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PROGRESS IN PEACEFUL APPLICATIONS OF NUCLEAR ENERGY DURING THE YEAR 1969-70

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INDIA

ATOMIC POWER

1. The atomic energy effort in India is in its twenty-fifth year, having begun with the establishment of the Tata Institute of Fundamental Research in Bombay in June 1945. The quarter century marks the commencement of the era of nuclear power in the country: the 380-MW(e) Tarapur Atomic Power Station, the first nuclear power station in India and the largest operating nuclear power plant in Asia today, was dedicated to the nation by the Prime Minister on 19 January 1970. The station commenced trial generation of power from 1 April 1969 and became fully operational on 2 October 1969.

2. Two other atomic power stations are under construction: the 400-MW(e) Canada-aided station at Rana Pratap Sagar in Rajasthan, and the Kalpakkam Atomic Power Station in Tamil Nadu. The first unit of the Rajasthan station is expected to be completed in 1971 and the second will be ready in 1974. The Kalpakkam station is being designed and built without foreign collaboration, and almost 80% of the material used is of Indian origin.

3. At the Bhabha Atomic Research Centre (BARC) in Trombay, the hub of nuclear research work in India, activities have increased and been diversified to meet the demands of the expanding nuclear programme of the country. Among the important activities of BARC is the preparation of radioisotopes and labelled compounds, which it also exports. In all, 24 countries, including France, Sweden, Hungary, Denmark and Austria, bought Trombay-produced isotope products and equipment in the period under review. Among the equipment exported were two irradiation units (Gamma Chamber 900) containing powerful sources of cobalt-60, which were exported to Burma and Kenya for use in agricultural and industrial research.

PLANT BREEDING PROGRAMME

4. The Biology Division of BARC is engaged in plant breeding programmes, among other investigations. It has evolved six ground-nut mutants which are being tested at several centres through the All India Oilseeds Research Project. And, in collaboration with the Central Rice Research Institute, New Delhi, it has isolated short, dwarf and early flowering mutants of rice. Four slender grain mutants, Trombay-6 to Trombay-9 have been included in the Slender Grain Varietal Trials conducted under the All India Co-ordinated Rice Improvement Project.

5. Research programmes on basic and applied aspects of cellular metabolism and the development of food irradiation procedures are being conducted by the Biochemistry and Food Technology Division of BARC. During the year, it continued experimental programmes on the development of promising radiation preservation procedures for perishable foods. Large-scale feasibility trials on disinfestation of wheat, extension of storage life of onions and preservation of fish and fish products are in progress at its Food Irradiation and Processing Laboratory.

6. Development work on medical uses of radioisotopes - for diagnosis and treatment and aimed at achieving an understanding of disease processes - is being done at the Radiation Medicine Centre of BARC. An essential part of the activity of the Radiation Medicine Centre relates to training of medical doctors and technicians in the use of radioisotopes in their practice.

ELECTRONICS

7. BARC's Electronics Division is engaged in intensive development work on nuclear and non-nuclear electronic instrumentation and equipment. It is also assisting the Electronics Corporation of India Ltd. (ECIL) at Hyderabad, a Government of India concern, through transfer of know-how. Thus items such as the on-line computer TDC-12, the 400-channel analyser, the medical spectrometer and processes relating to semiconductor devices, developed by the Electronics Division of BARC, are being taken up for production and further development by ECIL.

CHEMICAL ENGINEERING

8. The Chemical Engineering Division of BARC is producing nuclear-grade uranium metal for the CIRUS research reactor at Trombay, and ceramic-grade uranium oxide required for the first half charge of the Rajasthan Atomic Power Project reactors, at its Uranium Metal Plant at Trombay. It has designed the uranium oxide and zirconium oxide and enriched UO_2 plants for the nuclear fuel complex and is in the process of erecting and commissioning them at Hyderabad. It is contributing to the setting up of a heavy-water upgrading unit at the Rajasthan Atomic Power Project and also assisting the Indian Rare Earths Ltd. in the production of thorium nitrate by the solvent extraction process. In addition, the Division is engaged in training personnel for the nuclear fuel complex that is being built at Hyderabad.

FUEL REPROCESSING

9. The Fuel Reprocessing Division of BARC is working on the design of the Power Reactor Fuel Reprocessing Plant at Tarapur. The Atomic Fuels Division is engaged in developing and fabricating fuel elements and components for research and power reactors. It is fabricating half the initial fuel charge for unit 1 of the Rajasthan Atomic Power Station. It is in charge of designing, commissioning and constructing a Ceramic Fuel Fabrication Plant, an Enriched Uranium Oxide Fuel Fabrication Plant and a Zircaloy Fabrication Plant being set up at Hyderabad as part of the nuclear fuel complex.

HEALTH PHYSICS AND RADIATION PROTECTION

10. The country-wide studies on fall-out from nuclear tests in the southern hemisphere have contributed information of significance to the understanding of the origin of monsoons. From the studies of country-wide fall-out samples it has been observed that the levels for the different isotopes measured continued to decrease since the maximum values were reached during 1963-64. The Division in question also carried out extensive measurements at Trombay to study the sources and concentrations of a number of atmospheric pollutants.

During the year, the country-wide radiation safety programme conducted by the Directorate of Radiation Protection was expanded considerably. The film badge service provided by the Directorate covers some 16 000 radiation workers from about 1250 institutions all over the country.

