## RulemakingComments Resource

**From:** Mehdi Sohrabi <dr_msohrabi@yahoo.com>
**Sent:** Tuesday, August 25, 2015 10:51 AM
**To:** Gallagher, Carol; RulemakingComments Resource; Alfred Sorensen
**Subject:** [External_Sender] Universal Radiation Protection System
**Attachments:** Radiat Prot Dosimetry-2015-Sohrabi-457-8.pdf; Radiat Prot Dosimetry-2015-Sohrabi-459-66.pdf

**Dear All:**

Reference is made to the E-mail of July 17 from Mr. Alfred Sorensen requesting comments on the proposed rule change by the U.S. Nuclear Regulation Commission to change the linear no-threshold model of radiation protection to the radiation hormesis model. In this context, I like to make some comments on a "Universal Radiation Protection System" (URPS) which I have recently proposed and published. I think this will solve the existing radiation protection problem universally. Therefore, attached please find two papers on this topic:

1. Editorial; Eight International Conference on High Levels of Natural Radiation and Radon Areas Radiation Protection Dosimetry (2015), Vol. 164, No. 4, pp. 457–458. doi:10.1093/rpd/ncv335

2. A Universal Radiation Protection System Based on Individual Standardized Integrated Doses. Radiation Protection Dosimetry (2015), Vol. 164, No. 4, pp. 459–466. doi:10.1093/rpd/ncv336

A preliminary presentation of this Hypothesis was a Plenary Opening Talk of the 8th IC High Levels Natural Radiation and Radon Areas. 1-5 September 2014, Prague, Czech Republic, which I also had the honor of chairing the conference.
As you can see in the attached papers, I have recently proposed a new Hypothesis in radiation protection entitled "A 'Universal Radiation Protection System' (URPS)" which has a novel philosophy, concept and methodology based on "Risk Limits". It applies a 'Standardized Integrated Dose System' (SIDS) based on health risk limits for workers and public, no matter where they live in the world. The URPS assigns equal radiation health risk limit to an individual by integrating doses from national natural background (NBG) radiation and from man-made sources. For public, the SIDS integrates doses from planned exposure situations within a dose limit (e.g. 1 $mSv.y^{-1}$) on top of the mean national NBG dose in a country. For workers, the SIDS integrates within a dose limit (e.g. 20 $mSv.y^{-1}$) of occupational dose and doses from mean national NBG and from planned exposure situations as a member of public within the public dose limit. In addition the URPS standardizes individual doses for epidemiology studies as well as introducing fractionation effect into occupational doses which can increase the present dose limit significantly.
**This hypothesis can even simply bridge the LNT Model with the Hormesis Model.**
The concept is further being developed by me and I think the above proposal would be an ultimate standardized approach for solving the present problems which due to the lack of adequate standardization of radiation protection.
Advance countries in radiation protection which have good data base for radiation doses in particular on mean national natural background radiation and other doses an individual receives like the United States can simply apply the proposed novel URPS Hypothesis.
I will be available to further develop this system to have a Standardized National Radiation Protection System based on the URPS which for sure will be expanded universally. Would you have any questions, please let me know.

Kind Regards
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# Editorial

## EIGHTH INTERNATIONAL CONFERENCE ON HIGH LEVELS OF NATURAL RADIATION AND RADON AREAS

The eighth International Conference on High Levels of Natural Radiation and Radon Areas (HLNRRAs) was held in Prague, Czech Republic, 1 to 5 September 2014. It was organised by the International Committee on HLNRRAs in cooperation with the Czech Technical University through the Department of Dosimetry and Applications of Ionizing Radiation. The conference was one in the chain of the international conferences held in Brazil (1977), India (1981), Iran (1990), China (1976), Germany (2000), Japan (2004), India (2010) and Czech Republic (2014). The 1990 Conference in Ramsar proposed the formation of an International Committee on HLNRRAs to, among other things, organise such conferences every 4 y. This was materialised at the Beijing Conference in 1996.

After the Opening Remarks, two Plenary Lectures were presented; one by Mehdi Sohrabi (this author) on proposing 'A Universal Radiation Protection System (URPS) based on Natural Background Radiation' and the other by Malcom Creek, the Scientific Secretary of the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) on 'Attributing Health Effects and Expressing Uncertainties in Cancer Risk Estimation from Low Dose Exposure'. The URPS has a novel philosophy, concept and methodology through a standardised integrated individual dose system; the full paper is published in this Special Issue. The URPS is believed to solve some controversies of the present radiation protection system and is expected to ignite new thoughts and ideas by brainstorming, feedback, support, etc. towards protecting public and workers against harmful effects of ionising radiation. Creek presented major challenging issues relating to the analysis and communication of risks of health effects. He emphasised that cancer cannot be unequivocally attributed to radiation exposure because it is not the only possible cause and there are currently no known biomarkers that are specific to radiation. When estimating radiation-induced health effects in a population exposed to incremental doses at levels equivalent to or below natural background, the UNSCEAR does not recommend multiplying very low doses by a large number of individuals and applying notional risk factors. However, it recognises that making such estimations for public health decisions can be valid if applied consistently and the uncertainties are fully taken into account and communicated.

