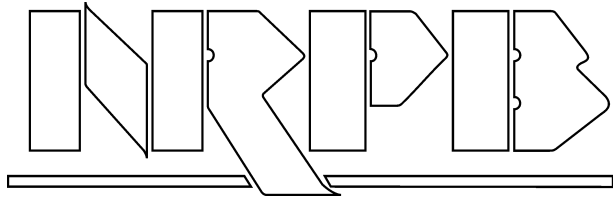


Radiological Protection Bulletin



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Power Lines and Cancer

The Advisory Group on Non-ionising Radiation (Chairman: Sir Richard Doll) has published its report on ELF electromagnetic fields and the risk of cancer (*Documents of the NRPB*, 12(1), 1–179, 2001). There is a summary of the report and its conclusions in this issue of the *Bulletin* (pp 10–17).

The Advisory Group report is a comprehensive and well-written review of work done over the last decade or so on this controversial topic. The source research papers on the epidemiology, biology, physics and risk assessments are published in a wide variety of specialised peer-reviewed journals, and the Advisory Group report is a timely, digestible read.

At the time of publication of the report, there was a great deal of news media interest in its conclusions. There is a considerable appetite in journalism for scoops and disclosures and the Advisory Group report suffered from its share of supposed leaks. The most notable claim of a leak was heralded with the headline, ‘Power lines are cancer risk – official’ which appeared in a Sunday newspaper a few days before publication of the report. This prior publicity led to a rather strange phenomenon on the day of publication – the report was welcomed by anti-power-line pressure groups and by the electric power industry. The pressure groups were happy as they felt they had some new ammunition, while the industry welcomed the report because it showed that any putative risk of cancer was very low and only applied to relatively high magnetic fields in homes. Such fields are rare in the UK compared to other countries, because of the specific nature of the electricity distribution system here. The distribution system is, for example, very different in North America, and higher magnetic fields are far more common.

So what are the facts about the risks from electric power lines, inside and outside our homes? The general conclusion of the Advisory Group is refreshingly clear (see p 13 in this *Bulletin* or p164 of the *Document*). There is no evidence that typical electromagnetic fields in houses could cause cancer in adults or children, but there is some epidemiological evidence that prolonged exposure to unusually high levels of power frequency fields, is associated with a small risk of leukaemia in children. The evidence is not at present strong enough to draw any firm conclusions, but an assessment of the risk from such elevated magnetic fields, has been provided. Sadly, there are about 500 cases of leukaemia in children each year and the Advisory Group estimated that between two and four of these (ie < 1%) could be caused by elevated magnetic fields in the home.

Elevated magnetic fields in homes are not necessarily due to proximity of overhead power lines. In fact, the majority of homes with elevated magnetic fields measured by NRPB staff for the UK Childhood Cancer Study, are nowhere near power lines or electricity substations. Why do some otherwise ordinary homes have elevated magnetic fields? It is presently rather a mystery and should be an important area of research so that any putative risks can be minimised.

Michael Clark

New ICRP Proposals

Since the 1970s, the International Commission on Radiological Protection has developed a system of radiological protection based on three principles – justification, optimisation and limitation. These are broadly in order of importance when setting standards. Any practice involving exposure to radiation must first be justified, then any exposures must be kept as low as reasonably achievable, and finally exposures must comply with dose limits recommended by ICRP. This system of protection has been highly successful and is accepted in most countries. However, there have been criticisms over the years that it could result in a misallocation of resources, because optimisation of protection concentrates on collective doses rather than individual doses. In 1990 ICRP introduced ‘constraints’ on optimisation to avoid this and to help concentrate resources on keeping individual doses low. Without such constraints, a great deal of effort could be expended on trying to reduce essentially trivial doses to large numbers of people.

The *Journal of Radiological Protection* (21(2), 113–23, 2001) has a progress report with some details of a revised, simpler approach being considered by ICRP. It places more emphasis on individual rather than collective doses. For each previously justified controllable source, the first consideration should be to establish restrictions on individual dose, and then make exposures as low as reasonably practicable. ICRP is proposing a scale in terms of fractions or multiples of natural background from which standards of protection can be set – called Protection Action Levels (PALs). These would replace dose limits for workers and the public, intervention levels, action levels for radon, constraints, exemption levels, clearance levels, and intervention exemption levels.

This is a change from the ICRP Publication 60 recommendations, but ICRP Chairman Professor Roger Clarke does not regard it as a radical departure. ‘It is more a change of emphasis in radiological protection, and is a genuine attempt to simplify things in a coherent manner.’

Dr Hylton Smith

Sadly, Dr Hylton Smith, a former Head of the Biology Department at NRPB and then Scientific Secretary to ICRP, died recently after a long illness. He made significant contributions to radiological protection and will be greatly missed. A fuller tribute to Dr Smith will appear in a later issue of the *Bulletin*.

More Orphan Sources

A farmer in Egypt found an iridium-192 sealed source (routinely used for industrial radiography) in a load of material bought for a home construction project. He didn’t recognise it as a radioactive source and, believing it to be valuable, took it home. Subsequently, a horrifyingly familiar tale has emerged. The farmer and his nine year old son went in May 2000 to a local doctor and reported skin burns. These were thought to be of viral or bacterial origin and medicines were prescribed. A month later the farmer took his whole family (wife, sister and four children) to a Cairo hospital, as they had all developed skin problems and felt very unwell. Within hours of arrival, the farmer’s nine year old son died and a week later the farmer died.

A second hospital in Cairo carried out blood tests on remaining family members, and noticed severe depression of the white blood cell count in all the family. Egyptian authorities quickly recognised this as a potential radiation exposure problem and sent a monitoring team to the farmer’s village. They identified the iridium source in the house and subsequently secured it in a shielded container prior to disposal. Subsequent investigations

revealed that the 1.8 TBq (50 Ci) iridium-192 source belonged to a local industrial maintenance company. The company was working on a contract to maintain liquified gas pipes in the area, and realised that the source had been 'lost', believing it to have been buried accidentally with the pipes. The company's management failed to notify the Egyptian authorities that the source had been lost, and appropriate legal action is being taken.

15th Anniversary of the Chernobyl Accident

Science has published a detailed news focus review of the after-effects of the Chernobyl accident (292, 420–25, 2001) to coincide with the fifteenth anniversary of the accident. Given the extent of radionuclide deposition in parts of Belarus and the Ukraine, and the doses received by residents and 'liquidators', the region and its inhabitants are the subject of an involuntary experiment on how radiation affects human health and the environment.

The main established health effect is the significant increase in thyroid cancer in those that were children at the time of the accident. Initially there was some scepticism in the west about the reported increase because, although it was recognised that very high thyroid doses had resulted from Chernobyl releases, the widespread medical use of radio-iodine for treatment of thyroid diseases had not shown a similar increase in cancer. However, the susceptibility of children to thyroid cancer had not been allowed for, and it is now accepted as a significant new finding. There are claims of other health effects in the region, including birth defects and some cancers in adults, but leukaemia does not appear to have increased. The main problem is one of sufficient funding for good research and international collaboration. There is a tendency in some quarters to blame all health problems in the region on the Chernobyl accident. This tendency, while perhaps understandable, needs to be balanced with good, well-funded research that stands up to scrutiny.

The exclusion zones provide ample opportunity to examine the effects of radiation on resident animals. There have been reports of chromosomal damage in some animals (eg bank voles) but recent work using improved techniques had led to a retraction of a paper in *Nature* reporting these effects. These studies are difficult to perform because of the extensive nature of the radionuclide contamination in the region, which makes it difficult to establish proper controls.

Leukaemia Mortality in UK Electricity Workers

The mortality experienced by employees of the former Central Electricity Generating Board in England and Wales has been investigated by the Institute of Occupational Health at the University of Birmingham (Harrington *et al*, *Occup Environ Med*, 58, 307–14, 2001). They looked at a large cohort of former employees of CEGB (nearly 84 000) who worked for at least six months during 1973–82, and examined their mortality records for the period 1973–97. They conclude that there are no discernible excess risks of leukaemia as a consequence of occupational exposure to magnetic fields in UK electricity generation and transmission workers.

The standardised mortality ratio (SMR) for all leukaemias in the cohort was 84 (observed 111, expected 132.3), and the SMR for all causes of death was 83 (observed 14 845, expected 17 918). No significant positive trends were observed for the risks of various clinical types of leukaemia, either with lifetime cumulative exposure to magnetic fields or with such exposures received five years before death. The exposures to magnetic fields were assessed using computerised work histories for nearly 80 000 workers (ie over 95% of the total).

Cancer Incidence in Radiation Workers

To date, most epidemiological studies of the health of radiation workers have focused on mortality, such as in the first two analyses of the National Registry for Radiation Workers (NRRW). However, a new analysis has looked at cancer incidence in about 190 000 people included in the National Dose Registry of Canada (Sont *et al*, *Am J Epidemiol*, **153**, 309–18, 2001). This registry covers large numbers of people monitored in the dental, medical and industrial sectors, as well as nuclear power workers. Overall, cancer incidence rates were lower than those in the general population. The estimated trend with dose in the relative risk of leukaemia was similar to that in the Japanese atomic bomb survivors, although this trend was not statistically significant. However, the corresponding trend in the relative risk for all cancers other than leukaemia was similar to that for leukaemia, and was significantly greater than zero.

In an accompanying commentary, Ethel Gilbert noted the contrast between the solid cancer findings in this study and those for the A-bomb survivors and from studies of mortality in other groups of radiation workers, including the NRRW; she also drew attention to potential sources of bias in the Canadian study. Nevertheless, with improvements in cancer treatment, data on cancer incidence are likely to become increasingly important in future epidemiological research, and it is planned to analyse such data in the NRRW.

DU Search Called Off

Following the crash of the Korean Airlines 747 cargo aircraft near Stansted Airport in December 1999 which killed all four crew, there has been an extensive search for the 22 counterbalance weights made from depleted uranium. They were contained originally in the aircraft's tail, but the force of the crash led to complete disintegration of the tailplane. The subsequent clear-up operation identified 21 intact DU counterbalance weights, and the search for the missing one involved draining a lake and scraping top soil from a large area. However, after a 12 month search, the remaining DU counterbalance has proved elusive and the search has been called off. It is presumed to be buried deep in soil somewhere near the crash site and therefore presents little hazard.

The Korean Airlines 747 was also carrying some radiopharmaceuticals, including radioiodine. These were destroyed in the fire following the crash, and were short-lived isotopes. (*Environ Health News*, **16**(7), 22, 2001.)

