INTERNATIONAL ATOMIC ENERGY AGENCY

IAEA-TC-PM-012
December 1993
Original: ENGLISH

COUNTRY PROGRAMME REVIEW
INT/0/053

BANGLADESH

Division of Technical Co-operation Programmes
DEPARTMENT OF TECHNICAL CO-OPERATION

Report on Mission Undertaken

on

21-26 August 1993

by

R. Kamel, Y. Maluszynski, Y. Maudarbocus
H.S. Cherif and P. Morre

CONTENT

INTRODUCTION

Experience has shown that many Member States have difficulty in identifying and prioritizing programmes in the light of their development plans and within the financial constraints of technical co-operation programmes. As a result, a large number of requests are received by the Agency without proper screening by the Member States. The IAEA's Technical Co-operation Programme approved at its Board of Governors for the biennium 1991-1992 includes an interregional project, INT/0/053, specifically designed to undertake in-depth reviews of past and present technical co-operation programmes in recipient countries. The reviews include a mechanism for identifying and prioritizing future technical co-operation with reference to past and present projects and to the countries national development plans. It is expected that this activity will lead to the establishment, in Member States, of medium-term plans for the utilization of nuclear technology which are consonant with overall national development objectives, and to the definition of a useful frame of reference for the future preparation, application, assessment and eventual approval of individual technical co-operation projects.

A five-expert mission was organized for this purpose from 21-26 August 1993 and this document reflects the findings and recommendations of the team. Intensive contacts with heads of institutions, scientists and decision making persons in various sectors in the country were co-ordinated by the Bangladesh Atomic Energy Commission.

The terms of reference of the mission were:

1. To assess the on-going TC projects.

2. To assist the Bangladesh nationals to finalize the formulation of the new requests for 1995-96 TC programme and to establish priority areas with regard to the introduction of national projects involving accelerated technological transfer in order to catalyze national development plans in specific areas.

3. To examine institutional framework suitable for the introduction of these priority nuclear techniques.

For this purpose, discussions were held with officials from the Ministry of Science and Technology, the Ministry of Agriculture, the Ministry of Industry, the National Planning Commission, BAEC, UNDP office and FAO office. The mission visited several institutions and held intensive discussions with the national authorities and local scientists.

1. COUNTRY PROFILE

Bangladesh lies in the north eastern part of South Asia. The country is bounded by India on the west, the north, and the north-east, Myanmar on the south east and the Bay of Bengal on the south. The area of the country is 143,999 square kilometers. The country is largely plain except for some small hills in the south eastern part and is criss-crossed by a number of major rivers and their tributaries. A large portion of Bangladesh lies in the delta of the Ganges, the Brahmaputra and the Meghna rivers.

Present population of the country is about 110 million, nearly 85% of whom live in the rural areas and the literacy rate is about 25%. Bangladesh is one of the least developed countries of the world. At present a programme on universal literacy is underway and primary education has been made compulsory and free with the aim to eradicate illiteracy at the earliest. Efforts are also being made to improve health by providing better health services to all by the turn of the century. Politically the country is governed by a Parliamentary form of Government, elected democratically through adult franchise.

National development strategies are drawn up on the basis of Five Year Plans, which define macro and micro development strategies for different sectors of the economy. At present rolling plans are drawn up under the five year plans in order to account for changes in micro plans and investment opportunities. The Planning Commission is responsible for the centralized and macro planning, while different ministries and agencies in the public sector are responsible for part of the micro planning and for project definition and implementation.

The GDP of the country in 1991-92 was Tk. 903,287 Billion (about US$ 23 Billion), and the per capita GDP was only US$ 208. Incentive packages are now being offered to the domestic and external private sectors in order to give an impetus to industrial activities through their active participation in all sectors of the economy. The total export from the country in 1991 was about US$1.5 Billion as compared to the import amounting to US$2.9 Billion.

2. NUCLEAR RESEARCH IN BANGLADESH

The Bangladesh Atomic Energy Commission (BAEC) is the central organization for research and development activities in the field of atomic energy in the country, and is the main recipient organization which operates two large research centres, namely the Atomic Energy Centre (AEC) in Dhaka and the Atomic Energy Research Establishment (AERE) at Savar, 40 KM from Dhaka. The AERE has under its domain five institutes, these are the Institute of Nuclear Science and Technology (INST), the Institute of Food and Radiation Biology (IFRB), the Institute of Electronics, the Institute of Computer Science and the Institute of Nuclear Medicine. The first four of the institutes are housed at the AERE at Savar, however the Institute of Nuclear Medicine is located in Dhaka. The other recipient institute is the Bangladesh Institute of Nuclear Agriculture (BINA) at Mymensingh. The BINA has been under the BAEC until it was transferred in 1983 to the Bangladesh Agriculture Research Council under the administrative control of the Ministry of Agriculture. At present there are nine nuclear medicine centres at Dhaka, Chittagong, Raj Shahi, Sylhet, Dinajput and other cities, all under the administrative control of the Ministry of Health.

The commercial food irradiation facility (Gammatech) at Chittagong is a joint venture company 51% of which is owned by the Government. The major facility at the AERE at Savar is the three MW TRIGA Mark II Research Reactor which was commissioned in 1986. At the AEC, Dhaka a 3 MeV Van de Graaff Accelerator is used for research in nuclear physics and nuclear analytical techniques.

Bangladesh has been a recipient of Technical Assistance since the mid 1960. The Agency is currently supporting 19 operational projects. The technical co-operation programme in Bangladesh is broad based covering practically all fields of activities in nuclear science and technology including applications of nuclear techniques in agriculture, medicine and industry, research reactor utilization for neutron activation analysis, neutron scattering and spectroscopy, repair and maintenance of nuclear instruments and safe handling of radioisotopes and radiation sources.

3. SECTORAL PROGRAMMES AND INSTITUTIONAL REVIEW

The following sectoral programme and institutional review is based on visits to various institutions and intensive discussions with the relevant authorities during the mission, as well as on available written information. The review covers seven major areas of nuclear applications, namely,

- Food and Agriculture
- Human Health
- Radiation Protection
- Research Reactor and Nuclear Power Programme

- Industrial Applications
- Nuclear Instrumentation and Maintenance
- Nuclear Analytical Techniques

A list of persons contacted during the mission and the programme of the mission are shown in Annexes 1 and 2 respectively.

3.1 FOOD AND AGRICULTURE

Agriculture, including forestry, livestock and fisheries, contributed nearly 40% of the country's Gross Domestic Product (GDP) in 1989-90. Crops alone accounted for about two-fifths, and rice, for almost a quarter of the national output (UNDP, 1989). Agriculture contributed to 13% of the country's total export in 1990 and comprised 24% of the total imports.

3.1.1 Nuclear Techniques to Improve Agricultural Production

Food grains account for about 30% of the average household expenditure and for about 45% of food expenditure. Performance of the food grain sub-sector is therefore the primary determinant of agriculture's growth and to a large extent the growth of the economy. Much of the 9 million hectares of cultivable land is utilized for food grain particularly rice. As a consequence, the country's food security is directly related to its self-sufficiency in grain production. There are expectations that this objective will be achieved before the year 2000. The substantial increased investment in irrigation and the introduction of high-yielding rice varieties have greatly contributed to the observed growth of cereal production in the mid seventies. Nevertheless, high-yielding rice varieties are used only in 30% of the whole rice production area. This indicates that traditional, local varieties, suitable for growing in rain-fed areas, are still widely used. Similarly, there is a lack of modern rice varieties suitable for growing under deep water conditions. High-yielding wheat varieties are used in almost 100% of wheat growing areas, jute in 73%, potato in 63%, and sugarcane in about 60%. The distribution of certified seeds covers a little more than 20% of wheat and jute but only one percent of the rice area. The current capacity to produce certified seeds is far below the required minimum. Crop diversification is very much desired with cropping labour intensive, high market value plants.

For feeding ruminant stocks mainly by-products and residues are used, except in small milk producing regions. Both nutrition and health of livestock are inadequate. It is estimated that routine vaccination by governmental agencies covers only 5-10% of the livestock population.

Agricultural Research Institutions :

R & D activities related to agriculture are the responsibility of six major institutes:

- Bangladesh Institute of Agricultural Research (BARI), Joydebpur
- Bangladesh Institute of Rice Research (BIRR), Joydebpur
- Bangladesh Jute Research Institute (BJRI), Dhaka

- Bangladesh Sugarcane Research and Training Institute (BSRTI), Ishurdi
- Bangladesh Tea Research Institute (BTRI), Srimangal
- Bangladesh Institute of Nuclear Agriculture (BINA), Mymensingh

The Technical Co-operation Projects of the IAEA related to soil science and mutation breeding are located at BINA, in Mymensingh.

<u>BINA is responsible for:</u>

- Breeding of new crop varieties with the use of nuclear and other advanced techniques suited to the whole country, but with a particular emphasis on suitability to areas with special conditions such as high salinity, marshy, hilly and dry zones. Cereals, pulses, oilseeds, fiber crops, sugarcane, important vegetables, fruits and ornamental plants are the subject of mutation breeding.

- Development of integrated pest management to reduce the use of pesticides, genetic control of insect pests of storage grains and pesticide residues management.

- Research and development on biological nitrogen fixation, management of soil for improving physical and chemical quality of soil for sustained productivity, improvement of problem soils, control of soil degradation and pollution, improvement of fertilizer use efficiency, development of bio-fertilizer and management of organic wastes.

<u>IAEA support of BINA:</u>

The BINA has been the only agricultural research institute in Bangladesh receiving TC projects from the Agency in the field of crop improvement and soil sciences. The Institute now has over 300 staff members and significant local support to conduct a research programme.

The IAEA has supported BINA activities since 1976 when it was established as an institute of the Bangladesh Atomic Energy Commission. The Institute is currently (since 1982) under the supervision of the Ministry of Agriculture. The first TC project BAN/5/03 (1976-1981) was implemented with financial support ($1.2 million) of the Swedish International Development Agency (SIDA). These funds were directed mainly for the institutional development of BINA. The next TC project BGD/5/009 on "Isotopes in Agriculture" was implemented from 1984 to 1987. The third project BGD/5/012 on "Nitrogen Fixation in Grain Legumes" was operational from 1986 to 1988 and the fourth one BGD/5/013 (UK funded) on " Nuclear Techniques in Agriculture" was initiated in 1988 and completed in 1992. The last two projects dealt mainly with nitrogen fixation and mutation breeding. Three research contracts related to mutation breeding (RC1921, RC5432, RC4897) and one to soil science (RC3727) were provided to the institute and successfully implemented through Co-ordinated Research Programmes of the IAEA. Currently a TC project (BGD/5/015) on Nuclear Techniques to Improve Agricultural Production (on soil science and plant breeding) and Research Contract RC4503 on nitrogen fixation is being implemented.

IAEA support was mainly concentrated on manpower development through an intensive fellowship programme, participation of young scientists in training courses, provision of expert services, and the building-up of infrastructure for research on mutation breeding and soil sciences.

Achievements :

The financial and technical support rendered to the institute through all the IAEA TC projects and research contracts so far have resulted in the transfer and development of many important technologies related to both mutation breeding and soil sciences. Through this support reasonably equipped laboratories were organized which are now used by well qualified scientists. Among them are a plant *in vitro* culture laboratory and a soil microbiology laboratory for inoculum production. To the best of our knowledge, these are the best equipped laboratories in these fields in the country possessing all the necessary facilities for undertaking work related to various biotechnologies for crop improvement. The *in vitro* culture laboratory in particular opens new possibilities for speeding up mutation breeding cycle of seed propagated crops and makes it possible to initiate the improvement of vegetatively propagated crops with the use of mutation techniques.

