

# MEDICAL PHYSICS and BIOMEDICAL ENGINEERING

BULLETIN of the DEVELOPING COUNTRIES COMMITTEE of the IUPESM

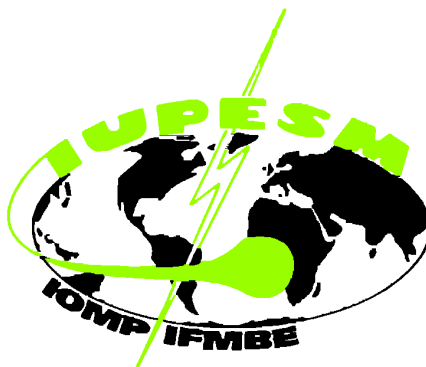
No.7

WARSAW

1996

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# MEDICAL PHYSICS and BIOMEDICAL ENGINEERING

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Spring 1996

## *10th Anniversary of the Chernobyl Accident 1986- 1996*

### International Events

**September 2-6,1996**

V International Conference on "Applications of Physics in Medicine and Biology"(Georgio Alberi Memorial), IX Congresso AIFB-EFOM Medical Physics '96 - EUTECH '96, Trieste, Italy. For further information **Dr A.del Guerra, Dept. di Fisica Universita, Piazzale Torricelli 2, I-56100 Pisa, Italy. Tel: 39- 532-781822, Fax: 39-532 781810.**

**September 10-14, 1996**

International Symposium on Biomedical Optics IV, Graz, Austria. For further information **EOS, c/o Françoise Chavel BP147,91403 Orsay Cedex, France (E-mail: francoise.chavel@iota.u-psud.fr).**

**September 16-20,1996**

Dosimetry of High Electron and X-ray Therapy Machines. The University of Texas MD Anderson Cancer Center, Dept.of Radiation Physics, Houston.

For further information **The University of Texas, MD Anderson Cancer Center, Radiation Physics Dept.,-544, 1515 Holcombe Boulevard, Houston, TX 77030, Tel: 713-792 3076, Fax: 713-794-1371.**

**September 22-26**

EFOMP (European Federation of Organisations for Medical Physics Meeting, in Switzerland (?))

For further information **Dr W.W.Seelentag, Klinik für Radio Onkologie, Kantonspital, CH-9007 St Gallen, Switzerland.**

**September 23-26**

15th Annual Congress, European Society for Therapeutic Radiology and Oncology (ESTRO), Vienna, Austria.

For further information **Dept. of Radiotherapy, Universit Hospital St.Rafael, Capucijnenvoer 33, B-3000 Leuven Belgium, Tel: 32-16-336413, Fax: 16-336428)**

**October 1-5, 1996**

EUROSON '96 -Ninth Congress of European Federation of Societies for Ultrasound in Medicine and Biology, Budapest, Hungary.

For further information **Dr Georgy Harmat, The Mad.Str.Ch Hospital, Madarasz u 22-24 ,POB 51, 1388 Budapest, Hungary**

**November 10-15 1996**

International Meeting of the American Nuclear Society and the European Nuclear Society, Washington DC,USA

For further information **Meetings Dept., American Nuclear Society,555 North Kensington Ave. La Grange Park IL 60524.**

### **From the Editor:**

*On Monday, April 29 1986, I had an unexpected visit from my friend from the Central Laboratory for Radiological Protection in Warsaw, who told me about high levels of radioactivity in the air, monitored in his laboratory. He pinpointed the source to the south-western part of Ukraine. Since we knew about the nuclear power station in Chernobyl, we concluded that there must have been an accident there. It was only 6 hours later that the Soviet authorities admitted that this had really been the case.*

*The current issue of the Bulletin is exclusively devoted to that tragic event. Let it be an alarming signal for all countries of the world that mankind is balancing on the brink of a catastrophe which may annihilate the life on our globe.*

*I would specially like to draw your attention to a most instructive article: "Radiation Risk Evaluation" (p.11).*

*Since I am planning to devote the next issue of the Bulletin to bioethical problems, I would appreciate it very much if you could send me your ideas and suggestions based on your experience by answering the Questionnaire on p. 20.*

*Oskar A.  
Chomiccki*



...Thank you very much for your bulletin. Send me please 10 copies in the future... I would like you to help me to [get] some books for the Ukrainian Medical Physics and Engineering.

**Dr Valeri E.Orel**, Ukrainian Research Institute of Oncology and Radiology, Lomonosova str. 33/43, Kiev-22, UKRAINE

**Editor:** I will be happy to write to Cathy Warmelink and dr Murthy to recommend some assistance for our friends in Ukraine.

\*\*\*

...After a long process of reorganisation and elections, we have now a new Board of the **Sociedad Cubana de Bioingenieria**, with Ing. Eduardo Corona as President...

...

**Ing Mario Otamendi** Secretary, Sociedad Cubana de Bioingenieria, Calle L No. 406 e/ 23 y 25 Vedado, Ciudad de La Habana CUBA

...We are in a very delicate situation. We have 14 Cobalt-60 machines, 90% are not working properly, they are 30 years old. ...We have very good service organisation, so installation, maintenance, etc. is not a problem. Is it possible...to find some donors or sponsors?

**Ing Eduardo Corona** President (see above)

**Editor:** First of all, congratulations on the newly elected Board of your organisation. After consultations with the IUPESM Officers at the meeting in Nice, 13-14 January 1996, I have approached several international organisations on your behalf, but from this place I would also like to appeal to companies to come to your help.

\*\*\*

...I'm sending you the Questionnaire and Report about Activities of the Moldova Association of Medical Physicists up till March 1995... One copy of your Bulletin will be quite enough.

**Dr G.S. Zakharchenko**, Asociatia fizicilor medicali Republica Moldova, str. Testimitanu 30, Chisinau, 277025, REPUBLICA MOLDOVA

**Editor:** Your abbreviated Report is published on p. , and let us hope that your Association will grow in numbers as well as activities in the future .

\*\*\*

..On the basis of long experience we have developed a new planning system PLANW. It is a programme for photon and electron beam treatment planning. It requires only PC 386SX, 2M RAM, MS DOS 6.2, WINDOWS 3.1.

If you are interested we can send you a demo diskette free of charge.

**Ing J.Mach E.Benese** c.5, 340 12 Svihov, CZECH REPUBLIC

**Editor:** The above programme looks attractive provided it is not too expensive for Radiotherapy departments in some Developing Countries.

\*\*\*

...I find the Bulletin very interesting and I am sure that our Medical Physics Society will send you some information for publication. The South African Medical Physics Society was established in the early 1960s and we have about 80 members. Medical physics is well organised in our country...our academic and practical training is of high standard... We also hold annual congresses.

**Dr Andries van Aswegen**, The University of Orange Free State, Dept. of Biophysics,

339 Bloemfontein 9300, REPUBLIC OF SOUTH AFRICA

**Editor:** I am looking forward to the promised materials for publication and, in the meantime, best wishes for future activities.

\*\*\*

I am happy to inform you that Association of Medical Physicists of India successfully organised the 6th Annual Medical Physics Conference, Nov.8-9, 1995. The occasion was also used to celebrate the centenary of X-rays...

Over the years the Journal of Medical Physics (India) has made an impression on the medical community of not only India, but also of the world... All this has been possible due to the...efforts by you and other members of the Editorial Board... Owing to my recent appointment as Head, Radiological Physics Div. BARC, I will not be able to devote sufficient time for the Journal.

**Dr M.S.S. Murthy**, Head, Radiological Physics Div., Bhabha Atomic Centre, Bombay 400 085. INDIA

**Editor:** Congratulations on the new and responsible post, but regrets that the JMP has lost its excellent Editor-in Chief.

\*\*\*

... I feel sorry that you have not been able to come to our Congress "Medical Physics '95"... Your Bulletin is very interesting for our readers. There is a lot of useful information in it, which can help us in our difficult work in organising education in Russia.

**Dr Tatyana Ratner**, Association of Medical Physicists of Russia, Moscow, RUSSIA

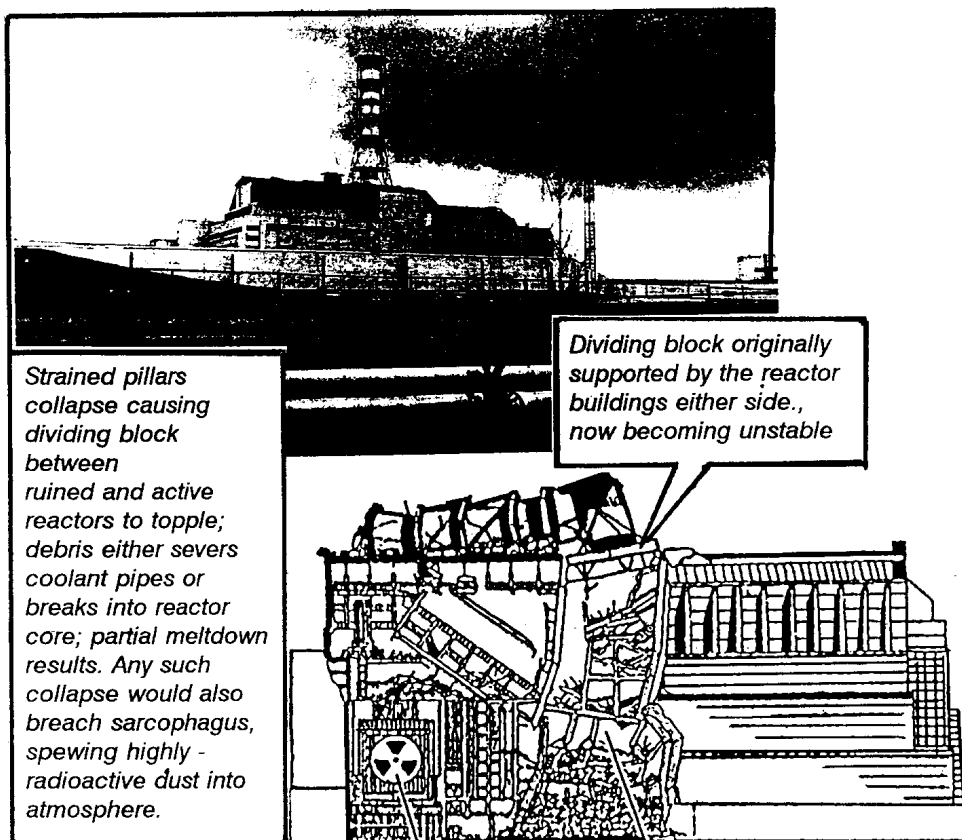
**Editor:** Many thanks for your kind words. A Report from your Conference is published on p.18.

