

# Radiological Protection Bulletin

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# Risks from Ionising Radiation

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**A new working group is being set up in the UK to examine risks from the ingestion and inhalation of radionuclides. There have been claims that the risks from internal emitters are underestimated, while others claim that at low doses, risks are overestimated.**

**R**adiological protection is an established, multidisciplinary, international science. In very broad summary, its main aims are to understand and quantify the possible health effects of exposure to radiation, to establish procedures whereby the risks can be minimised, and to communicate information about the risks to responsible authorities and the public. Roentgen discovered x-rays over 100 years ago and Becquerel discovered radioactivity soon afterwards. The invaluable use of x-rays in medical diagnosis was established within a year, but the risks to medical staff and patients from unprotected exposures also became apparent very quickly. Many pioneer radiologists and medical staff lost life and limb. Given the obvious risks from acute radiation exposures, radiological protection grew rapidly as a subject and as a profession. In the 1920s, the International Commission on Radiological Protection (ICRP) was set up. Since then, and particularly over the last 50 years or so, significant advances have been made in establishing risk estimates for non-acute exposures to external and internal radiation. This accumulated knowledge has led to the promulgation of risk estimates for fatal and non-fatal cancers plus hereditary effects in a population. Also there are extensive compilations of dose conversion coefficients for external exposure and for internal exposure, encompassing a wide range of radiation types, energies, and individual radionuclides.

Basic risk estimates and dose coefficients therefore come with an impressive research pedigree and there is an international scientific consensus on the quantities. Nevertheless, they are subject to continual review, and there have been changes over the years. At present, the basic risk estimates are questioned from two opposing views outside the broad consensus. There are scientists who regard the linear, no-threshold, dose-response relationship on which current protection standards are based as over-cautious or wrong at very low doses. In complete contrast, others claim that radiation risks are being underestimated, particularly from internal emitters.

In the UK there has been a significant development on the assessment of radiation risks from internal emitters. Following recent discussions between the Department for Environment, Food and Rural Affairs (DEFRA) and the Department of Health (DH), it has been decided to ask the Committee on Medical Aspects of Radiation in the Environment (COMARE) to set up a working group to review risks from the ingestion and inhalation of radionuclides (see *News and Affairs*, this issue). The working group will be broadly based and will reflect some significantly differing views on internal radiation risks. The aim is to establish a consensus; we look forward to seeing if this is attainable, and is of help in establishing what research is required to reduce uncertainties in risk estimates.

Michael Clark

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*Editorial*

Radiological  
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## Review of Radiation Risk Models

UK Environment Minister Michael Meacher has announced that the Committee on Medical Aspects of Radiation in the Environment (COMARE) has been asked to establish a new broad based working group to review the risks associated with internal radiation emitters and the need for further research.

Membership of the Working Group will be announced shortly and its remit will be 'to consider the present risk models for radiation and health that apply to exposure to radiation from internal radionuclides in the light of recent studies and any further research that might be needed'.

The Working Group is the outcome of recent discussions between the Department for Environment, Food and Rural Affairs, the Department of Health and COMARE about the best way to evaluate the risks from radiation to ensure that the most valid risk models are used in radiation protection. The Working Group will produce and publish a report that will be considered by COMARE which will then advise the Government.

Professor Bridges, Chairman of COMARE, welcomed the exercise. He said:

'The Government has recently given Chairmen of Scientific Advisory Committees the responsibility of ensuring that all views are heard and taken into account when Committees formulate their advice. The risk from internal radioactivity is an area where, despite broad international consensus, there are several dissenting and sometimes mutually opposed viewpoints.

'The Working Group will provide a real challenge to the holders of all viewpoints to argue their case and try and reach agreement. COMARE regards this as an important consultative exercise and will be listening carefully to the proceedings.'

(DH Press Release, 31 July 2001).

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## Iodine-131 and Thyroid Cancer

The accident at the Chernobyl nuclear power plant in 1986 caused a large release of radioiodine isotopes into the environment. In the most affected areas in Belarus, Ukraine and Russia, the incidence of thyroid cancer in children increased significantly from 1990 onwards. Estimates range from 10–100 times the normal incidence rate in the regions of childhood thyroid cancer. The geographical and temporal distribution of the tumours suggests that incidence is causally related to radioiodine exposure, including *in utero* exposures. UNSCEAR published a detailed study of this risk in 2000 (see *Bulletin* No. 224, 6–11, 2000).

Iodine-131 is widely used in medicine to investigate iodine uptake and function of the thyroid gland. A German/Swedish study (K Hahn *et al*, *Radiation Research*, **156**, 61–70, 2001) has investigated the risk posed by diagnostic amounts of iodine-131 in the juvenile thyroid gland. An epidemiological study was conducted on 2262 subjects who had been given a diagnostic procedure using iodine-131 and 2711 subjects who had diagnostic tests on the thyroid without using iodine-131. Follow up examinations were carried out on 35% of the exposed group identifying two cases of thyroid cancer, and on 41% of the non-exposed group showing three cases. The doses received in the exposed group were calculated to be in the region of 1 Gy, very similar to the Chernobyl reconstruction thyroid doses. However, there is no demonstrable risk in this particular group. The authors point out that only 10% of the children in the German/Swedish study were in the 0–5 years age group when exposed to iodine-131. Also, the Chernobyl exposures included other iodine

radioisotopes to which children could be more sensitive. The short-lived tellurium-132 and its progeny iodine-132 are possibilities here. Alternatively, it is possible that the thyroid doses to children exposed to Chernobyl fallout could have been underestimated.

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## Mobile Phones and Driving

Last year the report from the Independent Expert Group on Mobile Phones (*Mobile Phones and Health*, May 2000) concluded that currently, the only proven, quantifiable risk from mobile phones was from using them while driving. Of course, the risk is nothing to do with the radiofrequency waves produced by the phone. It is caused by the distraction of having to deal with a telephone call while driving. The (former) Department of the Environment, Transport and the Regions has produced a leaflet entitled *Mobile Phones and Driving* which gives some important messages. You should never use a hand-held phone while driving; it is best not to use a hands-free device while driving; you should use a message service and take regular breaks to avoid fatigue. Regulation 104 of the Road Vehicles (Construction and Use) Regulations 1986 states that 'drivers must have proper control of their vehicles at all times'. You can also be prosecuted for careless or inconsiderate driving, if using a mobile phone causes you to drive in this way. Penalties include an unlimited fine, disqualification and up to two years' imprisonment. It can also be an offence for employers to require their employees to use mobile phones while driving. Despite these rather negative aspects of mobile phones and driving, the leaflet does point out some obvious benefits, notably the use of phones to contact emergency services in the event of an accident. In such cases, having a mobile phone in a car is invaluable.

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## Environmental Law Association

Board Member, Pamela Castle, has been elected chairman of the UK Environmental Law Association (UKELA). She is the first woman to be elected to this post and her term as chairman will last two years. The main purpose of UKELA is to promote effective environmental law and practice, to inform the public on matters relating to environmental law and to encourage collaboration between all those interested in the subject. (CMS, Cameron McKenna, press release).

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## Gaia Goes Nuclear

James Lovelock, whose Gaia theory views the Earth, its creatures and eco-system as a vast living organism, is advocating nuclear power as an alternative to burning fossil fuels (*Daily Telegraph*, 15 August 2001). He regards the threat to Gaia from continued burning of fossil fuels as too serious to wait for renewable energy sources to make a significant contribution to reducing carbon dioxide levels in the atmosphere.

'Disinformation about its dangers sustains a climate of fearful ignorance and has artificially inflated the difficulties of disposing of nuclear waste and the cost of nuclear power. If permitted, I would happily store high level waste on my own land and use the heat from it to warm my home. There seems no sensible reason why nuclear waste should not be disposed of in the deep subducting regions of the ocean where tectonic forces draw all deposits down into the magma.'

Lovelock is renowned for his independent and original thinking. He is also an icon for the Green movement which is very anti-nuclear. Clearly he has grown apart from the movement he helped to inspire.

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## Child Dies During MRI

On 30 July, during a magnetic resonance imaging (MRI) session at the Westchester Medical Centre in the USA, a child received a fatal head wound when the machine's powerful electromagnet pulled a metal oxygen cylinder inside. The hospital said the child was sedated following an operation, and was undergoing a routine MRI examination to investigate post-operative complications. (Associated Press, 30 July 2001)

Attendees of Professor Fred Metler's Chilton Seminar on 22 June this year will recall that he compared this real acute risk from magnetic fields to other putative risks from exposure to MRI electromagnetic fields.

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## No New Heavy Elements

In 1999, scientists at the Lawrence Berkeley National Laboratory published a paper on the discovery of two new super heavy elements with 116 and 118 protons (*Physical Review Letters*, **83**, 1104–6, 1999). This was heralded as a major new discovery in nuclear physics and therefore had a mention in the *Bulletin* (No. 214, p 7, 1999). Unfortunately, the authors have re-examined their data using new software, and concluded there is no evidence for the elements after all (*Science*, **293**, 777–8, 2001). This followed some criticism of their paper from other laboratories. Even in carefully managed experiments, and using automated analysis of data, it seems there is still a tendency to see what you want to see.

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## Radon in Popular Fiction

The following passage appears in *Second Wind* by Dick Francis

'I thought of radon. Radon gas could be a problem the world over as it was produced by the decay of naturally occurring uranium in rocks and seeped unseen and unsmelled into people's homes, giving them cancer. But, I thought, radon needed an enclosed space to congregate and the hurricane had ensured there were no enclosed spaces left. And besides, limestone had little radioactive uranium in it to decay.'

Mr Francis is to be congratulated on this summary of the radon problem. It would be carping to dwell on his oversight regarding the possibility of biogenic uraniferous deposits in limestone. However, despite this promising beginning, Mr Francis allows himself to be distracted by violence and sex in exotic (geographical) locations and finally centres the story on the trade in fissile material and other bomb-making components. All in all, a chance missed. However, we look forward to his future work with anticipation.

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## NRPB Springboard to Success

Some NRPB staff might remember Roger Griffin who was at NRPB as an Assistant Scientific Officer in the Biology Department from 1973 to 1978. He has recently been appointed to the Chair of Medical Chemistry at Newcastle University. His special area of interest is anticancer drug design. After leaving NRPB in 1978, he obtained a BSc in pharmacy from Portsmouth Polytechnic and then a PhD from Aston University. He became a lecturer at Aston University and then moved to Newcastle University about ten years ago. In 1996 he was promoted to senior lecturer. As well as these academic distinctions, staff may recall he was a notable exponent of karate, a very necessary skill to have in some University Senior Common Rooms.