The **mutation breeding** programme resulted in the development of 8 officially released mutant varieties of rice, chickpea, jute, mustard, mungbean and tomato:

- **IRATOM-24** (released 1974), a boro and aus variety of rice; 10-15% higher yield, 15-20 days earliness compared to IR-8, can avoid rainy and stormy weather. Coverage about 7-10%.
- **Hyprosola** (released 1981), high yielding (20%) and high-protein (4%) chickpea variety; 45% increased protein production/unit area of land. Coverage: 10-12%.
- **ATOMPAT-38** (released 1988), 12-15% higher yield, stipules changed into leaflets (genetic marker), maintenance of seed purity easy, less adventitious roots. Coverage: 10-12%.
- **Binasail** (released 1987), an aman rice variety, partially photoperiod insensitive, low input and non-lodging, most useful for rehabilitation of late flooded areas. Coverage: 5-7%.
- Two new mustard varieties: **Agrani Sarisha** , a yellow, larger seeded variety released in 1991, which has taller and stiffer stem, and tolerance to *Alternaria* black spot and aphid and **Safal Sarisha** released in 1991, with high yield potential, stiff stem, yellow seed coat, 42% oil content and resistance/tolerance to black spot and aphid.
- **Bahar**, a mutant derivative variety tomato developed through hybridization between the mutant Anobik and the commercial variety Oxheart and released in 1992. Bahar gives higher yield than the parent varieties, larger fruit size, fleshier fruit and fewer seeds.
- **Binamung-1** , a mungbean variety released in 1992 which is 15% higher yielding than the recommended variety Kishoregonj and is resistant to *Cercospora* leaf

spot.

There are also a number of promising new mutant lines in pre-release trials including two other aman rice lines (BINA-6-89-4-115 and BINA-5-135-8-163), a boro rice line (BINA-4-39-15-13) and an aus rice line (BINA-4-5-17-19); a mustard line (BINA-2); a chickpea line (G-97); a summer mungbean line (MB-246); and blackgram line (M-25) other promising mutants with good characters like large seed in groundnut, waterlogging tolerance in sesame, earliness and photoperiod insensitiveness in tomato and jute are in the pipeline. The chickpea, mungbean, blackgram and jute lines are expected to be released in 1993.

Achievements in the field of **soil fertility** and **crop production** can be summarized under three sub-topics. They are:

(a) *Improvements in fertilizer management practices.*

Testing of arable soils in Bangladesh has revealed that most of them are grossly deficient in macronutrients N and P, and micronutrients mainly Zn and S. Experiments conducted through project BGD/5/009 concentrated on methods to find ways by which N fertilizer use efficiency of crops could be increased. Studies using ^{15}N labelled fertilizer has shown that only 30-40% of the urea applied for rice is utilized by the crop while the remainder is lost through ammonia volatilization, denitrification or leaching as nitrates. ^{15}N studies have also revealed that a 3 split application of the N fertilizer instead of a 2 split application resulted in better fertilizer use efficiency and 30-50% increases in rice yields. Through the Extension Services Division of the Department of Agriculture, these findings have been taken up to the end users, the farmers. Apparently it is this improved fertilizer management practice which is currently used throughout Bangladesh in rice farming. With the introduction of this 3 split application, rice yields have increased from 2 tons/ha to an average 2.8 ton/ha (a 40% increase). Presently, about 10.5 million ha (80%) of the 13 million cultivated land is under rice. Thus the total increase in grain yield from this alone is around 8.4 million tons which at the present market price (about US$ 150 per ton of rough grain) represents an additional income of US$ 1.3 billion to the farmers.

In another series of experiments where ^{32}P has been used as a tracer, phosphate use efficiency of crops such as wheat, sugarcane and cotton has been found to increase if broadcast and hoed in before planting of seeds instead of simply broadcast only. This practice is now reported to be widely used in the farming systems in Bangladesh. ^{32}P studies were also extended to evaluation of local phosphate rocks as a source of P fertilizer. Direct application of rock phosphate was not found to be suitable for calcareous and saline soils. However, it has been proven to be more effective than triple super phosphate (TSP) in acid soils.

The data generated from these and other conventional studies have now been incorporated into the National Fertilizer Recommendation Guide (1989) which is used by the Department of Agriculture in its extension services.

(b) *Soil physics and water management studies*

The Soil Science Division has carried out several field studies using the neutron probe and gamma density probes to determine the water requirements of various crops such as wheat, chickpea, lentils and mustard. Recommendations for irrigation scheduling have been made for soils in the regions of Ishurdi, Bogra, Madhupur and Satkhira, based on monitoring the changes in water content of the soil profile during the cropping season.

(c) *Biological nitrogen fixation and biofertilizer studies*

Grain legumes such as lentil, chickpea and groundnut play a vital role in providing proteins to the vast rural population which comprises over 70% of the total population in Bangladesh. However, the yields of these crops have been seriously limited due to the deficiency of N in the soil and due to the inability of the farmers to apply N fertilizers because of escalating high prices. Fortunately, these crops have the unique ability to fix and utilize atmospheric nitrogen when in symbiosis with the soil bacterium *Rhizobium* . But these bacteria are not always found in sufficiently high numbers in the soil resulting in poor N_2 fixation and low yields (often about 600-700 kg/ha for chickpea and around 1000 kg/ha for groundnut).

As there is limited scope for expansion of the legume grown area, BINA embarked on a research programme in order to find ways by which grain legume production could be increased per unit of area by increasing the capacity for N_2 fixation. Preliminary studies conducted at BINA under project BGD/5/012 using the ^{15}N isotope dilution technique demonstrated that certain elite *Rhizobium* strains isolated locally could increase N_2 fixation by 30-50% contributing 70, 80 and 100 kg N/ha nitrogen fixed for chickpea, lentil and groundnut, respectively. Biofertilizers (*Rhizobium* inoculum) developed from these resulted in yield increases of 30-40% in the farmers fields. Through assistance given under a subsequent project BGD/5/013, the counterparts also established pilot plants and developed technology for small scale production of biofertilizer packets. In collaboration with the Extension Services Division of the Department of Agriculture, the counterparts have conducted some 200 lentil trials, 1038 chickpea trials and 700 soybean trials in farmers' fields during the period 1991-93 alone. These trials have been accompanied by field training of farmers through mass media approach. In 1989-90, Bangladesh produced 155,000 tons of lentil, 70,000 tons of chickpea and 52,000 tons of groundnut amounting to a total of 277,000 tons which still could not meet even the national demand. Thus, a yield increase of 30% or an additional output of 83,000 tons could bring an additional income of US$ 27 million to the farmers. At present BINA produces about 20,000 packets of *Rhizobium* biofertilizer per annum each containing 250 grams of fertilizer. This is sufficient only for about 5% of the land presently under pulses. What is therefore urgently needed is to introduce technology for large scale production of biofertilizers and to develop the logistics for its country-wide distribution for use by farmers. To this end, BINA has recently entered into an agreement with a **private sector company** who is willing to embark on a large-scale biofertilizer production project with technical assistance from BINA. BINA's hope is that with this new venture Bangladesh will enter into a new era in legume production contributing substantially to the national economy.

The research of other divisions in BINA has also been basically supporting studies for the soil science and breeding programmes. Research in pest and disease management has been closely associated with screening new mutant crop lines as part of the plant breeding programme as well as development of suitable technologies for controlling major diseases through chemical means cultural practices and integrated pest management (IPM).

3.1.2 Food Irradiation

Shortage of food and agricultural products is considered to be the major problem in Bangladesh. Although food production has been rising rapidly, still the short fall remains the same or more due to increase growth rate of the population. Moreover, post-harvest losses by insects and other organisms during storage, marketing, etc stand at about 10-12% of the total produce. In Bangladesh, food preservation methods, such as canning, deep freezing, refrigeration are almost non-existent for home consumption and export purposes. To reduce the huge loss and to increase the availability of food, the Institute of Food and Radiation Biology (IFRB) has been conducting studies in the application of ionizing radiation for the following purposes:-

(a) Disinfestation of food and agricultural products and development of suitable packaging materials and methods for storage.
(b) Preservation of fresh fish, meat, etc.
(c) Sprout inhibition of potatoes & onions.
(d) Shelf-life extension of fruits & vegetables
(e) Sterilization of medical products.
(f) Control of management of pests in field.
(g) Techno-economic feasibility studies of irradiation processing of food and food products.

These R&D Programs have been successfully carried out and the research findings enable the end-users and private industrialists to adopt this technology. Moreover, in recognition of R&D achievements the Government of Bangladesh has accepted irradiation preservation of 13 food items in 1983.

For commercial implementation of the technology the IAEA TC Project on "Food Irradiation - BGD/5/010" was approved by the Agency in 1984 with the following objectives:-

(a) To continue further R&D activities for successful commercialization of Food Irradiation Technology for the benefit of the country.
(b) To establish a Demonstrating Irradiation Facility which would ultimately lead to the transfer of food irradiation technology to private enterprises in Bangladesh.

After encountering numerous delays and set-backs due to unforeseen reasons, the Gammatech Food Irradiation Facility at Chittagong was inaugurated by the Hon'ble

Minister for Education, Science & Technology on 30th March, 1993.

This joint venture project between BAEC and BEXIMCO was conceived as a purely service-oriented commercial enterprise by the sponsors of the Gammatech Ltd. The sponsors have invested about 1 (one) million US dollar in local currency mostly by taking bank loan with high interest rate.

Before handing-over the Gamma Irradiation Facility, the Russian Team measured the dosimetry of the source at different product density levels and estimated the total strength of the Cobalt-60 Radiation Source which was found to have decayed to the present strength of about 85,000 curie. Technical Staffs which now consist of Plant Manager, Radiation Safety Officer, Quality Control Officer, Scientific Assistants, 3 Operators and 2 Technicians were attached to the Russian Team during installation period and they were thus trained in their respective areas.

Present utilization of Gammatech Irradiation Facility:

Since the Plant was commissioned in late March, irradiating potatoes and onions this year could not be made as harvesting time of these crops lasts from December to February. By late March these crops were already stored in cold storage for conventional preservation. The chance of irradiating dried fish was missed as the peak season for catching and sun-drying of fish lasts from November-February each year. By late March, the dried fish is normally treated with pesticides for storage in whole-sellers' warehouses. Irradiation of any frozen foods could not be undertaken since with the present strength of the radiation source a processing time of more than 6 hours would be required to deliver the required doses and by the end of this time the ice would start melting. For the last few months irradiation of some food items and medical products were made. About 400 cft. of medical products for sterilization and about 5 tons of dried fish and 4 tons of pulses were irradiated for marketing demonstration. Most of the Pharmaceutical Manufacturers are presently using Ethylene Oxide for sterilizing their products. It will take some time before they can replace their arrangements and get used to the advantages of radiation sterilization and/or new industries are established depending solely on radiation sterilization services.

The Company has undertaken a promotional marketing drive by appointing a full-time Marketing Executive and has also published and distributed some brochures and leaflets highlighting the purposes and benefits of irradiating different food and medical products. It has enlisted the names of prospective clients for radiation services from the Food and Pharmaceutical Industries and approached them individually by personal correspondences and visits. The Company has got encouraging responses from them and expects to have reasonably good utilization of the Radiation Plant for irradiating food materials in the coming seasons. On the basis of this response full utilization of the radiation facility is prepared with the present 85,000 curie source. This will include annual irradiation of 1,600 tons of potato and onion, 3,000 tons of dried fish, 1,200 tons of pulses and grains and 30,000 cft of medical supplies with a total estimated annual revenue of 17 million taka. These figures only represent a small proportion of the country's production of these items, as for example, the yearly production of

Chittagong area alone is 66,000 tons of potato and 20,000 tons of dried fish. Moreover, there is a growing production of medical supplies including disposable gloves and eye drops containers. With the present source strength the plant has to run at a level of about 73% of the plant capacity just to reach the break-even point, which is a rather ambitious target in the first few years.

The mission visited the Institute of Food and Radiation Biology at Savar and the food irradiator facility at Chittagong and held detailed discussions with the counterparts and the Director General of the facility.

The Gammatech Ltd facility has numerous design deficiencies which compromise employee safety and the application of appropriate process control. These deficiencies are fully described in the mission's recommendations (Annex 3) and have already been discussed with the Director General and the technical staff of the facility.

3.1.3 Agrochemical Residues

The usage of pesticides in Bangladesh has been increased in recent years following an increase in food production. Although, per hectare consumption of pesticide chemicals is still low, the usage has been doubled in the last 10 years. It is estimated that insect pests destroy about one-third of the harvests and yield would probably decline by 30-75% without crop protection chemicals. The effects of these substances on non-target organisms, their accumulation by biota or their transfer to the higher trophic levels of the food chains under specific circumstances are uncertain and need to be studied.

