CONVENTION ON NUCLEAR SAFETY

National Report for Joint Eighth and Ninth Review Meeting, 2023
Islamic Republic of Pakistan

CONVENTION ON NUCLEAR SAFETY

National Report for Joint Eighth and Ninth Review Meeting, March 20-31, 2023

Government of the Islamic Republic of Pakistan

Prepared on behalf of the

Government of the Islamic Republic of Pakistan

by

Pakistan Nuclear Regulatory Authority

in collaboration with

Pakistan Atomic Energy Commission

August 2022

Pakistan Nuclear Regulatory Authority

G-8/1, Mauve Area Islamabad

ABSTRACT

On behalf of the Government, Pakistan Nuclear Regulatory Authority submits this National Report for peer review at the joint eighth and ninth Review Meeting of the Convention on Nuclear Safety at the International Atomic Energy Agency Vienna, Austria. The report demonstrates the continuous efforts of the Government of Pakistan to meet the obligations of the Convention during the reporting period and presents the steps taken to meet its main objective - to achieve and maintain a high level of nuclear safety by implementing and enhancing national measures and international cooperation.

This report includes the national position on the major common issues arising from Country Groups discussions which were identified in the President's summary report of the seventh Review Meeting. The report also addresses the progress on challenges identified during Seventh Review Meeting and presented in the National Report for eighth Review Meeting. In addition, the report includes the updates on actions taken to improve safety at nuclear power plants in response to Fukushima Daiichi accident as well as measures to implement the objectives of the Vienna Declaration on Nuclear Safety and measures taken during COVID 19 pandemic.

Changes made and new information added in comparison with the 8th NR are indicated by the underlined text.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

PART I

1 INTRODUCTION

1.1 Purpose and Structure of the Report

The Convention on Nuclear Safety (CNS) was signed by Government of the Islamic Republic of Pakistan on 20th of September 1994 and subsequently ratified on 30th of September 1997. Pakistan considers the CNS to be one of the most important instruments for enhancing nuclear safety. As a matter of policy, highest priority is accorded to the safety of nuclear installations in the country.

The joint eighth (8th NR) and ninth (9th) National Report (NR) of Pakistan to the Convention on Nuclear Safety has been prepared by the Pakistan Nuclear Regulatory Authority (PNRA) in collaboration with Pakistan Atomic Energy Commission (PAEC)and other governmental organizations in fulfillment of obligations under the Convention on Nuclear Safety on behalf of the Government of Pakistan.

This report presents the activities undertaken to ensure nuclear safety in Pakistan during the eighth and nine review cycles. Changes made and new information added in comparison with the 8th NR are indicated by the underlined text. The report starts with an introduction in Part I, followed by Part II that summarizes the progress made after the 7th NR. It also includes the status of actions completed or in progress to improve safety after Fukushima Daiichi accident, progress on open challenges of the Seventh Review Meeting of the Convention and new challenges identified in the 8th NR along with the activities undertaken for the implementation of Vienna Declaration on Nuclear Safety (VDNS). Brief description of the future challenges is presented in Part III and the report then continues with Articles 4 to 19 in Part IV according to the guidance provided in the INFCIRC/572 (Rev.6). Annexures are included to supplement information and data to elaborate the text of relevant Articles, where required.

The Government of Pakistan is committed to make all possible efforts to achieve and maintain a high level of safety and has met its obligations under the Convention on Nuclear Safety.

1.2 Electrical Energy Market in Pakistan

As of June 2021, the installed electricity generation capacity of Pakistan is 39772 MWe. Major sources of electricity generation in the country are fossil fuel fired thermal power plants and hydroelectric plants. The fossil fuel fired plants fall under the purview of Generation Companies (GENCOs), K-Electric and Independent Power Producers (IPPs). Nuclear Power Plants (NPP) are owned and operated by Pakistan Atomic Energy Commission (PAEC), whereas all the wind power plants, solar power projects and Bagasse cogeneration are run through IPPs, and the hydropower plants are operated by Water and Power Development Authority (WAPDA).

Table 1-1: Pakistan's Electricity Generation Capacity[1] (as of 30 June 2021)

Generation Type	Generation Capacity (MW)	Share (%) in Electricity Generation
Fossil fuels fired/Thermal	**25,098**	**63.104**
Hydroelectric	**9,915**	**24.929**
Nuclear	**2,612**	**6.567**
Renewable (Wind, Solar & Baggase)	**2,147**	**5.398**
Total	**39,772**	

1.3 National Policy Pertaining to Nuclear Energy

Nuclear and renewable energy are considered as valuable resources in the energy mix for the socio-economic development of Pakistan.

The contribution of Pakistan to total Global Greenhouse Gas (GHG) emissions is amongst the lowest in the world. However, it is among the countries which are the most vulnerable to climate change. Planning to minimize the consequences of climate change is firmly on the agenda of the Government of Pakistan which is vigilant in carrying out its responsibilities regarding preservation and improvement of the quality of the environment. The Government, through legislations, has established organizations at various levels to regulate salient sources of environmental degradation and to carry out research on climatic changes due to global warming. In case of nuclear energy, PNRA is the competent authority for regulating nuclear safety and radiation protection aspects whereas PAEC undertakes promotional activities for use and application of nuclear energy including research, development, education, etc. PAEC owns and operates all NPPs in Pakistan and has around fifty (50) years of NPP operating experience. The safety record of the operation of NPP has remained excellent as concluded from the findings of the national regulatory reviews and inspections. This has also been substantiated by international peer reviews.

Pakistan has been facing severe electricity shortage for the last many years which has adversely affected its economic growth. Nuclear power is a proven base-load electricity generation option to enhance the security of supply and diversity of the power production system.

After the Fukushima Daiichi accident, Pakistan has continued its policy of responsible use of nuclear power technology, with stringent safety controls. Progress on actions related to

[1] Source: Chapter 02 NEPRA State of Industry Report 2021

https://nepra.org.pk/publications/State of Industry Reports/State of Industry Report 2021.pdf

upgrades and modifications at NPPs in the light of Fukushima Daiichi experience feedback is presented in Part II (Section 2.3) of the report.

In fulfillment of the "Energy Security Plan 2005-2030" of Pakistan, PAEC intended to construct several more NPP to achieve the target of 8800 MWe of nuclear power by the year 2030. Accordingly, new sites are being identified for detailed evaluation. Recent installation of two PWR Units (K-2 and K-3) having capacity of 1100 MWe each at Karachi coast is a step in this direction.

1.4 Overview of National Nuclear Program

The national program related to nuclear installations is primarily focused upon installation of Chashma Unit-5 (C-5), decommissioning of Karachi Nuclear Power Plant Unit-1 (K-1) and on continued safe operation of already operating plants (C-1, C-2, C-3, C-4, K-2 & K-3).

During the reporting period, Karachi Nuclear Power Plant, Unit-1 (K-1) (previously known as KANUPP) remained in Long Shutdown (LSD) state for about eight (08) months in order to complete various safety related tasks following which it was granted permission to operate in May 2019. The plant was finally shutdown after completing 50 years of safe operation on August, 2021. Since the permanent shutdown of K-1, it is renamed as KANUPP Decommissioning Project (KDP) and along with the two new units K-2 and K-3 is collectively termed as Karachi Nuclear Power Generating Station (KNPGS).

Chashma Nuclear Power Plant C-1, C-2, C-3 & C-4 (the four units collectively termed as Chashma Nuclear Power Generating Station (CNPGS) continued to operate safely at Chashma site. Chashma site now has a total installed capacity of 1340 MWe. Moreover, construction, installation and commissioning activities at the site of Karachi Nuclear Power Plant Unit 2 and Unit 3 (K-2 and K-3) were completed during the reporting period following which K-2 started operation in May 2021 and K-3 in April 2022.

PAEC is continuously enhancing the capacity and quality of its key training institutes, such as Pakistan Institute of Engineering and Applied Sciences (PIEAS), Karachi Institute of Nuclear Power Engineering (KINPOE), and CHASNUPP Center for Nuclear Training (CHASCENT). Recently, MS (Cyber Security) has been added to the portfolio of Master's degree programs offered at PIEAS. Details are provided under Article-11.

The human resource development in PNRA continued to expand in terms of increase in manpower and enhancement of technical competence. This was achieved through organizing several basic, intermediate and advanced level training courses at the National Institute of Safety and Security (NISAS) of PNRA and other training institutes within the country. In addition, frequent participation of staff was arranged in international events e.g. workshops, training courses, fellowships etc. organized under the auspices of the IAEA. Details are given under Article-8.

