Comments and questions in view of the renewal of the ICRP recommendation on radiation protection.

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Zusammenfassung

Das bestehende Strahlenschutzsystem der Internationalen Strahlenschutzkommission (ICRP) gilt als Erfolgsgeschichte: Es ermöglicht (bei richtiger Handhabung) einen ausreichenden Schutz vor Strahlung am Arbeitsplatz sowie für die Bevölkerung im Allgemeinen. Es bietet Sicherheit im Umgang mit Strahlung und Radioaktivität. Es gilt sowohl für geplante und bestehende Expositionssituationen als auch für radiologische Notfälle. Allerdings ist Sicherheit immer relativ und die Risikowahrnehmung der Öffentlichkeit eher subjektiv. Dies zu berücksichtigen ist eine anspruchsvolle Aufgabe für alle jene, die das Regelwerk in der Praxis umsetzen.

Um diese Empfehlungen für die Anwender praktikabel, aber gleichzeitig auch für Laien verständlich zu machen, sollten die Praktiker des Strahlenschutzes bei der geplanten Erneuerung der Empfehlungen einbezogen werden, denn ihre Aufgabe ist es, diese in der Praxis anzuwenden, aber auch, sie den Anwendern, den Medien und der Bevölkerung zu erläutern. Überlegungen zur von der ICRP angekündigte Erneuerung der Empfehlungen sollen klären, was sich bewährt hat und beibehalten werden sollte und wo Änderungen erwünscht sind.

Im folgenden Artikel werden einige Ideen zur Diskussion gestellt, wie der Strahlenschutz optimiert werden könnte, basierend auf der Analyse der aktuellen Situation im Strahlenschutz durch Rolf Michel, Bernd Lorenz und Hansruedi Völkle, veröffentlicht in Ausgabe 4/2018 der StrahlenschutzPRAXIS.[1] Der vorliegende Text wurde deshalb in englischer Sprache verfasst, um auch Experten außerhalb des deutschsprachigen Raums eine aktive Beteiligung an der Diskussion der hier vorgestellten Vorschläge zu ermöglichen. Kritisches Feedback und Anregungen sind sehr willkommen.

Résumé

Le système de protection radiologique existant et élaboré par la Commission internationale de protection radiologique (CIPR) est considéré comme une réussite : il permet (s'il est correctement appliqué) une protection adéquate contre les radiations à la place de travail ainsi que pour la population en général. Il assure la sécurité et la sûreté lors la gestion des rayonnements et de la radioactivité. Il s'applique aussi bien aux situations d'exposition planifiées et existantes qu'aux urgences radiologiques. Cependant, la sécurité est toujours relative et la perception du risque par le public est plutôt subjective. Prendre cela en compte est une tâche difficile pour tous les responsables de la mise en pratique.

Pour que ces recommandations soient praticables pour les utilisateurs, mais en même temps compréhensibles pour les non-experts, les praticiens de la radioprotection devraient être impliqués dans ce processus de renouvellement des recommandations, comme il a été annoncé par la CIPR. Car leur devoir est de les mettre en œuvre dans la pratique, mais aussi de les expliquer aux utilisateurs, aux médias et à la population. Les réflexions concernant ce renouvellement devraient clarifier ce qui s'est avéré efficace et devrait être conservé ainsi que les domaines dans lesquels des changements sont souhaitables.

L'article suivant propose quelques points à discuter sur la manière dont la radioprotection pourrait être optimisée. Il se base sur l'analyse de la situation actuelle en radioprotection par Rolf Michel, Bernd Lorenz et Hansruedi Völkle, publiée dans le numéro 4/2018 de la StrahlenschutzPRAXIS.[1] Le texte qui suit a été rédigé en anglais afin de permettre aux experts extérieurs à l'espace germanophone de participer activement à la discussion sur les points présentées ici. Des commentaires critiques ainsi que des suggestions sont les bienvenus.

Summary

The existing system of radiological protection issued by the International Commission on Radiological Protection (ICRP) is considered a success story: It allows (if properly managed) adequate protection against radiation at the workplace as well as for the population in general. It provides security and safety in handling radiation and radioactivity. It applies to both, planned and existing exposure situations as well as to radiological emergencies. However, safety is always relative, and the public's perception of risk is rather subjective. Taking this into account remains a challenging task for all those responsible to put this into practice.