Prior to development of the agrochemicals research laboratory at IFRB, Savar under the IAEA footnote "a" TC Project BGD/5/014, supported by the Government of the United Kingdom, no serious attempt was made by any quarter to develop laboratory infrastructure for such studies of pesticide in the country. Within about 2 years of its existence, the analytical facilities are being fruitfully utilized in monitoring residues in food and environment and in carrying out specialized research to promote safe and effective regional activities. Under this project, the laboratory was provided with a gaschromatography equipment with various detectors, sample oxidizer, flame photometer, liquid scintillation counter, C-14 labelled pesticides, centrifuge, tissue homogenizer and other miscellaneous items of laboratory equipment and supplies.

As a result of the Agency support a pesticide residue analysis laboratory, first of its kind in the country, has been developed with basic equipment and facilities. The Agency support has also contributed significantly to manpower development in support of monitoring pesticide residues in food and environment and to conduct studies on various problems related to uses of pesticides.

Of food and environmental samples studied the results of a particular species of dried fish need special mention. Samples of dried fish collected from different retails and wholesale markets of Dhaka and Chittagong were investigated for pesticide residues. Most of the samples investigated showed DDT contamination ranging from 0.5 to 70 ppm which are relatively high concentrations for an internationally prohibited pesticide. Similarly cow milk samples showed the presence of DDT and its toxic metabolite. Surface and underground water, and soil samples from different regions of the country are also routinely monitored.

3.2 HUMAN HEALTH

Bangladesh with a population about 110 million and literacy rate of about 25% is one of the least developed countries of the world. The infectious, communicable and deficiency diseases are still formidable health problems.

To cope with the gigantic health problem, the Government has initiated several programmes. There are now 8 medical colleges in the country which impact training which lead to medical degrees. In addition there are facilities for training of nurses, paramedics and health assistants.

There is also an Institute of Post-graduate Medicine and Research situated in Dhaka which has been offering post-graduate studies in various fields. Several specialized Institutes like the Institute of Public Health, Institute of Ophthalmology, Institute of Chest Diseases and Institute of Orthopedics are affiliated to the post-graduate Institute.

All the Medical Colleges and above mentioned Institutes have attached hospitals with bed capacity ranging from 500 to 1000. These hospitals have diagnostic and therapeutic facilities.

The Government has also been taking necessary steps for eradicating infectious and communicable diseases and improving nutritional condition through its own resources and international aid agencies.

3.2.1. Nuclear Medicine :

The usefulness of application of nuclear techniques in medical diagnosis was felt long ago and the first Nuclear Medical Centre was established as early as 1962 in Dhaka. With expansion of national health programme, greater need for nuclear medicine was realized and two centres were established in Chittagong and Rajshahi by 1970. By this time, it was felt that such facilities should be created in all major hospitals in the country and a central institute would be necessary for training, standardization and co-ordination of activities in nuclear medicine. With this aim in view, Bangladesh Atomic Energy Commission (BAEC) established nuclear medicine centres in all major hospitals and an Institute of Nuclear Medicine was set-up in the premises of the Institute of Post Graduate Medicine and Research (IPGMR) Dhaka, which is a component of the Atomic Energy Research Establishment.

National Inputs in Nuclear Medicine :

Increased demand for the improved diagnostic ability and therapeutic services provided by nuclear medicine centres has resulted in the emergence of 9 centres in the country during the last 10 years. The influx of both in-and out- patient to these centres is increasing. There is a total of 10 Gamma Cameras in the nuclear medicine centres out of which only one has been provided by the IAEA. All radioimmunoassay facilities have been provided by the IAEA.

All required radioisotopes and related materials needed for the nuclear medicine centres are procured routinely by BAEC from its own resources. The annual expenditure in this sector is about 150,000 US$.

In addition to the assistance given by IAEA and other International Organizations, considerable efforts are also undertaken on a national basis for the development and upgrading of the nuclear medicine facilities in the following way:

Orientation courses are held at the Institute of Nuclear Medicine for newly recruited physicians, physicists and technologists in nuclear medicine technology. The Institute also conducts one year Diploma in Nuclear Medicine (DNM) at the University of Dhaka for physicians specializing in Nuclear Medicine.

In addition, workshops and training programmes are conducted as continuing education from time to time. These courses cover aspects of clinical nuclear medicine, physics and computer as related to nuclear medicine. Training of post-graduate students from other related specialities in medical science are also offered in the Institute of Nuclear Medicine routinely as a part of its participation in the activities of Institute of Post-graduate Medicine and Research.

Total scientific manpower in the existing nuclear medicine centres are given below:

70 Nuclear Medicine Physicians, 9 Medical Physicists, 3 Biochemists, and 120 Technologists.

A quality control programme has been adopted to ensure optimal quality of work. Quality assurance is achieved by applying Q.C. checks in all phases of nuclear medicine process on a routine basis. In addition to the materials provided by IAEA, BAEC's scientists has also innovated several quality control facilities including designing a phantom for gamma camera.

The electronics scientists and engineers of the commission have been engaged in routine repair, maintenance and upgrading nuclear medicine instrumentation in the country.

The IAEA technical assistance to Bangladesh in this field commenced in the year 1974. Assistance so far provided by the IAEA included the supply of equipment, training of manpower, expert services, and maintenance and quality control. The major equipment provided by the Agency included: whole body counter, liquid scintillation counter and one gamma camera to INM, two rectilinear scanners to NMCs, Rajshahi & Chittagong, thyroid uptake system to NMC, Sylhet, three channel renogram to NMC, Rajshai, and recently a SPECT has been provided to the Institute of Nuclear Medicine, Dhaka under a footnote 'a' project (BGD/6/011) supported by the Government of the USA.

The assistance provided under different projects have contributed greatly in the development of nuclear medicine in the country and has complemented the national efforts for procuring equipment. Development of trained manpower has resulted in better utilization and expansion of the resources with introduction of new studies and improved diagnostic abilities. This is also helping to build up a competent and knowledgeable nuclear medicine team in Bangladesh with experience and ability to conduct their own training programmes. The development of RIA laboratories in the Institute of Nuclear Medicine and in 5 nuclear medicine centres in Bangladesh have been a direct contribution of these TC programmes.

Imaging devices used routinely in the Nuclear Medicine Centres include rectilinear scanners and gamma cameras. Even though the rectilinear scanner has been largely replaced by the gamma camera, it is still used for thyroid imaging. During the last few years various mechanical and electrical faults of the scanner are being repaired in-house by the national equipment maintenance division.

Routine work includes imaging of different organs, dynamic studies, probe renogram, thyroid uptake studies, RIA of thyroid and other hormones, Vit. B_{12} absorption and RBC survival studies, and certain studies on communicable diseases.

3.2.2 Radiotherapy

Currently there are radiotherapy departments in Dhaka, Sylhet, Rajshahi, Mymensingh and Chittagong Medical College Hospitals. There is also a Cancer Research Institute in Dhaka providing radiotherapy services.

The status of radiotherapy is not satisfactory in the country due to multifactorial causes, chiefly limited resources and lack of funds. The cobalt and caesium machines available in the Dhaka medical college hospital are functioning properly. Management of cancer patients is limited and inadequate and a large population requiring radiotherapy are deprived of it. Recently the Government has taken up plans to upgrade and strengthen the cancer research institute in the country. But it would still be inadequate to cope with the increasing number of cancer patients. The nuclear medicine centres are already involved and are responsible for the treatment and follow-up of majority of thyroid cancer and other patients. The institute of post-graduate medicine and research where the institute of nuclear medicine is located has plans to create a radiotherapy department in the near future.

3.2.3 Tissue Banking

Bangladesh is a densely populated country where the number of road accidents, burn-wound and the incidence of various other diseases are very high. Thus various types of tissue allograft are very important for transplantation to cure these patients and save them from physical handicaps.

R & D work on "Tissue Banking" was started from December 1985 under the IAEA research contract No. 4158/RB and subsequently, as from 1991, under the on-going project BGD/7/005. Based on local availability, amnion membrane graft preparation work was started at first. Now amnion membrane grafts are supplied on a regular basis to the hospitals in Dhaka for the treatment of burnt patients as temporary biological dressing.

Work on "Bone Banking" procedures has been started under the on-going TC project from early 1992. Human and calf bone has been collected for establishing the procedure for bone graft preparation. On experimental basis, some radiation sterilized bone grafts have been supplied to the Dhaka orthopaedic hospital and Dhaka medical college hospital. Human bone granules have also been prepared and supplied for the treatment of dental patients. Till now, a limited number of patients were treated by the radiation sterilized bone grafts. In conclusion, the AERE at Savar now has a relatively well equipped laboratory for the preparation of tissue grafts (radiation sterilization, freeze drying and microbiological control) for surgical purposes.

3.3 RADIATION PROTECTION

The applications of radioactive sources and ionizing radiation are increasing in Bangladesh. There are several facilities in the country having large radiation sources. These include a 3MW TRIGA Mark II Research Reactor installed in 1986 at the AERE, Savar; Co-60 food irradiator at Chittagong; a 3 MeV Van de Graaff accelerator installed in 1964 at the AEC, Dhaka; a Neutron Generator installed in 1983 at INST, AERE, Savar; a large number of X-ray machines of different types and models used for medical diagnosis and therapy; industrial radiography equipment and radioisotope production facilities at INST, AERE Savar. A significant number of high radiation sources of varying strengths nominally ranging from 3 kCi to 113 kCi of Co-60 and a few kCi of Cs-137, including several teletherapy units, are installed in BAEC and several outside organizations including hospitals. Several SSDL calibration sources, 241 Am-Be neutron and Cf-252 fission sources are also available at BAEC. 6 MV linear accelerator has been installed at the Combined MilitaryHospital, Dhaka. Several sealed Ir-192 sources (each around 100 Ci) are constantly used for NDT purposes. A large amount of radioisotopes including radioactive labelled compounds are used in nuclear medicine, agriculture and research. A bulk volume of thorium nitrates is used by several private industries for gas mantle preparation. Several of Ra-226 needles are available in several hospitals. A large quantity of monazite tailings (thorium ore) is produced from the separation of heavy minerals of beach sands from Cox's Bazaar and an off-shore island in the Bay of Bengal. Low and intermediate levels of radioactive wastes, including spent resins, are continuously generated from the operation and maintenance of the TRIGA reactor.

The BAEC is the only organization in Bangladesh fully empowered by the Nuclear Safety and Radiation Control Law, 1993, and in principle responsible for looking into all matters pertaining to radiation protection activities in the country, in close collaboration with the relevant organizations and ministries. Health Physics Division of AEC, Dhaka, the Health Physics and Radiation Protection Division (HPRPD), INST, AERE, Savar, and the Radioactivity Testing Laboratory (RTL), Chittagong, have been functioning since 1965, 1983 and 1987 respectively. These laboratories are mainly concentrating on radiation protection and health physics routine and R&D activities including personnel and environmental dosimetry and radioactive waste management in addition to regularly offering local training and academic courses including DMRT and DMRD. The Nuclear Safety and Radiation Protection Division (NSRPD) has been functioning since August 1987, to assist (among other work) the BAEC and the Government in the activities relating to promulgation of the nuclear safety and radiation protection law and to supervise/co-ordinate R&D activities of different centres in safety and radiation protection disciplines.

The present manpower in BAEC for radiation protection numbers only 26, of which 11 have been trained abroad under the Agency's fellowship training programme. Several more persons trained earlier have either retired or left the country. BAEC provides basic orientation training in the nuclear field to newly recruited personnel.

Before promulgation of the Radiation Protection Act in June 1993, the NSRPD of BAEC had very limited radiation protection activities at a national level with only one radiation testing laboratory, established in Chittagong in 1987, undertaking certain limited tasks in the Chittagong area. However, the following activities are being organized on a limited scale by the NSRPD:

- Formulation of regulations, safety guidelines, directions, control and co-ordination of the activities involving radiation protection in the country under the provision of the Nuclear Safety and Radiation Control Act, 1993.

- Issue of licenses, permits for import, export and procurement of radioactive materials and conduct of surveillance activities involving the use of such materials.

- Assessment and evaluation of the background levels of radiation and radioactivity.

- Establishment of permissible levels, authorized limits, intervention levels, pertaining to radiation protection and safety.

- R&D activities for maintaining of radiation protection activities including radioactive waste management.

- Making contacts and maintaining liaison with relevant establishments and organizations/agencies both within the country and abroad on matters of nuclear safety and radiation protection.

- Advisory co-ordination activities including emergency planning preparedness, dissemination of information, international nuclear event scaling (INES) and reporting in the event of deviations, incidents, accidents or emergencies involving ionizing radiations.

