Annual Report

2002–2003

Pakistan Atomic Energy Commission
The submission of an Annual Report of Pakistan Atomic Energy Commission is a statutory requirement under the provisions of section 15(b) of the PAEC Ordinance, 1965. It's publication is aimed to document the achievements and concerted endeavours put in by all establishments and entities of PAEC towards the fulfilment of its programme.

The Commission records, with great appreciation and pride, the services rendered by all the scientists, engineers, technicians, administrative & financial managers, and their staff, whose untiring efforts and engagements have contributed to research oriented developmental programme undertaken by the Commission during the year 2002-2003.

(Dr. Khwaja Yaldram)
Secretary
Pakistan Atomic Energy Commission
Islamabad
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NUCLEAR POWER

From July, 2002 to June, 2003 Karachi Nuclear Power Plant, KANUPP generated a total of 236 GWh which raised the cumulative generation since Net Power Date (NPD) to 10,736.46 GWh. The total on-line time of turbo generator during the reporting period was 3,167.53 hours which raised the cumulative running time up to 30th June, 2003 to 152,430.76 hours. The gross capacity and availability factors during the period were 19% & 36% respectively. Life time average figures for these are 29% and 56% respectively.

Chashma Nuclear Power Plant, CHASNUPP generated a total of 1503 GWh of electrical output with 1386 GWh of it exported to WAPDA. The total on line time of the Turbine-Generator was 5243 hours thus raising the on line time of Turbine-Generator to 17384 hours since first grid connection. The average plant capacity and availability factors were 52.82% and 59.85% respectively. Numerous maintenance jobs were carried out by Maintenance personnel of CHASNUPP along with nearly 1000 outside personnel participated in Refueling Outage-1 (RFO-1).

The Applied Systems Analysis Group ASAG contributed in the preparation of PC-I document for the second unit of Chashma Nuclear Power Plant (C-2).

In order to obtain approval from the Government of Pakistan (GOP), members of the Group interacted with the relevant Departments of GOP and also assisted the senior management of PAEC in the high-level meetings related to C-2. The Group also contributed in the negotiations for C-2 related to cost and financial aspects.

Analytical engineering studies related to the Pressurized Water Reactors (PWRs) remained the mainstay of Institute of Nuclear Power, INUP's activities. The work assignments related mainly to the areas of reactor physics, core design, thermal hydraulic design, besides accident and transient analysis, in-core fuel management and fuel mechanical design.

Laboratories for radiation shielding studies, and nuclear instrumentation have been established. The Institute is gradually attaining the status of centre for diagnostic vibration analysis of moving components of machinery.

NUCLEAR SCIENCE & TECHNOLOGY

Reactor Operations & Experiments

Pakistan Research Reactor (PARR-1) was operated for 420 hours producing 3105 MWh of thermal energy. Five hundred and sixty nine capsules containing different samples were irradiated.

Pakistan Research Reactor (PARR-2) was operated for 133 hours producing 3868 KWh of thermal energy. Number of samples irradiated was 1234. Quality of reactor vessel/pool water was maintained up to the standard. Low and full power tests were carried out to meet the requirements of operating policies. Fire emergency and site emergency drills were also conducted. A series of experiments were performed for measurement of gamma doses in the gamma cell of PARR-1 with different combinations of retired LEU fuel elements.

Plasma Physics

Electromagnetic drift waves in electron-positron-ion plasmas have been studied. It is found that these waves can form the dipolar vortex structures in the nonlinear regime. Coupling of ion acoustic and Alfvén waves with the drift wave have also been investigated.

Fast Neutron Physics

The determination of boron in an iron base amorphous alloy as well as in steel samples has been carried out by prompt gamma neutron activation analysis setup at PARR-1. The re-estimation of absolute intensities by thermal neutrons capture in
Mn with \( k_0 \) standardization approach was done in the energy range from 50 keV to 3 MeV.

**High Temperature Superconductivity**

To investigate the effects of dopants in the CMR materials the synthesis of \( \text{La}_{0.49}\text{A}_{0.5}\text{Ca}_{0.05}\text{MnO}_3 \) (where \( \text{A}=\text{Nd, Sm, Gd, Yb & Y} \)) and characterization by the R-T and XRD measurements have been completed. Study of the effect of dopants on the spin glass behaviour for the CMR materials, \( \text{La}_{0.85}\text{Ca}_{0.15}\text{MnO}_3 \) and \( \text{La}_{0.85}\text{Ca}_{0.15}\text{Mn}_{0.95}\text{Fe}_{0.05}\text{O}_3 \), has been completed.

**Lasers Studies & Applications**

An extended cavity diode laser system has been designed and developed. A 75 mW, 785 nm diode laser system having a narrow line width ~ 100 MHz has been developed, which is tunable over a range of +/- 10 nm with laser power in excess of 50 mW. This newly developed laser can be used for ultra high resolution spectroscopy of Rb atoms. Twelve units of Laser land leveler were handed over to different organizations. Thirty units of laser land levelers are ready for delivery.

**Radio & Nuclear Chemistry**

Sorption behavior of Ag and Cr onto polyurethane foam (PUF) loaded with diphenylcarbazide; Eu, Tm, and Hg on PUF loaded with pyridylazoresorcinol (PAR); and the Cr onto unloaded PUF and loaded with trioctyl phosphine oxide (TOPO) has been studied from different mineral acids. Parameters affecting the sorption were optimized. Experimental work on adsorption of U and Cd on PUF loaded with 1-(2-pyridylazo)-2-naphthol (PAN) has been completed.

**Radioisotope and Radiopharmaceutical Cold Kits Production**

Regular production of I-131 was continued and 93960 mCi were dispatched to nuclear medical centres. 16 consignments of sodium phosphate (P-32) (141 mCi) and 07 consignments of MIBG-131 (52 mCi) were also supplied to medical centres. Total supply of radioactive products was 95972.35 mCi worth 5.49 million rupees. 8366 vials of eleven different cold kits MIBI, MDP, DTPA, MAG3, DISIDA, DMSA, Phytate, HMPAO pyrophosphate and glucoheptonate worth 5.32 million rupees were also supplied during this period.

**Applied Health Physics**

Personnel radiation contamination monitoring services were provided to radiation workers, trainees and visitors of PARR-1, PARR-2 NCD, IPD and others radioactive radiochemical laboratories of PINSTECH. Radiation/contamination surveys were conducted in different labs/plants of PINSTECH. Safe transportation of 1381 consignments of radioactive material/radiation sources were authorized.

**Computers**

Under PAK-CERN collaboration research programme, compact muon solenoid (CMS) events production site has been established in Computer Division. CMS events production activity, based on Monte Carlo production chain includes all calculation steps of events' generation, simulation, digitization and reconstruction. CERN computing environment was replicated to establish CMS events production site.

**AGRICULTURE & BIOLOGY**

Under crop improvement programme, research was carried out for evolving new varieties of crops suited to local environmental conditions.

A new cotton variety SOHNI endowed with high yield, early maturity and high lint ratio has been finally approved by Provincial Seed Council in its meeting held on 22nd Oct, 2002 for general cultivation in Sindh.

The Varietal Evaluation Committee (VEC) in its meeting held on April 23, 2003 at PARC HQ Islamabad unanimously approved high yielding, good grain quality variety, Sarshar for general cultivation in Sindh and Balochistan.

The wheat varieties Sarsabz and Kiran 95, evolved by NIA, have generated an additional annual income of Rs. 1568 million to the farmers of Sindh.
Under Plant Molecular Breeding, local rice varieties, *Oryza galaberrima* and some lines carrying chromat from upland rice were tested for tolerance to water stress.

Experiments were conducted to standardize procedures for seed protein fingerprinting of wheat varieties.

The research in the Plant Physiology field was focused to enhance the crop productivity by undertaking studies in stress tolerance physiology and exploring ways to cultivate sub-optimal lands profitably.

To prevent loss in yield of crops by insects, entomological studies & experiments were carried out on cotton pests, sugar borers, fruit flies, rice borers, etc.

A new project "Enhancing wheat productivity through efficient irrigation practices" was started with the objective to identify most sensitive and tolerant stages of crops to water deficit.

Search for novel and superior sources of disease resistance was carried out from 900 exotic wheat lines planted by NIFA wheat breeders. Performance data with regard to resistance level of each line against prevailing diseases have been provided to the concerned breeder for further improvement.

A highly sensitive method was standardized for the detection of aflatoxin B1 residues in poultry feed and its components using Enzyme Linked Immuno Sorbant Assay (ELISA).

7700 vials (77,000 vaccine doses) of the Haemorrhagic spitaemia (HS) vaccine were prepared and sold in the local market worth 0.70 million rupees whereas 12000 vials (1.2 million doses) of NIAB Newcastle disease (ND) vaccine were prepared and sold earning 0.54 million rupees.

A research project worth 21.77 million rupees was awarded by Ministry of Science and Technology for mass production of HS, Black Quarter and Infectious Bursal Disease vaccine under self reliance programme.

**BIOTECHNOLOGY & GENETIC ENGINEERING**

Six Divisions at the Center of Excellence National Institute of Biology and Genetic Engineering remained involved in research work related to Agriculture, Industry, Health and Environment.

Isolation of mutants of various microorganisms characterization of industrial enzymes, production of Biochemicals and Bio Transformation of industrially important compounds were the major areas of research, for which experiments were designed & results analyzed.

Upscaling of Bio degradation of textile effluent & Bio sorption process and fabrication of bench top model for metal removal remained important topics of research under environmental studies.

During this period, 58 patient samples were referred to diagnostic laboratory and were found to have karyotypes for Down syndrome, variant of Turner syndrome, Robertsonian translocation for Down syndrome, Sex chromosome mosaicism, Philadelphia chromosome and Fragile X syndrome. 186 samples of Mycobacterium tuberculosis, 730 samples of Hepatitis C Virus, 22 samples of Hepatitis B Virus, 05 samples of Salmonella typhi and 17 samples of bcr-abl translocation for chronic myeloid leukemia were analyzed.

**NUCLEAR MEDICINE**

PAEC medical centers are equipped with the latest machines including Co-60 teletherapy units, Linear accelerators, Deep & superficial X-ray machines, HDR remote after-loading machines, Superficial Appliances, etc. Simulators & Treatment Planning Computers help in planning the delivery
of proper dose to specific sites. During 2002-2003, 1,33,592 patients were provided cancer treatment as well as follow up.

Research work was continued on 22 IAEA sponsored and 33 other research projects in collaboration with different international and national agencies/organizations. The project "Development of Breast Care Clinics at all PAEC Nuclear Centres" was approved during the period under report by Planning and Development Division at the cost of Rs. 157.3 million. The Commission has ordered for nine sets of Mammography & Utrasoundography units which will be installed in near future. After installation of the equipment at Breast Care Clinics of PAEC, about 20,000 patients will be treated per annum.

NUCLEAR MINERALS

Major exploration activity was focused at Shanawah site of Bannu Basin where development drilling was carried out in the southern part of the prospect to estimate reserves in the RAR category. Manchar Formation in the Kirthar Range was studied in geological detail and controls for surface uranium mineralization were determined. Anomalous zones of Kohat Plateau were mapped and investigated in detail and were drilled for preliminary information.

Baluchistan was opened for the first time for uranium prospecting and regard Saidak-Taftan block was traversed on foot. Preliminary exploratory drilling and detailed geological studies were carried out at sites in Malakand and Ilum Granitic complexes. Applied research was carried out on uranium metallogene-

HUMAN RESOURCE DEVELOPMENT

Three hundred twenty seven PAEC scientists/engineers participated in various IAEA workshops, seminars, symposia, conferences, 141 attended meetings colleges, visits and training courses sponsored by IAEA. Eighty six fellowships/scientific visits were availed by PAEC scientists/engineers.

Computer Training Centre CTC started the 2nd batch of Master of Science in Information Technology, M.Sc (IT) Program in October 2002. CTC also started its 10th regular Post Graduate Computer Orientation Course (PGCOC-10) in Computer Systems Software & Hardware. The Computer Literacy courses were successfully conducted for the children of PAEC Employees. Workshops on Web Enabling Technologies, VLSI Design Techniques and Office Automation were also conducted.

Twenty engineers/scientists out of a total strength of 32 from Batch-8 Of Kanupp Institute of Nuclear Power Engineering graduated on September 27, 2002. Thirty two engineers & scientists of CHASCENT batch-I completed one-year postgraduate training, where as 14 technicians of batch-7 completed one-year post diploma training. 37 engineers & scientists of batch-2 are undergoing one year post graduate training, while 38 technicians of batch-8 are undergoing one year post diploma training as well.

SCIENTIFIC & ENGINEERING SERVICES

The Directorate manufactured and supplied jobs worth Rs. 98.65 million to PAEC, Government Organizations & National Industry including Heavy Mechanical Complex, Kot Adu Power Plant Co., KSB Pumps Co., Oil & Gas Development Corp., Heavy Industries, Taxila, National Refinery Ltd., Pak Arab Refinery, Ghazi Brotha Power Plant/WAPDA, etc. The Directorate signed commercial contract with CERN, Switzerland worth US $ 305,570 (Rs. 18.03 million) and delivered 1st consignment.

INTERNATIONAL RELATIONS

Mr. Parvez Butt, Chairman, Pakistan Atomic Energy Commission led Pakistan delegation as Governor from Pakistan in the Meeting of the IAEA Board of Governors held at Vienna (Austria) from 9-12 September, 2002. Chairman, PAEC led Pakistan’s delegation to the Forty-sixth IAEA Annual General Conference held at Vienna (Austria) from 16-20 September, 2002. He also visited European Organization for Nuclear Research (CERN), Geneva, Switzerland from 21-24 September, 2002.

Fifty IAEA Experts carried out assignments at different PAEC Establishments under IAEA Regular Programme of Technical Co-operation in various fields.
NUCLEAR POWER

KARACHI NUCLEAR POWER PLANT (KANUPP)
OPREATION AND MAINTENANCE

During the period from July, 2002 to June, 2003 KANUPP generated a total of 236 GWh which raised the cumulative generation since Net Power Date (NPD) to 10,736.46 GWh. The total on-line time of turbo generator during the reporting period was 3,167.53 hours which raised the cumulative running time upto 30th June, 2003 to 152,430.76 hours.

The gross capacity and availability factors during the period were 19% & 36% respectively. Life time average figures for these are 29% and 56% respectively.

Plant Life Extension (PLEX) jobs for Re-Licensing

KANUPP completed its nominal design life of 30 years and was shut down on 05-12-2002 for the implementation of safety upgrades and major maintenance/overhauling activities as a part of plant life extension and to meet the re-licensing requirements. Reactor fuel channel inspection was carried out as per contract between KANUPP and AECL, Canada.

The new ARC-PLC was successfully tested for Regulation Functions. The dump valves for the third trip channel were refurbished and installed in place of CMP-HG-CV1 and BMP-HG-CV2. The Change Approval (CA) on control logic for interconnection of 3rd Diesel Generator has been finalized and sent to PNRA for approval. Change Approval for strengthening masonry block wall by constructing another parallel wall of steel plates of Air conditioning room for improving Control Room habitability has been implemented partially.

Re-Licensing Outage (RLO) Activities

To meet the single failure criteria of IJW system, a Change Approval to install redundant valves of IJW system has been prepared. Another Change Approval for relocation of IJW panel has also been prepared. Both the Change Approvals are now under review by PNRA.

Reactor regulators ARC and BRC have been replaced with ARC-PLC and BRC-PLC, however their commissioning will be carried out during plant re-start up. As a part of re-licensing job, steam generator tubes eddy current inspection of SG # 5 & 6 and constriction monitoring of SG # 2,3,4,5 & 6 were completed.

All the eight Booster Rods (BS1 to BS8) were removed from reactor core and new shield plug were installed. Reactivity mechanism was installed back and all the boosters were stored in SS containers in spent fuel bay. Primary Coolant (PHT) require cleaning and decontamination to remove the deposited sludge in order to lower the dose rates and increase the heat transfer. Initially one steam generator was decontaminated and the project was named as KANDECON-1. The Total activity removed was 900 mci and 40 mci/L as CO₂.

The Jobs related with refurbishing of Water Treatment Plant (WTP) have been performed. Cation, anion, MBO, carbon filter and de-carbonator units were completely replaced with new fabricated units. Emergency D₂O and H₂O transfer system has been installed (EHWT) to transfer heavy or light water to the primary heat transport system (PHT) during small LOCA to cool and depressurize the PHT system for leak isolation. Storage capacity of heavy water is about 18 tons and storage capacity of light water is about 180 tons. The change approval to install automatic boiler crash cool down logic has been approved by PNRA. Installation/commissioning of the system will be done before the next start up.

Emergency Injection System (IJW) of Kanupp has no provision of recirculation for LOCA outside the boiler room. Emergency Sump Transfer (EST) system will be used to transfer spilled water in the accessible areas of reactor building to moderator area sump to ensure continuous supply of water for IJW system. The change approval has been prepared and approved by Kanupp Site Safety Committee and is now under review by PNRA.

Installation work of Fire Alarm system in all plant buildings has been completed. System is being commissioned and working under performance test. Work on rehabilitation of South and North Activity Monitoring rooms was initiated. The work involved complete replacement of all 208 sample chamber housings, replacement of 208 horizontal sampling tubes etc. All the fabrication and manufacturing was completed in-house at KANUPP. The tubes were fabricated welded and tested as per requirements of ASME Section III Class NB.

On line chemical Instrumentation of BFW system has been installed. PHT/MH and cover gas system is under installation. Final commissioning will be done at the time of plant start up. Inspection of tendon of reactor building was carried out along with PNRA representative with the assistance from Pakistan Navy and found to be in good condition.

HEALTH PHYSICS AND RADIATION SAFETY

The total radiation dose received by all personnel in KANUPP radiation zones was 3.254 Man-Sv. Out of this 30% was received as internal dose, due to tritium uptake, while the remaining
70% was the contribution from external dose. The average dose for radiation workers was 4.0 mSv per person-year for the reporting period.

Total gaseous radioactivity released from the plant during the reporting period was less than 2% of the derived maximum permissible release limit. The liquid radioactivity in the effluent released to sea during this period was less than 3% of the derived emission release limit for liquid.

**DESIGN AND DEVELOPMENT**

**Manufacture of Critical Spare Parts**

Twelve (12) snout jaws have been received from SES Directorate. Their soft nickel plating is to be done. Manufacture of snout jaw # 13 is in progress. Study work on manufacture of snout jaws to suit its use (without developing cracks before 2000 cycles) is initiated in collaboration with SES Directorate, Islamabad. Pump & valves have been installed in the EHWT system. Welding and penetrant test are in process. Closure Plug Discs (09 Nos.) after Soft Nickel plating & grinding have been delivered to Maintenance Division.

