Radiation Hormesis & Zero-Risk Threshold Dose: Two Scientifically Refuted, but Stubborn Myths

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Hormesis is the presumption that exposing people to increased doses of ionizing radiation from nuclear technology, over and above unavoidable cosmic or terrestrial background levels, will make them healthier (i.e. will strengthen their immune systems). This notion probably arose from a superficial but scientifically false analogy with beneficial effects of vaccinations, by ignoring the fundamentally different interaction of ionizing radiation with living tissue, as compared to that of bacteria, viruses, or chemicals. Hormesis has also been posited by an equally unwarranted generalization from laboratory observations in cells to the health status of people. Under certain conditions, isolated cells exhibit an "adaptive response", i.e. a decrease in their sensitivity to a poison or pollutant, including radiation, - after a first exposure - to subsequent exposures to the same agent. However, health studies on human populations have never shown any evidence for such protective effects of a previous exposure to radiation on subsequent health effects from chronic level occupational exposures *(provided all confounding selection effects [1] were taken into account)*. In other words, *there exists no credible evidence for a reduction in radiogenic risk for cancers or other diseases with increasing exposures above unavoidable background radiation.* Nevertheless, several erroneously interpreted epidemiological studies continue to be cited repeatedly as "scientific proofs"[2] by promoters of hormesis[3].

Promotion of hormesis in numerous scientific or popular publications, as well as in "expert" testimony before radiation regulatory commissions, appears to go hand and in hand with that of a *threshold model* for estimation of low-dose radiation health risks. Its champions posit that exposures of large populations to doses below a certain threshold value (e.g. natural background or a small multiple of it), will not initiate any radiogenic health effects whatsoever in *any* individual of that group (so-called "exposures below regulatory concern"). Such an assumption, ever so carefully veiled in technicalities, appears to be the basis for a newly proposed regulatory concept for setting allowable low-dose population exposures by the International Commission on Radiological Protection. Refuting such speculations, there exists, however, well-founded epidemiological [4,5,6,7] and microdosimetric [8] evidence contradicting the existence of both hormesis and a zero-effect threshold.

Epidemiologic Evidence

1. The decrease of lung cancer mortality among people who live in 1,759 counties of the United States, arranged according to increasing mean levels of Radon gas (as measured in 272,000 homes) has been interpreted by Cohen and others as an "irrefutable proof" of hormesis.[9] This contention has lead to an extended scientific debate that disputed Cohen's unwarranted conclusion as a misinterpretation of his data collective by neglecting critical confounding factors. [1,10,11,12]

2. Cancer mortality rates in US states at high average altitude (higher background radiation) have appeared to be *lower* than those in states along the Atlantic Ocean (lower background radiation) [13] suggesting – if taken at face value - a cancer protective effect of elevated background exposures. The same inverse association between background exposure and cancer mortality was observed in Great Britain.[4] However, when proper corrections are made for differences in oxygen pressure[14], demographic and socio-economic confounding factors, such as population density, or the number of physicians per capita in these different regions of the US, cancer mortality *always increases* with *increasing* background exposures, consistent with a no-threshold positive correlation between health detriment and exposure. The same is true for high background areas in other parts of the world. The British data actually suggest that *most* childhood cancers are associated with fetal exposure to radiation - background or man-made.[4]

3. Cancer mortality among nuclear workers, with mean occupational exposures to only *small fractions of the "allowable" level* , and equivalent to a small multiple of natural background, has always been found to be 15 – 20% lower than that among the general population. Some scientists have claimed that this apparent reduction of mortality among an exposed worker population (finding a reduced cancer SMR [15]) proves *hormesis*. (Would these experts claim that a nuclear installation such as Hanford, WA or Oak Ridge, TN is actually a health resort for its workers?).

In fact, the observed SMR < 1 signifies a well-understood "healthy worker effect" (HWE) due to *selective recruiting of considerably healthier than average persons into the industry who have continued access to much better than average health care*.[16,17]

The reduction in cancer SMR due to selection (HWE) tends to be numerically larger than the small increase in cancer mortality due to the generally low mean occupational radiation exposures well below "allowable" levels. However, when the SMR *for all causes of death, except cancer,* is compared with the *all cancers* SMR (among the same worker population), *the cancer SMR is generally slightly larger than that for all other causes of death* (in the range of 5 – 10%).[18,19] This increased cancer SMR is indicative of an increased risk for radiogenic cancer at dose levels comparable to background [5,6].

Only if all relevant confounding (or controlling) factors such as the HWE, levels of socio-economic status, ages at hire and exposure, etc., are taken into account, do radiation epidemiological analyses have the sensitivity to statistically detect small excess health detriment at low dose levels.[20] Most government- and industry-sponsored studies that found "no evidence of radiation health effects" have in fact neglected significant controlling factors, thus limiting their statistical sensitivity. Rather than "proving" no effects, those studies are in fact "inconclusive", contrary to their stated findings.[21] In analogy, in order to test for bacteria in drinking water, the use of a magnifying glass will practically guarantee a "pure water" finding, in contrast to using a microscope!