PART II

2 SUMMARY

2.1 Progress after the Seventh Review Meeting

The progress made in significant areas after the Seventh (7th) Review Meeting is presented below:

2.1.1 Regulatory Framework

During the reporting period, five new regulations were issued (or promulgated), while development/revision of several regulations remained in progress. Amendments were made in two regulations. A regulatory order and a national policy were published and promulgated during the reporting period.

Furthermore, several new regulatory guides were issued while the revision of others remained in progress. The details of these developments for strengthening the regulatory framework during the reporting period are provided under Article-7.

2.1.2 Organization of PNRA and PAEC

During the reporting period, the organizational structure of PNRA was revised and detail is provided under Article-8. Updated organizational structures provided in Annexure-III of the report.

Organizational structure of PAEC was also modified to include four new units C-3 and C-4 of CNPGS and K-2 and K-3 of KNPGS after start of their commercial operation under DG (NPG). The modified Organogram of PAEC is presented in Annexure-IV.

2.1.3 Nuclear Power Plants (NPP)

The major activities performed in relation to operating and under construction NPP are summarized in the following paragraphs.

K-1

During the reporting period, K-1 was granted further extension in OL (for shutdown state) up to April 2019 in order to carry out major maintenance and testing activities. These mainly included Fuel Channel Integrity Assessment (FCIA) campaign, thickness measurement of feeder pipes, overhauling of turbine generator and auxiliaries, overhauling of primary system pumps, motors and motorized valves, sludge lancing and eddy current testing of steam generators tubes as confirmatory activities to justify the long term operation. The plant was finally shutdown for decommissioning in August 2021.

During the reporting period, a World Association of Nuclear Operators (WANO) peer review mission was carried out at K-1. Details are described in Section 2.2.2 of the report

C-1

Chashma Nuclear Power Plant Unit-1 (C-1) continued its safe operation during the reporting period and underwent 11th, 12th, 13th and 14th Refueling Outages (RFOs) of its operation PNRA allowed criticality and subsequent power operation of C-1 upon satisfactory completion of RFOs activities. Further details are provided under Articles-6 and 14 of the report.

During the reporting period, IAEA Operational Safety Review Team (OSART) follow up and WANO peer review Missions were carried out at C-1.

A WANO common site follow up peer review mission was carried out at C-1 in February 2021.

C-2

Chashma Nuclear Power Plant Unit-2 (C-2) continued its safe operation during the reporting period and underwent 4th, 5th, 6th, 7th and 8th RFOs. PNRA allowed criticality and subsequent power operation of C-2 upon satisfactory completion of RFOs activities. Further details are provided under Articles 6 and 14 of the report.

During the reporting period, a WANO follow up peer review mission and a WANO common site follow up peer review mission were carried out at C-2.

Details of the mission are described in Section 2.2.2 of the report.

C-3

After satisfactory completion of the review of the licensing submissions, OL was granted to C-3 in May 2018. C-3 underwent its first RFO and upon satisfactory completion of the RFO activities, PNRA allowed criticality and subsequent power operation.

Chashma Nuclear Power Plant Unit-3 (C-3) continued its safe operation and underwent its 2nd, 3rd and 4th RFO. PNRA allowed criticality and subsequent power operation of C-3 upon satisfactory completion of RFOs activities. Further details are provided under Articles 6 and 14 of the report.

A WANO common site follow up peer review mission was carried out at C-3. Details of the mission are described in Section 2.2.2 of the report.

C-4

Initial grid connection of C-4 was made in July 2017 and plant was provisionally accepted by PAEC from vendor in September 2017. After satisfactory completion of the review of the licensing submissions, PNRA granted the OL to C-4 in May 2018. During the reporting period, C-4 underwent its 1st RFO and 2nd RFO. Upon satisfactory completion of the RFO activities, PNRA allowed criticality and subsequent power operation.

Further details are provided under Articles 6 and 14 of the report.

A WANO common site follow-up peer review mission was carried out at C-4. Details of the mission are described in Section 2.2.2 of the report.

K-2 and K-3

The commissioning of K-2 started in September 2019 and after successful commissioning, K-2 started commercial operation in May 2021. Construction work, cold and hot commissioning and commissioning after fuel loading of K-3 has also been completed and the plant started commercial operation in April 2022. Further details regarding the commissioning activities and verification by PNRA are provided under Articles-6 and Article-14 of the report respectively.

Details about operating experience, lessons learned and corrective actions taken in response to events at nuclear installations are provided in Article-6.

2.2 Major Common Issues Arising from Country Groups Discussions at the Seventh Review Meeting

This section has been included in the National Report in compliance with Section 25 of the President's summary report for Seventh (7^{th}) Review Meeting. Pakistan's position in nine major areas is given below.

2.2.1 Safety Culture

During the reporting period, PNRA conducted its Safety Culture Self-Assessment (SCSA). Following actions were performed for addressing the areas highlighted in the SCSA:

a. Revision of tasks and functions for harmonization of workload;
b. Rationalization of workforce;
c. Arrangement of motivational sessions, acknowledgment of outstanding performance, etc.

Utilizing lessons learnt from its SCSA, PNRA conducted the Safety Culture Assessments at C-1 and K-1 in 2019 and 2020 respectively. For this purpose, PNRA utilized IAEA methodology presented in IAEA SRS-83 along with the experience gained from implementation of its SCSA process. During conduct of activity, PNRA mainly focused on observations collected during routine plant visits, review of plant documents, especially root cause analysis reports, self-assessment reports, event reports, near misses reports, etc.

The findings of the reports are being utilized by plant management to plan activities for safety culture improvements at NPPs.

The detailed information on activities related to safety culture improvement at NPP is provided in Section 10.2.3 of this report.

2.2.2 International Peer Reviews

Pakistan has continued its policy of openness, and sharing of its experience with others. The activities at the NPP are reported to, and kept open for reviews at national and international levels. Significant events are reported to WANO and IAEA.

PNRA invited the full scope Integrated Regulatory Review Services (IRRS) Mission in April 2014. The details of this Mission were included in the previous report. During the reporting period, the activities of action plan developed to address the recommendations and suggestions of IRRS mission continued at PNRA. Pakistan invited IRRS Follow-up Mission which was conducted from 28 February to 07 March 2022.The IRRS team declared that Pakistan successfully implemented all 13 recommendations and 29 out of 31 suggestions of the initial IRRS mission of 2014. Moreover, the mission commended Pakistan on significant improvements in its regulatory infrastructure making it more effective and efficient.

During the reporting period, PAEC invited several international peer review Missions to its NPPs, the details of which are presented in the following paragraphs.

A WANO peer review was conducted at K-1 from December4-21, 2017. During the Mission, the WANO team identified following practices at K-1 as noteworthy strengths:

a. Station has utilized newly developed Control Instrumentation Regulation Utility System (CIRUS) in order to display, record and analyze plant regulation and control parameters during plant operations and plant transient condition in real time;

b. Station has achieved significant improvements in contamination control by implementing changes such as modification to single entry and exit for Zone-3, introduction of different color Personnel Protective Equipment (PPE) for distinguishing with non-contamination control area, segregation of conventional and nuclear tool cribs, introduction of beta whole body contamination monitoring at change room exit, etc; and
c. The station installed active and passive fire protection system in auxiliary area on the cable trays in the cable gallery to prevent the common mode failure in the independent trains of the safety systems due to fire in the cable trays.

The Team also identified following Areas For Improvement (AFI):

a. Non-compliance to important procedural requirements in a few instances observed on Emergency Diesel Generators (EDGs) surveillance tests and gaps in the equipment protection program during operation and maintenance activities that increase plant operational risk and reduce the safety margin;
b. On many occasions, plant key processes including work management, engineering analysis, and CAP have not been effective to resolve the long-standing equipment reliability problems and prevent significant events, which has adversely affected the plant performance. This could leave the plant vulnerable to other significant events in future; and
c. Station leaders have not set and reinforced sufficiently high standards that are needed to drive performance improvement.

The peer review team also considered plant performance against 10 Nuclear Safety Culture traits and identified that the trait Work Process has the largest room for improvement, followed by Leadership Accountability. Conversely, Continuous Learning was considered as the strongest trait.

A Follow-up OSART Mission was conducted at Chashma Unit-1 (C-1) from December 11-15, 2017 which assessed the progress made on the recommendations of OSART mission conducted in 2015. The Mission concluded that 97% of the recommendations, provided by original OSART Mission 2015, have been or are being addressed. However, one issue regarding the implementation of the operating experience program was assessed as having made insufficient progress. As a result of this recommendation, the process of CAP was revised to incorporate missing elements. A multidisciplinary group was activated to screen the conditions in daily meetings. The meeting frequency of Action Review and Approval Committee (ARAC) was increased to daily meeting for approval of screening results, causes of the conditions and subsequent corrective actions.