A number of invited talks were also presented by leading experts on 'Epidemiological Studies of Cancer Risk Associated with Low Dose and Dose Rate Radiation Exposure' by S. Akiba (Japan); 'Risk of Leukemia in Uranium Miners' by L. Tomášek (Czech Republic); 'Background Radiation and Circulatory Disease Mortality in Kerala, India—Karunagappally Cohort Study' by P. Sebastian (India); 'Overview of the Studies on Health Effects among the Residents in Yangjiang High-Background Radiation Area, China' by Q. Sun (China) (given by S. Akiba); 'Cellular Responses to Very Low Level Ionizing Radiation by M. Dvídková' (Czech Republic); 'On Quasi-Periodic Variations of Low Energy Cosmic Rays Observed Near Earth' by K. Kudela (Slovakia); 'Radiation Environment at Aviation Altitudes and in Space' by L. Sihver (Sweden); 'Water Treatment Plants and NORM—Czech Experience' by M. Neznal (Czech Republic); 'Radon and Thoron in High Background Radiation Areas, India and China' by S. Tokonami (Japan);' 'Ways to Detect Terrestrial Radionuclides' by T. Trojek and L. Thinová (Czech Republic); 'Report of Radon Calibration Activities: The 2014 NRPI International Intercomparison of Radon/Thoron Gas and Radon Short-Lived Decay Products Measurement Instruments' by K. Jílek (Czech Republic); 'Indoor Radon Measurement Methods and Strategies Focused on Energy Efficient Building Technologies' by A. Froňka (Czech Republic) and 'Regulatory Framework for Radon and NORM in the Czech Republic' by D. Drábová (Czech Republic). The papers presented provided the-state-of-the-art information with proactive discussions by the participants. Each talk opened a topical session after which some oral and poster papers were also presented.

Scientific tours to some medical and research facilities in Prague such as the Proton Therapy Center, Leksell Gamma Knife, Radon Chamber, Tokamak Fusion Reactor, Vrabec Fission Reactor, etc. have also been arranged. As a 'Bonus' to the conference, a 'Comparison Measurement in Radon-Aerosol Chambers' has also been arranged.

To continue the tradition set at the conference in Japan in 2004, the International Committee in order to express appreciation and to recognise outstanding and continued contributions of some senior scientists in the scope of the conferences in particular on health risk assessment of natural background doses presented 'Awards of Honor' to two senior scientists; to Professor Josef Thomas, National Radiation Protection Institute, Prague, a highly dedicated scientist with lifetime efforts on radon studies and to Professor Suminori Akiba, University of Kagoshima, Japan, for his extensive efforts and contributions to epidemiological studies of inhabitants of HBNRRAs and enhancing collaborations with some HBNRRA countries on epidemiology of inhabitants. The 'Awards of Honor' were presented at a formal conference dinner held at the Hotel Diplomat in Prague.

The 'Round Table Panel on Lessons Learned from Studies in HBNRRAs and Future Studies' attended by some International Committee members and invited speakers and participants lead concluded that:

(1) This chain of international conferences has been a success in enhancing the role of natural background radiation in upgrading the present radiation protection system, proposing a novel 'Universal Radiation Protection System', setting the national mean natural background radiation dose as a base in standardised integrated individual doses in order to imply equal health risks to workers around the world independent of the country living in and to public, proposing alternative methodologies to radiation health risk epidemiological studies, including national mean natural background doses in epidemiology studies of workers, providing more weight to thoron studies in addition to radon and the prospect for applying the proposed 'Education Standards and Standards Education Process in a National Education Cycle' as regard to radiation protection to better educate and train the relevant individuals in the national education cycle.

(2) Having scientific lessons learned and experiences gained through the organisation of this chain of conferences, the Panel was of the opinion that equal weight should be given to radiation health effects per unit dose of exposures either from natural background or from man-made sources. In particular, such experiences can be further expanded to also studies of all existing exposure situations independent of the source of origin. In this context, it was proposed and accepted that the theme of the International Committee on HLNRRAs includes all exiting environmental exposure situations, as defined by the ICRP 103 (2007). Therefore, the theme of the Committee was upgraded to 'International Committee on High Level Environmental Radiation Areas'. Then, the theme of the next conference will be '9th International Conference on High Level Environmental Radiation Areas' which includes all existing environmental exposure situations independent of the sources of origin.

(3) It is a tradition in this chain of the conferences to choose the venue of the next conference(s). Several countries including Islamic Republic of Iran (in the waiting list since a long time), Turkey, Spain, South Korea and possibly other countries expressed interest to host the ninth International Conference on High Level Environmental Radiation Areas. In order to having more firm commitment from the countries nominated to host the next conference, it was decided to postpone taking a decision on the venue of the next conference to after the conference in order to have enough time to communicate with the interested countries and confirm the organisation of the venue.

(4) The Panel was also of the opinion that due to the importance of the topics explored at the conference and the new scope of the International Committee and the International Conferences, the future conferences may be held possibly in every 2 y.

Last but not least, sincere appreciation is extended to the Technical University of Prague in particular the Department of Dosimetry and Applications of Ionizing Radiation for taking the burden of successfully hosting the 8th ICHLNRRAs, the International Scientific Committee, the Local Organizing Committee, the Congress Business Travel Ltd., the invited speakers, the participants for their contributions and sincere cooperation which made the conference a high success.

