RADIATION PROTECTION AT THE NATIONAL NUCLEAR RESEARCH CENTRE, PELINDABA*

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The ionizing radiations from X-ray machines and radioactive materials have been recognized as injurious to human beings since the closing years of the 19th century. Since that time, and especially in the post-war era of nuclear science, a great deal has been learnt about the biological effects of radiation and radioactive materials. These materials may be exceedingly toxic, and their radiations can be damaging even though they themselves remain outside the body. Radioactivity thus introduces hazards into what would otherwise be normal operations, and appropriate safety measures must be taken to ensure adequate protection against these dangers.

Radiologists were the first to become aware of the hazards of ionizing radiation, and at the Second International Congress of Radiology in 1928 (held in Stockholm) it was decided to establish an International X-ray and Radium Protection Commission. It assumed the present name of International Commission on Radiological Protection (ICRP) in 1950 in order to cover more effectively the rapidly expanding field of radiation protection. Furthermore, the need for internationally accepted units of radiation dosage had already led to the establishment of an International Commission on Radiological Units and Measurements at the First International Congress of Radiology in 1925 (held in London).

The policy adopted by the ICRP in preparing its recommendations is to consider the fundamental principles upon which appropriate radiation protection measures can be based, while leaving to the various national protection bodies the responsibility of formulating the specific advice, codes of practice or regulations that are best suited to the needs of their individual countries. This has resulted in a number of reports[1] by the ICRP and its various committees, covering all aspects of human exposure and with specific recommendations regarding maximum permissible doses and the resulting maximum permissible concentrations of radionuclides in air and water. It is important to realize that these values make provision not only for protection against acute effects of radiation, which may be detected clinically, but especially against long-term effects which can only be determined by physical methods of radiation monitoring, i.e. by health physics.

The ICRP recommendations have formed the basis of various codes of practice brought out by the International Atomic Energy Agency since 1958, covering the safe handling of radio-isotopes, operation of reactors, waste disposal, transport of radioactive materials and the provision of radiological protection services.[2]

In South Africa the ICRP recommendations, together with IAEA guides, form the basis of radiation protection as applied by the Atomic Energy Board in terms of the Atomic Energy Act of 1967 (replacing the previous act of 1948) and the Nuclear Installations Act of 1963, not only in its regulatory control over all users of radioactive material in South Africa (Government Notice No. R.1822 of 4 October 1968) but also as applied to the activities at its National Nuclear Research Centre, Pelindaba.

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AEB SCIENTIFIC PROGRAMME

The research and development programme of the Atomic Energy Board consists of 3 main themes: the development of nuclear raw materials (mainly uranium); studies on power production (electricity) by means of nuclear energy; and the application of isotopes and radiation. These are supported by the necessary fundamental research. This programme is carried out by a total personnel of 781 (including 150 scientists), most of them at the National Nuclear Research Centre, Pelindaba, but with 15 working in the field of extraction metallurgy at the National Institute for Metallurgy, Johannesburg, and a smaller number doing research in the life sciences at various medical and biological institutes in Pretoria.†

The Pelindaba site[3] is located approximately 17 miles (27 km.) due west of Pretoria, with the Crocodile River supplying the necessary water for cooling the research reactor, etc., as well as providing a medium for radioactive waste disposal.[4] The area of 118 acres (0·47 sq.km.) inside the security fence—total site area of 2,913 acres (11·5 sq.km.)—is occupied by the main scientific and technical buildings. The main radiation hazards are to be found in the buildings for chemistry, metallurgy, Van de Graaff accelerator, radioactive waste treatment, engineering and the reactor building. The first two are designed to handle considerable amounts of radioactive material for irradiation studies and isotope production; the last two contain nuclear reactors.

SAFARI-1[5-8] is a high-flux research reactor, similar in design to the Oak Ridge Research Reactor, intended for materials testing. It is fuelled with 90% enriched uranium, cooled and moderated with light water, and became critical on 18 March 1966. Although its past operation has been at a maximum of $6\frac{2}{3}$ MW, it is being modified for 20 MW operation as from 1969.