A focused area WANO Mission on Organization and Administration, Human Performance, Operation and Equipment Reliability was conducted at C-1 from March 12-16, 2018. WANO recommendations included improving management programs such as CAP, Self-assessment and Human Performance Program. In order to address these recommendations, C-1 took the following measures to improve performance:

a. Condition reports are reviewed and approved daily by the team of managers, chaired by Plant Manager;
b. Additional coded fields e.g. human performance, critical component failure, near misses, reactivity management, are added in CAP to be explicitly coded by screening team; and

c. 'Quality of cause evaluation' matrix is to be made part of root cause analysis reports.

At C-2, the Follow-up WANO peer review Mission was conducted in March 2017. During the Mission, the peer review team focused on areas for improvement identified in the last peer review in 2015. The performance improvement in these areas were assessed as either satisfactory or on track. The team also confirmed that remaining areas for improvement have been adequately addressed.

A WANO common site peer review Mission for Chashma Nuclear Power Generating Station (CNPGS) site housing four Units (C1-C4) was conducted from August-September 2018. The WANO team emphasized the need to enhance and maintain the quality and configuration of Structures, Systems and Components (SSC) to ensure safety. This was advised to minimize risk associated with configuration changes, plant activities and long-standing operating instructions, which could result in events.

WANO follow-up peer review for CNPGS was conducted from 15-26 February 2021. During the follow-up WANO team assessed progress in the areas identified for improvement and found the progress in most of the areas satisfactory.

2.2.3 Legal Framework and Independence of Regulatory Body

PNRA was established as an independent regulatory body under the PNRA Ordinance, 2001 to regulate all matters related to nuclear safety and radiation protection in Pakistan. The Ordinance explicitly defines functions and responsibilities of the regulatory body and ensures its effective separation from promoters of nuclear energy in Pakistan. The said legislation empowers PNRA to formulate safety requirements and perform regulatory oversight of the facilities to ensure that these are operated in a safe and secure manner. For further details, refer to Section 8.2 of the report.

2.2.4 Financial and Human Resources of PNRA

Section 41 of PNRA Ordinance, describes provision of funding to discharge its responsibilities without compromising safety. PNRA is financially independent from the organizations it is regulating. Funds provided to PNRA consist of grants from the federal government, income generated from the licensing fees and international grants. In addition, special grants under Public Sector Development Program (PSDP) of the government are also received for strengthening of regulatory infrastructure. These funds have so far been adequate to meet the financial requirements of PNRA.

The existing workforce of PNRA is around three hundred and forty-four (344) professionals. The latest rationalization of technical professionals conducted in 2021 showed that additional technical professionals are needed for performing the currently assigned regulatory tasks. PNRA continues to implement measures to enhance the technical competence of its personnel in emerging areas. Under PSDP of the Government, PNRA is executing various projects aimed to enhance the capabilities of PNRA staff in the emerging areas of NPP design assessment and analysis, cyber security and computer safety and emergency preparedness and response.

2.2.5 Knowledge Management

Pakistan is cognizant of the importance of Knowledge Management (KM) and considers KM as one of the vital components needed for sustainable regulatory oversight of nuclear program. PNRA has included KM in its management system in-line with the intent of IAEA

GSR Part-2. PNRA has been conducting several KM activities since the last fifteen years. These include identification of critical knowledge areas, development of knowledge portal, organization of knowledge cafes, after-action reviews, panel discussions, exit interviews and retention of corporate memory by hiring experienced and retired professionals.

During the reporting period, PNRA developed the interface of the KM system with its management system.

PAEC is cognizant of the importance of KM activities at the NPP and has developed in-house training and knowledge management strategies. In this regard, a knowledge portal for comprehensive plant database of documents and information was developed at K-1 and with the passage of time improved to cater day to day needs of plant knowledge sharing. Various e-learning packages have also been developed for sharing and storing knowledge and information related to plant technology.

Different KM techniques like job shadowing, on the Job Training (OJT), storytelling, mentoring etc. are used to improve knowledge culture and KM practices. After participation in any national or international training it is mandatory for all employees to deliver a post training presentation for dissemination of knowledge to other employees.

K-1 personnel are provided opportunities to participate in national and international seminars within PAEC domain and in various IAEA, WANO, and COG programs for bilateral sharing of knowledge with the rest of the world. Besides, a comprehensive Operating Experience Feedback (OEF) program is established for which a head of OEF is assigned the task to share knowledge along with divisional coordinators of OEF. Important and significant OEF are regularly shared in management meetings on weekly basis.

K-1 completed 50 years of its operation and has been permanently shut down. PAEC foresees that it may face challenges of knowledge retention for management of safe storage and deferred dismantling. The decommissioning organization has been established to cater for retention of knowledge during different phases of decommissioning.

To preserve and get advantage of the tacit knowledge, an Expert Advisory Pool (EAP) of retired employees with good performance record has been formed and when required young people may interact and collaborate with them and learn from their experience, skill and knowledge.

The accumulated collective knowledge and experience of years are corporate assets, which are important to be retained for the sake of long-term business and professional success while constantly meeting the highest standards of nuclear safety.

In order to cope with the risk of knowledge loss due to retirement of experienced employees, Nuclear Knowledge Management section at Operation Training Division, and Maintenance and Technical Training Division of CHASCENT is striving hard, through an integrated and systematic approach, to identify, acquire, transform, develop, disseminate, use, share, and preserve knowledge, relevant to achieving specified objectives. To achieve this purpose, key positions and people where potential knowledge loss is most imminent are identified and Knowledge Loss Risk Assessment is performed after which a plan of action to ensure the capturing of that critical knowledge is prepared and implemented to capture tacit knowledge by conducting exit interviews, knowledge elicitation interviews and audio and video lecture recordings.

A Local Area Network (LAN) based E-Learning Portal is indigenously developed where audio and video lectures by subject matter experts are shared and made available to be utilized by young employees to improve their knowledge, skills and expertise. E-learning initiative was appreciated by WANO in the form of Good Practice while knowledge management initiative was appreciated by C-1 corporate safety review as a Good Practice.

2.2.6 Supply Chain

Nuclear power projects have been installed in Pakistan as turn-key projects with many parties involved including owner, contractors, sub-contractors, vendors and suppliers. QA inspections of the said parties are conducted with comprehensive scope from owner to vendor and supplier to verify conformity of items with designer's specifications and code and standards requirements, fraudulent items, suppliers' evaluation and inspection process, and QA and management systems requirements. Regulations on the Safety of Nuclear Power Plants-Quality Assurance (PAK/912) (Rev. 1) provide basic requirements for establishing and implementing Quality Assurance Programs (QAP) related to the safety of NPP. Further, ageing of items and obsolescence are also assessed and managed through periodic safety review of NPP conducted after a period of every ten (10) years which also forms basis for decision making for license revalidation. Inspections are also conducted to verify measures taken by licensee to cater ageing, obsolescence and spare parts availability at NPP in accordance with requirements of regulations, SAR and procedures. In addition, PNRA has granted license to a few nuclear safety class equipment manufacturers upon fulfillment of all the requirements set forth in national regulations. In a number of instances, issue of availability of spare parts has been tackled by locally manufactured components.

K-1 operated safely for fifty years with a comprehensive supply chain system which ensured availability of spares, replacement of obsolete items/systems, effectiveness of ageing management program, etc. K-1 is currently in permanent shutdown state and is undergoing decommissioning as per deferred dismantling strategy.

K-2 and K-3 have commenced commercial operations during the reported period. A comprehensive list of necessary spares (supply chain) has been agreed upon with the Contractor for one-year as well as five-years spares to ensure the smooth operation of both NPPs for the next 5 years. In addition, extensive market surveys and procurement cases (local & foreign markets) are in progress for availability of spares and other items as well as for indigenization.

2.2.7 Managing Safety of Ageing Nuclear Facilities and Plant Life Extension

Implementation of the effective ageing management is one of the approaches leading to safe and Long-Term Operation (LTO) of NPP. PNRA Regulations on Safety of Nuclear Power Plants Design - PAK/911, Regulations on Safety of Nuclear Power Plants Commissioning and Operations - PAK/913 and Regulations for Licensing of Nuclear Installations - PAK/909 address the requirements for ageing management and operation beyond design life for NPP in Pakistan. PNRA has included regulatory requirements in revision of PNRA Regulations PAK/913 in-line with requirements of IAEA SSR 2/2 requiring plant management to ensure that effective Ageing Management Programs (AMP) are implemented. PNRA Regulations on the Safety of Nuclear Power Plants - Operation, PAK/913 have established requirements for ageing management during the operation phase through Periodic Safety Review (PSR) which is normally conducted after every ten (10) years. The purpose of AMP is to ensure that required safety functions of SSC are fulfilled over the entire operating lifetime of the

plant. For operation beyond design life, availability and implementation of AMP is ensured by the regulatory body through PSR.