Nuclear Rockets

Since the birth of the space age in the 1960s, serious proposals have been made for nuclear rocket propulsion. Billions of dollars have been spent on research, but nuclear rocket engines have never been tested in space. The main advantage suggested by proponents for nuclear propulsion is that nuclear rockets could halve the time taken to reach the planets. This could be crucial to the success of manned space flight to Mars, to more routine flights to the gas giants Jupiter and Saturn, and to any attempt to visit Pluto. The primary reason for the time saving, is that nuclear propulsion can provide rocket thrust for both acceleration and deceleration of spacecraft. The journey is quicker and there is still enough energy to slow down the spacecraft at the end of a voyage. Conventional rockets cannot do this as efficiently as nuclear propulsion.

Nature (**410**, 626, 2001) gives a review of recent proposals for nuclear propulsion in space. Its proponents regard the proposed mission to Pluto as crucial to the success of

nuclear rockets. If a case cannot be made here, it will not succeed anywhere at any time in the foreseeable future. Given the protests made about the use of plutonium to power thermal batteries for the Galileo mission to Jupiter (1989) and the Cassini Saturn mission (1997), the future for large-scale nuclear propulsion in space is not hopeful.

Sex and Fluoroscopy

It is well known that fluoroscopic procedures coupled with a barium enema can produce significant radiation doses, both to patients and to medical professionals. Such procedures are therefore only undertaken when there is a clear clinical need. A recent study from Finland throws an interesting new slant on patient dosimetry for fluoroscopy, because it shows that female radiologists are more likely to give higher doses to patients than their male counterparts (Vehmas and Kuosma, *Br J Radiol*, **74**, 255–8, 2001).

Various factors which could influence the difference in dose delivered were examined by the authors, including the extent of training and experience, and possible differences in the patients treated (eg their age, diagnosis or body type). However, the only discernible difference appears to be the gender of the examining radiologist. For example the mean dose–area products (DAPs) were 52.0 Gy cm² for female radiologists compared to 41.7 Gy cm² delivered by male radiologists. The number of exposures per patient and the screening times were also higher for patients treated by female radiologists. The study looked at 523 double contrast barium enemas performed by 21 radiologists (12 female, 9 male).

Choose your physician carefully, and save dose.

Coffee and Cancer

It has been suggested that coffee consumption might be associated with bladder cancer. Indeed, IARC has categorised coffee as ‘possibly carcinogenic’. But epidemiology is complicated by a strong association between bladder cancer and smoking. A pooled analysis of coffee consumption and bladder cancer in European non-smokers was designed to throw light on the question (*Cancer Causes Controls*, **11**, 925–31, 2001).

The results were broadly reassuring. Any risk was small and appeared to be limited to very heavy coffee drinkers – those consuming ten or more cups per day. The investigators could not exclude the possibility that even this effect was due to bias in the selection of controls.

The ten case–control studies in the pooling came from Germany (3), Italy and Spain (2 each), France, Greece and Denmark. The home countries were not represented, possibly on the grounds that no liquid drunk in the UK should be described as coffee.

There’s Someone Smoking in the State of Denmark

A recent paper in the *Lancet* (**357**, 871–2, 2001) shows that the all-cause mortality rate in women aged 45–74 years is declining in all western European countries except Denmark. Until 1978 the rate in Denmark followed the steady decline seen in 37 European countries. From 1978 it stayed steady or increased slightly until the mid-1990s. By then it had ‘caught up’ with the Scottish rate which was always much higher but declining at the same rate as other European countries. Smoking rates in women in Denmark are higher than those in 31 other European countries.

One hypothesis for this finding, which would not be expected from the high socio-economic status of Denmark, is that the Queen of Denmark is acting as a smoking role model for Danish women. She ascended to the throne in 1972 and is an enthusiastic and public smoker. The author comments that a test of the hypothesis would be to observe the effect of their queen quitting.

Childhood Cancer and Air Pollution from Traffic

One of the early American studies that suggested childhood cancer might be associated with proximity to sources of magnetic fields (Savitz *et al*, *Am J Epidemiol*, **128**, 21–36, 1988) also indicated a link with traffic density (Savitz and Feingold, *Scand J Work Environ Health*, **15**, 360–63, 1989). However, in its first report, the NRPB Advisory Group on Non-ionising Radiation raised concerns about possible artefacts in the findings from this study, owing to problems in identifying a representative set of controls (*Doc NRPB*, **3**(1), 1–138, 1992). More information on traffic-related air pollution has recently been published by Olsen *et al*, based on a large case–control study in Denmark (*Am J Epidemiol*, **153**, 433–43, 2001). The investigators had the advantage of being able to access national datasets on cancer and population residences, through which they identified 1989 cases of childhood cancer and selected 5506 controls in an unbiased manner. The information on addresses was linked with a pollution model to estimate concentrations of benzene and nitrogen dioxide for both cases and controls. In order to assess the validity of these calculated exposure estimates, measurements were made outside the residences of a sample of children and their personal exposures were assessed. This validation study showed a low degree of misclassification if calculated levels of pollutants were used as surrogates for measured levels outside the residence, but it was not possible to generalise these results to personal exposures because of other, non-traffic-related sources of pollutants.

The Danish study found no association between the risk of leukaemia, central nervous system tumours or all cancers combined and traffic-related exposure to benzene or nitrogen dioxide, either during pregnancy or during childhood. These findings contrast with the association between childhood cancer and traffic density reported in the American study. There was a significant trend in the risk of lymphomas (particularly Hodgkin's disease) with calculated values of pollutants in the Danish study, but the authors were unable to draw a firm conclusion concerning this finding.

Keep Well Wrapped Up

One of the more appealing medical ideas to have emerged recently is that hypothermia is effective in reducing the effects of acute brain injury. Unfortunately, a large multicentre study recently reported in the *New England Journal of Medicine* (**344**, 560–63, 2001) seems to have disproved the hypothesis.

Patients in coma were randomly assigned to hypothermia (body temperature 33 C) or not, otherwise receiving identical treatment. Not only did the cooled patients not do better, the older ones did rather worse. The study was terminated after rather less than 400 of the planned 500 patients had been treated because the negative result seemed already clear.

An editorial in the same issue of *NEJM* points out that the study would have been impossible if there had been an insistence on full informed consent. Some hospitals were

already using hypothermia for such patients on the basis of previous smaller or animal studies. Presumably they will now be encouraged to direct resources elsewhere.

One possibility remains for those who liked the original idea. Hypothermia may still be effective for brain injury if it is achieved more quickly than in this study, a mean of eight hours after injury.

Costs of Nuclear Power

Production costs of nuclear power in the USA have dropped below those of coal, oil and gas, according to the US Federal Energy Regulatory Commission. The 1999 figures in $\text{c}(\text{kW h})^{-1}$ (where $1 \text{ c}(\text{kW h})^{-1} = 1 \text{ cent per kilowatt hour}$) were nuclear 1.83, coal 2.07, oil 3.18 and gas 3.52 $\text{c}(\text{kW h})^{-1}$. These production costs do not include all the costs of nuclear power, especially the cost of eventual radioactive waste disposal. However, the true external costs of fossil fuel power, such as its contribution to global warming, are not included either. The debate will continue.

Internet Usage

Now that the *Bulletin* is a web-based publication, it helps to know your audience. An extensive review of UK internet usage has been published recently (*e.business review*, 1(12), 14–16, 2001). There are some surprises, and some indications of why ‘dotcom’ businesses are not doing so well. The average user is older and better educated than might have been thought and, although internet users are predominantly men, use by women is growing fast. There is a top ten for domains used in the UK, and sites such as the BBC and various search engines are high on the list. Not far behind are various sports, entertainment and travel sites. The peak audience time is 1900–2100 hours. The main feature is that people expect things free on the internet, and are not in a major rush to buy things on-line. Retail sites are therefore low on the list.

Enjoy Your Hols

One of the research ideas which many scientists might overlook is a study of holiday diarrhoea. But a multinational team reporting in the *Lancet* (356, 133–4, 2000) has taken up the challenge. The results will be of use in planning field trials of prototype vaccines against some of the organisms responsible, but they may be useful in reinforcing defensive behaviour as well.

Tourists visiting the four high risk destinations in the study were surveyed by questionnaire. About two-thirds of them had suffered diarrhoea. British tourists did markedly worse than other nationalities, in terms of both the frequency and severity of disease, even when their reported habits were the same. The authors have no explanation for this, but do point out that they were unable to collect data on potentially protective wine consumption.

The list of high risk food and beverages had few surprises, with ice cream and shellfish featuring strongly. It is odd that some people carefully avoid the local water, but cheerfully put ice in their drinks. The authors summarise: boil it, cook it, peel it – or forget it.

Written and compiled by Michael Clark, with contributions from
Gerald Kendall, David Lloyd, Jill Meara and Colin Muirhead

ELF Electromagnetic Fields and the Risk of Cancer

Report of an Advisory Group on Non-ionising Radiation

CHAIRMAN, SIR RICHARD DOLL

JOHN STATHER & RICHARD SAUNDERS

NATIONAL RADIOLOGICAL PROTECTION BOARD • CHILTON

After a wide-ranging and thorough review of scientific research, an independent Advisory Group to the Board of NRPB has concluded that the power frequency electromagnetic fields that exist in the vast majority of homes, are not a cause of cancer in general¹. However, some epidemiological studies do indicate a possible small risk of childhood leukaemia associated with exposure to unusually high levels of power frequency magnetic fields.

Modern industrial development has resulted in people being increasingly exposed to a complex mix of electric and magnetic fields and radiation that cover a wide frequency range. Major sources of exposure to electromagnetic fields (EMFs) arise from electrical power generation, transmission and use in residential and occupational situations, and from telecommunications and broadcasting. In addition, electronic devices for communications, security and process control have proliferated in industrial plants, in offices, homes, cars and in the environment.

NRPB has a statutory responsibility for advising UK government departments on standards of protection for exposure to non-ionising radiation. This covers static and low frequency electric and magnetic fields and radiofrequency radiations (including microwaves), as well as optical radiation (including ultraviolet radiation).

To provide support for the development of the Board's advice, the Director set up, in 1990, an Advisory Group on Non-ionising Radiation. The terms of reference of the Advisory Group are:

'to review work on the biological effects of non-ionising radiation relevant to human health and to advise on research priorities'

The Advisory Group was reconstituted in 1999 as an independent body and now reports directly to the Board of NRPB. The Advisory Group has to date issued four reports and statements related to concerns about exposure to electromagnetic fields and radiations²⁻⁵.

It is now nine years since the Advisory Group published its first main report on *Electromagnetic Fields and the Risk of Cancer*². Since then much of the experimental work that was being carried out at the time has been completed. A number of substantial residential and occupational epidemiological studies have been published, some of which have taken advantage of improved methods of exposure assessment and of experimental design^{eg 6-9}. In addition, a number of other reviews on health effects related to exposure to electromagnetic fields have been issued¹⁰⁻¹² and recent residential epidemiological studies

have been subject to pooled analyses^{13,14}. The Advisory Group has, therefore, thought it timely to undertake a further comprehensive review of the experimental and epidemiological studies that have been carried out since its first report.