I look forward to organisation of future conferences with a wider scope to cover all existing environmental radiation exposure situations independent of the source of origin to promote collective information and to better understand radiation health effects at low doses.

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# A UNIVERSAL RADIATION PROTECTION SYSTEM BASED ON INDIVIDUAL STANDARDISED INTEGRATED DOSES

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**A 'Universal Radiation Protection System' (URPS) is proposed in this paper with a novel philosophy, concept and methodology. It applies a 'Standardised Integrated Dose System' (SIDS) based on health risk limits for workers and public, no matter where they live in the world. The URPS assigns equal radiation health risk limit to an individual by integrating doses from national natural background (NBG) radiation and from man-made sources. For public, the SIDS integrates doses from planned exposure situations within a dose limit (e.g. 1 mSv y$^{-1}$) on top of the mean national NBG dose in a country. For workers, the SIDS integrates within a dose limit (e.g. 20 mSv y$^{-1}$) of occupational dose and doses from mean national NBG and from planned exposure situations as a member of public within the public dose limit. A panorama overview and the rationale in support of the URPS are presented and discussed with a hope to ignite further thoughts and ideas towards establishing the URPS for universal use.**



## INTRODUCTION

Over 100 y have passed since the first applications of ionising radiation with attempts on studying radiation effects on human health to establish, practise and evolve radiation protection (RP) philosophies, principles and mechanisms to protect man and environment from harmful health effects of ionising radiation. The RP philosophy presently is based on the linear no-threshold (LNT) hypothesis with an emphasis that at low doses and low dose rates, above the UNSCEAR's global mean natural background (NBG) radiation dose of ~2.4 mSv y$^{-1}$[1], the excess risk is proportional to dose[2, 3]. The ICRP philosophy is based on justification, optimisation and dose limitation[2]. However, the dose limit of public and workers in current RP practice only considers exposures from planned and emergency exposure situations and does not include the existing exposure situations such as the mean national NBG radiation dose. By scrutiny of the current RP philosophy and dose limitation being implemented worldwide, time seems ripe to have a closer look into the present RP system towards establishing a more standardised approach. Some examples of issues of concern in current RP system seem to include the following:

- lack of practically and explicitly assigning equal health risks to radiation from the NBG environment and from the man-made sources,
- setting a public dose limit of 1 mSv y$^{-1}$ on top of the UNSCEAR's global mean NBG radiation dose of ~2.4 mSv y$^{-1}$ (ICRP 82), instead of the real national mean NBG dose of a country,
- considering the LNT hypothesis with risk values proportional to dose above the ~2.4 mSv y$^{-1}$, whereas it should consider said the above, in order to respond consistently with a standardised, scientific, practical and systematic approach to face the risk response from zero dose independent of the source of origin,
- assigning a reference level of 1 mSv y$^{-1}$ for external public gamma exposure from commodities in addition to the 10 mSv y$^{-1}$ reference level recommended for radon indoors[4], which seems not practical from regulatory point of view,
- assigning 1 mSv y$^{-1}$ as public dose limit from planned exposure situations and 1 mSv y$^{-1}$ reference level for external public gamma exposure from commodities which is rather confusing for public, radiation workers and even regulatory authorities,
- setting a 5-y mean dose limit of 20 mSv y$^{-1}$ for workers from occupational exposure by ICRP 103 with no consideration of the mean national NBG dose, which is a committed dose consistently received by a member of the public and also by a radiation worker as a member of public with a value that is usually higher than that workers receive even in nuclear industries[1, 2],
- epidemiology of workers is now only based on occupational exposure with no consideration of the mean national NBG dose, which is a significant lifetime dose retrospectively,
- lack of considering fractionated dose in occupational exposure and unfractionated dose of natural radiation in epidemiological studies,
- lack of understanding of the present philosophy of radiation workers by the public and even workers and dose limitation which has caused widespread radiophobia, etc.

Having exiting problems in protection of workers and public, the presently practised RP system seems requiring to be evolved. To respond to the existing challenging

RP issues, a 'Universal Radiation Protection System' (URPS) with a novel philosophy, concept and methodology based on a 'Standardised Integrated Dose System' (SIDS) considering 'health risk limits' for workers and public is proposed in this paper. This paper was presented as the opening Plenary Lecture of the eight International Conference on High Levels of Natural Radiation and Radon Areas[5].

It is expected that the URPS will have a high impact for solving the present controversies in RP implementation universally. A panorama overview of the presently practised RP system and philosophy, concept and methodology as well as the rationale in support of the proposed URPS to respond to the present challenging RP issues are presented and discussed. It is hoped that this proposal ignites thoughts and ideas through braining storming, feedbacks, supports, etc. towards establishing the URPS for protecting public and radiation workers against harmful effects of ionising radiation.