To make these recommendations practicable for the users, but at the same time comprehensible for non-experts, the practitioners in radiation protection should be involved in this renewal process – as it was announced by the ICRP for

the coming years – as their duty is to apply the system of protection in practice, but also to explain it to users, the media and to the population. Reflections in regard of this renewal, should clarify what has proven successful and should be retained and where changes are desirable.

In the following article, some ideas are put forward for discussion on how radiation protection could be optimized, based on the analysis of the current situation in radiation protection by Rolf Michel, Bernd Lorenz and Hansruedi Völkle, published in number 4/2018 of StrahlenschutzPRAXIS.[1] This text was written in English in order to enable experts outside the German-speaking countries to actively participate in the discussion of the suggestions presented here. Critical feedback and suggestions are very welcome.

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The recommendations of the ICRP[2] provide dose limits for planned exposure situations at the workplace and for the general population from artificial radiation sources. For existing exposure situations (for example, remains or legacies from previous activities with radioactivity or increased radon levels in residential buildings) and for radiological emergencies it suggests dose reference levels which are determined and enforced case by case by the relevant national authorities responsible for such emergency situations. The system of recommendations is periodically reviewed and, if necessary, adapted to new scientific findings and new requirements. In this regard the ICRP has recently announced that its recommendations for radiological protection will be revised in the coming years, to make them fit for purpose. ICRP has expressed its intention to do this in cooperation with the radiation protection community. We should accept this invitation and actively participate in this process.

Suggestion 1: All radiation protection societies (within the IRPA community) should motivate their members – over all the radiation protection practitioners – to report their wishes and suggestions for the renewal of the recommendations in radiological protection of the ICRP.

1) Two major challenges in the system of radiation protection for which we need a solution.

In the view of practitioners, two issues deserve particular attention. On the one hand, we need an internationally coordinated and accepted set of rules for radon at the workplace and in the living area. To do this, we need uniform conversion factors to convert the radon exposure from $Bq \times h/m^3$ into an effective dose in mSv per year.[3]

Since the ICRP's radiation protection concept is based on the effective dose as a measure for the comprehensive radiological health impact of ionizing radiation (i.e. the detriment as it is defined by the ICRP), it makes sense – when communicating with the media and the population – to also state the effective dose for radon in mSv per year and not just as a radon exposure in $Bq \times h/m^3$, as the latter is too difficult to understand for non-experts. Radon is by far the largest single component of our radiation exposure. Its range of values extends over two to three orders of magnitude. It is important to raise awareness among authorities, the population and the media (as they are the most important communication channel between radiation protection experts and the public) about the issue of radon and the importance of countermeasures for buildings with high radon burden. For this purpose, the effective dose in mSv per year is the most suitable parameter, as it enables the comparison with the other dose components of our daily life.

Unfortunately, there is often a distorted perception here (even among experts and despite the clear definition of the effective dose by the ICRP): Fractions of a micro-Sievert per year due to radioactivity released by nuclear facilities are often subjectively judged to be more dangerous than the radiation exposure from radon in living areas, which in some cases can be up to or even more than 10 milli-Sieverts per year.

Suggestion 2: Uniform and internationally agreed conversion factors should be defined for converting the radon exposure into an effective dose in mSv per year.

The second question concerns the ICRP regulation for the dose to the lens of the eye from 2011: Does this make sense from the user's point of view? What are the cases where the dose to the lens of the eye is radiologically significant and justifies specific regulations and actions? Which activities pose the greatest risk, and which protective measures are most suitable and most efficacious?

Suggestion 3: Practitioners, primarily users of medical applications and particularly those in interventional radiology, should be asked whether these regulations are useful and make sense, or whether they should be changed.

2) Sustainability in radiation protection.