PNRA reviews and oversees the issues related to condition of SSC and ageing of NPP according to the regulatory requirements. Although approval of AMP by PNRA is not the requirement, nonetheless, licensee develops the AMP to meet the regulatory requirements which are established in regulations. PNRA ensures its availability and implementation during plant operation.

The challenge of maintaining the design and licensing knowledge-base during extended plant lifetimes is being ensured through development of KM system.

At K-1, ageing management activities were started in late nineties. IAEA first Ageing Management Assessment Team (AMAT) Mission visited K-1 in 1999 to review the on-going ageing management activities. Thereafter two IAEA expert missions were invited to review ageing assessment work done for Motorized Operating Valves (MOV) and in-core Instrumentation and Control (I&C) cables for guidance on establishing and maintaining AMP. Based on the recommendations of these Missions, a formal AMP was established in the year 2002 and all the relevant programs have been converged under this program. The aim of this program is to operate the plant beyond its design life by maintaining service life of the SSC, acquiring acceptable level of safety and performance and maximize return on investment. In October 2018, an IAEA Expert Mission based on Safe Long-Term Operation (SALTO) was held at K-1 and based upon learning from this Mission, K-1AMP is being restructured on the basis of IAEA Specific Safety Guide SSG-48 and Safety Report Series No. 82.

At CNPGS, a dedicated group for ageing management is in place which has support from external organizations on ageing management activities. The scope of AMP has been defined by screening all SSC out of which twenty-eight (28) from each NPP are selected for AMP at CNPGS. In addition, the identification of ageing mechanisms and their effects have been performed for all the selected SSC. Monitoring and mitigation of all ageing mechanism through a systematic way for each and every SSC is a continuous process at CNPGS.

At KNPGS a dedicated group for ageing management is in place which has support from external organizations on ageing management activities. The scope of AMP was defined by screening all SSC out of which twenty-nine (29) from each NPP were selected for AMP at KNPGS. In addition, the identification of ageing mechanisms and their effects for all the selected SSC is in progress.

2.2.8 Emergency Preparedness

As part of harmonization of national Emergency Preparedness and Response (EPR) arrangements with the international arrangements, Pakistan has established its national regulatory requirements for emergency preparedness based on IAEA safety standards. Currently, revision of the national regulatory requirements is in progress to make them in line with the IAEA Safety Standards GSR Part 7 "Preparedness and Response for a Nuclear or Radiological Emergency".

As a Contracting Party to the Convention on “Early Notification of a Nuclear Accident”, and to the Convention on “Assistance in the Case of a Nuclear Accident or Radiological Emergency”, Pakistan is committed to notify, exchange information and consider provision of assistance in case of a nuclear accident or radiological emergency in line with the provisions of the Conventions. In this regard, a dedicated 24/7 emergency center is in place. Being the

State Party to the Assistance Convention, Pakistan has registered its National Assistance Capabilities (NAC) in different functional areas in IAEA Response and Assistance Network (RANET) since 2008. The arrangements at PNRA for EPR are being strengthened by upgrading the National Radiation Emergency Coordination Centre (NRECC) under a PSDP project.

For the station having multi-units in operation (i.e. CNPGS), a joint procedure for interface during a nuclear emergency among all the Units is in place which defines communication links between Emergency Control Centers (ECC) and Main Control Rooms (MCR). In case of emergency at any single Unit, the respective MCR shift supervisor will notify to all other Units and the same class of emergency will be declared at these units. Consequently, all the Units will perform actions in accordance with their respective emergency plans and procedures which are harmonized at station level.

A two-pronged strategy for implementation of public awareness program has been adopted. First, as part of implementation of offsite emergency plans, the licensees are implementing site specific public awareness programs in areas around nuclear installations. Secondly, PNRA organizes awareness sessions and seminars for public in various cities across Pakistan. For awareness of first responders and public, PNRA has prepared, printed and distributed pamphlets and booklets regarding nuclear and radiological emergencies. The brochures are prepared both in English and Urdu (national) languages.

2.2.9 Stakeholder Consultation and Communication

PNRA has established open communication, cooperation and linkages with national and international organizations for improvement in regulatory performance and information sharing. PNRA keeps the general public informed about its significant activities and decisions through its website and annual report. Draft regulations are also placed on PNRA website for public comments. In addition, during the site evaluation process of NPP, the provincial EPA requires a public hearing on Environmental Impact Assessment (EIA)for the issuance of No Objection Certificate (NOC) which is a pre-requisite for registration of site for construction of NPP by PNRA.

CNPGS and KNPGS have implemented a Public Awareness Program (PAP) with the ultimate objective of building confidence among the public that NPPs possess appropriate emergency arrangements and liaison with local/ district administration to fulfill the requirements of national and international standards to ensure public safety during radiological emergency.

PAP focuses on the important groups in the public, who have frequent interaction in masses, herein after called target groups which include the following:

a. Professionals (Govt. and Semi Govt. employees);
b. Students;
c. Business community;
d. Residents around NPP at Chashma and Karachi; and
e. Political figures, local Union Counselors and Administrators.

In order to fulfill the regulatory requirement, CNPGS and KNPGS have established programs for Radiological Environmental Monitoring (REM) around NPP which are being implemented. Furthermore, Radiological Assistance Groups (RAG) have been formed at national level to

provide support to affected plant in case of emergency in the area of environmental monitoring.

Further information in this regard is provided under Article-8 and Article-16.

2.2.10 Special Reporting on Impact of COVID-19

COVID-19 pandemic affected every discipline of life. Measures taken by PNRA and PAEC (at its nuclear installations)during the pandemic are described below:

2.2.10.1 Pakistan Nuclear Regulatory Authority

A. Review and Assessment

The review and assessment of K-2/K-3 FSAR was carried out during the COVID-19 pandemic. PNRA completed the review and assessment process with minimum possible delay and without compromising on health and safety of its employees by observing following steps:

- Due to limitations of office timings and allowed attendance of staff, the review and assessment team was also allowed to work-from-home;
- Video conferences were conducted to resolve the issues with utility and designer instead of face-to-face physical review meetings. These video conferences were conducted by following COVID-19 protocols at different locations and were continued for almost two months.

During the pandemic period, Chashma NPP Unit-1 and Unit-2 applied for revalidation of their operating licenses with the submission of respective Periodic Safety Review Reports (PSR). The review and assessment of these reports was also carried out during the COVID-19 pandemic and the review queries were resolved by using a hybrid approach i.e. face to face and virtual meetings. The operating licenses were validated upon satisfactory resolution of all review queries and submission of Corrective Action Plan by the licensees.

B. Regulatory Oversight

The regulatory oversight of NPP was a very challenging task due to COVID-19 pandemic, and implementation of strict SOP. However, PNRA's regional directorates utilized a graded approach to prioritize the regulatory inspection and other activities so that there would be minimum possible impact on regulatory oversight. Following measures were taken by PNRA at NPP sites:

i. Number of inspections at all NPP were kept optimized through safety-oriented graded approach by minimizing the number of witness point inspections and increasing the record point inspections;
ii. Review of respective records was performed from home. However, reactive inspections (whenever needed) and official correspondence via telephone/email was continued;
iii. A strategy was devised regarding continuous regulatory oversight of newly built K-2 and K-3 NPP by establishing two office setups. At NPP site office, PNRA inspectors quarantined for two weeks followed by COVID-19 screening tests before participating in inspection of installation/commissioning activities. The PNRA inspectors at City Office provided continuous support to the site office through review of commissioning test procedures or licensee's other submissions.

2.2.10.2 COVID-19 Measures at NPP

The NPP utilities implemented the following measures to ensure safety at the NPP sites during COVID-19 pandemic.

A. General Measures at NPP sites:

i. Body temperature measurements of all personnel entering NPP were carried out using contactless hand-held thermal guns by dedicated staff.
ii. All plant personnel were instructed to inform medical staff immediately in case of probable flu and other symptoms.
iii. All plant personnel were given necessary gadgets for personnel protection like face masks, hand sanitizers, etc.
iv. Number and size of meetings were restricted to ensure safe distancing.
v. All personnel at site were required to use face mask all the time and periodic disinfection of vehicles and doorknobs.
vi. Interaction of PAEC personnel with personnel of contractors was restricted to minimum. People were asked to practice social distancing.
vii. Provision of hand sanitizer and carbolic soaps were ensured at site all the time.
viii. Daily commutation from city during early phases of COVID-19 was discontinued. Only those required to carry out contingent support activities were called at site.
ix. Use of biometrical devices and fingerprint scanners for plant access control was banned.
x. All cafeterias at plants were closed and lunch provided through parcels to restrict staff gathering. Group meals were prohibited.