- At present, the personnel monitoring service (for beta, gamma and X-rays) using film badges to a total number of about 1000 persons of 23 organizations (including BAEC, Defence Services of Bangladesh, etc.,), are being offered through the Health Physics Laboratory, AEC, Dhaka; the films are replaced on a quarterly basis. The programme of neutron dosimetry and beta-gamma personnel monitoring using TLD are being taken up at Health Physics Laboratory, AERE, Savar. Presently available personnel dosimetry services could not meet the above mentioned requirements.

A Radiation Protection Advisory Team (RAPAT) visited Bangladesh in June 1988 with the main objective of strengthening radiation protection activities. The mission assessed radiation protection activities in the country and identified priorities. It was then observed that the use of radiation sources was not regulated and that a number of them (mostly X-ray machines) were not under any control. As a result of the RAPAT mission, a radiation protection TC project on occupational radiation monitoring was initiated in 1989, designed to assist BAEC in preparing basic nuclear legislation and the regulatory framework for radiation protection. The detailed objectives may be seen in "RAPAT mission to Bangladesh" (IAEA-TA-2430 dated 30-01-1989). It was recommended in that report that a Radiation Protection Act, not existing in Bangladesh, should be promulgated at an early date. Under the provision of this act rules, regulations, standards, codes of practice, methodologies, etc. pertaining to the safe use of ionizing radiation would be formulated and implemented by a proposed radiation protection infrastructure.

The "Nuclear Safety and Radiation Control Bill 1993" was duly passed by the National Parliament on 14 July 1993. The bill empowers the BAEC to issue licenses, permits, orders and directives and to adopt necessary rules and regulations and by-laws to control all activities related to the use, production, import, export, transportation, storage, processing and transfer of all types of nuclear and radioactive materials and equipment for producing ionizing radiations.

The bill provides the establishment of necessary infrastructure and formulation of expert committees for implementation of the law, provision for issuing licenses and permits, etc. The bill duly authorized BAEC and the court to award prison sentences for a minimum of three years and maximum of seven years to violators of the Act.

3.4 RESEARCH REACTOR AND NUCLEAR POWER PROGRAMME

The BAEC installed the 3 MW TRIGA Mark II Research Reactor at the AERE at Savar in September 1986 aiming at establishing the basic infrastructure in nuclear science and technology for the promotion of peaceful uses of atomic energy in Bangladesh.

In support of this, the Agency, through its technical co-operation programme made possible the training of several reactor operators from Bangladesh at different TRIGA Reactor in various countries. In addition, equipment needed for start up, testing and maintenance, as well as expert services to assist with the initial fluxes measurements after commissioning and to conduct operator licensing examinations, were provided.

The reactor is now operational, but not at full power. In order to help the Bangladesh in improving the utilization of the research reactor, the Agency is assisting the INST at AERE to develop:

- radioisotope production
- neutron activation analysis
- neutron scattering studies
- and neutron radiography.

The TRIGA Mark II Research Reactor has had cooling and vibration problems in the past 2 years and is still not available for long term irradiation of samples for radioisotope production and for neutron activation analysis at high power. Only short irradiations, for a few hours at a time, and at power level not exceeding 2 MW can be performed on a limited number of samples.

3.4.1 Radioisotope Production

A radioisotope production laboratory has been built at the AERE, Savar. Under a multi-year TC project initiated 1982, the Agency has already provided a radioisotope production line for technetium-99m by methyl-ethyl Ketone (MEK) extraction method and an iodine-131 facility for iodine-131 labelling and dispensing, and related equipment, as well as experts services to advise on the production of primary radio isotopes. Mention should however be made that the I-131 production facility supplied by the Agency during 1987-88 was installed but was not utilized for production purposes. This is to an extent due to the fact that the research reactor was not working to its full capacity because of a problem in the primary cooling system of the reactor. The laboratory special ventilation system was not functioning properly. However, the two problems are over but still the reactor cannot be operated for a long time at its high power. With the help of the Agency expert the MEK facility was shifted into the new building of the Isotope Production. It has been noticed that some parts of the MEK facility and the I-131 labelling and dispensing lines were worn out and have to be replaced. Under an on-going TC project BGD/4/014 in cell equipment and technology for production of Mo-99/Tc-99m Column type generator production line is also being provided with a view to cutting down on the import of technetium generators. However, this project has suffered from certain delay in fabricating the shielding framework, lead bricks and the support table. The mission noticed that the laboratory ventilation system is in a good working condition. Scientists from BAEC have already been trained for Tc-Kits production as well as radioisotope production.

3.4.2 Neutron Activation Analysis

The INST at the AERE has a good infrastructure to conduct basic research and practical applications using neutron activation analysis, instrumental and radiochemical, as a powerful analytical techniques.

Equipment, mainly gamma spectroscopy systems, located in the neutron and reactor physics division and in the chemistry division, are already available for instrumental neutron activation analysis.

Several staff members from both divisions, the neutron and reactor physics division and the chemistry division, seem to be competent scientists to carry out neutron activation analysis. All of them have had training for sample preparation and in performing radiochemical neutron activation analysis. The training they had included the preparation of all possible samples to be irradiated in the reactor:

- preparation and use of chemical irradiation standards
- preparation of mixed standard solutions
- preparation of soil and ore samples for uranium and thorium determination
- preparation of air particulate samples
- preparation of water and sediment samples.

The main objectives that were set right from start by the neutron activation analysis group were to apply these techniques in a variety of fields where analysis of trace and major elements were needed, in industry, in mining, in agriculture, in environmental and health related problems. This programme was designed to lead to:

- the determination of uranium, thorium and rare earth elements content of geological samples,

- the analysis of industrial effluent and determination of toxicants like chromium from the discharge of leather and tannery industries, arsenic from glass and fertilizer factories and cadmium from the textile and the paper industries,

- the determination of major and minor elements in imported baby food,

- the determination of essential and toxic elements in biological samples like fish, meat vegetables, cereals, etc,

- the determination of iodine in drinking water and analysis of organochlorides.

The work performed so far by the team of scientists can be summarized as follows:

- all the basic laboratory facilities have been set up and are in operating conditions.

- analysis for uranium and thorium contents in rock samples from Pholtala, Rajkie, Merina and other areas of Moulavi bazaar (North East part of Bangladesh) were performed.

- soil samples from the surface and from different depths of Sylhet area were analyzed.

- analysis of heavy maculas like ilemenite, rutile and magnetite were carried out. Sample from Cox's Bazar beach sands are being analyzed for Ti. Gr, Li, Th, Fe, Cu, Ni, Zn and rare earth elements content.

The work that is still in progress covers the following areas:

- Analysis for the determination of uranium, thorium and rare elements content in sea bed sediments from karnafully estuary zone in the bay of Bengal.

- Analysis of tobacco from different brands for trace and toxic elements.

It should be noted that neutron activation analysis of river and sea bed sediment samples, are being performed in collaboration with Jahangirnagar University. 10 M. Sc. and M.Phil thesis students and one PhD student from Dhaka and Jahangirnagar Universities are working with the neutron activation analysis group, which provides good opportunities for advanced studies for young researchers and students.

3.4.3 Neutron Scattering

A triple axis spectrometer provided by the IAEAunder technical co-operation project BGD/4/009 was installed at the piercing beam port of the TRIGA Research Reactor in June 1992.

An opening in the wall of the reactor hall was made to house the control panel and the instrumentation of the triple axis spectrometer in order to have a direct view on it. This might prove to be a major safety problem for the operation of the reactor and has to be reviewed as early as possible.

The performance of the spectrometer has been tested using standard samples like Al and Al_2O_3. The results obtained were termed as satisfactory.

Studies of Potassium Di-phosphate (KDP), Ammonium Di Phosphate (ADP) and mixtures of both for structural analysis were carried out and are to be continued.

Neutron diffraction experiments on ferrite samples were performed and a collimator is being fabricated in collaboration with the engineering university (B.U.E.T).

The collaboration between the Institute of Nuclear Science and Technology and the University is taking form with the participation of one PhD student, two M.Phil and four graduate students to the experimental work of the neutron physics group.

3.4.4 Neutron Radiography

The facility for neutron radiography installed in the reactor hall includes a conical diverging collimator, a Bi filter,a sample and camera holder table, a beam stopper, a beam catcher and a biological shield house. A room outside the reactor hall is available for developing and analyzing radiographic films.

So far, the work performed allowed to determine the essential radiographic parameters-neutron flux,cadmium ratio, gamma dose, neutron to grammy ratio - the exposure time for different fails and the distance of the sample position from the biological shielding wall. Resolution tests were carried out using the sensitivity indicator (S.I) and the beam purity indicator (B.P.I).

The neutron radiography facility is being used to study the absorption of water in different types of bricks such as Siporex, Beton bricks and Opeka, and for testing the wielding quality of some samples supplied by Romu industries (Aluminum tubes and plate welding).

The future work programme of the group includes the study of corrosion and cracks in aluminum structures and the study of defects, voids and any inclusion in ceramics, rubber and plastic products.

3.4.5 Nuclear Power Programme

A fast growth in the electricity generation has been envisaged by Bangladesh authorities in the different energy planning and projections that were carried out. It was felt that a high growth rate of the electricity sector, as can be seen from the table below, is necessary for the growth of the entire country.

Year	1990	1995	2000	2005	2010	2015	2020
Energy Growth Rate	7.3%	7.4%	8.8%	9.9%	8.3%	8.6%	8.6%
Peak Load (MWe)	1717	2523	3893	5664	7885	10558	15705

Government studies have shown that reserves of indigenous primary energy resources of Bangladesh are not adequate to meet the increasing demand for electricity. Considering this and other factors, nuclear power was identified by the national energy policy makers as a viable option for the country as early as 1961.

A site for a nuclear power plant was selected at that time at Rooppur in Pabna (in the Western Zone of the country) on the basis of internationally acceptable criteria on sitting of nuclear power plants. Land for the plant and for a housing complex was acquired. A number of technical and economic feasibility studies were carried out since then, all of which confirmed that nuclear power was a viable proposition. Human resources for the project can be developed utilizing the available facilities and through contractual arrangements with the suppliers.

The Government of Bangladesh attaches top priority to the project. A committee has been formed, with the Prime Minister as its Chairperson, which has been entrusted with the responsibility to identify problems and suggest measures in solving them in order to facilitate early implementation of the nuclear power project.

It is worthwhile to note that IAEA assistance on development of human resources for nuclear power technology had started in the 60's, which had helped the country in building the core manpower. The delay in the implementation of the project has depleted this manpower. Many senior professionals were expected to retire in course of next 5-6 years, thereby resulting in a critical situation in human resources.

Offers for nuclear power plants were received in the past from some potential suppliers. It was felt that such offers did not materialize for different reasons like:

a. Lack of confidence that a nuclear power project could be implemented and operated in a developing country like Bangladesh;
b. Misgivings on the part of international development financing institutions and other financiers in technical and economic viability of nuclear power in the developing countries;
c. General notion that nuclear power is not safe, not environmentally compatible and problems of radwaste management are unsurmountable.

3.5 INDUSTRIAL APPLICATIONS

In the area of industrial applications of isotopes and radiation technology, two main activities are on-going, these are non-destructive testing and radiation processing technology.

3.5.1 Non-Destructive Testing

Non-Destructive Testing (NDT) is one of the most effective measures of quality control in industrial production, construction work, maintenance and safety testing. In Bangladesh there are many old and new industries like the oil refinery, power generating stations, oil and gas pipe lines, paper mills, steel mills, ship building, fertilizers factories, pharmaceutical industries, tube manufacturing plants and after chemical industries which need NDT services. Due to a good degree of awareness for testing, inspection, quality control and quality assurance, the NDT techniques are being applied in these industries, and their applications are growing rapidly.

BAEC is the pioneer and leading organization in Bangladesh for applications and development of NDT technology through assistance of UNDP, IAEA and RCA programmes since 1982. Beside BAEC some industrial organizations like Bangladesh Chemical Engineering Corporation, Bangladesh Oil, Gas and Mineral Corporation, Bangladesh Airlines and Bangladesh Railways have some NDT facilities of their own.