FAST BREEDER REACTOR

11. As a major step in the programme of developing fast reactors, the Atomic Energy Commission is planning to construct a Fast Breeder Test Reactor (FBTR) in collaboration with the French Atomic Energy Commission. An agreement for this was concluded early in 1969. A team consisting of Indian and French engineers, scientists and supporting staff worked during the year in France on the detailed design and drawing of the FBTR. A Design Review Committee consisting of senior staff from BARC operates from India. Simultaneously, civil construction work was started at the site of the new Reactor Research Centre by the side of the Madras Atomic Power Station at Kalpakkam, where the FBTR will be built.

AGRO-INDUSTRIAL COMPLEXES

12. Work on the detailed report on the setting up of nuclear powered agro-industrial complexes in India has been completed. In addition, studies initiated on some of the important local conditions related to water and agriculture in Western Uttar Pradesh as well as in the Kutch-Saurashtra region of Gujarat - where a desalination unit may be advantageous - are making satisfactory progress. Simultaneously research and development work on desalination and some of the important power-consuming industries of relevance to the agro-industrial complex programme, was initiated. Future programmes include the detailed feasibility studies of the different projects of the complex and the implementation aspects.

TATA INSTITUTE OF FUNDAMENTAL RESEARCH

13. At the Tata Institute of Fundamental Research, Bombay, the on-line data processer (OLDAP) built in the Institute has been installed and fully tested; it should soon be available as an on-line facility for analysis of bubble chamber film.

14. The 530-metre-long cylindrical radio-telescope at Ootacamund for studies in radio astronomy has been completed. It is a major facility for research in this area in India and is one of the largest steerable radio-telescopes in the world. Suitable for a systematic survey of weak extragalactic radio sources by the method of lunar occultation, it exploits fully the position of India near the geographic equator. The telescope, in its mechanical and electronic aspects, has been entirely designed and engineered in India.

ATOMIC MINERALS

15. The Atomic Minerals Division has intensified its underground development work at the Narwapahar and Bhatin mining prospects in the State of Bihar. It has also located uranium and other atomic minerals in the State of Rajasthan and the Himalayan ranges. The uranium mine at Jaduguda, which the Division developed, and the mill alongside it, are being operated by the Uranium Corporation of India Ltd. (UCIL), a Government of India concern set up in October 1967.

RARE EARTHS

16. Also dealing with minerals, in this case rare earths, is the Indian Rare Earths Ltd., another Government undertaking. The company commercially exploits the mineral sands on the beaches of the States of Tamil Nadu and Kerala, operating plants at Alwaye, Manavalakurichi and Chavara in South India. It is also operating the

thorium plant at Trombay. During the year, it concluded an agreement with the United States of America for the sale of substantial quantities of rare earths.

17. In recent years a complex of plants has been programmed to support the expanding role of nuclear energy in the country. Among these are: the nuclear fuel complex at Hyderabad, which will prepare nuclear-grade uranium oxide and cladding material for the country's nuclear power plants; the Power Reactor Fuel Reprocessing Plant at Tarapur and heavy-water plants near Kotah in the State of Rajasthan and at Baroda in Gujarat State. The heavy-water plant near Kotah will have a capacity of 100 tonnes a year. The plant at Baroda is being built by a consortium of French firms; its capacity will be about 67 tonnes per year.

18. The Physical Research Laboratory at Ahmedabad, the Saha Institute of Nuclear Physics, Calcutta, and the Tata Memorial Centre, Bombay, are among major units which are administratively responsible to the Department of Atomic Energy. The Physical Research Laboratory, besides its investigations in aeronomy, geomagnetism, astrophysics, space physics, theoretical physics and related sciences, is doing pioneering work in space research. It has developed a number of instrumented pay-loads for launchings from Thumba and is collaborating with scientists from other nations in meteorological and other experiments in Thumba. The Saha Institute carries on basic research in nuclear physics. It is collaborating with BARC in setting up a variable energy cyclotron for the Department of Atomic Energy in Calcutta. This cyclotron is being made in India, with some major components made at BARC and by Indian firms such as the Heavy Engineering Corporation Ltd., Ranchi, and Heavy Electricals (India) Ltd., Bhopal.

INDONESIA

REACTOR AND SUBCRITICAL ASSEMBLY

The Triga reactor at the Bandung Reactor Centre needs to be up-graded so as to make it possible to operate it 20 hours a day. Four additional fuels are being purchased from the United States of America and will be installed in due time. An effort to increase the power of this reactor to the maximum level of 1000 kW is under way. It is hoped that it will be possible to ship the fuel needed from the United States of America to Indonesia around March 1971. This fuel will be obtained through the Agency from the United States Atomic Energy Commission. A trilateral agreement to make this possible was signed on 19 December 1969.

Improvements in radioisotope production have been achieved. Certain short-lived radioisotopes, either for medical or for other purposes, are produced by the Bandung Reactor Centre. Messrs. Gopal and Desphande, Agency experts who served for seven and five months respectively, have assisted in achieving this goal.

The availability of the plutonium-beryllium neutron source for the subcritical assembly at the Gama Research Centre in Jogjakarta enabled this facility to resume its former activity. The source was obtained through the Agency and financed by the United Nations Development Programme.

Research work on neutron physics, reactor characteristics and magnetic materials is carried out, and ways are sought to complete such work within the shortest possible time.