The engineering building houses a subcritical as well as a critical assembly, intended for reactor physics experiments resulting from the AEB power reactor concept, PELINDUNA. The latter consists essentially of a zero power reactor, which uses 2% enriched uranium as fuel with heavy water as moderator, and became critical on 30 November 1967.

Other sources of radiation and/or radioactive contamination are a 3-MeV Van de Graaff accelerator, an 18,000-curie cobalt-60 irradiation cell and a variety of sealed and unsealed radioactive materials used for research. Furthermore, the Atomic Energy Board is also responsible for all radiation protection at the National Institute for Metallurgy (with a total staff of 290), where most of the radiation hazard is associated with its uranium work.

†Figures as at end of 1968.

Finally, the Radioactive Waste Treatment Plant is responsible for the disposal of all solid and liquid radioactive waste, and the associated manipulations, especially those for decontamination of equipment, are fraught with radiation and, more important, contamination hazards.

In so far as nuclear research is associated with the hazards of external and internal irradiation to personnel, it is the function of the AEB radiation protection organization to ensure the safety of its staff employed at Pelindaba and elsewhere, as well as of the population at large.

HEALTH AND SAFETY ORGANIZATION

It is a fundamental principle of radiation work at Pelindaba that each individual is primarily responsible for ensuring the safety of his undertaking. This is similar to the philosophy at certain overseas establishments,[9] where it has been shown that only one-half to one-third of the operational health physics staff is required as compared with the provision of a comprehensive health physics service.

The head of each division is responsible for having the established policy carried out by his personnel. This is done in consultation with the Building Head, who has to ensure the safety of his building.

A Safety Committee, consisting of specialists in all the fields associated with safety, is responsible for the general policy and, more specifically, for reviewing all proposed experiments which might present a hazard, as well as new facilities before they are commissioned.

The practical, including financial, aspects of the safety policy are the responsibility of a Safety Executive which reports to the Director General, who is ultimately responsible to the Board for all aspects of safety.

However, because of the specialized nature and extent of radiation hazards, which are not normally encountered in any academic curriculum, it is necessary to have specialists in radiation protection and control available. These persons are based in the Isotopes and Radiation Division and act as specialist advisers, as well as providing the necessary personnel for daily monitoring of each active area. They look after the compulsory training of all radiation workers and are also responsible for conventional safety.

A Building Health Physicist with an appropriate number of assistants (e.g. a total of 8 for SAFARI-1) is appointed to each building where a radiation hazard may arise, to co-ordinate radiation protection and to ensure protection of third parties. Basically he only acts in an advisory capacity, and any problems which may arise are solved through the normal channels; the only exception is when he is wholeheartedly convinced that serious damage will be done to personnel or AEB property. In such an instance he has the jurisdiction to act immediately. The health physicist's specific responsibilities include ensuring that:

(*a*) all radiation workers are medically fit (medical examinations are carried out by the medical staff on a confidential basis and only the positive or negative findings are submitted);

(*b*) each radiation worker has sufficient knowledge and experience to carry out his task safely, as well as being aware of the safety measures concerned;

(*c*) the prescribed rules and regulations are complied with; and

(*d*) the necessary dosimeters, monitors, protective clothing, etc., are available and in good working order.

Medical services are provided by the Life Sciences Division, including pre-employment and periodic medical examinations, as well as treatment in case of accidents, in close collaboration with the H. F. Verwoerd Hospital, Pretoria. This division also provides the necessary medical backing for the Isotopes and Radiation Division in the accumulation of excreta for bio-assay by the latter, as well as for whole-body counting to determine the body burden of internally accumulated radionuclides in each radiation worker.

The Chemical Operations Division is responsible for all decontamination and radioactive waste disposal services,[4] although the determination of released airborne activity has been delegated to the Isotopes and Radiation Division; health physics cover is provided to the former division in the same way as other operations at Pelindaba.