Intercepted gratings for active drainage sump were designed and fabricated. This completely bolted structure has already been installed around the AD-P8/P9 sumps.

KANUPP has purchased infrared (IR) thermography equipment recently. Equipment performance checks and commissioning activities have been completed. Infrared thermographic survey is being carried out on plant equipment on trial basis.

In accordance with the modified contract for Reactor Fuel Channel Inspection between KANUPP and AECL, Canada, a 15 member KANUPP team visited AECL for equipment familiarization.

Earlier to this KANUPP shipped 1993 leftover equipments (for refurbishment/re-qualification) and two end fitting for fabricating two fuel channel mock-up to AECL, Canada. After the completion of equipment familiarization program, KNPC personnel returned to KANUPP and started preparatory work to acquire the data (NDE, dimensional gauging and scrape sampling) on the selected fuel channels.

Furthermore G-12 pressure tube (removed in 1993) was also cut into required pieces, loaded in to IMT flask (sent by AECL) and dispatched to AECL for burst testing. AECL dispatched equipment after re-qualification/refurbishment.

**PROJECT SAFE OPERATION OF KANUPP (SOK)/ IMPROVE SAFETY FEATURES OF KANUPP (ISF)**

Local efforts continued to develop Neutron Power Instrumentation System for KANUPP (NISK). High grade electronic components of precise specifications are being procured.

The permanent installation of N-16 channels on protective channel-A, B & C were approved by PNRA for implementation. Change approvals on protective channels A & B (N-16 channels) have been implemented.

Action on Ageing Management Work Plan was prepared on the basis of recommendations given by the various IAEA expert missions for establishing Ageing Management Program (AMP) remained in progress. Technical Manuals on "Ageing Management Program" and "SSCs identification" have been issued.

AMP pilot projects on Instrumentation and Control Cables, Motor Operated Valves (MOVs), Fuel Channel Integrity Assessment (FCIA), and steam generator sludge cleaning remained in progress.

The recommendations of IPSART mission have been implemented and the final PSA report issued and sent to the Regulator. The first task of PSA Applications has been started and the proposed design modifications have been evaluated using the PSA.

**CONTROL & INSTRUMENTATION APPLICATION LABORATORY (CIAL)**

The static calibration services for test and calibration of pressure, temperature, flow and level devices were provided to KANUPP and other PAEC organizations. The test and measurement equipment were tested and calibrated by fluke primary standard. The test rig remained operational and dynamic testing of south/north activity monitoring system coils, return headers at designed parameters of 1550 psig, 565°F were carried out.

CIAL has acquired ISO 9001-2000 for implantation of Quality Management System at CIAL. Three certifying bodies i.e. USA, UK and Germany granted ISO 9001-2000 certificates. CIAL is the only organization in Pakistan, which got ISO certification in Architecture Engineering Services in C&I area. This achievement will be very help full for commercialization of CIAL.

NED University intends to build I&C center. CIAL engineers helped NED to prepare PC-I. Subsequently, two professors of the University were sent to CIAL for six months duration to train them at all facilities of CIAL and on-the-job training on CC&I backfitting project of KANUPP. They received comprehensive training and now would be able to establish I&C center at the University.

**COMPUTER DEVELOPMENT**

**CC&I Backfitting Project**

Test run of ARC-PLC was performed for which fourteen Regulation Analog inputs were disconnected from ARC-GEPAC and were connected to the MCIs of ARC-PLC. Six analog inputs, originating from steam pressure / steam flow transmitters (installed by TUP) were also connected.

Thirty digital inputs were wired from the RPR console, along with twenty-
Storing of used fuel in the spent fuel pool during RFO-I of CNPP

Pre-commissioning tests were performed on the bearing temperature signals (ML1T system), channel temperature monitoring, activity monitoring system, Man, Machine Interface System, Reactor Power Regulation system etc.

For CERN Project a prototype database and an application program were developed. Installation and configuration of Cern Software on Linux 7.3 was also done.

QUALITY ASSURANCE

Routine audit and surveillance activities of performance functions related to plant system were carried out. Audit finding report highlighting deficiencies were issued to concerned division/section of the plant. Verification of Procedures related to RLO activities were checked. Full scope Quality Assurance manual was prepared.

NUCLEAR SAFETY & LICENSING DIVISION (NSLD)

Proposal for Hardware modifications to reduce core damage frequency have been formulated and work on AOT evaluation has started.

The Equipment Performance Degradation Plan (EPMP) is being developed in three phases. A draft plan for safety and safety related systems has been prepared. Two RCAs, Apparent Causes Analysis (ACA) and one study on scram reduction has been completed. TIMS is being updated and maintained on a routine basis while safety issues are analyzed on as and when required. The safety PI, have been implemented at KANUPP.

The CAP program has been developed and a station instruction has been issued. Most of the re-licensing queries (RLQs) by PNRA on the PSR have been resolved while a work plan for those requiring further action has been prepared and submitted to PNRA.

CHASHMA NUCLEAR POWER PLANT (CHASNUPP)

PLANT OPERATION AND MAINTENANCE

CHASNUPP generated a total of 1503 GWh of electrical output with 1386 GWh of it exported to WAPDA. The total on line time of the Turbine-Generator was 5243 hours thus raising the on line time

Installation of 220 VAC UPS main distribution panels and power distribution panels, New MMI console in the control room and new transmitters of steam flow signals (TS loop) and Boiler Feed Water signals (BFW loop), etc has been done. Change Approval documents of annunciation system and Change Approval of "Standby Split Type A/C System", for UPS/battery room and electronics rooms, was prepared and submitted.
of Turbine-Generator to 17384 hours since first grid connection. The average plant capacity and availability factors were 52.82% and 59.85% respectively.

Numerous maintenance jobs were carried out by Maintenance personnel of CHASNUPP along with nearly 1000 outside personnel participated in Refueling Outage-1 (RFO-1). During RFO-1 total 3614 jobs were carried out including 3284 maintenance jobs, 11 modifications, 181 ISI jobs and 138 surveillance tests besides Refueling in which one third of core was loaded afresh and remaining Fuel assemblies were reshuffled.

Major jobs included Refueling, Turbine Generator Overhaul, Main Transformer and 220 kV / 132 kV GIS Overhaul, Reactor Coolant Pump-A Motor Overhaul, Main Feed Water Pump-A / Motor Overhaul, SRH Pump-B Overhaul, Steam Generators Tubes inspection, Sludge Lancing of Steam Generator secondary side, Structural Integrity (SIT) and Integrated Leak Rate Test (ILRT) of Containment.

During the reported period seventeen modifications have been completed and implemented. Some of these modifications include Alarm reduction program in MCR, installation of Turbine Lube oil cleaning system, repair of reactor upper internals deformed keyways, etc.

PLANT OUTAGES

The ten outages experienced were spread over a period of nearly one hundred seventy five days. The first planned outage took 23 days for performing surveillance tests while the second planned outage was RFO-1.

RFO-1 was planned for eighty one (81) days but it extended to one hundred and ten (110) days due to the various problems encountered during outage.

The largest unplanned outage started from 25 June 2003 and ended on 29 July 2003 due to grid transient in which Moisture Separator Re-heater (MSR) piping and bellows were damaged. The repair work took about 33 days.

EVENTS AND REPORTS

A total of thirty seven events were encountered out of which fifteen were reportable to Pakistan Nuclear Regulatory Authority (PNRA). Some of the major events included reactor trips on grid fluctuations, malfunctioning of main feed water control valve, damage of essential chiller, sticking of core upper internals, damage of TPAs/RCCA and damage of MSR piping & bellows.

SAFETY AND HEALTH PHYSICS

The maximum dose received at the plant by any radiation worker during the RFO-1 was 31.23% of the permissible annual dose. The second integrated emergency exercise was conducted on September 5, 2002 at site, which was witnessed by PNRA. Follow-up actions to remove the deficiencies observed during the emergency exercise are in progress.

QUALITY ASSURANCE & ASSESSMENT

Quality Assurance & Assessment Division (QA&AD) conducts audits of various departments/divisions to assess their preparation to handle different jobs assigned to them, issues deficiency reports and non-conformance reports if it detects any deficiencies at the plant or violation of procedures and programmes during operation and maintenance of the plant. During the reported period, QA&AD conducted five (05) internal audits and one external audit of NCNDT Centre Islamabad.

About two hundred (200) surveillance deficiency reports, non conformance notices and non conformance reports were issued by QA&AD.

PROCEDURES AND REPORTS

A number of administrative and technical procedures were developed for systematic implementation of various activities at the plant. A large number of these procedures were for RFO-1 jobs, their Q-Plans and ALARA plans.
APPLIED SYSTEMS ANALYSIS GROUP (ASAG)

The Applied Systems Analysis Group (ASAG) is engaged in research and planning activities related to energy, electricity and nuclear power in Pakistan and analysis of related economic, financial and environmental issues.

ASAG contributed in the preparation of PC-I document for the second unit of Chashma Nuclear Power Plant (C-2).

The Group assisted the Global Change Impact Studies Centre and IAEA in their capacity building efforts in developing countries through delivering lectures in training courses and undertaking expert missions.

INSTITUTE OF NUCLEAR POWER (INUP)

Analytical engineering studies related to the Pressurized Water Reactors (PWRs) remained the mainstay of INUP's activities. The work assignments related mainly to the areas of: reactor physics, core design, thermal hydraulic design, besides accident and transient analysis, in-core fuel management and fuel mechanical design. Laboratories for radiation shielding studies, and nuclear instrumentation have been established. The Institute, in addition is gradually attaining the status of centre for diagnostic vibration analysis of moving components of machinery.

CORE DESIGN AND FUEL MANAGEMENT

Various issues related to In-Core Fuel Management were routinely reviewed with CHASNUPP under the terms of reference of MOU between INUP and CHASNUPP. Prepared Nuclear Design Report for Cycle-2 of CHASNUPP. Flux Map Data Processing and Analysis of CHASNUPP for cycle 1 up to 484 EFPD was performed.

Uncontrolled RCCA bank withdrawal accident from a subcritical or low power startup condition of Cycle-2 of CHASNUPP was analyzed. Flux map data processing and analysis for cycle-2 of CHASNUPP up to 43 EFPD. Main steamline break (SLB) accident for Cycle-2 of CHASNUPP was analyzed. Severe accident, Station Black Out, for CHASNUPP was analyzed by using the computer code MELCOR 1.8.4. Sensitivity study, by using the computer program RTHP of various thermal hydraulic parameters of CHASNUPP was carried out.

Shield design and Source term analysis of spent KANUPP fuel and booster bundles is in progress. Multi-group shield design analysis of PWR type reactors by discrete ordinate methods is underway.

The design of concrete canisters and steel basket for "Dry storage project" for spent fuel is being revised. Verification of design of the adapter plate of top nozzle of CHASNUPP fuel assembly has been completed. A study of the design verification of top nozzle of CHASNUPP fuel assembly has been completed. A review related to 'Advanced Fuel Assembly', to reduce the operational cost of CHASNUPP, has been completed.

Work has been started for experimental measurements of neutron and gamma shielding properties of various materials in PARR-1. The work has been completed on the contract awarded to INUP by CHASNUPP for the delivery of indigenously developed DRM (Digital Reactivity Meter). Frequency testing of CHASNUPP steam turbine blades was carried out. Validation/development of expert software for loose parts monitoring system for KANUPP and CHASNUPP continued. Software development for data acquisition and processing is also in progress.

DIRECTORATE GENERAL NUCLEAR POWER (DGNP)

Coordination with World Association of Nuclear Operators (WANO)

The World Association of Nuclear Operators (WANO) is a non-governmental organisation with a mission to maximize safety and reliability of nuclear power plants. The office of Director (NPO) is the contact for cooperation/coordination with WANO.
The office has connection to WANO website through Internet for prompt receipt of useful technical information and plant performance data exchange. The office ensured participation of PAEC personnel in Meetings, Workshops, Seminars, Peer Reviews, Technical Exchange Visits organized by WANO.

During the reporting period cost free participation of 12 PAEC personnel was arranged in various WANO programmes held in other countries. In addition a WANO-Tokyo Centre workshop on "Effective Utilization of Operating Experience to Improve Operational Safety" was arranged at Islamabad on 21-23 January 2003.

This interaction of PAEC personnel with the international experts has helped in acquiring new knowledge about technical developments and performance of world nuclear power industry, which can be used for comparison and emulation.

NUCLEAR DESALINATION

Nuclear Desalination Demonstration Project

Studies for installation of a nuclear desalination plant of about 1 Million Gallons/Day capacity at KANUPP are being conducted under the auspices of International Atomic Energy Agency (IAEA). It is planned to design, manufacture and install the plant indigenously.

The project is being undertaken jointly by DGNP and KANUPP and equipment will be indigenously manufactured. The plant will be based on Multi Effect Distillation (MED) technology. Steam tapped from KANUPP will provide thermal energy to the desalination plant.

Various options of tapping steam from KANUPP have been analyzed from the technical, economical as well as safety point of view. Two IAEA expert missions visited Pakistan in September 2002 and June 2003 and reviewed the basic design work.

IAEA Coordinated Research Project (CRP)

An IAEA Coordinated Research Project (CRP) entitled "Economic Research on, and Assessment of coupling 137 MWe Karachi Nuclear Power Plant with a desalination plant of upto 1 MGD capacity" has been started from January 2002. This CRP is a part of IAEA’s CRP "Economic Research on, and Assessment of Selected Nuclear Desalination Projects and Case Studies". The work will contribute to the IAEA’s efforts to enhance prospects for demonstration and successful implementation of nuclear desalination in the IAEA member states.
Reactor Operation

Pakistan Research Reactor (PARR-1) was operated for 420 hours producing 3105 MWh of thermal energy. Five hundred and sixty nine capsules containing different samples were irradiated. The quality of primary and secondary water was maintained up to the standard. Low and full power tests were carried out to meet the requirements of operating policies. Fire emergency and site emergency drills were also conducted.

Pakistan Research Reactor (PARR-2) was operated for 133 hours producing 3868 KWh of thermal energy. Number of samples irradiated was 1234. Quality of reactor vessel/pool water was maintained up to the standard.

Reactor Experiments

A series of experiments were performed for measurement of gamma doses in the gamma cell of PARR-1 with different combinations of retired LEU fuel elements. Similar measurements were performed in wet storage bay for gamma dose due to retired HEU fuel elements. A maximum dose rate of 35 Gy/hr was recorded in gamma cell. This experimentation was performed with an intention to explore the possibilities of installation of a dry gamma irradiation facility for food irradiation at PARR-1 in collaboration with NIFA, Peshawar.

Reactor Physics and Safety

Keeping in view PARR-1 performance on mixed (HEU and LEU) fuel, from operational/safety limits and utilization point of view, some more mixed fuel PARR-1 core configurations were analyzed. On the basis of calculated neutronic and safety parameters, a core configuration with HEU fuel elements lying around the side water box was proposed for the final operation. Radiological consequence analysis for accidental releases for a 300 MWe PWR was continued. The computer code RASCAL along with the locally developed program PAKRAD is being used for dose calculations. In addition to this, work on acquiring the topographic and meteorological/wind data for use in the atmospheric dispersion modeling using a Lagrangian approach, has also been started.

Plasma Physics

Electromagnetic drift waves in electron-positron-ion plasmas have been studied. It is found that these waves can form the dipolar vortex structures in the nonlinear regime.

Coupling of ion acoustic and Alfven waves with the drift wave have also been investigated. Furthermore, this study has been extended to dusty plasmas, by considering the coupling of drift wave, ion acoustic wave and Alfven waves.

Computational Physics

In all Langmuir-Hinshelwood (LH) type models which give more realistic description of the surface reaction systems, the adsorption of two oxygen atoms was considered on a pair of vacancies found in the first nearest neighbourhood (a distance of one atomic spacing between two vacancies) of the site of impact. Recent experiments by scanning tunnelling microscopy on the dissociative adsorption of oxygen molecules on an Al (111) and Pt (111) surfaces pointed to a "hot atom" mechanism. It was found that the two oxygen atoms...
appeared in pairs, with average distances of two lattice constants. Appearance of two oxygen atoms in pair, having one atomic spacing distance has very small probability. This fact is being introduced in the LH type models.

Molecular dynamics simulation technique, based on N-body interatomic potentials has been employed to evaluate parameters for Au like lattice constants, energy per atom, coefficient of thermal expansion, heat capacity and mean square displacements as a function of temperature. Temperature for melting transition has been calculated for Ag and Au. Coefficient of self diffusion for Ag and Au has been calculated in the temperature range 1500 K – 2100 K. Results are being fitted to evaluate pre-exponential factor and the activation energy for the liquid state.

Fast Neutron Physics

The determination of boron in an iron base amorphous alloy as well as in steel samples has been carried out by prompt gamma neutron activation analysis setup at PARR-I. The re-estimation of absolute intensities by thermal neutrons capture in $^{55}$Mn with $k_e$ standardization approach was done in the energy range from 50 keV to 3 MeV. The work is being extended up to 8 MeV. The efficiency of HPGe detector from 50 keV to 8.5 MeV has been worked out using standard radioactive sources as well as captures gamma rays in Cl. The studies on thermal neutron cross-section and resonance integral of $^{160}$Tb has been completed after incorporating calculated thermal and epithermal shielding factors in the data. The causes of discrepancies in the measured results were ascertained.

Nuclear Cross-section Studies

To establish the production feasibility and to confirm the purity of new medically important radionuclides nuclear reaction cross-sections measurement studies is being carried out. In this regard the work on Ru and Fe for nuclear reactor production feasibility of $^{95m}$Tc and $^{54}$Fe is still in progress. The following reactions have been investigated so far: $^{55}$Ru(n, 2n) $^{54}$Ru$^{55m}$Tc, $^{54}$Fe(n, 2n) $^{53}$Fe and $^{54}$Fe(n, p) $^{54}$Mn.

Alpha Spectrometry

Preparation of thin sources of natural uranium by electrodeposition for alpha spectrometry was continued using the new electroplating cell with rotating electrode. Different parameters such as current, pH, metal ion concentration etc., for the quantitative electrodeposition of metal under investigation were optimized. The reproducibility of the plating system was checked and the calibration line in the range of 10 to 100 microgram of uranium prepared. It showed good linearity within the experimental error. Further work related to the thin source preparation is in progress.

