- studies on eradication of the Mediterranean fruit fly.

Other projects of lower priority include:

- water-retaining capacity of the different soil strata in Algeria;
- study of factors influencing the production and quality of olive oil in Tunisia;
- olive-fly eradication in Tunisia;
- genetic effects of radiation on vegetables.

IAEA has furthermore provided the funds for a research project concerning the investigation of the Wadi El-Natrun aquifer, including determination of effective porosity, permeability, storage coefficient and transmissibility; using different radioisotopes; also for a second project, as part of a co-ordinated programme, on the application of radiation techniques in water-use efficiency studies.

Dr. Ismail B. Hazzaa is the director of the Centre, active, dynamic, full of constructive ideas. He has been inspiring and directing the six training courses on the various uses of radioisotopes - general, agricultural, medical - since the beginning of the Middle East Regional Radioisotopes Centre in 1963, with a total of 195 trainees.

RADIOACTIVE WASTE DISPOSAL: SAFETY ACHIEVED, BUT ECONOMY ALSO NEEDED

Industrial use of atomic energy on an ever-increasing scale brings corresponding problems in disposing of radioactive wastes. From the point of view both of economic operation of nuclear plants and of avoiding embarrassingly large accumulations of wastes, there must be a continuous search for the most appropriate and effective methods.

There are no generally applicable "best" processes. So much depends on local conditions and on the quantity, kind and variety of the wastes to be treated. The location of the plant is most significant, because in some places very low level wastes can be safely dispersed in rivers or the sea, or suitable geological formations may make deep burial safe and simple. But elsewhere, population is dense, land for storage scarce, and dispersal not possible, so that the emphasis is on the maximum volume reduction and transportability of the wastes. In a small establishment, one general-purpose plant, such as an evaporator, may be employed to treat all kinds of liquid waste; the large establishment is more likely to differentiate and to seek more refined processes.

Since low and intermediate level wastes are of their very nature bulky, storage of untreated wastes is usually impracticable. In general, wastes are dealt with by concentrating the radioactive materials, which are then sealed in drums, incorporated in concrete or ceramic blocks, or otherwise made safe for storage. There is also considerable interest today in the use of bitumen as a material for fixing wolid wastes or sludges, since it makes possible a greater volume reduction, and the resulting block is less susceptible to leaching by water. In some establishments bitumen is already in routine use, although concrete still remains the normal material for the purpose. The methods of concentration include compression, incineration, evaporation, coagulation and filtration.

While the basic methods of disposal are well known, many establishments have worked out useful modifications and improvements of their own. Details of their procedures and experience were exchanged at a symposium in Vienna on "Practices in the Treatment of Low and Intermediate Level Radioactive Wastes", from 6 to 10 December 1965. The symposium was organised jointly by the International Atomic Energy Agency and the European Nuclear Energy Agency (ENEA) of the Organisation for Economic Cooperation and Development. Representatives of 26 countries and four international organisations attended.

"The intensive search for processes which would remove or control the radioactive isotopes from waste streams, which prevailed several years ago, is now past," said Mr. J.Y. Servant, Director of the IAEA Division of Health, Safety and Waste Disposal, in opening the meeting. "Effective processes have been found. However, much remains to be done to improve these processes and to make them suitable for the various applications. The desired results from certain treatment processes were not always obtained in the early days, due to a scarcity of reliable information and data. In some plants, processes were included in the original design that were not suitable for the particular type of waste, or else costs proved to be much higher than expected. We hope that the information exchanged and disseminated here will help to make the choice and use of the appropriate process for the treatment of a certain type of radioactive waste both easier and more dependable."

SAFETY REMAINS PARAMOUNT

Many cost figures, derived from operating experience, were quoted at the meeting. However, there were evident differences in the bases of cost calculations – a matter which has subsequently been examined by an IAEA expert advisory panel.

It is an indication of the maturity of the nuclear industry that such a symposium should be preoccupied with economic aspects, safety questions having long since ceased to be a matter for misgiving. However, some speakers, while stressing that safety considerations must always remain paramount, put in a plea against over-rigid standards, or restrictions originating in emotion rather than in a considered judgment of well-established facts.

There is no sharp distinction between the two types of waste treatment – concentration and dilution, according to A.W. Kenny (WHO), who discussed

the degree of treatment needed to prevent hazardous pollution of the environment. For example, discharge of liquid waste to ground may, by adsorption in the soil, create a contaminated soil in which radionuclides are virtually stored. There can be no real hazard to the public if storage or containment is completely successful, but in practice there is always a fear lest stored waste should by accident escape to the environment; methods of converting liquid wastes to solid represent a real lessening of the potential risk. There have been recent efforts to evaluate the effects on health of ionising radiation, and a committee of the World Health Organisation has compared them with other hazards. To some extent the radioactive industry is the victim of the intensive research into effects of radiation. Perhaps more is known of these than of the effects of any other industrial pollutant, but it can never be proved that the effect is zero at a specified low level - the old philosophical difficulty of proving a negative. There is a danger in trying to exclude radioactive pollution of the environment completely. The effort, measured in money, materials or manpower, will be at the expense of some other effort which might be more profitably devoted to other aspects of public health. However, a more cautious approach is needed than in dealing with most other pollutants such as genetically active chemicals; this is because the radioactive toxic character cannot be destroyed. We must therefore rely on dispersal and dilution processes of the environment with proper regard to the opposing forces of reconcentration.