By issuing the *Sustainability Development Goals*, the UN call 2015 for sustainability in all areas of our daily life. Sustainability has three pillars: Society, Environment, and Economy. How should this requirement be implemented in practical radiological protection? For the societal aspect, this means that applications of radiation and radioactivity – and not to forget also measures and actions to be taken in radiation protection – should be fair. So, an advantage in one population group should not become a disadvantage in another one. Everyone should have the same chance to benefit from applications and protective measures. The impact on the environment of applications and measures should be justified by a corresponding real benefit, i.e. an application should provide a real advantage. Measures taken in radiation protection should contribute to avoid a real amount (and not only a hypothetical one) of radiation dose, and so enable a real reduction of its associate radiological risks. The same applies to the expenditure on manpower, materials, energy, and costs for applications of radiation and radioactivity, as well as for measures to be taken in radiation protection. Measures that merely avoid only few hypothetical micro-Sievert but require a great deal of effort and lead to significant radiation doses for the employees involved in their implementation must be questioned regarding their sustainability. A further point is a respectful handling of raw materials, residues, and waste: As far as this is possible (i. e. where recycling makes sense and further is compatible with the principles of radiation protection), materials should always be recycled.

Suggestion 4: To the three principles in radiological protection – namely justification, optimization, and dose limitation – a fourth one should be added: Sustainability.

Suggestion 5: Today, as environmental impact assessments are required for most projects in many fields of our daily life, also applications of radiation and radioactivity as well as measures to be taken in radiological protection need to be checked for their sustainability, i.e. their societal, environmental, and economic impact and their justification.

3) Continue to maintain LNT or look for alternative concepts?

For the dose range above 100 mSv, the large epidemiological studies such as LSS and INWOKRS, [4, 5] show a clearly recognizable linearity between radiation exposure and radiological effects, especially in terms of cancer mortality. Several comments on the INWORKS study *(which includes over 300'000 employees from nuclear facilities in France, UK and USA for the years 1945 to 2005, covering 10.7 millions of person year)* criticize the fact that the study does not consider natural radiation exposure *(i.e. the cumulated radiation dose of between 20 to 100 mSv, according on the age of the employees and their duration of employment)* and further, the doses caused by medical applications (for diagnostic or therapeutic purposes) of radiation they had received so fare.

However, below 100 mSv linearity is not clearly recognizable by both mentioned studies. The question is justified as to whether there is a lower dose threshold below which health effects are not to be expected or even hormetic effects[6, 7] may exist. If there is such a lower dose threshold, it would probably have to lie within the variation range of the natural radiation to which we are all constantly exposed and to which nature has adapted during evolution. Natural radiation may even be useful for the evolution of species, as Aristotle states "*Nature does nothing uselessly*". If one ad the radiation doses from medical applications and from other anthropogenic radiation sources, then – when omitting the high natural background radiation areas (HNBR)[8] – the total radiation exposures of the populations of most countries are within a dose range of between 1 and 20 mSv per year.[16]

The LNT hypothesis – which goes back to the American geneticist Hermann Joseph Muller (1890-1967; Nobel Prize in physiology and medicine in 1946) and was adopted by ICRP in 1959 – cannot be proven by epidemiological studies for the dose range below 100 mSv per year and remains therefore a hypothesis. Since some years LNT is increasingly being questioned, and this also by serious scientists. Some of the points raised in their criticism are weighty and diverse.[9] Now that the ICRP's recommendations on radiological protection are due to be renewed, we should face this debate and examine whether we should maintain LNT or should limit its application to the range above 100 mSv per year or should look for alternatives and check their justification and usefulness for practical radiation protection. Ignoring this criticism and not engaging in this discussion would undermine the ICRP's credibility.[10] Of the many works that are critical of LNT,[11] the one commissioned by the French Academy of Sciences and the Academy of Medicine should be mentioned.[12] It is probably one of the most comprehensive and competent works on this topic.

In fact, all these questions have already been discussed several times by radiation protection experts. But until now, even those who have expressed themselves critically about the LNT have lacked the courage to consider any further actions, because a whole series of fundamental questions would then arise and need to be answered.

Another issue that would need to be discussed is the inclusion of radiation induced epigenetic effects[13] in the models used to calculate biological effects of ionizing radiation. Epigenetics describes the changes in genetic expression – which can be hereditable to a certain extent – but which are not changes in the DNA sequence itself. So, epigenetics makes the link between genotype and phenotype.