The Advisory Group provides in the present report¹ a comprehensive review of experimental and epidemiological studies relevant to an assessment of the possible risk of cancer resulting from exposures to power frequency electromagnetic fields that have been published since its first report in 1992. It is not concerned with exposures to high frequencies nor with other potential effects of exposure to power frequencies. The possibility of an association between neurological diseases, such as Alzheimer's disease, and magnetic field exposure is being considered separately. The report summarises the extent of exposure to power frequency electromagnetic fields at home and at work and reviews recent epidemiological studies of cancer incidence in humans following both occupational and domestic exposure. It also reviews recently published cellular, animal and human volunteer studies. The Board of NRPB issued a response statement at the time of publication of the Advisory Group report¹⁵.

CONCLUSIONS

Exposure assessment

Studies reviewed in the earlier report by the Advisory Group suffered from a lack of measurement-based exposure assessments. Since then, considerable advances have been made in methods for assessing exposure, both in the case of experimental studies and in epidemiological investigations. Instrumentation allowing personal exposure to be measured has become widely available and has been used in many of the more recently published studies. This has provided a substantially improved basis for many of the epidemiological studies reviewed by the Group.

Cellular studies

At the cellular level, there is no clear evidence that exposure to power frequency electromagnetic fields at levels that are likely to be encountered can affect biological processes. Studies are often contradictory and there is a lack of confirmation of positive results from different laboratories using the same experimental conditions. There is no convincing evidence that exposure to such fields is directly genotoxic nor that it can bring about the transformation of cells in culture and it is therefore unlikely to initiate carcinogenesis.

The most suggestive evidence of an effect of exposure to power frequency magnetic fields on biological systems comes from three different areas:

- possible enhancement of genetic change caused by known genotoxic agents,
- effects on intracellular signalling, especially calcium flux,
- effects on specific gene expression.

Those results that are claimed to demonstrate a positive effect of exposure to power frequency magnetic fields tend to show only small changes, the biological consequences of which are not clear.

Many of the positive effects reported involve exposure to time-averaged fields greater than 100 μ T which are unlikely to be encountered in a domestic situation where typical exposures generally fall in the range between 10 and 200 nT. It is usual to test

carcinogens at levels well above those normally encountered in order to demonstrate their potential to have an effect, on the assumption of a linear dose–response relationship without threshold. However, such an assumption may not be justified with non-genotoxic agents and risk assessment is most usefully focused on realistic exposure levels. Furthermore, the induced current density may be radically different *in vivo* as compared with that for cells in culture.

Animal and volunteer studies

Overall, no convincing evidence was seen from a review of a large number of animal studies to support the hypothesis that exposure to power frequency electromagnetic fields increases the risk of cancer.

Rodents, particularly mice, have been used extensively in studies of adult leukaemogenesis; there is, however, currently no natural animal model of the most common form of childhood leukaemia, acute lymphoblastic leukaemia. Most studies report a lack of effect of power frequency magnetic fields on leukaemia or lymphoma in rodents, mostly mice. These include several recent large-scale studies of spontaneous tumour incidence in normal and transgenic mice, and of radiation-induced lymphoma and leukaemia in mice. The transgenic mice used in two of the studies mentioned above develop a disease with some similarities to childhood acute lymphoblastic leukaemia. Further studies found no effect on the progression of transplanted leukaemia cells in mice or rats.

Rat mammary carcinomas represent a standard laboratory animal model in the study of human breast cancer. Three recent large-scale studies of rats found that lifetime magnetic field exposure had no effect on the incidence of spontaneous mammary tumours. The evidence concerning electromagnetic field effects on chemically induced mammary tumours is more equivocal. Two early studies suggested that exposure to power frequency magnetic fields increased the incidence or growth of chemically induced mammary tumours in female rats but two more recent studies have not corroborated these findings.

Whilst there is no natural animal model of spontaneous brain tumour, a recent large-scale study reported a lack of effect of exposure to power frequency magnetic fields on chemically induced nervous system tumours in female rats. In addition, the low incidence of brain cancers in three recent large-scale rat studies was not elevated by magnetic field exposure. With regard to studies of other tumours, particularly chemically induced skin tumours, the evidence is almost uniformly negative.

The possibility that the hormone melatonin acts as a natural tumour suppressor is controversial. Nevertheless, a number of studies have investigated the ability of power frequency electromagnetic fields to alter endogenous circadian melatonin rhythms. Most evidence from human volunteer studies suggests that melatonin rhythms are not delayed or suppressed by exposure to power frequency magnetic fields, although one recent study provided preliminary data indicating that exposure prior to the night-time rise in serum melatonin may have had this effect in a sensitive subgroup of the study population. In addition, the evidence for an effect of exposure to power frequency magnetic fields on melatonin levels and on melatonin-dependent reproductive status in seasonally breeding animals is largely negative. The evidence concerning power frequency electromagnetic field induced suppression of rat pineal and/or serum melatonin levels is equivocal and the physiological relevance of any effect (if any is produced) remains unclear.

There is no consistent evidence of any inhibitory effect of power frequency magnetic field exposure on those aspects of immune system function relevant to tumour suppression that have been examined. In addition, two studies were unable to correlate possible electromagnetic field induced changes in tumour incidence with significant changes in immune function.

Residential exposure

Recent large and well-conducted studies have provided better evidence than was available in the past on the relationship between power frequency magnetic field exposure and the risk of cancer. Taken in conjunction they suggest that relatively heavy average exposures of 400 nT (0.4 μ T) or more are associated with a doubling of the risk of leukaemia in children under 15 years of age. The evidence is, however, not conclusive. In those studies in which measurements were made, the extent to which the more heavily exposed children were representative is in doubt, while in those in Nordic countries in which representativeness is assured, the fields were estimated and the results based on such small numbers that the findings could have been due to chance. In the UK, very few children (perhaps 4 in 1000) are exposed to 400 nT or more and a study in the UK, with much the largest number of direct measurements of exposure, found no evidence of risk at lower levels. Nevertheless, the possibility remains that high and prolonged time-weighted average exposure to power frequency magnetic fields can increase the risk of leukaemia in children. Data on brain tumours come from some of the studies also investigating leukaemia and from others concerned exclusively with these tumours. They provide no comparable evidence of an association. There have been many fewer studies in adults. There is no reason to believe that residential exposure to electromagnetic fields is involved in the development of leukaemia or brain tumours in adults.

Occupational exposure

Study of populations exposed occupationally to electromagnetic fields can include groups exposed generally at much higher levels than members of the public. They may therefore have a greater potential to detect any adverse health effects. Although recently published studies of occupational exposure to electromagnetic fields and the risk of cancer are, in the main, methodologically sound, and some of them have considerable statistical power, causal relationships between such exposure and an increase in tumour incidence at any site are not established. The excesses, where they exist, are generally modest and are largely restricted to the two cancers that were noted in the 1992 report of the Advisory Group – that is, leukaemia and cancer of the brain. Conflicting evidence exists for the particular cell types of leukaemia associated with the greatest risk but acute myeloid leukaemia is the most cited. The evidence of any risk for brain cancer is conflicting, even that from the most powerful of the studies.

General conclusion

Laboratory experiments have provided no good evidence that extremely low frequency electromagnetic fields are capable of producing cancer, nor do human epidemiological studies suggest that they cause cancer in general. There is, however, some epidemiological evidence that prolonged exposure to higher levels of power frequency

magnetic fields is associated with a small risk of leukaemia in children. In practice, such levels of exposure are seldom encountered by the general public in the UK. In the absence of clear evidence of a carcinogenic effect in adults, or of a plausible explanation from experiments on animals or isolated cells, the epidemiological evidence is currently not strong enough to justify a firm conclusion that such fields cause leukaemia in children. Unless, however, further research indicates that the finding is due to chance or some currently unrecognised artefact, the possibility remains that intense and prolonged exposures to magnetic fields can increase the risk of leukaemia in children.

RECOMMENDATIONS FOR RESEARCH

The Advisory Group recognises that the scientific evidence suggesting that exposure to power frequency electromagnetic fields poses an increased risk of cancer is very weak. Virtually all of the cellular, animal and human laboratory evidence provides no support for an increased risk of cancer incidence following such exposure to power frequencies, although sporadic positive findings have been reported. In addition, the epidemiological evidence is, at best, weak. Nevertheless, considering the ubiquitous nature of power frequency electromagnetic field exposure and the concern about possible adverse health effects, the Advisory Group considers that the following areas of research merit further investigation.

Experimental studies

Further biophysical studies might suggest conditions of exposure more liable to affect carcinogenic processes. Particular attention should be given to weak magnetic field effects on biochemical processes involving radical pair intermediates. Consideration should also be given to the possibility that exposure parameters such as the higher frequencies associated with switching transients might be more biologically relevant than experimental data based only on the time-weighted average exposure. Additional dosimetric studies are required using improved tissue conductivity data in order to quantify more accurately the magnitude and distribution of induced current in the body. Consideration needs also to be given to the possible effects that might result from the dispersal of corona ions and the way in which any such effect might be assessed.

At the cellular level, further studies should be carried out of possible enhancement of genetic change caused by known genotoxic agents, effects on intracellular signalling and effects on specific gene expression. These studies should focus, where possible or appropriate, on the replication of studies that have previously suggested positive results.

For animal carcinogenesis studies, future work should be based on carefully designed, hypothesis-driven investigations. Such hypotheses may be derived from consideration of mechanistic investigations at the cellular level and epidemiological investigations. With regard to the epidemiological observations concerning possible increased risks of childhood acute lymphoblastic leukaemia, the absence of a natural animal model has imposed significant restrictions on experimentation. However, there are various transgenic mouse models of leukaemia which develop a disease having some similarities to childhood acute lymphoblastic leukaemia that may prove useful in future studies. It would, in addition, be valuable to study possible power frequency effects on the cellular structure and development of the prenatal and neonatal haemopoietic system

and any implications for cellular differentiation and clonal growth. There is no strong epidemiological or experimental evidence concerning increased risks of brain or mammary tumours and therefore there is less imperative for further study. However, a recently developed model of spontaneous medulloblastoma in *Ptch*-knockout mice and, more particularly, a mouse model of astrocytomas, a leading cause of brain cancer in humans, may prove useful in the investigation of electromagnetic field effects on spontaneous brain tumour incidence. In addition, further investigation should resolve present uncertainties concerning possible electromagnetic field effects on chemically induced mammary tumours.

With regard to possible effects on circulating melatonin levels, there is further scope for longer term volunteer studies in the laboratory and volunteer or observational studies in the workplace. However, careful consideration must be given to individual variability in melatonin fluctuation in addition to differences in lifestyle, night-time light exposure and other possible confounding factors.