Finally, an emergency organization has been established, including a link-up with the police headquarters in Pretoria, to provide for the possibility of an incident causing the release of radioactivity to the Pelindaba site or—though extremely unlikely—off-site release.

RADIATION PROTECTION

The Isotopes and Radiation Division (which is also responsible for non-biological applications of isotopes and radiation as well as the regulatory control of all users of radioactive material in South Africa) is divided into 3 subdivisions—(*i*) Radiation Control, (*ii*) Health Physics and Safety, and (*iii*) Radioactivity—each of which has other functions as well as those associated with radiation protection. The first is responsible for personnel dosimetry, including external exposure and internal contamination—the last-mentioned in collaboration with the Life Sciences Division; the second is responsible for the monitoring of working areas, including the provision of Building Health Physicists; the third is responsible for the determination of radioactivity in the environment of Pelindaba as well as using the radiometric techniques for bio-assay as required by the first. A total manpower equivalent of 35 (of which 6 are scientists) has been allocated to all aspects of radiation protection, about 15% of their time being devoted to associated research.

Personnel Monitoring

The monitoring of personnel for exposure to external radiation, as well as internal radioactive contamination, is the ultimate check on the long-term radiation safety of each individual worker. In the case of gross over-exposure, personnel monitoring is done to assist in deciding the initial treatment of the exposed personnel. Over-exposure, like any other disability suffered by man, is treated according to the severity of the clinical symptoms, but, since there is a time-lag between exposure and the appearance of symptoms, the dose estimates serve to select the potentially more serious cases.

All personnel who may be exposed to more than one-tenth of the maximum permissible 5 rem *per annum* (ICRP Publication 2)[1] are classified as radiation workers and receive routine medical examinations, including the measurement of internal contamination, and are issued with personnel monitoring equipment, protective clothing, etc. All radiation workers undergo a pre-employment medical examination as well as comprehensive annual examinations, including slit-lamp examination of the eyes and a recording of the fields of vision, full blood counts and urine examination, and also chest X-rays and ECG studies in many cases.

Internal contamination is determined directly by means of the AEB whole-body counter[10] on an annual basis, but is limited to gamma-emitters and energetic beta-emitters which give rise to detectable *bremsstrahlung*. The determination of alpha or soft beta contamination (e.g. uranium, tritium) is done by the bio-assay of urine, faeces, etc.; all radiation workers exposed to appreciable amounts of uranium have urine analyses performed on a monthly basis by the Chamber of Mines Uranium Safety Laboratory.

External exposure is recorded permanently by means of AERE/RPS film badges,[11] as supplied by the Radiation Protection Service of the South African Bureau of Standards (SABS), as well as by quartz-fibre pocket dosimeters which give an immediate indication; excellent correlation has been obtained between these two methods for short-term exposure.[12] Radiation workers who may be exposed to more than three-tenths of the maximum permissible dose wear their film badges for a 4-week period (total of 107 at Pelindaba plus 69 at the National Institute for Metallurgy), while the others do not change their badges for 13 weeks (total of 179 at Pelindaba plus 71 at the National Institute for Metallurgy), except in the case of a suspected over-exposure; a PTW-designed ring is used for determining the dose to fingers and hands. Where fast neutrons present a hazard, an additional neutron emulsion badge[13] (also SABS) is required to be worn on a 2-weekly basis (total of 91 at Pelindaba).

Where neutron over-exposure due to a nuclear excursion is possible, a so-called criticality dosimeter[14] is worn in which threshold detectors serve to give an indication of the neutron spectrum, which is essential for determining the biological dose equivalent as well as an estimate of the exposure. The whole-body counter can also be used to determine the sodium-24 formed by interaction with the normal body sodium. Furthermore, the activation of sulphur in hair, and of elements like nickel, gold, copper and iridium in personal items such as jewellery, pens, coins, belt buckles, dental fillings, etc. can be used to evaluate the neutron over-exposure. Excessive gamma exposures (> 10R) can be determined by stripping the more sensitive emulsion from one side of the double emulsion film.[11]

Table I presents a synopsis of the personnel monitoring methods used by the Atomic Energy Board.