**Main  
Topic**

# Chernobyl disaster and its legacy

Oskar A. Chomicki

*A short account is given of the greatest nuclear accident of the 20th century and its dire consequences that are still being evaluated by the international organisations and scientific community.*



The accident at the **Chernobyl** nuclear power station that consisted of four reactors (producing 1000 MW each), and was situated 65 miles (104 km) north of Kiev in Ukraine, occurred on April 25-26, 1986, when technicians were trying to install a new safety system. However, at the same time they inadvertently shut down several of the reactor's existing emergency systems, and they withdrew almost all control rods from the core. Thus, at **1.23 am on April 26** the chain reaction went out of control. As a result, the explosions and a fireball blew off the heavy steel and concrete lid and, since the reactor had in fact no containment, but an internal structure that could only withstand the loss of function of a single pre-

By early May, the heat and radioactive leakage from the reactor were contained at a heavy loss of life and radiation sickness induced in the army conscripts called for help. The highly radioactive reactor was "entombed" in a thick casing of concrete, called a 'sarcophagus'. Several tons

of radioactive materials escaped into the atmosphere, such as iodine-131, caesium-137, plutonium -237, etc. The so-called 'hot spots' were being found all over Europe. Around the Chernobyl power station a zone of over 30-km radius became highly contaminated and some 150,000 inhabitants

ssure tube (no ex-Soviet nuclear power stations were equipped with a containment building) large amounts of highly radioactive material went into the atmosphere. It was then that the monitoring stations in the neighbouring countries (Sweden, Poland, etc) detected unusually high levels of airborne radioactivity, which had been carried over great distances by air currents. The Soviet government was forced to admit the accident and began evacuation of several thousand inhabitants in the region. However, it turned out later that the largest amount of radioactive fall-out was recorded hundreds of miles from Chernobyl, mostly in Belarus, and significant amounts as far away as Switzerland, England or northern Sweden.

of radioactive materials escaped into the atmosphere, such as iodine-131, caesium-137, plutonium -237, etc. The so-called 'hot spots' were being found all over Europe. Around the Chernobyl power station a zone of over 30-km radius became highly contaminated and some 150,000 inhabitants

had to be evacuated. Human life in the zone practically ceased to exist, except for the workers employed at the still functioning Reactors 1, 2 and 3 (see the Current Story "SARCOPHAGUS" p.5). For more details involved in the disaster on medical problems, the reader is referred to the article: THE INTERNATIONAL CHERNOBYL PROJECT" HEALTH EFFECTS (p.7).

The figure on the preceding page explains the present situation at the Power Station: the top photo shows the whole station, and the diagram shows the inside of Reactor 4 (from an article in the *The Observer (London)* of 26 March 1995).

In 1995, a European Commission, consisting of French, German and British companies, as well as representatives of the UK Atomic Energy Authority, prepared a classified report on the situation in the Chernobyl power station. The main conclusion of the report is that the pillars supporting the damaged reactor may collapse sending debris crashing into Reactor 3 next to the Reactor 4 encased in the concrete sarcophagus, causing another core meltdown. What is more, the Commission found the sarcophagus, containing 740,000 cubic metres of highly contaminated debris and broken machinery, leaking. Worst of all, the dividing block originally supported by the reactor

building either side has become unstable.

The investigators found a strange metallic 'stalagmite' made of solidified remnants of the reactor core: uranium, plutonium, caesium, etc. Earlier, the reactor's operators who were afraid that the debris would leak out have decided to hose down the sarcophagus, causing the metal and concrete to rust. By 1993, the corrosion reached alarming levels, and a team of nuclear experts from the European Commission came to investigate. They found ten times more radioactive waste scattered round the remains of Reactor 4 than was previously estimated. A huge mountain of 700,00 cubic metres of rubble and reactor debris will have to be buried, together with 40,000 tons of highly radioactive waste and radioactive fuel. The Chernobyl's debris will remain radioactive for hundreds of thousands of years. A second sarcophagus could only be guaranteed to last 100 years.

The Ukrainians have agreed to close the three remaining operational reactors, but, obviously they need electricity, and any clean-up must be followed by building new and safe nuclear power stations with the assistance of the European Union. □

## RADIOLOGICAL SITUATION OF THE ENVIRONMENT IN UKRAINE IN 1994

Professor Olga Tson  
Institute of Geochemistry and Mineralogy (Kiev)

The contamination of the environment in Ukraine, resulting from the Chernobyl accident, is highly non-uniform. The radioactive materials that had been emitted into the atmosphere have later been found in the form of two kinds of fall-out: (1) fine grained irradiated fuel particles, and (2) condensation products of volatile radionuclides. In the 30-km radius area it is the fuel particles that predominate, whereas both in the north-eastern and north-western directions away from the reactor the contribution of the condensation products is greater. 'Hot' spots have been found to be stable in the natural environment, depending on their physical and chemical properties and their ability to retain radionuclides. In the condensation products, the concentration of soluble radionuclides was found to be higher than that in 'hot' spots by 1-2 orders of magnitude.

The contamination concentration of  $15 \text{ Ci km}^{-2}$  has been found not to be a decisive factor in determining the levels of radioactivity in naturally occurring products

(e.g. foodstuffs). The levels of radiological hazard (i.e. the effect of all factors on the population health) have seldom coincided with those of the radioactive contamination and exposure doses. Other factors, such as individual human response to radiation, climatic conditions as well as other forms of environmental pollution and topographical features seem to be also responsible for the radiological health of the population.

It seems that radioactive strontium and radon will pose a serious threat in the future.

Clean-up and self-cleansing of the environment depend strongly on the climate, geochemical and topographical conditions. The time factor has to be also taken into consideration. □

(A summary of the paper read at the Seminar of the Polish Society of Medical Physics at Bia\_ystok (North-east of Poland) in July, 1994)

**Current  
Story**

# SARCOPHAGUS

# Andrzej M. Zaucha

*Hidden in the sarcophagus is the world's largest radioactive dump containing a deadly debris of 610 kg of plutonium and 17 kg of its decay product, americium. The sarcophagus itself still features over one thousand square metres of cracks and fractures.*

"Relax! Radiation here and now?" I was reassured by my friends in Kiev, capital of Ukraine, when I went to visit Chernobyl in Autumn 1995.

So we set off at eight o'clock in the morning on our trip there, not a typical excursion into the countryside. On the way, we kept passing villages and small settlements in better or worse state of repair, with their Russian-style domes of Orthodox churches, their lands still owned by kolhozes, Soviet-type cooperatives, not yet in private hands. A dilapidated bus was taking us to our destination, some 100 km north of Kiev.

Almost ten years ago, three days after the explosion, thousands of people from 76 villages set off on the same road, but in the opposite direction. Before evacuation, they suffered a fall-out of radioactive dust and had to breathe airborne radioactive isotopes thrown out from the damaged Reactor 4 of the Chernobyl Atomic Power Station. They had only one hour to leave all their houses and belongings behind.

Now the Power Station is heavily guarded against any possible attack by mad terrorists. To get inside one had to apply to the authorities and wait several weeks. Once the permission has been granted (price \$100.00), another \$300.00 are required to be allowed to take pictures.

The Station is encircled by two wide belts of land with a different level of contamination: a larger belt - 60 km in diameter - has all the inhabitants removed, and a smaller belt - 10 km in diameter - is a strictly forbidden zone with movement restricted to roads with many layers of freshly applied asphalt. Every dozen metres large notices can be seen warning against the danger of burning dry grass and making bonfires.

On our way we passed again a small village with deserted houses, their windows still with intact glass and doors partly opened. Total silence. It looked as if the people had just left to attend to their daily chores. The harmony was broken by the sight of an irregularly shaped cluster of young trees. We were not allowed even to stop, but we were told that some 800 people had returned to their homes to stay. They tend to their gardens, grow vegetables and even have cows. "You can easily get used to radiation," they say. They have come to stay and die in peace and isolation. Being old and few they are usually not bothered by

radiation inspectors.

It is only once a year, at the beginning of May, that families get permission to visit the graves of their relatives. We saw white crosses in the cemeteries against the dark background of thick forests around that looked most attractive. We would have loved to stop, get off the bus and start picking plentiful mushrooms and wildberries. The sight was overwhelming.

There were several checkpoints along the road, especially when we entered the 10-km forbidden zone, surrounded with a barbed wire and numerous warning notices displayed everywhere.

Finally, we reached the Station's main administrative building decorated with a large brass bust of Lenin (see above). In the hall we were greeted with the only living animals we saw in the zone - small dogs wandering about. No special protection measures were visibly taken against radiation (20 microrentgens per hour against 12-26 microrentgens for the Kiev area) for the staff of 5000 people, mostly young men and women, among them some 500 of the old, pre-accident personnel.