What would be the consequences abandoning LNT or restricting it to the dose range above 100 mSv per year? We would then have to reflect on some of the basic principles in radiation protection, such as ALARA or the dose limit values. The setting of dose limit values for planned exposure situations – that means 20 mSv per year at the workplace and 1 mSv per year for the rest of the population from anthropogenic radiation sources – are until now based on a maximum tolerable value for the radiation risk in terms of detriment as defined by the ICRP. The dose corresponding to this radiological risk is then calculated using the ICRP radiation risk coefficients and the LNT hypothesis for the extrapolation to low doses. But the mentioned dose limits – i.e. 1 and 20 mSv per year – are at the lower end of the dose range from 0 to 100 mSv, where linearity is no longer evident. This leads inevitably to the search for other justifications for the dose limit values in radiation protection.

Suggestion 6: The use of LNT should be limited to the dose range where adverse health effects have been identified, i.e., above 100 mSv per year (or at least above 50 mSv per year). The ICRP should clearly communicate that below 100 mSv per year no binding statements about the radiological risk are possible.[14] What can be said, however, is the following: If the additional radiation doses at the workplace remain within the range of natural radiation domain (i.e., below 20 mSv per year), the additional risk[15] is insignificant (and no longer statistically detectable) compared to the risks of everyday life (with its large domain of variation), both private and professional. This also applies for the remaining population: If the additional radiation doses from anthropogenic radiation sources remain below the lower end of the range of the natural radiation exposure (i.e., below 1 mSv per year) health effects will be insignificant and are not statistically detectable, even in large population collectives.

Suggestion 7: Natural radiation exposure to which we are all constantly exposed should be used as reference values for determining the limit values in radiation protection.[1] Natural radiation has a large variation domain between 1 and 20 milli-Sieverts per year (except the regions of the world with high natural background radiation).[16] The upper end should then be the dose limit for the workplace (i. e., 20 mSv per year) and the lower end that for the population in general from anthropogenic radiation sources (i. e., 1 mSv per year).

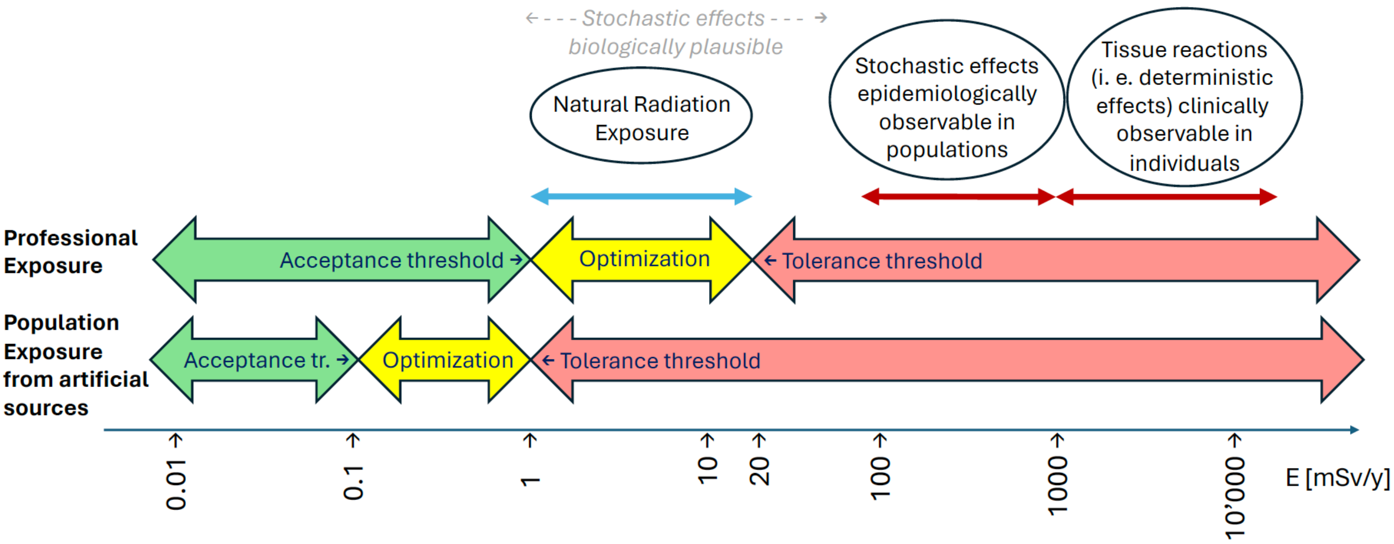
4) Do we need a lower end for optimization measures in radiation protection?