A seminar on nuclear power was held in Jogjakarta in January 1970, and the conclusion was reached that the Directorate General for Electricity and Energy together with the National Atomic Energy Agency should set up a joint committee to study developments in nuclear power.

SURVEY AND EXPLORATION

A three-month survey was made by the officials of the National Atomic Energy Agency on the island of Sumatra.

In collaboration with the French Atomic Energy Commission, surveys and explorations were carried out in West and Central Kalimantan, beginning in November 1969. In the coming few years further extensive explorations are to be done only in a more restricted area.

Surveys in West Irian and other areas of the country have to be postponed because of lack of funds and personnel.

APPLICATION OF RADIATION AND RADIOISOTOPES

Hydrology

An Agency expert, Dr. McHenry, spent three months at the Pasar Djumat Research Centre, where he conducted courses, including one attended by officials from various agencies.

A co-ordinated research programme has been set up jointly by the Department of Communications, Department of Public Works and Electricity, and the National Atomic Energy Agency, to study sedimentation in harbours and dams.

Studies have continued on the Sempor Dam and the Tjitandui river (west Java) within the framework of a flood control programme. A programme of work in the Tjimanuk river basin has been prepared.

Agriculture

An Agency expert, Mr. Kamra, made a proposal to the Agency for a revision of the Indonesian proposal on mutation breeding. Because of certain local conditions, Mr. Kamra's proposal could not be fully carried out, and research on mutation breeding of certain food crops has therefore been done by the Pasar Djumat Research Centre and the Bandung Reactor Centre, which is in accordance with the original idea. In this context, the advice of Dr. Kohler, an Agency expert who spent six months in Indonesia, has been one of the stimulating factors.

Co-ordinated research on the application of the sterile-male technique to certain agricultural pests is currently being carried out; pests affecting rice, cabbage and sugar cane are among the most important subjects to be studied. Participating agencies include: the Agricultural Research Centre, Bogor; the Gadjah Mada Agricultural College, Jogjakarta; the Estates Training Institute, Jogjakarta; the Brawidjaja Agricultural College; and the National Atomic Energy Agency.

Research relating to the study of efficient water uptake by rice is being done at the Pasar Djumat Research Centre; this research is financed by a grant from the Agency.

Medicine

A Nuclear Medicine Centre in Bandung has been in operation since September 1969. This Centre came into being as a result of co-operation between the Department of Health (Hasan Sadikin Hospital) and the Bandung Reactor Centre. It was officially inaugurated by the Minister of Health on the occasion of the fifth anniversary of the Bandung Reactor Centre. Dr. Vavrejn, an Agency expert in nuclear medicine, has spent 12 months at the Centre. Research on the sterilization of medical products, the use of radioisotopes in animal metabolism and other subjects is in progress.

Food preservation by irradiation

An Agency expert on food irradiation spent almost a year at the Pasar Djumat Research Centre. Various activities relating to food preservation have been conducted by the local staff at the Centre. Subjects that showed promising results are: disinfestation of cereals and pasteurization of fish and other marine products.

An Ad Hoc Committee on Food Preservation by Irradiation is to be formed within the framework of a National Committee on Food, sponsored by the Department of Health in collaboration with other departments in the country.

Radiography

Under the guidance of an Agency expert, Mr. S.J. Sully, a radiography programme was launched. This technique has been successfully applied to the newly built electric power station in Makassar, Celebes, where welded joints and other metal components were tested for faults. The Railway Workshop in Manggarai, Djakarta, has also made use of this technique and the Garuda Indonesian Airways have been using it for quite a long time; because of its wider and more extensive use in the future, the problem of the health hazards to the operators should not be overlooked.

HEALTH PHYSICS

Health physics activities have been carried out both by the Serpong Health Physics Centre and the Bandung Reactor Centre; the activities at the former Centre were mainly centred on problems relating to health physics. Recent agreement between the Government of the Republic of Indonesia and the Government of the Soviet Union indicated the possibility of the completion of the Russian-made reactor IRT-2000.

MADAGASCAR

CONTROL OF THE RICE HISPA

Report on preliminary experiments for the use of radioactive tracers

The work carried out by the Institut de Recherches Agronomiques (Agronomic Research Institute) had two main purposes: first, to test the radiotracer uptake and retention capacity of the rice hispa, Trichispa sericea guérin, at each stage of its development and, second, to determine the level of radioactivity in the labelled insects needed for detection by means of portable apparatus of a sensitivity and ruggedness in keeping with the requirements of in-situ counting in our wastelands and paddyfields, since recapture is considered impossible for some of the proposed ecological studies.

Phosphorus-32 was preferred to sulphur-35, at least for the preliminary tests, in spite of its appreciably shorter lifetime (14.3 days for ^{32}P against 87.1 days for ^{35}S), because its maximum beta particle energy is 10 times greater - 1.71 MeV as compared to 0.17 MeV for ^{35}S - and accordingly offers a better chance of detection in the field.

Furthermore, the concentration of the radioactive solution sprayed onto the hispa was chosen with a view to the large number of adults (several hundred per release) to be labelled in each ecological experiment, since the aim was to be able to estimate the size of populations by the isotopic dilution method.

Habitat typical of the different stages of evolution of Trichispa sericea guérin

The eggs are always laid individually, coated with a protective layer which the female covers with a heap of excrements, sometimes concealing the egg almost entirely; the bursting of this cover marks the hatching of the larva. We thought that this protective coating was likely to hinder penetration of the aqueous radioactive solution.

