long being assessed and several surveys exist which document that they involve definitely higher risks than the radiation exposure limit which is set by law in the European Union. The International Labour Organization has published a global average rate of 7.8 work related deaths/10,000 economically active population, rising to about 9.5/10,000 in Sub-Saharan Africa and the Caribbean. These rates correspond to risks of $1/1,282$ and $1/1,053$ respectively. Actual average global rate of fatal accidents is $1.24/10,000$ with rising to about $2/10,000$ in Sub-Saharan Africa and the Caribbean [15], corresponding to risks of $1/8,065$ and $1/5,000$ respectively. Things look brighter for workers in the 15-state Europe where work related, fatal, standardized incidence accidents rate (excluding transport related deaths) was estimated to be about $3/100,000$ in 2000. Another calculation by Eurostat published on 6-10-2005, using the ESAW 2003 Database, raised fatal accidents at work rate to about $6/100,000$ or a risk of $1/16,667$. However, millions of people in parts of Europe are exposed to much higher risks than these all-European averages as can be demonstrated by the maximum rate of $8/100,000$ which was observed in Portugal [16] and corresponds to a risk rate of $1/12,500$. Based on the ad hoc module of the 1999 Labour Force Survey (LFS) about 5% of those who have recovered from an accident at work, can't return to the same work (2.9% have to change job or employer, 1.8% have to reduce their working hours, and 0.2% never expect to return to work anymore). Based on the 2002 LFS ad hoc module about 0.9% of all 16-64 years old people in the EU Member States had a long standing health problem or disability which according to their judgement was due to an accident at work. The survey included both those who were still working and those who were unemployed or already retired. This means that there are about 2.3 million people in the EU Member States with such a health problem caused by an accident at work [17].

All these risks presented above, seem to be calmly accepted by the human society despite being several times higher than the maximum permissible LDLR radiation risk for the public which is set to $1/18,181$. This is so because, rightly or

wrongly, the activities related to them are considered to produce *sufficient net benefit in the broadest sense to society and thus not necessarily to each individual*. The diversion of resources to safeguard against the much smaller LDLR radiation risks, mostly for psychological reasons, have resulted both in restricting the benefits which may be obtained through the use of radiation as well as in harming the society because of under-funding safety and health in other sectors.

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