B. Isolation of Residential Colony and NPP

Plants and their colonies were isolated. Necessary operation and maintenance personnel were made available at colonies, and no one was allowed to come in or go out from the colony, except plant personnel. Every one coming in or going out of plant and colonies was being monitored for health checks. Daily communication from city was discontinued. Quarantine facility was established at site for those who were called from out station. No individual left the quarantine facility without clearance of COVID-19 test and 14 days quarantine period. People (from colonies/plants) were instructed and sensitized to offer prayers at home instead of mosques.

C. Measures for Operational NPP

1. Availability of Minimum Shift Operation Personnel

As initial COVID-19 response, routine operational shifts were retained at Karachi Nuclear Power Plant (K-1) site and supplementary shifts were made standby in Karachi city at their homes. Necessary food items were stored and made available at plant. At Chashma Nuclear Power Generation Station (CNPGS), all the operation crews of each unit were retained at Chashma site in the nearby colony. The super week crew and retraining crew remained on standby in colony. Till now all NPPs in Pakistan follow the routine shift rotation, operators didn't apply for the flexibility in scheduling staff during COVID-19.

2. Availability of Necessary Maintenance staff

Necessary maintenance personnel, health physics and chemistry personnel were made available at nearby colonies and at plants including fuel handling personnel. These personnel were provided with all necessary personnel protective equipment and logistic to perform the assigned activities. Necessary general shift staff were made available to perform duties on alternate basis.

3. Availability of Response Team

A Pandemic response team was formulated at plant sites comprising of management personnel and medical staff. They were continuously taking health updates of plant personnel and actions were taken accordingly in case of any unexpected/unforeseen situation.

4. Outage Management

Scope of outage work plans was reanalyzed for upcoming outages of NPP to limit necessary jobs only.

5. Disinfection and Hygiene

All plant areas, residential colonies, nearby banks, markets, and hospital were disinfected by NaOCl on regular basis.

i. Plant personnel work stations, cabins, key boards, mouse, telephone sets, and door locks etc. were disinfected on daily basis.
ii. Wall mounted hand sanitizers were installed on all floors near elevators.

D. Measures for Under Construction NPP

Measures taken at under construction NPP (K-2 and K-3) included the following;

i. Initially 10 operation and 10 commissioning personnel of K-2 and K-3 along with contractor's staff; were allowed to participate in installation/commissioning activities, after following the protocol i.e. 14 days boarding and lodging at specially controlled quarantine facility in residential complex.

ii. No foreign contractor’s personnel were allowed to enter the site since February 2020. Recently arrived were put in 14-day quarantine immediately.

iii. A meeting room having glass partition equipped with sound system used for meetings between PAEC and Chinese personnel. Any exchange of papers if required were made through leave-and-take shelf with only one party using it at one time.

iv. Because of lockdown in Karachi city, 40 K-2 and K-3 personnel were restricted at PAEC colony situated midway between site and city. Exit and entry of the colony were restricted since March 20, 2020 till relaxation of measures. Most of personnel involved were local area operators who commuted from site to colony only and vice versa.

v. Essential personnel required for operation of desalination facility were restricted to site at PAEC boarding/lodging facility at site.

E. Current Situation

i. All employees at operating NPP have been vaccinated and quarantine requirements are no more implemented. However, for suspected employees, COVID-19 test are

being conducted and home isolation is advised to them till they became healthy to join their duties. Official meetings are preferred through video conferencing, however, if unavoidable, face to face meetings were held on need basis. Use of face mask and hand sanitizers is still in practice.

ii. At K-2 and K-3, all local and foreign employees have been vaccinated. The site is under control of Chinese contractors where COVID-19 measures are still enforced both on local and Chinese employees, including quarantine requirements for employees entering or leaving the site. Use of face mask and hand sanitizers is still in practice.

2.3 Updates of Activities to Improve Nuclear Safety of NPP in Response to Fukushima Daiichi Accident

Post Fukushima assessment of NPP was conducted under the Fukushima Response Action Plan (FRAP) and issues identified during the assessment were addressed through short term, intermediate and long term actions. These were presented in the Second Extraordinary meeting of the Convention on Nuclear Safety held in August 2012 and their progress was reported upon in previous National Reports. The following table describes only the updated status of activities being performed or completed during the reporting period under FRAP.

Table 2-1: Updated Status of Activities under FRAP

Task	Target	Activity Status	Results
Topic 1 :EXTERNAL EVENTS			
Earthquake Hazard			
K-1			
Re-evaluation of seismic capacity of all structures for the revised seismic input of 0.2g	30-06-17	Completed	Earthquake hazard for K-1 site has been re-assessed based on new IAEA methodology, and the Design Basis Earthquake (DBE) of K-1 site has been revised from 0.1g to 0.2g. Seismic integrity of all important plant buildings for Peak Ground Acceleration (PGA) of 0.2g has been ensured, including the seismic qualification of essential feed water room at 0.2g PGA.
CNPGS (C-1,C-2,C-3,C-4)			
Study of combined effects of earthquake and flooding due to dam break to determine how much it differs from Design Basis	28-02-17	Completed	According to results of the study performed, existing design has sufficient margin.

Task	Target	Activity Status	Results
Determine and improve the worst earthquake and flooding that the plants can sustain with minor back fits (identify the most vulnerable equipment)	30-06-17	Completed	Based on walk-downs of Nuclear Island (NX) and Electrical Island (EX) buildings, entry points of cable trenches, piping galleries and drain lines were found potential sources of external flooding. The flood protection gates have been installed for these points.
Fire Hazard			
CNPGS (C-1,C-2,C-3,C-4)			
Revisit design basis of fire protection system	30-08-22	In Progress	Fire detection basis is being reassessed on case-to-case basis i.e., during investigation of fire related items.
Improve Resilience of fire brigade station to external hazards	30-06-17	Completed	Soft sheds have been constructed and are available for emergency vehicle parking at C-1
Augment equipment and training for Rescue and Recovery Operations	31-12-19	Completed	As part of the plan to strengthen the equipment base needed for typical rescue and recovery operations, all the equipment has been purchased.
Topic 2 :DESIGN ISSUES			
Electrical Power			
K-1			
Shifting of emergency lighting from 230 V DC to 220 V AC (UPS)	30-06-17	Completed	All nine (9) loops of emergency lighting have been shifted from 230 V DC to 220 V AC (UPS).

Task	Target	Activity Status	Results
CNPGS (C-1,C-2,C-3,C-4)			
Preparation of procedure for conserving DC Power to prolong its availability in case of Extended Loss of AC Power (ELAP)	30-06-19	Completed	Two Diesel Generators (DGs) of medium voltage have been procured and these moveable DG will be used to energize 6kV safety buses of NPP on requirement basis. The hook-up arrangements to energize these buses have been completed. Two (02) medium voltage Diesel Generators of capacity 2MW each have been commissioned and are in service to mitigate Extended Loss of AC Power (ELAP). FLEX Support Guidelines (FSGs) for MV DG staging, operation and 6kV bus preparation have been developed. This arrangement has waived off the requirement of DC power conservation.
Containment Integrity			
K-1			
Provision of hydrogen monitoring equipment as part of Post-Accident Monitoring System (PAM).	31-12-17	Dropped	Due to difficulty in procurement of hydrogen monitoring system, this item has been dropped. Instead of direct monitoring, pre-calculated charts for hydrogen build-up based on estimated oxidation percentage will be used.
Feasibility of installing system for relieving containment pressure automatically or manually	30-12-17	Dropped	After installation of FRAP modifications related to heat sink and power, installation of Passive

Task	Target	Activity Status	Results
			Autocatalytic Re-combiners (PAR) and availability of large containment volume, it is highly unlikely that containment pressure would rise beyond its design value. Considering these factors and remaining short operating life of K-1, the idea of installation of Containment Filtered Venting system is dropped.
CNPGS (C-1, C-2,C-3,C-4)			
Installation of PAR at C-1 (as of C-2)	31-12-19	Completed	Installation of fourteen (14) PARs has been completed at C-1.
Emergency Cooling			
Primary emergency make-up by introducing additional injection point and using FLEX arrangements in all units	31-12-21	Completed	Pre-requisite of design modifications (hookup arrangement) for primary and secondary emergency makeup have been completed at all units. Two (02) FLEX pumps each for primary and secondary emergency makeup have been procured and installed.
Secondary emergency make-up by introducing additional injection point and using FLEX arrangements in all units	31-12-21	Completed	
Ultimate Heat Sink			
CNPGS (C-1,C-2,C-3,C-4)			
Improvement in design of Essential Service Water (WES) pumping station entrance to prevent	31-12-22	In Progress	Flood protection doors of 15 out of 26 flood gates have been installed at C-1/C-2.

