Meetings

Inhaled Radioactive Particles and Gases

Approximately 15 years ago research on inhaled radioactive particles and gases was initiated at Hanford Laboratories, Richland, Washington. Some of the early work showed the carcinogenic properties of $Pu^{239}O_2$ and $Ru^{106}O_2$ in the lungs of mice. In order to discuss the current status of knowledge of the formation and properties of radioactive particles and gases, their behavior in the body, their biologic effects, possible therapeutic measures, and techniques for laboratory studies, a symposium was held at the Hanford Laboratories, 4–6 May 1964. More than 160 visiting scientists from Australia, Belgium, England, France, Federal Republic of Germany, Japan, Yugoslavia, India, Sweden, and the United States met with over 180 Hanford scientists.

It was anticipated that the symposium would contribute to the evaluation of radionuclide inhalation hazards and define areas requiring further studies. To support the discussions a special session included reviews of the anatomy, biochemistry, and fundamental physiologic processes of the respiratory tract concerned with particle inhalation. Each session dealing with a major subject area was initiated with a review by a specialist in the field. These reviews were followed by shorter papers describing current research.

In a "Statement of the problem," W. E. Lotz (U.S. Atomic Energy Commission) emphasized the increasing importance of knowledge of inhaled radionuclides brought about by the rapid advancement of peaceful uses of atomic energy. Specifically, he reviewed plans for using radionuclides in the SNAP (Systems for Nuclear Auxiliary Power) program and the Rover nuclear rocket propulsion program. Since safety considerations are basic to the success of these programs, he pointed out the need for information regarding the biological effects of the materials involved, as a function of chemical form, particle size, and radiochemical toxicity. Of particular importance is knowledge of the kinetics of the accumulation and elimination of inhaled radioactive nuclides for both acute and prolonged periods of exposure. There are still no data available for evaluating the comparative hazards of a single radionuclide particle in the lung and the same quantity of radionuclide dispersed throughout the lung. Lotz emphasized that decisions vital to the development of the SNAP devices and nuclear propulsion systems for space depend to a great extent upon biological considerations. For example, in case of malfunction during ascent, should the device be destroyed or propelled by retrorockets to a safe disposal area? During reentry, is it desirable for a device to return intact or be so constructed that it will burn up in the upper atmosphere? Since megacurie quantities of radionuclides such as Pu^{238}, Sr^{90}, and Pm^{147} are involved, these questions cannot be dismissed lightly.

T. T. Mercer (Lovelace Foundation) noted that particulate materials encountered in practice may be quite different from those employed in the laboratory. He singled out electrical properties of aerosols as a serious laboratory problem. Aerosol-generating devices which utilize suspensions or solutions of the material to be aerosolized generally produce charged particles at a rate exceeding the rate of discharge. In the field this is probably not the case. Since the charge on a particle may have a great influence on its deposition in the respiratory tract, he recommended discharging the aerosol, possibly with tritium sources, before it is presented to the experimental animal. As an alternate to the present method of determining mass distribution of particles by extrapolation from size distribution, Mercer believes the usefulness of the cascade impactor should be explored further.

K. Stewart (United Kingdom Atomic Energy Authority) presented a detailed discussion of the modes of formation and properties of aerosol particles. The two diametrically opposed modes of formation, by growth and by disintegration, were clearly defined. Examples were given to show the complexity of aerosols. For growth processes, both polonium and iodine, under certain conditions, may behave as a vapor, condense to nuclei that may aggregate to form larger particles, or be adsorbed on other nuclei present in the atmosphere. Conditions existing within various types of nuclear detonations were also explored for their possible effects on the formation of radioactive particles by growth processes, such as condensation. Stewart, as well as Mercer, pointed out that the use of impaction particle-sizing devices may be more justified than other sizing instruments in that they sample the air in a way comparable with inhalation. Finally, the difficulty of assessing the solubility of particulate material in pulmonary tissues and the importance of such information was emphasized.

In a paper of interest to those concerned with evaluation of weapons fallout hazards, C. A. Pelletier, A. V. Wegst, and G. H. Whipple (University of Michigan) reported that air samples collected during November 1962 showed a concentration of 2×10^4 particles/m^3 and in March 1963, 3×10^4 particles/m^3. The average radioactivities of the particles collected during these two periods were 5×10^{-4} and 2×10^{-4} pc, respectively. The effectiveness of spinning disk generators to produce monodisperse radioactive aerosols was described in papers by R. E. Albert (New York University), A. Kajland (Karolinska Institute), and L. C. Schwendiman (Hanford Laboratories). Kajland also reported on the use of a profile scanning technique for measuring lung clearance rates in rabbits.