Whilst the evidence concerning possible electromagnetic field effects on the immune system is mostly negative, the effects on tumour rejection *per se* have not been investigated and further study should be carried out using classical tumour rejection models.

Residential epidemiological studies

Residential studies published to date have mostly been difficult to interpret because of the potential for the control data to be biased. Further work is required to investigate the extent to which the methods of control selection that have been used could have affected the frequency with which relatively high exposures were recorded.

Nothing would seem to be gained by further study of more cases of childhood leukaemia in relation to exposure to extremely low frequency electromagnetic fields in the UK, as the number likely to have been exposed to fields of the strength that may cause a material increase in risk (namely fields \geq of 0.4 μ T or more) is too small to provide any useful information. There are, however, parts of the European Union, notably Denmark and Sweden, where such exposures are more common and, moreover, where unbiased evidence can be obtained through the use of national registers. It is, therefore, to be hoped that the European Union will fund an extension of the studies that have been reported from the Nordic countries, which alone might provide clear evidence of the existence of a risk (if one does in fact exist). If parts of the world can be identified where yet greater exposures to children occur frequently, and where good quality epidemiological studies are practical, then study of leukaemia risk in relation to electromagnetic field exposures in those places would be valuable.

If relatively high residential magnetic fields do not produce a risk directly, it is possible that they might do so in association with some specific (or near-specific) alteration in the cell's DNA. It might therefore be helpful to compare the characteristics of the DNA in cases of acute lymphoblastic leukaemia that occurred after exposure to such fields with the DNA in the general run of the disease. As there would be so few relevant cases in the UK, the research would be worthwhile only with international collaboration.

Occupational epidemiological studies

Although occupational studies based on job title suggest a consistent link to excess risks of leukaemia and possible brain tumours, occupational cohort studies have not confirmed this association and are at best equivocal. The more recent cohort studies using

better exposure characterisation for magnetic and electric fields either have not shown an association with leukaemia or brain cancer, or the association has been weak. Better quality exposure assessment is needed, preferably with detailed personal records of exposure in large well-characterised cohorts. In addition to cumulative exposure assessments, consideration should be given to the use of metrics such as rate of change of exposure, exposure peaks, duration of exposure above predefined exposure levels and rapid changes in exposure (transients). The paucity of good quality exposure data hampers progress and research within industry is required to correct this deficiency, define the most heavily exposed groups and quantify their exposure. In future cohort studies of exposed workers, note should be taken of the individual's residential history and, when residence had been near a high power transmission line, measurements of exposure at home should also be included.

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Articles

Radiological
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50th Session of UNSCEAR, Vienna, April 2001

ROGER CLARKE • NATIONAL RADIOLOGICAL PROTECTION BOARD • CHILTON

The Committee approved publication of a report on hereditary risks of radiation and agreed a programme of work for the next few years.

THE 2001 REPORT

During the past few years, the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) has undertaken broad reviews of the sources and effects of ionising radiation. Estimates of the carcinogenic risk from exposures to ionising radiation were presented in the UNSCEAR 2000 Report. In its new report, the UNSCEAR 2001 Report, the Committee has completed a comprehensive review of the risks to offspring (hereditary risks) following parental exposure to radiation. This includes, for the first time, an evaluation of those diseases which have both hereditary and environmental components, the so-called multifactorial diseases. The major finding is that the total risk of hereditary risk is 0.3–0.5 per cent per gray to the first generation following radiation and much less in subsequent generations. This is less than one-tenth of the risk of fatal carcinogenesis following irradiation presented in the UNSCEAR 2000 Report.

Radiation exposure has never been demonstrated to cause hereditary effects in human populations. The absence of observable effects in children of survivors of the atomic bombings in Japan, one of the largest study populations, indicates that moderate acute radiation exposures of even a relatively large human population must have little impact. However, experimental studies in plants and animals have clearly demonstrated that radiation can induce genetic effects. Humans are unlikely to be an exception in this regard.

FUTURE WORK ON THE HEALTH EFFECTS OF RADIATION

Document 1 The agreed title of the document is to be *Mechanisms and Consequences of Radiation Response in Tissues*. This document will take forward the cellular/molecular concepts developed in the UNSCEAR 2000 Report to address radiation effects in tissues. The work will centre on tissue injury, developmental effects and cancer and will include: responses after acute and protracted radiation, biophysical aspects of those responses, the influence of genetic variation and the utility of biological markers of radiation response. The mechanistic aspects of induction of diseases other than cancer (see Document 4) will be initially developed in this document. Given the broad range of topics to be addressed, it was agreed that two consultants should be appointed to work together on the document.

Document 2 The agreed title of the document is to be *Bystander Effects, Genomic Instability and Novel Aspects of Apoptotic Response*. The document would emphasise the potential *in vivo* consequences of these cellular processes and the extent to which their activity can be associated with health effects. The review would also require a summary of related aspects of cell and molecular biology in order to provide linkage with the UNSCEAR 2000 Report and to keep pace with general developments in these fields. In the event that other novel processes are identified, the title of the document would need to be reviewed.

Document 3 It was agreed that the work should continue on the epidemiological reviews that are central to the role of the Committee. The work should follow the model already established and presented in the UNSCEAR 2000 Report. The same title would apply, namely *Epidemiological Evaluation of Radiation-induced Cancer*. Data from the epidemiological study groups identified in the UNSCEAR 2000 Report should be updated, using the same form of tables. It was agreed that review of additional tumour types should be considered and that, when possible, the work should also cover the upcoming revision of the dosimetry for the survivors of the atomic bombings (DS02).

Document 4 It was agreed that the title of the document will be *Epidemiological Evaluation and Dose Response of Diseases other than Cancer*. During the first year, work will centre on review and discussion of cardiovascular diseases and evidence on the dose response. Depending on progress and data publication, attention will be given in subsequent years to other diseases. In these later years, the Committee will also give thought to incorporating mechanistic data from Document 1.

FUTURE WORK ON SOURCES

The Committee has decided to link sources to health effects (risks) through illustrative examples, for example, heavy particles in high altitude flights and internal emitters. An assessment of radon was to be considered as an example of the approach.

Document 1 This would be an overview of the pathways from source to humans that needed to be considered in developing an assessment methodology for future use by the Committee.

Document 2 The proposed subject area is a combined report on new data from natural, man-made and occupational sources. This document could provide the framework, at a later time, for source to effects assessments.

Document 3 The proposed subject is new data for medical exposures. Emphasis would be given to procedures delivering high doses, for example paediatric CT or interventional radiology, and should include a 'source to effects' assessment.

Document 4 This document should be a comprehensive assessment (source to effects) for radon at home or at work. This assessment is intended to serve as a model for potential future assessments.

Document 5 This topic deals with radioecology, including an examination of the effects of radiation on the environment. The following scope was agreed for this:

- define biotic endpoints for assessment, in part through a review of the literature,
- identify alternative methods used to evaluate pathways,
- methods to estimate doses to non-human biota,
- look at the available literature for evidence of impacts at specific sites.

CHERNOBYL

The Committee decided that it would continue to keep under review the emerging data on the health status in Bylarus, Ukraine and the Russian Federation. A report might be prepared to coincide with the 20th anniversary of the accident in 2006.

UNSCEAR WEBSITE

Finally, there was an instruction to the Secretariat to report next year on recommendations to the Committee for future uses of an UNSCEAR website on the Internet. The Committee will meet in May 2002 to progress the work.

New ICRP Guidance in the Medical Area

JACK VALENTIN • INTERNATIONAL COMMISSION ON RADIOLOGICAL PROTECTION

The guidance concerning medical applications of radiation given in some earlier ICRP Publications* could be classified as dealing with the system, the installation, the equipment, and the various groups of patients or other persons exposed to radiation. This is a logical organisation of the material, and it works for most current users of ICRP reports. However, it may also be useful to provide specific guidance on topical problems, thus in a sense cutting information in another direction. In addition, ICRP believes that such problem-oriented guidance may be particularly relevant for practising physicians, nurses, and other medical staff directly involved in the care of patients as well as for health physicists and engineers 'at the shop floor' in hospitals and clinics. While such categories of staff were always part of the intended readership for medical reports of ICRP, the earlier area-oriented guidance was also very much adapted to the requirements of readers at a more managerial level.

Several new reports are currently being finalised in line with these considerations. The first one, *Pregnancy and Medical Radiation*, is printed as ICRP Publication 84. Its rationale is that thousands of pregnant patients and medical radiation workers are exposed to radiation each year. Lack of knowledge causes great anxiety, and probably underlies unnecessary termination of many pregnancies. The report discusses how to deal with such problems and with the management of pregnant patients and pregnant workers. It is not intended as a complete reference work, but rather to provide a practical approach that can be used in varying situations.

A second report in this series, *Avoidance of Radiation Injuries from Interventional Procedures* (due in 2001 as Publication 85), focuses on the fluoroscopic use of x-rays to guide therapeutic and/or diagnostic interventions via percutaneous access for 'keyhole surgery with x-ray vision'. As many non-radiologists are increasingly using such techniques, and most have had little training in radiation protection, they need information about radiation risks and how to minimise such risks in their everyday practice.

A third report, *Accident Prevention in Radiation Therapy* (also due in 2001 as Publication 87), will draw on the experience of past accidents to analyse their causes and how to prevent similar events from happening again. It will address deficiencies in training, procedures, communication, defence-in-depth, equipment, attention, and decommissioning. Combinations of causes will be addressed, and managerial and institutional problems as root causes will be highlighted.

A fourth report, *Management of X-ray Doses from Computed Tomography* (again due in 2001 as Publication 88), addresses this rapidly increasing modality, which is already the major contributor to collective dose in medicine.

A report on the release of 'radioactive' patients from nuclear medicine clinics is also being prepared.

In addition to its publications in the *Annals of the ICRP*, ICRP intends to attempt to provide some guidance through other means. For instance, the ICRP website is used to provide

* In particular, ICRP Publications 33, 34, 44, 52, 53, 57, 62, 73 and 80; Publications 60, 75, and 76 also contain relevant parts.

advance information that is not yet ready for printing in the *Annals* (eg dose data for radiopharmaceuticals introduced very recently, so that this information is accessible while enough data are accumulated to permit a full printed report). ICRP will also investigate the possibility of circulating condensed guidance as posters, stickers, etc.

FUTURE BASIC ICRP RECOMMENDATIONS

The present general recommendations of ICRP in Publication 60 were adopted in 1990. Traditionally, such recommendations are revised every 15 years or so, and, in keeping with this, ICRP plans to issue recapitulated and/or consolidated new recommendations around 2005.

