SURFACE CONTAMINATION

UNDER the auspices of the American Association for Contamination Control, the Health Physics Society and the Oak Ridge National Laboratory, an international symposium on surface contamination was held at Gatlinburg, Tennessee, during June 8–12, 1964, and attracted about 170 scientists and engineers from nine countries.

Karl Z. Morgan (director of the Health Physics Division, Oak Ridge) opened the proceedings and described the type of accident which his department might have to deal with, according to the practical and fundamental knowledge at their disposal. Five years ago a small chemical explosion resulted in the dispersal of 600 mg of plutonium into the street, with more inside the building. They cleaned down to 30 disintegrations a minute and sealed over with paint. There was much curiosity about the physics and chemistry of the dispersal, attachment and removal of such contamination.

He then introduced A. M. Weinberg (director of the Oak Ridge National Laboratory) as a pioneer in reactor design and a dedicated research worker in the field of applying the vast and potentially cheap resources of nuclear energy to massive projects for the betterment of mankind. Dr. Weinberg spoke of the gas centrifuge, originally constructed for isotope separation but of limited value for this purpose, which was now being looked at by biologists as a potential separator of cell particles and viruses on a continuous scale. The discovery that *SM* 40 virus, a carcinogen in hamsters, had been present in live polio virus suggested the need of a purification process at the end of the production line; it was possible that the gas centrifuge might serve as a model.

The first of the four scientific sessions was opened by C. N. Davies (Medical Research Council and the London School of Hygiene and Tropical Medicine), who reviewed the deposition of aerosols from air in enclosed spaces. Gravitation, thermophoresis, photophoresis, diffusiophoresis and the electrical deposition of adventitious particles over a wide range of sizes were discussed and the respective rates of deposition were estimated. C. N. Segelstrom (Royco Instruments, Boston) gave an account of an electronic counter of airborne particles; light from a 2,850° K lamp, scattered at right angles by individual particles, is measured as a series of pulses which are claimed to be proportional to the square of the particle size, irrespective of its refractive index, complex or otherwise. In the discussion it was accepted that this claim was probably correct for sizes above 10μ, but the instrument was commonly used for smaller particles and a check was needed. The counter is well engineered and will operate, also, on liquid suspensions; it is widely used in hospitals and the electronics industry for monitoring airborne contamination.

A. A. Andersen (Provo, Utah) described a six-stage cascade aerosol sampler. Each stage consisted of a disk perforated with 400 holes which impinged on another disk, immediately below, made of aluminium or stainless steel. The flow rate was 1 ft.^{3}/min and the jet velocities ranged from 3·54 ft./sec for the first to 76·4 ft./sec for the sixth; the corresponding cut-off diameters for unit density spheres were 9·2μ–0·5μ. It was claimed that the use of multiple jets rendered adhesive films on the impaction plates unnecessary for many aerosols.

The investigation of surfaces was introduced by S. Ross (Rensselaer Polytechnic, Troy, New York), who described the effect of contaminating diatomaceous powders used in chromatography with 'Apiezon oil *B*', and tricresyl phosphate. The powders remained free-flowing, apparently dry and non-oily although carrying multi-layers of oil. Adsorption isotherms were obtained which were linear through the origin and the elution peak was symmetrical; the oil film evidently made the surface of the adsorbent more uniform. A single equation was derived for the isotherms produced with varying quantities of oil.

J. F. Pudvin (Bell Telephone Laboratories, Allentown, Pennsylvania) discussed methods of gauging the cleanness of metal surfaces in considerable detail. A new method involving cooling below the dew-point was described. Condensation patterns map the clean areas and the first formation of droplets indicates sites of hydrophylic activity. A neat method of measuring the contact angle had also been used. Gold was unusual among metals in always having a hydrophobic surface; on other metals the presence of oxide rendered the surface hydrophylic. These techniques provided a new standard for detecting contamination in the minutest traces.

An original way of measuring surface contamination had been developed by J. L. Anderson (Orlando, Florida). A film of decyl bromide containing 1–3 atoms of carbon-14 was applied to the surface in question and a thin end-window counting-tube was set close above it. Nitrogen was passed through the gap and, if the surface was clean, all the decyl bromide evaporated in 30–40 sec. Surface contamination slowed down the rate of evaporation and was characterized to some extent by the shape of the decay curve. The solvent used to apply the radiochemical absorbed the soft β-rays and was chosen, therefore, to be of much higher volatility.