In the special session devoted to a review of the biology of the respiratory tract, S. Engel (Royal College of Surgeons of England) reviewed the comparative anatomy and pulmonary air-cleansing mechanisms in man and several animal species. J. M. Felts (University of California School of Medicine) described recent developments in the long neglected area of lung biochemistry and detailed evidence for the synthesis in the lung of the phospholipid component of surfactant, the lipoprotein complex that has been shown to be important for alveolar stability.

Deposition of aerosols in the human lung was comprehensively reviewed by L. Dautrebande (Brussels, Belgium) and W. Walkenhorst (Silicosis Research Institute, Bochum, Federal Republic of Germany). The authors' review included experimental human data obtained in their laboratory; such data showed that particles sampled from the deep alveolar air were between 0.05 and 0.4 μ in diameter and never exceeded 1 μ.

The biologic processes involved in the clearance and retention of insoluble aerosols were reviewed by P. Gross (Industrial Hygiene Foundation, Pittsburgh). He separated pulmonary clearance into two processes. The physiologic process that accounts for 90 percent of the cleared dust involves the transport of dust from the alveoli or site of deposition to the pharynx where it enters the gastrointestinal tract. He then described the pathologic mechanism by which dust is transported into the lung interstitium and subsequently to satellite lymph nodes. L. J. Casarett (University of Rochester) postulated that alveolar epithelial cells are phagocytic and may carry phagocytized material into either the alveolar spaces or the interstitial tissue. He further suggested that the rate of clearance of particles from the alveoli is partially dependent on the phagocytic process which is influenced by the physical and chemical properties of the particle.

In a paper which will undoubtedly have an important bearing on evaluating inhalation hazards, C. N. Davies (London School of Hygiene and Tropical Medicine, London) presented evidence showing that the deposition of dust in human alveoli has been much overestimated. Because of the impossibility of making direct measurements, calculations regarding alveolar deposition have been based on respiratory gas exchange. Since aerosol particles possess a coefficient of diffusion negligible compared to gas, the actual aerosol dead space is significantly greater than gas-determined dead space.

New experimental techniques were described in several papers. The apparatus used to measure canine inhalation exposure utilizes a whole-body plethysmograph and shows promise for directly correlating deposition of aerosols with respiratory patterns (B. B. Boecker, Lovelace Foundation). A similar method for rats was used by R. Lie (Lovelace Foundation) to study the inhalation of Cs^{137}. Her data provided an interesting comparison with data obtained in man by whole-body counting techniques (C. E. Miller, Argonne National Laboratory). The longest biological half-lives observed in man were 73 and 84 days for inhaled $Cs^{137}SO_4$, as compared with about 13 days in rats for inhaled $Cs^{137}Cl$ and $Cs^{137}NO_3$.

B. Kahn (U.S. Public Health Service, Cincinnati) reported on the intake and retention of Sr^{89} and Sr^{90}, as airborne particles, by infants during the period April to July 1963. The intake of Sr^{89} and Sr^{90} varied from 3 to 14 pc/day and 0.6 to 1.7 pc/day, respectively. From these studies he computed a daily inhaled air volume, for infants, of 11 $\pm$ 4 m^3, which is greatly in excess of the generally reported values of 0.8 to 2.8 m^3.

In an examination of the problem of inhaled insoluble plutonium, W. S. Snyder (Oak Ridge National Laboratory) suggested the possibility that over long periods a significant fraction of the retained plutonium may be translocated to the skeleton and that this tissue, rather than lung, might be the critical organ.

A number of papers dealt with the uranium mine problem. H. E. Palmer (Hanford Laboratories) reported on studies conducted at mine sites with a mobile whole-body counter. Measurements of the radon daughter, Bi^{214}, in human beings showed nearly 100 percent retention of inhaled radon daughters during an exposure in a nonoperating mine. However, less deposition occurred when the same subjects were exposed to the air of an operating mine containing diesel exhaust fumes. The difference was attributed in part to the larger particles on which the radon daughters were adsorbed in the operating mine in comparison with the nonoperating mine. In both mines almost all of the inhaled radioactivity was associated with particles less than 0.5 μ.