Ideas for these new recommendations are currently being collected for discussion, evaluation, and development. One of the more comprehensive proposals that has emerged so far was suggested by Professor Clarke in 1999*. It brings out a concept of 'controllable dose' with the purpose of simplifying protection recommendations and avoiding confusion over scientific issues. ICRP has recruited the collaboration of IRPA, the International Radiation Protection Association, to ensure a comprehensive discussion among peers all over the world of this and other proposals for the new recommendations.

In the consultation process, some debaters have indicated that they doubt the applicability of this concept for radiological protection in medicine. In contrast, the present author feels that in fact it may be particularly well adaptable to protection of the patient. Some features of the controllable dose proposal follow.

- A controllable dose is defined as the dose, or the sum of doses, to an individual from a particular source that can reasonably be controlled by whatever means.
- The significance of a controllable dose would be judged by its magnitude, the benefit to the exposed person, and the ease of reducing or preventing the dose. In principle, similar actions would be attempted for doses of similar size, no matter what the source. (This in fact resembles the current system in many ways, but the advice would be organised much more transparently.)
- Protection would be focused on the individual rather than the collective (of course, the number exposed in 'critical groups' would still be an issue, and workforce doses would need to be treated much the same way as today to preclude 'dilution' of doses).
- Significantly higher doses than some tens of mSv would only be sustained in accidents and life-saving medical procedures.
- The intentional delivery of high doses in medicine, as in radiotherapy and at least some interventional procedures, would be outside the scope of controllable dose.
- In contrast to the current scheme of justification – optimisation – limitation, the proposed system would focus on individual limitation, followed by optimisation of protection against the resulting doses. It would be emphasised that justification is a societal/political exercise involving more than just health physics.

NEW RECOMMENDATIONS AND DIAGNOSTIC USES OF RADIATION IN MEDICINE

The drafting of proposed new basic recommendations continues, and will lead to further consultation. The extent to which the controllable dose proposal will be part of the final result is yet open to discussion. The proposal comprises several components, some of which are not indispensable prerequisites for the other components. It seems, however, relevant

* Clarke R H. Control of low-level radiation exposure: time for a change? *J Radiol Prot*, **19**, 107–15 (1999).

to analyse the possible impact of controllable dose on radiological protection in medicine. Gauging doses to patients from diagnostic procedures with x-rays or radiopharmaceuticals against the components of the proposal yields the following result:

such patient doses obviously fulfil the basic definition of controllable doses
– they are doses to individuals, they come from identified sources, and they can be controlled by reasonable means

As indicated above, the significance of doses is already being judged by their magnitude, the benefit to the exposed person, and the ease of reducing or preventing the dose. Diagnostic use of radiation in medicine is no exception, and the proposed system of controllable dose would only simplify comparisons with other situations.

A crucial property of patient doses is that the same individual usually sustains the radiation risk and gains the medical benefit (screening programmes, eg mammography of healthy women, may require some extra consideration). This means that the focus on protection of the individual characterising the controllable dose proposal is uniquely relevant in this context. While collective dose to patients can provide valuable information, it normally is not relevant for protection. As soon as one removes unwarranted examinations and unduly high doses per examination (both of which are individual-related), an increasing collective dose will only mean that benefit to the population is increasing because more people are allowed access to valuable medical procedures. (In contrast, in keeping with the comments above, some sort of supervision of workforce doses will probably continue to be required in the optimisation of protection of medical staff.)

An action level at about 30 mSv, and investigation levels at about 3, 0.3 and 0.03 mSv, would fit in very reasonably with typical doses from different procedures causing high or not so high doses. A CT scan could cause an effective dose of up to about 30 mSv, a thyroid examination using ^{99m}Tc would entail an effective dose well below 3 mSv, the effective dose from a cervical spine x-ray examination would usually be around 0.3 mSv, and the typical effective dose from a standard dental examination should be less than 0.03 mSv.

Here, it is essential not to mistake action/investigation levels for limits. While the protection specialist takes pains to achieve low average doses per examination, the practising clinician may come up with a unique combination of patient and circumstances requiring a higher dose than whatever predetermined level. This will not, however, constitute an infraction of any rule. Action/investigation levels are not absolute borders to the unacceptable; rather, they signal cases where extra care must be taken to ensure that, all things considered, doses are as low as reasonably achievable. Similarly, lengthy optimisation exercises will not be required in each individual case, just as they are not undertaken each and every time that radiation equipment is used in other contexts. Rather, it is the generic operating methods that need to be carefully optimised, and the success of that optimisation will be judged by comparing average doses and dose distributions, not individual patient doses, to guidance levels based on achievements in peer departments.

Finally, in diagnostic medicine, there are two levels of justification. Health and radiological protection authorities may wish to issue national advice on generic justification of methods, indicating situations where these methods are particularly likely or unlikely to be justified. Societal and sometimes political considerations will obviously have an impact on such advice. For the individual patient, it will be up to the patient and the attending physician to decide on the justification of using radiation in that particular case. Again, societal aspects will usually influence that decision on justification.

NRPB is a Public Health Organisation

Developing the Work Programme in Public Health

JILL MEARA • NATIONAL RADIOLOGICAL PROTECTION BOARD • CHILTON

When NRPB reviewed its strategy in 1999, it decided to develop a public health medical post. This article shows that NRPB is a public health organisation and describes its forthcoming public health work programme, which focuses on improving the way NRPB communicates with professionals and the public.

WHAT IS PUBLIC HEALTH?

Public health is the science and art of improving health through the organised efforts of society. Public health relies upon a number of scientific disciplines that combine to analyse, ameliorate and reassure members of the public about things that affect their health. Epidemiology is the basic science of public health. Planning and delivering actions to improve health or decrease risk of ill health based on the epidemiological evidence requires a wider range of skills including the social sciences, social policy, management and the ability to influence government and local decision makers. Public health involves highlighting risks that the public and politicians would rather ignore (smoking, drink-driving and exposure to sunlight are good examples). Public health is also realistic and reassuring about things that are more frightening to the public than their statistical level of risk would suggest. Within the Health Service, public health staff work with health professionals to ensure the most effective treatments are given and minimise risks to patients (x-rays are a good example). Public health doctors in the NHS are key local contacts in emergency planning. They need support from experts when incidents occur that are outside their normal range of expertise.

WHO DOES PUBLIC HEALTH?

Public health is a much broader activity than the work done by public health departments in the health service and academia. Local government has a big part to play. Environmental health departments are doing public health all the time. Schools and colleges contribute to public health by teaching students about risk, but more importantly by giving students the tools to earn a good living, which is still the best predictor of health the world over.

NRPB IS A PUBLIC HEALTH ORGANISATION

NRPB analyses and researches the risks of radiation using epidemiological and laboratory methods. It investigates the levels of risk from radiation in the home, industrial and environmental settings, and researches and advises on what can be done to ameliorate these risks. NRPB gives advice to the government, local authorities and the public about all this. It works at the policy level but also gives advice at the front-line of routine industrial radiation protection and during emergencies and exercises.

The 1999 Strategic Review confirmed the need to increase the public health dimension of NRPB work and to work more closely with the public (*Bulletin* No. 228, p 23). I have been appointed to take the work forward and have been in post for nine months now so I want to publicise the developing public health work programme and invite anyone to comment or contribute to this work. Although I am the focus for the public health work of NRPB, many people within NRPB and outside it play their part to protect the public from the harmful effects of radiation.

A PUBLIC HEALTH WORK PROGRAMME FOR NRPB

I have spent a lot of time talking to people both within NRPB and outside. I have talked to people in government departments, the NHS, the nuclear industry and members of the public. There is great willingness to collaborate to improve public protection against radiation hazards. In most areas, I have been pushing at an open door to develop my ideas. The priorities for my next year's work are shown below.

COMMUNICATIONS: NRPB, THE PUBLIC AND PROFESSIONALS

Public enquiries

NRPB responds to about 40 000 enquiries per year, with many from members of the public who are worried about the (health) risks of radiation. This volume of work makes it sensible to streamline the administration of call handling. NRPB must record details of enquirers and the topic of enquiries accurately. We need to use the information about what the public wants to know to develop new public information. Administrative staff and pre-prepared response materials should be used wherever possible to improve consistency of response and cut down on cost. The time of the scientists (and public health doctor) is precious. They need to prepare standard response material and to answer non-standard questions that are beyond the scope of the pre-prepared answers. We must respond to the public in a timely and professional way. An NRPB working group is developing a way to improve handling of public enquiries.

Redevelopment of the website

The NRPB website is being redeveloped to increase the amount of material aimed at the public and to let the web be the main publication vehicle for NRPB scientific documents. The contents of the parts of the site aimed at the public must be driven by the questions we get from the public and professionals. NRPB has engaged consultants to help develop the full potential of the web. We will be asking 'users' of our website and the public what is needed and develop materials to meet the needs. We also need to ensure that the NRPB website contains some 'health promoting' messages in areas where we know the public are exposing themselves to risk (for example, ultraviolet radiation and radon). We are currently testing whether publicly accessible summaries of the published NRPB reports and memoranda can be produced in simple language without losing scientific accuracy.

We will explore how to link the NRPB website with other official websites including the National Electronic Library for Health, NHS Direct and the Public Health Observatories. The public and professionals need to find easy ways to access NRPB advice.

We will develop ways to demonstrate the independence of NRPB advice through our website so that the public can make up their own minds about the validity of our advice.

New Radiation, Risk and Society Advisory Group

The 1999 Strategic Review proposed a new advisory group on communications. Sir Kenneth Calman, formerly Chief Medical Officer for England, has kindly agreed to chair the group. Potential members have been identified from a wide range of backgrounds. We hope to hold an initial meeting soon. Its remit will be to advise NRPB on the best practice in getting our message across. NRPB will need to change the way it talks to the public. It may also need to change the way it works to ensure that the end product is useful for the public and scientific audiences alike. We also want to hear a wider variety of public views and to that end will be setting up 'Environmental Issues Forums' to hear what people as individuals or in organisations want to say about radiation protection so that it can influence our work.

Developing the skills of NRPB staff to influence the public

We will develop the skills of NRPB staff to write in a way the public can understand. We will use these skills to develop new web pages and set up a quality assurance mechanism for publications. We will ensure good practice in risk communication by making use of good practice guidelines already published by the Department of Health and the Health and Safety Executive. This will include defining a risk taxonomy for radiation that is in line with current best practice.

NRPB, THE NHS AND LOCAL AUTHORITIES

Emergency response

Local authorities and health authorities are at the 'sharp end' when a radiation incident occurs on their patch. We need to continue to provide training for staff who may be called upon to deal with such incidents. Areas around nuclear installations are more familiar with emergency response procedures because they take part in exercises. Local authorities are likely to need much more help if an incident occurs away from a nuclear installation.