The next session was opened by Morton Corn (University of Pittsburgh), whose subject was mechanisms of dust redispersion. The removal of particles from a surface was effected by centrifuging up to 250,000*g* and by blowing with a tangential air stream; the aerodynamic force on the particle was calculated from the velocity profile of the boundary layer. In the blowing method it was found that time was a factor; this did not apply to centrifuging. Mica particles always lie flat and though their adhesion was less than that of glass, in the centrifuge, it was not possible to blow them off.

L. A. Masironi and B. R. Fish had also constructed a small wind-tunnel with a 0·25-in. working section for the investigation of re-entrainment. Using stroboscopic lighting the behaviour of glass spheres 28μ in diameter had been observed in an air current of 5,000 cm/sec. 32 per cent of the spheres blew right away; 6·5 per cent rolled first and were then detached. 6·5 per cent rolled but stayed on the surface and 55 per cent failed to move. The rolling velocity was only 10^{-5} of the air speed. R. L. Walker and B. R. Fish described an apparatus for oscillating a surface in order to apply acceleration; no 30μ particles had been shaken off using maximal acceleration normal to the surface of 90*g*.

Three papers followed which dealt with the redispersion of particulate material from surfaces. K. Stewart defined the re-suspension factor, *K*, as the air concentration in μc. per m^3 divided by the ground concentration per m^2. No good correlation of *K* with air velocity, particle size or density was obtainable and values ranged from 10^{-4} to 10^{-8}. It was not usually found that deposits from accidental spills out of doors weathered away; on the contrary, the material might weather into the top few millimetres of surface, rain and dew aiding this process and consolidating the surface. The re-suspension factor, in general, was smaller out of doors than indoors because of this effect and the rough nature of outdoor surfaces in comparison with those indoors. The half-life of outdoor ground contamination was 40–100 days for 10μ particles and less for coarser ones.

At Harwell, I. S. Jones and S. Pond found that values of K as large as 5×10^{-5} were associated with vigorous walking and detected a consistent difference between plutonium oxide and plutonium nitrate. Autoradiography indicated that activity was present in particles from 0·4μ to 60μ diameter with the number median size 5μ and the activity median 14μ. The particle size distributions were similar on the floor and in the air. At Windscale, R. T. Brunskill had measured values of K as high as 8×10^{-3}, due to dust from clothing.

Experiments on redispersion of settled dust, by B. R. Fish *et al.* (Oak Ridge), indicated that a person was likely to inhale about one particle per hour, around 3μ in size, for every 4,000 per m² on the floor when working in a room contaminated with dust of copper oxide or zinc sulphide. The mass concentration decreased by a factor of only 2 in going from ankle level to the breathing zone.

The session which followed was devoted to aerodynamic transport and deposition. S. K. Friedlander (California Institute of Technology, Pasadena) had developed an ingenious new sampling device for aerosols of particles between 70 Å and 0·1μ in diameter. It consists of a 1-in. diameter disk rotating at 2,000 r.p.m. A spiral flow towards the surface of the disk is induced which has a component normal to the disk; the normal velocity is the same at all radii and depends only on the distance from the disk. The diffusion of fine particles from this flow, on to the disk, is uniform over the entire surface. An electron microscope slide was set in the disk and runs of 10–70 h enabled size distributions to be obtained of fine atmospheric particles.

The next paper was by C. N. Davies, who reviewed the various mechanisms of deposition from moving air streams and directed attention to complicating factors in gravitational and turbulent deposition.

A method of estimating ground contamination resulting from the destruction of an aerospace vehicle was suggested by E. M. Wilkins (Dallas), who treated it as an instantaneous point source expanding according to turbulence theory, but made no allowance for changing conditions as the ground was approached.

