



Editorial

## Conservation of “Cause-Effect” by using Integrated Individual Radiation Doses towards Standardization of Epidemiology Health-Risk Estimates of Nuclear/Radiation Workers

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Major efforts have been in progress over the past few decades worldwide on applying low dose/low dose rate ionizing radiation exposures to epidemiological studies of public and in particular radiation workers to estimate radiation health risks to either further support the linear no-threshold (LNT) hypothesis or the hormesis model or any other acceptable models [1,2]. This is in fact the main challenging issue in the practice of present radiation protection philosophy for protection of workers, public and the environment in ionizing radiation applications. Presently, “occupational exposure” in the system of dose limitation and epidemiology studies of workers are only based on radiation doses received during radiation work with no consideration of any doses received from other sources such as chronic natural background (NBR) radiation.

In particular, in several extensive studies in recent progress by highly profound groups of world leading radiation protection and epidemiology expert groups, protracted low-doses/dose rates have been applied to the studies of human health effects and health risk estimation of public and workers [2-11]. Some examples of such studies include applying high doses/dose rates of high NBR radiation areas on residents [3-5], exposures of normal NBR radiation areas on children [6], or occupational low doses/dose rate exposures on radiation workers [7-11]. For example, as regards to NBR radiation exposures of public, the exposures from terrestrial gamma and cosmic rays have been applied to the studies on the risk of childhood cancer among 2,093,660 children <16 y in a census-based nationwide cohort study, suggesting that exposures from terrestrial gamma and cosmic rays may contribute to the risk of cancer in children, including leukemia and central nervous system tumors [6].

Other than the NBR radiation epidemiology studies of public which is based on chronic low dose/dose rate exposures, presently in epidemiology studies of workers only total or partial dose equivalent of occupational exposure of workers from man-made sources are

considered [2-6]; e.g. “external and internal occupational exposures” in the US Million Nuclear Workers Study, only “external occupational exposure” of the US radiologic technologists (1983-2005) in the risk estimate of basal cell carcinoma, and only the “external occupational exposure” with a mean individual cumulative external dose of 25 mSv in the international nuclear workers study (INWORKS) with relatively large cohort size of 308 297 workers of United States of America (USA), United Kingdom (UK) and France over the period 1945–2005 with a mean attained of 58 y age at the end of a mean duration follow-up of 27 years [9-11]. The study of the estimated dose–risk relationship, based upon analyses of the death rates from cancer other than leukemia depending on age and cumulative dose observed in the study cohort, and under the assumption that this relationship was causal, lead to an estimation that the proportion of death attributable to external exposure to radiation within the population of INWORKS was around 1% of all deaths from solid cancer, and around 6% of all deaths from non-CLL leukemia [7-11]. The INWORKS is in fact one of the series of papers published on the stated topic with a claim that the study assembled some of the strongest evidence to strengthen the scientific basis for the protection of adults from low dose, low-dose rate, exposures to ionizing radiation [9-11].

The above stated studies highly indicate the importance of also environmental NBR radiation exposures on public at large, including radiation workers as being exposed also as a member of public. In particular, the importance given to the major contribution of the NBR radiation dose to the health risks in children can be significant when integrated and extended over lifetime exposure of public in particular radiation workers being in principle members of the public.

By a close look into the present radiation protection philosophy, concepts and in particular protocols on individual occupational dose limitation and occupational doses applied to epidemiology risk studies, some major concerns and questions are raised in particular why the actual integrated individual radiation doses of workers have not yet been included into the system of dose limitation and in turn into the calculation of health risk estimates of workers and whether or not such human health risk estimates based on present epidemiology studies can be valid to be used in radiation protection [1,2,12,13]?

As also stated above, the presently practiced system of dose limitation of workers only applies occupational radiation exposures in the system of dose limitation [1]. Also only “occupational external doses” or “occupational external and internal doses” are applied for large-scale epidemiology studies of workers [7-11]. In fact the exposures a worker receives as a member of public is more in value and in principle can have even more health effects than the doses received from occupational exposure.

When human body is exposed to ionizing radiation no matter what the source (s) of radiation exposure is, the consistency of “cause and effect” should be carefully conserved. The “cause” is in this case the total integral effective dose of an individual, internal and external doses, the dose and dose rate, type and energy of ionizing radiation, and in particular whether the radiation exposure received is “chronic and unfractionated” (like exposures of public in general from the environmental NBR radiation) or “fractionated” (like occupational exposure), no matter where the sources of radiation are from; natural

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or man-made [2]. According to the recently proposed "Universal Radiation Protection System (URPS) Hypothesis", a radiation worker is an individual who receives ionizing radiation exposures as a member of public from natural and man-made sources in daily life and an additional occupational radiation exposure as an employee in a radiation/nuclear center" [2,12,13]. A parameter of crucial importance in radiation protection dose limitation system is in fact the effects of "fractionation of dose"; a parameter commonly applied in radiotherapy which has been recently also proposed to be applied in a radiation protection dose limitation system [2,12,13]. According to the URPS hypothesis, occupational exposure is considered highly "fractionated" and the NBG exposure highly "chronic and unfractionated" internal and external exposure [2]. Therefore, a worker is continuously exposed to radiation internally and externally for which effective doses should be considered.