In a recent historic reversal of position by the Secretary of the US Department of Energy (DOE), after more than fifty years of denial, a government commissioned report [22], admitted that even at the "allowable" exposure levels, excess cancers and other serious diseases had been found among workers in a large number of nuclear facilities. It was recognized that compensation for injury should

be considered a legitimate remedy. This official report amounts to an admission that fallacious conclusions of “no health effects” had been drawn for decades from scores of “negative”, i.e. inconclusive DOE-sponsored epidemiological studies. It also validates a 1992 critical review of the DOE’s epidemiologic research, published by Physicians for Social Responsibility.[21]

4. There are numerous reports in the refereed medical-scientific literature of increases in childhood cancers, infant or perinatal mortality, infant and adult thyroid disease, miscarriages, Down’s Syndrome, etc. after population exposures to the Chernobyl radioactive fallout in countries so far away from the site of the nuclear explosion that according to official dose estimates by the United Nations, combined with officially accepted radiogenic risk factors, *no such health detriment should have been observable.*[23] Yet, a large number of such studies are consistent with each other in reporting such health effects at those presumably too low exposures.[7,24] While these studies have low statistical power *individually*, their mutual consistency presents a serious challenge to official denials of adverse health consequences from Chernobyl fallout. Official risk estimates and radiation protection standards have ignored the growing evidence for substantially larger biological damage from internally lodged radioactive substances as compared to that from external gamma ray exposures.[25,26] These standards have been extrapolated from risks observed in A-bomb survivors who had been exposed to a flash of high doses of high energy gamma radiation, exposure conditions with very different biological effectiveness. In addition, extensive recent evidence suggests that due to the catastrophic effect of the A-bombs, the survivor population has been highly selected for exceptionally low radiation sensitivity and unusually high immunological competence, resulting in a strong “healthy survivor effect”.[27,28] The latter has consistently been ignored by radiation protection commissions.

These monitored populations constitute only the tip of the iceberg of likely injured populations around the globe as a consequence of nuclear weapons production and testing: what about the hundreds of thousands of atomic veterans, civilian populations exposed near radioactively contaminated sites such as Hanford, Oak Ridge, and Rocky Flats, and those exposed to the radioactive fallout from the Nevada and Pacific test sites, or the workers of the Southwestern US and Canadian Northwest Territories uranium mines, etc.?

Radiobiological and Microbiological Evidence

Current radiation protection standards also have failed to incorporate the growing number of findings of chromosomal aberrations and potentially genetic effects (genomic instability) *at the lowest possible dose level of one single track through a cell* by either a secondary electron from gamma- or X-ray exposure, or a primary electron or alpha particle emitted by an internal radioisotope. The existence of this well established detriment to human cells *at the lowest possible radiation dose levels* definitively contradicts both hypotheses of hormesis and a threshold dose. To quote from three very recent reports:

(1) “The background rate of *dicentric chromosomal aberrations (dic)* in the general adult population appears almost exclusively attributable to the clastogenic action of ionizing radiation from

natural and man-made sources. The sum of the clastogenic action from al other sources combined, including smoking, alcohol, and drugs could hence at best account for only a very small proportion of the background rate of *dic.*

Hence in this approach *dic* appear to be sufficiently specific for ionizing radiation to allow discrimination of excess radiation exposure from exposures to other environmental mutagens and clastogens in the general population. As a consequence, *dic* appear appropriate as a biomarker to assess previous exposure to ionizing radiation down to the low dose range which is of particular interest in environmental epidemiology."[29]

(2) "The data presented here have important implications for likely risks associated with low-dose exposure *in vivo.* They suggest that even a cell that has received only a single charged-particle traversal and survives may have a significantly increased probability of producing chromosomal changes *de nuovo* in subsequent generations." [30]

(3) " The human-hamster hybrid A_L cell line has been exposed to 100 kV X-rays at 0.1 to 5 Gy. The proportion of X-irradiation induced CD 59 mutants was quantified by flow cytometry after immunofluorescence labeling. The yield of mutants was a linear function of dose. The data are, therefore, in agreement with the assumption of a linear dose effect curve for carcinogenesis".[31] The authors of this work cite the relevant literature where more evidence for linear non threshold dose effect relation can be found.

In summary, a growing number of optimally designed epidemiological studies among nuclear workers, the low-dose data of the A-bomb follow-up, and studies of environmentally exposed populations, have been fully supported by microdosimetric studies on the cellular level. They leave no doubt that the claims for hormetic effects of low-dose exposures, and the existence of a "threshold" or "zero-effect" exposure range can no longer be based on undecided "scientific evidence". All the "proofs" and "studies" the crusaders for increased allowable radioactive exposures have continued to cite represent either invalid or misleading interpretations of flawed epidemiological studies.

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