The miner larva feeds on the parenchyma of the leaf, which dissolves at the burrow to form two filtering membranes, considerably reducing impregnation of the insect.

Since nymphosis occurs inside the burrow, the chances of labelling the nymph are essentially the same as for the larva. It is of course impossible to carry out impregnation by active feeding.

Although the winged insect can fly well on occasion, it generally moves little. When deposited on a plant it consumes the leaves one after another. Clearly sedentary, its movements on the limb are restricted to essential trophic and sexual activities.

Experimental procedure

Two procedures were used. First, we carried out impregnation by spraying a radioactive solution directly on batches of insects. The eggs and, to an even greater extent, the miners and nymphs in their burrows between the two layers of epidermis of the leaf, escape virtually all direct contact with the radioactive isotope. Raising hispa in the laboratory we have observed that all stages other than the fully-developed winged insect succumb fairly quickly to irradiation: the larva and nymph when withdrawn from their burrow and the egg when removed from its protective casing. The winged insect can withstand brief immersion in an aqueous radioactive solution, and this operation can be repeated provided a quick drying interval is inserted between two successive immersions.

Labelling by impregnation of the support (spraying the leaves or watering the roots) and active feeding of the larvae and adults is a matter of chance because of the very small amount of daily feeding per individual. More days of successive feeding would be required than are allowed by the biological half-life of the isotope (radioactive phosphorus in this case) for the absorbed radioactivity to reach a detectable level under the conditions prevailing in paddyfields. Moreover, only the adults are affected.

It occurred to me that "reflected" impregnation through friction with the impregnated support during the daily movements of the insects might be of greater interest than uptake by direct ingestion of the support. However, we must note straight away that only the imago is capable of such uptake and that the level of accumulation is stabilized quite soon since friction implies simultaneous and continuous additions and subtractions.

Our experiments included a comparative evaluation of radioactivity retained by the support (sampling of impregnated rice leaves) and by the winged insect, respectively.

Conduct of the experiments

Using parent solutions of ^{32}P periodically delivered to the Radioisotope Laboratory of Tananarive University by the French Commissariat à l'energie atomique, we applied the following radioisotope concentrations and compared their effectiveness on different stages of T. sericea (eggs, larvae, nymphs and adults):

- 40 µCi/litre aqueous solution of ^{32}P;
- 80 µCi/litre aqueous solution of ^{32}P;
- 120 µCi/litre aqueous solution of ^{32}P.

Counting was carried out on a Geiger-Müller counter in a lead castle with constant geometry, first immediately after impregnation and afterwards at weekly intervals; each experiment included a minimum of four counting operations, the last being performed in some cases on the supporting medium without the insects. Let us recall that the growth stages of T. sericea, in the Tananarive climate and in season, are about a week for the egg and the nymph, three weeks for the larvae and one to three months of active life for the imago. Hence the eggs and nymphs at least are involved only in the first counting carried out immediately after labelling.

A single experiment always included five batches of five pots, each containing three rice clusters. At the start of the experiment the plants had only recently tillered.

The pots were provided by our permanent T. sericea breeding programme. The rice, sown in the open field, was transferred to the pots three to four weeks after sowing between October and February and five to six weeks after sowing between March and June. At the time of labelling the plants, which were carefully standardized, had reached a homogenous state of growth and density of infestation: 150 eggs or 50 larvae, nymphs or adults per pot depending on the experiment, any excess population having been removed prior to spraying or watering with the radioactive

solution. Each pot received, depending on the experiment, either 50 ml of radioactive solution sprayed on the aerial parts of the plants (a wetting agent - Teepol in a concentration of 4 ml/litre - being added to improve impregnation of both insects and support) or 500 ml applied directly to the roots.

Each weekly counting operation covered one fifth of the population of the five pots in a batch. The pots were isolated in a meshed cage under shelter during the initial experiments and subsequently placed in the open field in order to determine the leaching conditions.

Results and programmes

The table at the end of this report gives the mean values obtained in our experiments.

50 ml of the aqueous test solution were applied in a fine spray to the insects and their support.

In parallel with each counting operation on the insects, we measured the radioactivity retained by a sample of 200 mg of the support - in this case the leaves within or on which the insects were located at the time of labelling.

Larvae, nymphs and adults were first extracted and withdrawn from the support, then anaesthetized and placed unprotected in the counting chamber; the eggs, on the other hand, were counted with a section of leaf and their protective envelope.

The ratio between the background of the counter and the level of radioactivity of the labelled insects seems to justify a certain amount of optimism, particularly if one remembers that the labelling of eggs, larvae and nymphs is of interest mainly in biological studies during which the counting operation can always be carried out under optimum conditions in the laboratory, and that the winged insects of interest in ecological research tend to group together and attain relatively high population densities (up to 400 individuals per square metre of paddy).

In conclusion it is worth summarizing the studies for which we propose to make use of radioactive labelling in cases where conventional methods of investigation have revealed their limitations:

(a) Migrations of populations, and the mechanism of extension of damage;

(b) Status of populations:

- quantitative aspect: density, increase or decrease;
- quantitative aspect: origin, constitution;

(c) Preferred food as a function of growth stages of both insect and rice plant;

(d) Census of secondary plant hosts;

(e) Mode of action and efficiency of insecticides as a function of their nature and conditions of application.

