Cosmic ray dosimetry: monitoring to protect the health of aircrew

radiation particles tend to be much more energetic and many of them enter the Earth's atmosphere, where they are slowed down and mostly absorbed. In the UK the average radiation dose that people receive is roughly 0.0026 sieverts per year (a sievert is a measure of risk from radiation). Of this amount, about 10% comes from cosmic radiation, which is modest compared to the contribution from the natural radioactivity of the Earth.

So, the Earth's atmosphere shields us here on the ground, but what if we don't have the complete atmosphere to protect us? For example, on board an aeroplane flying at 10 000 metres. It turns out that the cosmic radiation levels at this altitude are roughly 150 times higher than they are at sea level. Now if you are flying three or four times a year, this only makes a small difference to your annual radiation dose, adding perhaps 0.0001 or 0.0002 sieverts, well within the natural variation seen in the average levels around the UK. But what of aircrew, who may spend nearly 500 hours per year airborne? This means that their radiation doses could exceed 0.005 sieverts per year, which is higher than most people working in the nuclear industry! It is for this reason that airlines are now legally obliged to assess the radiation doses of their employees, just as in the nuclear industry.

Although scientists have been measuring cosmic radiation since early last century, it is only recently that the implications of the increased radiation levels at aircraft altitudes have been considered important. This is partly a reflection of the increasing number of hours spent by aircrew at altitude. Hence, during recent years scientists have made measurements with a number of different radiation detectors with the radiation dosimetry of aircrew specifically in mind.

For the past two years, NPL has been collaborating with the Civil Aviation Authority, Virgin Atlantic Airways, and the Mullard Space Science Laboratory to measure radiation doses on routes from London to cities worldwide. To date, the doses on roughly one hundred flights have been recorded and these results will provide valuable additions to the ever-increasing body of data on cosmic ray doses. As more information is collected it is hoped to learn more about the complex processes involved when cosmic radiation interacts with the Earth's and the Sun's magnetic fields, with the Earth's atmosphere, and ultimately with the passengers and crew of aircraft.

Radiation Processing

'Radiation processing' is the use of ionising radiation to produce beneficial physical, chemical or biological effects on an industrial scale. Typical examples are the modification of material properties, particularly in polymers, and the sterilisation of medical devices. Foodstuffs can also be irradiated to extend shelf life or reduce the numbers of harmful bacteria.

Articles commonly subjected to radiation processing

When ionising radiation passes through a material, it deposits energy. The amount of energy transferred is sufficient to cause both ionisation and the breaking of chemical bonds. The result is a cocktail of highly reactive chemical species. The great advantage of ionising radiation is that it allows these reactive species to be generated 'in-situ' and in a very precise and controllable manner. The total number of reactive species can be controlled by measurement of the absorbed radiation dose.

The biggest industrial use of ionising radiation is in the modification of properties of materials. Radiation can be used to either initiate polymerisation, or to cause cross-linking, to harden polymers and increase their melting point.

The other major use of ionising radiation is the sterilisation of medical devices. Approximately 50% of the single use medical devices (syringes, scalpels etc) in the UK are sterilised by ionising radiation. By delivering precisely measured doses of radiation, it is possible to ensure that any microorganisms on the devices are destroyed. Because the radiation easily penetrates the plastic or paper packaging, the device can be sterilised after it has been packaged and it will then remain sterile until the package is opened, making such devices safer for us all.

Dosimetry for Radiotherapy

Every year 200 000 people are diagnosed with cancer in England, and are treated with radiotherapy, chemotherapy and surgery. Radiotherapy treatment is given to about half of all patients, with intent to cure the cancer or to alleviate suffering.