Written and compiled by Michael Clark, with contributions from  
Robert Bulman and Gerald Kendall

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# 2001 Meeting of ICRP

ROGER CLARKE • NATIONAL RADIOLOGICAL PROTECTION BOARD • CHILTON

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The International Commission on Radiological Protection met, together with the members of its four standing Committees, in the Hague, the Netherlands, during September 2001. This was the first meeting of the members elected for the period July 2001 – June 2005 and the meeting was hosted by the Dutch Ministry for Housing, Spatial Planning and the Environment. During the first five days the Committees met to conduct their business in which the Main Commission members participated. The Main Commission itself then met to approve programmes of work for the Committees and itself for the next year.

## REPORTS APPROVED

The report on 'Basic Anatomical and Physiological Data for Use in Radiological Protection: Reference Values', produced by a Task Group of Committee 2 chaired by Bruce Boecker, was approved for publication by the Commission. This report is the culmination of a major project to update Publication 23, which dates from 1974. It will form the basis of new phantom development for use in internal and external dosimetry.

The publication will be posted shortly on the ICRP website for information and it will appear in the *Annals of the ICRP*.

Committee 3 provided two reports upon which the Commission was invited to comment. The first was 'Diagnostic Reference Levels in Medical Imaging', produced by Marvin Rosenstein. The Commission noted this short document which essentially recommends that national authorities adopt DRLs in order to reduce unnecessary exposures in diagnosis. It was decided that this should be available on the ICRP website and relevant medical and radiological journals as well as regulatory authorities should be notified that this advice is to be found on the web.

The second report from Committee 3 was 'Radiation and Your Patient: A Guide for Medical Practitioners', produced by Fred Mettler and Julian Liniecki. This text is produced in a question and answer format for easy reading and aims to provide basic information on radiation mechanisms, doses from different medical radiation sources, the magnitude and type of risk, as well as answers to frequently asked questions such as risk of radiation in pregnancy.

It is not intended to provide sufficient information for interventional cardiologists, radiologists, orthopaedic and vascular surgeons and others who actually use radiation sources. Rather it is meant for general medical practitioners, medical students and even patients. It is deliberately designed so that interested individuals can download it from the ICRP website ([www.icrp.org](http://www.icrp.org)) for use in medical training. The Commission decided it should be available on a dedicated education segment on the website.

Committee 3 has proposed that teaching modules in the form of PowerPoint 'Notes Pages' presentations be prepared and made available on the website to be downloaded. The Commission agreed, in principle, and Committee 3 will develop these modules.

## RADIOLOGICAL PROTECTION AT THE START OF THE 21st CENTURY

The Commission has a Task Group to take forward its protection philosophy, which has agreed that its objective is to state the principles for the practice of radiological

protection as the 21st century begins. A brief summary of the current position is given in the following article. Meanwhile the Committees discussed their contributions to the philosophy and proposed the formation of Task Groups or working parties to carry out the work.

The Commission reviewed these proposals and approved programmes of work for the Committees. The Commission intends to agree an initial outline of restated protection philosophy, which will be available to all four Committees to assist them in their work before their meetings in the summer of 2002.

## **TASK GROUPS APPROVED BY THE COMMISSION**

### **Committee 1**

There already exist three Task Groups of Committee 1, of which two are close to producing reports for approval. The first is reviewing relative biological effectiveness (RBE) data for radiological protection purposes, while the second is quantifying health effects of radiation on the developing embryo/fetus. These Task Groups will probably conclude their work in the coming year.

The third existing Task Group is on risks at low levels of radiation exposure. This is expected to continue for at least two years so as to interact with the Commission and answer questions that arise in the development of the protection principles. It will cover both reviews of epidemiological data as well as animal and mechanistic information to make judgements primarily on risks at the levels of exposure actually received, ie in the range of a few to a few tens of millisievert per year.

A new Task Group was approved on 'Input to ICRP Recommendations for the 21st Century' to be chaired by Roger Cox. This will provide a co-ordinated foundation document summarising the concepts and judgements on health effects of ionising radiation. It will take the scientific evaluations of the three existing Task Groups and build on them to recommend risk parameter values for protection purposes.

### **Committee 2**

The Task Group on Reference Values for Anatomical Physiological Data has essentially finished its work with the approval of its report. Committee 2 then has three Task Groups which were approved to continue work.

The first is the Task Group on the Human Alimentary Tract that complements the anatomy/physiology and respiratory tract models already approved. It is expected that this Task Group will produce its report during the coming year when it will form part of the basis for revised dosimetric calculations.

The second Task Group is that on Dose Calculations (DOCAL). The Commission determined that the major priority for this Task Group is the development of reference voxel phantoms, firstly with adult male and female characteristics. These will be required to calculate doses from internal and external sources once the Commission has finalised any revision to weighting factors for radiations and tissues.

The third Task Group is on Internal Dosimetry (INDOS) which has undertaken a major programme of work on dose coefficients for workers and the public since the publication of the 1990 recommendations. The Commission decided that the Task Group should concentrate on the review of biokinetic data over the next few years so as to be ready to work with the DOCAL models for the production of the next generation of dose coefficients after the Commission has begun to finalise its recommendations.

### Committee 3

Two existing Task Groups continue: the first is on the release of patients who have undergone radiotherapy or brachytherapy with unsealed sources. The report conclusions are expected within the next year. The second Task Group is addressing the issue of doses from commonly used radiopharmaceuticals. The immediate issues here are for  $^{99m}\text{Tc}$  depreotide, fatty acids labelled with  $^{123}\text{I}$  and various dopamine transporter and receptor substances, as well as PET substances.

A new Task Group was approved to address 'Dose Reduction in Digital Radiography' and be chaired by Eliseo Vañó. This new technique can lead to higher doses in diagnosis and the report is intended for manufacturers and users with recommendations to reduce dose.

Committee 3 will also be providing foundation information on the principles of justification and optimisation in the medical field that can be incorporated into the revised statement of the Commission's recommendations.

### Committee 4

Committee 4 is established to provide guidance on the application of the Commission's recommendations. The Committee discussed at length the issues involved in restating the Commission policy and proposed the formation of three new Task Groups, each of which was welcomed by the Commission.

A new Task Group is 'To Characterise Individual Members of the Public'. This will assist in defining the individual to be used for determining exposures of the public for avoidable and unavoidable sources. The Task Group is to be chaired by John Till. It will address demonstration of compliance and develop the critical group concept for the 21st century.

The second new Task Group is on 'Optimisation in Radiological Protection' and is to be chaired by Wolfgang Weiss. It will develop the Commission's ideas on stakeholder involvement in the process of optimisation as well as addressing the inclusion of numbers involved and the operational and managerial aspects.

The third new Task Group is on 'Radiological Protection in Space Flight' and to be chaired by Toshiso Kosako. The major aspects are low earth orbit extended flights and are relevant for the construction, operation and maintenance of the International Space Station. The radiation spectrum differs from that in other occupational exposures and specific dose limits will be derived to provide coherent international guidance.

### EMERITUS ELECTION

Dan Beninson was elected Emeritus Member of the Commission for his outstanding contribution to radiological protection over a working lifetime and, in particular, his guidance in the preparation of 1990 recommendations.

### NEXT MEETINGS

The Commission will meet in Vienna in May 2002 immediately after the UNSCEAR meeting in order to agree an outline of ideas on philosophy of protection for use by the four Committees. It will then meet in Albuquerque, New Mexico, during October 2002 to review input from the Committees.

# Radiological Protection at the Start of the 21st Century

## A Progress Report

ROGER CLARKE • NATIONAL RADIOLOGICAL PROTECTION BOARD • CHILTON

This paper provides an update on the thinking behind the development of protection criteria resulting from the meeting in June 2001 of the Task Group of the International Commission on Radiological Protection set up to take forward the Commission's protection philosophy.

The first obvious point is demonstrated by the title of this paper; the Task Group wished to address the preparation of a protection philosophy as the 21st century begins. A number of other important issues were raised and proposals made for progress to the next stage. Some of these are presented here, but the paper also traces the evolution of protection principles and the ethical bases used to establish standards as they now exist. It explains how collective dose and cost-benefit analysis became the recommended methods for optimising protection in the 1970s and why the Commission is now moving towards a more egalitarian, or individual-based ethical approach. This requires the establishment of criteria that might be called 'Doses for Protective Action', which can be justified in terms of the existence of natural background radiation. These would replace the present complex set of criteria that has been developed from the present recommendations of 1990. This includes the criteria shown below.

Intervention levels after accidents	Guidance levels in diagnostic radiology
Dose limits for workers	Intervention exemption levels
Action levels for radon in homes or at work	Clearance levels
Dose limits for the public	Exemption levels
Constraints	Exclusion criteria

The initiative represents a genuine attempt to simplify the system of protection to one that is more coherent and easily explicable.

### PRESENT SITUATION

In 1977 the Commission quantified the process of optimisation of protection and adopted, implicitly, a *utilitarian* ethical policy when it recommended the use of cost-benefit analysis which aims to answer the question,

'How much does it cost and how many lives are saved?'

This meant calculating collective dose and thereby emphasised the protection of society over that of individuals. This emphasis, however, does not necessarily provide sufficient protection for each individual. Classical cost-benefit analysis is unable to consider the individual, and the Commission attempted to address this by suggesting a non-linear cost to the unit of collective dose. This still did not recognise sufficiently the individual risk, so the Commission established in its 1990 recommendations an added restriction on the optimisation process. It modified the principle of optimisation by the introduction of the concept of a *constraint*. The constraint is an individual-related criterion, applied to a

single source in order to ensure that the most exposed individuals are not subjected to excessive risk and to limit the inequity introduced by cost-benefit analysis.

The use of collective dose, aggregated to include all levels of dose and all periods into a single value, has distorted the process of optimisation of protection. The Commission has made proposals for a possible simplification of the system of protection emphasising the dose to an individual from a controllable source. There would still be requirements to keep the individual dose both below a defined action level and as low as reasonably practicable (ALARP). The second requirement would not be linked to collective dose in its present form.