Arthur Korneyev, in charge of the Sarcophagus, is a nice and friendly middle-aged chief specialist. He says: "During my 16 years of work here, I've collected 120 rem (*maximum yearly dose is 5 rem*), but I have cheated my boss with the help of some doctors, because otherwise they would've sent me to do other, less attractive jobs," Asked how he managed to live in a place under constant threat of death, he answered: "Radiation is not that important, what really matters is here," and he touched his head. "Psychology, I mean. If you are an optimist, everything will be fine."

To get closer to the infamous Reactor 3, or strictly speaking, the Sarcophagus, we had to change into overalls, caps, boots and gloves. Then we were taken along wide and narrow corridors with the walls lined with metal and floor covered with concrete. Passing through several heavy doors with special locks, we got to the Station's main control room. Three energy units (called



# THE INTERNATIONAL CHERNOBYL PROJECT" HEALTH EFFECTS"

Fred A.Mettler, Jr. MD, MPH,  
Jonathan E.Briggs, ELS

University of New Mexico Department of Radiology Albuquerque, USA

The accident at the Chernobyl Plant was one of the world's largest radiation accidents. Five years after the accident thousands of square kilometers remain heavily contaminated by radioactive material, and there are over 100,000 persons who have been living continuously in these contaminated regions.

The health impact of the accident has been extremely difficult to deduce due to a large variety of factors. Credible information from before and since the accident has been difficult to obtain. A large number of poorly performed studies and public misconception and fear about radiation compound the problems that are always present when evaluating such a complex technological event.

To determine the health effects of the accident, the people involved must be categorized by the duration and degree of their exposure to radiation. Also, the radioactive and non-radioactive substances released by the accident must be identified and measured. Additionally, experts must estimate the effects of wind, rain and other factors on the effluents. Finally, time also is an important factor and must be taken into account in the evaluation of effects on human health because many of the radioactive substances, such as iodine 131, have very short half-lives and consequently are not dangerous or detectable after a few days or weeks. Others, such as cesium, strontium, and plutonium, will remain for decades.

Several major groups of persons involved with Chernobyl can be distinguished by the duration and degree of their exposure to radiation. One group for example, includes the workers and fireman involved in the immediate stages of the accident. In this group, the health effects became evident quickly; there were approximately 30 deaths attributable to acute radiation exposure and several hundred persons experienced acute radiation sickness. The second group includes the decontamination workers or so called "liquidators". The number of persons estimated to have participated in the clean-up phases of the accident is as high as 650,000. Radiation doses to these individuals are difficult to determine and most of the individuals have returned to their homes which are located all over the former Soviet Union. It is possible that, as a group, this population may incur the largest number of long-term health effects. A study of this group has not been performed because it is large and geographically scattered.

The goal of Task 4 was to answer three basic questions about the population living in contaminated villages and that had not been relocated. The first question was what health problems seen in these people might be related to Chernobyl? The second was what health problems might be the direct result of exposure to radiation?

The third question asked about the future - what adverse health effects can be expected?

The third group of interest consists of those persons who were evacuated or relocated to other areas. Again, the exact doses this group received were not

measured and are difficult to estimate. And now these persons have been relocated to many different areas of the various new republics making follow-up extremely difficult.

The fourth group consists of an extremely large number of persons who continue to live and work in areas of radioactive contamination, but are outside the 30 km zone immediately surrounding the accident site. Although this group may not have received the highest radiation doses, these persons are of particular interest because they continue to be exposed. Those in the first three groups may have received higher doses, but their exposures have ended.

## The International Chernobyl Project

In October 1989, the government of the USSR formerly requested the International Atomic Energy Agency (IAEA) to carry out: "...an international experts' assessment of the concept which the USSR has evolved to enable the population to live safely in areas affected by radioactive contamination following the Chernobyl accident, and the evaluation of the effectiveness of the steps taken in these areas to safeguard the health population."

A multi-national team was formed to undertake this assessment. The Commission of the European Communities (CEC); the Food and Agriculture Organization of the United Nations (FAO); the International Labor Office (ILO) from Geneva; the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR); the World Health Organization (WHO); and the World Meteorological Organization (WMO), all cooperated to form the International Chernobyl Project.

The ICP's goal was for international experts to make assessments of the Chernobyl accident in five areas of interest: the chronology of radiological events from the time of the accident to the present; environmental effects; radiation doses; health effects; and possible countermeasures for the future. The fourth part of the ICP, evaluation of the health impact, was known as "Task 4." A summary of the methods and results of Task 4 follow.

## Defining the Questions

The health consequences of an accident such as Chernobyl are extremely difficult to evaluate or predict. Many factors differentiate Chernobyl from other types of public health problems. Even the most destructive natural disasters involve familiar phenomena such as wind or rain.

Technological accidents involve complex, unfamiliar events and materials which produce psychological consequences different and perhaps more pervasive than tornadoes or

earthquakes.

The complexity of evaluating an event like Chernobyl must not be underestimated. For example, to determine radiation doses the factors that must be looked at include the variety and amounts of radionuclides released, the weather during and after the accident, the exposure times of people spread across a huge geographic area, transfer factors of radionuclides from soil to food and food to people, and finally the influence of protective measures taken.

Consequently, Task 4 required multiple, separate journeys to both the Chernobyl area and to other cities to obtain data and discuss the accident with Soviet citizens, scientists, and officials. The purpose of initial visits was to determine the concerns of the population as well as to initially assess the level of effects. A later trip was conducted to visit scientists in the major cities, including Kiev, Minsk, and Moscow. Soviet scientists were interviewed to determine what studies they had performed as well as to analyze their methodology and results. During the third visit, experts in selected fields reviewed Soviet data.

The final and most difficult portion of Task 4 consisted of three two-week field trips, one each to the Ukraine, Byelorussia and the Russian Federation. The purpose of these trips was to conduct an epidemiological study of selected settlements by examining village residents.

Each team included a physician who was an expert in one of the following fields: radiation effects, haematology, cancer and endocrinology, ultrasound, psychiatry or psychology, and general internal medicine. Team members were independently chosen. They had to be practicing physicians with no affiliation with either governmental organizations or the nuclear industry. Representatives were present from the World Health Organization during most of the trips.

As the baseline data available from before the accident had only limited usefulness, it was necessary to identify and visit both control (uncontaminated) and contaminated villages so that comparisons could be made.

The primary source of exposure in the villages studied was fallout containing cesium that contaminated the soil and food. The villages studied were independently identified on the basis of geographical spread and size. Each of the control villages was checked by ICP dosimetry teams to assure that had no significant contamination present. A total of 13 villages were visited (seven contaminated and six control).

The selection of villagers to be included also was carefully planned and performed. Sixty percent were children. Specific age groups were chosen for screening for specific medical reasons; for example, 2-year-old children were examined because of concerns relative to lead poisoning and anaemia. In all, five groups were examined

The children's blood samples were tested for lead. Lead in the diet may cause low haemoglobin, and large amounts of lead were poured into the reactor and probably vaporized and dispersed. Food was also examined for lead. All reported levels were within normal ranges. Consequently, lead was excluded as a cause of low haemoglobin. It was not possible to determine the cause of the low haemoglobin levels. Task 4 teams did not perform an analysis of either vitamin intake or of blood levels of vitamins.

including 2-, 5- and 10-year-old children as well as 40-year-old and 60-year-old adults. Participants were chosen by birth date and much care was taken to be sure representative samples from each village were obtained.

### **Data comparisons**

Task 4 did not repeat work already done. Instead, much of the data gathered by Task 4 was compared to earlier findings, when they were available. Results were classified into two main divisions. The first involved those health problems for which it was possible to review existing data and to correlate those findings with data obtained by Task 4. An example of such a health problem is the presence and incidence of anaemia. The second type of result came from review of existing data that could not be independently verified. This latter category included such items as cancer incidence and genetic effects. This data, Task 4 was only able to review for methodology and internal consistency.

## **RESULTS**

### **Haematology and Immunology**

No haematological changes were found in the village populations. However, studies of populations other than those from Chernobyl that have been exposed to high levels of radiation have shown haematological changes and Chernobyl fireman and plant workers did demonstrate such changes.

Unfortunately, it is not known how much anaemia there was in the villages studied prior to the Chernobyl accident. No pre-accident screening was done of either children or adults who were not symptomatic, therefore, cases of anaemia could have been present and have gone undetected. It is possible, that anaemias might have developed after Chernobyl, even though this would be unlikely as a direct result of radiation exposure. Because food was contaminated, governmental restrictions were placed on the consumption of milk, meat, and vegetables, possibly reducing the amounts of nutrients the people received and thereby causing anaemia. It is also possible that some villagers were so afraid of any amount of radioactivity in their food that they chose to eat very little and thus did not receive enough nutrients.

Task 4 did find low haemoglobin levels similar to those reportedly found in some village children by Soviet physicians. Haemoglobin levels and red cell size were essentially the same in control and contaminated villages.

A comparison of blood-cell size between US and Soviet children showed them to be the same, but the Soviet children's haemoglobin levels were slightly lower. Adult US and Soviet levels were the same.

### **The immune system**

The levels of lymphocytes in the peripheral blood system can be used as a means of determining radiation dose. The most sensitive tests to measure and count lymphocytes require prompt analysis using sophisticated equipment. The remote location of the villages studied precluded this detailed type of evaluation of the immune system.

Available Soviet data did not imply that any significant changes in the immune system were present as a result of the Chernobyl disaster. Minor changes, however,

could not be excluded.

