Biological Effects of Ionising Radiation

Stochastic effects

Continuing our brief overview of the biological effects of ionising radiation, in this issue of *The Source* we discuss stochastic effects. As discussed in Issue 18, for deterministic effects to occur a minimum dose or threshold has to be exceeded. Once the threshold has been exceeded the severity of the effect increases with dose. With stochastic effects, the probability rather than the severity of the effect increases with dose. The stochastic effects of radiation are normally delayed and do not appear for several years or decades after the original exposure.

The most important stochastic effect is the induction of cancer. Cancers of the breast, lung, thyroid, pancreas, skin, bone, brain, and blood (leukemia) have been observed as the result of radiation exposure. The probabilities of radiation-induced cancers are derived from studies of the Japanese A-bomb survivors and some therapeutically irradiated groups (eg, persons treated for ankylosing spondylitis, an arthritic condition of the spine). These groups have been exposed to high doses at high dose rates and there is considerable uncertainty in extrapolating this information to low dose and low dose rates in order to get probabilities of cancer induction applicable to the situations most often encountered in radiation protection. Values are derived by applying a dose and dose rate effectiveness factor (DDREF) which reduces the risk coefficient per unit dose applicable at high doses and high dose rates.

It would be ideal if the probabilities of cancer induction at low doses and low dose rates could be derived from population groups exposed to low doses. Some studies have been done but there are problems associated with them, such as insufficient sample size, lack of adequate controls, extraneous effects other than radiation, and inadequate dosimetry, which produce large uncertainties in derived risks.

The lifetime risk for a fatal cancer as determined by the International Commission on Radiological Protection (ICRP) for the general population is 0.05 per sievert and 0.04 per sievert for workers. These are risk factors for cancer deaths, not cancer incidence. Some cancers have a relatively low mortality rate so that the probabilities of cancer induction are higher by a factor of about 1.5.

If we assume that the excess fatal cancer incidence is proportional to the radiation dose then we can estimate the number of cancer deaths that might occur in an exposed group of people.

Number of deaths = collective dose x risk factor.

If a mixed population group of 100 000 people is exposed to 10 mSv (the average New Zealander receives approximately 2 mSv per year from natural sources of radiation), for example, then:

collective dose	=	$100\,000 \times 10 \times 10^{-3}$
	=	1000 man Sv
therefore, estimated deaths	=	1000×0.05
	=	50 deaths.

This number may be compared with about 25 000 deaths from cancer which would arise "naturally". In practice it would be impossible to determine whether any deaths from radiation have occurred in this population.

Genetic effects arise from radiation damage to the egg or sperm cells and may result in damage to subsequent generations. The ICRP risk factors for hereditary effects is 0.01 per sievert for all future generations for the whole population, and 0.006 per sievert for the population of working age. There is, however, no convincing human data that demonstrates genetic damage, and radiation risk estimates have been inferred from studies on small animals.

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ReSources

Newly available on the NRL website (www.nrl.moh.govt.nz):

- **NRL Report 2005/1. The CTBT verification significance of particulate radionuclides detected by the International Monitoring System**
  Follow the menu choices: Publications – Miscellaneous items – NRL Reports.

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Power lines are they safe?

One of the most common questions asked of NRL is "I am thinking of buying a house near power lines – is it safe?" The question first arose over 25 years ago when an epidemiological study suggested that living near power lines (not only large transmission lines, but also low voltage distribution lines) was associated with a small increased risk of childhood leukemia. Should the link truly exist, it was suggested that the extremely low frequency (ELF) magnetic fields around the lines might be the agent responsible. Such fields are present around any cables, appliances or equipment carrying mains electricity. Despite the thousands of papers published on the subject since then, we are still no nearer to a definitive answer.

Several high quality epidemiological studies were published in the 1990s, which were the subject of a pooled analysis by Ahlbom *et al*[1] in 2000. The results of the pooled analysis showed a weak but consistent association between exposure to time-averaged[2] magnetic fields greater than 0.4 µT and an increased incidence of childhood leukemia.