In addition to the development of radiographic inspection techniques using different radiation sources, several other NDT techniques have been developed at BAEC including ultrasonic inspection of metallic and non-metallic materials. Immersion testing techniques, eddy current testing techniques and Magnetic particles and Penetrant testing techniques. All leading industries in Bangladesh have been receiving necessary NDT services of various kinds from BAEC. In addition to NDT services, BAEC has also offered a comprehensive training and certification programme in Bangladesh with the objective to attain self reliance in the field of NDT technology. NDT personnel certification committee has been constituted with the objectives to attain self reliance in the field of NDT technology. NDT personnel certification committee has been constituted with the representative from different organizations with the approval of the Government of Bangladesh. Several courses have ben organized in various NDT techniques at different levels. Over 150 participants have been trained and qualified in these courses. These training courses were organized in accordance with standard IAEAsyllabi and specified in IAEATECDOC 407 "Training Guidelines in NDT Techniques" and ISO Standards as specified in ISO/TC, 135/SC7/N35-E DP 9712" General Standards for the qualification and certification of NDT personnel".

As a result of this comprehensive programme the country is nearly attaining self reliance in the field of NDT technology and the foreign dependance in this field is becoming greatly reduced. As a result, the local industries are getting NDT services which are more economical, readily available, and result in saving considerable amount of foreign exchange.

3.5.2 Radiation Processing Technology

In Bangladesh, the production of natural rubber latex has been growing steadily over the last several years. The use of wood is increasing day by day and there is a scarcity of high quality wood in Bangladesh either for furniture or for other qualitative wood work. Bangladesh export a substantial quality of leather products to foreign countries earning about 80 million US dollars annually.

The Agency, under a regional co-operative agreement project supported by UNDP, has been promoting the industrial application of radiation polymerization. The BAEC, which is taking part in this project, has carried out some research on such subjects as a polymer modification and the curing of surface coating with the aim of improving the quality of local low-grade woods and certain wood-related material and leather. A study on wood/plastic composites has been in progress since November 1985. Under two TC projects BGD/8/008 "Radiation Processing Technology" and BGD/8/008 "Radiation Induced Vulcanization of Natural Rubber Latex (RIVNRL). The technology for surface curing under UV radiation have been developed for wood, leather and paper.

The technology for RIVNRL has also been developed through UNDP/IAEA/RCA regional project. The TC projects are to complement the regional project and to establish the necessary infrastructure required for RIVNRLand for UV surface curing. The basic equipment, including a laboratory-scale ultra-violet light curing unit, have been provided. The Agency experts advised on organization of laboratories and research programme and AERE staff have been trained abroad on these technologies and the counterpart institute is now well prepared to carry out the research and to transfer the technology to local industry. All equipment provided under TC-projects were in a good working condition and well looked after.

3.6 NUCLEAR INSTRUMENTATION AND MAINTENANCE

In line with the recommendations of an Agency pre-project planning mission to Bangladesh, a technical co-operation project entitled "Nuclear Instrumentation", (BGD/4/011) was initiated in 1988 with a view to strengthen the repair and maintenance capabilities of the AERE, Savar, which also houses a TRIGA Mark II research reactor, a neutron generator, and a multi-purpose gamma irradiator, amongst other major equipment items. The intention was for this institute to serve the needs of the whole of the BAEC, including the AEC, Dhaka, as well as other institutions benefitting from the Agency's technical co-operation programme.

However, it soon became apparent that, primarily because of the distance between Savar and Dhaka, a supporting electronics unit had to be established at AEC, Dhaka to relieve the continuing problems with instrumentation. Thus, a second project on nuclear instrumentation (BGD/4/013) was approved and started in 1989.

Both projects were subsequently extended to cover the period 1993-94, under project number BGD/4/017.

These projects were successful in the sense that they helped to reduce considerably delays caused by non-functioning instruments, not only at the BAEC laboratories in Dhaka and Savar, but also at a number of other institutions including the institute of nuclear medicine in Dhaka and the nuclear medicine centres in Dhaka, Chittagong, Dinajpur, Rangpur and Sylhet as well as other centres. The major equipment items repaired comprise rectilinear scanners, spectrophotometers, ultrasonic flaw detectors, Hp(Ge) detectors, gamma cameras, liquid scintillation counters, whole body counters, thyroid uptake systems, renogram machines, multichannel analyzers, and dose calibrators amongst others.

Both AERE and AEC have also concentrated their efforts on the design and manufacture of some important equipment items which are commonly used in nuclear medicine and other applications of nuclear techniques. These include portable beta-gamma radiation monitors, pH meters, function generators, and a hand and foot contamination monitor. Some of these instruments have been installed in the BAEC laboratories and others sold to outside organizations. Moreover, with the assistance of Agency experts AEC designed and assembled a microprocessor-based general purpose controller for the automation of some experiments, as well as an automatic sample changer for PIXE spectrometric experiments.

Besides, training courses are organized on a regular basis for technicians of the various nuclear medicine centres. Some diploma courses for medical students also include components on nuclear electronic instrumentation.

3.7 NUCLEAR ANALYTICAL TECHNIQUES

There are two establishments of the BAEC, namely, the AEC, Dhaka, and the Institute of Nuclear Science and Technology, Savar, where nuclear analytical methods have been developed.

Since 1978, the Agency has been supporting the AEC to develop nuclear analytical services mostly based on a 3-MeV positive ion Van de Graaff Accelerator which was installed in 1964. Atomic absorption spectrometry and X-ray fluorescence analysis systems have been supplied and the local staff trained in their utilization through the provision of expert services and fellowship awards.

Apart from the available chemical analytical methods such as atomic absorption spectrophotometry, the facilities available at the AEC also include particle-induced X-ray emission (PIXE) analysis, energy-dispersive X-ray fluorescence (ED-XRF) analysis, and radioisotope-induced X-ray fluorescence (RIXRF) analysis. Besides, proton-induced gamma ray emission (PIGE) analysis is in the stage of development.

At the INST, the main facilities for nuclear analytical research are a 3 MW TRIGA Mark II Research Reactor (which has a thermal neutron flux of about 1.4×10^{12} n $/cm^2/s$) and a 14-MeV neutron generator.

The establishment of a fully equipped nuclear analytical laboratory at INST was discussed during an Agency pre-project mission and, in 1988, the Agency provided a gamma spectrometer and a gamma survey meter. The analytical facilities were subsequently extended through the implementation of various technical co-operation projects such as BGD/2/008, initiated in 1989, BGD/4/009 and BGD/4/018. Thus, an instrumental neutron activation analysis (INAA) method has been developed and calibrated for trace element analysis in soil, coal, fly ash and geological samples. Gamma spectrometric analysis of natural radionuclides is in progress, whereas there is some interest to introduce alpha spectrometric methods and radiochemical neutron activation analysis (RNAA). The 14-MeV neutron activation technique is being used mainly for nuclear reaction cross-section measurements.

The objective of AEC and INST is to develop analytical methodologies for practical applications in different sectors of the national economy, including the industrial, agricultural, environmental and health sectors.

4. FUTURE TECHNICAL CO-OPERATION ACTIVITIES AND RECOMMENDATIONS

4.1 FOOD AND AGRICULTURE

Over the last decade, BINA has become a well established institute with highly qualified staff and good facilities, successfully developing the use of nuclear techniques for crop improvement. To follow up the world's trends in plant breeding and genetics, it seems now necessary to concentrate scientific efforts on the implementation of modern biotechnologies to the ongoing mutation breeding programmes. This should be applied to both seed and vegetatively propagated crops. For example, a doubled haploid systems are widely used to speed up mutation breeding cycles of cereals (rice, wheat, barley), various *Brassica* crops or vegetables such as asparagus or most of the species belonging to *Nicotiana* or *Solanum* genera. Similarly micropropagation techniques of some vegetatively propagated crops are an exciting opportunity to initiate mutation breeding programme as demonstrated in banana, potato or chrysanthemum. Transferring of these technologies and developing new ones for other crops, which are significant for the country's economy, should be the highest priority programme of the Institute. Parallel to this, necessary steps should be taken to implement molecular marker techniques to breeding programmes.

BINA should put much more efforts to increase collaboration with other agricultural institutes in the use of mutation techniques and related biotechnologies for crop improvement. This should be implemented through organizing national workshops and/or training courses on mutation breeding and tissue cultures, through undertaking common programmes on improvement particular crops but also by including other institutes (e.g. BARI or Food and Radiation Biology Institute) as co-counterparts in the IAEA TC projects. Such policy will scientifically stimulate BINA's and other institute's researchers, BINA's leading role in the application of nuclear techniques and speed up the implementation of modern biotechnology in the country.

Conventional mutation breeding should be applied to wider spectrum of crop plants. This trend was already observed during our visit but should be further strengthened. This could be also achieved through more close collaboration with other agricultural institutes.

The progress made by BINA in the field of soil fertility and crop production has been very satisfactory. Several important findings have been made with respect to improving crop yields through better fertilizer management practices and increased N_2 fixation capacities of grain legumes especially lentil, chickpea and groundnut. Some of these findings are already in use by the farmers producing higher crop yields especially rice, while in the case of others such as with biofertilizers, the technology is rapidly being transferred to the end users, the farmers. There is an urgent need to introduce the technology for a large scale production of biofertilizers and to develop logistics for its country-wide distribution for use by farmers. Private sector and government should be approached by the institute to promote the technology of biofertilizers on large scale.

BINA is presently looking into the area of integrated fertilizer management practices which involves the combination of chemical fertilizers and fertilizers of organic origin. The organic components of interest in their future studies include N_2 fixing aquatic tree species such as *Aechynomene* and *Sesbania* which will be particularly useful in increasing the fertility of lowland rice cropping systems.

Extension programme needs special attention of the Institute. Even the best crop variety or the best biofertilizer, without proper testing in farmer's fields, cannot make a substantial contribution for improving crop production in the country. Taking into consideration that the extension programme of the Ministry of Agriculture is under reorganization, the Institute should establish a special strategy to increase mutant varieties cultivation areas and increase biofertilizer use for legume production. Multilocation demonstration plots should be organized in cooperation with local authorities. This activity can be followed by large scale certified seed production. Further collaboration with commercial companies or farmer cooperatives will be one of the possible solutions to find the necessary funds for this programme.

Gammatech Food Irradiation Facility, Chittagong

Given the positive attitudes expressed to the Review Mission by various authorities in the Bangladesh Government, the encouragement and assistance provided by the BAEC, the basic soundness of the irradiation facility, the very real problems of seasonal food quality and supply in the country and the evident eagerness of the staff of the facility, there is every reason to be confident that the Gammatech facility can be operated to a high technical standard, become commercially profitable and be the forerunner of other facilities in Bangladesh and other developing countries.

However, before that can be achieved, a number of design shortcomings must be corrected, procedures for radiation protection improved, measures for process control and good radiation practice instituted, schedules for equipment maintenance prepared and implemented and options for source upgrading examined. Most importantly, commitments from industry for the use of Gammatech's irradiation services must be secured. This process should begin immediately if there is to be a realistic expectation of satisfactory business in the 1993/94 season. Upgrading of the source strength should not be undertaken until it is warranted by the level of business.

Detailed specific recommendations are listed in Annex 3.

Agrochemical Residues :

The project has made a good progress in developing the facilities for monitoring pesticide residues in food stuffs and this work should continue, preferably at an expanded level. In addition, it is desirable that experimental data are generated to assess.

1. The pesticide residue levels that occur in major food crops, particularly those that may be exported, following pesticide use according to good agricultural practice.

2. The behavior and fate of commonly used, relatively persistent, pesticides in the environment under local conditions.

4.2 HUMAN HEALTH

Continued progress in nuclear medicine can only be made through modernization and development programmes. To achieve this goal the following programmes are essential:

1. Strengthening of the peripheral centres especially those centres which have been recently established. Candidates working in these centres should be given a preferential status for training abroad.

2. Modernization of nuclear medicine centres by setting up specialized units for nuclear cardiology, nuclear oncology and immunoscintigraphy.

3. Radiotherapy units in the country should receive special attention by BAEC and Certain TC support should be received by these units although they are not under BAEC authority.

4. Gearing up of the academic programmes. At present Diploma in Nuclear Medicine (DNM) is offered only for physicians. M.Phil. courses willbe available for physicians and being planned for introduction in the near future. Graduates of these courses should receive a priority for fellowship nominations under the Agency training programme.

5. To make the nuclear medicine services available to all the peripheral parts of the country, an expansion programme has been proposed to the Government to establish 3 more nuclear medicine centres.

6. Adaptation of a clinically and widely accepted instrument, the rotating gamma camera for emission tomography, has been provided with the ability to achieve simultaneous images in multiple adjacent planes. This will lead to more wide spread use of the technique leading to improved sectional image contrast providing essential diagnostic information.