Used initially in the campaign against the rice hispa, the method and programme described above will be extended and adapted for use against other crop pests which cause damage of economic significance and spread beyond local boundaries

Programme on the use of radiation in agricultural entomology

A research contract relating to use of the sterile male technique to combat T. sericea in Madagascar has been concluded with the Agency. The programme is to begin with the 1970 rice crop, and a radiation entomologist provided by the Agency under its Regular Technical Assistance Programme for 1970 will participate at the start. Furthermore, during 1970 the Agency is to supply the Malagasy Republic with a cobalt irradiation unit which, while installed at Tananarive University, will be used for a variety of purposes including the experiments in radiation entomology which concern us: the sterile male technique (as applied to rice hispa and fruit fly) and disinfestation of foodstuffs in storage.

The initial aim of the project is to develop appropriate and practical techniques and media for raising a sufficient number of insects for use in sterilization experiments and for ecological studies, since conventional research methods have shown themselves to be of limited value.

The second stage will entail mass rearing of rice beetles (hispa) and experiments that should enable us to assess the competitiveness of the sterile males as well as their survival and dispersion, and to try out different sterilization and release techniques. The results of this work should indicate how efficient the method is likely to be.

The project will also be aimed at finding the best solution to the many technical and administrative problems raised by the release of sterile males; for it is on the solution of such problems that the success of the sterile male technique as a means of achieving partial or total destruction of an insect pest within the specific context and conditions of Madagascar will depend.

STUDY OF MANGANIC TOXICITY

We are planning to study ways of correcting manganic toxicity in Ankêtrakabé soil by means of an experiment conducted in experimental pots with ^{54}Mn as radioactive tracer. We shall be able to begin the experiment very soon thanks to the assistance of the Radioisotopes Laboratory, which has been kind enough to provide us with the necessary equipment and sources. The experiment is designed to determine available manganese in this soil, which will be subjected to a variety of treatments by a method similar to that of Larsen and Blanchet (L value) for determination of available phosphorus. Chemical methods of extracting available manganese have so far proved incapable of reproducing the results obtained in field tests or pot experiments.

Finally, it should be mentioned that in October 1970, Mr. Oliver, a research worker in the Soil Science and Plant Nutrition Division, will undergo a period of training with the French Atomic Energy Commission (CEA) at Cadarache with a view to obtaining the necessary qualifications in the use of radioisotopes in agriculture.

STUDY OF THE PHOSPHORUS STATUS OF MADAGASCAR SOILS BY THE ISOTOPIC EXCHANGE METHOD

This study was carried out under Agency Research Contract No. 727/RB and has been reported in Document No. 229 of the Agronomic Research Institute in Madagascar.

Performed by Mr. Ngo-Chan-Bang, the study applied to certain Madagascar soils a method of evaluating available phosphorus which is based on measurements of isotopically dilutable phosphorus in the presence of the soil solution as entraining agent - a method described by Fardeau and Marini. The radioactive isotope ^{32}P is required.

In the course of this study the isotopic dilution method of determining available phosphorus was applied to different types of Madagascar soil, both in experimental pots and in the field. The soils were subjected to different water régimes, and some samples had received phosphorus fertilizer while others had not. The results were compared with the responses obtained from these same soils when enriched with phosphate fertilizer and used to grow various crop plants.

The report concludes that the different forms of soil phosphorus can be classified in accordance with increasing retention energy, i.e. decreasing rate of exchange. Four levels are distinguished in this way, and for each energy level a certain number of "sites" are defined, the degree of saturation of any given site being governed by the saturation of the following site.

This study on the phosphorus status of Madagascar soils is at present being continued and supplemented by a study on the exchange capacity of the different forms of phosphorus contained in them. For this work the fractionation method evolved by Chang and Jackson is being used, and the tracer is again ^{32}P (IAEA Research Contract No. 727/RB/IA).

The work is still in progress and no final conclusion can yet be drawn. However, it seems that in the soils studied the exchange capacity of the different forms of phosphorus can be graded as follows:

$$P - Al > P - Fe > P - Ca > P - Occlus$$

RADIOISOTOPE LABORATORY, TANANARIVE

The Radioisotope Laboratory has been operating for five years under the aegis of the National Foundation for Higher Education in Madagascar. The main activities during the past year are shown below:

Nuclear medicine, under the direction of Dr. J. Manambelona:

(a) Diagnosis of diseases of the thyroid, liver and kidneys, as requested by physicians;

(b) Various biochemical examinations;

(c) Training of specialized personnel; and

(d) Tests on a new unit for thyroid examination - the "spark chamber".

Radioagronomy, under the direction of Mr. P. Moutonnet (an engineer of the French Commissariat à l'énergie atomique on long-term assignment at the laboratory):

(a) Use of the neutron moisture meter on various types of soil;

(b) Co-operation in the United Nations project for development of the Morondava region;

(c) Co-operation with specialists of the Institut de recherches du coton et des textiles exotiques (Institute for research on cotton and exotic textiles) in connection with cotton-growing;

(d) Co-operation with forestry staff in connection with pine and poplar reforestation;

(e) Co-operation with the Office de la recherche scientifique et technique outre-mer (Office for Overseas Scientific and Technological Research) in connection with a hydrological study of a drainage basin;

(f) A project for irrigation of sugar cane plantations;

(g) Work with various tracers:

(i) Phosphorus-32 and sulphur-35 for soil improvement;

(ii) Tritium for hydrological studies; and

(h) Processing of the results of water concentration measurements on the IBM-1130 computer of the Faculty of Sciences, Tananarive.