L. P. Davis (University of Tennessee) calculated the deposition of particles in ducts combining inertia deposition, due to turbulence, with Brownian motion; the analogy between heat and mass transfer was used for the latter and coagulation was allowed for. Similar velocities of deposition were obtained for 10μ and 0·01μ diameter particles (about 0·1 cm/sec) with a minimum velocity between 0·1 and 1μ.

The preceding scientific sessions were followed by technical sessions on control, measurement and decontamination, including papers on micro-organisms and chemicals.

There was considerable discussion about working limits for radioactivity. H. J. Dunster (Harwell) claimed that the intake by breathing was negligible, and air sampling was unnecessary, if the surface contamination was below the maximum permissible limit. Surface contamination was easy and cheap to measure. He suggested maximum permissible levels of 10^{-4} μc./cm² for control areas and 10^{-5} for inactive areas and skin; these figures correspond to 20,000 and 2,000 α-disintegrations/min.100 cm² or 6,700 disintegrations per min from the hands.

This view was contested by H. Blatz and M. Eisenbud (New York University), who also outlined some of the legal difficulties associated with standards. H. Glauberman and W. R. Bootman (U.S. Atomic Energy Commission, New York) presented data showing the wide range of air concentrations associated with a given surface contamination in handling uranium and plutonium, a factor of more than 100 being involved, in agreement with the wide range of values of the re-suspension factor, K, which had been quoted in papers presented during the scientific sessions.

The necessity of avoiding undue interference with operations was stressed by G. W. Spangler (University of California School of Medicine). Permissible contamination limits were derived by evaluating the external radiation hazard from surface contamination and the risk of body deposition from airborne material released from the surface. Here limits were much narrower than the International Commission on Radiological Protection air concentration figures and were based on surface contamination causing no more than 10 per cent of the permissible dose. Inhalation came out as equated to the absorption by a 40 cm² wound, which is a considerable area.

The view of the Commissariat à l'Energie Atomique, France, was presented by J. Hamard. Inhalation was regarded as the main hazard from surface contamination which is not bound. It was indicated that, for a 40-h week, 10^6 times the maximum permissible concentration for air in μc./cm³ gave conservative limits in μc./cm² for surface contamination. On this basis external β-radiation from the surface is taken care of.

Four papers followed on measurement techniques. The filter paper 'swipe' had been studied by J. R. Prince and C. H. Wang (Oregon State University). Part of the paper was cut out after rubbing the surface, moistened with phosphor and placed in a standard vial for scintillation counting. Millimicrocuries could be estimated with efficiencies up to 5 per cent or more for tritium and 50 per cent for carbon-14. A dry swipe was better than a wet one. 10^{-4} μc./m² gave some 40 counts/min.

J. E. Dummer (Los Alamos) had made an examination of use of portable radiation survey meters for surface β-emitting contamination. Large areas were simulated by dotting the outline with solution of strontium-90 + yttrium-90 in equilibrium. Sources up to 5-cm diam. were found to act as point emitters; large correction factors were needed for calculating surface dose rates from the meter readings.

R. Wilson and G. A. Vivian (Ontario Hydro-Electric Power Commission) also discussed the relationship between the detector indication and surface activity, considering geometrical factors.

Adhesive paper, smear and 'smair' techniques for assessing surface contamination were compared by G. V. Royster and B. R. Fish (Oak Ridge). The smair sampler contained a filter in a housing which was pressed on the surface. A series of peripheral jets, inclined at 45°, blew air at 90 m/sec or more on the surface inside the hood and released contamination which was trapped on the filter. Although the actual quantity of activity collected by this device was often less than that removed by other methods it gave very much more reproducible and realistic results. For example, equivalent contaminations of dry and on oiled concrete were returned as the same by the filter paper smear method, whereas the 'smair' sampler detected less from the oiled surface.

An instrument developed at the Illinois Institute of Technology was described by D. Werle. This was for estimating traces of non-volatile residue in rocket fuels which created an explosion risk when present as contamination on the internal surfaces of empty fuel tanks. A sample of the fuel was sprayed in drops smaller than 3μ, and after evaporation of the volatile bulk of each drop the residual aerosol was measured by 40° forward light scattering. The apparatus was calibrated with dilute solutions in 'Freon' or trichloroethylene.