7 IAEA has provided one SPECT for INM and proposal for two more SPECT in the other nuclear medicine centres has been submitted to the Government for consideration.

8. Plans to introduce the new DNA technology at institute of Nuclear Medicine is underway. Personnel has already been trained for this and work will be started as soon as the necessary equipment are set up. It is hoped that DNA technology willimprove the study and diagnosis of communicable and infectious diseases in the country, like tuberculosis, filariasis, leishmaniasis, etc.

9. There are many countries which have the oncology and nuclear medicine units working under the same establishment. A similar arrangement in Bangladesh may be adapted. Thus the incorporation of the planned radiotherapy unit of IPGMR with the INM is hoped to improve patient management and treatment.

10. Future work on tissue banking will be devoted to extension of present activities for the utilization of prepared grafts like amnionte membrane and bone. In this connection, more and more medical surgeons should be motivated for their utilization. New grafts like tendom, and fascia lata may be introduced. Towards this end, a national tissue bank should be established to provide all hospitals in Bangladesh with their need of various types of tissue grafts for surgical purposes.

4.3 RADIATION PROTECTION

The Nuclear Safety and Radiation Control bill was passed by the National Parliament on 14 July 1993. It is essential that BAEC should enforce and implement the bill. In this connection, it is necessary to strengthen the radiation protection body responsible for its implementation. The NSRPD (Directorate) is the most proper candidate to become the regulatory body. In RAPAT mission report it was recommended that a central directorate at Dhaka and four Zonal Radiation Protection Centres (ZRPC) at Chittagong, Khulna, Rajshahi and Sylhet should be established to cover radiation protection activities all over the country. At present, insufficient manpower is available at the NSRPD Directorate. BAEC is to recruit additional manpower and to train them for licensing and inspection activities all over the country. BAEC will need adequate controlling instrumentations to organize the whole activity systematically and effectively on national basis.

BAEC should prepare a realistic long term strategy regarding personnel dosimetry to assure that all workers occupationally exposed to ionizing radiation are monitored, the method of monitoring needs to be selected, and activities directed accordingly. With this regard, a more precise survey should be conducted to ascertain the number to be monitored. As one of the priority tasks the regulatory body must establish a comprehensive inventory of all existing radioactive sources in the country, including all X-ray machines in order to be able to properly assess the problems of the radioactive sources. It is necessary to strengthen the legal basis for radioactive waste management and to establish, at a national level, a regulatory body to license and control all aspects of radioactive waste management in Bangladesh. A construction of a central waste treatment and storage facility should be considered.

BAEC should hold periodic short courses on radiation safety which would be required for continued use of radiotracers. Attendance is required at least once every 3 years for every one working with radiation. Radiation protection body directorate should be given certain autonomy, should be chaired by BAEC's Chairman, and should be assigned certain authority to allow it to perform its duties.

4.4 RESEARCH REACTOR AND NUCLEAR POWER PROGRAMME

The TRIGA Mark II Research Reactor is the most important central element for any future development of nuclear technology in Bangladesh, and in this respect it is a truism to assert that it has to be maintained in good operating conditions at all times. All the research, development and application activities in radioisotope production, neutron scattering, neutron activation analysis, neutron radiography, material testing, silicon doping and in many other scientific and technological areas willnot be possible if the reactor is not available at all times and at fullpower for fairly long periods of time, except for routine shut downs for maintenance and repair. In this respect the reactor staff and manager have a great responsibility for operating the reactor and above all keeping it in excellent running conditions so that all the research, development and application work will not suffer from any delay. Any perturbation in the reactor operations will no doubt have a negative influence on the activities of all the scientific and technical teams working around the reactor, will disturb their work plan and most of all will certainly affect their moral and faith in any future scientific or technological endeavor.

The research reactor has many fold implications for the INST that is in charge of it, in relation to the research, production, development and training programmes in terms of the safe operation of the reactor.

There has been some changes in the reactor hall configuration to house the control panel and instrumentation of the triple axis spectrometer. This will undoubtedly have repercussion on the safety features of the reactor and must be analyzed thoroughly in light of whatever safety evaluation and report that should have been made by the safety commission before authorizing any modifications in the reactor building and structure. Continuous functioning of the ventilation system and negative pressure drop must be secured for any safe operations of the reactor.

It is recommended that through the IAEA Integrated Safety Assessment of Research Programme, a mission should be sent to Savar to make a complete assessment of the safety measures and review whatever system and structure modification or malfunctioning that had occurred.

It is also recommended that safety reassessment should be made whenever any changes are made, particularly when these changes are significant.

Permanent training and retraining of all staff, independent of whether they are on the operation side or the utilization side, should be given utmost priority and attention to ensure that all personnel are quite familiar with the procedures and that they are aware of all the safety features. When the personnel turn-over is high, training and retraining bears even a more particular significance for safety. Appropriate training programme for operators and other staff should be set up and implemented on a regular basis to ensure the best qualification of all personnel.

Attention should also be paid to the preparation and organization of safety procedures and the training of specialized personnel to face up any emergency or accident. Another aspect related to the safe operations of the reactor should not be neglected. It concerns the proper maintenance and repair of equipment, inspection and testing of key components, and the routine monitoring of essential parameters.

Radioisotope Production :

BAEC has to plan and optimize their reactor operation to undertake cost-effective production of certain radioisotopes used in medicine and industry. Iodine-131 capsule for diagnostic purposes and iodine 131 solution for therapeutic purposes and I-131 labelled hippuran should be given priority. Radioisotope production team should concentrate their effort to produce Tc-Generator and Tc-Kits. MDP, DTPA, DMSA should be given the first priority and to be produced regularly. Quality control procedure should be strictly followed.

The worn out parts of the MEK Tc Production and I-131 labelling and dispensing facilities should be substituted and the facilities should be operational for their future use. It is essential that there should be at least another 4 full time scientists (2 pharmacist, a chemist and a biologist) allocated to the radioisotope production department to assist the existing staff with laboratory and QA/QC work.

Neutron Activation Analysis:

The neutron activation analysis activities have had a good start and need to be strengthened more in the future.

To increase the number of scientists and technician using this technique, there is a vital and necessary need for collaboration and co-operation between the different divisions of the institute of nuclear science and technology, namely the division of chemistry, the division of radioisotopes and the division of neutron and reactor physics.

To extend further the capabilities of the research groups, application of radiochemical separation technique should be introduced in the neutron activation analysis scheme.

Once instrumental and radiochemical neutron activation analysis have been well in hand of the scientists at the institute, the application must be diversified and beneficiaries must be sought in the different activity sectors of the country.

Since a new room is being prepared for neutron activation analysis outside the reactor hall and a new rabbit system is being installed more attention should be paid to the radiation protection aspects of the facility through better shielding of the pneumatic tube and the loading and unloading station. Rules for proper manipulation and handling of the irradiated samples during transportation to the analytical laboratory and for observation of appropriate cooling time should be prepared and implemented.

Neutron Scattering :

The neutron scattering research groups need some more time to master perfectly this technique, particularly for application purposed.

The future work programme of the group should, as it has been proposed, relate to:

- the development of small angle scattering and inelastic scattering techniques, and
- the studies of different types of crystals, alloys and magnetic materials.

The development of sample preparation facility for low and high temperature measurements should be left to a later stage.

Neutron Radiography :

The neutron radiography team must be advised to work closely with the NDT group from the AEC in Dhaka which has a long experience in applying non-destructive techniques and which has well established reputation in the country and good contacts with the industrial sector.

Neutron radiography can have users from the national airline company, the railway company, the petrochemical industry and the electricity company. A strategy need to be developed to approach all these potential beneficiaries so that the research and development work of the neutron radiography team could be sustained by direct applications in the future.

Nuclear Power Programme :

The IAEA has been providing valuable support to the Government of Bangladesh, especially in the field of human resource development for the nuclear power project. The IAEA participated also in the past in the process of site selection and in reviewing the evaluation of a technical proposal for the project.

Bangladesh would presumably benefit more from this direct assistance it is getting from the Agency if it is combined with activities oriented towards follow-up investment. A detailed scheme needs to be worked out for that purpose.

On the other hand, the authorities of the BAEC have somehow neglected the training of manpower through the utilization of the TRIGA Mark II research reactor for the training programme. Since the commissioning of the nuclear reactor in 1987, no training programme in nuclear engineering, nuclear technology and nuclear applications has been undertaken. The only initiation to nuclear reactors in the country is through a course in reactor physics given for a Master's degree in nuclear physics at Dhaka University.

The BAEC should set up in the INST a training programme in nuclear engineering and technology together with Dhaka university, if adequate human resources in the country are to be maintained for the nuclear power programme which is considered as a future priority by high ranking officials from the BAEC and from the national energy planning commission. Allthe facilities for the training programme are available in the INST. (The TRIGA Mark II nuclear reactor and the associated laboratories).

4.5 INDUSTRIAL APPLICATIONS

In view of the fact that the demand for NDT services in Bangladesh is growing rapidly. BAEC should strengthen and upgrade the NDT activities through the following:

a. To expand its R&D activities on NDT technology with more participation and collaboration of the universities and other research organizations.

b. To support development of NDT applications in specific industries like concrete, ceramics, plastics and composite materials.

c. To provide NDT services to the local industries for QC and QA programmes.

d. To promote technology transfer of new advanced NDT techniques e.g. image processing.

e. To train more people in the field of NDT technology (levels 1,2 and 3 in accordance with ISO 9712 Guidelines and to develop regional standard test pieces for training purposes for qualifying examinations. To adopt a national standard on qualification and certification of NDT personnel in accordance with international guidelines.

f. The NDT Team of BAEC has provided NDT services to a wide range of end-users but there was no mention of any changes or only nominal changes received through these services. The NDT team should be encouraged to expand their services and to establish certain procedures to generate income for their services and to establish a mechanism for motivating the NDT team through the payment of additional allowances for their services. The NDT activity should be self sustained, however, the Agency willcontinue to update knowledge of the NDT team through providing training in the new technologies emerged under this field.

Radiation processing technology is now well established in Bangladesh and the counterpart should carry out the research to transfer the technology to local industry. A pilot plant for surface coating curing using ultra-violet light source is recommended since the AERE have acquired the experience and the state of art in this type of technology. Private sector should be encouraged to be involved in such a project and BAEC may act as a consultant to the project. The donor organizations may also be considered, for financing the facility.

4.6 NUCLEAR INSTRUMENTATION AND MAINTENANCE

The mission noted with satisfaction that most of the equipment items supplied within the framework of IAEA-supported technical co-operation projects in the country are in working order. To a large extent, this is due to the successful implementation of the nuclear instrumentation projects at both AERE and AEC. The training of technicians by visiting experts and through the award of fellowships, coupled with the various training courses conducted at national level, contributed appreciably towards the establishment of local capabilities to deal with the repair and maintenance of nuclear instrumentation.

However, in view of the rapid progress in electronics and the consequent steady increase in the complexity and sophistication of nuclear instrumentation, the assistance of the Agency in this field should continue for a few more years. The nuclear maintenance groups should be encouraged to expand their services and to establish certain procedures to generate income for their services in order to be a self sustained activity and to establish a mechanism for motivating the staff involved through the payment of additional allowances for their services. Apart from contributing towards the building up of repair and maintenance capabilities, it is equally important to assist the local counterparts in their endeavors to design and develop nuclear medical equipment locally and to establish a microprocessor laboratory.

Although some collaboration is apparent between the scientists at AERE and those at AEC who are working in the field of nuclear instrumentation, such collaboration should be consolidated in order to promote the sharing of resources in terms of expertise and equipment and to avoid duplication of work.

4.7 NUCLEAR ANALYTICAL TECHNIQUES

The mission noted a very genuine desire on the part of the local scientists to expand the nuclear analytical methodologies in order to perform more complex structural analysis of materials and to consolidate the environmental studies. In that context, they evoked the necessity to establish X-ray diffractometry for the structural analysis of materials including clay and magnetic materials, mass spectrometry for the isotopic analysis of hydrogen, oxygen, carbon, nitrogen, phosphorus and sulphur for development and protection of water resources, Rutherford backscattering for industrial applications in materials development and environmental studies, fluorimetry for organic analysis in aqueous media, scanning electron microscopy for materials science, environment and medicine, reflectance spectroscopy for black carbon analysis, and ion-chromatography for water characteristics studies. Furthermore, the scientists expressed the wish to develop an experimental channel of the existing 3 MeV Van de Graaff accelerator for proton microprobe analysis of biological specimens, surface analysis and defects analysis of solids.

