INEA STATEMENT ON RADIATION AND HEALTH - CONFIRMING EVIDENCE

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Nuclear technologies already provide humanity and the environment with the enormous benefit of a large supply of non-polluting electrical energy. The benefit from nuclear energy could be increased substantially by employing it to desalinate sea water. However, nuclear technologies are being abandoned because of the social concerns and fears that have been created about the health effects of nuclear radiation, specifically about the risk of excess cancer deaths from any exposure, no matter how small. This is apparent from public and government reactions to the consequences of the Fukushima NPP accident and the concerns of many physicians and patients regarding potential risks of x-rays and nuclear radiations used in medical imaging. The real effects of ionizing radiation are very different from current and past beliefs. High, intense radiation is indeed harmful, but a low dose or a low dose rate actually produces remarkable, positive effects in all organisms. How can this be?

The reason is not difficult to understand. Every living thing adapts to its environment, which includes natural background radiation. When a perturbation occurs—for instance, an increase in the radiation level or a high short-term exposure—the activities of the protection systems increase, both the immediately-acting ones and the delayed adaptive defences, some of which persist for days, weeks and much longer. The stimulated protection systems act, not only on the additional damage that was or is being produced by the radiation increase, but also on the much more extensive damage that is occurring continuously due to the natural endogenous processes (e.g., oxygen in metabolism, thermal effects) and the changes being caused by the external disturbances, such as injuries, infections and ingestion of chemicals. The overall response to the radiation increase results in an improvement in health, including a reduction in the risk of cancer.

Powerful medicinal properties of x-rays and radium were observed soon after their discovery[1, 2] and medical practitioners began to cure many illnesses using these radiations in imaging and therapies. However, the early radiologists suffered from burns and a higher incidence of neoplasm mortality than did their peers. Protection advice began to appear in 1913. Soon after, the British Roentgen Society issued a warning and then recommendations in 1921.[3] A 1981 study of the British radiologists covered the period 1897-1954 and revealed that those who entered the profession after 1920 actually had a lower incidence of cancer mortality and mortality from all causes.[4] In 1925, the International Congress of Radiology was formed, evolving into the International Commission of Radiation Units and Measurements (ICRU) with the subsequent creation of the International Commission of Radiological Protection (ICRP). In 1928, the ICRP issued recommendations for radiologists, emphasizing that they should avoid unnecessary exposures. Its 1934 meeting recommended a dose limit, a tolerance dose of 0.2 roentgens per day,[3] implying the concept of a safe threshold. This limit, about 700 mGy[*] per year, had been recommended in the 1924 meeting of the American Roentgen Ray Society. The ICRP became active again after WWII and began addressing the concerns of potential harm being raised by geneticists at the time. Its 1950 report recommended a maximum permissible dose of 0.5 roentgen per week. In 1980, Lauriston Taylor stated: "No one has been identifiably injured by radiation while working within the first numerical standards set by the NCRP and the ICRP in 1934."[27]

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[*] The Gray (Gy) is the System International unit of absorbed radiation dose. 1 Gy = 1 joule/kg

While physicians were treating patients with radiation, biologists were studying its effects on all other organisms. They discovered that low doses produced beneficial effects and high doses caused harm. A 1915 study showed high x radiation rendered mice susceptible to transplanted tumors, but the damaged defences were regenerated. However, a small dose to the animals stimulated very strong protection, a complete immunity, against their spontaneous cancers.[5]

Meanwhile, geneticists were studying potential causes of genetic change. Several of them reported that germinal changes could induced by x or radium rays. Hermann Muller was the first to demonstrate inducible heritable changes by an environmental agent, i.e., x-rays. His 1927 paper, which led to his Nobel Prize, indicated that he was a eugenicist who wanted to produced mutations "to order" and create artificial races.[6] He produced true gene (sex-linked recessive lethal) mutations in the germ cells of fruit flies, by a "heavy treatment" of x-rays— a dose rate 8000 R/h and irradiation times of 12, 24, 36 and 48 minutes.[7] At the highest dose tested, the mutation rate was 150 times the rate in untreated germ cells. The rate varied as the square root of the dose. Experiments by others at high dose rates indicated a linear dose-response relationship. A linear no-threshold (LNT) model supported the physics-based target theory concept that had been established prior to Muller's discovery of inducible mutations.[8]

Radiation target theory as applied to mutations was formulated by the detailed interactions and collaborations of leading radiation geneticists and theoretical physicists during the mid-1930s. They established a conceptual framework for gene structure, target theory for the induction of mutations via ionizing radiation, the single-hit mechanism hypothesis to account for the shape of the LNT dose response, and the application of this dose-response model for what is modern cancer risk assessment. This theory saw mutations as a purely physical action following an "all or none" law. The energy of ionizing radiation was assumed essentially to be transformed into a genetic effect, which is in contrast to normal physiology that invariably deals with large numbers of molecules of many kinds in the evolution of genetically determined body changes, and where the elimination of a single molecule would not result in observable effects.[8]

Muller, who collaborated in the establishment of target theory, was so committed to the LNT model of radiation-induced mutations that he ignored the scientific evidence of a threshold in an experiment that he reviewed prior to receiving his Nobel Prize in December 1946. Muller, not understanding the complexity of generating a body change from an alteration of genes, misled the world during his acceptance speech in which he stated that there is “no escape from the conclusion that there is no threshold.”[9, 10, 11]

Scientists had questioned whether the dose-response would still be linear with a low dose-rate, so Ernest Caspari measured the fruit fly mutation rate for a dose of 52.5 R[†] delivered in 21 days. This dose was 30 times lower than the lowest dose Muller used, and the 0.10 R/h dose rate was 80 thousand times lower than used by Muller. Caspari measured a threshold dose-response, which contradicted the LNT model. The control cultures and the experimental cultures numbered 56,252, and 51,963 respectively. The first two statements in the summary of his paper are:

1. The rate of lethal sex-linked mutations in Drosophila exposed to gamma-rays of 2.5 r units per day through 21 days (total 52.5 r) was determined.
2. In a total material of 108,215 chromosomes tested, no significant difference between experimentals and controls was found.