AEB personnel monitoring results for 1967 are presented in the annual report[15] in the form of 3 tables setting out beta-gamma exposures, neutron exposures and uranium urine analyses for the various buildings. Thus far the exposures have been very low, with only 14·1% of all the monitored personnel showing any detectable beta-gamma exposure of which only 4·7% (i.e. 0·7% of the total, representing 2 individuals) recorded an exposure in excess of 1 rem, i.e. one-fifth of the permissible annual exposure. Complete exposure records for each individual radiation worker are maintained so that the 'radiation status' of a person is always available; such records may be required as evidence in claims for damages.

Area Monitoring

All areas where there is a possibility of personnel exposure to radiation are clearly labelled, using a zoning system that has been adapted from that employed at Harwell.[9] A distinction is made between external radiation hazards and surface or airborne contamination hazards. Either type of hazard may be present in the absence of the other (e.g. there is no contamination hazard associated with the operation of an X-ray machine), and so each zone is given a double classification. Zones are colour-coded with the relative hazard increasing from zero for white through blue and red to purple, which denotes a very serious hazard.

Details of these zone classifications are given in Tables II and III for radiation and contamination hazards, respectively. Specific procedures are laid down for each colour zone and it is the responsibility of each individual radiation worker to ensure that these are rigidly followed. It is the Building Health Physicist's job to have zones specified according to the probable hazard and according to the results of the routine radiation and contamination surveys which constitute an important part of his work. He ensures that the required barriers, protective clothing bins, signs and monitors are placed in position.

By means of appropriate lectures and demonstrations by the health physics staff, through the training appropriate to his own work, and by on-the-job experience, each radiation worker should be familiar with the procedures applicable to the different zones. He consults the health physics staff whenever it is necessary for him to undertake a job in a hazardous area or where special precautions have to be taken.

Basically, the approach is to keep areas of high radiation and/or contamination hazard as small as possible, to restrict the access of personnel to such zones to the absolute minimum, to limit their time in a hazardous radiation zone as much as is practicable and, where contamination is concerned, to ensure that it is confined to the appropriate zone. This is achieved by enforcing a rigid protective clothing routine at barriers to 'red' and 'purple' contamination zones and by providing monitors with which the personnel can check hands, shoes and clothing for contamination at these points; a total of 79 stationary and 107 portable monitors (approx. value R200,000) are available.

In general, mean radiation, surface contamination and airborne activity levels have been well within permissible limits. Airborne concentrations of radioactive isotopes above ICRP levels have occurred from time to time, but adoption of the appropriate protective measures has ensured that no radiation worker has inhaled or ingested anywhere close to the maximum permissible body burden for the isotope concerned. The greatest hazards to date