NRPB is developing collaboration with SCIEH, the Scottish Centre for Infection and Environmental Health. This body, which is part of the Scottish Health Service, supports local health authorities' response to infectious and environmental health risks. They lack detailed experience of radiation protection and want support from NRPB. They would be very useful to NRPB in helping to set up follow-up studies of 'accident victims' to define any adverse effects.

'Non-nuclear' authorities train to cope with chemical incidents, which are much more common than radiation emergencies. We will make links between the responses to chemical and radiation emergencies to make it easier for local authorities to respond. We want to develop help for local authorities, available on the web, which meets their needs in an emergency.

We have also developed collaboration with the Institute of Naval Medicine in Portsmouth. The doctors there have extensive knowledge of radiation medicine and occupational health. This complements the public health expertise now available at NRPB.

Stable iodine prophylaxis

A Department of Health working party is looking at whether to recommend a change to the emergency reference level for stable iodine prophylaxis to fit in with new WHO recommendations. Prophylaxis is a public health measure and needs the wide public health view of all its risks and benefits, including side-effects, and social and financial costs.

PSYCHOLOGICAL ASPECTS OF RADIATION INCIDENTS

A number of people are in contact with NRPB because they fear they have been damaged by radiation. In most cases, objective measures of their exposure are reassuring, but the personal distress may continue. NRPB needs to keep up to date with best practice to reassure such people and ensure that psychological consequences of radiation incidents are taken into account when advice is given.

COMARE

I will be providing the public health medical input to the COMARE Secretariat. I will also act as the Medical Secretary for Independent Review Panels for radiation workers who appeal against being excluded from work on medical grounds.

INTERNATIONAL FOCUS

My first three months kept me busy within the UK but subsequently I ventured beyond these shores. NRPB had had great success in winning European Union contracts for research work. I want to enhance the relevance of this work for public health. Over the next year, NRPB needs to develop its public health presence in radiation protection within the international context. A visit to WHO has reinforced the position of NRPB as a WHO Collaborating Centre. We hope to develop more public health collaboration with WHO. I have also attended a REAC/TS conference on the Medical Basis of Radiation Accident Preparedness, Focus on Clinical Care, in Florida (see p 39 this issue).

FUTURE DEVELOPMENTS

When the first round of objectives is completed there will still be much more to do. Some new areas of work have been identified already; others will flow from the changing needs of NRPB. Topics already identified include:

- developing the public health aspects of NRPB role as a WHO Collaborating Centre,
- developing a training post for a Public Health Specialist Registrar,
- forming an academic attachment to the Institute of Health Science in Oxford,
- defining a role for public health within the Advisory Groups on Ionising and Non-ionising Radiation,
- developing a health promotion role for NRPB, especially in relation to ultraviolet radiation and radon.

CONCLUSION

NRPB is a public health organisation. I see my role is to demonstrate the public health potential of NRPB to a wider audience and make NRPB a more confident advocate for public health in radiation protection.

Guidance Notes for Dental Practitioners on the Safe Use of X-ray Equipment

TONY HUDSON • NATIONAL RADIOLOGICAL PROTECTION BOARD • LEEDS
(Chairman of the Working Party* and Editor of the Guidance Notes)

The cycle, which commenced with ICRP Publication 60 in 1991, new European Directives in 1996 and 1997, and new UK Ionising Radiations Regulations in 1999 and 2000, has now been completed for dental practitioners with publication of new Guidance Notes (GNs) concerned with the safe use of dental x-ray equipment.

Dental radiographic examinations represent one of the most frequently undertaken radiological investigations in the UK. A survey for the period 1997/98¹ estimated that dentists were taking 19 million intra-oral radiographs each year and more than 2.9 million panoramic radiographs. The effective dose delivered to the patient per radiograph is very small but the collective dose is significant because of the large number of radiographs that are taken.

The aim has been to provide dental practitioners with a convenient publication upon which to evaluate and base their compliance with those parts of new ionising radiations regulations (the Ionising Radiations Regulations 1999, IRR99², and the Ionising Radiation (Medical Exposure) Regulations 2000, IR(ME)R2000³) that apply to the use of x-rays in a dental practice. The drafting was undertaken under an informal agreement between the British Dental Association (BDA), the Institute of Physics and Engineering in Medicine (IPEM) and the National Radiological Protection Board (NRPB). IPEM has revised the more general Guidance Notes that relate to both medical and dental uses of ionising radiation and which apply principally to the hospital environment.

BACKGROUND

The GNs are innovative in that a definitive document has been produced aimed specifically at the use of dental x-rays outside the hospital sector. Furthermore, the Working Party was chosen to ensure that the GNs were written for dentists by dentists and by people who specialise in dental radiology.

The whole document consists of five chapters, supported by seven technical appendices that provide more detailed guidance on specific topics of particular importance in terms of meeting legal requirements. Chapters 3 and 4 ('practical and procedural aspects of dental radiology' and 'equipment aspects of dental radiology') contain technical detail that is common to all dentistry, ie within and without the hospital sector. These chapters will be technically consistent with the more general medical and dental guidance being produced by IPEM. The remainder of the GNs reflects an administrative structure that is very different to that found in a hospital. They are written to assist the 'stand-alone' dental practitioner who does not have day-to-day, on-site access to specialist technical advice.

*The organisations represented on the Working Party that prepared the Guidance Notes are given in the panel.

Organisations represented on the Working Party

British Dental Association
British Society of Dental and Maxillofacial Radiology
Royal College of Radiologists
Faculty of General Dental Practitioners (UK) of the Royal College of Surgeons of England
Health and Safety Executive
Institute of Physics and Engineering in Medicine
National Radiological Protection Board

The material in the GNs derives principally from two sources, namely:

- Chapters 5 and 6 ('dental radiology' and 'equipment for dental radiology') of the 1988 Guidance Notes for the Protection of Persons against Ionising Radiation arising from Medical and Dental Use⁴,
- Guidelines on Radiology Standards for Primary Dental Care, produced by the Royal College of Radiologists and NRPB in 1994⁵.

The information from both documents has been thoroughly updated and considerable additional material has been included. In particular, it has been necessary to add a lot of material concerned with patient protection in order to reflect the requirements of IR(ME)R2000. The aim here has been to eliminate exposures which have no merit (ie those that are not justified or do not have any clinical value) and to optimise all justified exposures.

OVERVIEW OF THE TECHNICAL CONTENT

Chapter 2 lays down an administrative structure for dental radiology outside the hospital sector. Of particular significance in this chapter is the new material, relative to previous GNs, relating to patient exposure. Justification and optimisation are addressed, and the concept of diagnostic reference levels is introduced as an aid to optimisation.

Chapter 3 addresses the practical and procedural aspects of dental radiology, including guidance on the maintenance and testing of x-ray equipment, with greater detail appearing in Appendix 5.

Chapter 4 contains technical specifications and recommendations for dental x-ray equipment, including, for the first time, recommendations for the dimensions of rectangular x-ray beams

Chapter 5 addresses all aspects of a quality assurance programme relevant to radiology in a dental practice. A particular innovative procedure, which builds on the previous RCR/NRPB Guidelines⁵, relates to the setting of minimum standards for radiographic quality. This involves a regular, subjective quality rating of radiographs to reflect their diagnostic acceptability and value, supported by a regular analysis of the results for comparison with recommended targets.

The seven technical appendices include detailed guidance for preparing 'Notifications' and 'Risk Assessments' under IRR99, as well as the essential content of a Radiation Protection File that incorporates provisions from both IRR99 and IR(ME)R2000. Appendix 3 contains guidance on meeting the IR(ME)R2000 requirements for adequate training and for continuing education and training, in respect of practitioners and operators.

Of particular note here is Appendix 6, which was included to provide dental practitioners with a summary of their essential legal requirements.

CONCLUSION

The Working Party commenced its task with the intention of providing positive guidance for dental practitioners, and in the hope of avoiding the use of 'weasel words' that would leave too many issues open to different interpretation. This approach has inevitably led to a very comprehensive document that addresses virtually all aspects of practical importance to radiation protection for dental practitioners.

The comprehensive nature of the GNs may well make them appear rather daunting to the average practitioner, who does not require such detail on a day-to-day basis. As a consequence, the appendix on essential legal requirements was included as a convenient summary of what must not be missed.

Responses during the period of open consultation in August and September 2000, however, indicated that the comprehensive coverage achieved by the GNs is welcomed by the many radiation protection professionals who are required to advise dentists. This has been confirmed by the 'professional response' to the final drafts of the GNs. Indeed, one of the most common responses received has been along the lines 'It is very good but already rather lengthy – however, don't you think you should add advice on ...!'

The Working Party hopes that it has produced the authoritative point of reference in radiation protection guidance for dental practitioners, and that the GNs will fulfil this role for many years to come. Equally, it is hoped that dental practitioners will welcome the comprehensive approach.

ACKNOWLEDGEMENTS

The Working Party was appreciative of the support given for the technical content of the GNs by the Standing Dental Advisory Committee of the Department of Health. It also wishes to acknowledge the Department of Health's decision to fund both publication and distribution of the GNs, and for the Department's support in providing an observer on the Working Party. In the Foreword, the GNs are commended to all dental practitioners by Nairn Wilson, the President of the General Dental Council. The full text of the GNs is available on the NRPB website (www.nrpb.org.uk/dentalgn.htm) and it is hoped that printing and distribution to dental practices will take place later this year.

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The Work of NRPB as a WHO Collaborating Centre

JILL MEARA • NATIONAL RADIOLOGICAL PROTECTION BOARD • CHILTON

NRPB was officially designated as a WHO Collaborating Centre in April 1997. The period of designation lasts four years. A report of NRPB activities in support of the collaboration has recently been compiled in order to apply to be redesignated for another period. This report summarises NRPB work in emergency preparedness and response, the health consequences of the Chernobyl accident, ultraviolet radiation protection (the INTERSUN Project), the International Electromagnetic Fields (EMF) Programme, and health effects of depleted uranium.

WHAT IS A WHO COLLABORATING CENTRE?

An article in the WHO constitution assigns a function to 'promote and conduct research in the field of health'. As early as 1949 it was established that this could best be done by collaboration with leading research organisations throughout the world. Collaborating Centres do not just do work which is shared internationally. They also pledge to strengthen information, services research and training to improve health in their own countries.

Collaborating Centres are selected on a number of criteria including:

- scientific and technical standing of the organisation nationally and internationally,
- quality of leadership and of the staff of the organisation and its personnel and funding stability,
- influence the organisation has within its own health system and its working relationships at national and international level,
- ability of the organisation to support WHO research programmes over a significant time.