## OVERVIEW OF PRESENT RADIATION PROTECTION PHILOSOPHY

The present RP philosophy is based on an evolvement of the philosophy, concept and methodology over 100 y through international efforts[6]. It is based on the LNT hypothesis with an emphasis that at low doses and low dose rates above the UNSCEAR's global mean NBG radiation dose of ~2.4 mSv $y^{-1}$, the excess risk is proportional to the dose[2]. This hypothesis in brief states that any level of radiation dose no matter how small it is has a certain degree of health risk as genetic defects or cancer. The RP philosophy is also based on three fundamental principles namely 'justification', 'optimisation' and 'dose limitation'. The 'justification' is any decision that alters the radiation exposure situation and should do more good than harm. The 'optimisation' is the likelihood of incurring exposure, the number of people exposed and the magnitude of their individual doses which should all be kept as low as reasonably achievable (ALARA), taking into account economic and social factors. The 'dose limit' is the total dose to any individual from 'regulated sources in planned exposure situations', other than medical exposure of patients, which should not exceed the appropriate limits specified by the ICRP 103 for workers and public[2]. The ICRP 103[2] also defines existing, planned and emergency exposure situations. The past and present philosophy and principles of the RP system of ICRP and other relevant organisations have been taught, preached and implemented by the author of this paper over the long professional years at different academic and professional capacities worldwide. However, with all respects to the ICRP and other relevant organisations, some inconsistencies are observed in the present RP philosophy and methodology, which are not easy to justify, optimise and limit the doses with a standardised approach.

One of the main issues causing inconsistencies in the present RP system is individual's exposure (either as a member of public or a worker as a member of public) by living indoors and outdoors in particular from national NBG radiation dose in addition to doses from 'regulated sources in planned exposure situations'. For example, according to NCRP 160[7], a member of public in USA, either an ordinary member or a radiation worker, receives a national mean dose of 6.20 mSv $y^{-1}$ from which ~50 % is attributed to natural sources ( ~37 % from radon and ~13 % natural sources including cosmic rays, terrestrial radiation and internal exposure) and ~48 % due to medical exposure. When the public dose of a specific country is concerned[8], the UNSCEAR has reported national mean NBG doses of different countries ranging from ~1 to ~10 mSv $y^{-1}$ or even higher with a global mean NBG radiation dose of ~2.4 mSv $y^{-1}$[1]. Some residents of high NBG radiation areas such as Ramsar receive doses of >200 mSv $y^{-1}$[9–12].

The International Atomic Energy Agency in a recent Safety Standards Series[13] provides the state-of-the-art information and recommendations by ICRP, WHO, etc. on meeting the requirements for exposure of the public from living indoors due to NBG dose. The ICRP specifically in few recent publications on public exposure indoors due to radon and gamma radiation from commodities makes the following recommendations:

- The ICRP103[2] recommends a reference level 10 mSv $y^{-1}$ for radon gas in dwellings which corresponds to an activity level of 600 Bq $m^{-3}$. This activity level was reduced to 300 Bq $m^{-3}$ by the ICRP in its 'Statement on Radon' in 2009 based on new findings[14]. In this context, WHO proposes a reference level of 100 Bq $m^{-3}$ to minimise health hazards of exposure indoors due to radon. The WHO also states that if this level cannot be reached under the prevailing country-specific conditions, the chosen reference level should not exceed 300 Bq $m^{-3}$ based on the new findings[15]. However, such reference levels are for internal doses only from radon gas and do not include gamma doses from commodities.
- In ICRP 82[4], a reference level of ~1 mSv $y^{-1}$ from a dominant type of commodity amenable to control by intervention which could in some circumstances be a significant cause of prolonged exposure. This reference level is in addition to the reference level of 10 mSv $y^{-1}$ for radon gas in dwellings, as stated earlier.

With regard to workers, the ICRP recommends a 5-y mean dose limit of 20 mSv $y^{-1}$ provided that the annual dos limit does not exceed a maximum dose limit of 50 mSv $y^{-1}$[1]. This dose limit is only due to occupational exposure and does not include doses a worker receives also as a member of public from other sources in a country such as from the national mean NBG and from planned exposure situations within the dose limit of 1 mSv $y^{-1}$ or even doses from medical exposure (if medical doses has to be taken into consideration; e.g. for epidemiological studies of radiation workers). It should be noted that the doses a worker also receives as a member of public can be even higher than that received from occupational exposure (e.g. in diagnostic radiology, nuclear industry, medical laboratories, etc.)[1]. By considering the LNT hypothesis, there seems to be a duality in considering risks to radiation workers and public in terms of such exposures in particular with regard to NBG radiation dose.

By applying the LNT hypothesis at low dose and dose rates and by considering equal radiation exposures either from NBG or from man-made sources carry equal health risks, it seems the present RP system requires further evolvement and standardisation in particular with regard to total radiation health risks of a worker at work and as a member of public.