High Temperature Superconductivity

To investigate the effects of dopants in the CMR materials the synthesis of $\text{La}_{2-x}\text{A}_x\text{Ca}_{0.5}\text{Mn}_2\text{O}_3$ (where $\text{A}=$ Nd, Sm, Gd, Yb & Y) and characterization by the R-T and XRD measurements have been completed. Study of the effect of dopants on the spin glass behaviour for the CMR materials, $\text{La}_{2-x}\text{A}_x\text{Ca}_{0.5}\text{Mn}_2\text{O}_3$, has been completed. Simulation techniques based on the energy minimization procedure were applied to investigate the crystal properties of ZrSiO$_4$ and Ruthenates.

Double perovskites $\text{A}_x\text{LaMnFeO}_5$ (where $\text{A}=$Ca, Sr, Ba) polycrystalline samples were synthesized by conventional solid-state reaction. The sintering of these pellets was carried out at 1250 °C for 72 hours in air and 48 hours in O$_2$ flow at 900 °C. The structural refinement was carried out using Rietveld refinement program.

Mössbauer Spectroscopy

Ni-substituted Mn-ferrites, $\text{Mn}_x\text{Ni}_y\text{Fe}_2\text{O}_4$ (x=0-1.0) have been studied at room temperature by Mössbauer spectroscopy. It shows that $\text{Mn}^{2+}$ ions occupy both the tetrahedral and octahedral sites while $\text{Ni}^{2+}$ ions occupy octahedral sites only. Variation of internal magnetic fields ($H_m$) for both sites has been investigated. The line widths of the most of octahedral sites decrease and no significant change is observed in isomer shift with an increase of Ni concentration. NiFe$_2$O$_4$ was found to be completely inverse spinel while all other compositions including MnFe$_2$O$_4$ are partly inverse spinel. The measurements on CMR materials, at and below room temperature, for different concentrations of iron doping in place of Mn indicate no magnetic hyperfine interaction at room temperature: Isomer shift and Quadrupole splitting decrease and line-width increase with the increase of Fe up to 4%. After this the behaviour is reversed. All Mössbauer parameters indicate that iron is found in $\text{Fe}^{3+}$ state only.

Low Energy Physics

An electrostatic energy analyzer has been installed in the main accelerator. The analyzer has been extensively studied, and after carefully aligning and characterizing, a beam of specific energy of charged particles can now be selected. The selected beam has been detected by specially designed Faraday cage detector. A special shielding arrangement has been made to reduce the noise for detecting a current of charged particles as low as fraction of a Pico-ampere. Fabrication of 250 keV accelerator for GC University Lahore under the joint programme is progressing well. Some parts of this accelerator have been shifted to Lahore for assembling. The main components e.g. cluster ion source, ExB velocity filter for beam analysis and faraday cage detector have been fabricated and ready for trial operation.

Electron Microscopy

Study of surface modification of Hastelloy C-276 by SiC addition and electron beam melting shows nickel
rich dendrites with Mo depletion in the modified surface. Surface modification of Ni-base single crystal superalloy was carried out by electron beam melting. Scanning electron microscopy (SEM) revealed Al-Ti rich dendritic structure. Hardness of the molten zone is reduced by 50% as compared to the as cast material. Electron beam welding of dissimilar alloys Zircaloy-4 and Al-Fe-Ce has been carried out and microstructure of fusion zone and heat affected zone has been studied by SEM. Hot cracking is observed in the fusion zone. Different phases produced during welding are being identified. A project has been initiated to investigate solid solubility of Si in Al by ball milling. Alloys with different contents of Si are being prepared.

Neutron and X-Ray Diffraction

A powder neutron diffractometer has been successfully installed at beam tube no. 4 of PARR-1. This instrument, which is totally designed and developed at PINSTECH, is fully automated and is equipped with two sets of detectors, a single He³ counter and a position sensitive neutron detector. It is being used for investigations of residual stress measurements in commercial brass heat treated at temperature upto 800°C. The ipilim collimator for the new SANS instrument designed at PINSTECH and fabricated in SES has been installed. The focusing monochromator assembly and detector table are designed and being fabricated here in PINSTECH workshop. The data analysis for PbSe and PbSeO₃ has been completed and report is being written. Fault was located in the pre-amplifier of the x-ray diffractometer and it was repaired.

Studies of structural property relationship in the amorphous state of As-Ti-Se alloy have been carried out and the data analysis etc. have been completed. The effect of valency of Ti on structure and different physical properties of the resultant alloy composition in the As-Ti-Se matrix have been studied. Characterization of uranium silicide (U₃Si₂) is being continued. Efforts are being made to explore the structure of this material.

Nuclear Interaction Studies

The kinematical analysis of the heavy ion reaction (16.7 MeV/u)²³⁵U + nat Au using mica track detector was carried out previously on event-by-event basis using the spherical polar coordinates of the correlated tracks of multipronged events observed in this reaction. Now the study of analysis of reaction step preceding the sequential fission process is being carried out. Three mica samples of the heavy ion reaction (11.67 MeV/u)¹⁹⁷Au + ²³⁵²³⁶Au have been scanned. Projected lengths and depths of each of the correlated tracks of two- three- and four-pronged events were measured. Reaction cross section has been determined. The track parameters of the binary events observed in the reaction (14.5 MeV/u) Xe + Bi (CR-39) have been measured again for the separation of elastic events from total binary events. The quarter point angle has been determined from elastic data and used to calculate the reaction cross-section. The experimental and theoretically calculated values of the reaction cross sections have some differences which are being resolved.

SLIM is an international collaboration project aimed to detect light magnetic monopoles at high altitude. The detector wagons comprising of CR-39 and Lexan detectors covering 82 m² area were installed. The detectors for radon and neutron background measurement have been retrieved from the site after one year exposure and replaced with new detectors. Some of the detectors have been etched in 6N NaOH for three hours at 70°C to reveal the tracks of alpha particles emitted from radon present in the environment of experimental set-up.

Lasers Studies

An extended cavity diode laser system has been designed and developed. By using grating feedback, a broadband (~tens of GHz) free running diode laser can be converted into a narrow band (~100 MHz) and a tunable extended cavity diode laser. We have developed a 75 mW, 785 nm diode laser system having a narrow line width ~100 MHz, which is tunable over a range of +/- 10 nm with laser power in excess of 50 mW has been developed. This newly developed laser can be used for ultra high resolution spectroscopy of Rb atoms.

In a Nd-YAG laser, laser rod was successfully assembled in the amplifier assembly. Now the laser is functioning properly. A long awaited power supply of an Argon ion laser system has been successfully repaired.

Track Detectors Applications

To study the response of CR-39 to the neutrons of different energies, an optical photometer has been employed to measure the transmission of light through etched samples exposed to different fluences of neutrons. It has been found that the transmittance falls exponentially with the increase in etching time interval for each of the values of neutron fluence. However, the optical properties of the detectors exposed to thermal neutrons are different than the detectors exposed to the energetic neutrons. In order to determine various etching parameters of Na₂CO₃ enriched NaOH solution, tracks of fission fragments have been measured after etching the ²³⁵²³⁶U-exposed detectors at 50°C in solutions containing varying concentration of Na₂CO₃ for 5-15 minutes time intervals up to a total etching time of 210 min. The etching will be continued at higher temperatures also to deduce the required results.

Nuclear Geological Studies

Fission-track age of 31.27 ± 0.81 Ma was calculated for the Durango (Mexican) apatite using external detector method and absolute approach. A (zeta is a constant) calibration factor of 317.04 ± 10.43 (years cm⁻²) was
calculated for Durango apatite by simultaneously irradiating it with glass monitor, SRM 612 in PARR-1 Reactor. This value of zeta will be used in future in fission track dating of apatite while using the age standard approach. The fission-track dating studies of apatite crystals from Jawar and Jambil carbonatites using grain by grain method and absolute approach yielded average ages of 24.05 ± 1.07 Ma and 22 Ma, respectively. Boron and uranium concentrations in drinking water samples from the natural springs of Reshian and Muzaffarabad areas have been found with an average of 0.161 and 1.36 µg/l, respectively, using the technique of (n , α) and (n , f) reactions observed with solid state track detectors.

**Radiation and Isotope Application**

Vitamin A, trace elements, body composition and milk output of malnourished anemic lactating women were determined by standard analytical techniques for the IAEA project 11530/RB. The results have suggested that milk production and quality of breast milk of mother were limited to some extent by the maternal nutritional status. A "Breath Mat™" system was installed at Nuclear Medicine Oncology and Radiotherapy Institute (NORI) Islamabad for commercialization of urea breath test (UBT) for the diagnosis of Helicobacter pylori. The facility for routine UBT test is being provided to gastro patients. VG ISOGAS Mass Spectrometer was calibrated and stable nitrogen isotope ratios were measured on 105 samples received from Biofertilizer Division, NIBGE, Faisalabad.

**Stable Isotope Hydrology**

Methodology for stable isotope analysis of nitrogen and oxygen in aqueous nitrate and AgNO₃ samples was optimized and applied for δ¹⁵N and δ¹⁸O determination in samples for the IAEA Project-29104 (Korea). Under the IAEA project INT/5/144 "Sustainable Utilization of Wasteland Saline Groundwater for Plant Production", analytical services including ²⁰⁸O, ²³H, ¹³C, ¹⁵N stable isotope analysis of more than 1400 water samples were provided to the IAEA/RCA member states.

¹³C, ¹⁸O and ²³H stable isotope analysis was completed on soil & water samples received from NIAB and KANUPP. 115 groundwater samples pertaining to IAEA TC project were processed and analyzed for stable isotope of Sulphur (³⁴S).

**Non-Destructive Testing**

In connection with the R&D programme of low enriched uranium (LEU) silicide fuel for research reactors, fabricated LEU fuel plates were examined critically by X-ray radiography to investigate the homogeneity of the LEU fuel material and dimensions of the rolled fuel met to standardize the manufacturing process. Depleted uranium rods of 28mm diameter were radiographed using gamma and neutron radiographic techniques to detect discontinuities introduced during fabrication. Examination of HT cable from HPD, graphite element from PARR-1, classified samples from Nucleonic Systems Labs., PAEC and TT straps from army aviation was also completed using X-ray and neutron radiographic techniques.

**Environmental Research**

Seawater, sediment and biota samples were collected from 960 km long coastal strip of Pakistan for the IAEA/RCA Marine Project. Seawater samples were analyzed for ¹³C, ¹⁸O and isotopes, chemical constituents & CFCs to determine groundwater age and interconnection between aquifers. Tritium analysis services (165 water samples) were provided to various countries under IAEA/RCA projects.
\(^2\)H and \(^{24}\)S stable isotope contents in water and its dissolved carbon and sulfur fractions as well as tritium (\(^3\)H) and uranium series radionuclides, major ions, and Fecal Coliform contamination. Significant depletion in \(^{13}\)C contents of total dissolved inorganic carbon and aqueous sulfate, electrical conductivity and salinity coupled with higher values of tritium confirmed the impact of pollution from industrial and/or domestic drains into shallow marine environment of southeast coast of Karachi.

Cysts of *Pyrodictium Bahamense* were determined in a sediment core collected from inter-tidal zones of Gawadar coast. This has raised concerns with respect to the issue of harmful algal bloom (HAB) concerns along this coast. 63 groundwater samples pertaining to shallow wells, deep wells and hand pumps were collected & analyzed for IAEA research contract "Isotopic investigation of saline water intrusion and related impact on potable water quality in coastal aquifer of Karachi Pakistan.

**Industrial Applications**

A radiotracer test was developed in cooperation with the IAEA for the study of wear in piston rings of vehicle engine. The test was successfully carried out for Inspectorate of Vehicle and Engineering Equipment (IV&EE), Pakistan Army, Rawalpindi. Wear of piston ring of a vehicle engine was determined at different conditions of RPM and load. Under the pilot program, "Application of thin layer activation (TLA) technique for wear, erosion and corrosion measurement in industrial systems" at Pakistan Oilfields (POL), further measurements for the loss of material from three TLA coupons installed at Meyal and Pindoori were carried out and another TLA coupon was installed at Pariwali.

**Laser Applications**

Twelve units of Laser land leveler were handed over to different organizations respectively, i.e. 3 units to PCRWR, 1 unit to OFWM, D. I. Khan, for testing, 2 units to private farmers at Gujranwala and Hyderabad (Sindh) and 6 units to private farmers of Sargodha, Sahiwal, Rahim Yar Khan, Muzaffar Garh, Gujranwala and Sialkot through OFWM Training Institute Lahore against crop maximization project in Punjab. Thirty units of laser land leveler are ready for delivery.

The design and fabrication of laser beam delivery system of \(\text{CO}_2\), consisting of beam focusing optics, cooling and gas/air injector has been successfully completed. \(\text{CO}_2\) Laser workbench is modified by introducing smoke suction facility. A computer controlled interfacing software program for laser material processing (LMP), which was used earlier with an imported Unidex motion controller, was successfully changed with an easily available motion controller.

**Chemical Material Studies**

Sorption studies of various radioisotopes such as \(^{63}\)Ni, \(^{56}\)Co, \(^{137}\)Cs and \(^{90}\)Sr on the natural polymer chitosan and activated charcoal were performed under variable physicochemical conditions like pH of sorptive media, agitation time, sorbate concentrations and temperature. The main purpose of this research is to find a suitable ion exchanger for the treatment and containment of radioisotopes.

Synthesis of hydrogels for agricultural use was carried out. Crosslinked poly(acrylic acid-co-acrylamide) hydrogels were prepared and water uptake measured.

**MATERIAL SCIENCE**

**Special Materials Studies**

Work on pilot plant for production of 1.0 kg/day metallurgical grade silicon from rice husk was initiated. A flow-sheet was developed, design work and cost estimation was completed. A comprehensive report regarding the establishment of materials processing lab. for training fresh engineers was made. The units are being fabricated and installed. These include: heat exchanger, mixersettlers, miniature cooling tower, fluid flow rig, absorption column, pulse column, rotary drum vacuum filter (RDVF) and filter press.
Synthesis work on selective polymers were started. These selective polymers were synthesized by immobilizing o-hydroxycetophenone, its oximes of hydroxylamine and its Schiff's bases of aniline and ethanol amine, on the matrices of low crosslinked styrene-divinyl benzene copolymers. The polymers synthesized were investigated for Fe$^{3+}$, Cu$^{2+}$, and Zn$^{2+}$ uptake studies which were found to be pH dependant.

Corrosion Studies

Previously plasma vapour deposition (PVD) technique was applied to get the Ni-coatings of various thicknesses on low alloy steel (LAS) ASTM 516 G-70. Electro-deposition technique was employed to get the improved Ni-plating on LAS. Various makes of Aluminium fuel cladding fin tubes were again analysed by other PAEC laboratories to reconfirm the previous results. The SSRT in air and DMW revealed better mechanical properties for the Swiss make tube both in the longitudinal and transverse direction than the other two makes. The results of immersion testing of tube specimens in DMW at PARR-2 fuel storage bay concluded that all the three tubes are resistant to pitting and general corrosion.

R&D work was carried out to establish parameters of various steps involved in the fabrication process of Alumina laboratory wares. With this technique different shaped crucibles and instrument parts have been casted successfully.

Alloy Preparation & Mechanical Testing

In continuation to the ongoing project of LEU fuel fabrication for PARR-1 the evaporation of silicon during arc melting was overcome by increasing the weight of charge from 50 g to 150 g and increasing %age of Si from 7.5 to 11%. A total 7 billets and 7 plates were made and sent for NDT to check clad thickness, fuel homogeneity and bonding of clad and fuel. Work is in progress.

Process Development Studies

Work on computer codes for the simulation of a solvent extraction process and for the design of mixer-settler and pulsed coulumn was completed. These codes can simulate extraction, scrubbing and stripping operations of solvent extraction process and can work out the chemical as well as mechanical design parameters. Fluidisation experiments were performed using carbonate powder having different average particle size (i.e. 37μm, 60μm 74μm & 125μm). It was observed that fluidisation is not smooth with fine particles (<37μm) whereas it was uniform and smooth when 74μm particle size powder was used. Design verification study indicated that the experimental values and the calculated values for design parameters were quite close to each other.

R&D study on the purification of commercial TBP was completed. The impurities like MBP, DBP or organophosphate compounds hinder extraction, re-extraction and form emulsion during solvent extraction operation. Chemical method was selected, for purification and optimised in terms of various process parameters, 150 litres of purified TBP of required purity was produced and handed over to NLP.

Fuel Fabrication

Experiments were performed to study the sintering behaviour of the mixture of aluminium and copper oxide powders. Powders mixed in a ball mill have shown better results than those mixed in an oblique mixer. Metallurgy of sintered compacts revealed that Al$_2$O$_3$ particles produced during sintering are uniformly distributed.

Aluminium composite reinforced with in-situ produced Al$_2$O$_3$ particles has been fabricated and characterized by using DTA, XRD and metallographic techniques. These results revealed that mixing step during processing of the composite is very critical in developing a homogeneous microstructure.

Work is in progress to setup a pellet fabrication lab. Green pellets of natural uranium based UO$_2$ have been prepared.

Green density and dimensional requirements conforming to the specifications of PWR fuel pellet have been achieved. Sintered pellets have shown good structural integrity and have sintered density within the specified range.

Polymer Processing and Radiation Studies

Work on the project, "Development of high speciality flame retardant, radiation resistant wire insulation for use in defense, automotive, aeronautics and construction industries" continued. This project of Rs. 7.16 million funded by the Ministry of Science and Technology was initiated during the previous year.

Various formulations for flame retardant and anti-rodent material were developed by radiation crosslinking. Chemically crosslinked material was also developed which is flame retardant. Their electrical, mechanical and flame retardant properties were tested. Formulations based on PVC, LDPE/EVA were developed and master batches for industrial utilization were developed.

ANALYTICAL TECHNIQUES

Environmental Studies (Radiation and Biological)

A high purity germanium (HPGe) detector, provided by IAEA, has been set up in the RPD laboratory in connection with the IAEA-TC project entitled "Development of country profile of environmental radiation levels".

The spectra of 35 soil samples of different areas of Pakistan have been collected using this detector system. These spectra are being analyzed for the measurement of gamma activities due to $^{238}$U, $^{232}$Th and $^{40}$K.
A dynamically modified silica phase has been investigated for the determination of uranium in various IAEA, SRM, and ore samples such as torbinate and pitchblendy.

Tetra alkyl ammonium compound has been used as ion-pairing reagent and phosphate buffer at pH 2.5 as mobile phase with UV as detector. The uranium has been determined in 70-fold excess of Fe (III) in above mentioned ore samples.

An adsorption column for GC has been prepared by coating alumina with Fe$_2$O$_3$. The adsorption material has been characterized by SEM. This packed GC column has been successfully utilized for separation of LPG (ethane, propane, butane); manufacture gas B (H$_2$, ethane, methane, CO) and quality assurance of nitrous oxide.