Such an ambitious programme can only be realized in the long term and requires considerable financial resources from donor organizations and government. Besides, it could not be ascertained whether local skills and expertise are available for the utilization of the various techniques.

Of immediate concern is a need to renovate the Van de Graaff accelerator, which has been in use since 1964, in order to improve the beam availability. Some work along this line is being accomplished through the implementation of the on-going TC project BGD/2/009 and could be further consolidated if required. The existing XRF system, which is used for elemental analysis, is limited by the lack of sensitivity of the system for low atomic number elements. It is anticipated that the provision of a total reflection XRF system within the framework of the same project, namely BGD/2/009, should solve this problem to a certain extent.

The local counterparts should now focus on the optimal utilization of the available nuclear analytical facilities, with special emphasis on environmental, medical and industrial samples. In the short-term, there is a need to develop an additional channel of the Van de Graaff accelerator for proton microprobe analysis of biological specimens.

In the medium-term, the introduction of new techniques, such as mass spectrometry, could be envisaged, but this should be preceded by an appropriate training programme to ensure the availability of local expertise to deal with the new techniques.

The future programme can only be considered in the light of the successful implementation of the above-mentioned activities.

Seminar on the Role of Nuclear Techniques in the National Development Plan

A one day seminar was organized in which 12 National papers were presented. Mr. Kamaluddin Ahmed, Chairman of the Seminar gave the opening speech, Mr. Quaiyum, Chairman , BAEC also addressed the seminar on BAEC activities. Mr. Cherif, Mr. Kamel and Mr. Maluszynski gave presentations on three topics which were; the mission objectives and its terms of reference; the IAEA activities on Bangladesh and the new concept of Model Projects and that each project should has a social or economic impact; and the achievements under agriculture research programme supported by the Agency. All national speakers presented their achievements and their future programme under the Agency TC programme. The seminar was attended by about 60 scientists from BAEC and other institutions in the country. Gammatech General Manager attended the seminar and presented a summary on the activities of Gammatech. The presentations were followed with lively discussions. The seminar was the first opportunity to many scientists to present their views directly with the BAEC in such an open forum. It was clear from the presentations in the seminar that there are several activities in Bangladesh which could be qualified as good or may be considered as model projects in the future, for example, the food irradiation facility, the NDT project and BINA biofertilizer production programme. The seminar helped mission members to familiarise themselves with the overall programme in Bangladesh. The 12 presentations covered all the important activities in the country, (the programme of the seminar is shown in Annex -4).

Visit to Ministry of Science and Technology

BAEC is under the new Ministry of Science and Technology. The mission accompanied by the Chairman of BAEC visited the Ministry and met Mr. Mannan, the Minister of Science and Technology. The Minister thanked the Agency for the support given to Bangladesh through the technical co-operation programme and in organizing the mission. The mission briefed the Minister about the mission objectives and the Agency's TC programme in Bangladesh and discussed the new concept of Model Project, according to which each project should be practical in nature and oriented towards the end-users, have a strong social and/or economic impact, be integrated within the national development plan. Special mention was made of the Agency's support in establishing the first gamma irradiation facility for food irradiation in Chittagong which was inaugurated in April 1993. The mission also mentioned about the progress made by BINA in the field of crop breeding, production and soil fertility and that BINA mutation breeding programme resulted in the development of 8 officially released mutant varieties of rice, chickpea, jute, mustard, mungbean and tomato. Biofertilizers (Rhizobium, inoculum) developed at BINA increases the yield of lentils, chickpea and groundnut by 30 - 40%, the mission mentioned that there was an urgent need to introduce this technology on a large scale production of biofertilizers and to develop logistics for its country - wide distribution for use by farmers.

The Minister mentioned that BAEC will receive more attention under his Ministry and he will make the necessary contact with other ministries concerning the application of the technologies developed by BAEC and BINA.

Visit to Ministry of Agriculture

The mission visited the Ministry of Agriculture and met with the Ministry Secretary Mr. Yosif. The mission briefed the secretary about the Agency technical co-operation programme in Bangladesh with more emphasis on the projects in Agriculture sector specially the progress made by BINA in the field of soil fertility, crop breeding and production and that there is an urgent need to introduce the technology of biofertilizers for large scale production through the Government and private sector support. The Secretary was informed about the gammatech food irradiation facility at Chittagong and its utilization for irradiation of dried fish, potato and other food items.

The secretary mentioned that from the policy prospective, the Agricultural policy emphasis on rice production as first priority crop in Bangladesh and they almost have self sufficiency on rice. He mentioned that Bangladesh Rice Institute released 25 varieties and extension was given a high priority to rice. He added that there was a modest programme assisted with the Canadian for crop diversification. Other project on pulses, oil seeds is supported by Holland. A project on integrated maize production is supported by USA. The secretary mentioned that there were crops having higher value than rice like pulses, oil seeds. However only 1 million tons of these crops are produced while the consumption requirement is over 2.5 million tons. To achieve balance there is a lot to be done in this area. The World Bank is supporting a project on this field. On production of vegetables a project supported by the Asian Development Bank is on-going. He added the Ministry had a plan to increase the irrigated land from 3 to 4 million hectars. In this connection, there are a number of irrigation projects in the north of the country and one in the south. Surface water resources as well as ground water resources will be investigated for this purpose. He mentioned that the soil in Bangladesh was degraded rapidly. In improving soil fertility,a lot of effort is required and the Ministry at this stage has only one small project.

The Secretary indicated that the Government has been supplying farmers with good quality seed but the Government in the near future will go out of the seed business and private sector will take care of this task. Fertilizer business was already privatized and he expected that private sector would be interested in establishing a pilot plant for biofertilizers production.

Meeting with Minister of Industry

On the occasion of a dinner party organized by Mr. Md. Sarwar-e-lam managing Director, Probal Associates Limited, the mission met Mr. Shomsul Islam Khan, Minister of Industries and briefed him about mission objectives and the on-going TC activities of the Agency in Bangladesh and about the new concept of Model Project and that each TC project should be end-users oriented and has a strong economic or social impact. The Minister thanked the Agency for the support given to Bangladesh in the nuclear technology applications in industry and other fields. Mr. Serwar mentioned that he was planning to establish a private Gamma sterilization facility near Dhaka and he enquired whether he can get the Agency technical advice on this project. Mr. Serwar mentioned that he did not require any funds for the building or for the equipment. The mission informed him that it was possible to get the Agency's support but only through BAEC. He appreciated that and he was seriously considering this project as a private sector contribution to extend the technology acquired through the TC programme in Bangladesh. It may be mentioned that Mr. Serwar was a staff member at the Institute of Food and Radiation Biology at AERE, Savar, but he left the institute about 10 years ago to run his family business.

Discussion with the Planning Commission

The planning commission in Bangladesh is the highest authority responsible for the planning policy and the national development plan of the country. The commission is also responsible for handling the national budget and setting the priority areas in the country.

The mission accompanied by Chairman of BAEC visited the planning commission and met Mr. Mokammal, Director of Socio-Economic Infrastructure Division and briefed him about the mission objectives and about the on-going TC programme in Bangladesh. The Director thanked the Agency for the support given to Bangladesh and mentioned that the nuclear power programme was not a priority to the country at this stage. However, the applications of nuclear techniques in agriculture, industry and environment are within the priority sectors of the country.

The mission informed the director about certain TC projects that have social and economic impact including the food irradiation facility at Chittagong, BINA results on crop varieties with a high yield and biofertilizer use for legume production which resulted in an increase in the yields of lentil, chickpea and groundnut by 30-40%.

Mention was also made of the radiation technology for curing surfaces of wood and leather. In this connection the director asked his assistant to organize a meeting with leather industrialist in the private sector and to encourage them to embark on this technology. The director promised to give more support to BAEC commission activities in the country.

Visit to UNDP Office, Dhaka

The mission visited the UNDP office in Dhaka and met with the Deputy Resident Representative and thanked him for the support given to the Agency in implementing TC projects. The Deputy Resident Representative was briefed about the mission objectives and its terms of reference. The priority areas identified by the mission were also discussed and that the Agency TC programme would be on this line of activities with more emphasis on those projects which have a strong socio and/or economic impact and projects should be oriented towards end-users and has certain impact on the national development plan of the country. The Deputy Resident Representative supported the new concept of TC projects and mentioned that the UNDP programme was fully committed towards certain priority areas other than those supported by the Agency.

Visit to FAO Office, Dhaka

The mission accompanied by Mr. Enayat, Director, International Cooperation Division, BAEC visited the FAO office in Dhaka and met with the Deputy Representative of FAO Mr. Yoshikawa and with Project Officer Mr. Reza. The mission briefed them on the mission objectives and on TC programme of the Agency in Bangladesh with special reference to the projects in Food and Agriculture sector. These projects included the Gammatech Food Irradiation facility at Chittagong, BINA activities on mutation breeding, soil fertility, pesticide management and insect control projects.

The mission requested the FAO to support BINA programme and to promote the cultivation of a larger area with the new varieties produced at BINA. Mention was also made of the results of use of biofertilizers for increasing legume production. The Deputy Representative agreed that the extension services is not well developed in Bangladesh. He mentioned that not many agricultural commodities were exported outside the country and that the infestation of spices is a problem in Bangladesh and the food irradiation facility could help in solving the problem. The Deputy Representative mentioned that there were several projects supported by the FAO including projects on fish processing, and a regional project on integrated pest management in rice.

Final Discussion with Chairman and Members of BAEC

The mission was concluded by a final meeting with Chairman and Members of

BAEC. The mission briefed the Chairman and Members about the mission observations and recommendations on the TC programmes of the Agency in Bangladesh and on the priority areas identified by the mission. The mission discussed in detail the criteria and certain programming issues for the 1995-96 TC programme of the Agency within the new concept of fewer but larger projects and that each project should be practical in nature and focus on the benefit of the end-users and that TC projects should be integrated with the national development plan.

Among others, these are the main points which were raised during the discussion:

1 Concerning future TC programme, the Chairman and the Members were informed that the mission has discussed with the technical counterparts on their proposals for the 1995-96 TC programme within the priority areas. The Chairman and Members agreed that their projects will be submitted under the mentioned priority areas which the BAEC would support.

2. The mission drew the attention of BAEC on that the Gammatech facility has numerous design deficiencies which compromise employee safety and the application of appropriate process control and these deficiencies should be corrected according to the mission's recommendations. In connection with the utilization of the facility, some promotional material has been distributed and prospective clients have been contacted. However, commitments from industry for the use of Gammatech's irradiation services must be secured for the next season. Upgrading of the source should not be undertaken until it is warranted by the level of business.

3. BAEC should give more attention and support to agricultural projects in the country including the use of biofertilizers and mutation techniques and related biotechnologies for crop improvement. In this connection BINA should establish a special strategy to increase mutant varieties cultivation areas and increase biofertilizer use for legume production. It would be important to have close collaboration with the Department of Agriculture, especially for distribution and extension work. Further, the Government or private sector support would also be essential during the commercial scale production of the biofertilizers.

4. BAEC should prepare a realistic long term strategy to enforce the Radiation Protection Law. NSRPD is the most proper candidate to become the regulatory body which should be under the direct responsibility of the Chairman of BAEC. All workers occupationally exposed to ionizing radiation should be monitored. In this connection more thorough survey should be conducted to ascertain the number of workers to be monitored, and a comprehensive inventory of all existing radioactive sources in the country should be established.

5. Nuclear Medicine Centres outside Dhaka should receive more attention at this stage to upgrade their services in order to cope with the high demand on their routine work. Candidates servicing in these centres should be given preferential status for training abroad.

6. BAEC has to plan and optimize the reactor operation in order to undertake cost-effective production of certain radioisotopes used in medical applications and in industry. Radioisotope production team should concentrate the effort to produce Tc-generators and Tc labelled radiopharmaceuticals including MDP, DTPA and DMSA as a first step.

7. The NDT and the nuclear maintenance and repair teams should be encouraged to expand their services and to establish procedures of charging for their services and to establish a mechanism for motivating the teams through additional allowances for their services and their activities should be self sustained in the future.