## INCONSISTENCIES IN PRESENT RP SYSTEM

While the RP philosophy of the ICRP and other international bodies is highly respected, one can discuss that the 'dose limits' and 'reference levels' recommended by the ICRP[2, 14], for workers and members of public, have not considered the total radiation health risks of each individual in a justified, consistent and in particular standardised approach. For example, workers and members of the public living in different parts of the world receive national mean NBG doses, which differ from one country to another. Some inconsistencies, controversies and shortcomings are discussed below:

(1) The health risks of one unit radiation dose from national NBG radiation and from man-made sources are not presently equally weighted and have not been considered in the dose limitation system. The LNT hypothesis on which the radiation risks are based upon has increasing controversies for and against it since there is not enough health risks convincing evidence so far at low doses either ways. In particular, considering the LNT as a valid hypothesis as currently practised, then the role of national mean NBG dose becomes extremely important due to its level of health risks, compared with doses received even occupationally by workers. In order to scientifically justify and standardise doses received by an individual, the doses received from all sources either natural or man-made can be integrated in a standardised integrated dose system. Presently, the integration of the national mean NBG dose is not even considered in the lifetime dose of workers, e.g. the on-going epidemiological studies of US workers[16, 17].

(2) Over three decades ago, the UNSCEAR's global mean NBG dose of ~2.4 mSv $y^{-1}$was included by the author for the first time into an RP system by inclusion in a Dose Band System (DBS), for the following reasons[9, 18, 19]:

   (a) classify existing exposure situations of public by a DBS to prevent calling any NBG radiation area as high or very high to prevent radiophobia among public,
   (b) apply in the above-proposed DBS levels, the maximum dose limit of 50 mSv $y^{-1}$ and 5-y mean dose limit of 20 mSv $y^{-1}$ to correlate a synergy between the exposure of workers and the public in existing exposure situations,
   (c) propose recommendations, in each dose band, some regulatory criteria and mechanism for decision-making for remediation of existing and prolonged exposure situations and
   (d) include the concept of NBG dose into a DBS by setting the upper level of the lowest band of the DBS as 5 mSv $y^{-1}$ (about two times the UNSCEAR's global mean NBG dose of ~2.4 mSv $y^{-1}$, within which no need to regulatory actions was recommended.

(3) The proposed UNSCEAR's global mean NBG radiation dose of ~2.4 mSv $y^{-1}$ and the DBS concept and methodology were adopted with some alterations by ICRP 82[4] as discussed below:

   (a) New doses were assigned for each level of the bands in the DBS,
   (b) The 1 mSv $y^{-1}$ public dose limit from regulated sources was added on top of UNSCEAR's global mean NBG radiation dose of ~2.4 mSv $y^{-1}$ and
   (c) The ~1 mSv $y^{-1}$ reference level for gamma of a dominant type of commodity amenable to control by intervention was recommended an additional dose to the 10 mSv $y^{-1}$, the recommended reference level for radon indoors.
   (d) Adding 1 mSv $y^{-1}$ as dose limit on top of ~2.4 mSv $y^{-1}$ by ICRP has a limitation since the national mean NBG dose varies from ~1 to ~10 mSv $y^{-1}$ or even higher in different countries[1]. Accordingly, a member of public and also a worker (as a member of public) in any country receive different levels of national mean NBG dose. Therefore, in order to set relatively total radiation risk-based dose limits and reference levels, the actual national mean NBG dose of a member of public in a country should be considered as a base in the public dose limit instead of the UNSCEAR's mean global NBG radiation dose[1, 2, 4].

(4) The ICRP 103[2] considers the LNT hypothesis as a dose response that 'above the UNSCEAR's global mean NBG dose, the risk is proportional to the dose'. One may ask whether the health risk from NBG dose is also proportional to the dose at low doses. A member of public and a worker in a country integrate doses from planned exposure situations within a dose limit of 1 mSv $y^{-1}$, from the national NBG dose of existing exposure situations, etc. A worker in addition receives occupational exposure. Even the mean national NBG dose can be higher than that of the occupational doses in majority of cases. Therefore, building LNT response proportional to radiation dose above the UNSCEAR's global mean NBG dose or even above the mean national NBG dose ignores the doses from the national NBG radiation. Radiation protection specialists interpret the base point of the LNT response above the UNSCEAR's mean global value differently[20], which is one of the main drawbacks. The risk versus dose in the LNT response, if accepted, should start from zero to include risks from any types of radiation independent of the source of the origin of the exposure.

(5) The ICRP's 5-y mean dose limit of 20 mSv $y^{-1}$ for workers includes presently only occupational doses. As also stated earlier, a worker also receives, as a member of public, doses from the national NBG dose which its mean varies from country to country (or in general from exiting exposure situations), from planned exposure situations (within 1 mSv $y^{-1}$ dose limit for public) and possibly from other sources, from nuclear incidents, or from medical exposure. Therefore, workers in different countries presently bear different risks due to different levels of national mean NBG dose not considered in the dose limit.

(6) The $\sim$1 mSv $y^{-1}$ reference level recommended by ICRP 82[4] for public external gamma exposure from commodities indoors is an additional dose to the 10 mSv $y^{-1}$, the recommended reference level for radon indoors. The implementation of these two reference levels in practice for regulatory control and for remediation, if required, is not without serious problems. In addition, this 1 mSv $y^{-1}$ reference level and the 1 mSv $y^{-1}$ dose limit from planned exposures situations for public are sources of confusion for public, workers and even among RP practitioners.