Under IAEA project sampling of air particulate matter (APM) at SES, I-9, Islamabad and PINSTECH is continued. In this regard 100 more samples were collected and analyzed for short-lived radionuclide and black carbon.

The experimental work is in progress to investigate the long-lived indicator radionuclides in human milk, infant head hair and medicinal herbs.

In order to establish some correlation with a disease and metal concentration in human blood, 17 blood samples of hypertensive patients have been analyzed for their Cu, Zn and Li contents using atomic absorption spectrophotometry.

**Radio and Nuclear Chemistry**

Sorption behavior of Ag and Cr onto polyurethane foam (PUF) loaded with diphenylcarbazide; Eu, Tm, and Hg on PUF loaded with pyridylazo-sorcinol (PAR); and the Cr onto unloaded PUF and loaded with triocetyl phosphine oxide (TOPO) has been studied from different mineral acids.

Parameters affecting the sorption such as shaking time, concentration of sorbent and sorbate etc. were optimized. Experimental work on adsorption of U and Cd on PUF loaded with 1-(2-pyridylazo)-2-naphthol (PAN) has been completed. Analytical method for the Hg determination based on IDA using Cyanex 471 in benzene from perchlorate media has been developed.

The validity of the method has been checked by standard addition in the synthetic seawater as well as in the IAEA standard reference material.

**SERVICES AND PRODUCTS**

**Radioisotope and Radio-pharmaceutical Cold Kits Production**

Regular production of I-131 was continued and 93960 mCi were dispatched to nuclear medical centres. 16 consignments of sodium phosphate (P-32) (141 mCi) and 07 consignments of MIBG-131 (52 mCi) were also supplied to medical centres. Moreover, sodium carbonate (Na-24) (490 mCi) supplied to R-Block, while I-131 (1305 mCi), sodium phosphate (P-32) (500 mCi) Tc-99m (23 mCi) and one consignment of Fe-59 (0.85 mCi) were supplied to HPD/R/AD/PIAES on complementary basis. Total supply of radioactive products was 95972.35 mCi worth 5.49 million rupees, whereas supply on complementary basis was 1819.35 mCi worth 0.83 million rupees.

8366 vials of eleven different cold kits MIBI, MDP, DTPA, MAG$_3$, DISIDA, DMSA, Phytag, HMPAO pyrophosphate and glucosheptonate worth 5.32 million rupees were also supplied during this period. Precursors such as DISIDA, di HMPAO, MIBI were synthesized locally. New cold kits for $^{99m}$Tc radiopharmaceuticals e.g. Dextran, Ciprofloxacin, and Adenosine were also formulated, which are under clinical trials at different medical centres. R & D work on preparation of highly concentrated solution of $^{99m}$Tc and improvements in labeling of MIBI and MAG$_3$ are under way.

**Analytical Services**

During this period, 723 samples were analyzed by ICP, AAS, XRF, AES, HPLC, IR Spectrometer, Ion-Chromatography and GC and a revenue of Rs. 32,200/- was generated. These samples were received from different centers of PAEC as well as outside PAEC. The beneficiaries were NMD, RIAD, NCD, APD, RPD, ACL, UML, CHASNUPP, A.E. Min. Centre Lahore, DGRE, KNFC, NDC, HMC-3, KRL, POF, Wah, Machine Gun Factory, Wah, Naval Headquarters, Air Weapons Complex, Wah, Cirosc Enterprises Ltd., Qarshi Industries, National Techno Commercial Services (Pvt) Ltd Lahore, Ahmed Chemicals, Capital Trading Corporation, NCPC, Shamsi Brothers, Islamabad and PEPSI Cola International (Pvt) Ltd.

**Applied Health Physics**

To enhance the safety culture from unwanted radiation exposure, radiation protection services were provided for safe operation of nuclear facilities on country level. Personnel radiation contamination monitoring services were provided to radiation workers, trainees and visitors of PARR-1, PARR-2 NCD, IPD and others radioactive radiochemical laboratories of PINSTECH. Radiation contamination surveys were conducted in different labs./plants of PINSTECH.

Safe transportation of 1381 consignments of radioactive material/radiation sources were authorized. An up-to-date inventory of radiation sources being used in various divisions of PINSTECH was prepared and physically verified. Radiation and contamination survey of seven radiography sources of INSPECTEST (Pvt.) Limited, Lahore was conducted. Radiation/contamination survey of Co-60 industrial gamma camera and probe helium leak test was done at SES, Islamabad.

The probe was found contaminated with Co-60, which has been decontaminated.
Environmental Monitoring

To ensure radiological safety of Pakistani environment and general public, radiation monitoring services were provided to various PAEC and non-PAEC organizations on routine and research basis. Radiological assessment of 263 air particulate samples received from countrywide radiological environmental monitoring network was carried out. Radiometric analysis was performed in 1791 environmental samples (charcoal filter, pool water, sump water, etc) received from different laboratories of PINSTECH for the detection and measurement of fission fragments and activation products. Thyroid scanning facility was provided to 48 radiation workers of iodine plant. Services of mobile radiation monitoring laboratory (MRML) were rendered in emergency preparedness and off-site radiological environmental monitoring and hazard assessment programme. Measurement of ambient gamma dose level around PINSTECH using G-2 TLD cards was made and an average dose rate of 0.157 ± 0.041 μGy was obtained.

Radiation Dosimetry

To ensure radiological safety of radiation workers, personnel monitoring services for external radiation monitoring were provided on country level, using TLD and film badge dosimetry. The services were provided on monthly basis to 2850 radiation workers from 280 establishments. During this period about 25000 dosimeters were processed, 690 G-2, TLD cards for environmental/area monitoring were provided to various groups of HPD, BC-1, KCP-II, and ISL (Taunsa) and processed for the determination of ambient dose.

Secondary Standard Dosimetry

Secondary standard dosimetry facility for the calibration of radiation monitoring/delivering equipment was provided to various establishments of the country. During this period, 94 protection level survey meters, 210 pocket dosimeters, 98 radiation monitoring detectors, 7 neutron survey meters and 40 pen type/alarm dosimeters received from various PAEC and non PAEC organizations were calibrated and certificates were issued. Therapy level calibration services were also provided for 2 therapy level dosimeters and beam output measurements of 4 teletherapy units at various radiotherapy institutes of the country were made. 275 TLDs and 4 ring type dosimeters were irradiated using Co-60/Cs-137 irradiation facilities. To provide quality services and maintain secondary standard instruments in adequate agreement with international measurement system, PINSTECH participated in therapy level IAEA TLD postal dose inter-comparison programme. The percentage deviation of PINSTECH result was in excellent agreement with the IAEA mean measured dose.

Radioactive Waste Management

Approx. 927 m³ of low-level liquid waste and 6.4 m³ of low-level solid waste having short-lived beta/gamma emitting radionuclides, received from PARR-1, PARR-2, IPD and NCD was disposed off after necessary treatment. About 15 kg of medium level solid waste was received from IPD for decay and disposal, respectively. 154 samples of exhaust air from PARR-1, PARR-2 and IPD (I³¹) plant were collected and got monitored for any abnormal release. Bore-holes were monitored 11 times, to check the underground movement/migration of radionuclides from disposal area. Five spent sealed radiation sources were collected from M/S Inspectest Lahore and placed in an interim storage. Research and development work on immobilization/solidification of radioactive waste and standardization of procedures for the solidification of the secondary waste was carried out.

Electronics Instrumentation

Design and development of nuclear instruments modules and channels for a PAEC project is in progress. Field testing of nuclear instrument modules developed at RIDG is in progress at KCP-II. A new logarithmic amplifier has been developed and tested. A dc-dc converter, a power supply and a pulse decoupling unit has been designed, fabricated and tested. A logic-linear reactor power measuring channel has been developed for KANUPP and tested at PARR-1. A delayed neutron monitoring channel for KANUPP is being designed. A handy portable device was developed for radiation workers. Three DC power supplies were developed for HPD. Thirty seven transformers and seventy eight printed circuit boards were made for repair, research and development work.

Computers

Under PAK-CERN collaboration research programme, compact muon solenoid (CMS) events production site has been established in Computer Division. CMS events production activity is based on Monte Carlo production chain and includes all calculation steps of events' generation, simulation, digitization and reconstruction. To establish CMS events production site, CERN computing environment was replicated. Thus a PC cluster framework was established and all necessary production tools were installed. CERN authorities then offered a no. of assignments to test this local setup. After successful completion of these assignments, Pakistan was included in regional center (RC) list at CERN as the only events production site in Pakistan. Now-a-days PINSTECH is participating in the pre-challenge production (PCP-03) activity. To participate in the real time event production task data challenge (DC-04), Monte Carlo RunJob (McRunJob) was also installed and commissioned at PINSTECH cluster. Progress of the event production site can be viewed at the following address against the data set ID710.http://cmsdoc.cern.ch/cms/production/www/cgi/data/Statistics.php

Goal of the face recognition system project was to detect and recognize the human faces providing secure
Identification solutions. In this project facial images of three persons were segmented out from complex background and their statistical parameters were calculated. These statistical parameters were given as input to the back propagation algorithm engine. This back propagation algorithm is developed in VC 6.00 using object oriented methods. The engine trained for three images produced excellent results. Work was completed at lab. level.

For the “Design and development of an expert system for process monitoring & control”, all analog input signals coming from process are grouped in different screens. Each screen having different parameters displays on-line digital values up to six characters with graphics for a preset interval of time. The parametric values can also be displayed separately with an enlarged graphics with all previous values.

The SUN computer systems continued to work satisfactorily round the clock. Computational services worth Rs. 3.48 million against 3477.18 CPU hours were provided during the period.

A dynamic web-based online library package was developed using MySQL as database and PHP for server end programming. A one week workshop on “Scientific computing for large hadron collider (LHC)” was arranged at National Center for Physics (NCP), Islamabad for 30 participants from NCP, COMSATS, KANUPP and HMC-III.

**Scientific Information**

Many services of dissemination were provided to different establishments of PAEC and other R&D organizations including selective dissemination of information (SDI) services from INIS database on monthly basis. Similarly SDI from other in-house databases i.e. technical reports and TOC’s of journals received in SID were also provided to the respective users. During this period SDI services were provided extracting from 48,452 documents from INIS database, 20,155 documents from technical reports and 18,365 documents from TOC’s of journals respectively. About 325 on-line retrospective search results were provided from INIS database on CD-ROM to the users from PAEC and other R&D organizations. Similarly, IAEA’s non-conventional literature (NCL) and current contents database received weekly on floppy diskettes were also provided to the users as and when required. As SID is the national center for International Nuclear Information System (INIS) in Pakistan, this year about 240 inputs were processed and sent to INIS database of IAEA. Similarly 120 documents have been dispatched to INIS to assist IAEA as voluntary contribution by Pakistan. Other activities related to INIS and NEA databank of OECD have also been performed.
AGRICULTURE & BIOLOGY

Three agriculture centres of PAEC namely Nuclear Institute of Agriculture (NIA), Nuclear Institute for Agriculture and Biology (NIAB) and Nuclear Institute for Food and Agriculture (NIFA), through their activities contributed towards promoting R&D in agriculture sector of the country by utilizing application of nuclear techniques and other modern approaches. The objective was to develop better adapted crops, increased yield, crop protection and optimum utilization of lands affected by water logging and salinity.

CROP IMPROVEMENT PROGRAMME

Wheat

The wheat varieties Sarsabz and Kiran 95, evolved by NIA, have generated an additional annual income of Rs. 1568 million to the farmers of Sindh. New wheat variety Marvi 2000 has been inducted in the system after being approved by the Provincial Seed Council in its meeting held on 22nd Oct. 2002, for general cultivation in the province of Sindh.

Pre-basic seed of Sarsabz (7 ha), Kiran 95 (4.2 ha) and Marvi-2000 (2.8 ha) varieties was multiplied on Experimental Farm. The crop was inspected and certified by of Federal Seed Certification & Registration Department.

The seed of candidate varieties Bhita and Khirman was also multiplied on 1.6 ha and 0.2 ha respectively. The proposal of candidate high yielding disease resistant variety Bhita had been submitted to the Technical sub-Committee for the Approval of Varieties and Techniques, Government of Sindh. Another high yielding candidate variety Khirman was evaluated in the low water requirement trials by managing different irrigation levels at different locations in Sindh. The variety confirmed its high yielding performance at different sites.

Twelve future lines were evaluated in zonal (multi-environmental) trials at six sites in Sindh. A large number of advance lines remained under evaluation for yield and yield components in various yield trials.

33.7 tons seed of different categories (BNS, Prebasic and certified) of the two NIFA wheat varieties i.e. Bakhtawar-92 and Fakhre Sarhad produced during 2001-2002 and 2002-2003. A new candidate wheat line CT-00231 was got included in NUWYT (2002-2003) for its first year mandatory evaluation for yield, disease resistance and adaptability through out Pakistan. The result of the NUWYT planted at NIFA revealed that the line CT-00231 ranked third producing a grain yield of 4433 kg/ha against the 4217 kg/ha of the check variety Fakhre Sarhad.

About 38 tons of quality seed of the two rainfed wheat varieties Tatara and Takbeer was produced during 2001-2002 and 2002-2003 and was disposed off in the province for further seed multiplication and commercial utilization. Data regarding plant height, fertile tillers/m², maturity and spike architect was recorded for all the NIFA/National yield trials and international observation nurseries. Necessary selection followed by roughing, harvesting and threshing was completed for all the trials and nurseries.

Cotton

A new cotton variety SOHNI endowed with high yield, early maturity and high lint ratio (GOT%) has been finally approved by Provincial Seed Council in its meeting held on 22nd Oct, 2002 for general cultivation in Sindh. It maintained its superiority in yield of seed cotton (kg/ha) and ranked first among twelve varieties of Sindh and Punjab while tested in comparative trials conducted by Cotton Botanist, ARI, Tando Jam during 2002. The approved variety Chandi-95 is being grown over more than 12000 ha and earned an economic return of 503 million rupees since release to 2001-02.
The requisite testing and evaluation of mutant NIAB-98 a candidate variety for commercial release has been completed. To meet the seed requirements for approval, seed multiplication is in progress. A proposal of NIAB-999 was presented in the meeting of experts sub committee for its approval based on the 2 years yield performance in NCV and DGR trials. Later Punjab Seed Council in its meeting held at Lahore on 23rd April, 2003, approved NIAB-999 for general cultivation. True to type seed of NIAB-999 and of candidate strain (NIAB-111) was supplied to different seed producing agencies and progressive cotton growers in Punjab and Sindh provinces.

Rice

The Varietal Evaluation Committee (VEC) in its meeting held on April 23, 2003 at PARC HQ Islamabad unanimously approved high yielding, good grain quality variety, Sarshar for general cultivation in Sindh and Balochistan.

Pre-basic seed (1772 kg) of rice varieties (Shadab, Shua-92, Khushboo-95 and Sarshar) was grown and supplied to progressive farmers of Sindh and Balochistan provinces for multiplication and post release verification trials. These varieties covers about 58% of the total area of Sindh province under rice. An additional annual income of Rs. 1555.2 million has been generated through the cultivation of these varieties.

A high yielding short stature mutant namely NIAB-2000 (aromatic) already tested in NURYT ranked first in yield on average basis throughout Pakistan. 32 entries from 10 countries of the region were planted in an IAEA Regional Rice Mutant Multilocation Trial and data on various morphological traits and disease reaction were recorded. Mutants from Bangladesh produced highest paddy yield followed by those from Thailand. On the basis of grain characteristics and yield a mutant from Thailand is being multiplied for National Uniform Rice Yield Trial (NURYT) testing.

600 kg pure seed of NIAB Imi-9 was produced and supplied to the progressive growers, private seed corporations and Punjab Seed Corporation for further multiplication. Five single plant progenies of Kashmir Basmati were planted in the field. Sixty Kg pre basic seed was produced and supplied to the Agriculture Department of Azad Kashmir.

Chickpea

175 plant progenies in M2 generation, 76 advance mutant lines and 690 hybrid progenies of (F2-F3) were screened in the blight nursery at NIAB, AARI Faisalabad and NARC Islamabad. 13 mutant lines exhibited consistent resistant reaction (3-5) across the location. Multilocational yield trials of advance desi and kabuli chickpea mutant lines were laid out at six different locations. Mutant CM3837/97 exhibited the highest yield.

300 single plant progenies each of good looking true to type plants of CM2000 and CM98 were planted for production of pre-basic seed. 40 kg pre-basic seed each of CM2000 and CM98, and 567 kg and 179 kg certified seed of CM2000 and CM98 respectively was produced at NIAB Seed Farm Kundian.

33 advanced mutants derived from the mutagenized populations of Pb-91 along with check varieties were evaluated in three sets of replicated yield trials at NIFA research field. The plant height and days to maturity of all the high yielding mutants in these trials were at par to the standard check varieties.

Oilseed Brassica

On the basis of high yield and other agronomic traits, 10 rapeseed (Brassica napus) varieties (canola type), 10 mustard (B. juncea) strains / varieties (zaid kharif), 9 mutant strains of Agati Sarhein (B. juncea), 4 mutants strains of Toria Selection-A (B. campestris) and 4 mutant strains of S-9 (B. juncea) were evaluated in yield trials. All the mutants showed better performance than parents and check.

About 240-kg BNS and 200 kg Pre-basic seed of Abasin-95 was developed at NIFA for maintaining the seed purity of this variety. Seed from 141 progeny rows and 245 single plants was also harvested for raising BNS and plant progenies respectively next year. A total of 102 rape-seed/mustard mutants and hybrids were evaluated in eight advanced yield trials.

A new research project entitled "Development of canola quality mustard (B. juncea) genotypes" was awarded. Based on visual observations, selection of 53 desirable putative mutants were selected. All the elite and advanced breeding material of rapeseed, canola and mustard mutant lines were screened for the desirable quality traits such as fatty acid composition, total oil, glucosinolate and protein contents etc. on Near Infrared Reflectance Spectroscopy System (NIRS, Foss 6500).

Two Advanced Yield Trials consisted of 36 potential mutants of rape & mustard were conducted simultaneously at three different locations viz. NIFA, Peshawar, BARI, Chackwal and NIA, Tandojam under IAEA Technical Co-Operation Project lines 2K-99 of rapeseed and 2K-1 of mustard has been selected as future candidate lines.

Fresh mutagenized population "M1 generations" of oilseed rape / mustard were conducted in a new IAEA Research Contract "Exploitation of physical mapping technologies for the breeding of canola mutants in oilseed brassicas" were raised at NIFA, Peshawar as well as at Hill Agriculture Research Station Kaghan. Oil quality of about 1500 samples of different brassica oilseeds breeding material was determined on Near Infrared System FOSS-6500 through non-destructive and with out using any kind of chemicals, during the period under report.