For comparison, typical field levels in houses are around 0.05 – 0.15 µT, exposures near appliances can reach several microtesla to tens of microtesla, and beneath transmission lines are 0.3 – 5 µT.

Despite the apparent consistency of the results, there are doubts over whether this association represents a true cause and effect relationship. Ahlbom *et al* commented that "The explanation for the elevated risk estimates is unknown, but selection bias [ie, an artefact of the way the studies were carried out] may have accounted for some of the increase."

It has also been noted that the apparent association can be critically dependent on the exact choice of exposure data used in the study. There is no physical mechanism known which could explain how magnetic fields at these levels could have any effects at all, and laboratory research does not suggest that ELF fields could affect the development of cancer.

The National Radiation Laboratory and Ministry of Health continue to recommend the use of exposure guidelines published by the International Commission on Non-Ionizing Radiation Protection (ICNIRP) in 1998. The ICNIRP is an independent scientific organisation recognised for its expertise in this area by the World Health Organisation. Their guidelines are based on the avoidance of effects whose existence and causes are well established[3] and, at the frequency of 50 Hz used for power distribution in NZ, set a reference level (similar to an exposure limit, but with some subtle differences) of 100 µT for the public. The ICNIRP considered carefully the research suggesting effects on the incidence of childhood leukemia at much lower exposure levels, and while they acknowledge the associations which have been found, they also note the factors which could have boosted the apparent association, and comment that the results are "difficult to interpret in the absence of a known biological mechanism or reproducible experimental support of carcinogenesis". Put another way, the ICNIRP does not consider that a risk has been established. Rather, there is a possibility that there might be a risk, albeit a very low risk. The ICNIRP has maintained surveillance of the research since publishing the guidelines, but has not seen the need to revise them.

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If the association does represent a true cause and effect relationship, it has been estimated that in the UK magnetic fields would be responsible for 0.5% of the childhood leukemia cases there. A New Zealand study conducted by the University of Otago which formed part of the Ahlbom *et al* pooled analysis included 86 cases of childhood leukemia reported over a four-year period and found that none of them had been exposed to time-average fields greater than 0.4 µT. While this does not prove that there is no risk, it does give an idea of the magnitude of any risk which may exist.

The concept of "prudent avoidance" has been advocated as a means to control exposures to ELF fields if there is any doubt that they are harmless. "Prudent avoidance" suggests that reasonable low or no cost measures should be taken to minimise exposure to ELF fields, both from existing sources and new installations. For example, an individual may choose to turn off an electric blanket at night (a prudent measure from the point of view of electrical safety as well), and the manufacturer may alter the design of the blanket to reduce the level of fields around it.

Although it is difficult to make hard and fast definitions concerning what constitutes prudent avoidance, there are general understandings of what measures it might entail. Undergrounding a transmission line, for example, would be a very effective means of reducing exposures but could not be considered a prudent avoidance measure as it is far from low-cost. On the other hand, there are ways of arranging the conductors on a double-circuit transmission line (reverse-phasing) which reduce the fields considerably compared to other configurations.

The NRL and Ministry of Health encourage the voluntary adoption of such low- or no-cost measures to reduce or avoid exposures. This is consistent with Ministry recommendations for other agents. The Ministry does not support the adoption of arbitrary lower limits, as has occurred in a few countries, which have no sound basis in the research data. On the one hand, they risk creating unnecessary alarm should exposures exceed the arbitrary level chosen. On the other, if there are genuine adverse health effects, an arbitrarily chosen exposure limit could create a false sense of security if those effects actually occur at a lower exposure level. Recent research suggests that "precautionary approaches" such as these can actually heighten concerns rather than alleviate them.

To come back to the original question – what about a house near a power line? Measurements by NRL staff have found that magnetic field levels around power lines generally decrease to the levels found in many houses (from wiring and appliances) within about 50 – 100 m of the line. Even directly beneath the line, fields are considerably lower than the ICNIRP guideline level of 100 µT. While proximity to power lines might be one factor considered by house buyers, the evidence available to date does not suggest that they pose a significant health risk.