### **Thyroid function and nodules**

Because significant quantities of radioactive iodine were released by the Chernobyl accident, and because the thyroid gland readily accumulates radioactive iodine if preventative measures are not taken, it was necessary to evaluate thyroid function. Too much radioactive iodine can cause hypothyroidism, which in turn causes an imbalance of thyroid hormones. To determine if such imbalances were present, the Task 4 teams measured the levels of two of these hormones from blood samples taken. Both adults and children were tested, but the greater interest was in children, especially those who were infants at the time of the accident. These children were expected to have had the highest doses of radiation to their thyroids from milk contaminated with radioactive iodine.

There was neither clinical evidence or evidence from blood hormone levels that indicated changes in thyroid function. Although researchers have reported that delayed hypothyroidism may be a problem after radiation exposure, the same investigators indicate that half of the cases should be apparent within five years. Consequently, it is unlikely that hypothyroidism will be a major public health problem as a result of Chernobyl. This does not mean, however, that certain children or other people who can reasonably be suspected of having received very high thyroid doses should not be continued to be screened.

The presence and frequency of enlarged thyroid glands (goiter) and nodules was also investigated. Ultrasound and physical examinations were made of the participants from both control and contaminated villages. No differences were found between these two groups. Ultrasound measurements of thyroid gland size were slightly larger when compared to measurements from other parts of the Soviet Union.

### **Cardiovascular health**

High blood pressure (hypertension) is a common cause of disability and death throughout the world. It has many causes including heredity, too much salt in the diet, obesity, and stress. The heart and its blood vessels, however, are not easily affected by radiation. Despite this fact, hypertension, myocardial infarction, stroke and heart attacks all were reported to have increased since the accident and prior to the Task 4 study.

All the study participants, except the two-year-old children, were evaluated for hypertension. Many of the villagers from both the control and contaminated settlements had high blood pressure. Most were already aware of their

Another cause of uncertainty and anxiety is the prospect of relocation. The lifestyle of many of the villagers studied is based on agricultural rhythms and practices. Relocation poses a major possibility of disruption in the lives of these people. Government interventions since the accident, as well as economic and political changes in the nation as a whole, also have increased the villagers' anxiety.

### **Nutrition and growth**

Food was the primary source of radiation exposure for most villagers. Thus, two areas of inquiry specifically concerned nutrition. First, did the restricted diet imposed by the government to prevent people from eating contaminated

condition. No cause for the hypertension was identified. The causes are most likely different for different individuals and groups. For example, many of the villagers consume large amounts of salt, many others are overweight. And, of course, all of these people have been experiencing increased stress from the accident, as well as social, political, and economic disruption.

### **General health**

Non-radiation related general effects of the accident, such as improper nutrition and stress were present. The Task 4 teams compared the results of the physical examinations for age-matched people living in contaminated and control villages. High blood pressure as a condition was not included in the comparison. Overall, 3 to 5 percent of the children and 10 to 20 percent of the adults needed medical care or supervision. The only difference found between control and contaminated villages was in the category of stomach disorders. These were more frequent in adults living in contaminated villages. No causes for these disorders were identified. Another common problem was poor dental hygiene. These findings are consistent with the fact that there is no epidemiological evidence that exposure to radiation increases the incidence of all types of disease.

The children were growing along US and Soviet standards. Overall, the Task 4 teams found that the people were generally healthy compared with similar populations in other countries except for high incidences of hypertension, dental problems, and obesity.

### **Psychological effects**

At the time of the Task 4 evaluations, the psychological effects went well beyond the direct biologic effects of radiation. The primary cause of the negative acute health effects seen in these villages was anxiety and concern about the accident. Many of the people believed that radiation had made them ill. In addition, many of the residents in both contaminated and uncontaminated villages showed pessimism, depression, and fear, especially about the future.

Uncertainty about both what has happened and what will happen to them is definitely a major influence on the mental health of everyone affected by Chernobyl. Because of the technological nature of the accident, uncertainty is high. The radiological phenomena involved are very complex, unseen, and are closely associated with potential negative effects such as cancer. Objective information has done little to reduce this uncertainty.

food have an effect on the villagers' general health, especially the children's? Second, were the villagers complying with these restrictions? No evidence was found of problems from the new diet. Also, whole-body radiation counts were performed by ICP investigators. Because these counts were low, it was surmised that most were complying with the prescribed diet.

Levels of food consumption were compared for control and contaminated villages and no differences were found. Comparisons of height and weight also showed no deficiency in nutrition in any of the age groups examined.

### **Cancer**

Although, it is generally accepted that exposure to ionising radiation increases the incidence of cancer in humans, there are many factors that influence this deceptively simple cause and effect relationship. For example, different organs have different sensitivities to radiation. Also, tumours caused by radiation are similar to those that occur spontaneously and so are not readily identifiable as radiation induced.

Because of thyroid gland and bone marrow sensitivity to radiation, an increase in cancers in these organs can be expected after exposure. No clear evidence was found of increases in cases of either leukaemia or thyroid cancer in the village populations, despite reports of such increases by some Soviet physicians. However, the Soviet tumour data collection system uses a limited number of tumour categories, it was, therefore, not possible to exclude the possibility of small increases in these types of cancers.

Adverse effects also are known to result from the *in utero* exposure to radiation. These effects include microcephaly, mental retardation, and decreased intelligence and are primarily caused by exposure at 8-16 weeks' gestational age. Doses higher than any of those estimated to have been received by the villagers studied are required to produce these effects. No evidence was found to suggest an increase in congenital disease from radiation.

Possible adverse genetic effects from *in utero* exposure also were considered. Again, no evidence of an increase due to radiation was found, but data received was limited and future work on this subject is needed.

#### Genetic effects

Radiation dose estimates by ICP teams indicated that absorbed doses outside the 30 km zone around the accident site were too low to expect positive biological dosimetry results. However, it was still considered useful to perform cytogenetic evaluation as a means of determining if there was an increase in detectable cell mutation or damage.

Blood samples for cell analysis were obtained from adults in both the control and contaminated villages. Children were not included because of the large amount of blood required. Farmers and foresters were chosen, as they would have spent greater amounts of time in

Neither Task 4 nor any of the ICP teams attempted to reach conclusions as to what should be done in the future.

This decision is properly the province of the respective governmental authorities based upon their economic abilities and scientific and socio-political considerations.

Recommendations were made in regard to the need for more modern scientific and medical equipment, improved scientific methodology and quality assurance, and education.

In addition, it was recommended that specific high-risk groups continued to be monitored.

Technological disasters have human consequences that are very different from those of natural disasters. The Chernobyl accident caused a severe loss of **expected control**. This produced psychological consequences very different from those encountered after floods, earthquakes and volcanic eruptions. Another important psychological difference between Chernobyl and other natural disasters or man-made accidents is that often these are observable to everyone: victims, relief workers and authorities. Their

contaminated areas (out-of-doors) and thus would have received the highest doses. To expedite sample transport to Japan for analysis, blood samples were taken only during the last week of the field trips and shipped immediately. No quantitative proof of changes in somatic mutation were seen. Many factors may have affected these findings, however. Only small amounts of data were obtained and many samples degenerated during shipment. Future work is needed to better determine the genetic effects, if any.

## CONCLUSIONS

This study was unable to confirm many of the widely publicized media reports of substantial negative health effects as a result of the Chernobyl accident. This is not surprising for two reasons. First, not enough time has elapsed since the accident for all potential radiological effects to be seen. Second, the doses the population received is lower than originally thought. The International Chernobyl Project calculated that the average dose to persons who have been living in these contaminated villages was approximately 30 mSv (3 rem) during the five-year period since the accident.

The doses are lower than expected mostly due to the ability of the Soviet Government to bring clean food into the highly-contaminated region and thus limit the amount of radioactive material consumed. Typically the acute health effects are not identified at absorbed chronic doses of less than 100 rem.

This study can, with scientific validity, exclude the large claims which have appeared in the popular press. However, this study is not adequate to exclude or negate claims that there have been increases in conditions such as leukaemia and thyroid cancer. In addition, the Soviet data reviewed was not sufficient to indicate that there is such an increase present at this time.

The results of this study cannot be taken to mean that there will not be a future increase in tumours in the villagers studied. Given total projected doses calculated by the ICP, such increases should not be large in terms of a percentage increase, but in numbers may account for several thousand cases of fatal cancer.

effects also are relatively easy to see and understand, as are the measurements and directions of experts. By contrast, the ultimate effects of Chernobyl may take years to emerge and its explanations and countermeasures are unfamiliar and mysterious.

Perhaps Chernobyl's worst feature is its continuous threat and the continuing fear it generates in the people involved of possible future illness or genetic defects. These fears actually may have increased since the accident and show little sign of abating. Let us hope that some of this fear may be ameliorated by studies such as the one carried out by Task 4 and other ICP teams, and other objective scientific studies in the future.□

*(The paper read at the Symposium: "Health Effects of Ionising Radiation" of the Polish Nuclear Medicine Society and the IAEA, 22-24 October 1992, by permission of the "Problemy Medycyny Nuklearnej", Warsaw, Poland, 7, 1993)*

# RADIATION RISK EVALUATION:

## CONCEPTS AND UNITS OF MEASURE

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The health effects of ionising radiation have been studied for almost a century. As early as 1905, the health effects that are important today - radiation-induced cancers and the direct effects such as tissue necrosis - were described. By the 1930's both scientific review groups and radiation protection organizations had been established. Today, the amount of information available on the effects of ionizing radiation is enormous, and comprehensive reviews of radiologic issues are performed on a periodic basis by the United Nations Scientific Committee on Effects of Atomic Radiation (UNSCEAR). This group reviews the data and, with international cooperation, establishes the best current estimates of the magnitude, sources, and effects of radiation.

Another organization concerned with radiologic issues, the International Commission on Radiation Protection (ICRP), was established nearly sixty years ago. This is a commission of the International Society of Radiobiology, but functions as an independent, international commission which develops and promotes radiation protection philosophies and recommends dose limits.