For planned exposure situations the dose limits of 20 mSv per year for the workplace and 1 mSv per year for the rest of the population from anthropogenic radiation sources are well established and are not seriously questioned. A further reduction of these limit values is not considered necessary by the radiation protection community. For years, however, we have been discussing on the interpretation of *ALARA*, as well as on the meaning of *Justification*, *Optimization* or *Reasonableness*. Optimization is a basic principle not only in radiological protection. Optimizing a process means finding the greatest benefits with the fewest disadvantages. However, it would be wrong to understand optimization only as the requirement to minimize radiation exposures.

The following questions should be discussed with practitioners: How should the recommendation of optimization in radiation protection be understood? How far down should this optimization go? Is there an acceptance threshold for the dose below which measures to further reducing radiation exposure are neither sensible nor justified. This means that no further regulations would be necessary in this dose domain in the sense of the Roman legal principle: *De minimis non curat lex*. This approach gives those involved in radiation protection more personal responsibility (so that they are more than just enforcers of legal measures) by allowing them to use their own professional experience and expertise. However, even where the law does not provide any regulations, the usual precautionary measures when handling dangerous substances and devices must be observed and it remains important to act responsibly.

Applied in practice, this could mean (as has been suggested by Michel et al on behalf of the German-Swiss Fachverband für Strahlenschutz[1]) that no further measures are necessary below 1 mSv per year at the workplace, or below 0.1 mSv per year for the general population from anthropogenic radiation sources. In the opinion of the authors[1], measures below the stated values are no longer justified, as their contribution to the reduction of the total radiation exposure (and the corresponding radiological risk) is insignificant and has no measurable impact on public or individual health, compared to the already existing doses and risks and their large variation domain.[17] Of course, the usual basic rules should not be disregarded, i.e. avoid staying in the radiation field unnecessarily, only people in the radiation protection area who must be there, contamination controls where there is a risk of contamination or incorporation of radioactivity.

Suggestion 8: A traffic light model should be introduced in radiation protection,[18] as illustrated in the graph bellow. It has a **red** area that is considered as intolerable, a **yellow** one (domain of optimization) in which measures must (or can, according to the possibilities and the specific circumstances) be taken and a **green** one that does not require any measures beyond the usual precautionary rules. The border between the red and yellow areas is the **tolerance** threshold (where are the dose limits), and that between the yellow and green areas is the **acceptance** threshold.



5) Do we need a holistic assessment of radiation doses and radiation risks?

Security and safety are always relative. How safe an activity or facility is can only be assessed by comparing it with appropriate alternatives. Unfortunately, the perception of safety or risks is rather subjective, as is the balance between the appreciation of the benefits (or the chances) that an activity or facility provides and the willingness to accept the associated risks. Providing factual and objective information about safety and risks is therefore a major challenge for the radiation protection experts. When optimizing activities and facilities with the aim to minimize risks, one should be focused on the objectively largest ones, as this is the best way to significantly reduce the overall risk. This shows the need for a holistic assessment of both the risks and – in radiation protection – the exposure to radiation and its associated risks.

Specifically, this means that an individual's radiation exposure from anthropogenic radiation sources can only be assessed objectively in comparison to her or his radiation exposure from natural and all other sources combined. Natural radiation exposure – above all that caused by radon in living areas – is by far the largest component of the overall radiation exposure and has a very wide range of variation. It depends on many parameters, such as geology, altitude, radon in the living area, building materials, diet, and other influencing factors. In exceptional cases, such as residential buildings with very high levels of radon or in high natural background radiation areas, the radiation doses can go up to 200 mSv per year, in some cases even more than that. Apart from the high natural background radiation areas, the natural radiation exposure in most countries lies between about 1 and 20 mSv per year. In addition, there are doses from medical applications and, in some cases, from professional activities. Here, civil aviation personnel are among the people most exposed to radiation, and not, as one might assume, the employees of nuclear facilities.

If a person receives an additional dose of 0.1 mSv per year through an activity or a facility, this means an increase in the total radiation exposure of 10 %, in the case this person receives annually 1 mSv from natural radiation sources; it means an increase of only 0.5 % in the case she or he receives 20 mSv per year from natural radiation sources.