1 Ahlbom A *et al.* A pooled analysis of magnetic fields and childhood leukemia. British Journal of Cancer 83 (5), 692 – 698 (2000).
2 In fact the geometric mean exposure, rather than the arithmetic mean.
3 Specifically, effects caused by the induction of currents in the body by ELF fields.

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Personal radiation monitoring

The following concludes our short series of articles on personal dosimetry. More information about the service we offer may be found on our website at www.nrl.moh.govt.nz by selecting Services & Products – Personal Dosimetry Service from the menu.

Where should personal dosemeters be worn?

Dosemeters should be worn continuously at work from the time of receipt until the next set arrives, even when you are not actively engaged in the use of radiation. This provides the maximum likelihood that you will be monitored for both normal working conditions and any other incidents. A reasonable exception to this rule is extremity monitors when used in conjunction with body monitors. In this case, the extremity monitors may be stored when your work does not actively involve the use of a radiation source.

Dosemeters should be worn free from any other devices (such as pagers and pens, belt buckles etc) that could shield the dosemeter from radiation and distort any dose assessment. The pictures show two of the more dramatic example images of films that have been obscured to some degree. In both cases, a dose estimate was produced, but with less accuracy than can be achieved when the holder is not obscured.

Shielded by a pager or other electronic device

Shielded by a ball point pen

The following regime has been designed to monitor the part of the body most likely to receive a dose that approaches internationally recommended dose limits.

Monitoring extremities

In situations where some parts of the body are much closer to the source than others (as is often the case with hands) or the radiation source is localised, wearing positions other than the body may give valuable information about exposure to radiation. Ring dosemeters may be of use where radiation fields are very localised, such as when handling phials containing unsealed radioactive material or performing maintenance tasks on sealed sources of radioactive material. Body dosemeters may be attached to the wrist if the radiation field is likely to be slightly less localised.

Ring dosemeters

Disposable gloves should always be worn over the top of rings (to prevent both your hands and the ring from becoming contaminated with any radioactive material you may handle), and to protect the ring from damage. The ring should be worn in such a way that it is both as comfortable as possible for you and is as close as possible to any radiation source you may be near or handling. The part of the ring containing the radiation-sensitive element should face the radiation source.

Body dosemeters

Attach to the wrist or ankle. Attaching the dosemeter to a piece of elastic is a suitable way of achieving this.

Monitoring the body

Where the radiation source is x-rays for diagnostic purposes:

Personal protective clothing is often available in this situation, and the appropriate wearing position (to monitor for the dose limit most likely to be exceeded) alters with the availability and use of such clothing, as follows:

Use of protective clothing	Recommended wearing position
Where a lead-rubber apron is always worn over the trunk and only one dosemeter is used:	In situations where a lead-rubber apron is always worn, the dosemeter should be worn outside the apron at collar level as a means of assessing dose to the eyes (the body organ most likely to be at risk in this situation).
Where a lead-rubber apron is sometimes worn over the trunk and only one dosemeter is used:	For persons performing general radiography (where the lead-rubber apron is not or is only occasionally worn), or performing both fluoroscopy and radiography duties, the dosemeter should be worn on the side of the body closest to the radiation source somewhere between waist level and chest level. For the times when an apron is being worn, the dosemeter should be under the apron. This will ensure that the dose reported gives a reading that is consistent with the exposure received by the trunk of the body.
Where the use of a lead-rubber apron is inappropriate or a lead-rubber apron is never worn over the trunk and only one dosemeter is used:	The dosemeter should be worn on the side of the body closest to the radiation source between waist level and chest level.
Where it is thought that more than one dosemeter should be used:	In radiography or fluoroscopy situations where scattered radiation levels are high and workloads are high, it may be reasonable to wear two dosemeters – one on the body under the lead-rubber apron and the other outside the apron at collar level.

Where the radiation source is other than x-rays for diagnostic purposes:

In these circumstances the dosemeter should always be worn on the side of the body closest to the radiation source somewhere between waist level and chest level.

For some users in nuclear medicine departments or practices, a lead-rubber apron is sometimes worn over the trunk. In these cases the dosemeter should be under the apron.

For further information contact the NRL Personal Dosimetry Service (pds@nrl.moh.govt.nz).