## JUSTIFICATION

The Commission's present recommendations for justification require that the practice should do more good than harm. This procedure implies a quantified balance of costs and benefits, but in practice, governments, physicians, or individuals do not make decisions about courses of action in a predominantly quantitative way. A qualitative approach is more common and usually more appropriate.

The judgement that it would be justifiable to introduce or continue a practice involving exposure to ionising radiation is not usually taken by radiological protection authorities, although they should influence the decision. The responsibility for judging justification usually falls on governments or government agencies.

The medical exposure of patients to a particular technique should be justified in a general sense, as is any other practice. In addition, a more detailed justification has to be introduced. The principal aim of medical exposures is to do more good than harm to the patient, subsidiary account being taken of the radiation detriment from the exposure of the radiological staff or of other patients. If the necessary resources are available, the responsibility for the justification of the particular use of a particular procedure falls on the relevant medical practitioners.

## SYSTEM OF PROTECTION

The system of protection for medical exposures will be treated separately. It will consist of a need for individual justification for an examination using a generically justified technique, followed by the specification of reference levels as indicators of best practice. It is not considered further here, but will be considered and developed by ICRP Committee 3.

For non-medical exposures, it is the control of radiation doses that is the important issue, irrespective of the source. In the first place, therefore, consideration should be given to the dose to an individual from a particular controllable source. The doses may be received as result of work or from radioactive sources in the environment, natural or artificial. The doses may have already been received, or will be received in the future, from the introduction of new sources or following an actual or potential accident.

For each previously justified, controllable source, the first consideration in the proposed system of protection is to provide a minimum level of health protection for individuals by means of *Doses for Protective Action or Protective Action Levels*. The need for protective action is influenced solely by the individual dose, but not by the number of exposed individuals. The second consideration stems from the recognition that there is likely to be some risk to health, even at small doses. This introduces a moral requirement, for each controllable source, to take all reasonable steps to restrict both the individual doses to levels below the action level and the number of exposed individuals. At present, the optimisation of protection provides this criterion.

For uncontrollable sources, where it is feasible only to modify the pathways by which people are exposed, consideration can also be given to the development of Doses for Protective Action or Protective Action Levels.

Doses for Protective Action do not apply to justified medical exposures.

### DOSES FOR PROTECTIVE ACTION (DPAs)

In general, despite the complexity of the present protection philosophy, doses to individuals are kept below about ten times the average background dose. So, occupational dose limits in practices, or intervention levels for the public either in emergencies or for radon in homes, are set at some few tens of millisievert. Added doses from environmental releases are kept to about one-tenth of background. In many regions of the world, exemption from regulatory oversight is allowed if doses are below about one-hundredth of background. This suggests the basic DPAs as set out below.

Doses for Protective Action or Protective Action Levels		
<b>For people</b>	Workers, for evacuation of members of the public, radon	~20 mSv in a year
<b>For discharges</b>	Added increments of dose from single sources	<300 $\mu$ Sv in a year
<b>Exemption</b>	From registration or licensing	<10 $\mu$ Sv in a year

DPAs can be considered as establishing a minimum level of health protection, which may be applicable globally. However, for any particular source there is a need to reduce the doses to a level that is as low as is reasonable under the prevailing circumstance.

### OPTIMISATION OF PROTECTION

The process of taking all reasonable action to reduce exposures is still likely to be called the optimisation of protection. The initial proposals suggested that the optimisation of protection as it is now usually understood should be replaced by a different requirement. This would be that the residual doses, after the application of the DPAs, should be kept as low as reasonably practicable. The Task Group considered that differential equations should not be overused, and that the use of 'common sense' would often be more important.

The process of optimisation in future may best be carried out by stakeholder involvement to determine or negotiate the best level of protection in the circumstances. This would involve the presentation of costs and residual doses for a range of options either in the workplace or for exposures of the public. While the DPA thus represents a basic standard of individual health protection, stakeholder involvement determines how far below the DPA is as low as reasonably practicable. This would represent the optimum level of protection from the source under control or for an uncontrollable source. The achievement of consensus would replace the previous formal cost-benefit analysis.

### CONCLUSION

This brief summary indicates how the development of the Commission's concepts is progressing. It takes into account the views that were expressed at the inaugural meeting of the Commission's Task Group, which has been established to proceed with the exposition of radiological protection in the 21st century.

The Commission will next consider a first draft outline document that expresses its intentions in developing a philosophy for protection at the start of the 21st century. This will be available for discussion next year.

# X-rays – How safe are they?

## A New Information Leaflet for Patients

BARRY WALL • NATIONAL RADIOLOGICAL PROTECTION BOARD • CHILTON

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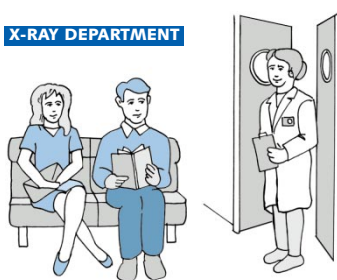
A simple eight-page leaflet is now available that explains in layman's terms the benefits and risks associated with medical x-ray examinations. The intention is that, having read the leaflet, concerned patients will be able to make an informed decision on whether the usually very small radiation risks arising from these diagnostic medical exposures are sufficiently outweighed by the expected benefits as described by their doctor. The leaflet has been prepared by NRPB in collaboration with the College of Radiographers, the Royal College of Radiologists and the Royal College of General Practitioners. It is also available on the NRPB website and there are links to the leaflet from the websites of the collaborating Colleges. Healthcare professionals wishing to print-off copies from the website for their own use or for giving to concerned patients are encouraged to do so.



## X-rays

### How safe are they?

X-RAY DEPARTMENT



**T**hirty years ago, X-rays were the only way to see what was going on inside your body. Now other methods of medical imaging are available, some using different types of radiation from X-rays. They are briefly described on the next two pages. Patients are sometimes concerned about the possible harmful effects of radiation, so this leaflet goes on to explain the risks and to put them into perspective.

It is not easy for members of the public in the UK to obtain information on the radiation risks associated with diagnostic medical exposures. Doctors who refer patients for medical imaging examinations using ionising radiation and even the radiographers and radiologists performing the examinations are not always well informed in these matters. Concerned patients frequently resort to NRPB for advice. In the past, the NRPB website provided answers to a list of frequently asked questions about medical exposures (which were accessed about 40 times a week) and NRPB dealt with one or two direct telephone enquiries each day. However, not all concerned patients have Internet access or are aware of the existence of NRPB, so there is a need for more readily available information clearly expressed for the layman. Hence the leaflet.

Considerable care was required to ensure that the leaflet did not appear to be alarmist, trivialising or patronising. It needed to put the doses, risks and benefits of medical imaging procedures into perspective in a way easily comprehended by patients. Unfounded fears about the hazards of ionising radiation had to be allayed while acknowledging and clearly describing the true extent of the risks. By providing both printed and electronic versions of the leaflet, it is readily available to GPs to help them reassure anxious patients at time of referral and also to hospital radiology department staff so that they can advise patients who express concern at time of examination. Over 30 000 copies of the leaflet have already been distributed to health care professionals.

## **HOW TO PUT THE DOSE LEVELS ASSOCIATED WITH MEDICAL EXPOSURES INTO PERSPECTIVE?**

The dose levels associated with most types of diagnostic x-ray examination are extremely variable from one hospital to another and from one patient to another. NRPB surveys of patient doses in the UK indicate that inter-hospital variations in the mean dose delivered for a particular type of x-ray examination span a factor of four to seven (between the 5th and 95th percentile)<sup>1</sup>. Inter-patient variability due to individual differences in physique and pathology can add a further factor of two to three. It is consequently unwarranted to be over-precise in attributing 'typical' doses to x-ray examinations. In the leaflet x-ray examinations have simply been divided into four broad effective dose categories, each spanning a factor of ten. Estimates of the 'typical' effective dose for each type of examination were derived from information in the NRPB National Patient Dose Database up to the end of 1995<sup>2</sup>.

The public is generally unfamiliar with radiation quantities and units, so it is not helpful to express levels of exposure in 'millisievert' or to try to explain complex concepts such as 'effective dose'. An approach that has proved to be very helpful in practice is to put medical exposures into perspective with everyday exposures by comparing them with the equivalent period of natural background radiation<sup>3,4</sup>. Admittedly, this uses the concept of effective dose to make the comparison, but the public only needs to appreciate that the dose measure used is roughly related to the total radiation risk from the exposure. In the leaflet, each of the four broad dose categories is related to the equivalent period of natural background radiation, expressed in a similarly imprecise fashion, eg 'a few days', 'a few months' or 'a few years' (see the table below).

<b>Broad levels of risk for common x-ray examinations and isotope scans</b>		
<b>X-RAY EXAMINATION (OR NUCLEAR MEDICINE ISOTOPE SCAN)</b>	<b>EQUIVALENT PERIOD OF NATURAL BACKGROUND RADIATION</b>	<b>LIFETIME ADDITIONAL RISK OF CANCER PER EXAMINATION*</b>
<b>Negligible risk</b>		
Chest Teeth Arms and legs Hands and feet	A few days	Less than 1 in 1 000 000
<b>Minimal risk</b>		
Skull Head Neck	A few weeks	1 in 1 000 000 to 1 in 100 000
<b>Very low risk</b>		
Breast (mammography) Hip Spine Abdomen Pelvis CT scan of head (Lung isotope scan) (Kidney isotope scan)	A few months to a year	1 in 100 000 to 1 in 10 000
<b>Low risk</b>		
Kidneys and bladder (IVU) Stomach – barium meal Colon – barium enema CT scan of chest CT scan of abdomen (Bone isotope scan)	A few years	1 in 10 000 to 1 in 1000

\* These risk levels represent very small additions to the 1 in 3 chance we all have of getting cancer.

## HOW TO COMMUNICATE RADIATION RISKS?

Feedback on initial drafts of the leaflet from the radiology profession, and particularly from members of the public, indicated that there is enormous potential for a leaflet of this sort to appear alarmist, trivialising or patronising, depending on the standpoint of the reader. In an attempt to present a balanced view, it starts by explaining clearly what the likely effects of radiation are at the dose levels encountered in diagnostic radiology and, just as importantly, what they are not, as follows.