The supervisor Curt Stern, a long-time supporter of the linear dose-response model, deleted the threshold dose-response conclusion and published Caspari`s paper with a negative discussion

[†] An exposure of 1 R (roentgen) means that the radiation dose to ordinary tissue is about 9.3 mGy.[25]

to explain why these data should not be accepted and utilized. This marginalized paper[12] did not receive an independent peer review.[10, 13, 14]

The dropping of atomic bombs in 1945 to end the war in Japan was followed by development, testing and large-scale production of nuclear weapons. Fears of nuclear warfare drove many scientists to strong political actions against the nuclear arms race. One of their strategies was to create and promote extreme social fear of low-level radiation from radioactive "fallout."[15]

With sixty years of prior knowledge and experience in the use x-rays and radium to diagnose and treat a wide variety of illnesses, without a significant increase in cancer mortality, how was it possible for scientists to create such a strong fear of radiation in the 1950s? And how could this phobia persist over the subsequent sixty years, and continue even today, as important scientific advances were being made in biology and genetics and effects of radiation on cells, tissues and organisms?

The Stern and Muller deceptions contributed to the 1956 decision of the U.S. National Academy of Sciences to recommend a linear dose-response policy for assessing risks to the genome from ionizing radiation, replacing the threshold dose-response model.[16] This recommendation initiated a series of advisory and regulatory actions in essentially all countries to adopt linearity and apply it to somatic effects, that is, cancer risk assessment, for ionizing radiation and later for chemical carcinogens.[13] The ICRP began to produce many new recommendations that were based on 1) the concept of the LNT hypothesis, 2) the notion of "stochastic" health effects, and 3) the high-dose cancer mortality statistics of the atomic bomb survivors.

The radiation protection organizations and nuclear regulators have made errors of omission by ignoring information on the following very important discoveries:

1) DNA molecules are not stable—single and double-strand breaks occur spontaneously at very high rates due to natural, internal causes.[17]
2) Organisms have very powerful protection systems, immediate and adaptive, that deal with cell damage and all other injuries and health risks.[18]
3) Many of these protection systems are up-regulated by radiation, a low acute dose or a low chronic dose rate, to produce beneficial health effects that outweigh harm, including a reduced risk of cancer.[19, 20]
4) Many different and important medical treatments were carried out, starting in 1896, using low doses of radiation to cure serious illnesses without causing cancers.[21, 22] Humanity risks losing important health benefits if it continues to ignore this evidence.[24]
5) The 1981 study of the British radiologists.[4] It demonstrated that radiation protection based on the tolerance dose concept, introduced in 1921, is effective and more than adequate.

Recommendations:

1) Professional societies should organize events to learn and discuss the facts that have been discovered about biological effects of radiation. They should question risk concepts that are based on primitive target theory.
2) Professionals should urge the nuclear regulators and the radiation protection organizations to examine all the data, both beneficial and harmful, and to comply with the requirements of The Scientific Method in setting safe limits for acute and chronic radiation exposures.
3) Regulators should develop and implement a communication program to explain the real effects of radiation to all people, and should stop regulating harmless radiation sources, such as radon in homes. The radon level in many homes in Ramsar, Iran is much higher

than in most homes elsewhere, and no significant detrimental effect, such as increased incidence of cancer has been observed there.[26]

4) For radiation protection, use a dose-response relationship that is based on scientific evidence.[23] Stop calculating risk of excess cancers using the invalid LNT methodology.
5) In medical diagnostics, physicians should not avoid x-ray images and CT-scans because of unjustifiable concerns about cancer risks calculated using the LNT hypothesis. A low dose of radiation up-regulates adaptive protection systems that induce beneficial health effects, including a lower incidence of cancer.
6) Humanity should learn the most important lessons from the Chernobyl and Fukushima accidents that have not yet been learned:
   - Severe accidents release radioactive materials that result mainly in low dose levels.
   - Long-term evacuation of residents is not appropriate unless there is a real risk of harm in remaining at home. The radiation limit should be based on the threshold for harm.
   - Unnecessary precautionary measures should be avoided because they cause severe psychological stress that results in many premature deaths.
7) The radiation level for precautionary measures, in the event of an accident, should be set as high as reasonably safe,[28] based on the known thresholds for biological harm. The scientific evidence reviewed in Reference 15 suggests that the threshold for harm, due to a continuous exposure, is a dose rate of about 700 mGy per year. The UNSCEAR 1958 data for leukemia incidence among the Hiroshima atomic bomb survivors suggest that the threshold for harm for an acute exposure is about 500 mGy.[15]

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