RADIATION EMERGENCY PREPAREDNESS AND ASSISTANCE NETWORK (REMPAN)

- NRPB hosted one of a series of REMPAN meetings at its Chilton headquarters in June 2000. Sessions covered: reports from REMPAN and its Collaborating Centres; presentations on national and international work programmes; experience from recent accidents; public health issues; the future programme for REMPAN. The meeting attracted public health and radiation protection specialists from a range of countries as well as international organisations.
- NRPB has presented over 100 training and awareness courses on radiation emergencies during the four-year period. Topics covered have included response to nuclear, radiological and transport accidents. The attendees have come from a wide range of backgrounds, both within the UK and overseas including front-line emergency services, public health and clinical specialists, as well as radiation protection and emergency planning specialists.

BIOLOGICAL DOSIMETRY AFTER ACCIDENTAL EXPOSURES

- NRPB staff contributed one talk and co-authored another at the REMPAN conference that NRPB hosted last year.
- NRPB contributed to the IAEA report on the Istanbul accident where ten scrap yard workers were severely irradiated.

- NRPB is involved in a cytogenetic follow-up of the five worst cases from the Istanbul accident.
- NRPB has also collaborated on cytogenetic follow-up of the Kiisa, Estonia, accident of 1994 and is currently combining the data from four laboratories for publication.
- NRPB is collaborating with the Moscow REMPAN Centre on the medical treatment/dose reconstruction of an accident to three men in Russia in Autumn 2000.
- NRPB published two papers, jointly with the Moscow REMPAN Centre, in 1999, on treatment and dose reconstruction on the 1995 fatal overdose to a truck driver in Russia.
- NRPB published a paper on triage of irradiated casualties jointly with an IAEA-sponsored fellowship trainee.
- NRPB hosted another IAEA-sponsored fellowship trainee from Turkey in 2000.
- NRPB staff have written over half of an IAEA manual on biodosimetry, currently in press.

INTERNATIONAL PROGRAMME ON THE HEALTH CONSEQUENCES OF THE CHERNOBYL ACCIDENT (IPHECA)

- Under the auspices of the European Commission, NRPB has assisted in the epidemiological training of scientists from the former Soviet Union who are involved in research relating to the Chernobyl accident. In particular, NRPB hosted six scientists for training in March 2000, and contributed to epidemiological courses run in Tallinn (Estonia) in 1997 and 1998.
- NRPB has published two papers on cytogenetic dose estimates for Ukrainian Chernobyl liquidators and evacuees from Prypiat, and Belarus children. All seem to have had higher exposures than physics model/reconstruction would suggest. Currently NRPB staff are collaborating with Ukrainian and Belarus colleagues in further follow-up of these populations sponsored by a European Union Inco-Copernicus contract.
- NRPB has contributed to the development of IAEA detailed guidance on emergency planning and response. Staff have contributed to a number of TECDOCs and draft Safety Guides on the topic.

WHO INTERSUN PROJECT

NRPB has initiated or collaborated on a wide range of UVR projects in support of the WHO INTERSUN Project. This has included the INTERSUN aims and objectives around public information, education and research on UVR, particularly in relation to solar exposure.

- Implementing the Global Solar UV Index in the weather and media forecasts in the UK with collaboration from the UK Department of Health, the Meteorological Office and media representatives.
- Participating in meetings to improve and develop public understanding of the Solar UV Index globally, the most recent was held in Munich in December 2000.
- Continuing the coordinated solar radiation measurement programme within the UK, Ireland, the Falklands and Greenland, to provide real-time UVR data in support of media weather forecasting and the promotion of the Global Solar UV Index. The UK measurements are available on the Internet.

- Organising and hosting in association with WHO and ICNIRP a three-day international workshop entitled *Ultraviolet Radiation Exposure, Measurement and Protection* in Oxford, October 1999, and hosting a subsequent WHO workshop at NRPB, Chilton. The proceedings of the Oxford Workshop were published in *Radiation Protection Dosimetry*. This meeting was used as an opportunity to develop a database of researchers and research, convene an expert panel, identify gaps in knowledge and encourage funding agencies to support new research.
- Developing through international standards committees, such as CEN and CIE, reports and guidelines relating to sun protective clothing, as well as publishing in the scientific literature on these and other relevant topics. Standardised tests for determining UVR protection factors for clothing have been developed and tests have been established for assessing UVR protection of shade structures and sunglasses.
- Preparing a WHO fact sheet on UVR exposure in occupational environments, submitted to WHO in July 2000.
- Collaborating in the production of UVR precautions as part of the WHO Guidelines for Safe Recreational Water Environments (Coastal and Fresh Waters).

IN VITRO UVR BIOLOGY RESEARCH PROGRESS

Work on UVR effects on cell signalling pathways in human keratinocytes involved in the 'UVR survival response' has been completed, as has work on the effect of increased intracellular melanin concentration on the survival of ultraviolet-irradiated human melanoma cells. The latter study found a marginally protective effect of melanin against UVB radiation. The current research programme focuses on the wavelength dependence of UVR-induced cytogenetic damage and effects on cell cycle progression in normal human melanocytes and in various stages in the neoplastic progression to malignant melanoma. Studies are in progress using a human melanoma cell line and normal human melanocytes.

INTERNATIONAL EMF PROGRAMME

Dr Alastair McKinlay of NRPB chaired a European Commission Expert Group on 'Mobile Telephony and Human Health' that completed a report on research needs in this area. The recommendations in this report contributed substantially to the global research agenda on radiofrequency radiation that has been drawn up by WHO. It also provided impetus to the EU 5th Framework Research Programme activity in this area.

Dr McKinlay and other colleagues at NRPB have worked closely with WHO on the International EMF Programme. Dr McKinlay was also Vice-Chairman of the International Commission on Non-Ionizing Radiation (ICNIRP) (1996–2000) and is now its Chairman (2000–2004). The collaboration between NRPB and WHO, which has also involved Dr McKinlay in both his roles, has included:

- Membership and occasional chairmanship of the Scientific Advisory Committee of the International EMF Programme.
- Organising an international workshop that was sponsored by WHO and ICNIRP on Exposure Metrics and Dosimetry for EMF Epidemiology.
- Publication of that Workshop's proceedings in *Radiation Protection Dosimetry*.
- Provision of advice and comments on various WHO draft advisory documents on EMFs and human health.
- Scientific contributions to various international workshops and seminars jointly organised by WHO and ICNIRP.

- Scientific input to three comprehensive reviews on EMFs and human health being carried out by ICNIRP and provided as advice to WHO for its health hazard assessment on extremely low frequency fields (ELFs):
 - review of the epidemiology related to ELFs – completed and submitted for publication 2001,
 - review of the biology related to ELFs – to be submitted for publication 2001,
 - review of the physics and engineering related to ELFs – to be submitted for publication 2001.
- Collaboration with WHO on its EMF exposure standards global harmonisation initiative.
- NRPB staff published a handbook on EMFs for local authorities (world-wide) for the WHO Regional Office in Copenhagen. It has had wide distribution and is currently being revised.
- The biological dosimetry group currently has a project to examine whether 50 Hz magnetic fields at 0.2, 0.5 and 0.7 mT modify the repair of chromosomal damage caused by gamma rays.

HEALTH EFFECTS OF DEPLETED URANIUM

A number of NRPB staff have been asked to contribute to a publication in the WHO Monograph Series on uranium and depleted uranium which is about to be published. This work included detailed review of a draft. NRPB staff have also written sections for the revised draft and attended editorial review meetings in Geneva. The main author of the Monograph has spent some time at NRPB working with staff on the draft.

PLANS FOR FUTURE COLLABORATION

- Expanding the public health role and developing efficient ways to enhance public understanding and decision making in the fields of radiation and radiation protection.
- The NRPB website is presently the subject of a substantial review with the focus being broadened to engage the interest of the general public rather than the scientific specialist. The *At-a-Glance* series of leaflets continues to be extended and updated.
- Continuing to provide support for activities to enhance emergency preparedness. We will continue to collaborate in assessing the effects of past accidents as an aid to accident prevention and future planning of accident response.
- In the UVR field, many of the projects outlined above will continue into the future. We would like to work with WHO to raise the profile of UVR protection with national governments and encourage more funding for research in this area.
- In the EMF work NRPB will continue to collaborate closely with WHO, principally through its combined support for ICNIRP activities as follows:
 - continued cooperation in the global EMF exposure standards project,
 - scientific input to three comprehensive reviews on EMFs and human health being carried out by ICNIRP and provided as advice to WHO for its health hazard assessment on radiofrequency radiation (RF):
 - review of the epidemiology related to RF – work initiated 2001,
 - review of the biology related to RF – work initiated 2001,
 - review of the physics and engineering related to RF – work initiated 2001,
 - cooperation in organising an International Workshop on Thermophysiology and RF Dosimetry – 2002,
 - scientific input to future joint WHO–ICNIRP workshops and seminars.

Risking it in KU World

JOHN HALLAM • NATIONAL RADIOLOGICAL PROTECTION BOARD • CHILTON

BAAS SCIENCE WEEK

Each year the British Association for the Advancement of Science runs National Science Week to celebrate science and its importance to our lives. It provides the general public with chances to find out about science and the opportunity to take part in science-based activities and discussions. Amongst other aims, National Science Week tries to promote an appreciation of the role of science, engineering and technology in our lives and to encourage the study of science, engineering and technology beyond the age of 16 years.



AN NRPB CONTRIBUTION, 2001

As part of its contribution to National Science Week during March 2001, NRPB produced an Internet site looking at risk. This was chosen since it is fundamental to radiological protection and many other topics related to health and safety. A good public understanding of the issues involved in this area is essential if there is to be informed public input into political debate.

AIMS OF THE SITE

In view of the potentially transient nature of the site and its likely young audience, it was decided to use the development of the site as an opportunity to try out material and a presentational format very different from the usual NRPB style. The site represents a new departure for NRPB in its intended audience, its format and its scope.

Audience

A major audience for Science Week activities is GCSE and A-level students, their teaching staff and interested adults. NRPB publications have rarely been aimed at an audience as young as this.

Format

The format chosen for the site was an interactive game with a number of small prizes, in the hope of securing as much initial interest in the target audience as possible.

Scope

Rather than trying to convey factual information, as most NRPB publications do, the site was intended to stimulate thought and discussion around the topic of risk, particularly in a school situation where several pupils may be attempting the game together or competitively. It tried to provoke questions such as:

- How should decisions about risks be made?
- Who is making these decisions now?
- Do I have a part in it?
- Where do I get my information?
- How do you deal with uncertainty?
- How should the priorities be assigned?
- Should there be compulsory rules about risks?
- How do radiation-associated risks fit into this?

Links are also provided to other websites, including the main NRPB site, where more information and data on the activities included and risks in general can be found.

THE GAME

Players are invited to make decisions about risks on behalf of the population of the imaginary KU World. This population then acts on their advice. The aim of the game is to protect as many of the population as possible from the hazards, both immediate and in the future, from a number of activities. The everyday activities are smoking, motorcycle riding, scuba diving, horse riding and playing football, and the radiation-related activities are using a mobile phone, sunbathing, receiving the enhanced cosmic radiation from a transatlantic flight, living in a high radon area, and living near a nuclear power station.