Estimates of the radiation dose delivered to human respiratory tracts by inhaled radon and radon-daughter products were carefully detailed in separate papers by B. Altshuler (New York University Medical Center) and by W. Jacobi (Hahn-Meitner Institut für Kernforschung, Berlin, Federal Republic of Germany). Altshuler calculated that the alpha doses to the basal cells of the segmented bronchi would be 30 rads/working year of 2000 hours in a mine atmosphere containing 100 pc of radon, 200 pc of total daughters, and 150 unattached daughter atoms per liter. Jacobi's estimate was about 30 percent lower.

G. Saccomanno (St. Mary's and Veterans Administration Hospitals, Grand Junction, Colorado) reported on the incidence of lung cancer among miners on the Colorado uranium mining plateau; he emphasized the difference in tumor cell types between miners and non-miners. In uranium miners, 56 percent of the lung tumors were of the undifferentiated type, primarily oat cell, compared with about 15 percent in non-miners. It was also found that uranium miners contracted lung cancer at an earlier age than non-miners. V. O. Archer (U.S. Public Health Service, Salt Lake City, Utah) also reported that long exposures within uranium mines resulted in decreased pulmonary function; however, other factors such as silica dust, age, and cigarette smoking were also implicated.

The work at Hanford Laboratories on inhaled $Ce^{144}O_2$ and $Pu^{239}O_2$ in beagle dogs was reported by B. O. Stuart and J. F. Park. Deposition of 2 mc $Ce^{144}O_2$ resulted in lung damage and death 8 months after exposure. The most consistent effect of inhaled $Pu^{239}O_2$ in dogs is an absolute lymphopenia. Other later effects include blood-gas changes and right heart enlargement. Four dogs that died 3½ to 4 years after deposition of 5 to 10 μc $Pu^{239}O_2$ showed bronchiolo-alveolar tumors. (Both papers were progress reports of long-term studies.)

Papers by I. Schmidtke (Robert-Koch-Klinik, Freiburg, Federal Republic of Germany), F. Gensicke (German Academy of Sciences, Berlin, German Democratic Republic), and E. G. Tombropoulos (Hanford Laboratories) illustrated the effectiveness of certain chelating agents such as diethylenetriaminepentaacetic acid and hexametaphosphate in removing the inhaled radionuclides, Ce^{144} and Y^{91}. It was stressed that work on the development of therapeutic procedures for removal of inhaled radionuclides has been long neglected and further work is urgently needed.

Lung models were discussed by a panel composed of J. N. Stannard (University of Rochester), G. L. Helgeson (General Electric Company, Pleasanton, California), H. A. Kornberg (Hanford Laboratories), K. Z. Morgan (Oak Ridge National Laboratory), H. Schulte (Los Alamos Scientific Laboratory), and L. S. Taylor (National Bureau of Standards). It was generally concluded that there are two needs for models—one for the practicing health physicist, and the second, a research model, should serve to improve the first by suggesting avenues of needed research.

One of the highlights of the meeting was a "soul searching" banquet address by J. N. Stannard (associate dean of Graduate Studies, University of Rochester) on the subject "Gentlemen, scholars, and scientists." Stannard pointed out that since the scientist is often asked to make "scientific decisions" which are not really scientific (and which differ from other decisions only in that they are made by scientists), he is obligated to make it clear that the decision was not arrived at by the scientific method.

The symposium was jointly sponsored by the U.S. Atomic Energy Commission and the Hanford Laboratories of the General Electric Company. The proceedings will be published as the 1964 December issue of *Health Physics* and will be available in book form from Pergamon Press Limited, Oxford, England.

Session chairmen were H. D. Bruner (U.S. Atomic Energy Commission), G. H. Crook (General Electric Company, Richland, Washington), M. Eisenbud (New York University), J. L. Liverman (U.S. Atomic Energy Commission), T. Rich (General Electric Company, Schenectady, New York), J. N. Stannard (University of Rochester), and B. Wagner (New York Medical College).

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Forthcoming Events

October

19–21. National **Electronics** Conference, Chicago, Ill. (NEC, Inc., 228 N. LaSalle St., Chicago, 60601)

23–24. American **Physical** Soc., Chicago, Ill. (R. G. Sachs, Argonne National Laboratory, Argonne, Ill. 60440)

23–25. Association of **Clinical Scientists**, Washington, D.C. (R. P. MacFate, 300 N. State St., No. 5422, Chicago, Ill. 60610)

23–25. Experimental **Gerontology**, symp., Basel, Switzerland. (Prof. Verzar, Inst. de Gerontologie Experimentale, Nonnenweg 7, Basel, Switzerland)

24–29. American Acad. of **Pediatrics**, annual, New York, N.Y. (AAP, 1801 Hinman Ave., Evanston, Ill.)