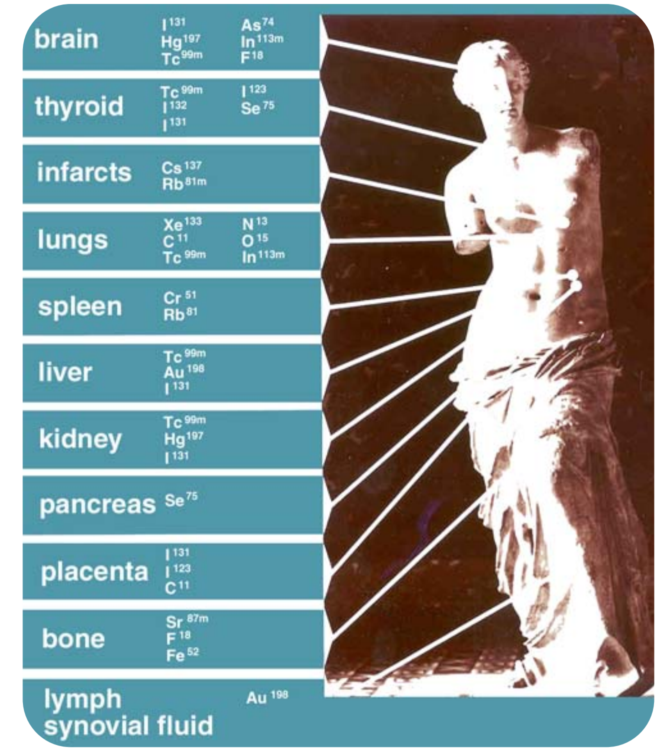
The radiation may be given in the form of external beams of high-energy electrons or X-rays, or it may come from radioactive sources placed inside the patient (brachytherapy, nuclear medicine). For radiotherapy to effect a cure, it is essential that the correct amount of radiation (absorbed dose) be delivered to the patient. Too small a dose, and one or more cancerous cells may survive, leading to recurrence of the disease. Too large a dose, and the healthy tissue surrounding the tumour may be destroyed. Optimal treatment of, for example, some head and neck tumours, requires that the dose delivered should be within only a few percent of that prescribed.

Every treatment is monitored with instruments whose calibration can be traced back, via accurate secondary standard dosemeters, to the primary standard instruments held at national standards laboratories such as NPL. These standards measure absorbed dose or air kerma directly from first principles, and are subject to regular comparisons with other national standards worldwide. Reference instruments calibrated against these primary standards allow the determination of absorbed dose by following the relevant Codes of Practice recommended, in the UK, by the Institute of Physics and Engineering in Medicine. Accurate dosimetry is essential to maintain and improve radiotherapy and ultimately to improve cancer survival rates.

Radioactivity Measurements for Medical Uses

Ionisation chamber system for use in calibrating radioactive sources in hospitals

Radioactive materials are used widely in medicine, dentistry and veterinary practice therapeutically and for diagnosis.



Examples of radionuclides used to label or treat organs in the body

450 000 patients receive radionuclides for diagnostic purposes each year using a wide range of radiopharmaceuticals - chemical compounds, selected to accumulate in one part of the body. The radiation emitted is detected outside the patient and can be used to provide a map of the relevant part of their body. An example in common use is radio-labelled iodine compounds that are used to investigate problems with the thyroid glands in the neck.

Radionuclides of particular importance are 'positron emitters', these decay by emission of two γ-rays always in exactly opposite directions. Detectors placed around the body can use this fact to pinpoint the source of the γ-rays and hence build up an accurate 3D image. This technique, known as Positron Emission Tomography or PET, produces images that can show if tumours are present, if an organ is enlarged or if a part of an organ is not functioning correctly. The safe and successful use of radionuclides for medical diagnosis depends critically on accurate measurement of the activity administered to the patient.

In most cases activity measurements are made in hospitals using a relatively simple device called an ionisation chamber. All such devices in UK hospitals are calibrated using reference materials or other standards from NPL, which in turn have been calibrated against NPL's primary standards of activity. Ionisation chambers provide extremely reliable, efficient and economic measurement standards to the medical community. The one shown was developed at NPL for use in hospitals.

Clubs

NMS Alpha and Gamma-Ray Spectrometry Users' Fora act as a focal point for discussion of problems and dissemination of information between users of alpha and gamma-ray spectrometry.

NMS Ionising Radiations Metrology Forum facilitates the exchange of information about UK calibration and testing facilities, for those who must comply with the requirements of the current Ionising Radiations Regulations.

NMS Neutron Users' Club is a club to promote information exchange concerning the production, use and metrology of neutron fields including the calibration and use of neutron detectors.

NMS Radiotherapy Standards Users' Group is a group for those interested in accurate dosimetry in radiotherapy.

NMS Liquid Scintillation Users' Forum is for the benefit of all users of liquid scintillation counting techniques.

NMS Air Monitoring Group will provide a forum for discussion of all aspects of air monitoring for radioactivity.

The first NMS Radionuclide Calibrator Users' Forum will be organised early next year for the benefit of all users of the NPL Radionuclide Calibrator and similar devices.