A holistic assessment is also recommended when it comes to the assessment of risks, especially those of cancer mortality. Carcinogenesis is a complex process in which age, genetics (and epigenetics), gender, lifestyle (for example cigarette smoking), diet (nutritional habits), air pollution, geographical region of residence, occupational exposure, and many other factors – probably including individual mental health – play an important role. Cancer incidence and cancer mortality show a large range of variation. In 29 European countries the average cancer mortality rate per country varies between 200 and 350 per year per 100'000 inhabitants. Furthermore, cancer mortality increases sharply with age and is approximately one and a half times higher in men than in women. Of the overall cancer mortality, only a small part is probably attributable to natural radiation exposure, while the contributions of other influencing factors remain certainly more important.

Suggestion 9: Radiation doses and the resulting radiological risks should be evaluated in a holistic view, i.e. in comparison to natural radiation exposure and the risks of everyday life.

6) Should radiation protection go towards individual dosimetry and risk assessment?

The radiation risk of an individual depends not only on the dose she or he receives, but also on gender, age, genetics (eventually also on epigenetics), lifestyle, geographical region of residence, as well as previous exposures to other causes that can induce a cancer (because of the multiplicative radiation risk projection). The Detriment adjusted nominal risk coefficients of ICRP for cancer and heritable effects (usually given in 10^{-2} per Sievert effective dose) are population averaged and age standardized values (and only for a standard adult person) and do not consider the individual radiation sensitivity nor a multiplicative connection between radiation risk and the spontaneous or baseline (mainly cancer) risk of an individual. The use of these risk coefficients is problematic for two reasons: They should not be used to calculate an individual person's risk of death from cancer (or a heritable disease among his or her descendants), nor – the ICRP explicitly warns against this – should they be used in the low dose range (where linearity between dose and detriment is not evident) to calculate hypothetical cancer deaths in collectives.[19]

Where else should these risk coefficients be used at the end? This justifies the question of whether we need an individual dosimetry and an individual assessment of the radiation risks to take the above-mentioned issues into account appropriately. The ICRP risk coefficients should therefore not be used for calculations for which they are not intended (i. e. by the ICRP). An improper use of these risk coefficients may cause unfounded concern about radiation[20] and fear of radiation may make more people sick than radiation itself. And this precisely is not the aim of radiation protection and is further incompatible with its ethical principles.

Suggestion 10: Models for individual dosimetry, as well as for the estimation and evaluation of the associated individual radiological risk – in terms of detriment, as defined by the ICRP – should be developed. [21]

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[2] ICRP Publication 103: *The 2007 Recommendations of the International Commission on Radiological Protection*. Annals of the ICRP, Vol. 37, Nos. 2 – 4, 2007; Elsevier; ISBN 097-0-7020.3048-2(200704/06) 37:2-4;1

[3] HANSRUEDI VÖLKLE, ROLF MICHEL and BERND LORENZ: *Kommentar: Radon-Konversionsfaktoren*. StrahlenschutzPRAXIS, Vol. 3/2020, pp. 110-112

[4] KLERVI LEURAUD, DAVID B. RICHARDSON, ELISABETH CARDIS, ROBERT D. DANIELS, MICHAEL GILLIES, RICHARD HAYLOCK, MONIKA MOISSONNIER, MARY K. SCHUBAUER-BERIGAN, ISABELLE THIERRY-CHEF, AUSRELE KESMINIENE and DOMINIQUE LAURIER: *Risk of cancer associated with*

low-dose radiation exposure: comparison of results between the INWORKS nuclear workers study and the A-bomb survivors study. Radiation and Environmental Biophysics, Vol. 60; pp. 23–39 (2021)

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[6] *"The hormesis hypothesis states that most chemical and physical agents may stimulate biological effects at doses lower than a threshold, while they are toxic at doses higher than this threshold."* from J. KOCH and T. SCHLESINGER in: *Radiation hormesis: Beneficial effects of exposure to low levels of ionizing radiation – A critical review*. Radiation Safety Division, Soreq Nuclear Research Center, 81800 – Yavne, Israel; E-mail: koch@soreq.gov.il

[7] T.D. LUCKEY: *Radiation Hormesis: The Good, the Bad, and the Ugly*. Dose-Response Vol. 4(3), pp. 169–190 (2006)

[8] JOLYON H HENDRY, STEVEN L SIMON, ANDRZEJ WOJCIK, MEHDI SOHRABI, WERNER BURKART, ELISABETH CARDIS, DOMINIQUE LAURIER, MARGOT TIRMARCHE, and ISAMU HAYATA: *Human exposure to high natural background radiation: what can it teach us about radiation risks?* J. Radiol. Prot. Vol. 29(0): pp. A29–A42 (June 2009)

[9] A list of publications that are critical of LNT is available from the author.