‘You will be glad to know that the radiation doses used for x-ray examinations or isotope scans are many thousands of times too low to produce immediate harmful effects, such as skin burns or radiation sickness. The only effect on the patient that is known to be possible at these low doses is a very slight increase in the chance of cancer occurring many years or even decades after the exposure.’

The delayed nature of the possible effect is emphasised in the leaflet and very approximate quantitative estimates of the chance of it happening in the remaining lifetime of the patient are indicated in the last column of the table. Again, in view of the wide variability in the patient doses and the considerable uncertainties in radiation risk coefficients, especially when applied to an individual, only broad indications of the risk are justified. The ICRP nominal probability coefficient for all radiation-induced fatal cancers averaged over the whole population (5% per sievert)<sup>5</sup> was used to derive approximate risks for each type of examination. Since each examination category in the table spans a dose range of a factor of ten, the range in risk indicated for each category also spans a factor of ten. The boundaries of the categories have been chosen to coincide with risk levels that are exact powers of ten.

It is also emphasised in the leaflet that the risks are much lower for older people, who undergo the majority of medical imaging procedures, because there is less time for delayed radiation-induced cancers to develop. Conversely, the risks are a little higher for children and unborn babies, for whom special attention is paid to justifying and optimising medical exposures.

Having broadly indicated the usually very small chance of delayed radiation-induced cancer following a diagnostic medical exposure, the leaflet then tries to put these levels of risk into perspective. Sir Kenneth Calman, the Chief Medical Officer in the UK at the time of the BSE (*bovine spongiform encephalopathy*) outbreak in British cows, has used the same 'power of ten' classification of risk levels in an attempt to answer the public's questions as to what is meant by 'safe'<sup>6</sup>. He suggested using the expressions 'negligible', 'minimal', 'very low' and 'low' to describe the level of risk in each category to help individuals to decide whether the risk is acceptable. The same expressions have been used in the leaflet (see the table).

The title of the leaflet, *X-rays – How safe are they?*, was deliberately chosen to indicate that 'safe' is a relative term. Activities are generally regarded as being 'safe' when the risk of something unpleasant happening falls below a certain level, and the lower the level of risk, the 'safer' the activity becomes. The leaflet points out that most people would regard activities involving a risk of below 1 in 1 000 000 (the 'negligible' risk category) as exceedingly safe. Simple x-ray examinations of the chest, teeth or limbs fall into this category, whereas the more complicated examinations carry a 'minimal', 'very low' or 'low' risk. The acceptability of any of these risk levels to an individual depends critically on the perceived personal benefit from the activity giving rise to the risk. So the leaflet emphasises repeatedly that the benefit to the patient from the x-ray examination, in terms of making the right diagnosis and consequently giving the right treatment, should always outweigh these relatively small risks. The higher dose examinations (that fall into the 'low' risk category) are normally used to diagnose more serious conditions when a greater benefit to the patient is to be expected.

To provide a further perspective, the risks from diagnostic medical exposures were compared with other, more familiar risks in daily life. However, it became apparent that public perception of both the level and the acceptability of everyday risks is notoriously fickle, being influenced by personal experiences and, particularly, by media attention. For example, it was intended to suggest that the 'minimal' risk examinations were as safe as travelling by train (1 in 500 000 risk of death in train accidents per year in

the UK), until the recent spate of railway disasters at Paddington, Hatfield and Selby. Although these accidents (with a total of 45 fatalities) will not substantially increase the risk in the long term, the intense media coverage that they received meant that most people's perception of rail transport safety underwent rapid re-evaluation.

The leaflet starts with a brief description of the different methods of medical imaging that are currently available (using x-rays, radioisotopes, ultrasound or magnetic resonance imaging, MRI). It then goes on to explain the risks and put them into perspective and concludes with a summary of the important points to remember, which is reproduced below.

- In radiology departments, every effort is made to keep radiation doses low and, wherever possible, to use ultrasound or MRI which involve no hazardous radiation.
  - The radiation doses from x-ray examinations or isotope scans are small in relation to those we receive from natural background radiation, ranging from the equivalent of a few days worth to a few years.
  - The health risks from these doses are very small in relation to the underlying risks of cancer, but are not entirely negligible for some procedures involving fluoroscopy or computed tomography (CT).
  - You should make your doctor aware of any other recent x-rays or scans you may have had, in case they make further examinations unnecessary.
  - The risks are much lower for older people and a little higher for children and unborn babies, so extra care is taken with young or pregnant patients.
  - If you are concerned about the possible risks from an investigation using radiation, you should ask your doctor whether the examination is really necessary. If it is, then the risk to your health from *not* having the examination is likely to be very much greater than that from the radiation itself.
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## The World of Medical Radiation Exposures

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Ionising radiation is firmly established as an essential tool for diagnosis and therapy in medicine. Medical radiology thus represents a significant source of exposure for populations, although patterns of practice vary widely between different countries of the world. Global assessments of medical radiation exposures have been conducted periodically since 1955 by the United Nations through its Scientific Committee on the Effects of Atomic Radiation (UNSCEAR). The most recent analysis for the period 1991–96 is published in the UNSCEAR 2000 Report<sup>1</sup>, as part of a comprehensive review of sources and effects of radiation. This authoritative study includes unique information on the resources, frequencies and doses for national, regional and global practices in diagnostic radiology, diagnostic nuclear medicine and radiotherapy. The report is now available online as a PDF file ([www.unscear.org/pdffiles/annexd.pdf](http://www.unscear.org/pdffiles/annexd.pdf)).

### MODELLING GLOBAL PRACTICE

Ionising radiation has been used in medicine for more than 100 years, following early imaging and therapy with x-rays after their discovery in 1895. The subsequent discovery of natural radioactivity led to initial biological tracer studies in plants and animals and to the development in the 1940s of clinical nuclear medicine with the administration of artificial radioiodine to patients. Advances in technology have in general fuelled a continuing evolution and expansion of practice in medical radiology, although even today much of the world still has insufficient access to radiological imaging and therapy services.

Annex D of the UNSCEAR 2000 Report<sup>1</sup> includes information on medical radiology practice for 118 countries of the world, gleaned from 60 responses to a global survey by questionnaire and a review of over 1100 scientific references. Even so, data concerning the number of x-ray examinations, for example, were available in relation to only one-half of the world population of 5.8 billion (1996). Practice world-wide has therefore been assessed by extrapolation from the limited national data available on the basis of a global population model, in which countries are stratified into four levels of health care determined by the number of physicians per million population, as defined in Table 1.

Key results from the analysis by UNSCEAR are summarised in Tables 1 and 2 and discussed below in relation to the three broad practices in medical radiology. These assessments should not, however, be over-interpreted beyond the significant uncertainties in the reliability and representativeness of the underlying data<sup>1</sup>.

TABLE 1 Annual frequencies of medical radiological procedures					
PRACTICE	FREQUENCY OF PROCEDURE PER 1000 POPULATION				
	HCL I <sup>a</sup>	HCL II <sup>b</sup>	HCL III <sup>c</sup>	HCL IV <sup>d</sup>	World <sup>e</sup>
<i>Diagnosis</i>					
Medical x-rays	920	150	20	20	330
Dental x-rays	310	14	0.2	0.2	90
Diagnostic nuclear medicine	19	1.1	0.3	0.02	5.6
<i>Therapy<sup>f</sup></i>					
Teletherapy	1.5	0.7	0.5	0.05	0.8
Brachytherapy	0.2	0.02	0.02	0.02 <sup>g</sup>	0.07
Radionuclide therapy	0.2	0.04	0.02	0.0004	0.065
<i>Notes</i>					
(a) Health care level I: >1000 physicians per million population (26% of world population).					
(b) Health care level II: >300–1000 physicians per million population (53% of world population).					
(c) Health care level III: 100–300 physicians per million population (11% of world population).					
(d) Health care level IV: <100 physicians per million population (10% of world population).					
(e) World population in 1996: 5.8 billion.					
(f) Complete courses of treatment.					
(g) Assumed value in the absence of data.					

TABLE 2 Annual doses from diagnostic medical exposures					
DIAGNOSTIC PRACTICE	PER CAPUT EFFECTIVE DOSE (mSv)				
	HCL I	HCL II	HCL III	HCL IV	World
Medical x-rays	1.2	0.14	0.02	0.02	0.4
Dental x-rays	0.01	0.001	<0.0001	<0.0001	0.002
Diagnostic nuclear medicine	0.08	0.008	0.006	0.0003	0.03
All diagnostic practice	1.3	0.15	0.03	0.02	0.4

## DIAGNOSTIC RADIOLOGY Techniques

The most widespread use of radiation in medicine remains diagnostic radiology, which involves imaging with x-rays. A wide range of basic techniques is utilised, including conventional radiography (static images captured on film loaded between intensifying screens in cassettes) and fluoroscopy (dynamic imaging with an (electronic) image intensifier). Contrast media are often administered to the patient in order to enhance the visibility of particular tissues, such as the use of barium compounds in relation to the

gastrointestinal tract and iodine compounds in relation to the blood vessels (angiography) and urinary system (urography). Digital methods for the processing and display of x-ray images were first introduced into clinical practice with the advent of computed tomography (CT) in 1972. This provides high quality cross-sectional images using a rotating fan beam of x-rays, albeit with relatively high patient doses. Continuing technological developments, such as spiral (or helical) scanning and multi-slice scanners, have improved both the speed and quality with which such images are obtained and so fuelled a steady growth in CT. Advances in computer technology have also promoted the general development of digital radiology, most recently using novel detectors for the direct acquisition of images in digital format. Digital modalities provide attendant advantages for the manipulation, storage and transmission of images.

Such improvements in imaging and in catheter technology have facilitated the development of interventional radiological techniques, in which diagnostic x-rays are used to help guide and evaluate minimally invasive therapeutic procedures. Common techniques include angioplasty (dilatation of blood vessels by the expansion of a balloon catheter so as to improve blood flow) and embolisation (occlusion of blood vessels). Interventional radiology often provides a unique treatment or an alternative to surgery. However, the prolonged use of fluoroscopy and multiple radiographic imaging can under certain circumstances lead to high localised absorbed doses and there have been over 100 documented cases of serious deterministic effects in patients.