The adverse health effects caused by ionizing radiation are divided into two general classes: stochastic and deterministic. Stochastic effects result from faulty repair of single-strand DNA breaks. The most common effects in this category are cancer induction and genetic damage. Stochastic effects are probabilistic in nature; the higher the dose, the higher the probability that the effect may occur. In theory, even a very tiny dose has an associated tiny potential risk. The severity of stochastic effects is not dose related; a cancer induced by a small amount of radiation can be just as malignant and have the same lethal potential as a cancer induced by a large dose of radiation. Although in theory no definable threshold for stochastic effects exists, cancer induction has not been statistically demonstrated at very low doses. This is most likely either because the DNA is repaired by natural means or because the risk is too small to statistically detect, given the magnitude of spontaneously occurring cancers.

Deterministic effects occur at high doses and result from double-stranded DNA breaks and subsequent cell death. An example is the induction of hypothyroidism after the administration of very large doses of radioiodine. These effects have a practical threshold; hypothyroidism is not induced unless doses to the thyroid gland exceed a certain level. The severity of deterministic effects is dose related.

The recommendations of the ICRP are forwarded to national advisory groups on radiation protection in various countries. These groups may modify the recommendations based upon their judgements, as well as particular conditions existing within their country. Usually, the recommendations of the national advisory groups are forwarded to the government and subsequently become legislated guidelines or limits.

UNSCEAR and the ICRP are concerned with ionising radiation: energy forms or particles which have sufficient power to cause ionisation, ions, and to generate free electrons. The ion pairs produced, for the most part, recombine, but if they do not they are capable of causing chemical change in and damage to biological tissues.

Humans encounter ionising radiation continuously. Natural background radiation alone cause over 150 million ionisations in an individual's body each day. Only a very few ionisations result in demonstrable harm. If all of them were detrimental, even to a minor degree, the human species would not survive for long.

The higher the dose, the worse the effects and the greater the injury to the tissue involved.

### Units of Exposure and Dose

Patients often want to know how the risk of a chest x-ray or other radiologic procedure in medicine relates to the risk of natural background radiation. Several factors must be taken into account before such a comparison can be made. For instance, there is a difference between the risks from a localized exposure to radiation and the risk of whole-body irradiation. Other factors that must be taken into account include the amount and type of radiation that is involved and the varying sensitivities of different tissues to radiation. Several units of radiation exposure and dose have been developed in an attempt to make useful measurements and comparisons.

As radiation passes through air, ionization in the air can be measured; this is typically referred to as *exposure*. The unit of exposure traditionally used is the roentgen (R). Overall, exposure is the least suitable quantity for the evaluation of radiation-related health effects because it does not take into account critical factors such as the penetration of the radiation, the organs affected, or tissue sensitivity.

A more valuable (but still not entirely satisfactory) measure of exposure is *absorbed dose*. Absorbed dose

refers to the energy actually deposited in tissue. It can be expressed as entrance or skin dose, exit dose, organ dose, midline dose, and the dose to a particular point in the body.

An older unit of measure, the *rad*, was defined as the deposition of 100 ergs per gram of tissue. The new international unit is the *Gray* (Gy) which equals the deposition of one joule (J) per kilogram of tissue. One hundred rads equal one Gy.

Although the use of absorbed dose to an organ is better for estimating biological damage to an organ than is exposure, is still is not entirely satisfactory because it does not account for the fact that different types of radiation deposit their energy differently, even within a given cell. For radiation protection purposes, the ICRP uses the average dose to a specific organ (D).

Certain radiations such as x-rays and gamma rays are sparsely ionizing and often distribute their energy quite evenly along the track of the radiation. Sparsely ionizing radiations are referred to as low-LET (linear energy transfer) radiations. Densely ionizing radiation, such as alpha particles, are referred to as high-LET radiations because they deposit a large amount of energy along the particle track, particularly near the end of the path. Low-LET radiation passing through a DNA molecule would exert substantially less effect than would high-LET radiation. For these reasons, the ICRP has adopted the use of a radiation weighting factor ( $W_R$ ).

### Weighting factors

Radiation weighting factors are closely related to the previously used quality factor (Q) and are also related to LET and radiobiological effectiveness (RBE). For radiation protection purposes the RBE for tumor induction is generally used. The radiation weighting factors given by the ICRP in their 1990 recommendations are given in Table I. The absorbed dose in an organ multiplied by a weighting factor for the particular type of radiation allows for differences in energy distribution. This is called the equivalent dose in tissue ( $H_T$ ) and also is expressed in joules per kilogram and it is measured in *sieverts* (Sv). The formula for equivalent dose is as follows

One other factor needs to be considered and that is the differing sensitivity of various tissues to tumor induction.

To compensate for these differences the ICRP developed a tissue weighting factor ( $W_T$ ). Before the derivation of the tissue weighting factor can be understood, however, the concept of dose response and its effect on tumor induction need to be addressed. Most of the available data for tumor induction in humans comes from absorbed doses in the range of 0.5 to 10 or 20 Gy. In this range, the number of induced cancers is roughly proportional to the dose. Above 10 or 20 Gy, the dose-response curve flattens because the higher dose kills cells rather than transforms them. At very low doses, the dose response curve is assumed to extend straight back through the origin or 0. This is the linear dose response model. It is considered very conservative and may over estimate the risks for low doses. Another alternative is the linear quadratic model. This model takes into account possible repair of DNA radiation damage and shows little effect in tumor induction at low doses. After a certain dose is exceeded, the curve rises proportionally with the dose. Usually, when applied to epidemiological data from humans, it is not possible to differentiate between these models, but

$$H_T = (\Sigma \sigma / R) \times D_{TR} \times W_R$$

Where  $D_{TR}$  refers to dose in a particular tissue or organ for a given type of radiation,  $W_R$  refers to the radiation weighting factor for that radiation. When the product of these is summed over all radiations, it equals the equivalent dose for that tissue ( $H_T$ ).

Table I. Radiation Weighting factors<sup>1</sup>

Type energy range	Radiation weighting factor, $W_R$
Photons, all energies	1
Electrons and muons, all energies <sup>2</sup>	1
Neutrons, energy <10 keV	5
10 keV to 100 keV	10
>100 keV to 2 MeV	20
>2 MeV to 20 MeV	10
>20 MeV	5
Protons, other than recoil protons, energy >2 MeV	5
Alpha particles, fission fragments, heavy nuclei	20

<sup>1</sup> All values relate to the radiation incident on the body or, for internal sources, emitted from the source

<sup>2</sup> Excluding Auger electrons emitted from nuclei bound to DNA.

(Adapted from the 1990 Recommendations of the International Commission on Radiological Protection, ICRP Publication No 60., Annals of the ICRP, Pergamon Press, Oxford, 1991 )

for purposes of radiation protection and to be conservative, most groups use the linear model.

Because of the apparent cause and effect relationship established by these models, most people assume that all radiation is harmful. This cannot be proved or disproved; however, it is clear that, if there are effects from doses below 10 mGy, they are so small that they cannot be discerned with current scientific methodology. Their statistical incidence, for example, is very small compared to the incidence of spontaneously occurring cancer.

In addition, to be able to evaluate and compare the risks of different types and amounts of radiation exposure, any model used must take into account the fact that radiation-induced cancers and leukemias have a latent period; it is usually years or decades after the radiation exposure before neoplasms become clinically apparent. The number of tumors produced after a latent period is commonly modeled in one of two ways: the absolute and multiplicative (relative risk). The absolute model assumes that the cancers are produced at a certain rate over time and are not proportional to the incidence of naturally occurring

tumors. The multiplicative-risk model, on the other hand, assumes that the radiation-induced cancers are a multiple of the naturally occurring incidence, and thus, increase rapidly with age. Overall, the multiplicative model yields risk estimates that are factors of two or three higher than the absolute-risk model. For radiation protection purposes, the ICRP currently uses the multiplicative-risk model. ICRP risk coefficients for 1977 and 1990 for fatal cancers developed are shown in

Table II.

The estimated risk factors for fatal cancers have increased by a factor of 4 between 1977 and 1990. This was due to a number of reasons: revised dosimetry at Hiroshima and Nagasaki, use of the multiplicative-rather than the absolute model, realization of increased sensitivity in children compared to adults, and clarification of organ-specific risk coefficients which were not previously available.

Since most of the information on risk factors comes from high-dose rate exposure it has been reduced by a factor of 2 to account for some repair when exposure is chronic. This dose-rate reduction factor is actually felt to lie between 2 and 3. Scientific data from a number of studies indicate both higher and lower values.

Any determination of the potential detriment from radiation exposure also needs to include both deaths from fatal cancer and some accounting of nonfatal cancers. Consequently, the ICRP has assigned values to different

( Adapted from the 1990 Recommendations of the International Commission on Radiological Protection, ICRP Publication No 60., Annals of the ICRP, Pergamon Press, Oxford, 1991 )

tissue types based on their varying sensitivity to radiation. The result is an estimate of the relative proportion that each of the tissues may be involved in the detriment as a whole. These are shown in Table III.

Because these values suggest more precision in the estimates than may actually be obtainable and because use of different factors for each organ becomes cumbersome, the ICRP has assigned rounded or simpli-

Table II. Lifetime Mortality in a Population of all Ages from Specific Fatal Cancer after Exposure to Low Doses. Fatal probability coefficient ( $10^{-4} \text{ Sv}^{-1}$ ).

Organ	ICRP (1977)	This report
Bladder	--	30
Bone marrow	20	50
Bone surface	5	5
Breast	25	20
Colon	--	85
Liver	--	15
Lung	20	85
Esophagus	--	30
Ovary	--	10
Skin	--	2
Stomach	--	110
Thyroid	5	8
Remainder <sup>1</sup>	50	50
Total	125 <sup>2</sup>	500 <sup>3</sup>

<sup>1</sup> The composition of the remainder is quite different in the two cases.