Miscellaneous

(a) Training: construction of experimental equipment in nuclear physics (including a neutron source), for students of the Faculty of Sciences; and

(b) Electronics: improvement of equipment and adaptation for local requirements.

Development

New structures at present going up will house two valuable items of equipment which will serve all interested research workers in Madagascar - a gamma irradiation unit provided by the Agency and an electron microscope acquired by the University.

TABLE OF RESULTS

Counting dates	^{32}P/40 µCi/litre				^{32}P/80 µCi/litre				^{32}P/120 µCi/litre			
	Stage and number of insects	Radioactivity in cpm			Stage and number of insects	Radioactivity in cpm			Stage and number of insects	Radioactivity in cpm		
		Background	Insect	200 mg leaf		Background	Insect	200 mg leaf		Background	Insect	200 mg leaf
D: day of labelling	30 eggs	21	1547	1580	30 eggs	22	3137	3066	30 eggs	21	1638	2586
	10 larvae	23	148	2248	10 larvae	20	225	1680				
	10 adults	23	68	1668	10 adults	25	1526	3298	10 adults	23	80	1980
D + 8	10 larvae	24		1925								
	10 nymphs	19	78	2097	10 nymphs	19	100	1215				
	10 adults	18	230	935	10 adults	22	1238	2715	10 adults	24	35	2234
D + 15	10 adults	22	51	472	10 adults	24	124	3046	6	24	25	2021
D + 21	10 adults	25		160	10 adults	25	30	2058	10 adults	23	62	868

PAKISTAN

INTRODUCTION

1. The Pakistan Atomic Energy Commission (PAEC) is charged with the development of peaceful uses of atomic energy in Pakistan. Having started with the application of radioisotopes in medicine, agriculture and industry, PAEC is now carrying out a programme of nuclear power generation. Useful research and development is being carried out at PAEC's research establishments.

NUCLEAR POWER

2. The first nuclear power plant in Pakistan, the 137-MW(e) Karachi Nuclear Power Project, is nearing completion. The reactor is expected to go critical by October 1970 and full power operation is expected by June 1971. The plant employs a natural uranium reactor with heavy water as the moderator and coolant.

3. A 200-MW(e) nuclear power plant at Rooppur in the north of East Pakistan has been approved by the Government of Pakistan. The plant will be based on a pressurized water reactor using enriched uranium fuel. It is expected to be operational by 1975.

4. Feasibility studies are being made with respect to the establishment of a dual-purpose nuclear power-cum-desalination plant near Karachi producing about 400 MW of electricity and up to 100 million gallons of fresh water per day. The plant would meet some of the increasing water and power requirements of the greater Karachi area.

AGRICULTURE

5. Useful development work is being carried out in the agricultural sector at the Atomic Energy Agricultural Research Centre, Tandojam, the Radiation Genetics Institute, Lyallpur, and the Atomic Energy Centre, Dacca. Among the programmes which are in progress may be mentioned:

(a) The evolution of new dwarf, short-culm, and early-maturing rice mutants and two mutants of the IR-8 rice variety;

(b) The evolution of rust-resistant wheat varieties;

(c) The development of more resistant cotton varieties; and

(d) The evolution of new sugar varieties.

The application of the sterile-male technique has been extended to the rice stem borer under an IAEA Research Co-ordination Programme. Similarly, the applications of radiation techniques are being extended to the evolution of high-yielding and red-rot resistant sugar cane varieties, and early and high-yield Aus and Aman rice strains are being evolved. A soil map of East Pakistan is also being prepared.

6. The Radiation Genetics Institute, Lyallpur, which has been functioning since last year, has commenced working in full swing. It is undertaking studies on wheat through gamma-ray, X-ray, neutron (thermal and fast) and ethyl methane sulphonate doses. It proposes to extend studies to:

(a) The gamma-irradiation of rice;

(b) Soil tolerance of sunflower;

(c) Irradiation of soyabean; and

(d) The evolution of better cotton varieties.

The other Radiation Genetics Institute at Mymensingh is nearing completion, while land for the establishment of the Irradiation and Pest Control Research Institute has been acquired.

HEALTH

7. The PAEC Medical Centres at Dacca, Karachi, Lahore, Multan and Jamshoro have registered further progress. To quote one instance, the number of patients examined at the Lahore Medical Centre went up from 1206 in 1967-68 to 1854 in 1968-69. There is thus a growing increase in the number of patients referred to the Atomic Energy Medical Centres. The Rajshahi and Chittagong Medical Centres have been completed.

INDUSTRY

8. Several new and useful instruments have been developed, such as power units, a solid state digital voltmeter, and a scaler capable of counting both negative and positive pulses at a maximum rate of 2.5 megahertz. The design and construction of a detector simulator have also been undertaken, while experiments are in progress on a dust collector model. Radioisotope production is being extended to include carrier-free ^{51}Cr and ^{99m}Tc generators. Gamma radiography for checking welds and joints has become well established in industry.