(7) The 10 mSv $y^{-1}$ reference level for indoor radon corresponding to a radon activity level of 600 Bq $m^{-3}$ was later reduced to 300 Bq $m^{-3}$[1, 14]. The WHO by reflecting the epidemiological evidence that public exposure indoors due to radon is responsible for a substantial number of lung cancers in the general population reduced the level to 100 Bq $m^{-3}$ to minimise health hazards of exposure indoors due to radon[15]. The WHO also added that 'if this level cannot be reached under the prevailing country-specific conditions, the chosen reference level should not exceed 300 Bq $m^{-3}$. One might expect more synergy between the international authorities to accommodate scientifically agreed limits and levels which might be due to lack of a standardised approach.

(8) In the epidemiological studies of workers in general and for the US nuclear workers in particular[16, 17], the lifetime national mean NBG dose (i.e. 50 y $\times$ 3.1 mSv $y^{-1}$ = 155 mSv) may be added in the lifetime occupational doses of workers. In fact, one may further argue that the total mean national dose (i.e.: 50 y $\times$ 6.2 mSv $y^{-1}$ = 310 mSv)[7] may be considered in the lifetime dose of workers for epidemiological studies.

(9) The effects of fractionated occupational doses and unfractionated or less fractionated NBG doses has not been yet considered in the presently practised RP system. While this concept is well studied and practised in radiotherapy, at low doses such information seems lacking. In fact if such data are available, one may expect a change in the dose limits especially for workers. This concept is more pronounced in the URPS proposed in this paper.

## UNIVERSAL RP SYSTEM

The URPS is proposed here in order to consistently, scientifically and systematically respond to the exiting inconsistencies in RP system based on total health risks of an individual from different radiation sources with a standardised approach. The URPS concept, as recently proposed by this author[5], has a novel philosophy, concept and methodology based on integrating doses from all exposures an individual, either a worker or a member of public, receives in daily life or at work. The URPS is based on three main basic principles which:

(1) Assigns equal radiation health risks to an individual per unit radiation dose either from NBG or from man-made sources so that the health effects of radiation are a function of dose independent of the origin of radiation source, as shown in Figure 1.

(2) Applies a 'Standardized Integrated Dose System' (SIDS) to any dose limit, reference level, etc. based on integrating all doses from existing exposure situations (e.g. NBG dose) and planned exposure situations in a country. This concept is to equalise and standardise the total radiation health risks of an individual, either a worker or a member of public, in particular for workers epidemiological studies.

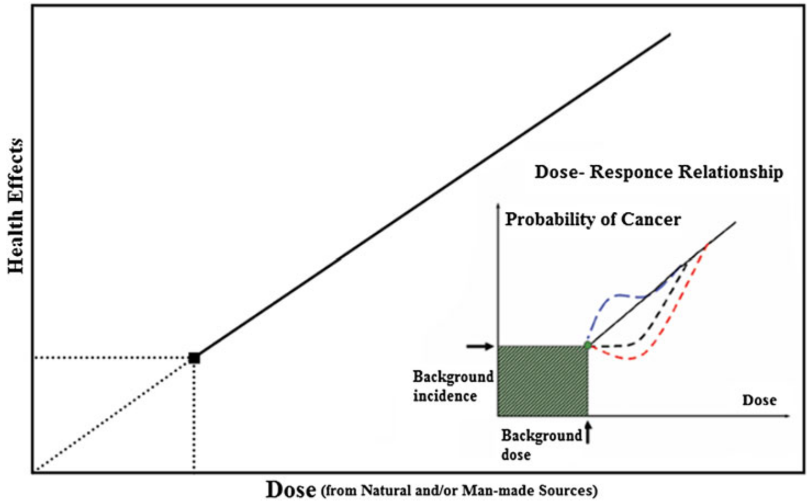


Figure 1. LNT response: health effects versus dose independent of the origin of radiation source (presently dose above the mean global NBG dose is also shown).

(3) Considers and takes into account any parameter or confounding factor affecting the effective dose (e.g. fractionation effect of exposure situations) in setting the total risk-based dose limits or reference levels and in any epidemiological studies of an individual.

Based on the three principles discussed earlier, the URPS philosophy, concept and methodology are presented, discussed and justified in terms of:

- dose limit of a member of public,
- dose limit of a radiation worker,
- fractionation effect correction factor and
- integrated dose for epidemiological studies.

**Dose limit of a member of public**

A member of public in daily life under normal conditions receives radiation exposures from existing and planned situations. The existing exposure situation is in general the national mean NBG dose (cosmic and terrestrial exposures), which ranges from ~1 to ~10 mSv $y^{-1}$ and possibly higher[1] and exposures from planned situations within a dose limit of 1 mSv $y^{-1}$[2]. In order to overcome the stated inconsistencies in public dose limit, to facilitate the implementation of any dose limit or reference level, to diminish or reduce radiophobia and set dose limits and reference levels based on total doses and potential radiation health risks, the URPS establishes the following concepts with regard to public exposure:

(1) The actual national mean NBG dose of a member of public of any country is considered as a base in setting the public dose limit or reference levels. In this context, the doses limit for public from planned exposure situation, e.g. 1 mSv $y^{-1}$, is accordingly set on top of the national mean NBG dose of a country, instead of using the UNSCEAR's global annual mean NBG dose, which is the current recommendation of the ICRP[2, 4]. Therefore, the dose received by public include the following:

$$\text{Dose limit}_{(\text{public})} = 1\,\text{mSv}\,\text{y}^{-1}\ \text{on top of}\ E_{(\text{mnbg})}$$

$$(\text{note: presently on top of} \approx 2.4\,\text{mSv}\,\text{y}^{-1}$$

where $E_{(mnbg)}$ is annual national mean NBG dose (mSv $y^{-1}$).