The technical basis for assessing permissable levels in waste disposal is the recommendations of the International Commission on Radiological Protection. The fundamental recommendations of the ICRP, however, relate to dose delivered to ill-defined sections of the community. The subsidiary calculations of "maximum permissible levels" are to be used cautiously, since "it is repugnant to the scientific spirit and no service to the compilers to use them inflexibly and dogmatically, as though they were religious or political creed." They are often based on very tenuous biological data, and a maximum permissible level which takes no account of chemical form is at best merely a first approximation.

STRINGENT STANDARDS

Dealing with ground disposal of liquid wastes, the paper described results of elaborate studies made at Hanford, USA, where a low water-table and low rainfall provide favourable conditions. Radionuclides are adsorbed in the soil and move slowly down until trace amounts of the most easily leached reach the ground water, when further disposal is stopped and a new site started. At the abandoned spot, the adsorbed material continues to move down very slowly as rain-water percolates through; complete removal will take centuries and appreciable decay will take place. Wherever waste is disposed of to the ground, the ultimate use of the site must be considered. If the site is to be returned to public use, permissible standards and perhaps rules for management have to be set. Quite highly active waste may be buried under a metre or two of soil; but there are long-term effects to consider - dispersal of buried material by weathering, reconcentration of specific radionuclides by living organisms, and raising of radionuclides to the surface by deeprooted plants.

In sea disposal, the limits are set by measuring the environmental pollution to identify any reconcentration in human foods and then to set limits so as to keep irradiation below ICRP limits. At Windscale (UK) the critical foodstuff is an edible seaweed; at Hanford (USA) reconcentration of zinc by oysters has been identified.

The radioactive industry has set new standards, not remotely approached in most other industries, for safeguarding the public by exhaustively examining each act of waste disposal and its implications for the public. For major wastes a preliminary safe assessment should be made, and environmental pollution continuously monitored during disposal. For minor wastes which do not require so much detail, the cumulative effect of all such disposal needs to be assessed. The justification for all these limits is that the public should not be exposed to levels exceeding those laid down by the ICRP. A broad monitoring programme of activity levels in food and water, in commonly-used goods and materials and of general environment is an essential part of the supervision of waste disposal.

Waste management constitutes much more than finding means of disposing of unwanted products. D.J. Kvam (USA) showed that it can have an important influence on operations as a whole. The waste management programme at the Lawrence Radiation Laboratory has two main functions - the first is to assist in reducing the generation of wastes, and the second is disposal. Waste volume is reduced by continuous review of laboratory projects and practices, and by a decontamination programme. Decontamination techniques such as high power-density ultrasonics have extended the possibilities of reclaiming contaminated materials economically. In 1964, decontamination returned equipment valued at $2 million to service, which otherwise would have been considered waste. Despite an expanding programme and increased manpower at the laboratory, not only the levels but the waste volumes have decreased for the third consecutive year. At Kjeller (Norway) a wide variety of wastes - gaseous, liquid and solid, of specific activities ranging from relatively high level fission product solutions down to tracer level - are treated. B. Gaudernack and J.E. Lundby (Norway) said that because of the limited release possibilities in the area, parts of the low-activity effluents must be purified before release. It is also necessary to solidify medium-level liquid waste for convenience of storage and eventual final disposal and to compress the solid waste in shielded containers for storage. The cost of the waste treatment plant (building and equipment) was about $170 000, and an extension under construction is costing about $130 000. Annual operating costs (exclusive of capital charges) are about $30 000.

CHOICE OF SYSTEMS

The questions to be answered in selecting a method of treating liquid effluents were outlined by E. de Robien, J. Pomarola and M. Brodsky (France). These are: Is it possible to use on site the dispersal capacity of the adjoining hydrological network? Can concentrated liquid effluents be stored on site? Is it convenient and economical to do so? If neither of these courses is possible, it is necessary to determine how the treatment of liquid

wastes can be most economically coordinated with the method selected for solid wastes. In many parts of Europe possibilities of river disposal are slight or non-existent, and on-site storage of liquids is seldom feasible. This leads to the necessity of reducing the concentrates to some non-leachable form providing adequate protection against radiation hazards; evaporation offers a suitable method. An entirely automatic and electronically controlled evaporation plant, used for continuous scavenging of reactor coolant water, was described by A. Nazarov, E. Golubev and S. Metalnikov (USSR). In the operation of a reactor installation, the quality of the coolant water must be maintained at a specified level in respect of salt content, activity, corrosion products etc. After purification the scavenging water is returned to the reactor circuit.