X-ray examinations characteristically involve partial-body exposures and result in complex patterns of energy deposition. Such diagnostic exposures are in general characterised by relatively low doses to individuals that in principle are the minimum necessary for the required clinical information. Patient doses vary widely between different types of examination, with effective doses typically in the range from 0.1 to 20 mSv, although there are significant variations in practice for a given type of examination between individual patients and also different x-ray departments.

### Practice with x-rays

The annual total of all medical x-ray examinations estimated for the world in 1996 is about 1.9 billion, corresponding to an annual frequency of 330 examinations per 1000 world population (Table 1). This frequency is about 10% higher than the previous estimate for the period 1985–90<sup>2</sup>, whereas the annual *per caput* effective dose has risen from about 0.3 to 0.4 mSv (collective effective dose of 2.3 million man Sv) between assessments (Table 2). Dental x-rays provide a further 0.5 billion examinations world-wide (annual frequency of 90 per 1000 world population), but a largely static (within uncertainties) annual *per caput* effective dose of only 0.002 mSv (collective dose of 14 000 man Sv). The mean effective doses per x-ray examination were about 1.2 mSv for medical procedures (up 20% from the estimate for 1985–90) and 0.03 mSv for dental procedures.

There is also a very uneven distribution of examinations between countries, with significant differences in patterns of practice; mean data for the four health care levels of the global model vary by factors of about 50 in the case of frequency of medical x-rays (Table 1) and 60 in relation to the associated *per caput* dose (Table 2). Over 75% of all x-ray examinations and over 80% of the resultant global collective dose arise in the

(developed) countries of health care level I, which account for only one-quarter of the world population. On a global scale, chest examinations remain the most common procedure (41% of all medical x-rays), although CT (only 5% of total number) dominates population exposure, contributing 34% of the annual *per caput* dose. This represents a significant increase over the previous assessment<sup>2</sup> of 14%, with there also having been relative increases in importance for other complex (and relatively high dose) procedures such as angiography and interventional radiology. CT accounts for 41% of the *per caput* dose in health care level I, yet only 5% in health care level II (dominated by chest fluoroscopy) and 2% in health care levels III–IV (dominated by examinations of the lower gastrointestinal tract).

## NUCLEAR MEDICINE

### Techniques

Diagnostic radiological procedures are also conducted by the administration of radiopharmaceuticals to patients, by injection, inhalation or ingestion, so as to study organ or tissue function in the practice of nuclear medicine. A wide range of pharmaceuticals is utilised, according to the nature of the particular investigation, and more than 20 radionuclides are commonly incorporated as labels for effective and efficient imaging. In practice, <sup>99m</sup>Tc forms the basis for over 80% of all radiopharmaceuticals, although <sup>131</sup>I is also still widely used in many countries, particularly in the developing world.

Uptake of the radiopharmaceutical in particular organs, such as the thyroid, can be measured with a simple radiation detector, whereas imaging is carried out using a rectilinear scanner or, more commonly, a large field of view gamma camera. In addition to conventional planar imaging, techniques have also been developed to allow emission tomography which, rather like x-ray CT, provides cross-sectional information. These techniques include single photon emission computed tomography (SPECT) and the specialised technique of positron emission tomography (PET), which uses short-lived biologically active radionuclides, such as <sup>15</sup>O, <sup>11</sup>C, <sup>18</sup>F and <sup>13</sup>N. In general, the typical effective doses from diagnostic nuclear medicine procedures span a similar range to those from diagnostic x-ray examinations.

### Practice with radionuclides

Diagnostic nuclear medicine continues to expand, but it is still a much less common practice than examinations with x-rays. The annual total of all diagnostic radionuclide administrations estimated for the world in 1996 is about 32 million, giving rise to an annual *per caput* effective dose of 0.03 mSv (collective effective dose of 150 000 man Sv). These figures are less than corresponding data for medical x-rays by factors of about 60 and 15, respectively. The annual frequency of 5.6 nuclear medicine procedures per 1000 world population (Table 1) is about 20% higher than that for the period 1985–90<sup>2</sup>, whereas the estimated *per caput* dose (Table 2) has remained largely unchanged between assessments. The mean effective dose per nuclear medicine procedure is about 4.6 mSv, which is down about 30% from the estimate for 1985–90<sup>2</sup>, but is nearly four times the present mean for medical x-rays. Once again, practice is very much concentrated in the developed world; nearly 90% of all procedures and over 80% of the

collective dose occur in health care level I, and there are significant differences in the mean frequencies and *per caput* doses between the different health care levels (Tables 1 and 2).

Diagnostic nuclear medicine has applications across a wide range of medical disciplines, with the three most important procedures on a global scale being bone scans for metastases (24% of the total frequency and 23% of the total *per caput* dose), thyroid scans (22% and 17%, respectively) and cardiovascular scans (14% and 25%, respectively). Patterns of practice also vary between different countries with, for example, uptake studies and scans of the thyroid dominating in the lower health care levels.

## RADIOTHERAPY

### Techniques

The third quite different and least common application of radiation in medicine is in radiotherapy, where the aim is to achieve cytotoxic levels of irradiation to well-defined target volumes of the patient, whilst as far as possible sparing the exposure of surrounding healthy tissues. Prescribed doses are typically in the range 20–60 Gy in order to eradicate disease, principally cancer, or to alleviate symptoms. Effective dose is clearly inappropriate for characterising such therapeutic exposures and practice is principally summarised by UNSCEAR in terms of frequencies. Three different treatment modalities are employed.

The principal mode of treatment is teletherapy, in which external beams of radiation are focused on to a target treatment volume. Superficial treatments utilise lower energy x-ray beams or electrons, whereas deep-seated tumours are treated with high energy photon beams from conventional x-ray units, linear accelerators, or large sealed radionuclide sources, principally  $^{60}\text{Co}$ . Treatments are carefully planned and delivered, and typically include multiple fields and series of exposures over time. On a global scale, over a fifth of all teletherapy treatments involve the breast (21% of total number), with the next most important broad categories being lung (17%), followed by head/neck and brain (13%).

The second important treatment modality is brachytherapy, in which an encapsulated source, or group of such sources, is positioned on or in the patient by surface, intracavitary or interstitial application. Sources may be implanted temporarily into superficial and easily accessible tumours in the form of wires, pellets or needles of  $^{137}\text{Cs}$ ,  $^{60}\text{Co}$  or  $^{192}\text{Ir}$ . These may be positioned manually or loaded remotely following implantation of an applicator. Permanent implants are sometimes used for deep-seated tumours, as grains or sutures incorporating, for example,  $^{198}\text{Au}$ ,  $^{125}\text{I}$  or  $^{103}\text{Pd}$ . One of the most recent developments is endovascular brachytherapy to inhibit restenosis of blood vessels after angioplasty. Brachytherapy is used overwhelmingly for gynaecological tumours (75% of all treatments world-wide), often in combination with external beam therapy. In some areas of the world, these treatments are still conducted for economic reasons using  $^{226}\text{Ra}$  sources, with which brachytherapy techniques were first developed.

Radiotherapy is also conducted by the direct administration to patients of unsealed radiopharmaceuticals, generally incorporating medium energy beta emitters, to provide biological targeting of dose. Such radionuclide therapy is an important treatment

modality for both malignant and benign disease, particularly in relation to the thyroid and the use of  $^{131}\text{I}$ . Treatments for hyperthyroidism account for nearly two-thirds of all practice, with about a further quarter being for thyroid malignancy.

### Therapeutic practice with radiation

About 85% of all complete courses of radiotherapy treatment are by teletherapy, with an estimated annual global total for 1996 of 4.7 million treatments and a corresponding frequency of 0.8 per 1000 world population (Table 1). Brachytherapy and therapy with radiopharmaceuticals each provide about 0.4 million treatments per year. In all cases, the majority of practice arises from countries in health care level I. The combined frequency of teletherapy and brachytherapy (0.9 treatments per 1000 world population) is about the same as the estimate for 1985–90<sup>2</sup>, whereas the figure of 0.07 per 1000 for radiopharmaceutical treatments represents an apparent rise of about 60%.

### CONCLUSIONS

Ionising radiation is used increasingly widely in medicine, principally for diagnosis with an annual global total for 1996 of about 2.5 billion examinations (78% from medical x-rays, 21% from dental x-rays and 1% from nuclear medicine). Therapeutic exposures are also important, but less common, with a further annual total of about 5.5 million complete courses of radiotherapy treatment world-wide (over 90% by teletherapy or brachytherapy and only 7% by radiopharmaceuticals). The annual average dose to the world population from all diagnostic exposures has been revised from<sup>2</sup> 0.3 to 0.4 mSv *per caput* (collective effective dose of 2.5 million man Sv), with about 6% due to nuclear medicine. This dose represents about 14% of the total from all sources including natural radiation, whilst accounting for over 95% of that from all man-made exposures.

Medical radiological examinations and treatments are distributed unevenly amongst the population, predominantly to elderly and sick patients, but involving significant numbers of children. There are also significant variations in practice between countries, with over three-quarters of all diagnostic procedures and over one-half of all treatments occurring in those developed countries (classified in level I of the UNSCEAR global population model) that collectively represent only one-quarter of the world population. The overall trends are for increasing numbers of diagnostic and therapeutic procedures and increasing population exposures, fuelled by continuing developments in technology and evolution in clinical practices. The significant scale of medical radiology necessarily dictates that such exposures are an important focus for radiological protection in order to manage effectively the benefits and risks.

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# Regulating Nuclear Medicine in the UK: the Work of the ARSAC Support Unit

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Nuclear medicine involves the administration of radioactive substances to patients for the diagnosis or treatment of disease. The radioactive material is usually injected into the patient, but is occasionally inhaled or swallowed. The substance is chosen to concentrate in the organ of interest. For diagnosis, the distribution of the radioactive material in the body is either measured with a small detector or, more commonly, imaged by a gamma camera, which detects the gamma rays that are given off. The take-up of the material gives useful information about the way the organ is functioning. For treatment, the quantity of radioactive material is sufficient to affect the functioning of the organ, by killing off a high proportion of the cells.

About 750 000 nuclear medicine procedures are carried out each year in the UK. Less than 20 000 of these are for treatment, the vast majority being for diagnosis<sup>1</sup>. Most of the diagnostic procedures use <sup>99m</sup>Tc, which has a half-life of six hours and emits 140 keV gamma rays. Imaging devices readily detect rays of this energy, but their emission decays fairly rapidly so that the dose to the patient is minimised. The commonest imaging procedures involve studies of bone, lung, kidneys or heart<sup>2</sup>. The most common type of nuclear medicine therapy is the administration of <sup>131</sup>I to treat the thyroid gland<sup>1</sup>.