TABLE I. SUMMARY OF PERSONNEL MONITORING METHODS USED AT PELINDABA

Exposure	Body part	Monitoring: Principle	Monitoring: Equipment	Range of exposure measured	Frequency of monitoring	Remarks
β–γ radiation	Whole body	Blackening photographic emulsion	Kodak RM films and RPS-AERE holder	20mR–8R (both emulsion) 10R–800R (slow emulsion only)	Worn for 4 weeks or 13 weeks at a time	Potentially exposed to doses $\geqslant$ 100 mR/month Exposure rate $\geqslant$ 30 mR/month highly unlikely
	Fingers and hands	Blackening photographic emulsion	ADOX finger films in PTW rings	20mR–20R (β) 50mR–300R (γ)	Worn for 4 weeks	As required where hands come close to sources, e.g. in source preparation
	Whole body	Ionization	Pocket dosimeters and alarm dosimeters	10mR–200mR 500mR–5R 5R–50R	Read daily as worn As required As required	If potentially exposed to levels $\geqslant$ 20mR/day As required for rescue, decontamination or other work under planned exposure
Contamination with γ-emitters with energy >100 keV or β-emitters with energy >1 MeV	Whole body (by ingestion, inhalation or entry through wounds)	Gamma spectrometry	Whole body counter	Depends on energy and decay scheme, e.g., 10^{-5} of MPBB for ^{51}Cr and 10^{-1} of MPBB for ^{235}U (not natural U)	Annually as part of medical examination or as required	Whole-body counter is regarded as part of medical examination and serves to establish baseline of normal body radioactivity against which suspected contamination is weighed
Thermal neutrons	Whole body	Blackening of film under Cd strip due to capture γ's	As for β–γ radiation	30mR and up, but threshold dependent on neutron-gamma ratio	As for β–γ radiation	$D_n = \frac{\text{Apparent } \gamma\text{-dose under Cd} - \text{Apparent } \gamma\text{-dose under Sn}}{3 \cdot 4}$
Fast neutrons	Whole body	(a) Track counting on nuclear track emulsions	Kodak NTA emulsion in personnel monitoring pack	20 mrem/track/sq. mm. (minimum No. of tracks counted = 3)	Worn for 2 weeks	Changed every 2 weeks to minimize latent image fading. Not very satisfactory, does not work below 500 keV
	Whole body	(b) γ-spectrometry activation of body Na	Whole-body counter	100 mrem and up	As required	The average man contains about 100 G of sodium-23, which has a fairly large cross-section for a (n, γ) reaction giving ^{24}Na which is readily detectable
	Whole body	(c) Activation analysis of threshold detectors	AERE criticality dosimeters containing a S pellet, In foil and 2 Au foils, one of which is shielded by a Cd foil		Is worn continually but only processed if wearer was involved in an incident where high neutron fluxes could have occurred. Activation of In strip in β–γ badges is indication that criticality dosimeters must be processed	No neutron dosimeter with a response proportional to the absorbed dose exists, and since the neutron dose is very energy dependent, it is necessary to obtain some idea of neutron energy spectrum at the time of the incident. The relative activities of the various threshold detectors give an approximate spectrum
Alpha	Whole body (internal)	Bio-assay	Standard counting equipment	Depends on method of assay	Not done as routine	By sampling excreta, nose-wipes, biopsy samples, etc., it is usually possible to form a reasonable idea of the exposure, provided the source of alphas is known
Tritium	Whole body (internal)	Bio-assay of urine	Liquid scintillation counter	Lower limit of about 0·05 MPBB for untreated urine	Not done as routine	Tritium in the form HTO equilibrates rapidly with body water and hence urine, plasma activities are very representative of body burden
Uranium	Whole body (internal)	Urine analysis	Fluorimeter	Lower limit 5 μg.U/litre urine	Spot samples taken once a month at beginning of work week	Where possible, samples are taken at beginning of work week, so that no uranium was handled for at least 2 days before sampling. This ignores initial rapid excretion of highly soluble U and allows an estimate to be made of actual body burden

TABLE II. RADIATION ZONE CLASSIFICATIONS

Zone	Radiation limits (mrem/hr)	Procedures
White	<0·25	No restrictions, no dosimeters
Blue	⩾0·25 <2·5	Film badges for radiation workers, quartz-fibre dosimeters for visitors
Red	⩾2·5 <25	Film badges and quartz fibre dosimeters for radiation workers. Special provision, such as time limitation or additional shielding, must be made for control of external radiation exposure. No visitors allowed
Purple	Very high, say ⩾25	No access without special authorization; then only after special precautions have been taken and health physicists have given special instructions
Intermittent	As above when source on	Same as above when source of radiation is *on* (e.g., accelerator or X-ray machine) or source exposed (irradiation unit). Otherwise, white zone

have occurred in the Radioactive Waste Treatment Plant, as a result of the decontamination of components from the reactor building. However, the decontamination centre has been designed for work of this nature, and close supervision by the health physics staff has enabled the work to be carried out in a safe manner.