8. Different scientific teams working in the field of Nuclear Analytical Techniques should co-ordinate their effort and give special emphasis on analysis of environmental, medical and industrial samples.

Acknowledgment

The mission was warmly received at all places in Bangladesh and is thankful to the officials of the BAEC and wishes to acknowledge the help given by Mr. Quaiyum and Mr. Hasnat who provided the co-ordination necessary to make the mission a success. The mission is thankful to the counterpart scientists and institutes for their kind hospitality and co-operation.

ANNEX 1

LIST OF MOST RELEVANT PERSONS MET IN BANGLADESH

Institutions	Positions
Ministry of Science and Technology	
Prof. M.A. Mannan	Minister
Ministry of Industry	
Mr. Shamsul Islam Kahn	Minister
Ministry of Agriculture	
Mr. A.N.M. Yosif	Secretary
Planning Commission	
Mr. Mokammel	Director, Socio-Economic Infrastructure Division
Bangladesh Atomic Energy Commission (BAEC), Dhaka	
Mr. M.A Quaiyum	Chairman
Mr. K. Ahmed	Member, BAEC
Mr. M. Ahsan	Member, BAEC
Mr. A. R. Faruquee	Director, Planning and Development
Mr. W. Miah	Member, BAEC
Mr. K.A. Hasnat	Director, International Affairs Division
UNDP Office, Dhaka	
Mr. P.M. Kamayana	Assistant Resident Representative
FAO Office, Dhaka	
Mr. N. Yoshikawa	Deputy Representative
Mr. G. Reza	Project Officer
Atomic Energy Centre, Dhaka	
Mr. A.H Khan	Director General
Mr. Munsur Rahman	Director, NSRPD
Mr. Md. Solaiman Ali	Chemistry Division
Mr. Khaliquzzaman	Head, Accelerator Facilities Division
Mr. Abdul Majid	Magnetic Material Division
Mr. Mdd. Sana Ullah	Head, NDT Division
Mr. M.M. Kasim	Head, Physics & Solar Energy Div.
Ms. Mahfuza Begum	Head, Health Physics Division
Mr. M. Zahur Ali	Head, Electronic Division

Atomic Energy Research Establishment (AERE), Savar

Mr. Serajul Islam M.	General Director
Mr. Nurul Islam Molla	Director, Institute of Nuclear Science and Technology
Mr. Naiyynm Choudhury	Director, Institute of Food and Radiation Biology
Mr. Mahfuzur Rahman	INST
Mr. A.O.M. Abdul Ahad	Head, Reactor Engineering
Mr. M.A. Matin	IFRB
Mr. Dayen Pohriy	IFRB
Mr. D.H. Sikder	Head, Isotope Hydrology
Mr. M.A. Taher	Director, Institute of Electronics
Mr. Idris Ali	Radiation Technology Lab.

Bangladesh Institute of Nuclear Agriculture, Mymensingh

Mr. M.M. Miah	Director
Mr. M.A.Q. Shaikh	Head, Plant Breeding Division
Mr. Idris Ali	Division of Soil Science

Chittagong Radiation Monitoring Laboratory

Mr. M. Alam	Director
Mr. Abu Md Ishaqui	Scientific Assistant
Mr. Akano	Scientific Assistant

Gammatech Ltd., Chittagong

Mr. Mosharraf Hossain	Director General
Mr. Mohammad Sultan	Plant Manager
Mr. Md. Enayetur Rahman	Safety Officer
Mr. Mridha Md. Shahid Babu	Quality Control Officer
Mr. Md. Guisuddin Mridha	Commercial Officer
Mr. Md. Sajedur Rahman	Marketing Executive
Mr. Kazi Ezabul Khalid	Operator
Mr. A.K.M.Azad	Operator
Mr. Md. Mahiuddin Khan	Operator
Mr. Md. Zakir Hossain	Technician
Mr. A.S.M. Emdadullah	Technician
Mr. Md. Masud Matbar	Scientific Assistant

ANNEX 2

PROGRAMME FOR IAEA COUNTRY PROGRAMME REVIEW MISSION TO BANGLADESH 21 TO 26 AUGUST 1993

18 August (Wednesday)	-	Detailed Discussions on implementation issues of TC Projects at AERE, Savar. - Dr. R.S. Kamel
19 August (Thursday)	-	Detailed Discussions on implementation issues of TC Projects at BAEC, HQ, AECD, INM, NMC, Dhaka & BINA. - Dr. R.S. Kamel
		Main Mission Programme.
21 August (Saturday)	-	Meeting with BAEC Commission
	-	Visit and discussion on TC Projects at BAEC HQ, AECD, INM, Dhaka.
22 August	-	Seminar on the Role of Nuclear Technology in the National Development of Bangladesh
23 August (Monday)	-	Visit and discussion on TC Projects of INST, AERE, Savar.
	-	Visit and discussion on TC Projects of IFRB, ICS, IEMS & E&GS, AERE.
24 August (Tuesday)	-	Departure for Chittagong.
	-	Visit Gammatech, NMC. Ctg. RTL. Ctg. - Mr. Kamel & Mr. Moore
	-	Departure for Mymenshing
	-	Visit BINA - Mr. Cherif, Mr. Maluszynski & Mr. Maudarbocus
	-	Departure for Dhaka
25 August (Wednesday)	-	Visit Ministry of Science & Technology.
	-	Visit and Discussions, AEC
26 August (Thursday)	-	Visit UNDP, Dhaka Office, Visit FAO.
	-	Visit Ministry of Agriculture.
	-	Final discussions with the Commission.
27 August Friday)	-	Departure.

ANNEX 3

GAMMATECH FOOD IRRADIATION FACILITY CHITTAGONG

RECOMMENDATIONS

1. A wire fence about 3 metres high should be erected to separate treated and untreated product. The fence should be built from the entry to the irradiation cell to the opposite wall. A turnstile or similar arrangement to allow cross movement of people but not bulk goods should be installed. A larger gate should be installed also to allow the movement of heavy items. This gate must be kept locked during normal operation with the key under the control of the Plant Manager. It must only be used under his supervision.

2. A source release mechanism must be designed, installed and tested without delay. The mechanism should allow the source holder (or source rack) to be released from the source hoist and fall under gravity or be separately lowered into the storage position. Since this is into concrete instead of the usual water tank, some means for shock absorption may have to be incorporated to prevent damage to the source.

3. The source release mechanism should be tested after installation with the radioactive pencils replaced by dummy steel pencils of similar weight and dimensions. This will enable access to the cell during testing. It will be necessary to override the safety system for these tests. This must be done under appropriate supervision.

4. Staff must receive prior training in the removal and replacement of radioactive pencils before testing of the release mechanism is undertaken. Instructions should be obtained in the first place from the Russian contractors.

5. The release mechanism must be regularly tested during normal operation to ensure that it continues to work as intended. Testing at 3 month intervals is recommended. This could later be extended if test results provide evidence that longer intervals between testing are warranted. Records of testing must be maintained.

6. Wire screens should be erected to prevent contact between a protruding package and the source in the raised (operating) position. Microswitches could be installed to stop the conveyor and lower the source when the screens are contacted.

7. The access/control key should be attached by a light chain to a radiation monitor to ensure that the monitor is carried whenever the floor grates are activated and the cell is entered.

8. Procedures for raising the source should require the operator to enter the irradiation chamber by one passage to press the enabling button and leave by the other.

9. Suitable measures should be taken to allow safe exit from the irradiation cell in the event of a power failure.

10. To prevent damage to the product by over-irradiation, the source must be returned to the safe (ie storage) position in the event of a power failure or stoppage of the conveyor. Ideally, this should be done automatically by the control mechanism rather than through action by the operator.

11. Simple barriers should be installed to prevent loading and unloading from the wrong positions.

12. The treated products storage area should be divided into two sections, the first for goods awaiting checking and clearance, the other for released goods awaiting shipment.

13. Goods in the untreated and treated products stores must be labelled or tagged on each pallet load to show their status.

14. All gauges, indicators and equipment presently labelled in Russian must be relabelled in English.

15. The incorrect control panel must be replaced.

16. Faulty equipment supplied by the Russian contractors must be repaired or replaced at Russian expense before the warranty expires.

17. The Russian contractors should be required to supply operational and maintenance manuals in English for all plant and equipment.

18. Conversion of the single speed conveyor to multi speed should not be done at this time. However, the method and cost of conversion should be investigated to assist consideration in the future.

19. Upgrading of the source strength to 250,000 Ci should not be undertaken until it is warranted by the level of business. Gammatech should be required to contribute to the cost of source replenishment.

20. A television monitor for routine operations is not recommended.

21. Gammatech should begin immediately to assemble the technical information needed for a decision on source replenishment.

22. Further information regarding the Russian yellow plastic film dosimeters should be obtained. The possible advantages and costs of changing to coloured

perspex dosimeters should be determined and a case presented.

23. At least one dosimeter should be in the irradiation chamber at all times during operation. The dosimeter should be placed on the carrier or on the outside of the product load in a position having a previously determined relationship to the dose rates at the maximum and minimum dose positions in the product load.

24. Every manufacturer's batch of routine dosimeters must be calibrated against reference dosimeters traceable to a primary standard.

25. Detailed, step-by-step instruction manuals covering every operation from the receipt and inspection of incoming goods to the despatch of treated goods should be prepared as soon as possible. These should be updated periodically and superseded copies removed and replaced.

26. Formal checking procedures using specially prepared forms should be instituted as soon as possible. These should be filed as part of the record of treatment.

27. Each consignment of goods for treatment must be identified by a unique batch number. This number should appear on every outer container in the consignment.

28. A sequential log of batch numbers and other relevant details of treatment should be maintained and kept in the control room.

29. A system for the regular calibration, testing and maintenance of all equipment should be introduced as soon as possible. Records of calibration etc should be maintained.

30. A system of key control should be introduced.

31. In-house training should commence and be appropriately recognized.

32. Coloured irradiation indicator spots should be used on the outside of all outer packages as an additional means of showing, whether the package has been treated by radiation.

33. R&D support should be provided by the Institute of Food and Radiation Biology.

34. The facility should be inspected and its methods of operation audited annually by the Bangladesh Standards and Testing Institute and formal authorization to irradiation food and/or other goods issued.

35. Inclusion in the International Inventory of Authorized Food Irradiation Facilities should be sought as soon as possible after the major shortcomings in equipment and quality assurance practices are rectified.

36. The number of operators should be increased from three to four.

37. The forecasts of earnings for 1993/94 and 1994/95 should be revised to reflect current and likely future conditions.

38. Firm commitments from food producers for 1993/94 season should be obtained. This should be given a high priority and begin immediately.

ANNEX 4

PROGRAMME OF THE SEMINAR ON THE ROLE OF NUCLEAR TECHNOLOGY IN THE NATIONAL DEVELOPMENT OF BANGLADESH

9:30 AM - INAUGURATIONS

- Guests taking their seats
- Telewat from Quoran-e-pak
- Introductory speech by President of the seminar Dr. Kamaluddin Ahmed
- Speech by Dr. Cherif, Objectives of the Mission
- Speech by Dr. Kamel, IAEA TC Programme
- Speech by Dr. Maluszynski, Nuclear Techniques to Improve Agricultural Production
- Address of the Chief Guest, Topics: BAEC Activities Mr. Quaiyum

PRESENTATIONS

1.	Nuclear Medicine & Radiotherapy in Bangladesh	:	Dr. M. A. Karim, Director, INM
2.	Tissue Banking	:	Dr. Naiyyum Chowdhury, Director, IFRB (Inst.Food Rad.Biol.)
3.	Research Reactor Utilization	:	Dr. N. I. Mollah, Director, INST
4.	Radio-Isotope Production	:	Mr. Mahfuzur Rahman, INST
5.	Food Irradiation	:	Mr. A. D. Bhuiyan, IFRB
6.	Gammatech Project	:	Dr. Mosharraf Hossain, Director General, Beximco
7.	Radiation Protection & Health Physics	:	Mr. Mansurur Rahman, Director, NSRPD
8.	Non-Destructive Testing	:	Dr. Sanaullah, Head, NDT
9.	Radio-analytical Techniques	:	Dr. Amir Hossain Khan Director General, AEC
10.	Agro-chemical Residues	:	Mr. M. A. Matin, IFRB
11.	Nuclear Techniques in Agriculture	:	Dr. Shaikh, BINA representative
12.	Maintenance & Instrumentation	:	Mr. M. A. Taher, Director, IEMS