(2) The rationale behind this concept is the national mean NBG dose which varies from country to country and should be considered for the estimation of the total risk. For example, if a country has a national mean NBG dose of ~6 mSv $y^{-1}$, the dose limit of 1 mSv $y^{-1}$ for public from planned exposure situations is set on top of ~6 mSv $y^{-1}$. This approach can be well justified, supported and accepted by a regulatory authority. The public or a worker can also easily understand a small dose on top of the national mean NBG dose for which the public (including workers) is committed to receive it daily anyway. So, the risks of a small dose against its benefits can be easily justified, optimised and limited. One may even argue that the 1 mSv $y^{-1}$ may be added on top of

the mean national public dose received from all sources, e.g. the ~6.2 mSv $y^{-1}$, the mean national public dose from sources[7].

(3) The ICRP 82 and 107[2, 4] recommendations of two reference levels for public exposure from natural radiation, i.e. ~1 mSv $y^{-1}$ for gamma exposure from commodities indoors and ~10 mSv $y^{-1}$ for radon gas indoors, can be combined into one reference level, e.g. 10 mSv $y^{-1}$, which can be better implemented by a regulatory authority and service providers.

(4) Using RP quantities such as equivalent dose, effective dose, etc. and units such as mSv $y^{-1}$ are also difficult for public to understand and digest. A simple term such as a 'Dose Unit' can be simply used for public information and mass media reports with a meaning 'mSv' or 'mSv $y^{-1}$'.

## Dose limit for a worker

A worker in daily life, like any member of public, receives radiation exposures from the existing and also planned situations or possibly from emergency situations. In addition, a worker receives occupational doses. At present, only the occupation exposure of a worker is considered and limited to 20 mSv $y^{-1}$ with no consideration of doses or risks from other sources received by a worker. Even, long-life doses from national mean NBG dose of a worker have not been considered in the extensive one million US nuclear workers' epidemiological studies[16, 17]. In this context, a dose limitation system is formulated here for workers in order to:

(a) overcome the inconsistencies and shortcomings for dose limits of workers worldwide,
(b) facilitate implementation of dose limit or reference level with an standardised approach,
(c) set dose limits and reference levels by considering risks from all exposures a worker receives in daily life and at work and
(d) standardise and equalise the total radiation health risks of a worker independent of the country the worker works and lives in.

Therefore, the URPS integrates doses of a worker either received occupationally or as a member of public within a dose limit, independent of the sources of origin, based on the following equation:

$$\text{Dose limit}_{(\text{workers})}(\text{mSv}\,\text{y}^{-1}) \geq E_{(\text{oe})} + E_{(\text{pes})} + E_{(\text{mnbg})} + (\text{ possibly } E_{(\text{m})})$$

where $E_{(oe)}$ is annual occupational dose as a worker (mSv $y^{-1}$); $E_{(mnbg)}$ is annual national mean NBG effective dose as a member of public (mSv $y^{-1}$); $E_{(pes)}$ represents annual dose from planned exposure situation within the public dose limit as a member of public (mSv $y^{-1}$) and $E_{(m)}$ is possibly annual medical exposure at least for epidemiological studies (mSv $y^{-1}$).

By applying the URPS philosophy concept, the risks from at least two major exposure situations (existing and planned) are integrated within a dose limit, i.e. the occupational exposure and the national mean NBG doses. If the NBG dose is not available, the information should be determined in a country as a priority. Some examples of such dose limitation system by considering the national mean NBG dose from ~1 to ~10 mSv $y^{-1}$and even applying the present 5-y mean dose limit of 20 mSv $y^{-1}$ are as follows:

- If a country has a national mean NBG dose of ~1 mSv $y^{-1}$, the occupational dose to be received by a worker in that country is up to ~19 mSv $y^{-1}$.
- If a country has a national mean NBG dose of ~10 mSv $y^{-1}$, the occupational dose to be received by a worker in that country is ~10 mSv $y^{-1}$.

If the present mean dose limit of 20 mSv $y^{-1}$ is kept as it is, the above-mentioned method is still functional since occupational doses in real situations as reported by UNSCEAR are extremely low in general and even in the nuclear industry compared with the national mean NBG dose of a country[1]. However, if the presently dose limit of 20 mSv $y^{-1}$ needs to be increased, the present limit can be kept as a 'Dose Constraint' under an upper dose limit of for example 25 mSv $y^{-1}$; i.e. within a dose band of 5 mSv $y^{-1}$.