W. J. Kerrigan (of Du Pont, Aiken, South Carolina) had prepared a series of standard dusts in sizes of 0·2μ–44μ by sieving and air elutriation. Ground uranium oxide and Alcoa aluminium were available and redispersed well after storage in bulk.

A. K. Baker (Chandler, Arizona) described air-flow problems in outflow hoods designed to protect delicate operations from contamination by room air. The formation of vortices downstream of objects in the working zone led to the entrainment of room air.

A neat new tool for changing the gloves in a glove box without opening up the box was described by J. B. Owen (Dow Chemical Co., Golden, Colorado). The change could be effected in less than 2 min.

The last two papers of this section, from North American Aviation and Grumman Aircraft, were devoted to the routine of controlling dust-free areas in factories. More than 70 per cent of missile failures are due to contamination; the high degree of reliability which is aimed at necessitates the use of 'clean-rooms' and the organization of appropriate training for the staff who build the complex miniaturized electronic navigational devices.

Regular observations of the dose rate from radioactive fall-out had been maintained by Th. Franke of Frankfurt, Germany, using a 4·5-in. sodium iodide crystal for γ-ray spectrometry. An increase from 1·5 microrads/h to 4·0 was observed during 1962–63. Snow cut the rate by 50 per cent.

E. D. Graham (Argonne National Laboratory) described the α-particle monitoring programme which was established when a reactor at Idaho Falls was switched to plutonium core loading. The routine included aerosol sampling, monitoring surface contamination and external radiation, evaluation of internal exposure of personnel and the dosimetry of external exposure.

The control of surface contamination at the Atomic Weapons Research Establishment, Aldermaston, was explained by W. N. Saxby and J. A. Hole. The general strategy was one of containment in limited areas where protective clothing was worn. Monitoring equipment was described and the derived working levels used in contamination control were summarized.

L. K. Burton (Berkeley Nuclear Laboratories) stated that a serious problem at nuclear power stations was the lack of a quick method of assessing the relative proportions of plutonium, uranium and natural α-emitters. In the presence of large masses of concrete the background of radon daughter products was high and confused the picture. Air sampling was to be performed with a small filter attached to the worker which, when combined with a solid-state radiation detector, would indicate large, active individual particles.

Five papers dealt with microbial contamination. T. W. Kethley (Georgia Institute of Technology) had carried out numerous experiments with bacterial aerosols which could be detected down to one particle, or 10^{-13} g/ft.^{3}. The mathematical calculation of concentration in ventilated rooms was explained for steady-state and transient conditions. In practical situations the equivalent settling diameter of bacterial particles was 10–20μ, due to their association with foreign matter.

K. R. Goddard (U.S. Public Health Service, Savannah, Georgia) had used various sampling methods in investigations of bacterial distribution in hospitals. Counts of airborne viable organisms of 40–50/ft.^{3} were regarded as high and at 150 conditions were bad. Investigations of surface coatings had shown epoxy paints and varnishes to be a good substitute for tile; they could be applied directly to concrete block walls, using the correct undercoat.

G. S. Michaelsen and D. Vesley (University of Minnesota) presented two papers. The first was based on work with the Casella slit sampler, supplemented by the Andersen sample for finding size distributions. Low bacterial counts were found to be associated with the pressure ventilation of operating rooms. The counts correlated with the movements of personnel and it was clearly desirable to avoid unnecessary movements. The peaks ranged from 5 to 20 particles/ft.^{3}. Local sources of bacteria included the chutes for soiled linen, which were efficient disseminators and transferred contamination from floor to floor. Work with selective media had been facilitated by a multi-point tool for inoculating plates. The prevalent organisms tended to differ from one hospital to another; the higher Gram-positive cocci were associated with people and the lower ones, rods and moulds with dust.

Their second paper was a statistical evaluation of 'Rodac' agar contact plates which, in addition to having some advantages over Petri dishes, when used in the ordinary way, could be pressed, without sliding, on a surface to record the surface contamination. An analysis of floor contamination in hospitals was made and the efficiency of floor disinfection methods was evaluated.