## WORK OF THE ARSAC SUPPORT UNIT

The Administration of Radioactive Substances Advisory Committee (ARSAC) was set up in 1979 (following the MARS Regulations 1978<sup>3</sup>) to advise the Health Ministers on matters relevant to the granting of certificates to practise nuclear medicine. Members of ARSAC are mostly medical practitioners and medical physicists, all of whom have special expertise in nuclear medicine. In the UK it is a criminal offence to administer radioactive medicinal products to a human being unless the person is a medical practitioner holding a certificate issued by the UK Health Ministers, or is acting under the direction of a doctor or dentist who holds such a certificate.

The ARSAC Secretariat, based at the Department of Health in London, organises meetings and services ARSAC. The ARSAC Support Unit, based at NRPB, Chilton, provides administrative support to ARSAC, and is responsible for processing applications for certificates within the guidelines set out by the Department of Health. All applications from medical practitioners throughout the UK are dealt with by the Support Unit, amounting to about 1100 per year. Every application is checked for completeness, entered on to a computer database and a paper filing system, and then sent to ARSAC for assessment. An application for a certificate must include information about the applicant's training, and the facilities and scientific support available to the applicant. A typical certificate holder is at consultant level, and has had comprehensive training and developed

considerable expertise in the appropriate procedures. The Support Unit monitors the progress of the application and can provide up-to-date information on that progress to the applicant.

The ARSAC members will assess the application and return their comments to the Support Unit, which is often asked to obtain further information from the applicant to enable ARSAC to reach a final decision. Once the application has been fully approved by ARSAC a certificate can be issued, typically within six weeks of receipt of the application.

ARSAC certificates can be issued to clinicians for any one of three purposes: diagnosis, therapy or research. Over 3000 certificates are current, with 45% of these being for diagnosis, 27% for therapy, and 28% for research. Certificates are 'site specific' so a separate certificate is required by each applicant for each site where administrations will be undertaken.

Certificates for diagnosis and therapy are valid for five years from the date of issue. During the period of the certificate, the clinician can apply for additional radiopharmaceuticals to be added to the certificate schedule. Shortly before the certificate is due to expire, a reminder letter is sent to the clinician inviting him to renew the certificate for a further five years.

Certificates for research are valid for two years or the duration of the research project, if shorter. These certificates are not routinely renewed, but the clinician can request an extension for a further period by providing written justification.

In addition to the routine applications for certificates, urgent requests can be made for a special administration to a particular patient. These are submitted in cases where the certificate held by a clinician is not appropriate, often because the radioactive substance that is urgently needed for the particular patient is not one that is administered routinely. Each case is assessed individually and authorisation obtained from the Department of Health within a few days. This type of certificate is valid for one patient on one specified day only.

The ARSAC Support Unit acts as an important point of contact between health service clinicians and NRPB. Provision of this service to ARSAC has been a key target in the NRPB Business Plan for the past four years. The Support Unit has performed to the satisfaction of ARSAC members and the vast majority of the applicants. It provides the administrative assistance that enables the proper authorisation and control of the use of radioactive sources in the health service, so ultimately its performance has an impact on the safety of patients undergoing nuclear medicine procedures.

Further information on approved practices in nuclear medicine and the procedure for gaining a certificate are contained in the Guidance Notes issued by ARSAC<sup>4</sup>.

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## Informing the Public and Media about UVR Clothing Protection

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On two days in late May and early June 2001, NRPB had the opportunity to provide a public presentation on the UVR protective properties of clothing at the Science Museum, London. On both occasions, the visitors to the museum were asked to submit items of clothing for assessing the protection factor and were very interested in the results.



**At the Science Museum**

Generally, a protection factor of 15 – which reduces exposure to about 7% of that of unprotected skin – is adequate to protect against sunburn during the summer months in Europe, although a higher level of protection may be advisable for equatorial regions. Most items of clothing offer a good level of protection, but protection factors as low as 2 were recorded on some items, which is half the value measured on, say, a paper tissue. A number of children's T-shirts had protection factors in the range 10 to 15, which could well give rise to an insufficient level of summer UVR protection if the fabric was wetted or stretched.

On the first day of the presentation during the Spring Bank Holiday Week, the Cancer Research Campaign was also represented and reporters and photographers from national and local press captured the event and undertook interviews.

The second day of the presentation coincided with the launch of the new European Standard logo on UVR clothing protection. For clothing to be assigned this logo, items of fabric have to be tested to a European Standard by an approved laboratory. The fabric has to attain a level of protection of at least 30, when tested dry and unstretched. The high protection factor offered by this standard takes account of any possible reduction in protection factor due to wear, stretch and wetting of the fabric.



European logo

For this launch, BBC Breakfast Television was interested in providing a feature and NRPB was interviewed about UVR clothing protection and the requirements for standardisation of test procedures. Following the publicity from this launch, local television and national newspapers provided additional reports of clothing protection as part of a wider sun protection policy. This policy includes avoiding outdoor exposures when the sun is high in the sky, seeking shade whenever possible, wearing wide brim hats and wrap-around sunglasses and applying broad spectrum sunscreen to unprotected skin.



BBC Breakfast TV interview

It is envisaged that further presentations on clothing protection will be made to members of the public and the media. NRPB also provides a measurement service for assessing the UVR protection factor of fabrics. Anyone wishing to obtain more details about this service, or to seek further information about this article, should please contact [colin.driscoll@nrpb.org.uk](mailto:colin.driscoll@nrpb.org.uk).

# A Healthy Lifestyle, Radon and the Palace of Westminster

MARTYN GREEN • NATIONAL RADIOLOGICAL PROTECTION BOARD • CHILTON

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**There is always a tendency, especially for the more cynically minded, to believe that politicians have a strong survival instinct and are very good at protecting their own interests. In matters of personal health and safety, this is a trait we should all emulate and, indeed, we are constantly cajoled by the Government, the media and the medical profession to strive towards a more healthy lifestyle: to eat less fat and more fruit and vegetables, to moderate our intake of alcohol, to take more exercise, to protect ourselves from the sun's rays and to stop smoking.**

In this plethora of advice, the importance of reducing the high radiation exposure of the estimated quarter of a million or so British people who live in homes with high radon levels is sometimes overlooked. The lower end of the annual dose range to these people, living in homes with radon concentrations at or above the Action Level of 200 Bq m<sup>-3</sup> of air, is of the order of 10 mSv. This implies for these individuals a significant increase in their lifetime risk of lung cancer. The highest doses are well in excess of 100 mSv; such doses would incur the immediate attention of the health and safety inspectorate if they occurred in the workplace.

In contrast to the lack of concern shown by many people, both in private and public life, to the matter of excessive radon exposure, our Westminster Members of Parliament are leading by example. Right at the start of the national radon campaigns, back in the 1980s, radon levels both in the main debating chambers and in the extensive cellars under the Palace of Westminster were measured and found to be low. However, one of the downsides to being a politician is job insecurity: the average term for a Westminster MP is under ten years. This means that the majority of current Members know relatively little about radon and were not present to hear the almost regular parliamentary questions on radon asked and answered during the 1990s. This potential lack of knowledge has now been addressed with the publication by the Parliamentary Office of Science and Technology (POST) of a four-page 'postnote' on reducing radon risks in the home. POST is an office of both Houses of Parliament, charged with providing independent and balanced analysis of public policy issues that have a basis in science and technology. Leaflets in the postnote series are sent to all MPs and peers in the House of Lords; they provide a concise summary of individual topics. The radon postnote (number 158 and published in June) covers the risks from radon, the control strategy based on the dual concepts of a radon Action Level and radon Affected Areas, a radon probability map of the UK, radon remedies for existing dwellings and radon prevention in new dwellings, as well as sources of further information. There is also a brief history of successive government radon campaigns since 1987 and a more detailed discussion of the new three-year roll-out programme involving over 30 local authorities. This was announced by the Environment Minister, Michael Meacher, in July last year and began in earnest early this year in the North West of England.

Copies of postnotes and more details of POST can be found on the POST website: [www.parliament.uk/post/home.htm](http://www.parliament.uk/post/home.htm).

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# Radon Exposures from the Use of Natural Gas in Buildings

DARYL DIXON • NATIONAL RADIOLOGICAL PROTECTION BOARD • CHILTON

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The naturally occurring radioactive gas  $^{222}\text{Rn}$  is present at low levels inside all buildings and is the principal source of radiation dose for members of the public. The ground is the main source of indoor radon but there is some contribution from the building materials and outside air, water and natural gas<sup>1</sup>. Indoor exposure caused by natural background levels of radon in buildings is routinely evaluated in UK homes by measurements, and these will automatically include the contribution from radon in natural gas. Nevertheless, doses from the use of natural gas have been estimated to provide a perspective on the potential for radiation exposure in different circumstances and the factors that affect levels of exposure.