Sesame

Small-scale multiplication of mutants Pr. 114-2 MS 1, Pr. 19-9-100-94-10 and S-17-6-94 was carried out. The germ plasm consisting of 107 entries was maintained for utilization in na-
tional breeding program. Germplasm comprising 106 genotypes of local and exotic origin have been planted in the field for evaluation. M1 generation of 11 genotypes has been raised after treating the seed with eight split doses of gamma irradiation for creation genetic variability.

Castorbean

About 30 germplasm lines have been collected from different sources and planted in the field for further evaluation. Seed of variety DS-30 was irradiated with 100-1000 Gy of gamma radiation for the creation of genetic variability. 129 M-i single plants progeny rows have been raised in the field for selection of desirable mutants in M2 generation.

Mungbean

Efforts were made for induction of mungbean variety AEM-96 in the cropping pattern of agriculture in Sindh province.

The area under mungbean is gradually increasing and the variety covers around 2000 ha in Sindh. High quality pre-basic seed (1374 kg) was produced and made available to the progressive growers, 37 advanced recombinants derived from eight different cross combinations resulted from the crosses between the exotic and local mungbean genotypes along with standard check varieties were evaluated for yield and some important agronomic traits in replicated yield trials at NIFA during kharif 2002.

An elite line NM 1 secured first position in Mungbean National Uniform Yield Trial during the year 2000-2001 and 2001-2002. Single plant progenies of this line were grown and uniform progenies were selected.

Lentil

The Breeder Nucleus Seed (BNS) of NIAB Masoor 2002 was produced at NIAB. Four lentil elite lines viz. NL 20-9-4, NL 20-27-2, NL 20-39 and NL 768-2-1 were evaluated in Lentil National Uniform Yield Trials.

150 selections were made in the segregating germplasm originating from the crosses of exotic and local germplasm. Twenty cross combinations involving alien germplasm from ICARDA, Syria and indigenous landraces having acceptable seed coat colour and quality traits were made. Candidate variety AEL 49/20 evaluated in Lentil National Uniform Yield Trials, ranked 4th on Pakistan basis and 2nd on Sindh basis in seed yield.

Another candidate variety AEL 49/20 which gave the highest seed yield (1602 kg/ha) in zonal trials during 2000-01 has been promoted to national trials. In LUNYT 2001-02 candidate variety AEL 49/20 stood 1st in Sindh.

Sugarcane

The sugarcane variety NIA-98 covered more than 2000 acres of land during 2002 and has brought an additional income of about Rs. 70.19 million to the farmers since its release.

On the basis of better performance for cane yield, pol% and sugar yield, in zonal trial, clone AEC86-347 was advanced in national trials (NUCVT). The clone AEC86-347 showed promising performance. The clone AEC86-347 was tested for agronomic trials and post harvest losses as pre-release requirement of a variety.

Banana

Thirteen banana clones having genomic combinations of AAA, AAAA and AAAB were imported / collected from INIBAP, Belgium, as in vitro proliferating material and these are being multiplied at NIA, Tando Jam for rapid multiplication through micropropagation technique. Micropropagules of basrai has been established for in-vitro mutagenesis. The LD50 for banana micropropagules has been studied.

Vegetables

To meet the increasing demand of vegetables in the country and to save huge amount of foreign exchange on the import of Hybrid Seed of different vegetables, research on vegetables has recently been initiated at NIAB. Initially the focus of breeding activities is on tomato. The main objectives of tomato breeding are development of high yielding tomato varieties and hybrid seed production.

ENTOMOLOGY

Sugarcane borers

NIA helped in maintaining production of the laboratories established at Al-Noor Sugar Mills, Moro, Habib Sugar Mills, Nawabshah, Fauji Sugar Mills,
Khoski and Matiari Sugar Mills, Matiari, by providing host and parasitoid cultures and the expert services.

The laboratories produced the required number of parasitoids for the treatment of more than 0.2 million acres of sugarcane crop in the four districts of Sindh during 2002-2003 seasons.

**Fruit flies**

Six chemicals proved effective and captured higher number of females of peach fruit fly. The chemical PRH-DA-3.7 captured maximum number of the females as compared to rest of the chemicals tested, followed by PRH-DA-4.6 and PRH-DA-1.9. Results indicated that a mixture of ammonia and protein hydrolyzate attracted more number of females as compared to the others.

Traps baited with the attractants, indicated that all the trap design captured varying number of flies but closed bottom dry traps with two holes captured the highest number of fruit flies followed by closed bottom dry trap with three holes. Catches of fruit flies showed some selectiveness with the trap design and the chemicals used.

Studies under ALP fruit fly project indicated that application of IPM (MAT and BAT) reduced population incidence, fruit infestation and damage by 73.3 - 85.9%, 51.1 - 66.3% and 68.3 - 85.4% respectively at Kohat and Haripur. Similarly in biopesticide (Neem oil) treated orchard, the decrease ranged between 43.5 - 78.9%, 44.8 - 73.6% and 75.2 - 79.8% for population incidence, fruit infestation and damage respectively. Relative abundance of species showed that Bactrocera zonata was dominant (97.9%) at Kohat while B. dorsalis (84.4%) at Haripur. Two fruit fly parasites Dichasmimorpha and Tribliographa were also recorded from these areas.

**Cotton pest**

The Jassids appeared on cotton crop from the 1st week of May and reached to the peak in the 3rd week of August. The thrip population reached to the economic threshold in the last week of May. Population of whiteflies reached to economic injury level in the 2nd week of May and remained at the same level upto the 1st week of September. The maximum number of whiteflies was recorded in the 3rd week of August.

Six different agricultural grade (AG) insecticides were bio-assessed in recommended doses against H. armigera under controlled laboratory conditions. Observations on mortality were taken after 24, 48 and 72 hrs. Results showed that Curacron 500EC, Thiodan 35EC and Somialfa 110EC caused 100% mortality after 72 hrs in 1st instar larvae. Thiodan 35EC and Curacron 500EC caused also 100% mortality after 72 hrs in 3rd instar larvae.

**Rice borers**

Genotypic responses of 65 rice genotypes (36 aromatic and 29 non aromatic) showed that among aromatic genotypes, Basmati-15-1 harboured minimum infestation of rice stem borers and gave the best grain yield followed by Khushboo-95.

On the other hand, the variety 'Sonahri Sugdasi (P)' harboured the highest borers attack and yielded the lowest. Among the non-aromatic genotypes, Sarshar received the least infestation and generated highest grain yield whereas, the genotype IR6-15-10 harboured maximum infestation and yielded less grain.

**Brassica aphids**

The canola genotype W-97-0.75/11 was observed as resistant while. CON-III was found most susceptible for aphid infestation. Whereas, the brassica genotype Agati sarson (P) received the least aphid attack and produced the highest yield followed by S-9-S-97-100/48. TSA-1005/95 showed the most sensitivity and failed to sustain its yield at desired level.

**Pulse beetle**

The genotypic responses revealed that none of the tested genotypes have shown complete resistance against pulse beetle. But wide range of variations existed in population built up of adult insects, percentage of grain damage and weight of the frass material. The maximum number of adults was observed in genotype L1 P5/5/89, while minimum in AEM-96. Mean percentage weight losses were maximum in genotype L1 P5 /5/89 and minimum in AEM-96.
Gram pod borer

Screening of chickpea plants against chickpea pod borer exhibited partial resistance in some mutants. Pheromone traps installed at Karak, showed the start of chickpea pod borer activity in February 2003 reaching its peak in March. Application of water extract of neem (6%) reduced chickpea pod borer larval population by 51% and pod damage by 42%.

Results indicated that genotype No. 96051 of chickpea was susceptible in holding larval population, pods infestation and least grain yield, while genotype C-727 was observed as the highest grain yielding and holding the least pod infestation. This finding of resistance can be exploited for the management of gram pod borer infestation in chickpea crop.

PLANT MOLECULAR BREEDING

Local rice varieties, upland rice *Oryza galaberrima* and some lines carrying chromatin from upland rice were tested for tolerance to water stress. It was found that the varieties and lines that showed better tolerance to water stress produced more heat shock proteins (HSPs) or even showed small amounts of HSPs in control plant profiles indicating acquired thermo tolerance type of response.

Experiments were conducted to standardize procedures for seed protein fingerprinting of wheat varieties. Some lines were found having better quality, more high molecular weight glutenins, than the available varieties and may be used for future improvement of wheat.

Microbial diversity was evaluated from rice field soil with varied levels of salt stress. A total of 112 bacterial strains were selected, isolated and maintained. The number of organisms determined in different soil samples revealed population sizes of up to $2.06 \times 10^8$ cells per g of soil. Among 16 rice varieties observed under normal soil conditions, LP-7 was dominant variety showing the highest microbial population ($2.06 \times 10^8$), whereas, IR-6 manifested the lowest microbial density ($5.8 \times 10^6$).

PLANT PHYSIOLOGY

The research in the field was focused to enhance the crop productivity by undertaking the stress tolerance physiology and exploring ways to cultivate sub-optimal lands profitably such as: screening for salinity and drought tolerance in cereals and oil seeds and study of physiological responses of these crops under saline and drought environments; (ii) alleviation of the effects of salinity by using phytohormones; and (iii) chemical control of minimizing boll drop in cotton and increasing yield in wheat.

Screening studies for the identification of sunflower varieties suited for cultivation in normal and saline lands remained in progress. On the basis of evaluation of comparative performance, these varieties under normal, saline conditions at seedling stage and growing them up to maturity. Some varieties were found to be salt tolerant and having more than 50% oil content.

Germination of 100 wheat (*Triticum aestivum* L.) genotypes tested under control and water stress (-0.25, -0.5, -0.75 & -1.0 MPa through PEG-6000). Fifty-seven genotypes have shown better response to all stress treatments, while 43 showed variable response at -0.75 and -1.0 MPa.

Wheat genotypes have been grown in cemented tanks to study potassium induced salinity tolerance. The wheat genotypes showed increased seedling growth due to process of external K under salinity (100 mM NaCl).

Wheat cultivars were grown to conduct the experiment, using growth regulator NAA and acetyl salicylic acid. It was observed that NAA and acetyl salicylic acid enhanced the yield of the wheat. Field experiment on minimizing fruit drop in cotton (cv. Sohni) with different growth regulators/chemical spray was done using different concentration at NIA experimental field. It was observed that spray of acetyl salicylic acid enhanced the boll retention.

SOIL SCIENCE

Work on the project "Evaluation of NIFA advanced legumes lines/ geno-
types for BNF capability continued, and it was found that NIFA-95 produced maximum nodulation and derived maximum N from atmosphere. While Pyrifos was the most harmful insecticide for chickpea Rhizobia population of the soil, Larsban was found to have no effect on nodulation and soil Rhizobial counts in experiment "Effect of insecticides on soil population of chickpea Rhizobia".

A new project "Enhancing wheat productivity through efficient irrigation practices" was started with the objective to identify most sensitive and tolerant stages of crops to water deficit. Preliminary results indicated that the boot was the most and the milky the least sensitive stages of wheat crop to water stress.

Results of foliar feeding of crops indicated that yield of crops increased when N and P were applied together foliarly.

Under the Farmers Participatory Saline Agriculture Project, three demonstration plots were developed where nurseries of salt tolerant grasses and forest/fruit trees were transplanted. Formation of five community organizations was also completed. Training of the community for nursery raising and successful adoption of biosaline technology continued. Prospects of aqua, bee and poultry development in the area were being studied.

Studies conducted with wheat to monitor the residual impact of cotton-legume intercropping showed significant positive response in terms of higher grain harvests. The magnitude of increase varied from 21.8 to 28.6% depending upon the competitive effect of different cotton cultivars.

Long term studies conducted to assess the suitability of MOP vs SOP in wheat-cotton-wheat cropping system revealed that MOP though cheaper than SOP should not be applied as a K source to crops, since cumulative application of MOP for 10 years elevated the soil test chloride levels by 50-60%, which inflicted detrimental effect on cotton and wheat harvests.

PLANT PATHOLOGY

Chickpea lines (474 entries) received from NIAB, NARC, AARI were screened against Fusarium wilt in the wilt-sick field. On the basis of early wilt incidence, 190 lines were resistant, 102 moderately resistant, and 19 were highly susceptible. Later the wilt incidence increased drastically and no entry remained highly resistant, 3 were resistant, 8 were moderately resistant rest were either susceptible or highly susceptible.

52 entries/varieties of basmati rice and coarse rice were screened for resistance against Bacterial Leaf Blight (BLB) and blast diseases under field conditions at NIAB. No entry/variety was found resistant to BLB, only one entry PARC-185 was found moderately resistant while remaining were moderately susceptible to highly susceptible. Against blast disease, four entries/varieties found highly resistant 15 were found resistant and remaining were moderately resistant to highly susceptible.

Occurrence of six major diseases of wheat i.e. yellow rust, leaf rust, loose smut, helminthosporium leaf blotch, basal glume rot and BYD were detected during field studies. Prevalence of these diseases varied between 19-86% in wheat material grown at NIFA. Currently prevailing leaf rust races were found highly virulent on 94% of the commercial varieties tested while Faisalabad-83, Sarsabz, Punjab-96, Shakhtar-95 and Soghat were found resistant to both BYD and loose smut. For building up multiple disease resistance more than 130 lines from NIFA, NIA and national wheat improvement programmes were evaluated and technical data has been provided to the concerned quarter.

Search for novel and superior sources of disease resistance was carried out from 900 exotic wheat lines planted by NIFA wheat breeders. Performance data with regard to resistance level of each line against prevailing diseases have been provided to the concerned breeder for further improvement.

Field and Lab. Research project on various aspects of tomato and cucumber pathology was undertaken and successfully completed which was funded by Pak-Swiss Project for Horticultural Promotion (PHP) in NWFP.

BIOLOGICAL CHEMISTRY

Eucalyptus leaf oil from five different species, collected from Punjab Forestry Research Institute, Faisalabad, was extracted and analyzed. The oil of Eucalyptus crebra was found to be the most suitable for medicinal
purposes as it contained maximum oil (1.47%), free from phalendrene and having 1,8 cineole above 70%. The oil extracted from *Eucalyptus citriodora* may be useful in perfumery as it was found containing high concentration of lemon scented compound, citronellall (74.65%).

**FOOD SCIENCES**

Irradiation treatment of fresh poultry meat and fish increased the total volatiles especially in fish samples. The concentration of carbonyls and sulfur containing compounds increased with the increase of radiation dose. ESR studies on bone samples of chicken irradiated with dose range of 1-5 kGy revealed that asymmetrical spectrum was quite different from the spectra observed in unirradiated chicken bone indicating the possibility of use of ESR as a tool for the identification of irradiated food stuffs.

Minimally processed and irradiated tomatoes stored at 15°C for 2 weeks were within safe microbiological limits on the basis of total bacterial and fungal counts when exposed to 2.5 kGy dose of radiation. In the case of cabbage bacterial counts of 2 kGy were within permissible limits while a dose of 2.5 kGy completely decontaminated the sample from fungal colonies up to 14 days at refrigerated storage.

Studies on development of low cost bottled fruits/vegetables were initiated. Bottled peas of (local variety) were pretreated using different combined treatments and packaged in glass bottles for subsequent analysis.

**POST-HARVEST TECHNOLOGY**

Grains of 22 chickpea genotypes, NIAB, were screened for resistance to pulse beetle (*Callosobruchus analis* F.). The results revealed that number of eggs laid, adults emerged, grain weight loss and number of damaged grains was significantly low in CM 3142-2, CM-88, Pb-91, CM 3142-3 and CM-72 indicating resistance to the insect pest.

Studies on susceptibility of 12 wheat varieties to Angoumois grain moth (*Sitotroga cerealella* Oliv.) revealed that moth progeny produced was significantly low (83.67) with minimum weight loss (5.52%) in Chakwal 86 followed by Blue Silver, Pasban 90 and Parwaz 94 indicating resistance to *S. cerealella*. Highest number of moths emerged in Iqbal 99 (159.67) inflicting maximum weight loss (13.75%) followed by Kohistan 97, MH-97, D-97 and Chenab-99 exhibited susceptibility to the grain moth. Higher number of moth emergence and grain weight loss had positive and significant impact on wheat grain susceptibility.

Important macro- and micro-elements in different chickpea and lentil genotypes were determined. Potassium, Mg, Mn and Cu were higher in chickpea, Na and P contents were higher in lentil whereas Ca, Fe and Zn contents were comparable in both the pulses. Coefficient of variation (CV) for different elements varied from 4.76% (Mn) to 15.09% (Na) in chickpea and 7.66% (Na) to 21.39% (P) in lentil. Correlations between protein content and different minerals in chickpea were not significant.

A highly sensitive method was standardized for the detection of aflatoxin B1 residues in poultry feed and its components using Enzyme Linked Immuno Sorbant Assay (ELISA).

Detection limit for aflatoxin B1 of about 5 ng/L was achieved.

About 73% of commercial feeds and 85% feed components contained aflatoxin B1. Highest values were recorded in layer starter crumbs (15.8 ug/g) and corn meal (14.7 ug/g) in feeds and its components, respectively.

Through an exposure dose of 20 Gy to the dormant bud of the highly seeded (25 ± 5 seeds/fruit) parents *kinnow* (*Citrus reticulata* Blanco), a sparse seeded (5 ± 3 seeds/fruit) mutant has been evolved. Fruit quality attributes both in the parent *kinnow* and its seedless mutant resembled very closely except the number of seeds per fruit. The continuity of the induced mutation up to mV was confirmed during the period under report. During the flowering period (March – April) 2003, fruiting in 5 plants of the mV progeny was recorded.

**ANIMAL HEALTH AND REPRODUCTION**

7700 vials (77,000 vaccine doses) of the Haemorrhagic spicicaemia (HS) vaccine were prepared and sold in the local market worth 0.70 million rupees where as 12000 vials (1.2 million doses) of NIAB Newcastle disease (ND) vaccine were prepared and sold earning 0.54 million rupees.
A research project worth 21.77 million rupees was awarded by Ministry of Science and Technology for mass production of HS, Black Quarter and infectious Bursal Disease vaccine under self-reliance programme. Most of the equipments and their related consumables and chemicals have been purchased for preparation and sale of vaccines.

