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"LOW DOSE" AND/OR "HIGH DOSE" IN RADIATION PROTECTION: A NEED TO SETTING CRITERIA FOR DOSE CLASSIFICATION

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ABSTRACT

The "low dose" and/or "high dose" of ionizing radiation are common terms widely used in radiation applications, radiation protection and radiobiology, and natural radiation environment. Reading the title, the papers of this interesting and highly important conference and the related literature, one can simply raise the question; "What are the levels and/or criteria for defining a low dose or a high dose of ionizing radiation?". This is due to the fact that the criteria for these terms and for dose levels between these two extreme quantities have not yet been set, so that the terms relatively lower doses or higher doses are usually applied. Therefore, setting criteria for classification of radiation doses in the above mentioned areas seems a vital need. The author while realizing the existing problems to achieve this important task, has made efforts in this paper to justify this need and has proposed some criteria, in particular for the classification of natural radiation areas, based on a system of dose limitation.

In radiation applications, a "low dose" is commonly associated to applications delivering a dose such as given to a patient in a medical diagnosis and a "high dose" is referred to a dose in applications such as radiotherapy, mutation breeding, control of sprouting, control of insects, delay ripening, and sterilization having a range of doses from 1 to 10^5 Gy, for which the term "high dose dosimetry" is applied [1].

In radiation protection and radiobiology, although the terms "low dose" and "high dose" are frequently used, they have been rather vaguely defined, mainly based on the domain of the application and the researcher's interest. Some criteria used for the term "low dose" include: dose levels experienced with typical occupational (below allowable dose limits) and medical diagnosis exposures [2]; or 1 mSv y^{-1}, the dose limit for public as a practical meaning of low level neutron monitoring [3]; or a small cumulative dose, e.g. under 10 rem (0.1 Sv) [4]; or low dose effects such as single traversal of charged particles through individual cells [5]; or low dose radiation cancer risks for doses $<$ 20 cSv (rem) [6]; or doses above background levels yet below that which could induce acute effects usually associated with cell death [7]; or a dose level below which control of radiation exposures would be deliberately and specifically curtailed which must be below any established limit for specific practices, known as *"de minimis dose"* [8]; etc.

On the other hand, the term "high dose" in radiation protection and radiobiology has been considered a level for which the radiation risk is clearly detrimental, the scene being dominated by the detrimental effects, e.g. death via the acute radiation syndrome [9]. By considering a "low dose" in the ranges given above, and a "high dose" when the effect is detrimental, the range between them has not yet been classified and the doses between are usually referred relative to a "low dose" or a "high dose" level. Even the term "low dose" in radiobiology based on a single traversal of a charged particle through the nucleus of a cell, while it can be considered a "low dose" when averaged over the whole volume, it will be a "high dose" when only mass of the volume of the affected area around the trajectory of the particle is concerned.

The term "high level" has also been commonly applied to natural radiation environment, where the potential exposure is even few times higher than that of normal background areas. For example, the exposures even between 15 to 30 μR h^{-1} with small peaks between 35 and 45 μR h^{-1}, as it is in Fichtelgebirge, Germany, have been considered high [10], as compared to 9 mR h^{-1} in some areas in Ramsar, Iran [11]. This has been a common practice based on which at least four international conferences on high level natural radiation areas (HLNRA) have been organized [12]. Using the term "high level" is in fact not always a justified practice and it can cause radiophobia among public living in areas not having high enough exposures to be classified as a real HLNRA. So, for biological and epidemiological studies, it has been also necessary to set criteria for classification of natural radiation environment based on potential exposures and/or internal and external exposures of the public.

For a HLNRA, some criteria have also been proposed. For example, a HLNRA has been characterized as an area where one or more parameters such as the exposure rate over an extended area, long-term alpha activity ingested or inhaled, radon concentration of potable water, and ^{222}Rn and ^{220}Rn levels in air are higher than certain levels, and a population higher than 1000 [13,14]. The NCRP has used the term "unusual exposure", i.e. a level different from the mean with concerns for values above the mean [15].

For a radon prone-area, the criteria given by ICRP include an area with more than 1% of dwellings having radon concentrations more than 10 times the national average value [16]. The NRPB in UK has used the term "affected area" rather than "radon-prone area" and has expressed it as an area within which a certain percentage of present and future dwellings might exceed a predetermined action level and from which certain consequences would follow [17]. Also Scott [18], selecting one of the three concepts for radon-prone areas he proposed, defines a radon-prone area as an area where the average risk (radon concentration) to public is high enough to justify an action program.