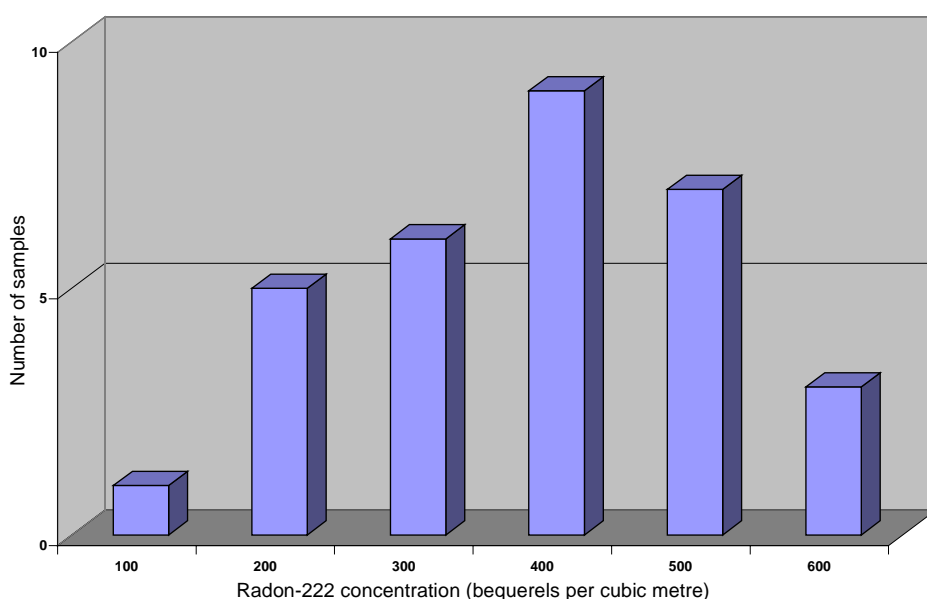
It is well known that levels of radon in the ground are often high and the presence of significant radon levels in natural gas has been known for many years<sup>2</sup>. Radon concentrations in natural gas are generally highest at points closest to the gas reservoir, which for practical purposes is the wellhead and other offshore equipment. The level of radon in gas from individual wells depends on many factors, including the nature and extraction history of the reservoir as well as operational factors such as the extraction method, process conditions and rate of gas extraction, which may vary over time. As a gas, radon passes unaffected through process equipment and filters to become distributed throughout the whole gas supply network. Levels of the decay products in the gas stream increase as the radon atoms decay and in the newly formed state, the products are able to deposit readily on to internal surfaces.

Decay products can also attach to dust, increasing the particle size, which reduces their mobility and, consequently, deposition rate<sup>3</sup>. Dust levels in distributed gas are, however, generally low so most decay product activity would be expected to be removed from the flow quite rapidly. This implies that in most parts of the system there is a relatively small proportion of decay products in the gas flow, and that significant amounts of activity can become deposited inside equipment such as filters.

Natural gas from the North Sea is transported to UK gas terminals through pipelines from some 80 or more fields<sup>4</sup>, many with multiple platforms and wells, amounting to several thousand individual wells, each of which can, in principle, produce gas with a different radon content. The results of radon measurements in individual wells world-wide during the 1970s are summarised in the table, with the calculation of mass concentration based on a nominal density of  $0.76 \text{ kg m}^{-3}$ .

Average radon levels will tend to be determined by the largest volume producing fields, but no single field dominates the supply of gas to any terminal so variations in production quantities from a field or platform should have relatively little effect on the overall average. Generally, users will receive gas from their nearest terminal, but some, particularly those close to the boundary of a supply area for a particular terminal, may receive blended gas, in which the proportions from different sources vary in response to seasonal demand.

Illustrative levels of radon in natural gas			
COUNTRY	RADON CONCENTRATION		
	AVERAGE	RANGE (Bq m <sup>-3</sup> )	MAXIMUM (Bq g <sup>-1</sup> )
<i>Europe</i>			
Germany	–	40–360	0.47
Netherlands	–	40–1 600	2.1
United Kingdom	170	40–3 400	4.5
<i>Canada</i>			
Alberta	2 300	370–7 600	10
Ontario	6 300	150–30 000	39
<i>USA</i>			
California	–	40–4 000	5.3
Colorado	940	410–1 670	2.2
Texas, Kansas	–	190–54 000	71



**FIGURE 1** Distribution of <sup>222</sup>Rn concentrations in 31 samples of natural gas from the southern basin of the North Sea

Various measurement programmes have been conducted over the last ten years and provide a guide to the range of levels and degree of variability that might be expected of radon levels in gas distributed from the terminal. The distribution of measurements on 31 samples of gas from the southern basin which supplies about 20% of all UK gas and for which the largest number of measurements is available, is shown in Figure 1.

Smaller numbers of measurements on other gas streams show the radon levels to be consistently lower in gas from more northerly fields which is supplied through, amongst others, St Fergus terminal. The average radon level for all UK gas supplies is

220 Bq m<sup>-3</sup> which reduces to 170 Bq m<sup>-3</sup> when weighted for the production quantities at different terminals. The quantity of interest for assessing radon exposure of members of the public is the average concentration in distributed gas and the data suggest that 200 Bq m<sup>-3</sup> would be a robust estimate for UK natural gas.

### POTENTIAL FOR EXPOSURE

The national distribution system delivers natural gas to a wide range of domestic and industrial premises in which people may be exposed to an enhanced level of radon when gas is burnt in non-flued equipment. Groups of people who will be exposed to radon from natural gas used in buildings include householders who use natural gas for cooking or heating as well as employees in commercial kitchens where combustion products might accumulate. Exposures in other workplace buildings are considered unlikely to be significant

The average radon level in gas of 200 Bq m<sup>-3</sup> is assumed to represent the typical radon concentrations in distributed gas averaged over a whole year notwithstanding the possible effect of seasonal factors on radon level. The radon concentration in gas supplied to individual consumers' premises will be lower than that measured at terminals as a result of radioactive decay during transport of gas to the consumer. The concentration of radon in gas will fall by a factor of two in about four days as a result of radioactive decay. The transit time will generally be less than 12 hours, however, and doses are therefore estimated with no reduction for delay in transit.

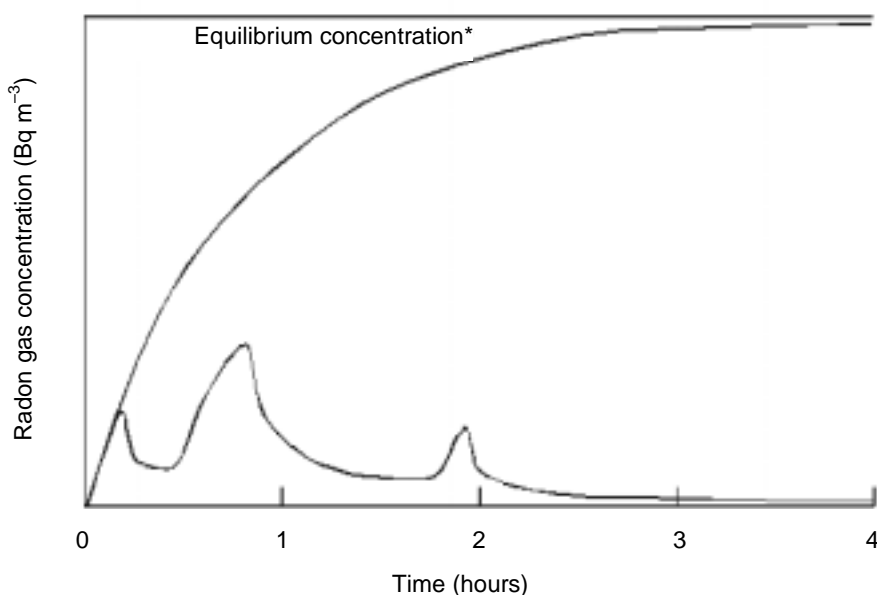
Gas used in central and water heating boilers will normally exhaust combustion products through a flue and will not contribute to radon in the living space so the principal source of non-flued gas combustion in domestic premises is assumed to be cooking. The gas consumption rate of a typical domestic hob burner is 0.28 m<sup>3</sup> h<sup>-1</sup> corresponding to about 3 kW. It is unlikely that burners would be used at full setting for long periods, but more than one might be in use at the same time. As a representative value therefore it is assumed that the combustion rate averaged over a cooking session is 0.5 m<sup>3</sup> h<sup>-1</sup>, allowing for the use of several burners at intermediate settings, and that the typical volume of the room is 25 m<sup>3</sup> with a natural ventilation rate of one air change hourly.

Data on the regional rates of demand for gas suggest that the volume of gas used by a typical family for cooking is about 100 m<sup>3</sup> in a year and the indoor radon concentration produced by the associated input of radon is calculated for 400 half-hour periods and 200 one-hour periods to represent a range of conditions. An illustration of the build up of radon that will occur is given in Figure 2, showing the fall in concentration caused by natural ventilation after each period of combustion.

The annual dose arising from the use of gas with the average radon level is about 3 and 5 μSv for 1/2 hour and 1 hour combustion periods, respectively, and 5 and 10 μSv for gas from the southern basin. Doses are calculated for a decay product equilibrium factor of 0.5, which for the short occupancy times concerned, is likely to overestimate doses somewhat, perhaps by as much as a factor of two.

### COMMERCIAL CONSUMERS OF NATURAL GAS

The greatest potential for exposure will arise, perhaps, from the use of non-flued appliances in commercial catering premises. Large commercial kitchens are likely to have fume extraction systems and a high rate of ventilation to maintain a comfortable working



\* The equilibrium concentration is the radon level in gas supplied multiplied by the ratio of gas supply rate to room ventilation rate, typically a factor of about 0.02.

**FIGURE 2 Illustrative profile of radon levels during use of natural gas**

environment. The highest exposures from catering are likely to occur, therefore, in kitchens of intermediate or small scale, where relatively large quantities of gas are used, but where there is little additional ventilation or extraction. The consumption of gas will generally be higher in commercial premises as they will have more burners, higher usage rates, and longer periods of work, assumed to be 500 hours annually. The annual dose under these conditions at a gas combustion rate of  $1 \text{ m}^3 \text{ h}^{-1}$  and a radon level of  $200 \text{ Bq m}^{-3}$  would be about  $19 \text{ } \mu\text{Sv}$ , based on a room volume of  $25 \text{ m}^3$ , 2 hour combustion periods and an air exchange rate of  $2 \text{ h}^{-1}$ .

### EXPOSURES FROM DISCHARGE TO ATMOSPHERE

The use of natural gas in numerous homes and workplaces throughout the country leads to the release into the environment of small quantities of radon as combustion waste distributed more or less evenly across the whole land area of the UK.

A perspective on radon released with natural gas combustion products is provided by comparison of the rate of natural gas consumption with the emission rate of radon from the whole land mass of the UK, which is responsible for the background radon level observed in the outdoor environment. The rate of radon emission from ground in the UK is typically  $0.02 \text{ Bq m}^{-2} \text{ s}^{-1}$ , which leads to a total radon production rate for Great Britain<sup>2</sup> of about  $5 \cdot 10^9 \text{ Bq s}^{-1}$ . The current rate of consumption of natural gas by all UK consumers is about  $7.5 \cdot 10^{10} \text{ m}^3 \text{ y}^{-1}$ , which, when combined with an average radon concentration of  $200 \text{ Bq m}^{-3}$ , leads to a radon emission rate as combustion waste of about  $4.4 \cdot 10^5 \text{ Bq s}^{-1}$ . This emission represents less than  $10^{-4}$  of the natural emission rate from the ground and therefore a negligible addition to individual dose.