SALINITY AND ENVIRONMENTAL MANAGEMENT

Experiments on adaptability of new cultivars of wheat, *brassica* and sunflower in saline environment were conducted. Farmers of Shorkot and Lodhran area under Saline Agriculture Farmer Participatory Development Project (SAFPDP) showed great interest in cultivation of salt tolerant varieties of these crops due to their excellent performance. Field trials on the use of fertilizer/soil amendments like phosphoric acid, nutrient calcium, calcium chloride manufactured locally by the Sitara Chemical Industries, Faisalabad, revealed encouraging results in the saline environments.

At BSRS-II, Pacca Anna, more than 14,000 seedlings of salt tolerant tree/shrub species were transplanted in the newly prepared land for agroforestry trials and about 8600 kg seeds of different salt tolerant plants were supplied to various project sites in Pakistan.

SOIL BIOLOGY & PLANT NUTRITION

To utilize the fallow period of 75 to 90 days after harvesting of wheat and before transplanting of rice crop, a short duration Mungbean variety (NM-92) was sown in last week of April. Crop was grown without any fertilizer inputs; however, three irrigations were applied. Pods were harvested at 90% maturity, and 1295 kg grains ha⁻¹ (containing 48.6 kg N) worth more than Rs.19,700 was obtained from this legume crop. This study showed that by growing a short duration Mungbean crop between wheat and rice, a significant benefit in terms of money (more than Rs.19,700) and increase in soil fertility can be obtained by the farmers.

Organic wastes, such as Filter cake (FC) from sugar mills and Poultry waste (PW) from poultry industry, were integrated with chemical fertilizer, single super phosphate (SSP), in 2:1 P ratio; and evaluated against SSP applied. Data showed that increase in rate of P application significantly increased plant height, number of tillers per plant, straw and grain yield as well as phosphorus uptake in grain over control. Optimum P rate ranged from 50 to 100 mg kg⁻¹ soil for getting maximum yield. The study revealed that integrated use of PW and SSP in 2:1 P ratio could prove more economical substitute for the expensive chemical fertilizer.

Studies on C and N transformations in soil revealed that the rate of nitrification was significantly enhanced at elevated CO₂ levels. This observation is important in terms of nitrification vis-à-vis organic matter decomposition and nitrification-mediated N₂O emission to the atmosphere. Elevated CO₂ also had a significant positive effect on growth and N₂ fixation in leguminous crops like *Trifolium* and *Sesbania*.

BIOTECHNOLOGY AND GENETIC ENGINEERING

At the Center of Excellence National Institute of Biology and Genetic Engineering, six Divisions, namely, Plant Biotechnology, Biofertilizer, Industrial Biotechnology, Bioprocess Technology, Health Biotechnology and Environmental Biotechnology remained involved in research work related to Agriculture, Industry, Health and Environment.

PLANT BIOTECHNOLOGY

Molecular Virology

A particularly virulent strain of cotton leaf curl virus (CLCuV) that has overcome disease resistance has emerged recently (2002) in Pakistan. Molecular characterization of this resistance breaking strain revealed that DNA beta associated with Burewala strain is 92% homologous to DNA beta reported to be associated with CLCuV-Multan of 1992-93 epidemic. A PCR based test has been developed to differentiate Burewala strain from the old strain. Chilies were identified as a new host of cotton leaf curl virus with widespread occurrence in Vehari and other districts.

A novel disease on melon showing leaf curling and enations on the top of the leaf was recorded on melon in Vehari and Sahiwal districts. This devastating disease was found to be associated with a begomovirus and DNA beta.

Coat protein gene of potato leaf roll virus (PLRV) has been isolated, cloned, characterized and sequenced.

Genetic Engineering of Plants

Evaluation of transgenic cotton (Cocker and elite cultivars) for virus resistance at NIBGE as well as Vehari Research Station conducted for the last and two years. Transformation of cotton with newly designed truncated replicase gene and RNAi based constructs of CLCuV and potato transformation with RNAi based construct of coat protein gene of PLRV have been started.

Rice Molecular Biology and Transformation

Bacterial blight resistance (*Xa21*) gene was introduced into Super Basmati along with other varieties like Basmati-385. Integration of the transgene was confirmed in eight transgenic lines. *T₀* seeds were collected and sown in May 2003 to raise *T₁* generation.

A synthetic spider neurotoxin gene, known to confer resistance against the lepidopteron larvae, was got synthesized based on polypeptide sequence through reverse engineering. This gene was introduced in tobacco
through *Agrobacterium* mediated transformation method. Further study regarding its expression in the transgenic plants and characterization of the toxin protein is in progress.

### Plant Genomics

Genetic diversity between 19 different rice germplasm lines along with Bas. 370, Bas. 385 and Super Basmati was estimated using forty (40) different RAPD primers. This study indicated that Basmati varieties have very distinct relation with the used land-races and these germplasm can be used to incorporate useful traits after proper screening against biotic and abiotic stresses.

### Tissue Culture Technology

A novel direct regeneration system has been developed where 2 to 3 thousands tiny original plants from single leafy top are produced usually which are discarded in traditional tissue culture technology where only 5-6 plants per cane top are being developed. It is being anticipated that the newly developed system will reduce time from 15 years to 3-5 years, for mass propagation of a desired elite/transgenic line, and this is the first system of its own kind in monocots to develop transgenic plants and is trade marked as Smart Greencane™ Seedlings.

### Characterization of Chickpea Nodules Isolates

14 typical and atypical chickpea nodule isolates were characterized by using RAPD analysis and 16S rRNA gene amplification. Typical *Mesorhizobium* (IC94, IC2002 and TAL-1148) and atypical (Ca-18) were used as reference strains. 16S rRNA and RAPD of 18 typical and atypical chickpea isolates placed typical isolates in Mesorhizobium genus while atypical isolates in genus Agrobacterium.

### Characterization of Pigeon pea and Sesbania Nodule Isolates

Twenty (*Bradyrhizobium*) strains isolated from Pigeon pea and Sesbania were characterized for their effectiveness on host plant in three types of soils. These strains have also been tested for phosphate solubilization ability and only on strain from Pigeon pea showed the ability to solubilize phosphate. Only five strains showed cross reactivity. Biofertilizer, (Biopower) has been developed for Pigeon pea and Sesbania.

### Bioculture of Pathogenic Diseases by Using PGPR

Role of PGPRs isolated from rice rhizosphere against *Fusarium sp.* and *Xanthomonas oryzae* that cause fungal blight and bacterial blight respectively in rice is being studied. Five PGPR strains have been screened for their effect on *Xanthomonas oryzae*. PGPR strain Z.4.1 inhibited the growth of *Xanthomonas oryzae*.

### Screening of Bacteriocin Producing Rhizobium Strains

Fifteen different strains of *Rhizobium* have been screened for bacteriocin production. The *Rhizobium leguminosarum bv. vicieae* strain Lc-31 was the best as bacteriocin producer. This strain has been used as reference for the screening of other *Rhizobium* strains.

### Molecular Ecological Studies of Rhizobacteria

Conditions have been optimized for DNA extraction directly from soil to understand the importance of bacteria associated with rhizosphere of different crops. The study has been started to explore the microbial communities on molecular basis. The DNA has been extracted from 6 wheat rhizosphere soil samples (0.5g each) and purified for further analyses to assess the contribution and role of these microbes in the rhizosphere.

### Ultrastructure Localization of Cotton and Maize Root Associated PGPRs

The randomly selected PGPR strains S-1 and S-8 were studied for their ultrastructure localization in the rhizosphere of cotton.

*Azotobacter* sp. S-8 was found below the epidermal layer in contrast to the *Enterobacter* sp., which resided only in the crevices present in characteristic foldings of cotton root cells. Polyclonal antibodies raised against S-1 and S-8 strains were sensitive and specific.

### Immunogold Labeling to Study Nodule Co-occupancy

Immunogold labeling of cowpea nodule sections that were formed either through inoculation of *Bradyrhizobium* strains TAL-102 alone, or by combined inoculation with TAL-102 and *Agrobacterium* Ca-18, was carried out. The nodules were formed only with *Bradyrhizobium* strain TAL-102, but *Agrobacterium* Ca-18 coexists with TAL-102 within the infected nodule cells.

### Effect of Bio-Power and Fungicide Application on Wheat

Lab experiments and field trials were conducted to study the effect of fungicide on inoculated seeds. In the lab experiment, the effect of four commonly used fungicides was tested on the growth of 20 different PGPR strains. Vitavax and Darosal decreased the number of cells but Benlate and Captan did not show harmful effect on bacterial growth. Similar observation were made when young wheat roots from field were subjected to MPN count through serial dilution.

### Culture Collection and Maintenance

Forty four PGPR strains isolated from sugar cane, rice, pigeon pea and sesbania were preserved on slants and in 20% glycerol. Three rhizobial strains of chickpea and received from Puttagal were also preserved. One *Azorhizobium* strain received from England was also preserved in BIRCIN culture collection. Twenty-one PGPR strains from maize were revived from preserved
About 2000 Cotton BioPower bags were provided to the farmers in Dera Ghazi Khan, Muzafargarh, Kabeer Wala, Multan, Melsi areas. Field experiments regarding the evaluation of Cotton BioPower were conducted in CCRI, Multan and PAEC project area, D. G. Khan. 12,000 bags of Rice BioPower were provided to the farmers in Hafizabad, Pindi Bhatian, Shiekh Pura, and related field areas. Commercial promotion of BioPower is also going on in Naseerabad, Kot Allahyaar and Badin Saline stations.

Production and Distribution of BioPower

Fifteen putative mutants of Chaetomium thermophile and Humicola lanuginosa were characterized for production of xylanases in submerged fermentation. An overall improvement of 1.4-fold was attained for xylanase activity. The mutational results showed a significant increase of 40-42% in case of H. lanuginosus (TH 1) while 46-47% for H. insolens (HI 1) as compared to wild parent strain.

Characterization of industrial enzymes

Invertase was produced in SSF and purified to homogeneity level using ammonium sulphate precipitation, and FPLC chromatography. The purified enzyme was immobilized in polyacrylamide gel to study the kinetic and thermodynamic behaviour of immobilized and free enzymes. Xylanases produced by Chaetomium thermophile purified to homogeneity level were characterized for their molecular and kinetic properties.

Production of Ethanol/Methane

A derepressed mutant of Saccharomyces cerevisiae was isolated. The comparative studies were performed to compare the parental and derepressed mutant by using sucrose to observe substrate uptake, ethanol formation, and invertase formation parameters. All kinetic parameters for substrate utilization and ethanol production for parent strain of S. cerevisiae were studied on 15% total sugars in molasses at different temperatures. Thermotolerant mutant was 1.45-fold improved over its parental culture for ethanol production at 40 °C.

Production of biochemicals

Among different fungal strains, R3, R5, R14 and R17 gave invertase activity of 10.52, 13.32, 10.15 and 12.26 U/ml/min at 37 °C respectively in SSF. In submerged fermentation on 4 % sucrose maximum enzyme activity obtained was 43.86, 48.28, 32.16 & 17.6 U/ml/min at 37 °C respectively after 48 h of fermentation. It was observed that wheat bran is good carbon source for invertase production and gave 5580 U/l flask using 5 g substrate in each flask.

Bacillus licheniformis, wheat bran supported 150 IU/ml in solid state fermentation and 92 IU/ml in submerged fermentation. Production of amylase by Bacillus strain was both growth- and non-growth-associated. It was also observed that its production was constitutive as well. Activation energy of starch hydrolysis using different enzyme preparations derived from different Bacillus spp. indicated that they needed varying amounts of activation energy for hydrolysis of 1M starch and deactivation of enzyme.

In order to improve the delta endotoxin proteins the Bacillus thuringiensis (Bt), subsp kurstaki strain NSTD was mutated using UV to select mutants of Bt named M1-90, M2-90, M3-90, and M1-150 which were enriched on 1% 2 deoxy-D-glucose in NYSM liquid medium and selected on above solid medium.

Fossil Fuel Biotechnology

Work on upscaling of coal biodepyritization process was continued and a 20 ton experimental heap of Khushab coal having dimensions 8m x 5m x 1.5m was constructed for this purpose. Elemental analysis of solid coal samples taken at 7 days interval from different points of heap showed about 45-60% decrease in pyritic sulfur within 5 weeks. Experiments were also conducted to explore the enzyme system involved in the oxidation of various energy sources such as ferrous ions, sulfur and pyrite by bacteria involved in coal biosulfurization.
A CHNS/O analyzer being employed for investigating microbial desulfurization of coal

**Extremophiles**

Fourteen environmental samples were collected from Pakistani and Kenyan extreme environments. Microorganisms were screened from Pakistani samples while the Kenyan sample was used as such for further studies. 16SrDNA sequence analysis established microbial diversity between cultured microorganisms. Culture-dependent and culture-independent gene mining studies using integron specific probes indicated presence of different genes (37) that were cloned sequenced and deposited with GenBank, USA. Such studies supported horizontal gene transfer theory and indicated the usefulness of integron associated gene mining approach in place of traditional methodologies.

**Biotransformations of Industrially Important Compounds**

Acremonium chrysogenum (ATCC-48272) is being used to examine CPC hyper production with Lactose, Sucrose and Galactose. Up till now, better production of CPC was found in the presence of lactose as carbon source.

To enhance the production of cephalosporin C by suppressing the mRNA of CahB gene (Cah B gene protein destroy the CPC) experiments, a 230bp glyceraldehyde-3-hydrogenase intron has been amplified using PCR. An expression vector (pBARMTE1) has been acquired from Fungal Genetic Stock centre USA. To get hyper-producer strain, a PCR amplified product of intron is being restricted with appropriate enzyme for cloning in pBARMTE1 vector to get RNAi expression vector. Confirmation of clones is under progress.

**Analytical and Consultancy Services to Other Organizations**

Professional scientific services were provided to various industries including WAPDA, WASA, Chenab Fabrics and Processing Mills, Arzoo Textile Mills, Sandle dyestuff, Crescent Greenwood, etc for the analysis of various parameters including heavy metals and anions such as Cyanide and Flouride in samples which is a prerequisite for ISO-9000 and 14000 certification. Similarly, microbiological analyses of varied nature of water samples and quality assurance work were also carried out for various industries.

**HEALTH**

**Typhoid**

The emergence of antibiotic resistance in *Salmonella typhi* has made it important to understand various mechanisms of Virulence and pathogenicity associated with *Salmonella typhi* infection. In recent years, biofilm production has come to the fore as one of the major mechanisms of bacterial pathogenicity.

The findings suggested that the ability of bacteria to attach to each other and to surface depend in part on interaction of hydrophobic domains. Efforts have been made for the characterization of biofilm matrix. Multiplex PCR conditions for molecular identification of pathogenic *Salmonella* species were optimized. Fifteen strains have been studied till now. Some strains have shown very interesting patterns.

**Hepatitis C**

PCR-RFLP technique was used to analyze 200 HCV patient samples. Among them, 160 were found to be of genotype-3, 25 and 05 samples belonged to genotype-2 and genotype-1 respectively.

**Hepatitis B**

Hepatitis B is a serious health problem in the world. In Pakistan, HBV affects 28% adults and 3-5% are carrier. Present available diagnostic techniques are not so therapeutically helpful. A highly sensitive PCR based diagnostic test for detection of hepatitis B Virus DNA in serum/plasma of the infected subjects was established and results were compared with commercially available ELISA assay. PCR was found to be more sensitive, specific and accurate for detecting low level of HBV infection as compared with other conventional tests like ELISA or surface antigen detection.

**Chronic Myeloid Leukemia (CML)**

A Quantitative RT-PCR was developed using patients' cDNA as target and clones as internal control (competitor). This Q-RT-PCR will help in detection of MRD and monitoring of anticancer therapy in CML.
patients. Blood samples were collected from 40 CML patients and DNA was extracted. PCR was optimized to amplify a 0.9 Kb fragment from ABL breakpoint region. PCR products were processed (purified) for DNA sequencing. The study will help in prognosis of familial CML.

**Acute Lymphoblastic Leukemia (ALL)**

NIBGE is running an IAEA multicentral research contract for standardization and quality control of the technique used for MRD detection. The study is being carried out to know more prevalent mutations related to ALL. Samples are being collected from Cancer Hospitals. Some of the samples have been processed for PCR amplification of fusion gene. The products were analyzed and most of them were positive for bcr-abl transcript.

**Automated chromosome analysis system**

CV Chromoscan is currently installed and being used for Karyotyping, Fluorescent In Situ Hybridization (FISH) and Comparative Genome Hybridization (CGH). The system is used for detection of chromosomal abnormalities including polyploidy, trisomies, monosomies, translocations, deletions etc.

**Detection of Chromosomal Abnormalities by Karyotyping**

During this period, 58 samples of patients were referred to diagnostic laboratory and were found to have karyotypes for down syndrome, variant of turner syndrome, Robertsonian translocation for Down syndrome, Sex chromosome mosaicism, Philadelphia chromosome, Fragile X syndrome. Genetic counseling was provided to five families with the history of congenitally malformed kids.

**Diagnostic Services**

186 samples of Mycobacterium tuberculosis, 730 samples of Hepatitis C Virus, 22 samples Hepatitis B Virus, 05 samples of Salmonella typhi and 17 samples of bcr-abl translocation for chronic myeloid leukemia were analyzed.

**ENVIRONMENT**

**Upscaling Biodegradation of Textile Effluent**

After successful biodegradation of Bismillah Textile effluent in shake flask, these studies were extended to 5L Fermentor. The results of three different samples without the addition of nitrogen within 6 days at 370°C with constant aeration showed 35%, 57%, 66% COD and 70%, 68%, 69% BOD reduction respectively. By the addition of nitrogen 51%, 63%, 67% COD and 71%, 72%, 77% BOD reduction respectively in same time.

**Up Scaling of Biosorption Process**

Previous lab work of biosorption was studied and then keeping in view the obtained results the pilot-plant 50L capacity (for heavy metal Removal) was designed, which was fabricated in March 2003.

Various modifications were carried out to make the plant commercially feasible and in the present conditions the plant is in full capacity to be run for further studies.

**Fabrication of bench top model for metal removal**

A glass model plant for heavy metal removal has been fabricated through Pak-Kazakh project. The model serve as the best for lab scale study regarding biosorption as well as the up scale studies to commercial level. Moreover, it will use for onsite demonstration of biosorption process in exhibitions and S&T stalls.

**PCR based analysis of rinderpest samples**

Fourteen samples were received from NARC for the analysis and diagnosis of rinderpest by using reverse transcriptase polymerase chain reaction (RT-PCR) method. For this purpose following were carried out: extraction of RNA from different tissues, cDNA synthesis by reverse transcriptase, DNA amplification by PCR, Analysis of PCR products.