Task	Target	Activity Status	Results
inundation in case of extreme flooding			
Spent Fuel Cooling			
Study of measures against Spent Fuel Pool (SFP) loss of cooling or drainage	31-12-21	Completed	Pre-requisite for SFP emergency makeup were completed at all units. Two (02) FLEX pumps for SFP emergency makeup were installed.
Topic 3:SEVERE ACCIDENT MANAGEMENT			
K-1			
Availability of all necessary equipment and gears for implementing Emergency Operating Procedures (EOP) and Severe Accident Management Guidelines (SAMG).	30-12-18	Completed	All necessary equipment and gears required for the implementation of EOP and SAMG are now available.
CNPGS (C-1,C-2,C-3,C-4)			
Preparation of SAMG	31-12-19	Completed	SAMGs have been developed, validated and placed in respective TSCs of all CNPGS units.
Development of a reserve force of workers to cope with severe accident consequences	31-12-22	In Progress	Upon completion of Post Fukushima improvements, the emergency response force requirements for on-site SAMG actions will be identified and arranged accordingly.

Task	Target	Activity Status	Results
Preparation of proposal for common alternate ECC and resource center for Chashma site	30-06-17	Dropped	C-3 and C-4 ECC can be used as alternate ECC, the proposal was dropped.
Availability of necessary equipment/gears for implementing SAMGs	30-12-21	Completed	Procurement and installation of equipment completed
Topic 4: NATIONAL ORGANIZATIONS			
PNRA			
Revision of PNRA regulations in the light of feedback from Fukushima Daiichi accident	31-12-19	Completed	Regulations on Safety of NPP Design and Operation have been gazette notified.
PAEC			
Review of progress of all NPP on FRAP		Continuous Action	Since NPP have been following FRAP as per commitment, therefore, frequency of review by the corporate office has been reduced from biannually to annual basis. The progress review is now conducted at PAEC Headquarter by Corporate Safety Review Committee (CSRC).
Topic 5: EMERGENCY PREPAREDNESS AND RESPONSE AND POST-ACCIDENT MANAGEMENT (OFFSITE)			
K-1			
Provision of PAM equipment	30-03-17	Completed	All thirty (30) Accident Management Instrumentation (AMI) loops have been installed and commissioned.

Task	Target	Activity Status	Results
CNPGS (C-1,C-2,C-3,C-4)			
Reassessment of Emergency Planning Zones (EPZ)	31-12-22	In Progress	Generic EP zoning from GSR part 7 will be implemented.
Assessment and development of possible additional access routes to the site	31-12-24	In Progress	Initial studies have been completed. Accordingly, it was decided to build an additional 2-lane seismically qualified bridge on Chashma-Jhelum (CJ) link canal, but construction could not be started due to certain limitations including COVID-19. Revised bidding is in process, construction to be started by the end of 2022 with two years completion time. Design has been finalized and is now at implementation stage.
Development of Public Awareness Program	30-06-17	Completed	Program has been developed and is being implemented.
Topic 6 :INTERNATIONAL COOPERATION			
Detailed information on international peer review Missions is provided in Sections 2.2.2 of the report.			

2.4 Progress on Challenges

A. Challenges Identified during the Seventh Review Meeting 2017

Following challenges were identified for Pakistan during the Seventh Review Meeting of the Convention:

Challenge 1: Enhancing organizational capabilities of PAEC and PNRA for decommissioning of nuclear installations.

Challenge 2: Enhancing organizational capabilities for design review and regulating advanced designs (Digital I&C, passive safety systems, etc.).

Challenge 3: Sustainable development of human resource for operation and maintenance of nuclear installations in view of government's Energy Security Plan 2030 to increase the share of nuclear power to 8800 MWe.

Challenge 1: Enhancing organizational capabilities of PAEC and PNRA for decommissioning of nuclear installations

Strategies to optimize the use of personnel and other resources for decommissioning and initiating preparatory activities for decommissioning were prepared. The initial decommissioning plans of all operating NPP at CNPGS are in-place after approval by PNRA and are being regularly updated.

National Policy on Safe Management of Radioactive Waste, Decommissioning and Spent Nuclear Fuel in Islamic Republic of Pakistan-(RWP-01/2018) was prepared and issued by PNRA in 2018. Salient features of the policy include establishment of the role and responsibilities of different stakeholders; ensuring the availability of decommissioning fund and ensuring provision of financial resources even in case of premature shutdown of facility. The Regulations on Decommissioning of Facilities using Radioactive Material – (PAK/930) were also promulgated in 2018.

Several national and international training courses, workshops, expert missions, scientific visits, etc. on decommissioning were conducted at PNRA and PAEC in collaboration with IAEA to enhance the capability of the staff of regulatory body and operating organization. PAEC joined Decommissioning Peer Group (DPG) and Waste Management Peer Group (WMPG) of COG in order to enhance decommissioning capabilities. A scientific visit to Canadian facilities under decommissioning was also performed in February 2019 to acquire first-hand knowledge. Training programs and procedures have been developed by the licensee for the fuel handling crew and operating personnel performing defueling and de-watering.

In the light of above mentioned capacity building efforts, PAEC has finalized K-1 Final Decommissioning Plan and submitted to PNRA. The plant is permanently shut down since August 2021 and had applied for decommissioning license along with relevant regulatory submissions. The fifty years of decommissioning timeline includes Phase I (15 years - Preparation for SAFSTOR) followed by Phase II (30 years - SAFSTOR) and Phase III (5 years - decontamination and dismantling). Thus, Pakistan has met the challenge.

Challenge 2: Enhancing organizational capabilities for design and regulating nuclear installations of diverse and advanced designs (Digital I&C, passive safety systems etc.)

CNPGS houses generation II power plants which are maintained and operated safely and efficiently; while, K-2 and K-3 are generation III power plants. Training programs related to K-2 and K-3 basic and detailed design participation, Operation and Maintenance (O&M) and OEF were organized by PAEC to enhance the technical skills of its engineers and scientists. After going through afore mentioned training program, PAEC engineers and scientists participated in the design review process and contributed towards improvement in the plant design and documentation.

The manpower of C-1, C-2, C-3 and C-4 has a vast experience of O&M and up gradation of obsolete and degraded systems to enhance the performance and efficiency of the plant. Technical work force is being trained locally (in training centers) as well as internationally with the help of IAEA, WANO and relevant design organizations.

During the reporting period, regulatory review and assessment capabilities of PNRA officials in digital I&C systems, were enhanced through IAEA-PNRA joint workshops and fellowships focusing on modeling, design and regulatory review of digital I&C systems. In addition, PNRA initiated a project titled "Reinforcement of PNRA's Capacity and Regulatory Oversight against Vulnerabilities of Digitized Controls and Cyber Threats" (Cyber Security & Digital Safety) under the Public Sector Development Program (PSDP) of the Government. Under this project, PNRA aims to develop expertise in relevant core regulatory functions e.g. development of regulatory framework, review & assessment and inspection of software based I&C systems of NPPs. Moreover, laboratories on digital safety and cyber security at are in the process of establishment of laboratories and equipment/standards are being procured. Efforts are also being made for acquiring expert level trainings and international certifications which could not be materialized timely mainly due to pandemic situation. Furthermore, collaboration with IAEA and different Chinese organizations is in progress regarding development of organizational capabilities in the area of fuel integrity assessment and review and assessment methodologies of passive safety systems of advanced designs in the form of scientific visits, fellowships and workshops.

K-2 plant has been put into operation and started its commercial operation since May 2021 and K-3 in April 2022. The PAEC trained O&M team took-over plants from the Chinese contractors and are operating them safely. PAEC acquired this capability over a period of time through rigorous training of manpower involved in O&M both at plant of similar design (Fangiiashan NPP) and other operating PWR units in Pakistan. However, continuous improvement in the operational safety of digital I & C equipment through effective attainment and dissemination of operation experience and strengthening of the electrical design and control based engineering setups is in progress to develop in-house capabilities for troubleshooting and maintenance of digital I & C systems in the operating organization. Hence, the challenge is still open.

Challenge 3: Sustainable development of human resource for operation and maintenance of nuclear installations in view of GoP's Energy Security Plan 2030 to increase the share of nuclear power to 8800 MWe

As soon as new NPP projects are approved and work initiated, appropriate number of posts are created and manpower is recruited over a period of time in proportionate to the project

(and plant) requirement. Such new recruitments are initiated mainly through various PAEC training centers. After getting initial trainings pertaining to nuclear technology, such incumbents are attached in various disciplines of operating NPP for hands-on experiences. Mandatory licensing of operating personnel is also acquired in due course of time. Experienced manpower is then finally deputed to parent projects to enable takeover of responsibilities.