<sup>2</sup> This total was used for both workers and the general public.

<sup>3</sup> General public only. The total fatal cancer risk for a working population is taken to the 400  $10^{-4} \text{ Sv}^{-1}$ .

TABLE III. Relative Contribution of Organs to the Total Detriment.

Organ	Probability of fatal cancer $F$ (per 10,000 people/Sv)	Severe genetic effects (per 10,000 people Sv)	Relative length of life lost $l/l,^-$	Relative non-fatal contribution (2-k)	Product $F(l/l,^-)(2-k)$ (per 10,000 people/Sv)	Relative contribution
Bladder	30		0.65	1.50	29.4	0.040
Bone marrow	50		2.06	1.01	104.0	0.141
Bone surface	5		1.00	1.30	6.5	0.009
Breast	20		1.21	1.50	36.4	0.050
Colon	85		0.83	1.45	102.7	0.141
Liver	15		1.00	1.05	15.8	0.022
Lung	85		0.90	1.05	80.3	0.111
Esophagus	30		0.77	1.05	24.2	0.034
Ovary	10		1.12	1.30	14.6	0.020
Skin	2		1.00	2.00	4.0	0.006
Stomach	110		0.83	1.10	100.0	0.139
Thyroid	8		1.00	1.90	15.2	0.020
Remainder	50		0.91	1.29	58.9	0.081
Gonads <sup>1</sup>		100	1.33	-	133.3	0.183
Total	500				725.3	1.000

<sup>1</sup> Gonads (including cancer in ovary).

\* Adapted from the 1990 Recommendations of the International Commission on Radiological Protection, ICRP Publication No 60., Annals of the ICRP, Pergamon Press, Oxford, 1991.

fied weighting factors for the organs as shown in Table IV. With development of the weighting factor for tissue radiosensitivity ( $W_T$ ), it is now possible to improve upon the equivalent dose discussed earlier. The product of the equivalent dose in the tissue ( $H_T$ ) and the tissue weighting factor ( $W_T$ ) summed over all tissues leads to the *effective dose* or  $E$ . This is similar in concept to the effective dose equivalent previously used by ICRP. The effective dose is expressed in sieverts.

Having defined the concept of effective dose and a means of establishing it, it is now possible to compare the risk to a person from different sources of exposure.

The average effective dose from natural background radiation is 2.5 mSv per year. The effective dose from a chest x-ray is about 0.1 mSv and from most nuclear medicine procedures it ranges from about 0.1 to 1.0 mSv. The annual dose from living in a highly contaminated settlement near Chernobyl is approximately 6 mSv per year.

Some other units and concepts are useful in the determination of the health effects of radiation. The *curie* (Ci), a unit of radioactivity, is defined as  $3.7 \times 10^{10}$  disintegrations per second. This has been widely replaced by the *becquerel* (Bq), an international unit, which is a reciprocal second or, essentially, one disintegration per second.

*Half life* is an important concept when dealing with radioactive materials. Half-life is a general term and may refer to the *physical half-life* ( $T_{1/2p}$ ), *biological half-life* ( $T_{1/2b}$ ), or the *effective half-life* ( $T_{1/2eff}$ ). Each of these is useful in its own way. For example, if milk has been contaminated with iodine-131, the physical half-life of this isotope is used to determine how long the milk will need to be stored before it can be consumed. On the other hand, biological half-life is a critical factor in an accident involving the ingestion of elements such as plutonium. s:

Table IV. Tissue Weighting Factors <sup>1</sup>

Tissue or organ	Tissue weighting factor, $W_T$
Gonads	0.20
Bone marrow (red)	0.12
Colon	0.12
Lung	0.12
Stomach	0.12
Bladder	0.05
Breast	0.05
Liver	0.05
Esophagus	0.05
Thyroid	0.05
Skin	0.01
Bone surface	0.01
Remainder	0.05

<sup>1</sup> The values have been developed from a reference population of equal number of both sexes and a wide range of ages. In the definition of effective dose they apply to workers, to the whole population, and either sex.

( Adapted from the 1990 Recommendations of the IRPA, see tables above)

While plutonium has a physical half-life of thousands of years, it does not stay in the body because its biological half-life is only a few hours or day (plutonium is rapidly cleared through the intestinal tract). Both the biological and effective half-lives must be considered for organ dosage and in these circumstances the effective half-life is the important factor.

Now that some of the units and concepts of radiation exposure and dose have been described, it is important to consider the questions that need to be asked before it would be possible to give a medical opinion on the potential health effects or risks of exposure. Clearly, the effective dose to the organ of interest needs to be determined. The type of radiation will determine which radiation-weighting factor to use; the organ will indicate which tissue-weighting factor to use; and the absorbed dose will indicate the energy deposited.

The age of the individual involved is also important. The risk factors given earlier refer to a population of average age. If an individual is 65- or 70-years-old and is exposed to ionizing radiation, the subsequent potential risk of radiation-induced cancer is extremely low. The latent period for tumour induction is typically 10 or more years and the statistical probability is that the individual would have died from something else. Thus, for very old individuals the actual risk from low level radiation may be close to zero. On the other hand, if a child is involved, the risk will be higher than those given in the earlier tables. The effective dose should be calculated to determine the health effect. An extremely high dose will lead to deterministic effects, and a dose below one Gy would mostly be responsible for stochas-

tic effects, such as cancer and or genetic effects.

If cancer induction is the issue in question, then it should be remembered that the overall risk factor for lethal cancer is approximately 5% per Sv and this can be compared with a normal risk of fatal cancers of about 17% on a spontaneous basis.

Finally, a few words about the concept of "hormesis" are necessary. Hormesis is the notion that small amounts of radiation may, in fact, be beneficial rather than harmful. Stimulatory or beneficial effects of radiation have been observed in some instances, specifically as an increase in lymphocyte function and the effectiveness of the immune system. It appears that suppressor lymphocytes are more sensitive than other lymphocytes to radiation. Therefore, doses of radiation may allow the immune system to become more active by selectively killing suppressor lymphocytes. This condition may last for a period of minutes or hours, but during this time, the individual is able to fight off insults (such as tumour transplants) better than if the radiation had not been administered. Most scientists do not believe that the beneficial effects of radiation occur in enough circumstances to be useful for modifying recommended dose limits. In fact, most scientists still assume that radiation exposure should be kept as low as reasonably achievable, after economic and social constraints are taken into account.□

*(The paper read at the Symposium: "Health Effects of Ionising Radiation" of the Polish Nuclear Medicine Society and the IAEA, 22-24 October 1992, by permission of the "Problemy Medycyny Nuklearnej", Warsaw, Poland, 7, 1993)*

# RADIATION PROTECTION EDUCATIONAL PROGRAMMES IN EGYPT

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*Radiation protection educational programmes during the last 10 years are mentioned, such as training courses and regular studies for M.Sc. degree in Diagnostic and Therapeutic Radiology, as well as one-day Seminars. Several important publications on Radiation Protection have been translated into Arabic.*

During the years 1987-1991 more than ten 4-5 weeks' training courses on radiation protection, recognized by the central organisation for radiation protection in Egypt "CORP", have been organized annually. Some of them were sponsored by the IAEA. Their programme included 120 hrs of theory and 30 hrs of practical classes.

In Egypt, there are six accredited institutions responsible for organising such courses. Occasionally, special courses are also organised. Regular tuition embraces teaching curriculum for M.Sc. degree in Diagnostic and Therapeutic Radiology (4-5 two-hour lectures), as well as lectures and practicals in a one-year course for physics B.Sc. graduates, leading to a Diploma in Radiation Physics at

the Faculty of Science of Cairo, Ain-Shams, Menufia and Zagazig Universities. Starting in 1991, one-day seminars have been given to a large population of scientific personnel at their home site (eg. National Centre of Research, or Medical Faculty of the Al-Azhar University in Cairo) by Professors M.A. Gomaa and A. M.El-Naggar. This practice of popularising radiation protection education to non-specialists proved to be very successful and the organisers intend to make it more common.□ ( (Adapted from an article in *Radiat.Phys. Chem.* vol.44, pp. 245-246, 1994)

# Quality assurance in ultrasound

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Northern Ireland Regional Medical Physics Agency

The quality of an ultrasound image is determined by its *resolution, contrast, sensitivity, uniformity* and lack of artefact. Quality assurance is often performed in order to compare a machine's performance with that of others of similar price or with specified standards. Most often, however, it is made to check that a machine's performance has not deteriorated from the date it was put into operation.

In terms of function, an ultrasound scanner can be divided into three elements: (1) a probe, (2) electronics to generate and control the image, and (3) a monitor to display the image. Out of these three elements, the item most likely to change is the the probe, particularly the mechanical sector probes. Other types of probes are also sensitive. The monitor may change as a result of wear or fault, or due to inappropriate alteration of contrast or brilliance. Modern electronics are very stable.

There are three levels of testing. First, there are

## **baseline measurements**

which should be carried out at acceptance and whenever a new probe or hardware or software upgrade is added. This should be a rigorous set of tests, defining the technical performance of the machine. A *British Standard*<sup>1</sup> has been published, which defines the parameters which manufacturers should use to describe their scanners and the means of measuring these parameters.

They can also be useful in the selection of the equipment in combination with clinical assessment.

Second, there is

## **routine quality assurance testing**

which should be carried out every six or twelve months. They should be limited to those which have relevance to normal use of the scanner and which are likely to detect deterioration in performance.