**Setting of PCR based facilities for Infectious Bursal Disease (IBD) virus**

Basic facilities for reverse transcriptase polymerase chain reaction (RT-PCR) method for diagnosis of IBD have been established with collaboration of Deptt of Vet. Microbiology, University of Agriculture Faisalabad. For this purpose optimization and establishment of following were carried out; extraction of RNA from different tissues, cDNA synthesis by reverse transcriptase, DNA amplification by PCR, Analysis of PCR products.

**Commercial Services**

418 samples received from WAPDA (different canals and rivers of Punjab), textile industries and mineral water companies under PIBS project and were analysed for different parameters such as COD, BOD, calcium, magnesium, sodium, potassium, Ammonia-Nitrogen and Phosphorus, phenolic, carbonate, bicarbonate, hardness, solids, acidity and basicity.

**Products/Patents**

Cotton varieties NIBGE-1, IR-FH-901, IR-CIM-448, IR-NIBGE-1 & IR-CIM-443 were developed and placed in various national/regional trails.

**NUCLEAR MEDICINE**

PAEC's initiative in the field of nuclear medicine started right from its inception. The first Cancer Hospital was established in 1960 at Karachi and since then 12 more centers have been added. The contribution of PAEC through its integrated programme in diagnosis of different kinds of cancer and allied diseases and
Cobalt-60 Teletherapy unit, an effective tool for advanced cancer cases

their treatment has received considerable acclaim in the public. PAEC Cancer Hospitals are catering to about 80% of cancer patients from every part of the country. During the year 2002-2003, utilizing the maximum capacity of the machines available at PAEC Cancer Hospitals, more than 3,200,000 patients were attended. Major disciplines available in PAEC nuclear medical centers are (a) Nuclear Medicine and Radioimmunoassay and (b) Oncology & Radiotherapy.

Nuclear Medicine deals with the diagnosis and treatment of various diseases using short-lived radioisotopes, planar SPECT and whole-body images of the diseased organs are obtained using gamma cameras, these images provide information about the shape, size physiological and functional status of the organs. Facilities are also available for the treatment of thyrotoxicosis, thyroid cancer, polycythemia, palliative bone pain, malignant pleural and Operatioinal effusion etc. Radioimmunoassay techniques are used to detect small quantities of hormones and antibodies. The assays routinely carried out at PAEC medical centers include thyroid, pituitary, steroid hormones, gonadotrophins and various tumor markers. Besides, Radiology, Mammography and Ultrasound for diagnosis, evaluation and prognosis of diseases are also available.

During the year 2002-2003, 1,86,148 patients benefited form the nuclear medicine facilities.

Oncology and Radiotherapy deals with the treatment of cancer. PAEC medical centers are equipped with the latest machines for this purpose. These include Co-60 teletherapy units, Linear accelerators, Deep & superficial X-ray machines, HDR remote after-loading machines, Superficial appliances, etc.

Simulators & Treatment Planning Computers help in planning the delivery of proper dose to specific sites. During 2002-2003 1,33,592 patients were provided cancer treatment as well as follow up.

Research Projects

Research work was continued on 22 IAEA sponsored and 33 other research projects in collaboration with different international and national agencies/organizations. PAEC medical centers are involved in research activities in collaboration with national & international agencies. IAEA fellows from various countries are trained at PAEC nuclear medical centers. Expert services available at these Centres for the use of in-vivo and in-vitro nuclear technique centers are extended to regional countries.

Development Project - Establishment of Breast Care Clinics

Breast Cancer is the commonest type of cancer in Pakistan. The women population of Pakistan is approximately 49.5%. The incidence of Breast Cancer is reported to the 30% of all the cancers reported in women. The new cases of Breast Cancer in the country can be estimated up to 45000 per annum. The project "Development of Breast Care Clinics at all PAEC Nuclear Centres" was approved during the period under report by Planning and Development Division at the cost of Rs. 157.3 million. The Commission has ordered
for nine sets of Mammography & Ultrasonography units which will be installed in near future. After installation of the equipment at Breast Care Clinics of PAEC, about 20,000 patients will be treated per annum. In pursuance of Development of Breast Care Clinics, the Commission is also going to start "Awareness Clinics".

**Upgradation and Expansion**

Renovation of main reception at CENUM, Lahore has been accomplished with the help of a philanthropist under his own supervision. Recently LINAR has installed 13 computers in scientific Labs: and doctors O.P.Ds linked through Network. Window based software is used to enter patients data maintain record of treatment and follow-up.

Establishment of Local Area Network (LAN) to create fully automated environment at CENUM, Lahore is completed.

A Computer Treatment Planning System, a Diagnosis C-ray system, a Distillation Apparatus, a Gamma Counter (12 channel), a SPECT Gamma Camera (ADAC) have been purchased and heir installation is under process at INOR Abbottabad. A Cheniluminescence system has been installed at MINAR and tumour markers studies have been started on this system.

Computerization and Networking of CENAR has been completed. Acquisition of land for the expansion of PINUM is completed.

**Teaching & Training**

Doctors of PAEC Nuclear Medical Institutes are regularly teaching Nuclear Medicine and Radiotherapy to the MBBS students of the attached Medical Colleges. They also teach MCPS, FCPS, DMRT, DMRD students and also provide guidance to M.Sc. Nuclear Medicine and M. Phil students in collaboration with post-graduate institutes. Ten students from different hospitals are receiving training for FCPS at INMOL, NORI and KIRAN.

**Publications**

PAEC Nuclear Medical Centres published 6 papers in local journals, eight doctors attended different IAEA training courses/workshops/meeting and thirty-five doctors participated in international/national seminars/conferences/workshops during this period.
Atomic Energy Minerals Centre and its Regional Exploration Offices at Peshawar, Karachi & Quetta continued prospection and exploration for nuclear minerals. The working areas include Bannu Basin, Kirthar Range, Kohat Plateau, Salt Range, Malakand and Swat.

Major exploration activity was focused at Shanawah site of Bannu Basin where development drilling was carried out in the southern part of the prospect to estimate reserves in the RAR category.

Manchar Formation in the Kirthar Range was studied in geological detail and controls for surface uranium mineralization were determined. Water table monitoring wells were established at four sites to facilitate exploration.

Anomalous zones of Kohat Plateau were mapped and investigated in detail and were drilled for preliminary information.

Baluchistan was opened for the first time for uranium prospecting and in this regard Saidak-Taftan block was traversed on foot. Preliminary exploratory drilling and detailed geological studies were carried out at sites in Malakand and Ilum Granitic complexes.

Applied research was carried out on uranium metallogenesis in Siwaliks, geochronology of granitic intrusives and uranium in Permian rocks of Salt Range.

The activities in the offices & laboratories supported the field activities by providing various chemical and mineralogical analyses.

Apart from the above, geotechnical drilling, geophysical surveys and neotectonic studies were carried out for PAEC establishments. Ore Processing Group conducted leaching studies on Shanawah core samples.

Hydro-geochemical sampling was also done. An area of 115 km² was checked and water samples were collected from stream sediments, wells & springs. Carborne Spectrometric Survey was conducted along 26 traverses totaling to 552 km road length in the Bahadur Khel area. High counts in uranium channel were recorded along 2.5 km road length.

Malakand

Reconnaissance geological map at a scale of 1:50,000 of Kulangai Granite Complex was prepared over an area of 350 km². The map depicts that NE-SW trending, elongated body of granite gneiss is occupying the area between Sillai Patti (Malakand) and Talash (Dir). The orthogneisses are multiphase; the younger phase is fine grained, hard and compact while the older phase is coarse grained, sheared and fractured. Radioactivity is observed in the biotite concentrations, in tourmaline granites of older phase. Ground radiometry was carried out in granite gneiss exposed at Nigram Qila, Gidar Killi, Gurgarai and Inzarai locality (Dir). Significant radiometric spots were recorded in medium to coarse grained, sheared,
tourmaline granite showing hematitic alterations along 1 km length from Inzari village to Gurgarai locality. High radioactivity is associated with biotite concentrations along the joint planes. Further exploratory work is planned.

SIND

Kirthar Range (Dadu)

Uranium occurrences of Wahi Pandi (Dadu) were studied and mapped at a scale of 1:50,000 over a strike length of 26 km displaying two radioactive sandstone horizons in the Manchar formation.

Detailed geological mapping of Sori Rind and Taki area was done at scale of 1:2000. Alteration haloes, uranium mineralization and radioactivity were recorded in anomalous sandstones. Four trenches were excavated at Gaji Kumb, Haleli, Sori Rind and Kukrani sites. Observations were made along-with selective rock sampling to substantiate field data with laboratory analyses.

Carborne spectrometric survey of a part of Dadu area was accomplished over 138 km road length. Preparation of an inventory on the favourable rock formations in Sind Province was in progress.

Regional studies were compiled to identify areas and lithological units favourable for uranium accumulation in the lower Indus Basin. Sufficient literature from external and internal sources has been scanned. Six rock formations namely Manchar, Gaj, Nari, Laki, Rani Kot and Pab were selected for detailed study. Nari & Manchar formations exposed in the synclines are located in Khairpur district need to be physically checked through radiometric traverses.

PUNJAB

Eastern Salt Range

Already known occurrences of uranium, in the Permian sandstones were examined in detail by the Applied Research Division. Lithofacies and lateral variations were recorded in the Matin Kalan and Gahi areas. Uraniferous phosphatic nodules show high radioactivity whereas chemical \( U_3O_8 \) varies from 78-430 ppm. The role of uraniumiferous phosphate nodules in uranium deposit formation is being studied.

Southern Potwar Plateau

Foot radiometric data of Lawa area was synthesized and the uranium potential was evaluated. In addition to above studies hydro-geochemical interpretations were made.

BALUCHISTAN

Prospection for uranium was started in the western part of Chagai Magmatic Belt near Tuftan in Block-II of Eruptive Zone. Ground radiometry was conducted in Juzzak, Saindak and Amalaf formations (Paleocene-Oligocene age). These formations host volcano-clastic rocks, which may be the possible uranium source. Higher than background radiation is recorded in andesitic sills within Saindak & Amalaf formations. Rock samples have been retrieved for laboratory studies. The studies were made over an area of 20 km². Preliminary work on preparing an inventory of elements of economic importance like Cr, Mg, Th, Ti, Li and REEs has been done.

EXPLORATION AND EVALUATION

Baru Site, Malakand

Detailed evaluation of Malakand granite gneiss was completed. Uranium mineralization is hosted by the fine grained, fractured granite filled by mica. Heamatization is also observed in the fractures while the excavated trenches indicate some solution movement. Structural studies were also done and the fracture trends are NE and NW.

The radioactivity is associated with NE set of fractures with mica filling. A block of one km length was selected for shallow drilling. Eight shallow bore holes were drilled for a cumulative depth of 151 meters. Six lenses were encountered showing 650 ppm of \( U_3O_8 \) with a maximum thickness of 19 meters. Radioactivity increases by digging and the fractures control the phenomenon of mineralization.

Swat Area

Evaluation studies of Ilum Granitic Complex were carried out. Land Sat data images of Sangar, Amluk Darra and Shoprang sites of Buner district were interpreted and a set of fracture system was identified in the intrusive phases.

A reasonable stretch of muscovite-tourmaline granite is found in the Shoprang area, whereas uranium to thorium ratio is 1:5. Shallow drilling was proposed in this area. Geological mapping at 1:10,000 & 1:1000 scales was done to depict the mineralized zones with controlling features.

Shanawah Site

Exploratory drilling has been done in a block of 1000x300 meters. In total, 37 holes were drilled amounting to 13243 meters and reaming job of 4786 meters. Reasonable thicknesses of uranium ore zones above & below the water table were intercepted.

Nari Panoos-South Kohat Plateau

Evaluation studies have been conducted at three occurrences at Nari Panoos. Detailed geological mapping along 2 km length of Nari Panoos syncline was completed at a scale of 1:2000. Lithofacies studies were conducted along 2.4 km long geological sections at a scale of 1:1000. Observations were made on 55 cross sets to determine paleocurrent direction.

Reconnaissance exploratory drilling is in progress in the area, where 10 shallow bore holes were drilled upto
a depth of 110 meters. Drilling amounts to 802 meters with additional reaming job of 100 meters. Weak showings have been recorded which warrant deeper drilling to intercept the ore below the zone of oxidation.

Wahi Pandi

Four bore holes were drilled to monitor water table at Gaji Kumb, Sori- Rind, Taki and Haleli sites. Water table at all the sites is 67 meters ASL. Drilling amounts to 936 meters with additional reaming job of 1429 meters.

A composite geological map of Haleli to Momani area has been prepared at a scale of 1:50,000. Exposures of Nari, Gaj, Manchar, Dada conglomerate and sub-recent deposits have been marked. The two anomalous sandstone horizons GS-1 and GS-2, along with survey grid lines, location of anomalies and prominent structures have also been marked. In addition to the field observations, LAND SAT Imagery and available GSP maps of the area were also utilized for mapping.

Lithostratigraphy maps along two sections were prepared at Haleli and Sori Rind areas. Sedimentological studies indicate fine to medium grained sandstone, transported through saltation process. Detailed geological maps of Haleli, Gaji Kumb, Sori, Taki and Momani sites have been prepared at a scale of 1:2000 depicting lithology, paleo channel, mineralization and alteration haloes.

GEOPHYSICS

Data processing and interpretation of the Resistivity Survey carried out in Wahi Pandi (Dadu) along 11 VES upto depth of 250 meters has indicated depth of water table at 100 m ± 10 m depending upon the local topographic level. Using this data further exploration work on site was carried out.

Drilling was continued to confirm depth of water table and continuity of mineralization in the prospect area.

Radon- On-Activated Charcoal Survey (ROAC) was done on different occurrences of Nari Panoos area. Eleven Profiles covering 7.5 km line length were attempted which include implanting of 413 ROAC cartridges. A newly purchased logging unit was installed and commissioned. Hole deviation survey was conducted in two holes at Shanawah site. The unit was checked for all its functions; data acquired was compared with the available unit at ISL Qabul Khel project and the unit was found in perfect working condition.

GEOTECTONICS

In order to identify feasible site for waste disposal, available sedimentological, seismic and tectonic data on southern Kohat Plateau were studied in detail. Land Sat data was utilized for interpretation. A field programme was also conducted to confirm the structural features on ground. Additional field observations were also recorded where deemed necessary. Further work includes processing and interpretation of data. A report of Kohat area was submitted.

Gamma resistivity and SP Bore hole logging at Shanawah

REMOTE SENSING

LandSat TM image of Chagai-Dalbandin area, Baluchistan was processed and produced at 1:65000 scale. Digital image processing of Land Sat TM data and SPOT XS data were carried out in Sind, lower Swat (Ilum Granitic Complex), south Kohat Plateau, Chashma-Khushab and Turbat areas. Lithology and structure of the areas were enhanced. Images were produced at 1:65,000 scale for further plotting of features, ground checking and interpretation. A mosaic of Pakistan was prepared after the processing of the
Landsat Imagery data, annotation of major cities and other pertinent land features were highlighted. SPOT XS & Spot pan data along the motorway from Islamabad to Bhera and Turbat area were processed & printed.

LABORATORIES

Mineralogical studies were carried out on 764 rock samples for petrography, Sieve Analysis, XRD, Autoradiography, Heavy Minerals Separation, etc. Chemistry laboratories carried out nearly 21,000 estimations for 7423 rock & water samples supplied by different field groups, for varied nature of elements/radicles.

MINING AND HEALTH PHYSICS

Due to deeper setting of uranium ore body in Shanawah, conventional mining method would be uneconomical. Therefore a combination of In-situ Leach Mining with Underground Mining is considered feasible at this site. It is planned to drive two inclines with 50 meters spacing, at 15° slope to intercept the ore, 10 meters above the water table. Each incline is planned to be of 900 meters length; one will serve as an approach/entry while the other shall be used for ventilation.

Cross-cuts will be made after every 100 meters interval to join these inclines. Provision of galleries are intended to provide room for development/construction of the injection and production wells to be drilled up to the ore in the below water table zone.

After recovery of the ore from this zone, the ore body in the above Water table zone shall be mined out by cut and fill technique. Further advancement in adjacent areas shall be continued by In Situ leach mining followed by cut and fill in the above Water table zone. Total time required for driving two inclines and a set of gallery for developing two injection and one production wells shall be 3 years and estimated cost will be Rs.157.5 million.

Mining Plan was also designed to excavate uranium ore from soft rocks of Taunsa. Rock samples collected from Taunsa area were tested at SOILCON rock testing labs.

ORE PROCESSING

Two sets of experiments on the 'apatite' and 'pyrochlore' fractions of carbonatite ore from Sillai Patti area were performed at NMD (PINSTECH), Islamabad. The results indicated low leaching efficiency of REEs in pyrochlore fraction while in apatite fraction, lanthanum, samarium and uranium were leachable upto 69%, 64% and 99.24% respectively.

Insitu leach studies were conducted on core-samples from Shanawah. \( \text{NH}_4\text{HCO}_3 \) was used as lixiviant and \( \text{H}_2\text{O}_2 \) was used as oxidant. Repeated irrigations improved recovery from 72% to 80%.

Experiments were conducted to observe the effect of loading time on preparation of Hafnium dioxide and for removal of Iron prior to extraction of (Hf + Zr) metal by organic solvent.

Processing for the up-gradation of chromite ore from Hero Shah (NWFP) was initiated in the light of mineralogical & chemical lab tests.

Experimentation for a process development to produce Silicon from rice husk was continued. Rice straw contains ample quantity of Silicon. Some impurities created hinderance to produce pure silicon.

Monazite concentrate collected from Karachi is a possible resource for the production of thorium. Tests are underway to recover thorium, REE, phosphate and uranium.
HUMAN RESOURCE DEVELOPMENT

Human resource development plays a pivotal role in achieving the goals and objectives set aside by any organization. Pakistan Atomic Energy Commission, through its exclusive establishments, namely Computer Training Centre (CTC), KANUPP Institute of Nuclear Power Engineering (KINPOE) and CHASNUPP Centre for Nuclear Training (CHASCENT) is imparting training to the scientists, engineers and other technical personnel for keeping pace with achievement of its goals and also coping with the increasing needs of professionally trained manpower at all levels.

FOREIGN TRAINING

Three hundred twenty seven PAEC scientists/engineers participated in various IAEA workshops, seminars, symposia, conferences, 141 attended meetings colleges, visits and training courses sponsored by IAEA. Eighty six fellowships/scientific visits were availed by PAEC scientists/engineers.