Players are asked to categorise the risk of each of the activities as high, medium or low. Significantly underestimating a risk leads to more people taking part in the activity and increases the adverse consequences, whilst significantly overestimating the risk leads to the activity being abandoned in favour of other, potentially more hazardous, activities. Only one risk can be dealt with at a time and so, to be successful, players must prioritise the risks and deal with the most hazardous first.

The initial population is taken to be 600 000, equating to approximately a year group in the UK. The population decreases at each cycle of the game (a year) due to both natural causes and the actions of the player. The statistics used to categorise the risks and to calculate the annual losses are loosely based on those for 20 year olds in the UK. The player

with the maximum protected population at the end of a ten-year period (corresponding to making a choice about each of the ten activities) is the winner. Only initial scores are entered on to the scoreboard and prizes were offered to the 40 highest scoring players during National Science Week. Players can play the game as many times as they like and the site will keep track of their highest score to date across multiple playing sessions.

Getting 'help'

At any stage of the game a player can enlist the help of Aidem to provide more information about the hazards associated with the activities. This character gives assistance in the form of two, contradictory, newspaper articles about the topic. These are quotes from stories appearing recently in the media.

Look of the site

The site aims to appeal to a young audience and to sustain players' interest in the game by providing varying visually stimulating content. To achieve this the allocation of risk to each activity is accompanied by an animated cartoon sequence illustrating the activity. A still from the sunbathing sequence is shown in the figure.



Development

The site was developed over about three months by a small, interdisciplinary team of NRPB technical and communications staff and an external web designer from MediaAgency.com. It was written in Macromedia Flash. It was consumer tested by a group of Year 9 pupils from King Alfred's Community and Sports College, Wantage.

The site in National Science Week

The website was activated on Thursday 15 March 2001 and a copy of the database of results was made on the morning of Monday 26 March 2001. During this period over

400 players registered to play the game and around 300 played to the end and recorded a score. Approximately 20% of players came from overseas. They came from over 50 locations in more than 20 countries. The 'clustering' of these locations suggests that individuals who found the site were sufficiently entertained that they encouraged their family/colleagues/friends to have a go themselves.

RESULTS

The winning score, 584 416, was remarkably good since it is only one less than the theoretical maximum score. The overall winner came from Santiago, Chile, and nine other winners in the top 40 were from overseas. A small prize of a baseball style sunhat embroidered with the KU World logo was awarded to the 40 prize winners who scored 583 991 or more. The average score was 583 297, whilst the average score for NRPB players was 583 628, showing that they had only a slight advantage! Thirty players managed to make the situation worse by scoring less than 580 850, the score that would be achieved by doing nothing.

LESSONS LEARNED

The site records some data about players. These include the number and age group of visitors and their initial views on risk. These will provide data relevant to the future presentation of complex material in a simpler format and on the Internet. Follow-up e-mails to all players have invited comments on the game and the experience of playing it.

The development of the site and consumer testing have already highlighted a number of points.

- A significant amount of material can be generated from a very small quantity of information, the whole site in essence is a tick list of ten activities each with three alternatives.
- Sites of this kind will hold young people's interest and they will read the peripheral material associated with the game. In general, young players expressed some disappointment that the game finished too soon and they requested further activities to assess.
- As evidenced during the consumer testing, communal playing of the game does generate significant informed discussion even amongst quite young pupils.
- The task of presenting complex concepts and data without all of the usual caveats associated with a scientific statement is difficult – but essential.

GO ON, RISK IT

The site remains active and players can still get on to the top 40 score board if their initial attempt achieves a high enough score. Players may return to the game as often as they like and the site will keep a record of their best score to date. It can be found at www.riskit.org.uk.

NRPB is looking to build on this experience. It may well provide a communications opportunity on which a number of organisations involved in safety could collaborate.

Optimisation of Patient Dose and Image Quality in Dental Radiology

TONY HUDSON • NATIONAL RADIOLOGICAL PROTECTION BOARD • LEEDS

Overall this was a valuable meeting containing a significant amount of useful information and fully justifying the five CPD points that were offered for attendance. In an ideal world, one would have hoped for rather more substance in some of the later papers. The meeting was organised by IPEM and held at the National Railway Museum in York in March 2001.

IPEM can be congratulated on its choice of meeting place enabling, as it did, many of us to reminisce over railway history and, especially, to view some wonderful steam engines from the past. The meeting itself was very well attended (two or three more seats would have helped!) and tended to use history as a guide to what dental radiation protection needs for the future.

Peter Hirschmann, Leeds Dental Institute, and Anne Walker, Christie Hospital, decided on a joint presentation to provide an overview of the background to and content of the forthcoming 'Guidance Notes for Dental Practitioners on the Safe Use of X-ray Equipment'. A fuller review of these Guidance Notes (GNs) also appears in this *Bulletin* (p 27). It was perhaps appropriate that these GNs should receive their first 'public hearing' at such a meeting, because the need to satisfy the Ionising Radiation (Medical Exposure) Regulations 2000 means that they now include very much detail relevant to patient protection. Justification and optimisation are addressed, and the concept of diagnostic reference levels (DRLs) is introduced as an aid to optimisation. DRLs were the subject of a later paper by Ian Napier, NRPB, who presented an analysis of patient doses that, it is hoped, will provide the necessary impetus to develop and adopt DRLs for dental radiology. The GNs include a full chapter on quality assurance in dental radiology, including recommendations for regular assessment of subjective image quality and an analysis of the data for comparison with proposed targets for image quality.

Keith Horner, Manchester Dental Hospital, suggested that the prescription of radiographs by dentists is frequently at variance with scientific evidence and that there is scope for a more rational and effective use of dental radiology. A much better understanding and application of appropriate selection criteria is needed before the majority of dental radiographs can truly be regarded as justified. A number of interesting, specific examples were given.

Two papers, from staff at the Regional Radiation Protection Service at the Royal Surrey County Hospital, addressed the need for a much greater emphasis on quality control and maintenance procedures in dental radiology.

Andrew Lecomber, Newcastle General Hospital, reported on an interesting evaluation of collective effective dose and detriment from dental radiology. He reported that whilst dental radiology accounts for some 25% of diagnostic examinations, it represents only about 1% of collective effective dose, which is the lowest of all diagnostic techniques. However, dental radiology is predominantly of lower aged patients, whilst many other diagnostic techniques are predominantly of elderly patients. Lecomber referred to the NRPB advice on the variation of detriment with age and concluded that the true detriment from dental radiology is considerably greater than that implied by calculations of effective dose. His re-evaluation transfers dental radiology to one of the highest of the low detriment diagnostic techniques, thereby possibly affecting the perception of dental radiology.

A number of papers were concerned with the measurement of dose and dose–area product in the primary beam of both intra-oral and panoramic dental x-ray sets, and the use of such measurements as an aid to establishing DRLs for dental radiology. Concern was expressed that many panoramic sets, even new ones, appear to be unable to meet the dose–width product suggested in Napier’s paper as a basis for a DRL. There was probably agreement that dose–area product is a more useful measure as a DRL, than dose–width product. However, what became very apparent is that rigid measurement protocols will have to be established and associated with any progress towards the development of DRLs for dental radiology. The various papers provided a useful overview of measurement options and their strengths or limitations.

Radiation Accident Preparedness

JILL MEARA • NATIONAL RADIOLOGICAL PROTECTION BOARD • CHILTON

Report on the REAC/TS conference: The Medical Basis for Radiation Accident Preparedness IV: Focus on Clinical Care, Orlando Florida, March 2001.

The conference was attended by more than 150 people. About half were from the USA. The rest were from all over the world. About half were physicians, the rest physicists, nurses etc. The British contingent comprised most of the physicians employed in the nuclear industries.

The first half-day was a pre-conference teaching session which aimed to:

- explain the difference between exposure and contamination,
- define ionising radiation and selected units of measurement (including the fact that the USA is statutorily required to stick with rads and rems),
- outline biological effects of radiation,
- describe the signs and symptoms of acute radiation injury,
- describe how to control contamination while treating a trauma victim.

The second day was devoted to diagnosis, dosimetry and treatment of the prodrome, latent phase and acute haemopoetic syndrome. Attendees at previous REAC/TS events said there was not much new work presented. The role of growth factors (cytokines) and bone marrow transplants has not evolved beyond the research stage and some of the more promising compounds have been withdrawn from use in the USA, presumably because of toxic effects. A lot of experience with these techniques has been drawn from animal models and cancer patients who are deliberately irradiated prior to bone marrow transplant. It is uncertain how good a model these make for radiation accident victims. REAC/TS was keen to promote its services and be called in throughout the world, should an accident lead to radiation casualties.

The third day had a more international feel with descriptions of the latest techniques to treat the GI syndrome and wounds. Cytokines and other growth factors may prove helpful but the backbone of the treatment remains good supportive care (fluids and antibiotics).

The final day described the medical care of some of the recent accident victims (Arasmus, Georgia, Thailand, Tokai Mura and Egypt). These demonstrated how the various techniques had been used, worked or failed to work in practice.

As I am new to radiation medicine, I learned a great deal. Those who were more familiar with the topic said that the science is making only slow progress. They found the case reports on the last day the most interesting aspect of the conference.

Breast Cancer Statistics

EDITOR – In your news article on breast cancer statistics (*Bulletin* No. 226, October 2000), you state that ‘it is known that cancer mortality statistics are more complete than those for incidence’. This is true only in the sense that the fact of death in an individual is virtually always recorded through the death certification system. Cancer mortality statistics, specifically, cannot be said to be complete since only some 60% of patients diagnosed with cancer will die from the disease. Some cancer registries are able to achieve ascertainment levels of 98% or more by using multiple data sources, including death certificates and clinical databases such as the one described in your article.

As the concern of radiological protection is with reducing the risk of cancer induction from radiation exposure (rather than the risk of death once diagnosed), it should be recognised that mortality data are of limited value in epidemiological risk assessment. With adequate resources and management, cancer registries in some parts of the UK have demonstrated the feasibility of providing accurate and complete data. Elsewhere, the support of the radiological protection community and other key data users would help to raise standards.

Roger Black
Head, Scottish Cancer Intelligence Unit
Edinburgh

Dental Uranium

EDITOR – Although I shall miss the look and feel of the printed version, I must say that the first electronic *Bulletin* was quite attractive.

It was particularly agreeable to read your praise for the small study by John Hunt and me so many years ago of uranium in dental porcelains. Our youthful pride was hurt at the time by an American manufacturer who wrote that the report was ‘like a Texas steer with a few sharp points and a lot of bull in between’. We were not consoled by knowing that his simile was – in a veterinary sense – defective.

Michael O’Riordan