Both baseline and routine QA testing can be done in-house. However, it is sometimes more practical to leave it a third party. Finally,

## **user testing**

should be carried out at intervals of one to four weeks. These should be simple tests, requiring a minimum of equipment and consuming as little time as possible while relating directly to the aspects of scanner functions on which users depend for clinically meaningful results. For scanners with a variety of probes, successive tests should be carried out using probes in rotation, so that each probe is tested at least every four weeks. The medical personnel should be in a position of responsibility and they should be aware of all faults or idiosyncrasies that develop. They should be interested in performing these tests and have enough time to do it.

The tests recommended by the Institute of Physical Sciences in Medicine are as follows<sup>2</sup> :

## **ULTRASOUND QUALITY ASSURANCE TESTS**

<b>baseline tests</b>	<b>routine QA tests</b>	<b>user tests</b>
<i>monitor (adv.*<sup>1</sup>)</i>	<i>monitor (adv.)</i>	<i>monitor (basic)</i>
<i>hard copy (adv.)</i>	<i>hard copy (adv.)</i>	<i>hard copy (basic)</i>
<i>callipers (adv.)</i>	<i>callipers</i>	<i>callipers</i>
<i>penetration (adv.)</i>	<i>penetration (adv.)</i>	<i>penetration</i>
<i>spatial uniformity</i>	<i>spatial uniformity</i>	<i>spatial uniformity</i>
<i>safety (adv.)</i>	<i>safety (adv.)</i>	<i>safety (basic)</i>
<i>power output</i>	<i>power output</i>	<i>functional checks</i>
<i>resolution</i>	<i>resolution</i>	
<i>scanner settings</i>	<i>scanner settings</i>	
<i>dead zone</i>		
<i>functional checks</i>		

\* Adv.= advanced

Some of these tests are more relevant than others. For example, the accuracy of the measurement callipers in most machines is usually very stable, but if a change occurs it could be very serious in obstetric examinations. The same is true for acoustic power output.

Recommendations for testing of Doppler ultrasound equipment are given in another IPSM report<sup>3</sup>, whereas the protocols for ultrasound scanners used in breast screening programme are defined in an NHSBSP publication<sup>4</sup>.

Testing of image quality is often overlooked and left to the user to confirm by clinical examination alone. The perfect operation of a scanner cannot be taken for granted. Of course, the user is the most important part of a QA programme, and it is up to him to see that proper functioning of the machine is ensured. □

( Adapted from an article in RAD Magazine, December, 1995)

## **References**

1. *British Standards Institution: Medical electrical equipment: method for declaring parameters for ultrasonic diagnostic equipment using test objects. BS5724 Part 3.26, 1990.*
2. *Price R. (Editor): Quality assurance applied to ultrasound imaging systems. IPSM Report No.71, 1995*
3. *Hoskins P.R., et al. ( Edit.): Testing of Doppler ultrasound equipment, IPSM Report No.70, 1994.*
4. *Davis M, et al.: A protocol for quality assurance of diagnostic ultrasound scanners used in the breast screening programme. NHSBSP Publication 27, 1993.*

# Medical Physics in the World

## EUROPEAN NETWORK MEDICAL PHYSICS/ ENGINEERING

### Bulletin of the Network and the Working Groups for European Education & Training

✦ During the Workshop in Kraków (Poland) a **Polish Sub-Network** was established bringing together more than 50 academic MRP/E professionals from 17 educational institutions. The Coordinator is Prof. M. Wasilewska-Radwa\_ska from Kraków (fax: 4812 340010).

✦ The **Latvian Medical Engineering and Physics Society** has recently been established. The Council consists of representatives of Latvian Universities, firms and medical and physics professionals. Prof. Yu. Dekhtiar has been elected as President and Dr. Ing. R. Darguzka as Secretary General.

✦ A successful **Romanian-Hungarian Workshop** in Cluj-Napoca with more than 100 participants dedicated to the Roentgen Centenary has been organised.

✦ In Romania, the Ministry of Education has approved the establishment of a **Medical Physics Department** at the Bucharest University.

✦ **Dr T. Ratner**, the Secretary General of the Russian Association of Medical Physicists, announced that medical physics education would be started this year at three Institutes near Moscow.

✦ In Riga, a new M.Sc. programme in **Biomedical Optics** has been started at the University of Latvia. The programme is supervised by Prof. J. Spigulis. The course centres on lasers, optical fibres, sensors and other medical equipment.

*(Adapted from EN Bulletin, No.2, December '95)*

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## MOLDOVA ASSOCIATION OF MEDICAL PHYSICISTS

In 1992, the Physical Society of Russia came forward with the suggestion of establishing a medical physics society in Moldova. And then the *Moldova Association of Medical Physicists* was subsequently set up by three persons: G.S. Zakharchenko, N.N. Bass and S. S. Rabinovich. In 1994, the Association officially joined the IOMP at the World Medical Congress in Rio de Janeiro.

Between 1992 and 1995, the members of the Association have vigorously participated in a number of national and international meetings, seminars and courses, such as the Summer School "Physics in Radio-therapy" (Poland), IX Conference of Radiologists of the Republic of Moldova, and the World Medical Congress in Rio de Janeiro.

In the same period of time, 6 publications appeared and 4 papers were in print. It signifies a great

advance of medical physics in Moldova, since in the preceding 10 years only two articles on medical physics had been published.

In 1994, a Library of Medical Physics was established at the Moldova Oncological Institute with the assistance from the IOMP International Library Programme. The library has more than 120 books and receives copies of several professional journals.

At present, although the Association has only four regular members, it is the best example that even a small, but active group of people can achieve significant results.

*Dr G. S. Zakharchenko, President, Asociatia fizicelor medicali Republica Moldova, str. Testimitanu 30, Chisinau, 277025, REPUBLICA MOLDOVA*

## "MEDICAL PHYSICS '95" (MOSCOW)

This was the Second National Conference, held in Moscow, Russia, on 4-8 December 1995, and organised by the Association of Medical Physicists of Russia and the Cancer Research Centre RAMS, Dept. of Radiation Topometry and Clinical Dosimetry, Moscow, Russia. The President of the Organising Committee was Professor V.A. Kostylev and the Secretaries were Drs T.G.Ratner and M. Suschikhina.

The programme included:

1. Ionising radiation in diagnostic radiology (new techniques and equipment),
2. Ionising radiation in therapy (new techniques, Quality Assurance and equipment for tele- and brachytherapy),
3. Non-ionising radiation in diagnostics and therapy,
4. Physical methods and environment in medicine,
5. Medical physics: education and training.

There were over 200 participants from Russia and abroad (Australia, Belarus, Ukraine, USA, Poland and Italy).

The Conference was combined with an exhibition

of medical equipment used in diagnostic and therapeutic radiology.

The Conference was divided into subject sessions. For example, Session I was devoted to the 100th Anniversary of Roentgen's discovery of X-rays.

A total of 80 papers were presented which made it possible to become acquainted with the advance in medical physics made in Russia and other countries. At the time of the Conference the General Assembly Meeting of the Association of Medical Physicists of Russia was also held.

The publication of two issues, Nos.1 and 2, of the new Russian journal devoted to Medical Physics, "MEDITSINSKAYA FIZIKA" coincided with the Conference, No.1 containing main EFOMP documents, such as 'The Responsibilities and Status of the Clinical Medical Physicist', 'Medical Physics Education and Training', and No.2 including the summaries of all papers presented at the Conference. □

(Prof. M. Radwa\_ska-Wasilewska, Poland)

## SEVENTH NATIONAL CONFERENCE ON BIOMEDICAL PHYSICS AND ENGINEERING

Sofia, 17-19 October 1996

### TOPICS

Biomedical Physics, Biomedical signal processing, Decision support in medicine, Drug monitoring and intensive care, Mathematical modelling in biology and medicine, Bioprocessing engineering, and Miscellaneous.

**OFFICIAL LANGUAGE:** English

**PARTICIPATION FEE:** \$ 100.00

**DEADLINE FOR SUBMISSION** of the *Preliminary Registration Form and Abstracts (1 page)* : **30.04.1996**

**ADDRESS:** Prof. B. Gramatikov, Centre of Biomedical Engineering, G.Bonchev Str. Bl.105, 1113

**SOFIA, BULGARIA**, E-mail: clbme@bgearn.bitnet

✂ .....

SEVENTH NATIONAL CONFERENCE ON BIOMEDICAL PHYSICS AND ENGINEERING

Sofia 17-19 October, 1996

### PRELIMINARY REGISTRATION FORM

Name.....

Position/Title (Prof., Dr, Eng. Phys.).....

Institution.....

Address for correspondence .....

I would like to participate in the Conference and present.....paper(s), with Abstracts enclosed.

I suggest you should send information about the Conference to .....

.....

Date:.....

Signature.....

# 75 YEARS OF PHYSICS AT WARSAW UNIVERSITY

On January 30, 1921, the **Physics Department** of the re-established **Warsaw University** was opened in the wake of the victorious Polish-Soviet War of 1919-1920. Poland regained its independence as a result of World War I, having been partitioned for almost 120 years by the Tsarist Russia, Austria and Prussia. There existed a University in Warsaw, run by the Russians in the early 1900s, but most talented young Polish men and women went to study abroad (*vide* M. Skłodowska-Curie). After the war, most Polish scientists and scholars, who had made careers at various universities in Europe, started to return to their native country, where other new universities were founded, in addition to the existing famous 400-year-old University of Kraków and the University of Lwów in Eastern Galicia. Among them was *Stefan Piekrowski*, Professor of Physics at the University of Louvain (Belgium). Full of energy, excellent manager and top scientist, he succeeded in having the main physics building erected in Warsaw in a record time of 15 months (*see photo at top*). Being familiar with the current developments in physics, he based his research projects on atomic and molecular optics and structural investigations with X-rays. Fifty years later, he fell victim of his early work with harmful radiation dying of polycythemia.