There is international agreement that space-vehicles landing on other planets must be sterile, and L. B. Hall (special assistant for planetary quarantine, National Aeronautics and Space Administration, Washington, D.C.) gave an account of the difficulty of implementing a guarantee of absolute sterility. He approached the subject historically, from the Mosaic laws pertaining to food. Experiments showed that the die-off of organisms on steel surfaces was complete in 48 h at 25° C and in 8 h at 50° C so long as the relative humidity was in the neighbourhood of 45 per cent. Higher or lower humidities favoured the retention of viability.

The Boeing Co., Seattle, was also concerned with the same problem, and Karl Kereluk, R. Meyer and A. J. Pilgrim went into the problem of constructing a highly complicated and completely sterile planetary lander. 'Rodac' plates were used in this work.

Two papers on beryllium followed. J. J. Cohen and R. N. Kusian (University of California) had found it difficult to correlate surface contamination with health hazard on account of the many factors governing redispersion. R. N. Mitchell and B. C. Eutsler (Los Alamos) examined the air and surface contamination in a beryllium store. Small cyclones, operating at 2 ft.^{3}/min, and May pre-impingers passed, respectively, 6 and 10 per cent of the airborne material, indicating that most of the beryllium was in coarse dust. Floor contamination ranged from 860 to 1,860 μg/ft. and the air concentrations, during resuspension tests, were between 2·9 and 25·8 μg beryllium/ft.^{3}.

A session on insurance and economics was opened by R. G. McAllister (Liberty Mutual Insurance Co., Hopkinton, Mass.). A major release of fission products had been regarded as a risk which involved a potential liability of such magnitude that two pools, involving more than 250 private companies, had been formed to deal with this business. The Price–Anderson amendment of 1951 extended the cover to 500 million dollars for any one nuclear incident. Exclusion clauses in domestic and automobile policies were explained; these were intended to prevent duplication of coverage. The total cost of an incident was linked with the stringency of standards for residual contamination in public places and safe, but realistic, limits were necessary.

R. G. Gallagher (Pittsburgh) gave an interesting account of a number of incidents in which radium, for medical use, had become disseminated by breakage of containers. P. Loysen (U.S. Atomic Energy Commission, New York) described six episodes where decontamination of buildings had been undertaken. The cost ranged from 0·11 to 2·54 dollars per square foot. Here, again, the specification of realistic levels for residual contamination was a vital economic factor.

The symposium was terminated with three papers on decontamination from France, Japan and England. P. Cerre and E. Mestre (Saclay) gave an account of a 500-kg furnace which was used for melting lead. The contamination was held in a slag of the oxides of aluminium, silica and calcium at the surface and was separated when the lead was run off into ingot moulds. An output of 2 tons a day was possible. Acetic acid and hydrogen peroxide were used for cleaning surfaces. An electrolytic polishing process had also been developed.

Y. Nishiwaki spoke of the theory of decontamination, and the use of EDTA and DBS. They had experienced highly active rainfall in 1961, from Russian tests, which contained giant particles of 0·1–1 μc. each. Instruction had been issued for fruit and vegetables to be washed and bread containing activated charcoal had been issued.

G. W. Clare gave a short history of the development of the decontamination service at Harwell. The building and plant, now in use, had paid for itself in only two years when costed on equipment which had been saved and put back into service. They moved everything by overhead tackle, which was much more satisfactory than trucking, and grid floors, with all services below, had been very successful. The centre is adjacent to the Active Waste Disposal Building and carries its own trained staff.

C. N. DAVIES

STRUCTURE AND FUNCTION OF LIPID-CONTAINING SYSTEMS

A JOINT meeting of the British Biophysical Society and the Biochemical Society attracted more than 200 participants to the University of Birmingham during April 20–21. A comprehensive survey of research relating to lipids and cell membranes was undertaken in three sessions devoted to physical chemistry of lipid systems, composition and molecular structure of cell membranes, and the role of lipid in membrane activity.

An introductory talk by Dr. D. G. Dervichian on the general theme of the symposium was followed by 20 papers.

