



## Effects of Low Doses of Radiation:

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The results of research presented at the 15<sup>th</sup> Pacific Basin Nuclear Conference (15PBNC) directly challenge the assumption, made for the purposes of radiation protection, that risks observed at acute doses of 500–1000 mGy can be extrapolated reliably down to zero dose and to low dose rates (the LNT model). The research shows that different biological responses to radiation predominate at doses and dose rates that are substantially lower than those at which risks have been observed. Hence, the dose–response relationship is non–linear and risk is not as predicted from the LNT model. If anything, there is health benefit instead of risk at low levels of exposure.

It is extremely important that these matters should be understood and put into proper perspective –

- to assist society in making technological choices that involve the use of radiation, radioactive materials and nuclear power;
- to ensure that appropriate decisions are reached concerning regulation of human–caused radiation; and
- to assure the public that these choices and decisions are being made on the best possible scientific basis.

We are all exposed to low levels of ionising radiation from natural sources. In the vast majority of cases, this is at less than 10 mSv/y. Most of us are exposed occasionally to additional diagnostic doses from medical sources, ranging from less than our annual dose due to natural background radiation up to about 10 mGy for a typical CAT scan and 100 mGy for some whole body scans. Doses to both cancer cells and normal tissues from medical therapy may be several orders of magnitude higher than diagnostic doses. Some workers in the nuclear industry are occupationally exposed at additional levels, which can be comparable to, but are usually less than, natural exposures. Members of the public may be exposed, at very much lower levels (generally much less than 1 mSv/y), to radionuclides that are in their environment due to the operations of the nuclear industry.

For doses of  $\beta$ ,  $\gamma$  and x–radiation up to a few hundred mGy, there are essentially two biological effects that have potential health consequences:

1. Damage to living cells, which could initiate the development of adverse delayed health effects, such as cancer. However, this effect is minute compared with the on-going amount of cell damage from endogenous causes, such as the reactive oxygen species produced by our oxygen-based metabolism.
2. Induction or activation of cellular protective capacity, additional to that which exists normally to protect against damage from all causes. This “adaptive response” to radiation involves prevention, repair and removal of damage. It reduces the effects of damage from other causes, as well as from radiation.

At low doses, typical of public and occupational exposures, not all cells are hit by a radiation track. A cell which is hit may interact with neighbouring cells by intercellular communication systems – the “bystander effect” – thus causing damage to appear and possibly stimulating protective capacity in the unirradiated cells, tissues and organs.

Experiments with irradiation of animals have shown that the enhancement of protective capacity, described in 2 above, predominates over detrimental effects at low levels of radiation exposure, with beneficial net health consequences. Such an effect, sometimes called “radiation hormesis”, has been observed experimentally in cells from virtually all types of organisms, in whole plants and animal species other than humans, and in human cells. For doses greater than about 100 to 300 mGy in animals, it has been observed that detrimental effects dominate, i.e. there are dose thresholds for harm. As the rate of accrual of the dose decreases, the protective effect of radiation increases and the detrimental effects decrease.

Hormetic effects occur widely in nature, including the human species, and relate to most substances that are usually regarded as toxic, e.g. heavy metals, arsenic and various naturally-occurring chemical compounds in food and water, as well as to naturally-occurring radiation. It is a fundamental tenet of evolutionary biology that organisms and species adapt to their environment. Hence, the hormetic model also applies to oxygen, sunlight and many other familiar agents.

The effect of radiation on human health could be expected to vary from person to person, based on individual genetic make up. Currently, individual genetic sensitivity or susceptibility to low dose exposure cannot be predicted for any specific person. The net effect is measurable only on an exposed group or population by epidemiology, as an average probability of benefit or harm for members of the exposed population.

However, the carcinogenic effect of radiation is quite weak, compared with natural and other causes, and the symptoms and physical forms of cancer are not distinguishable as being caused by radiation. Hence, in humans, this effect is discernible only by an increased incidence of cases that correlates with exposure to radiation. This has been demonstrated for high doses by data from studies of the survivors of atomic bomb explosions in Japan. These studies have shown small but statistically significant increases in the incidences of leukaemia (with latency periods mainly in the range 5 to 10 years) and solid tumours (with latency periods generally more than about 10 to 20 years) for exposures that exceed about 200 mGy.

Effects on the health of human populations, which have been accidentally exposed to low levels of ionising radiation, and atomic bomb survivors with low levels of exposure, have not been demonstrated using epidemiological techniques.

Both increases and decreases in the incidences of cancers have been reported from medical exposures greater than 100 mGy, depending on the rate and total accrual of dose and the conditions of irradiation. These data were not discussed comprehensively at 15PBN and require further consideration.

For acute doses less than about 100 mGy in humans, there is not clear evidence of any health effect, either because the evidence is not statistically significant or

because there **are** no health effects – this is genuinely uncertain. Changes and effects in the body may be observed at the cellular and molecular levels but there is no discernible link to clinical harm or benefit.

There is no evidence to support the LNT model for chronic exposures, such as those due to natural background radiation – which ranges around the world from less than 1 to more than 200 mSv per year, with an average of about 2. Cancer incidences are, if anything, lower in areas of high background radiation than in areas of low background radiation. However, epidemiological studies are confounded by many factors, particularly tobacco smoking, and populations living with very high background dose rates may be too small for reliable statistically based conclusions to be drawn.

In summary, research reported at the 15PBNC showed that the popular concept of radiation being harmful at any level of dose or dose rate (no matter how small) is not supportable, *viz*:

- The risk of cancer generation is trivial or zero up to more than a hundred times the average of natural background radiation.
- There are adaptive responses to low levels of radiation exposure, which reduce the effects of damage from all causes, including those from radiation, thus reducing risk to levels lower than those observed in the absence of the radiation exposure.
- Because of this adaptive effect or effect of hormesis, the dose and dose rate effectiveness factor (assumed to be 2 in the application of the LNT model for the purposes of radiological protection) becomes very large and can be assumed to be infinite at low doses and low dose rates.

Claims that the LNT model under-estimates risks from low level radiation by orders of magnitude have been vigorously expounded elsewhere and used as the basis for attacks on the nuclear industry. There is no credible, consistent evidence to support these claims.

Challenges to the assumptions used in our current system of radiological protection, and their policy implications, are to be outlined in an OECD Nuclear Energy Agency report “Implication of Sciences and Technology on the Radiological Protection System”, which was presented in draft form at the 15PBNC.

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