## DISCUSSION

The annual dose received by most people from radon in natural gas is less than 10  $\mu\text{Sv}$  and a few tens of microsievert for the critical group of commercial users of natural gas supplied from the southern basin. As a comparison, the estimated dose for a member of the public is, on average, about 1% of the exposure from radon naturally present in homes. Data on the variability of radon in natural gas indicate that it is extremely unlikely that any individual doses from radon in gas will approach levels of concern.

Individual exposures received by domestic gas users are small, reflecting the small quantity of radon activity that is released into buildings from natural gas, and are likely to be of little concern to suppliers or customers. Ingress of air from the ground into normal buildings commonly amounts to a cubic metre or more per hour, and may contain several thousand  $\text{Bq m}^{-3}$ , which implies a daily input of perhaps 50 kBq of radon into a building. By contrast, typical usage rates of natural gas with the measured radon levels amounts to a daily input of only about 0.2 kBq, so the scope for exposure from radon in natural gas, even at quite large volumes and radon levels, seems always likely to remain small in relation to natural sources.

Exposure of the population to radon in homes is reviewed regularly by national authorities, principally because radon levels that occur naturally in some houses can reach levels of concern, but even the average radon level in most houses will completely dominate any contribution from radon in natural gas. It is important, nevertheless, to keep all radiation sources under review, particularly when the exposed population is large, and to ensure that they are properly managed. Although higher exposures would not necessarily be a cause for concern, it is desirable to identify any long-term trends, particularly if sources of gas change.

The wide range of radon levels in gas may reflect, in part, variations in the selection of sites and methods of measurement and the increasing numbers of companies that are becoming involved in gas supply may exacerbate matters. In order to promote consistency and reliability of radon measurement programmes, a protocol has been developed in association with the Institution of Gas Engineers<sup>5</sup>. The protocol includes detailed guidance on the practicalities of sample collection, measurement and interpretation of results and should maximise the benefit of measurement programmes. Additional data on radon would enable the trends and significance of different sources to be evaluated and support estimates of doses.

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## Radiation Risks in Kyoto

COLIN MUIRHEAD • NATIONAL RADIOLOGICAL PROTECTION BOARD • CHILTON

The city of Kyoto, known throughout the world both as the cultural centre of Japan and for the protocol on controlling climate change, hosted an international symposium on radiation risk assessment and mechanisms of radiation carcinogenesis in July 2001. Nearly 200 delegates attended, mostly from the USA, Europe and Japan.

Whilst many of the talks were concerned with radiation biology, this article focuses on the epidemiological findings that were presented. Dale Preston gave a preview of the latest cancer incidence results for the Japanese atomic bomb survivors, based on follow-up to the end of 1995. Since the leukaemia findings are similar to those from earlier analyses, he concentrated on solid tumours, and described how the new follow-up provides extra information on how both age at exposure and attained age affect radiation risks, on both relative and absolute scales. Furthermore, as reported in a paper last year (*Radiation Research*, **154**, 178–86, 2000), the solid cancer incidence data now provide statistically significant evidence of a dose response over the range 0–100 mSv. In their talks, Albrecht Kellerer and Warren Sinclair referred to the recent release by the US National Academy of Sciences of a status report on neutron dosimetry for A-bomb survivors in Hiroshima (see <http://stills.nap.edu/books/0309075599/html/>). It is not yet possible to be precise about the impact of any revisions to doses, although the present indications are that changes in risk factors would be within the existing range of uncertainty in these values.

Whilst the Japanese atomic-bomb survivors received an acute dose, several large groups of people in the former Soviet Union received protracted exposures to a wide range of doses. Elaine Ron summarised recent and preliminary findings for these groups. For example, studies of workers at the Mayak plant in the Southern Urals have shown raised risks of lung, liver and bone tumours in relation to plutonium exposure, and increased risks of leukaemia following exposure to gamma radiation a few years previously. Among people who lived near the Techa River, downstream from Mayak, increased risks of leukaemia and solid cancers have been seen that show similar patterns to the corresponding risks in the atomic-bomb survivors. In both of these studies, and in research in progress near the Semipalatinsk nuclear weapons site, the dosimetry is currently being re-evaluated. Regarding thyroid cancer following childhood exposure near Chernobyl, Dr Ron noted that the latency period does not appear to differ greatly from that in studies of external exposure. In doing so, she pointed out that atomic-bomb data on solid cancer incidence were not complete until 13 years after exposure, and therefore are not informative on thyroid cancer latency.

Two talks covered epidemiological studies of groups with medical exposures to radiation. Roy Shore reviewed analyses of cancer and of mental and developmental effects following exposures *in utero*, based on both medical studies and the atomic-bomb survivors. In particular, he drew attention to areas where information is sparse; for example, on the effects of irradiation in the early part of pregnancy, and on the shape of the IQ dose response at low doses. Margaret Tucker described studies of second cancers in groups with genetic susceptibility, such as patients with heritable retinoblastoma. Radiotherapy has been linked to high relative risks (RRs) of bone tumours in these patients, with a possible decrease in the RR at long times after exposure. She also drew

attention to an increased risk of melanoma in this group, and mentioned that investigations are in progress to improve estimates of the patients' exposure to the sun.

Cancer risks in areas with high levels of background radiation were the focus of the talk by Luxin Wei on a cohort study in Yangjiang (China), and of a workshop held immediately before the symposium that covered both this study and other investigations that are in progress (in Kerala, India) or under consideration (in Ramsar, Iran). Improvements have been made in the Chinese study in recent years, such the collection of data on possible confounding factors and on levels of radon and thoron, the latter of which contributes a substantial proportion of the total dose from natural radiation in some areas. Whilst raised cancer risks were generally not apparent in the Chinese study, the statistical precision of the findings was limited. Furthermore, as I pointed out in my talk at the symposium, small levels of bias or confounding can affect low dose studies generally. Nevertheless, such studies do provide direct information on cancer risks in humans, and further follow-up and refinements should increase their value.

The remainder of the symposium focused on radiation biology. Whilst I do not claim to be an expert in this field and recognise that it is invidious to pick out particular talks, I was impressed by the presentations by Jack Little on the 'bystander effect' (ie the transmission of damage signals from irradiated to non-irradiated cells); Tom Hei on how the bystander effect might be modulated by the 'adaptive response' (ie whereby exposure to a low level of DNA damage renders cells resistant to a subsequent exposure); Harvey Mohrenweiser on variation in DNA repair genes in humans and possible relations to cancer risk; and Mike Atkinson on the identification of genes influencing individual sensitivity to radiation-induced osteosarcoma. The closing session included some speculations on the shape of dose-response relationships at low doses, and whether it is still possible to ascribe values to a DDREF (dose and dose rate effectiveness factor), given the complexity of the biophysical and experimental findings. Clearly it will be important for bodies such as ICRP to continue to monitor developments in radiation mechanisms. From a personal perspective, it was heartening to hear the statement that epidemiologists are still needed to point towards gaps in knowledge and areas where further research would be fruitful.

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## Internet-based Gamma-ray Spectrometry Course: a New Way of Learning

In the January 1996 issue of the *Radiological Protection Bulletin* I wrote a review on a book entitled *Practical Gamma Ray Spectrometry*. One of the authors, Gordon Gilmore, is behind a new venture to provide an online gamma-ray spectrometry course. This is based on highly respected one- and two-day conventional courses but this new course is very much more comprehensive, and can be completed without ever leaving your desk.

The list of topics covered is far ranging, from decay data and statistics of counting through spectra interpretation and nuclide identification to more complicated subjects such as true-coincidence summing and decision limits. These topics are split into about 35 modules, which are individually downloaded from the Internet, most of which have associated on-line assessments. Some of these assessments are computer marked which gives immediate replies, however care is needed to quote answers exactly as specified! Tutor marked assessments work much better because of the freedom they

allow in the response and with the comments contributed by the marker. More details about the course content can be found on the Nuclear Training Sources website ([www.nucleartraining.co.uk](http://www.nucleartraining.co.uk)).

The main advantages of this type of course are that no travel and accommodation are required so the overall cost is lower and that students may work at their own pace. It is also possible to work at times which are most convenient and there is no time away from the place of work. There are also disadvantages, particularly the lack of discussions with the tutor or fellow students. However, it is planned to include sessions on an Internet Relay Chat channel for occasions when many participants are working through the course.

Gamma-ray spectrometry is a very practical subject so how can an Internet-based course be as useful as time spent with a laboratory full of equipment? This course overcomes this rather well by using a virtual gamma-ray spectrometer which has the look and feel of a real system. This can actually be used to acquire data to produce spectra for a wide variety of practical exercises. Other useful training resources are a virtual oscilloscope, which is used for a fault finding exercise, and a variety of Internet links and spreadsheets.

In conclusion, this is a course I can recommend to anyone with an interest in gamma-ray spectrometry and, in particular, to those who have difficulty finding time to attend a conventional course. It was comprehensive, interesting, and very well presented.

**Michael Youngman**

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## ICRP Proposals

**EDITOR** – In *Bulletin* No. 230, there is a news item headed New ICRP Proposals. From this I quote:

'In 1990 ICRP introduced 'constraints' on optimisation to avoid [misallocation of resources] 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 a large number of people.'

I could almost not believe my eyes when I read this. The fact is just the opposite! Source-related dose constraints were not introduced to avoid 'reduction of trivial doses to large numbers of people' but to protect the most highly exposed individuals and prevent a situation where optimisation of protection would be carried out in such a way that the collective dose was shared by a few people who would then have obtained high doses. When these people were protected by the constraint, it became necessary to choose a protection option which had not been the optimum choice without the constraint. This could have been a more expensive option with all doses, including the trivial ones, reduced, or it could have been a more detrimental but less expensive option with the collective dose, otherwise comprised of these high doses, shared by more people. The resulting, and preferred, situation in the second case would be a higher collective dose with more people exposed to small individual doses.

**Bo Lindell**

**Swedish Radiation Protection Institute, former Chairman ICRP**

*Editor's Comment: Professor Lindell is of course correct and we apologise for the error. It arose because a line of text went missing during the editorial process for the item in News and Affairs.*

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