As early as 1928-1930, the Physics Department became a world-known centre of research, attracting many foreign students working for their Ph.D. degrees. Thanks to a generous donation by the Rockefeller Foundation (\$50,000), the Department purchased modern equipment and enlarged its premises. Extensive experimental work was localised at the main building, whereas theoretical investigations under *Professor C. Białybrzeski*, who was first to postulate radiation pressure in stars (prior to Sir Arthur Eddington), were conducted at a smaller scale elsewhere.

Before World War II, Professor Piekrowski decided to initiate a new field of research: atomic nuclear studies with a high-energy accelerator and a Wilson chamber. Plans were also made to build a cyclotron.

Also before 1939, several international conferences were organised and most distinguished physicists visited the Physics Dept., which was responsible for 40% of all papers published in physics in Poland at that time.

When the Nazis entered Warsaw in September 1939, they soon confiscated all apparatus, books, research

materials and sent them to Germany.

Happily enough, although 90% of Warsaw lay in ruins after the war, the Physics building was only devastated. Again, Prof. Piekrowski was the driving force behind the reconstruction and modernisation of the Department. New faculties were established, a high-energy accelerator was built and research was successfully carried out in many fields: solid state, particle physics, etc. In the latter field, Professors *J. Pniewski* and *M. Danysz* were first to discover hypernuclear matter in 1962. When Professor *L. Infeld*, A. Einstein's well-known co-worker, returned to Poland in 1950, he founded a school of theoretical physics of international fame.

Along with the development of the Physics Department, two other physics institutions were established in Warsaw in the 1950s: the Institute of Physics of the Polish Academy of Sciences and the Institute of Nuclear Research. However, the Physics Dept. retained its leading position in teaching and in research in some other fields such as biophysics and **medical physics**, etc. (*see the article: "Education and Training of Medical Physicists in Poland", Medical Physics World, p.6-8, vol.2, No.2, 1986*). Several thousand graduates (M.Sc.) and several hundred doctors (Ph.D.) have had their education at the Physics Department of Warsaw University.

The research studies done at present encompass a very wide range of problems in experimental and theoretical physics, resulting in more than 300 publications annually in foreign journals. The Department has been in cooperation with the world's greatest physics centres, such as CERN (Geneva), DUBNA (Russia) and has been responsible for organising numerous international conferences, meetings, symposia and summer schools. Polish physicists have taken significant positions at various universities the world over.

May I add that I take personal pride that I graduated from the Physics Dept. and was the last assistant employed by Prof. Piekrowski before his death in 1953. □

(Adapted and translated by O.A. Chomicki from the article by A.K. Wróblewski in "Wiedza i ycie", Jan. 1996)

# PROFORMA FOR STATUS OF MEDICAL PHYSICISTS

At the Brasil Congress of Medical Physics and Biomedical Engineering Dr *Carri Borrás*. Chairperson, Long Range programme Committee, IOMP, presented a report on the status of medical physicists in developing countries. Dr Keth Boddy, President, IOMP, has assigned to the Developing Countries Committee the responsibility of identifying the status of medical physicists and any associated problems in these countries. In order to fulfill this obligation it is necessary to obtain input from medical physicists from developing countries. With this in view, the accompanying proforma has been developed. It is requested that medical physicists may take a few minutes to fill in the proforma and return it to the address shown below. Any further suggestions to help evaluate the status of medical physicists will be very much welcome.

## PROFORMA

1. Name of Medical Physicist.....  
.....
2. Address for correspondence.....  
.....
3. Name and address of the competent authority responsible for regulating medical application of radiation in your country.....  
.....
4. Is there a regulatory requirement for the appointment of Medical Physicists in radiation therapy /radiodiagnosis/ nuclear medicine centres in your country?  
 YES       NO
5. If yes, please briefly state the requirement:  
.....  
.....
6. Is Medical Physics recognized as an independent discipline by the national medical education authority?  
 YES       NO
7. Name and address of the national medical education authority for further correspondence in this reg8. Minimum

qualifications and experience required to be appointed as Medical Physicists:  
.....  
.....

9. Facilities for Medical Physics training:  
.....  
.....
10. Opportunities for career advancement:  
.....  
.....
11. Responsibilities of Medical Physicists:  
.....  
.....
12. Emoluments of Medical Physicists in comparison with other medical and paramedical staff:  
 Satisfactory       Unsatisfactory
13. Any other information.....  
.....  
.....
14. How do you think IOMP can help improve the status of Medical Physicists in your country?  
.....  
.....  
.....

*Please return to:*  
**M.S.S. Murthy, Ph.D.**  
**Chairman, DCC IOMP,**  
**Head, Radiation Dosimetry & Training Section**  
**Bhabha Atomic Research Centre**  
**Bombay, 400 085 INDIA, Fax: 91 22 556 0750**

## Bioethical Questionnaire

**Answer the following questions in full and send your answers to the Editor,**  
**\_owicka 21a m.2, 02-502 Warszawa, Poland**

1. What is ethics' place in medical physics and/or biomedical engineering?
2. What is the scientific research integrity?
3. What is the boundary between research practice and research ethics?
4. Where do practical problems arise?
5. Have you ever encountered, or heard of bioethical problems in your practice?

# NEWS IN BRIEF

√ **Geometric patterns** in bacterial colonies are being studied by physicists, biologists and mathematicians to discover pattern formation in nature. Several models have been proposed. Pattern formation results from the complex interplay between a chemical attractant and the rate at which the bacteria spread out on the surface.

√ **Medical Physics** profession in the USA faces growth limits. For the last 20 years its growth has been annually 4%, largely surpassing the demand. The reason for this is strictly related to the present economic and social situation in medicine itself.

√ **Cooled CCD** camera systems from AstroCam Limited have been incorporated into the first commercial neutron radiography system, developed by Rolls Royce and Associates Ltd. and Oxford Instruments plc. It uses a compact superconducting cyclotron. Many images produced with this system have very low contrast and wide dynamic range, which enable fine details in the image to be observed.

√ **No threshold** dose-response relationship has been reaffirmed in the booklet *Risk of Radiation-induced Cancer at Low Doses and Low Dose Rates for Radiation Protection Purposes. Documents of the NRPB, vol.6 No.1 (1995) HMSO.*

√ **Surgery without** knives is now possible due to an instrument combining an MRI machine with simultaneous therapy. The MRI system makes the diagnosis and then guides advanced laser or ultrasound surgical tools directly at the affected area without implicating healthy tissue.

√ **Worldwide sales** of diagnostic ultrasound equipment will grow from \$ 2 billion in 1994 to \$ 2.8 billion by the year 2001. Radiology applications accounted for 42 % of 1994 revenues, cardiology 30%, obstetrics and gynaecology 12%, etc. Ultrasound is regarded increasingly as the best non-invasive imaging technique. Key advances will include improvements in transducer technology, 3D imaging and the more extensive use of contrast agents.

√ **Mammography** can be a lifesaver, but breast implants may make it harder to find a small breast tumour. *Toni Young of the National Women's Health Network in Washington, D.C.* warns that breast implants may be associated with other health hazards, including a serious autoimmune disorder.

√ **As many as 15,000** lung cancer deaths in the USA annually may result from radon according to federal health officials. However, other authors reported in *J.Ntl. Cancer Institute, Dec.*

*21,1994*) have not been able to demonstrate any association between exposure to indoor radon and cancer. Radon concentrations were found to be the same in the homes of women who had cancer and those who did not ( 1.82 picocuries per liter of air).

√ **In Turkey**, new tea shoots forming at the time of the Chernobyl accident ( April-May 1986, *see previous articles in the Bulletin*), incorporated enough cesium-137 from the fallout to produce a peak

radioactivity of up to 25,000 Bq per kilogram of dry leaves. By 1992, ce activity in new shoots dropped to 200 Bq/kg. On the other hand, whole- exposures to cesium from a year's drinking tea (Turkish çay) may have amo- to 0.66 millisieverts.

√ **Human irradiation** data are now available on *Internet* provided by Dept. of Energy's Office of Human Radiation Experiments ( *h* [www.eh.doe.gov/ohre/home.htm](http://www.eh.doe.gov/ohre/home.htm)).

√ **MRI** of inhaled noble gases optically pumped to high levels of nu polarisation offer a good technique for lungs imaging, as reported by *Ha and Allan Johnson of the Duke University Medical Center* (l

## NEW BOOKS

**Atoms, Radiation, and Radiation Protection**, by J.E.Turner, Wiley, New York, 1995, 555p. \$69.95.

**Marie Curie: A Life**, by Susan Quinn, Simon & Schuster, New York, 1995, 509pp. \$30.00.

**Contemporary Health Physics, Problems and Solutions**, by J.J.Bevelacqua, John Wiley & Sons, New York, 1995, 440pp, \$64.95.

**Doppler Ultrasound: Principles and Instrumentation**, by F.W.Kremkau, Saunders via Harcourt Brace &Co, \$550.00

**Nuclear Medicine-Science and Safety**, by A.C.Perkins, John Libbey and Co.Ltd., \$30.00

**Routine QA of Ultrasound Imaging Systems-Report 71**, by R.Price et al., IPSM Publications, \$25.00.

**Introduction to Efficacy in Diagnostic Radiology and Nuclear Medicine**, NCRP Commentary No.13, NCRP, \$30.00.

**Radiographic Imaging - a Practical Approach**, by Roberts and Smith, rev. by C.Gunn, Churchill Livingstone, \$40.00.

**New Frontiers in Medical Device Technology**, A. Rosen, H.D.Rosen, Wiley, New York, 1995, 364pp. \$ 69.95.