PAEC have assessed the capacity of its training organizations to cater for increase in HR for new NPP and found the facilities to be adequate. The experience of developing manpower for K-2 and K-3 has proved extremely encouraging and a cornerstone for developing future human resource for ambitious nuclear power program of PAEC. The manpower recruitment and its job specific training along with engagement for on-the-job training at sister NPP followed by their timely placement at various stages of the project had been a great learning experience because of multi-disciplinary aspects involved. Therefore, PAEC not only met the challenge but also established a nuclear power specific human resources development department at corporate office. This will help in fulfillment of future requirement of a trained manpower and grooming of exiting human resources in line with their job requirement. Considering the sustainability and effectiveness of human resource, PAEC has newly established Directorate of Staff Competency and Effectiveness to promote human performance excellence in O&M activities at nuclear power stations. Thus, Pakistan has met the challenge of sustainable development of human resource for operation and maintenance of nuclear installations in accordance with GoP's energy security plan.

B. Open Challenge from 6thNR

Risk Informed Regulatory Approach

Submission of Full scope Level-1 Probabilistic Safety Assessment (PSA) of NPP complying with regulatory acceptance criteria is a requirement for issuance of operating license.

PNRA had already developed PSA level-1 regulator's model for full power internal initiating events for Chashma Unit 1 NPP. This model can be applied to all CNPGS NPP units and used in the review of Safety Analysis Reports (SAR) and assessment of NPP design modifications. Development of PSA level-2 regulator's model for CNPGS is in progress which will be used to validate regulatory acceptance criteria of offsite release frequency. Development of PSA level-1 regulator's model for K-2 and K-3 has also been completed.

Risk insights are used to identify list of vulnerable systems and components based on PSA models developed by regulator as well as utility and the input is utilized in prioritizing regulatory inspections.

PNRA also utilizes PSA regulator's model to prioritize operator actions on the basis of their risk significance which are assessed during operator's licensing examination (test, interview and practical demonstration on simulator).

Several training courses and workshops have been conducted at the national level to enhance capability in the discipline of risk informed decision making. Various areas of risk informed applications are being implemented in regulatory processes e.g. prioritization of regulatory inspections, PSA-based analysis of operational events, etc. Moreover, some areas are also identified for future development in consultation with national and international experts e.g. categorization of inspection findings, risk informed regulations etc.

Thus, Pakistan has met the challenge of utilizing risk based regulatory approach in its regulatory functions.

C. Progress on New Challenges Identified in the 8th NR

Challenge 1: Enhancing regulatory capabilities in the area of review and assessment of cyber security of nuclear installations

Realizing the need for capacity building of PNRA for licensing of nuclear installations in the area of review and assessment of cyber security, PNRA initiated a Public Sector Development project titled "Reinforcement of PNRA's Capacity and Regulatory Oversight against Vulnerabilities of Digitized Controls and Cyber Threats" (Cyber Security & Digital Safety). Under this project, PNRA aims to develop expertise in core regulatory functions e.g. development of regulatory framework, review & assessment and inspection of software based I&C systems of NPPs, mainly focusing on the following areas:

i. Design requirements of software based I&C systems (Defense-in-depth and diversity etc.);
ii. Software qualification (software V&V and software safety and hazard analysis etc.);
iii. Computer safety of critical infrastructure and digital safety systems of nuclear power plants;
iv. Impact of cyber security measures on the performance of protection and control systems of NPP;
v. Cyber security of Data / Voice Network.

Some measures being undertaken are described above in challenge No.2 of section 2.4(A) above.

PIEAS has started a Masters level course in Cyber Security to groom subject specialists for the operating organization and the regulatory body in the relevant area. However, the challenge is still open as further efforts are required to fulfill the intent of this challenge.

Challenge 2: Consideration of ageing management of SSC of NPP at the design and manufacturing stages

Appropriate margins in the design have been considered taking due account relevant mechanisms of ageing, neutron embrittlement and wear out and of the potential for age related degradation to ensure the capability of items important to safety to perform their necessary safety functions throughout their design life. PAEC corporate office developed and disseminated guidelines in the following areas to harmonize ageing management at NPP:

1. Standardization of the Development and Implementation of Ageing Management Program at Nuclear Power Plants/Projects, DTech.NPG-AP-04, Rev. 0;
2. Development and Implementation of Obsolescence Management Programs at Nuclear Power Plants, TEC-GL-13(A), Rev. 0;
3. Scoping of Structures, Systems and Components (SSCs) for Ageing Management, TEC-GL-20(B), Rev. 0;
4. Ageing Management of NPP Spares During Storage in Warehouse, TEC-GL-22(B), Rev. 0;
5. Development and Implementation of Ageing Management Program for Emergency Diesel Generator, TEC-GL-19(B), Rev. 0;

6. Identification of main deficiencies in Ageing Management and Corrective Measures, TEC-GL-21(B), Rev. 0;
7. Ageing Management of Lead Acid Batteries, TEC-GL-23(B), Rev.0.

During the reporting period, PAEC work force has been trained in the area of ageing management in local training centers as well as internationally with the help of IAEA. Following trainings on ageing management were organized for PAEC work force (at corporate office & NPP):

1. Training Course on Ageing Management Programme within PAEC (Level-1) in four batches at corporate training centre, Islamabad. (Batch-1 from 17~20 June, 2019, Batch-2 from 14~18 Oct, 2019, Batch-3 from 27~31 Jan, 2020, Batch-4 from 11~14 Oct 2021);
2. IAEA-CNPGS National Workshop on Ageing Management of Nuclear Power Plants at Chashma, Mianwali from 24~26 September, 2019;
3. IAEA SALTO National Workshop on Ageing Management at KANUPP from 05~07 November, 2019;
4. IAEA-CNPGS National Workshop on Equipment Qualification of Nuclear Power Plants at Chashma, Mianwali from 26~28 November, 2019.

After going through aforementioned training programs, PAEC engineers and scientists participated in the mechanical ageing tests, irradiation tests, and performed seismic analysis calculations during the design review process for K-2/K-3 which contributed towards improvement in the plant design and documentation. Thus, Pakistan has met the challenge of ageing management considerations at design and manufacturing stages of SSC.

Challenge 3: Reliability of National Grid

PAEC established a dedicated working unit for close coordination with the grid operator in order to improve the performance of grid. Regular meetings are being held between PAEC and grid operators to monitor the progress of issues / improvement related to grid stability.

At CNPGS/NTDC

Several actions were taken by PAEC/NTDC at CNPGS for improvement of Grid stability/performance which are as follows:

a. The transmission line protection coordination schemes and settings have been thoroughly reviewed and over current protection settings have been revised at both ends of all 220kV circuits connected with/around CNPGS;
b. The auto re-closer and tele-protection schemes have been implemented at both ends of all 220kV circuits connected with CNPGS to restore the lines in case of momentary faults;
c. An over frequency protection scheme has been implemented for large load rejection case by isolating the units from grid one by one with a definite time delay to avoid the complete loss of all units;
d. The grid has been strengthened by adding two more 220kV double circuit transmission lines from DI-Khan to CNPGS and related 132kV distribution system;
e. Level of communication between NPCC and CNPGS for planned and emergency shutdown on 220kV lines connected/around CNPGS plants, has been markedly improved;
f. The reliability and performance of national grid has been considerably improved during last two years. The grid performance indicators set by National Electric Power

Regulatory Authority (NEPRA) like System Abnormal Interruption Duration Index (SAIDI) and System Abnormal Interruption Frequency Index (SAIFI) were zero during 2019 & 2020 around CNPGS NPPs;

g. Implementation and proper tuning of Power System Stabilizer (PSS) in CNPGS to dampen Low Frequency Oscillations (LFOs);
h. Implementation of cross tripping scheme automatically to isolate one or more units from grid and to reduce the generation of remaining plants in case of large load rejection to avoid tripping of all CNPGS units.

A country wide blackout occurred on 09-Jan-2021 due to some technical fault at a conventional power station. As a lesson learnt, National Transmission and Dispatch Company (NTDC) has taken number of preventative measures to mitigate recurrence of incidence such as:

a. Availability of spinning reserve by strengthening auto load shedding technique on under frequency;
b. Fresh relay setting calculations & protection relays coordination;
c. Implementation of house load operation on over & under frequency conditions in generating stations at the south of the country.

NTDC has also allowed House Load Operation (HLO) on under and over frequency to CNPGS NPPs so as to reconnect to the national grid on foremost availability of grid. Presently, HLO at under frequency (U/F) has been implemented at C4, while rest NPP will implement it in their respective RFO.

After the implementation of above actions, the grid reliability has been improved for CNPGS NPPs during the recent period and no major grid related event occurred since June 2018.