Only one incident involving an over-exposure to radiation has occurred during the 5 years of operations at Pelindaba. This resulted from the malfunction of a tool for automatically removing hydraulic rabbit capsules from their outer sleeves after irradiation in the reactor. The person concerned manually dislodged the capsule from its outer sleeve and, in so doing, sustained a whole-body dose of 3·08 rem of β-radiation and 0·28 rem of γ-radiation. He was not wearing a film ring at the time of the exposure, but the dose to his hands was estimated to be in the range 20 - 40 rem, i.e. more than the 20 rem that may be accumulated in any 13-week period, but probably not more than twice that amount. In consequence, it was recommended that this person be removed from duties involving exposure to radiation for the next 13-week period.

However, an incident which resulted in more serious radiation and contamination hazards of a long-term nature took place when the plutonium-beryllium start-up source failed during the commissioning of SAFARI-1 by the subcontractors in April 1966. An estimated 10% of the 160 G of irradiated plutonium, with its fission products, escaped into the various reactor systems, with the result that serious radiation and contamination hazards arose. Notwithstanding this, no personnel suffered injury, ingested radioactive material or received radiation exposures in excess of ICRP maximum permissible limits. Furthermore, no danger to the general public arose in any way as a consequence of the incident.[12]

District Monitoring

During the normal operation of most nuclear research centres, especially where reactors are in operation, radioactive waste is produced, some of which is subsequently released to the environment. Releases to the environment are normally controlled so as to comply with the ICRP recommendations for radioactivity in drinking water and air, but there is still the possibility of secondary concentration processes which may lead to unacceptable concentrations in the food chain. A survey is therefore performed before commencement of operations, to determine the background radioactivity due to natural sources as well as nuclear bomb fall-out. Subsequently, any increase due to operational release of activity or a nuclear incident may be positively identified and evaluated; it is, however, important to realize that the occurrence of an accidental release will be indicated by a prompt monitor, and only the extent

TABLE III. CONTAMINATION ZONE CLASSIFICATIONS

Zone	Contamination: Surface α $\mu Ci/sq.cm.$	Contamination: Surface β $\mu Ci/sq.cm.$	Contamination: Airborne $\mu Ci/cu.cm.$	Procedures
White	$<1{\cdot}3 \times 10^{-7}$ (= 30 d.p.m. per 100 cu.cm.)	$<4 \times 10^{-6}$ (= 1,000 d.p.m. per 100 sq.cm.)	None	No restrictions
Blue	$< 10^{-5}$	$\leqslant 10^{-4}$	None	Laboratory coats or overalls for radiation workers. Visitors must wear overshoes
Red	$\leqslant 10^{-4}$	$\leqslant 10^{-3}$	Some but not great. Below MPL	No visitors allowed. Special provision may be required, such as overshoes, gloves, respirators, etc.
Purple	$> 10^{-4}$	$> 10^{-3}$	Hazard > MPL	No access without special authorization by a health physicist, who will prescribe appropriate protective clothing (e.g., respiratory protective clothing)

of its subsequent dispersion by the environmental survey.

At Pelindaba a pre-operational survey was started 18 months before the reactor became critical and the total alpha and total beta background activities were established in samples of soil, vegetation, water, sediment, plankton, fish and milk. Through a statistical (variance) analysis, limits were calculated which, if exceeded in future samples, would indicate a statistically significant increase in the environmental activity, necessitating analyses for specific nuclides.[9,10]

A comprehensive programme of collection and measurement of fall-out radioactivity has been established not only at Pelindaba but at a number of centres over the country. From these the effect of the fall-out on the environmental activity was established.[17,18]

At Pelindaba regular releases of radioactive waste are made to the Crocodile River, and are controlled by a formula[4] based on the ICRP recommendations, viz:

$200 \times {}^{226}$Ra-activity $+ 20 \times {}^{90}$Sr-activity $+ 2{\cdot}86 \times \alpha$-activity $+ \beta$-activity $\leqslant 4{\cdot}54$ curie/13 weeks,

on condition that a rate of 20·8 mCi/h (i.e. 10 × average) should not be exceeded. This formula ensures that even at the minimum average daily flow of the river, the ICRP values for drinking water for the general public will not be exceeded.