If you have an interest in any of the above please contact:
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FORTHCOMING EVENTS

22-25 October 2001 Saint-Louis, France 10th International Metrology Congress
Contact: Keith Berry
Tel: 020 8943 6033
E-mail: keith.berry@npl.co.uk

31 October 2001 Birmingham Metrology Awards Gala Dinner
Contact: Anne Kearney
Tel: 020 8943 6557
E-mail:
anne.kearney@npl.co.uk

31 October 2001 NPL Force & Hardness Group Annual Meeting
Contact: Gayle Carter
Tel: 020 8943 6449
E-mail: mechclubs@npl.co.uk

6-8 November 2001 Harrogate National Measurement Conference incorporating BEMC
Contact: Hannah Edmunds
Tel: 020 8943 6260
E-mail:
hannah.edmunds@npl.co.uk

6 November 2001 NPL Optical Radiation Measurement Club / Temperature and Thermophysical Properties Awareness Club Meeting 'Emissivity and Solar Heat Gain'
Contact: Fiona Jones
Tel: 020 8943 6743
E-mail: fiona.jones@npl.co.uk

7 November 2001 NPL Ionising Radiations Metrology Forum Meeting
Contact: Clare Scott
Tel: 020 8943 6208
E-mail: clare.scott@npl.co.uk

8 November 2001 NPL New laser safety standard - training course
Contact: Richard Stevens
Tel: 020 8943 6484
E-mail:
richard.stevens@npl.co.uk

14 November 2001 NPL Torque 2001
Contact: Gayle Carter
Tel: 020 8943 6449
E-mail: mechclubs@npl.co.uk

19-22 November 2001 NPL MTDATA Week, including introductory courses, group meetings and workshops
Contact: John Gisby
Tel: 020 8943 7098
E-mail: john.gisby@npl.co.uk

20 November 2001 NPL Gamma-Ray Spectrometry Users' Forum
Contact: Simon Woods
Tel: 020 8943 6424
E-mail:
simon.woods@npl.co.uk

22 November 2001 Kempton Park Electronics Assembly MASTERCLASS - Martin Verguld & Caroline Beelen-Hendrikx - Philips - 'Trends in Electronics Packaging & Lead Free Soldering'
Contact: Deborah Lea
Tel: 020 8943 6065
E-mail:
deborah.lea@npl.co.uk

22 November 2001 NPL FREEMET Antenna Calibration Training Course
Contact: Sara Fletcher
Tel: 020 8943 6827
E-mail: sara.fletcher@npl.co.uk

5 December 2001 NPL EMMA-Club meeting
Contact: Bob Clarke
Tel: 020 8943 6156
E-mail: bob.clarke@npl.co.uk

11 December 2001 NPL Training course on testing the numerical correctness of scientific software
Contact: Jan Kane
Tel: 020 8943 7100
E-mail: jan.kane@npl.co.uk

12-13 December 2001 London W1 AGAC/RSC Monitoring Ambient Air - an update
Contact: Clare Murphy
Tel: 020 8943 6819
E-mail: clare.murphy@npl.co.uk

FURTHER INFORMATION

For additional copies of this newsletter, or for more information on any aspect of NPL's work and the range of services available from the Laboratory, call the NPL Helpline:

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NEWS FROM THE National Physical Laboratory

METROMNIA

Radiation in Our Lives: The Benefits and Risks

The presence of ionising radiation in our environment is an inescapable fact of life. We are all exposed to it. As we breathe, small amounts of the radioactive gas 'radon' enter our lungs. The ground and buildings around us are slightly radioactive. Our bodies contain natural radioactivity from our food and drink, and cosmic rays fall on us all the time.

We can use radiation for our benefit, the main uses being in healthcare. Most of us are familiar with chest and dental X-rays, investigation of bone fractures or other diagnostic procedures. Radiotherapy is a commonly used technique to cure cancers or reduce suffering and many medical products are sterilised by high doses of radiation.
Unfortunately exposure to radiation is often an unwanted side effect of a process e.g. air flight, the generation of electricity by nuclear power and the provision of the healthcare benefits above. In these processes people must be protected from radiation and we must work to minimise their doses.

Cosmic Ray Dosimetry

The Earth is bathed in radiation from space. People are familiar with one type of space radiation (i.e. UV radiation from the Sun), but are perhaps less aware of other types. If we think of the Sun as an enormous, fusion-powered nuclear reactor, then it should come as little surprise to find out that it generates nuclear particle radiation, or solar radiation. But there is more: we are also being bathed by 'galactic' radiation from outside our solar system, generated by violent cosmic events.

Fortunately, here on Earth we are well protected from this cosmic radiation. The Earth generates, and is surrounded by, a magnetic field that is strong enough to deflect most of the radiation coming from the Sun. However, galactic cosmic

NPL National Physical Laboratory

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