The health effects of radiation

The controversial view that small amounts of radiation might actually be harmless could have huge social and economic consequences, as **Robert P Crease** explains

Few physics-related issues are as politically sensitive or have as much potential impact on society as the health effects of low levels of radiation. If the limit on the amount of radiation that someone can be exposed to is set too high, individuals would suffer radiation damage. If the limits are too low, many clinical and diagnostic techniques – as well as research tools that rely on radioisotopes – would become impractical or impossible to use. Such limits would also force billions of dollars to be spent on cleaning up tiny, harmless amounts of radioactive substances.

This issue is about to be shaken up even more. "There is a paradigm shift happening in radiation biology," says Antone (Tony) Brooks, a radiation toxicologist at Washington State University. Since 1999 he has been involved in a research programme sponsored by the US Department of Energy (DOE) that looks at the effects of small amounts of radiation on organisms. Brooks is now science advisor to a university website (lowdose.tricity.wsu.edu) that tracks the DOE programme and presents information to the public on this topic. It turns out that the impact of small amounts of radiation is much more complicated than previously suspected, with a cocktail-like mixture of beneficial and harmful effects that – below a certain threshold – may be harmless to an organism.

This paradigm shift has enormous social and economic implications, and is bound to incite controversy. The idea that humans may not need to worry about radiation below a certain threshold, for instance, runs contrary to the assumptions and interests of anti-nuclear activists. They regularly cite the supposed negative health effects of extremely small doses of radiation in campaigns against nuclear power plants, the shipment of radioactive materials, and the storage of radioactive waste. This may make enacting regulations with a scientific basis politically unpopular.

The old paradigm

Brooks has a personal stake in radiation research. He grew up in Utah about 100 miles from a US military above-ground test site for nuclear weapons. The shots were detonated in the early morning, and Brooks would often watch them light up the sky and feel them make the earth shake. In 1953, while in high school, one of the most notorious of these tests, named "Dirty Harry", spread fallout over his home town after an unexpected change in wind direction.

Brooks became concerned about fallout

Control point – where should radiation limits be set?

and its effects. In 1963, for his master's degree at the University of Utah, he conducted fallout studies in state dairy farms. For his PhD at Cornell, he studied the effects of radiation on chromosomes and learned the complexities of the "effect/dose curve", which plots the biological harm to an organism against the dose that it receives. Data for this curve range from large doses down to doses of about 25 rads, where the cancer risk is not significantly different to that for background radiation. Below that point, no data existed, until recently at least.

So what happens below that dose? The traditional way of answering that question – the old paradigm – was to simply draw a straight line between the lowest data point and the origin of the graph. In other words, people assumed that any amount of radiation – no matter how small – causes some harmful effect; there was no threshold below which doses had no meaningful impact. The guess – and it was only a guess – was made more compelling by a physical picture called "hit theory", which says that one cell hit by one ionizing particle leads to one mutation.

"Hit theory provided a nice, neat picture that the physicists loved," Brooks says. "But we biologists believed the physicists for too long."

The new paradigm

The DOE low-dose radiation research programme is designed to study the interaction between low doses of radiation and biological systems. Research from this programme has led people to appreciate various factors that conflict with the assumptions of the old paradigm. Three of the most important are adaptive response, bystander effects and genomic instability.

Adaptive response means that when a cell or other biological system is hit, it can adapt to the injury – it becomes resistant not only to further hits but also to other kinds of harmful exposures, such as to free radicals. Bystander effects mean that a hit on one cell can affect that cell and neighbouring cells as well; non-hit cells, for instance, can contribute to adaptive response. Genomic instability means that the effect of a hit on one cell may not show up immediately but only after the cell has undergone a large number of cell divisions. The first two of these factors can have a beneficial final result, while the third is harmful.

For several decades the idea that low doses of radiation can have positive health effects has been called "hormesis", with which adaptive response has sometimes been confused. But hormesis, Brooks says, belongs to the old, one-hit-one-effect paradigm, only changing the sign of the impact on the organism from negative to positive. The new research, he adds, suggests our entire understanding of how a cell moves from normal to malignant must be changed. A complex mixture of factors is at work, things happen at high doses that do not happen at low doses, and a threshold may well be involved.

The critical point

There are two dangers in being precautionary by creating radiation limits that are far too low. One is financial: an overly conservative limit would waste limited resources on less serious or even non-existent threats, while continuing to expose people to more serious threats that are less politically and emotionally incendiary, such as those involving chemical pollutants or unsanitary conditions. Another danger is conceptual: an overly conservative limit fosters a fear of minuscule or non-existent threats and thus undermines the ability of society to distinguish between real and unreal dangers. An overly conservative radiation-protection limit can easily turn into an environmental Maginot Line – something harmful because it wastes scarce resources, is vulnerable to political manipulation and promotes public ignorance not safety.

Radiation-protection limits provide yet another area where ideologies threaten attempts to ground policies in sound science.

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