Regular samples of water, sediment, water-plants, plankton and fish are taken from the Crocodile River and the Hartbeespoort Dam for analysis and compared with the control levels. (All results are reported semi-annually to the Department of Water Affairs which is the controlling body for effluent released into public streams.) Increases and variations found so far could all be attributed to fall-out from nuclear bomb tests or variations in natural activity; no increases due to operations at Pelindaba were found.

Releases to the atmosphere take place continuously and are more difficult to control than liquid discharges. Fortunately, atmospheric releases are normally restricted to the gaseous activity ^{41}Ar (predominantly from SAFARI-1), which is produced by neutron activation of the stable argon in air; particulate activity which might be present is removed through highly efficient filters. The activity is released to the atmosphere through a 70-metre stack, which provides an average atmospheric dilution of about 10^5. Theoretically, the variation of maximum ground-level concentration under extreme atmospheric conditions will be within a factor of 5. More important is the fact that the distance from the stack to the point of maximum concentration varies from 300 metres under very unstable conditions to 10 km. for very stable conditions. (The AEB site represents an exclusion area with a radius of 1·5 km.) However, the normal releases are such that even under the worst dilution conditions the atmospheric concentrations are negligible. Furthermore, because the released activity is gaseous, it does not produce a cumulative deposition hazard.

Although a nuclear reactor cannot explode like an atom bomb, an uncontrolled release of fission products to the atmosphere may take place as a result of a nuclear incident. Consequently it is a prerequisite, before the operation of any major nuclear facility is approved by the Safety Committee, that the effects of a so-called maximum credible accident be analysed. This involves the calculation of the dispersion of activity to the surroundings, which has to be based on actual micrometeorological observations. These consist of continuous recording of wind direction and speed at 5 m. above ground level as well as the top of the stack, and also of the temperature profile along the length of the stack. In addition, actual dilution factors are at present being determined experimentally. This advance information will enable prompt decisions to be made at the emergency control centre in case of a large release of activity.

CONCLUSION

The AEB organization for radiation protection and control has been established, implemented and proved—also for emergency conditions as evidenced during the plutonium incident.

In addition to the scientific work already mentioned, health physics research is also well-advanced in fields such as whole-body counting, the correlation of lung cancer in uranium miners with radon exposure, radioactive fall-out from nuclear bomb tests, radiation shielding, the dispersion of airborne effluent and aerosol physics. The last-mentioned studies have included the very important aspect of testing the efficiency of the filters in the SAFARI-1 ventilation system.

SUMMARY

The organization and results of radiation protection and control at the National Nuclear Research Centre, Pelindaba, which is the research institute of the South African Atomic Energy Board, are described. The site has been occupied since July 1963, and had a total staff of 781 (including 150 scientists) by the end of 1968. The main radiation facilities are the materials-testing research reactor SAFARI-1 (ORR-type, criticality achieved 18 March 1965, at present being converted from 6⅔ to 20 MW), the critical assembly PELINDUNA-ZERO, an exponential assembly, a 3-MeV Van de Graaff accelerator and an 18,000-curie cobalt-60 irradiation facility, as well as the Radioactive Waste Treatment Plant.

Personnel dosimetry is based on regular medical examinations, radiation exposure monitoring by filmbadge and quartz-fibre dosimeter, and the determination of internal contamination by means of whole-body counting and radiochemical methods of bio-assay.

Area monitoring is accomplished by the appointment of the required health physicists for the various buildings, and provision of suitable monitoring equipment. Radiation and contamination incidents are analysed and the relationship between radiation protection staff and scientific/technical personnel is discussed.

Environmental surveys were carried out around Pelindaba before operations began. The present programme is aimed at detecting any hazardous build-up of radioactivity which may occur due to normal releases of radioactive effluent to the atmosphere and the Crocodile River, as well as during emergency situations.

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