The above criteria or definitions more or less have classified only two extreme classes of "low" and "high" doses with no levels defined between them. Also, the levels should be defined specific for each area including: (i) radiation applications, (ii) radiation protection and radiobiology, and (iii) natural radiation environment. One approach is to classify the whole dose range into four dose classes: e.g. "low dose", "medium dose", "high dose" and "very high dose". Setting such criteria will provide: (1) Standardized levels for dose classes for harmonized worldwide studies, (2) Proper classification of; (i) radiation applications for implementation of regulatory practices; radiation protection and radiobiology for harmonized radiation effect studies and for proper setting of criteria for protection of workers and public, and (iii) natural radiation environment for biological and epidemiological studies and risk assessment, implementation of remedial actions, prevention of radiophobia, and uniform protection of public, (3) Establishment of a regulatory system and framework for implementation of regulatory practices, and (4) Worldwide harmonization of radiation protection implementation and regulatory practices.

In radiation applications, the four dose classes, for example, may be defined based on type of sources, type of applications (e.g. medicine and industry), and potential exposures involved. In radiation protection and radiobiology, the four dose classes may be defined: for example, up to the ICRP dose limit for workers as a "low dose"; from this level to a dose of a few hundred mGy from which measurable health effects can be detected as a "medium dose"; and from this level to a dose where health effects are clearly shown as a "high dose", and above this level which can considered lethal as a "very high dose". The above are just some examples given and further research are underway for more specific classifications.

For natural radiation areas, another criteria have been proposed [19,20], applying the annual global average effective dose of 2.4 mSv y^{-1} from normal background areas of UNSCEAR [21], as well as the ICRP dose limits [22], based on which four dose classes have been defined as follow:

1. A "low dose natural radiation area" (LDNRA) or a "low level natural radiation area" (LLNRA); an area or a complex of dwellings where the cosmic radiation, and cosmogonic and terrestrial radionuclides in soil, outdoor air, indoor air, water, food, etc. lead to exposures and/or radioactivity levels causing an internal and/or external public exposure, which falls below or is equal to two times the average global annual effective dose from natural sources given for example by UNSCEAR [20]; i.e. $2 \times 2.4 = 4.8$ or ≈ 5 mSv y^{-1} or a dose level ≤ 5 mSv y^{-1}. No remedial action is recommended for such LLNRAs although some simple measures can always mitigate the national average annual effective dose.
2. A "medium dose natural radiation area" (MDNRA) or a "medium level natural radiation area" (MLNRA); an area or a complex of dwellings where cosmic radiations, and cosmogonic and terrestrial radionuclides in soil, outdoor air, indoor air, water, food, etc. lead to exposures and/or radioactivity levels causing an internal and/or external public exposure which is higher than the upper limit for LLNRA, or 5 mSv y^{-1}, but it falls below or is equal to a pre-established level or limit; for example the dose limit of 20 mSv y^{-1} for radiation workers [21]. A remedial action is required to be implemented within a time frame to be determined; for example within 5 years.
3. A "high dose natural radiation area" (HDNRA) or a "high level natural radiation area" (HLNRA); an area or a complex of dwellings where cosmic radiation, and cosmogonic and terrestrial radionuclides in soil, outdoor air, indoor air, water, food, etc. lead to exposures and/or radioactivity levels causing an internal and/or external public exposure which is higher than 20 mSv y^{-1}, the upper limit for a MLNRA, but it falls below or is equal to, for example, 50 mSv y^{-1}, the former ICRP dose limit for radiation workers. A remedial action should be implemented subject to a regulatory control within a time frame to be calculated; for example within one year.
4. A "very high dose natural radiation area" (VHDNRA) or a "very high level natural area" (VHLNRA); an area or a complex of dwellings where the cosmic radiation, and cosmogonic and terrestrial radionuclides in soil, outdoor air, indoor air, water, food, etc. have exposures and/or radioactivity levels to lead to an internal and/or external public exposures higher than the upper limit for a HLNRA; i.e. 50 mSv y^{-1}. Evacuation is recommended as the first step in the remedial action program to be enforced by a regulatory authority.

Based on the criteria proposed, some areas in the world known as HLNRA have been tentatively classified as LLNRA or MLNRA. The criteria can also be easily applied as a regulatory framework and a system for implementation of remedial actions, and for biological and epidemiological studies. They can also be directly applied to define radon-prone areas and to classify them accordingly.

In conclusion, the above proposals are just examples so that other criteria may be further proposed; yet they are open for criticism, improvement, and/or approval to be used as criteria for worldwide use. Further research are underway by the author.

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