Information derived from X-ray diffraction (V. Luzzati) and infra-red spectroscopy (D. Chapman) served to emphasize the liquid crystalline nature of lipid layers under a variety of conditions and the complexity of phase relationships in mixed lipid systems. D. Attwood and L. Saunders, and D. B. Gammack, discussed the characteristics of dispersions of lipid in water as examined by light-scattering techniques, and A. D. Bangham and D. A. Haydon the interpretation of birefringence measurements. J. A. Lucy and M. Glauert presented a molecular interpretation of their electron micrographs of negatively stained lipid preparations and discussed its possible significance in relation to cell membrane structure.

A review by G. M. Gray of data on the compositions of a variety of cell membranes was followed by a report on the lipid components of membranous fractions from brain homogenates by J. Eichberg and R. M. C. Dawson. B. R. Malcolm presented evidence for the α-helical configuration in protein layers at air–water interfaces and A. A. Eddy and P. Johns speculated about the possible arrangements of lipoprotein sub-units in the red cell membrane. J. B. Finean summarized present views on the molecular structure of cell membranes and N. R. Silvester discussed the analysis of the remarkably detailed X-ray diffraction patterns obtained from membrane material derived from cilia. P. F. Millington spoke of the various factors which influenced the widths and densities of lines which characterize cell membranes in electron micrographs, and R. Dourmashkin discussed correlations between the number of sites of interaction of immuno complexes with the surface of the red cell as seen in electron micrographs and the rate of lysis of the cells.

In the final session, J. N. Hawthorne undertook an assessment of present ideas on the role of individual phospholipid components in ion transport and A. D. Bangham and J. C. Watkins suggested that their observations on the accumulation of ions inside lipid micelles might have some relevance to this problem. G. Hübscher discussed the problems associated with the assessment of the influence of lipid components on the activities of enzyme systems and A. Martinosi presented biochemical and electron microscope data relating to the inactivation and reactivation of muscle microsomes by removal and restoration of the lecithin components. L. L. M. van Deenen summarized a variety of data relating to the metabolism of phospholipid fatty acids in cell membranes.

J. B. FINEAN

RESEARCH EXPENDITURE AND INDUSTRY

IN his presidential address to the twentieth annual general meeting of the Institution of Metallurgists on May 13, Dr. L. Rotherham dealt with the interrelationship of the growth of numbers of qualified scientists and technologists, the national economy as a whole, productivity and the proper expenditure on research and development. As such, his address was a noteworthy contribution. Although obviously directed to the metallurgist in the first place, it is worthy of close study by all concerned with the more general problems.

The new industries, such as electronics and man-made fibres, have achieved commercial success by exploiting scientific and technological advances and in the process have ploughed back large sums for increasingly expensive researches. Thus during a period of time they have been able to produce and sell a succession of products. In contrast, some of the older industries have been relatively slow to adopt new techniques though the pace will probably quicken in the next few years. The danger is that they will not put aside the money required to develop ever-better processes and products. In 1962 industry employed some 9 qualified men per £1 million of 'gross domestic product' outside the research and development departments. In 1956 it had been 7·9, and on the basis of a 4 per cent economic growth and what appears to be a reasonably steady figure of 10·5 qualified men per £1 million of 'gross domestic product', an additional 100,000 scientists and technologists may expect to find employment in industry between 1962 and 1970. If all employers, even the smaller, were to raise the number of 'qualified men' (that is, those with degrees, diplomas and those who take the examinations of professional institutions) employed to that of the highest percentage, almost half as many more would be needed. This increased number of scientists and technologists is seen by Dr. Rotherham as being increasingly provided by university graduates.

In 1961–62 about one-fifth of Britain's total qualified men were engaged on research and development, and if this ratio remains constant, between 1962 and 1970, about 25,000 extra people will be required. The annual cost, on the average, is of the order of £11,000 per man engaged in such work, and for this increase a rise in productivity of some 3·8 per cent would suffice. The calculation, however, depends on the assumptions that research expenditure remains at the 1961–62 level of 2·7 per cent of the 'gross domestic product' and that research costs per man do not increase by more than 3 per cent per annum. In Dr. Rotherham's opinion, it might be prudent at this time to raise the percentage of the 'gross domestic product' devoted to research in order to counterbalance any shortfall in productivity, say, to 3 per cent (the American figure is already more than this). After making the usual allowances for rising costs, this should provide for an extra 6,000 research workers per annum. The