[10] HANSRUEDI VÖLKLE: *Die Diskussion über LNT kommt nun endlich in Gang*. StrahlenschutzPRAXIS Vol. 3/2023, pp. 57-59 (2023)

[11] JOHN CARDARELLI II: Response to A. A. Bahadori (Comment to *The History of the LNT Model*): Correspondence to the Editor of Health Physics Vol. 124/6, pp. 486-490 (2023).
And (among many other publications of the same author): EDWARD J. CALABRESE: *LNT and cancer risk assessment: Its flawed foundations part 2: How unsound LNT science became accepted*. Environmental Research, Vol. 197 (2021)

[12] ANDRÉ AURENGO (RAPPORTEUR), DIETRICH AVERBECK, ANDRÉ BONNIN, BERNARD LE GUEN, ROLAND MASSE, ROGER MONIER, MAURICE TUBIANA (CHAIRMAN), ALAIN-JACQUES VALLERON, FLORENT DE VATHAIRE: *Dose-effect relationships and estimation of the carcinogenic effects of low doses of ionizing radiation.* March 30, 2005. https://www.radiochemistry.org/documents/html/033005_rad.html

[13] MAURO BELLI and MARIA ANTONELLA TABOCCHINI: *Ionizing Radiation-Induced Epigenetic Modifications and Their Relevance to Radiation Protection.* Int. Journal of Molecular Sciences, Vol. 21, 5993, pp. 1-34 (2020)

[14] The German philosopher Ludwig Wittgenstein said: «*Where you know nothing, you should remain silent.* »

[15] There is some confusion considering a real risk (as a threat) and a hypothetical risk that requires clarification: If someone goes out during rain without an umbrella, he or she will get soak. This is real. If a person goes for a walk during dry weather without an umbrella, there is a certain risk that it will rain and only then the person will get soak. This is hypothetical.

[16] In Switzerland, the Federal Office of Public Health published a balance sheet and the approximate range of radiation exposure for the Swiss population in its 2020 annual report on radioactivity of the environment. Some possible scenarios were presented: Living in regions with low or high levels of natural radioactivity, respectively with low or high radon concentrations in living areas; frequent or no air travel; regular smoking; professional exposure (for example as a pilot in the civil aviation); doses by diagnostic examinations and/or radiation therapy in medicine. While the scenario with the lowest overall dose yields only 1 mSv per year, the calculations for the highest scenario result in 22 mSv per year. In: SYBILLE ESTIER and PHILIPP STEINMANN (Editors): *Umweltradioaktivität und Strahlenexposition in der Schweiz*. Bundesamt für Gesundheit, Bern (July 2021). www.bag.admin.ch

[17] HANSRUEDI VÖLKLE, ROLF MICHEL and BERND LORENZ: *Comments and suggestions on fundamental principle of radiation protection*. Letter to the editor, Radiation and Environmental Biophysics, published online September 1st, 2021.

[18] HANSRUEDI VÖLKLE: *Ein Ampelmodell zur Optimierung für den Strahlenschutz*, StrahlenschutzPRAXIS, Vol. 3, pp. 55-70 (2021)

[19] Caution is required when calculating collective doses: They should only be used for very specific and precisely defined groups of people and not for the whole population of a country.

[20] The best "antidote" against fear (of radiation) is objective and comprehensible information about radiation and its possible health effects. «*Nothing in life is to be feared, it is only to be understood. Now is the time to understand more, so that we may fear less.* » (Marie Curie).

[21] A very similar trend can be observed in medical treatments, namely towards personalized medicine, in which, among other things, the composition and dosage of a medical treatment are tailored to the specific needs of an individual person.