9. PAEC is collaborating with the Karachi Port Trust in tracing the movement of silt near the Karachi harbour with radioisotopes. Work has been initiated on neutron activation analysis of minute trace amounts of micro nutrients in the Mexi-Pak wheat variety. Another application of activation analysis has been the non-destructive testing of archaeological samples like ancient coins.

10. Investigations on various solar cell and battery parameters are in progress. The efficiency of a solar still at various angles of mirror for solar desalination has been determined.

11. The Solar Desalination Project at Gwadur is being commissioned and should help to demonstrate the application of solar energy for water distillation for small communities living on the Mekran Coast.

RESEARCH AND DEVELOPMENT

12. Research and development work is in progress at the two Atomic Energy Centres at Dacca and Lahore and at the Pakistan Institute of Nuclear Science and Technology (PINSTECH). The Van de Graaff accelerator at Dacca and the 5-MW Pakistan Atomic Research Reactor at PINSTECH offer extensive research facilities. Among the research projects are those relating to theoretical physics, experimental physics, electronics, health physics, chemistry, agriculture and genetics.

SEARCH FOR NUCLEAR MINERALS

13. The geologists of PAEC have established the presence of a large deposit of valuable minerals, such as ilmenite, zircon, rutile and monazite, along the Bay of Bengal beach in East Pakistan. After the extent of deposits has been determined, it is proposed to install a pilot plant to study the cost economics and separation of heavy minerals by the end of 1970.

14. Assistance under the Special Fund valued at US $435 900, has been approved for the development of uranium resources of the Dera Ghazi Khan district in West Pakistan. Extensive drilling operations will be carried out in order to evaluate the uranium reserves of this area. The actual investigations on the site are scheduled to commence late this year. PAEC also plans to install a semi-industrial pilot plant to process 1000 lb of uranium ore per day.

UNITED KINGDOM OF GREAT BRITAIN AND NORTHERN IRELAND

INTRODUCTION

1. In the United Kingdom statement last year reference was made to the concentration of British nuclear design resources, both of industry and of the United Kingdom Atomic Energy Authority (UKAEA), into two design and construction companies - The Nuclear Power Group Limited and British Nuclear Design and Construction Limited.[1/] They are composed of firms with a wide range of experience in the technologies necessary for the successful design and construction of complete nuclear stations and have been licensed for access to the full range of the UKAEA's reactor technology. Thus the two companies are well equipped to deal with all existing and future British systems. The reorganization enables effective competition within the United Kingdom to be maintained while ensuring a more efficient and economic integration of technological and industrial resources.

2. A Bill, to transfer the production activities of the UKAEA to a nuclear fuel company and a radiochemical company, will be introduced when Parliament assembles in the autumn. The nuclear research and development establishments of the UKAEA will continue to provide a sound scientific base for the commercial exploitation of nuclear power.

3. The United Kingdom Government believes that these new arrangements will facilitate the forging of industrial links broad.

NUCLEAR POWER PROGRAMME

4. Nuclear power stations supplied nearly 12% of the electricity generated in the United Kingdom during 1969, and the proportion is expected to rise substantially during the 1970s. The first nuclear power programme, comprising 4800 MW(e) from Mark I gas-cooled reactors (MAGNOX), will be completed when the Wylfa station is commissioned later this year. Four Mark II advanced gas-cooled stations (AGR), to produce a total of 4950 MW(e) are already under construction, and tenders for two more have been received. The Central Electricity Generating Board is planning a continued programme of nuclear power station construction. Plans to install a nuclear station in the north of Scotland have also been announced.

1/ See document GC(XIII)/INF/113/Rev.1, statement 13, para. 1.

with the CAMAC Scheme which was first specified by the European Standards of Nuclear Electronics (ESONE) Committee. This newly adopted international standard is becoming widely used, especially for on-line computer control assemblies.

FUSION RESEARCH

22. The nuclear fusion research programme at Culham concentrated on investigating the confinement of plasma in magnetic traps of the "closed-line" class. During the year construction commenced on two major new experiments of this class, the High Beta Toroidal Experiment and the Superconducting Levitron.

23. An important event in the field of nuclear fusion, both as regards scientific progress and international collaboration, was the Anglo-Russian experiment to measure the temperature and density of the deuterium plasma confined in the Tokomak device at the Kurchatov Institute in Moscow. The results showed that the expected high temperatures and densities are obtained, and confirmed the potential value of closed-line systems as a basis for fusion reactors.

24. The first international conference on nuclear fusion reactors was held at Culham Laboratory in September 1969 under the auspices of the British Nuclear Energy Society. It reviewed the whole range of technological and engineering development required for fusion reactors nd provides a base for developing the UKAEA's programme in this area, taking account of work being carried out overseas.

INTERNATIONAL COLLABORATION

25. The United Kingdom has continued to collaborate to the full in the peaceful uses of atomic energy, both with international organizations such as the International Atomic Energy Agency, the European Nuclear Energy Agency and the European Atomic Energy Community (EURATOM), and bilaterally. In addition the UKAEA has arranged exchanges under the many collaborative agreements it has with organizations in other countries. The opening of negotiations on 30 June 1970 for United Kingdom membership of the European Communities brings with it the hope for even closer collaboration with EURATOM on peaceful nuclear matters.