As an example, the INWORKS cohort has a mean cumulative external dose of 25 mSv from a highly "fractionated" external occupational radiation exposure with a mean attained of 58 y age [9-11]. Then each member of cohort for example in the United States has received additionally a mean national exposure of 6.2 mSv.y<sup>-1</sup> [14], from which 3.1 mSv.y<sup>-1</sup> is from chronic unfractionated NBG radiation exposure. Accordingly, even at this stage of development of the "URPS Hypothesis" if only the mean NBG exposure (3.1 mSv.y<sup>-1</sup>) from 6.2 mSv.y<sup>-1</sup> is considered, an INWORKS worker has received from birth approximately 58 y x 3.1 mSv.y<sup>-1</sup>=180 mSv from unfractionated NBG exposure, as a member of public (assuming a constant mean annual NBG dose since the birth). This 180 mSv lifetime dose a worker has received also as a member of public in USA (or in other countries) is a "chronic and unfractionated dose" of NBG radiation exposure which is overall >7.2 times higher than the 25 mSv a worker has received from "fractionated" occupational exposure as a profession. A worker for example in France, UK and USA or in many other countries in the world works 250 days in 50 weeks per year and 8 hours per day making a total of 2000 man-hour work per year. There is at least 16 hours between two occupational exposure periods during week days and about 68 hours during the weekends, at least 15 days during annual leaves in developed countries and very long durations in some developing countries due to many holidays. Therefore, it is extremely important to consider the "fractionation effect" of occupational doses for estimating risks of radiation workers. If a "fractionation factor" of 1 is applied to "unfractionated NBG dose" and a "fractionation factor" as an example of 0.~5 is applied to occupational exposure, then the ~ mean corrected dose for fractionation applied to INWORKS cohort member will be reduced to 12.5 mSv (25 mSv x 0.5). Therefore, the total exposure, even by ignoring other national exposures in USA, will be 180 + 12.5=192.5 mSv which is >15.4 times higher than the presently applied occupational external exposure of INWORKS. Therefore, considering only partial (external) or total (external + internal) occupational exposure received by a worker in any health risk estimates without adding the lifetime NBG dose of a worker and applying "fractionation factors" lacks conservation of "cause and effect" and it highly overestimates workers' radiation health risks. Consideration of the confounding factors is also a major concern in such studies which have not dealt with in this study.

The epidemiology studies of workers in progress have some high strengths such as highly distinguished top-notch expert groups; large cohort sizes; advanced and long-term individual dose and health registries (occupational and public) and high national and international supports [7-11]. Therefore, such studies deserve having

a new look into an alternative approach based on the "standardized integrated individual dose system" of the "URPS Hypothesis" [2,13,14]. To apply this alternative URPS radiation dosimetry protocol to dose limitation and in particular to epidemiology of workers, the individual effective doses to be integrated should include: effective doses a worker receives occupationally from external/internal x, γ, β, neutron exposures; retrospective effective doses as a member of public from national NBG exposure (such as radon) monthly/lifetime, doses up to 1 mSv.y<sup>-1</sup> ICRP dose limit of public from man-made operations and doses from other sources such as possibly from medical exposure. Even the effects from other exposures such as non-ionizing radiations and other confounding factors should also be taken into the "effects" consideration to fulfill the requirements for a correct effect for acceptable risk estimation. Last but not least, in this novel alternative "standardized integrated individual dose system" proposed by the "URPS Hypothesis", the occupational exposure should be considered as highly "fractionated" and the national NBG radiation exposure as "chronic and unfractionated" [2,12,13].

To conclude, the author believes that the present dose limitation system and in turn the individual doses integrated over an extended period a worker is occupationally exposed to radiation as applied to epidemiology studies are considered only partial doses and not the actual doses. In addition, the doses an individual occupationally received is also highly fractionated which highly reduce the effective dose a worker receives. Therefore, it is a vital need to apply a new philosophy, concept and methodology for dose integration. The "URPS Hypothesis" is believed being novel, scientific, logical, standardized and consistent while also conserving and standardizing the "cause and effect" principles of ionizing radiation exposures for epidemiology studies as well as for "dose limitation" of a worker and public. In particular, it makes the radiation protection system universally standardized by having all radiation workers "risk limit" independent of the country they live in [2]. In this context, the "standardized integrated dose system" of the "URPS Hypothesis" is recommended for setting a dose limitation system and for estimation of radiation health-risks of workers in radiation/nuclear applications.

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