P. Linder, K.J. Björkqvist, G. Linderoth and S. Lindhe (Sweden) described why an evaporator was selected as the only treatment plant at the Studsvik research establishment, in preference to chemical treatment, ion exchange, electrodialysis, or simple storage and decay. The first three methods are sensitive to variations in the chemical characteristics of the different liquids, with the risk that some active component will not be removed. Storage without concentration would involve large and expensive volumes. D.W. Clelland and A.D.W. Corbet (UK) said that chemical precipitation and ion exchange are generally most suitable for large quantities of low level wastes because of their inherent economy, while evaporation is generally used for medium and high level effluents because it can give high separation efficiencies. But evaporation they considered to be an inherently costly process because of its heat requirements, the high standard of plant fabrication required, and corrosion problems. Showing how local conditions may offset such considerations, however, P.A. Bonhote and E.D. Hespe (Australia) described an unusually cheap and simple solar evaporator. At the Lucas Heights research establishment, costs of filtering sludge were too high for the volume of sludge involved. A concrete storage area surrounded by a kerb one foot was fitted with a flat steel roof running on rails mounted on the kerb. Sludge in the pond is exposed during the day, and covered at night and during rain or high wind. The capital cost was about $5900 and operating costs negligible; the cost per gallon of sludge treated is 1.6 cents. The volume of sludge for disposal has been reduced to one-fifth of its original volume, and a reduction almost down to one-tenth is expected to be achieved. The method seems unlikely to be of use, however, in places having a mean annual evaporation of less than 30 inches (at Lucas Heights it is 43 inches).

CONTAINMENT IN BITUMEN

When wastes have been concentrated into the smallest volume they must be rendered insoluble, and N. van de Voorde and P. Dejonghe (Belgium) described a successful method of achieving this by incorporating the wastes in asphaltic material. This achieved much greater volume reduction than is possible when vermiculite or cement is used. In the discussion, R.H. Burns (UK) gave cost estimates for fixing a given annual volume of wastes by four different methods - cement, £49000; cement-vermiculite, £74000;

Sorting of radioactive wastes inside a sealed area, by men in pressurized suits. (From paper by R.H. Burns and others)

bitumen, £15 000; bitumen after "freeze-thaw" processing, £12 000. Leaching, he said, was of the order of 100 times greater with cement and cement-vermiculite than with bitumen. However, costs of a bitumen installation were relatively high, so that the method would not be appropriate for general use. J. Rodier, M. Allès, P. Auchapt and G. Lefillâtre (France) described the use of bitumen for incorporating sludges. In a populated region on-site storage, as currently practised, required absolute security against dispersion; bitumen can provide this security without being prohibitive.

Burial on or near the site of a waste producing establishment is by far the cheapest means of disposal, according to R.H. Burns, G.W. Clare,

A.J. Smith and D.A. Dunkason (UK). Sometimes it is not acceptable for political or practical reasons; if the area is limited, some processes of volume reduction may still be necessary. Incineration and incorporation into bitumen or other impermeable materials may go a long way to making burial more acceptable to the authorising bodies. Describing procedures for first sorting of low activity wastes at Harwell, the paper said that until a year ago, this was carried out in a large glove box. Then a sorting table was set up in a pressurised suit area, and this showed that operators working freely at table level could handle a given volume of waste much more quickly and more safely.

In a survey of current research and development R.E. Blanco, W. Davis, H.W. Godbee, L.K. King, J.T. Roberts, W.C. Yee, G.J. Alkire, E.R. Irish and B.W. Mercer (USA) said that the objective in the United States is to devise new or improved processing methods to achieve greater retention of radionuclides and lower operating costs. The desired final goal is an economical continuous bulk treatment system which would allow the treated wastes to be discharged while the extracted radioactive residues could be incorporated in asphalt or other plastic media for storage or ultimate disposal, or injected into the earth in suitable locations.

In their work on the handling of radioactive wastes, described in a survey by V. Balukova, V. Kulichenko, A. Nazarov and A. Sibirov (USSR) the Soviet Union, Czechoslovakia, Hungary and Bulgaria are trying to improve existing methods of purification and storage. At the same time an effort is being made to find and use more advanced techniques and new materials having many advantages over those used at present. Research is being carried out to increase the efficiency of purification of liquid wastes, and work is also being done on the concentration of activity in the solid phase, on volume reduction of wastes, and on reducing the cost of processing and storage. In a number of countries the possibilities of natural and mineral sorbents are being studied with a view to making the ion-exchange method economically more attractive. For the application of natural sorbents. Czechoslovakia is producing a new line of equipment operating on the principle of counterflow sorption in solid sorbent suspensions, and employing electro-coagulation at the precipitation stage.

Research and development in ENEA countries was described by E. Lopez-Manchero (ENEA). A substantial part of the research effort is devoted to the treatment of liquid effluents, from which the separation of the long-lived fission products in solid form remains a major target. The important effort on treatment of solid wastes generally fits more into the development work.