NUCLEAR FUEL SERVICES

5. The new facilities for large-scale oxide fuel manufacture introduced at Springfields in 1968/69 were brought into full operation during the year. The major task at Springfields, until recently the manufacture of natural uranium metal (MAGNOX) fuel for the Mark I gas-cooled reactors, is now to provide enriched oxide fuel for advanced thermal reactor systems. Fuel is being produced not only for the United Kingdom reactor programme, but also for reactors in a number of countries.

6. The installation and commissioning of the new full-scale fast reactor plutonium fuel plant at Windscale was virtually completed during the year, and manufacture is about to start of the initial fuel charge for the prototype fast reactor at Dounreay.

7. The reprocessing plant at Windscale operated at a higher plutonium throughput as the returns of irradiated fuel increased. The new head-end plant for the pre-treatment of irradiated oxide fuel completed its first active campaign, with fuel from the Windscale AGR and from the Garigliano boiling light-water cooled and moderated reactor in Italy.

8. At Capenhurst, the modified diffusion plant is now operational. The plant has sufficient capacity to supply the enriched uranium needed for the United Kingdom programme for the next few years. Future increases in enrichment capacity will be based on the gas centrifuge process, on which development work is continuing. This work will now proceed within the framework of the British/Dutch/German agreement for collaboration signed at the beginning of March 1970. Negotiations for the formation of the two tripartite companies to effect this collaboration are well advanced and it is expected that by next year the enrichment projects in the three countries will have been integrated into the operations of these two companies.

REACTOR DEVELOPMENT

9. Development work and other support for the Mark II gas-cooled reactors (AGRs) has continued. The prototype reactor at Windscale has operated with high availability which has averaged 83% over seven years, and a substantial programme of irradiation experiments, particularly to test improvements in fuel design, has been carried out.

10. The programme to develop a Mark III high-temperature gas-cooled reactor (HTGCR) using low enrichment coated particle fuel and helium coolant, has now been fully defined. The HTGCR draws on the extensive United Kingdom experience of gas-cooled reactors and incorporates technology developed by the Dragon Project, in which the United Kingdom continues to participate.

11. An alternative advanced thermal reactor system which is available from United Kingdom development is the steam generating heavy-water reactor (SGHWR). The 100-MW(e) SGHWR at Winfrith has operated very satisfactorily since achieving full power in January 1968. In the autumn of 1969, a scheduled shut-down was undertaken to change some of the reactor's fuel; at the same time, the primary circuit and steam drum were cleaned, decontaminated and inspected, and six experimental pressure tubes were removed and replaced. After returning to power, the reactor's availability was 84% for the rest of the year under review. Commercial designs of SGHWR stations have been developed by the nuclear industry.

12. Construction of the 250-MW(e) prototype fast reactor at Dounreay is being undertaken by the Nuclear Power Group for the UKAEA. Both the nuclear and conventional aspects of the work are now well advanced. The UKAEA, the design and construction companies and the generating boards are closely associated in the direction of the development programme on fast reactors. Increasingly the emphasis in present fast reactor work is on commercial designs in the 1300-MW(e) range.

13. The Dounreay Fast Reactor (DFR) completed three full-power runs during the year, carrying out an extensive range of irradiation experiments. Attention is being turned to optimization of particular fuel design features to improve fuel cycle economics. Information is also being built up on the alternative fuel concepts to exploit the full potential of the low fuel cycle costs of fast reactors.

14. Collaboration and technical discussions on sodium-cooled fast reactors have continued with a number of countries, including France, the Federal Republic of Germany, Japan, Norway, Spain, Sweden and the United States of America.

DESALINATION

15. The UKAEA, in conjunction with leading firms in the field, has continued to investigate water desalination. Cost reductions were achieved in electrodialysis plant, and new materials promising better performance were developed for flash

distillation. Work on pilot plants for freezing and reverse osmosis proceeded satisfactorily, and work continued on the application of reverse osmosis to treatment of polluted water.

APPLIED RESEARCH AND DEVELOPMENT

16. Significant advances were made in understanding the damage caused by radiation to reactor and other materials, and new techniques were developed for irradiation and post-irradiation examination.

17. Industrial use of large irradiation sources continued to expand. Demands for wood-plastic composites and on the commercial package irradiation service increased. Construction of three more gamma-irradiation plants is under way by the UKAEA's licensees, bringing the total of British-built plants to 15 (of which seven are overseas). Significant progress was made in electron beam curing of paint, especially in plant development. The assembly of scientific data designed to establish the safety of irradiation preservation of white fish for human consumption neared completion.

18. The use of radioactive tracer techniques was developed both in hydrological and coastal sediment studies, and also in industry, especially for accurate flow measurements and to study the dynamics of industrial process plants.

19. Heart pacemakers, using isotope-powered thermoelectric batteries developed at Harwell, were successfully implanted in two human patients in July 1970, following exhaustive laboratory tests and clinical trials in dogs. The five RIPPLE generators on evaluation trials have now performed satisfactorily for three years. A 33-watt generator has been ordered from Harwell as part of an extended study of unmanned lighthouses.

20. Field trials of the prototype of a portable radon monitor for detecting deep-lying uranium deposits were encouraging and a portable field spectrometer to discriminate between uranium and thorium is being developed. A new method of ore sorting was devised which appears promising, especially for the quartz-pebble-conglomerate type of ore.

21. Modular systems of nuclear and digital data handling equipment are providing a means of rationalizing the complexities of modern instrumentation. The Harwell 2000 and 7000 Series were developed for this purpose; the latter is compatible