COMPUTER TRAINING CENTRE

CTC started the 2nd batch of Master of Science in Information Technology, M. Sc (IT) Program in October 2002. M. Sc (IT) is a two years program, comprising of five semesters. CTC also started its 10th regular Post Graduate Computer Orientation Course (PGCOC-10) in Computer Systems Software & Hardware. The Computer Literacy courses were conducted for the children of PAEC Employees. Workshops on Web Enabling Technologies, VLSI Design Techniques and Office Automation were conducted.

M. Sc. (IT)

The 3rd and 4th semesters of M. Sc. IT, session 2001-2003 were conducted from 15-07-2002 to 09-04-2003, while the 5th semester of session 2001-2003, which is completely reserved for thesis work, started on 21-04-2003 with 15 students. The M. Sc. (IT), session 2002-2004 started on 07-10-2002 with 19 fellows joining the program. After successful completion of zero semester, the first semester of M. Sc. (IT) session 2002-2004 started on 16-12-2002 with registration of 17 fellows. Terminal examinations for the 1st semester were conducted from 11-04-2003 to 18-04-2003.

PGCOC Program

The 10th batch of six months Post Graduate Computer Orientation Course (PGCOC-10) started from 7th April, 2003. Twenty three (23) nominees of PAEC & Universities joined the course. The course will be completed on 6th October, 2003. 10 HEC nominees from various universities and 13 from PAECS's different establishments participated. Workshops, on "Web Enabling Technologies" & "VLSI Design Techniques" were arranged for 23 Participants from various universities and other R&D organizations &50 nominees from different PAEC establishments. An Office Automation Workshop was arranged for 43 staff members of PAEC HQ from 09-09-2002 to 01-11-2002.

CTC facilitated the conduct of an Orientation Camp from 22nd to 28th June 2003 for participants of 8th meeting of Nobel Laureates in Lindau, Germany (June 30 – July 4, 2003). This orientation camp was arranged for Pakistani Scientists to prepare them well prior to their departure to Germany. Prior to the orientation camp, interviews for selection of the candidates for participating in the said program were also conducted at CTC on 05-05-2003.

Computer Literacy Program for the Children of PAEC Employees

A Computer Literacy Programs was organized for 71 children of PAEC employees, who had appeared in their matriculate examinations.

KANUPP INSTITUTE OF NUCLEAR POWER ENGINEERING (KINPOE)

Master of Engineering (Nuclear Power)

Twenty engineers/scientists out of a total strength of 32 from Batch-8 graduated on September 27, 2002. The examinations of fourth semester of Batch-9 have been completed. Total strength of this batch is 38. The final examinations of first semester (Batch 10) ended in the second week of May 2003. Forty-four fellows out of a total strength of fifty-eight qualified for the second semester.

Post Graduate Training Program

Final semester examinations were held during March 2003. All the 32 trainees have successfully completed their training. The process of induction of second batch is in final stages.

Post Diploma Training Program (Technicians Training)

Batch-31 of PDP, comprising 56 trainees, completed their training on October 22, 2002. The certificate awarding ceremony of this batch was held on November 08, 2002. Final examinations for first semester of Batch -32 were conducted during April-May, 2003. Strength of the class in second semester is fifty-seven. The process of induction of Batch-33 is in progress.

KINPOE Website Development

KINPOE website was made available on Internet in March 2003, meant primarily for assisting in the admission process. The main features of the website are: advertisement, application form downloading facility, applicants'
status before and after the test etc. KINPOE website address is www.kinpoe.org.pk.

CHASNUPP CENTRE FOR NUCLEAR TRAINING (CHASCENT)

32 engineers & scientists of CHASCENT batch-I completed one-year postgraduate training, whereas 14 technicians of batch-7 completed one-year post diploma training. 37 engineers & scientists of batch-2 are undergoing one year post graduate training, while 38 technicians of batch-8 are undergoing one year post diploma training as well. General employees’ training was conducted for Chinese and Contractors’ personnel during RFO-1. 150 technicians of operation crews completed 2 month retraining whereas 45 MCR engineers completed 2-month retraining.

SCIENTIFIC & ENGINEERING SERVICES

10 Training Courses were conducted at National Centre for Non-Destructive Testing (NCNDT) in the field of Non-Destructive Testing Techniques and 138 participants from local industries & various organizations of PAEC were trained out, of which 88 were declared successful. The total amount receivable was Rs. 2.042 million. The centre also provided professional inspection & testing services to local industries worth Rs. 3.324 million. The industries served were Pakistan International Airlines (PIA), Interglobe Commerce Pakistan Ltd. (ICPL), Uch Gas Processing Plant, Qadirpur Gas Processing Fields, Project Management Organization (PMO), Air Weapon Complex (AWC), Water & Power Development Authority (WAPDA), Mangla Power Station and National Development Complex (NDC) etc. NCNDT has successfully provided In-Service inspection services to M/s UCH Power Plant, Dera Murad Jamali, Balochistan and M/s Chashma Nuclear Power Plant (CNPP) during its First Re-fueling Outage (RFO-1).

Pakistan Welding Institute (PWI) has conducted 09 different welding courses and imparted welding training to approx. 143 engineers, technicians & welders. An amount of Rs. 1.290 million were charged as a course fee from the participants. The Institute also provided technical services to local industries worth Rs. 1.990 million. The industries served were Pakistan Council of Renewable Energy Technologies, Mirage Re-build Factory (MRF), Pakistan Aeronautical Complex (PAC), Kamra, PAF Base-Chaklala, NDC, M/S PEL and HMC etc.
PROJECTS

WORKS

Construction of PAEC Foundation School, Phase-I
Block-A at NIBGE, Faisalabad

The work has been completed in all respects and handed over to the end user.

Construction of Mass Rearring Lab. at NIAB, Faisalabad

The work has been completed and handed over to the end user.

Renovation & Miscellaneous Works at NIAB, Faisalabad

The renovation works have been initiated and are in progress.

Establishment of INORE, Abbottabad

The building works and infrastructure approved in the PC-I i.e. Ward Block, Lift, additional heating/cooling dual feeder supply etc. have been accomplished well in time and handed over to the end user.

Construction of Rest House and other facilities at KANUPP Colony, Karachi

The entire work was accomplished on time and to entire satisfaction of the end user after which it was also handed over.

Soffit Slab of PSW Bays of Cooling Water Pumping Station at KANUPP, Karachi

The entire work of improvement has been accomplished satisfactorily and handed over to the user.

Construction of Access Control Building at KANUPP, Karachi

The work is progressing and expected to be completed by end of December, 2003.

Construction of Foundry Shop at NEW-II, Karachi

The construction work was accomplished with entire satisfaction to the end user.

Construction of Phase-II at KIRAN, Karachi

After finalization of architectural drawings, estimates were prepared and sent to PAEC HQ for administrative & Technical sanction of the competent authority.

Construction of Category-V type House CENAR, Quetta

The construction work was accomplished and houses were handed over to the end user.

PC-II from Mineral Survey Salli Patti, Malakand

The scheme is still pending as the implementation shall be taken subject to the availability of funds.

Construction of Cafeteria for staff at PINSTECH

Implementation of the scheme was held-up due to non allocation of funds by the Government.

PC-II for detail exploration of Uranium resources in D.G Khan Phase-VII

Exploration work remained in progress. However, PC-II Form for Phase-VII (i.e. 2004-2009) has now been prepared and being submitted to Planning & Development Division for approval.

SCIENTIFIC & ENGINEERING SERVICES (SES)

SES has established the latest knowhow in Design, Engineering & Development, state-of-the-art Fabrication & Welding Equipment, CNC machining facilities, Large Stress Relieving Furnace, Specialised Aluminium Foundry, Destructive & Non-Destructive Testing Facilities and High Pressure/High Temperature Test Loop, etc. to undertake the manufacture of sophisticated high tech. & value added jobs for power plants, in particular; and chemical, petrochemical, fertilizer & industrial plants, in general.

Design & Manufacture Of Equipment/Components

SES manufactured and supplied jobs worth Rs. 98.65 million to PAEC, Government Organizations & National Industry. The major jobs were for Heavy Mechanical Complex, Kot Addu Power Plant Co., KSB Pumps Co., Oil & Gas Development Corp., Heavy Industries, Taxila, National Refinery Ltd., Pak Arab Refinery, Ghaiz Brotha Power Plant/WAPDA, National Development Complex (NDC), Dr. Abdul Qadeer Research Lab., Ravi Rayon, Directorate of Technical Development (DTD), Kundian Nuclear Fuel Complex, and Chashma Nuclear Plant Project (CNPP). SES has signed commercial contracts with CERN, worth US $ 305,570 (Rs. 18.03 million) and delivered 1st consignment.

Internal & Surveillance Audits on ISO-9001 were carried out and all the pointed out non-conformances were addressed. The Federal Boilers and Pressure Vessels Safety Board has granted provisional approval for
manufacture of boilers, pressure vessels and heat exchangers.

PHASE DEVELOPMENT

All the construction works of Assembly Shop, QA Labs., Instrumentation & Control Labs have been completed. Erection of Heavy Duty Lathe and commissioning of 12-m Plate Heating Furnace has been completed. 200-ton Transport Bogie and 30-ton & 50-ton Roller Supporters, etc, are under manufacture.

The construction work if Pakistan Welding Institute building started in January 2003 and about 40% work has been completed. Design & rectification of industrial electrical works for special equipment workshop and general workshop is in progress. The civil construction of Foundry has been 90% completed. The electrification & installation of machines is in progress.
Chairman’s Visits Abroad

Mr. Parvez Butt, Chairman, Pakistan Atomic Energy Commission led Pakistan delegation as Governor from Pakistan in the Meeting of the IAEA Board of Governors held at Vienna (Austria) from 9-12 September, 2002. Chairman, PAEC led Pakistan’s delegation to the Forty-sixth IAEA Annual General Conference held at Vienna (Austria) from 16-20 September, 2002. He also visited European Organization for Nuclear Research (CERN), Geneva, Switzerland from 21-24 September, 2002.

Chairman, PAEC attended Meetings of Governing Board of World Association of Nuclear Operators (WANO-Tokyo Centre) held at Tokyo, Japan on 2 October, 2002 and 18 April, 2003. He also led PAEC delegation for negotiations on C-2 with high level officials of China National Nuclear Corporation (CNNC), Beijing, China from 20-21 April, 2003.

Chairman, PAEC attended Canadian Nuclear Society (CNS) Annual Conference held at Toronto, Ontario, Canada from 8-11 June, 2003 and CANDU Owners Group (COG) Annual General Meeting held at Toronto, Ontario, Canada on 12 June, 2003.

Appointments of PAEC Officials Abroad

Dr. Muhammad Naeem, was appointed as Senior Lecturer at Radiological Sciences Department, University of Kuwait for a period of one year. Mr. Muhammad Tariq, carried out six months assignment as KANUPP Representative with CANDU Owners Group (COG) Office at Toronto, Canada from 3 December, 2002 under Project – Improving Safety Features of KANUPP.

Dr. Muhammad Salim, has been employed for teaching/clinical Assignment as Registrar at College of Medicine and King Khalid University Hospital, Ministry of High Education, Riyadh, Saudi Arabia for a period of one year. Mr. Azhar Zia, is currently undertaking 6 months assignment as KANUPP Representative at Candu Owners Group (COG) Office, Toronto, Canada from 06 June, 2003 under Project-Improving Safety Features of KANUPP.

PAEC Scientists/Engineers as IAEA Experts

Twelve PAEC scientists/engineers carried out assignments abroad in various fields including Sustainable Radioactive and Radiation Measurements, Biofertilizer Technology, Mass-Spectrometer Operation and Maintenance, Review Input Data to WASP Model and suggest Improvements and Review Initial Results of WASP Analysis, Conditioning of Spent Radioactive Sealed Sources and to develop their detailed Technical Procedures, etc.

IAEA Experts in Pakistan


Foreign Delegations

Mr. Guoan Wu Staff Member of World Association of Nuclear Operators, visited CHASNUPP, Kundian from 9-15 December, 2002 to assess preparations for the WANO-TC Workshop.

Mr. Naicheng Xu of China, Programme Management Officer, East Asia and the Pacific Section, Department of Technical Co-operation, IAEA, Vienna (Austria) visited different PAEC establishments from 30 June – 01 July, 2003 to review ongoing Technical Co-operation Projects and discuss new Project Requests submitted to IAEA for consideration.
PAEC Delegation Abroad


Activities under RCA

Pakistan has continuously played its effective role in the programme of the RCA and has gained substantially in the peaceful applications of nuclear technology in the areas of Agriculture, Health, Industry, Quality Assurance and Research Reactors Utilization. Pakistan has participated in almost all the RCA projects.

Foreign Trainees in Pakistan under IAEA Award

Ten trainees from Malaysia, Jordan, Tanzania, Philippines, Bolivia, Sri Lanka, Yemen, Nigeria availed fellowship training at various PAEC establishments.

Technical Assistance by IAEA

Twenty-two Operational IAEA Technical Co-operation Projects broadly covering the fields of Biofertilizers for Increasing Sustainable Crop, Nuclear Medicine and Radiotherapy Support, Development of Suitability Assessment of Radiation Sterilized Medical Products, Initiation of Master of Science Medical Physics Degree Programme, Research Reactor Utilization, Upgrading the Analytical Facilities for Applying Isotope Hydrology in Water Resources Management, NDT Equipment Calibration and Concrete Testing, Non-Destructive Evaluation of Pressurized Components and Concrete Structures, Development of ISI Facilities for NPPs, Multi-function Simulator for Enhancing Nuclear Safety, Loose Part Monitoring for NPP Safety, Environmental Radioactive Pollution in Pakistan and Human Resource Development and Nuclear Technology Support, were being carried out.

The Technical Assistance received during 2002 under IAEA Technical Co-operation Programme was US $11,43,946, which include Experts visits, Equipment delivery, Fellowship/Training and Scientific Visits.

Research Contracts

IAEA awarded a sum of US$ 117,000/- for undertaking research in various PAEC laboratories in different fields of nuclear science. The amount represents the Agency's financial support for nine new Research Contracts and renewing fourteen existing Research Contracts.

IDB Award to PINSTECH

Islamic Development Bank (IDB) awarded to PINSTECH, Islamabad prize of US $ 100,000 for outstanding contribution to the Advancement of Science and Technology. Dr. Abdul Ghaffar Director General, PINSTECH visited Burkino Faso from 20-27 October, 2002 to receive that IDB Award.
Pakistan Atomic Energy Commission received funds from the following sources during the year, 2002 – 2003.

- Federal Government
- Provincial Governments
- Sale of Electricity
- Generated Receipts

Funds received from Federal Government are utilised to meet the current as well as development expenditure of the Commission except Karachi Nuclear Power Complex (KNPC) and Chashma Nuclear Power Project (CNPP) which meet their expenditure from their own generated income. Funds from generated receipts, Provincial Governments and other sources are mostly utilized for development activities.

Actual expenditure during the financial year under review along with its comparison with preceding year is given below:

### A. DEVELOPMENT EXPENDITURE

<table>
<thead>
<tr>
<th>Name of Sector</th>
<th>2001-2002</th>
<th>2002-2003</th>
<th>± %-age</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nuclear Power</td>
<td>3.218</td>
<td>8.508</td>
<td>(+) 164.387</td>
</tr>
<tr>
<td>Mineral Development</td>
<td>75.882</td>
<td>90.292</td>
<td>(+) 18.990</td>
</tr>
<tr>
<td>Agriculture</td>
<td>15.771</td>
<td>57.161</td>
<td>(+) 262.443</td>
</tr>
<tr>
<td>Health</td>
<td>82.504</td>
<td>169.270</td>
<td>(+) 105.165</td>
</tr>
</tbody>
</table>

Total Development Expenditure 177.375

325.231 (+) 83.357

### B. CURRENT EXPENDITURE

The current expenditure on different activities is as follows:

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Agriculture</td>
<td>197.232</td>
<td>235.036</td>
<td>(+) 19.167</td>
</tr>
<tr>
<td>Health</td>
<td>290.185</td>
<td>305.122</td>
<td>(+) 5.147</td>
</tr>
<tr>
<td>Physical Sciences</td>
<td>496.030</td>
<td>502.933</td>
<td>(+) 1.391</td>
</tr>
<tr>
<td>Mineral Development</td>
<td>102.060</td>
<td>127.263</td>
<td>(+) 24.694</td>
</tr>
<tr>
<td>Other Projects</td>
<td>44.715</td>
<td>27.829</td>
<td>(-) 37.763</td>
</tr>
<tr>
<td>PAEC Hqrs</td>
<td>181.524</td>
<td>208.333</td>
<td>(+) 14.768</td>
</tr>
<tr>
<td>Long Term Advances</td>
<td>-</td>
<td>7.531</td>
<td>(+) 100.00</td>
</tr>
<tr>
<td>Total Current Expenditure</td>
<td>1,311.746</td>
<td>1,414.047</td>
<td>(+) 7.799</td>
</tr>
</tbody>
</table>
C. SELF FINANCING

KARACHI NUCLEAR POWER COMPLEX

Rupees (in million)

\[
\begin{array}{ccc}
2001 - 2002 & 2002 - 2003 & \pm \% - age \\
\hline
\text{Current Expenditure} & 635.147 & 847.644 & (+) 33.456 \\
\end{array}
\]

CHASHMA NUCLEAR POWER PROJECT

Rupees (in million)

\[
\begin{array}{ccc}
2001 - 2002 & 2002 - 2003 & \pm \% - age \\
\hline
\text{Current Expenditure} & 2,396.940 & 1,904.634 & (-) 20.538 \\
\end{array}
\]

The revenue earned & receipt of KNPC and CNPP are as follows: -

KNPC, Karachi

\[
\begin{array}{ccc}
2001 - 2002 & 2002 - 2003 \\
\hline
\text{Electricity Sales Revenue} & **1,472.072 & 703.790 \\
\text{Receipts of Sales Revenue} & 1,370.647 & 816.822 \\
\end{array}
\]

** Including GST. Rs. 91.799 Million

CNPP, Chashma

\[
\begin{array}{ccc}
2001 - 2002 & 2002 - 2003 \\
\hline
\text{Electricity Sales Revenue} & 3,561.146 & 3,246.608 \\
\text{Receipts of Sales Revenue} & 2,759.567 & 2,392.880 \\
\end{array}
\]

** Including GST. Rs. 128.108 Million

On successful operation of Chashma Nuclear Power Project (CNPP) at Chashma Mianwali since June, 2000 by Pakistan Atomic Energy Commission (PAEC), Government of Pakistan has entrusted the Commission for establishment of 2nd Unit of Chashma Nuclear Power Project.

CONCLUSION

An analysis of total expenditure of PAEC reveals that 7.241% constitutes development activities while current expenditure represents 31.482% and self-financing is to the tune of 61.277%.
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