## Fractionation effect dose correction

It is generally known from experimental radiobiology that as the absorbed dose of radiation increases, the number of cells survived or survival fraction decreases. In fact cell killing requires a greater total dose when given in several fractions due to self-repair mechanism that may occur for a tissue. This self-repair of course depends on many factors such as type of radiation, energy, LET, dose fractionation, number of fractionations, environmental conditions, etc. The fractionation concept is well practised at high doses in radiotherapy. However, fractionation effect is less known at low doses and dose rates as occurs in RP. This does not mean that there is no fractionation effect at low doses unless otherwise it is proven. This effect is in fact important when lifetime occupational exposure for epidemiological studies is of concern or even for setting the dose limit and annual dose calculations based on the URPS principles. The annual effective doses of a worker are highly fractionated in 250 working days in 50 weeks per year: at least 250 times per year (each duration maximum up to 8 h per d). There is at least 16 h between two fractionations in consecutive days and 72 h during the weekends, at least 15 d during holidays in developed countries and very long durations in some developing countries due to many holidays.

On the other hand, the NBG dose is approximately unfractionated. When the URPS philosophy and concept are applied, then the fractionation of occupational dose and non-fractionation of the national NBG dose of a worker are of concern. If fractionation is considered for occupational exposure, then one may expect even the dose limit to be larger than that presently applied. Until enough information is available, one may assume a fractionation correction factor ($C_F$) of 1 for occupational exposure and 1 for NBG exposure, which needs further to be studied.

### Integrated dose for epidemiological studies

The epidemiological study of workers is of highest importance and should be based on a correct total radiation-based health risks. So far, except for cases of natural radiation in high NBG radiation or radon-prone areas as well as radon in mines and or/dwellings[9, 12], only lifetime occupational exposures have been considered in general and even in studies of one million US radiation workers in particular[16, 17]. The national mean NBG dose of workers is an important contribution to epidemiological studies. By assigning equal health risks per unit dose from NBG and man-made sources, the national mean NBG dose in particular for prolonged lifetime exposures can be a significant dose that plays a major role in epidemiological results of workers. For example, the lifetime 50-y mean NBG dose in the USA is ~155 mSv (e.g. 50 y × 3.1 mSv $y^{-1}$ = 155 mSv), which is much higher than the lifetime doses of 76 % of workers under study in the lifetime occupational doses[16, 17]. In fact, one may further argue that the mean national dose of 6.2 mSv $y^{-1}$ in USA (50 y × 6.2 mSv $y^{-1}$ = 310 mSv) should be included in the lifetime occupational dose. When the doses are integrated, then dose fractionation can be considered significant in epidemiological studies.

Having said the above, the total effective dose of workers for epidemiological studies by considering fractionation factor ($C_F$) may be given as follows:

$$E_c = E_{(oe)} \cdot C_{(Foe)} + E_{(mbgr)} \cdot C_{(Fnbg)} + E_{(pes)} \cdot C_{(Fpes)}$$

where $E_c$ is annual effective dose of a worker corrected for fractionation effect; $E_{(oe)}$ is annual occupational dose of a worker; $C_{(Foe)}$ represents dose fractionation factor for occupational exposure (to be considered ≤1); $E_{(mnbg)}$ is annual dose from national mean NBG dose; $C_{(Fnbg)}$ is dose fractionation factor for NBG dose (to be considered ~1); $E_{(pes)}$ is annual dose from planned exposure situation and $C_{(Fpes)}$ is dose fractionation factor for planned exposure situation (depending on the situation, it can be considered ~1).

## CONCLUSIONS

The URPS proposed here has a novel philosophy, concept and methodology based on a 'Standardized Integrated Dose System' (SIDS) approach. The URPS:

(1) Assigns to an individual either a member of public or a worker in any country equal radiation-based health risks per unit effective dose either from national NBG or from man-made sources,
(2) Respects the LNT, based on the present-state-of-the art practised worldwide, but by considering radiation effects as a function of dose independent of source of origin,
(3) Integrates for a member of public doses from planned exposure situations within a dose limit (e.g. 1 mSv $y^{-1}$) on top of the national mean NBG dose,
(4) Integrates for workers the doses from occupational exposure, national mean NBG and planned exposure situations within a dose limit to equalise radiation health risks worldwide,
(5) Integrates lifetime doses (e.g. 50 y) from national mean NBG and occupational exposure of a worker for any epidemiological studies applying also a fractionation effect correction factor,
(6) Applies a user-friendly universal system by simple philosophy understandable by all including members of the public, workers and even a regulatory body to prevent radiophobia,
(7) Assigns equal standardised radiation-based health risk limits for workers no matter where they work and live in the world,
(8) Simplifies regulatory service provision,
(9) Possibly bridges the gaps between hormesis and LNT concepts to minimise controversies and

The URPS is believed to be a solution to the controversies in the present RP system. It for sure ignites thoughts and ideas by brainstorming, feedbacks, support, etc. in order to be universally accepted and applied towards protecting man and the environment. The URPS is believed to have a high impact on its standardised approach to decision-making and to better regulate RP of workers and public and communication with them. It is hoped and expected that the URPS will be considered by the world leading commissions, committees and organisations dealing with RP decision-making worldwide. The concept is being further developed by the author hopefully in cooperation with the world RP specialists and regulatory authorities worldwide such as UNSCEAR, ICRP, NCRP, IAEA, WHO, ILO, etc. The author is available to cooperate with any national and international organisation, commission, committee, etc. to develop and evolve the RP of workers and public by a standardised approach.

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