At KNPGS/NTDC

At KNPGS Site, K-2/K-3 plants each of 1100 MW gross capacity have been installed adjacent to the existing K-1 Site. K-2 and K-3 plants started commercial operation in May 2021 and April 2022 respectively. The 500kV transmission lines network of K-2/K-3 comprises of four following circuits as an interim arrangement:

- Line-1: K2/K3 – Northern Karachi Interconnection (NKI)
- Line-2: K2/K3 – Jamshoro-1
- Line-3: K2/K3 – Jamshoro-2
- Line-4: K2/K3 – HUBCO

The interim grid configuration suffers continuously by the power and frequency fluctuations which will be improved after completion of the designed scheme of transmission lines i.e.

- Line-1: K2/K3 – NKI
- Line-2: K2/K3 – Jamshoro-1
- Line-3: K2/K3 – Matiari
- Line-4: K2/K3 – Port Qasim

This scheme is expected to be implemented by the end of next year. Furthermore, as part of up-gradation process, installation of a number of new transmission line circuits and enhancement in capacity of grid stations is being performed by NTDC in the vicinity of K-2 and K-3 and their load centers which will improve the reliability of national grid.

NTDC has carried out a detailed short circuit analysis and load flow study to assess the stability and reliability of national grid after induction of K2/K3 Plants. On the basis of load flow & transient stability studies, the interconnection scheme for K-2/K-3 plants has been found reliable for their power evacuation to the national grid. The plants on national grid have no adverse impact on the switchgear equipment of the existing and proposed 500 kV substations in their vicinity as far as the rise in short circuit levels are concerned. The results of transient stability analysis for various operating scenarios of Plants reveal that the generators of power plant and the power system remain stable as per stability criteria, mentioned in NEPRA grid code and there is no adverse effect of K-2/K-3 power plant on the power system.

The short circuit analysis carried out with the induction of K-2/K-3 switchyard and other substations in its vicinity shows that the maximum three phase and single-phase short circuit levels at the 500 kV switchyard of K2/K-3 will remain below 50 kA, which is adequate for the switchyard equipment of K-2/K-3 power plant.

Thus, Pakistan has met the challenge of reliability of national grid.

Challenge 4: Retention of plant knowledge for decommissioning (deferred dismantling) of K-1

Historical plant data (design, operating records, event reports etc) and decommissioning plan/ procedures are being stored for long term in soft as well as hard form at site as well as at corporate office that will be used in Phase-III decommissioning (decontamination & dismantling).

De-fueling of reactor core is one of the major tasks of plant decommissioning program. For this purpose, a dedicated fuel handling crew is available to perform the job. The crew consists of licensed fuel handling engineers and console operators. The licensing procedure covers the lectures based on theoretical aspects as well as hands on training at fueling machines and their consoles for fueling machines maintenance and console operations.

During decommissioning, each operation crew will be provided training according to revised syllabus. Special focus will be given on plant systems, decommissioning activities, modifications etc. The effective training program of fuel handling crew is very important to perform de-fueling job in safe and secure manner. All the crew members are qualified in radiation protection training, as part of the job will be performed in high radiation zone. In order to train the said crew for defueling, a training program has been established focusing on all the de-fueling activities that will take place time to time. Training of operating personnel during defueling and de-watering of core is an important decommissioning task. Programs and procedures have been prepared and being implemented accordingly.

Thus, Pakistan has met the challenge of retaining plant knowledge during deferred decommissioning of K-1.

2.5 Implementation of the Vienna Declaration on Nuclear Safety (VDNS)

The fundamental safety objective in all nuclear applications is to protect people and the environment from harmful effects of ionizing radiation. Pakistan, along with other Contracting Parties, agreed to uphold and implement the Vienna Declaration during the CNS Diplomatic Conference held in February 2015.

The first principle of the VDNS is:

"New nuclear power plants are to be designed, sited, and constructed, consistent with the objective of preventing accidents in the commissioning and operation and, should an accident occur, mitigating possible releases of radionuclides causing long-term off site contamination and avoiding early radioactive releases or radioactive releases large enough to require long-term protective measures and actions."

After Fukushima Daiichi accident in 2011, two NPPs (i.e. K-2 and K-3) have been installed in Pakistan which recently started operation. K-2 and K-3 are advanced design PWR reactors with passive safety features for prevention and mitigation of accidents to practically eliminate early and large radioactive releases viz-a-viz VDNS principle 1. Previously, PNRA Regulations on Design and Operation PAK/911 were based on NS-R-1 and PAK/913 based on NS-R-2.These Regulations address the basic design objectives of Defence-in-Depth (DID), Common Cause Failures (CCF) and criteria to prevent accidents in the commissioning and operation of NPP. Currently, PAK/911 and PAK/913 have been revised on the basis of revision-1 of IAEA Specific Safety Requirements SSR-2/1 and SSR-2/2 to address the following major lessons learnt from the Fukushima Daiichi accident:

a. Practical elimination of plant event sequences that could result in large or early radioactive releases to the environment;
b. Inclusion of removal of heat from the fuel storage in the fundamental safety functions
c. Use of passive safety features in design;
d. Enhancing plant's capability to withstand design extension conditions without unacceptable radiological consequences;
e. Use of non-permanent equipment for restoring the capability to remove heat from the containment and spent fuel pool; and
f. Establishment of an accident management program that covers all plant states.

The second principle of the VDNS is:

"Comprehensive and systematic safety assessments are to be carried out periodically and regularly for existing installations throughout their lifetime in order to identify safety improvements that are oriented to meet the above objective. Reasonably practicable or achievable safety improvements are to be implemented in a timely manner."

PNRA regulations require conducting of periodic comprehensive and systematic safety assessments of existing NPP at least after every ten (10) years and this includes re-evaluation of the site related aspects along with other factors.

The safety assessments are performed against criteria and benchmarks provided in relevant IAEA Safety Standards. Scope and strategy for conduct of PSR is agreed between regulatory body and utility. A corrective action plan is finalized against the review findings of PSR and regulatory body ensures the implementation of plan.

The findings of the PSR review are categorized in short, medium and long term on the basis of safety significance and actions are implemented accordingly.

The performance of PSR was initially based on IAEA Safety Guide "Periodic Safety Review of Nuclear Power Plants"(NS-G-2.10) and currently IAEA Safety Guide SSG-25 is being followed. During the reporting period, C-1 and C-2 conducted their second and first PSR respectively.

In view of the lessons learnt from the Fukushima Daiichi accident, additional requirement for Periodic re-evaluation and re-assessment of all hazards (natural or man-made) has been proposed in “Regulations on Safety of NPP- Site Evaluation (PAK/910)".

After the Fukushima Daiichi accident, PNRA required the licensees of NPP to revisit and re-assess the design and safety features and accident management guidelines as well as emergency preparedness measures and submit a detailed action plan.

PAEC carried out initial safety assessment of its NPP at corporate level and formulated a plan called FRAP in May 2011.

The actions taken under the FRAP have been reported in the Special National Report (2012), Sixth National Report and the Seventh National Report. Progress on the actions and upgrades is provided in Section 2.4.

In addition to this, PAEC corporate management have been conducting three kinds of regular reviews at each nuclear power plant; namely Corporate Safety Review (CSR), Internal Peer Review (IPR) and QMS Audit. The details are provided under Article 2.2.2.

The third principle of the VDNS is:

“National requirements and regulations for addressing this objective throughout the lifetime of nuclear power plants are to take into account the relevant IAEA Safety Standards and, as appropriate, other good practices as identified inter alia in the Review Meetings of the CNS.”

Pakistan’s national requirements and regulations related to NPP take into account the relevant IAEA Safety Standards throughout the life-time of a NPP. The regulatory framework is mainly based on IAEA safety standards covering nuclear safety, radiation safety, waste safety, transport safety, physical protection and emergency preparedness areas.

This was also mentioned in the IRRS Mission report[2] “All areas of PNRA’s responsibility are covered by PNRA regulations. Regulations and guides closely reflect IAEA safety standards.”

2 Report of IRRS Mission to Pakistan: Section 9.7 Summary of Chapter 9 Regulations and Guides available at https://www.iaea.org/sites/default/files/documents/review-missions/final_report.pdf

PART III

3 FUTURE CHALLENGES

The future challenges include the following:

i. Development of regulatory framework for Small Modular Reactors (SMRs);
ii. Safety Assessment of Human Factor Engineering at C-1 NPP;
iii. Establishment of risk monitor (real time risk assessment tool) for operational NPPs.

PART IV

ARTICLE 4 – IMPLEMENTING MEASURES

Each Contracting Party shall take, within the framework of its national law, the legislation, regulatory and administrative measures and other steps necessary for implementing its obligations under this Convention.

This report presents legislative, regulatory and administrative measures and steps that Pakistan has taken, within the ambit of its legislative framework, which are necessary for the fulfillment of its obligations under this Convention. These measures have been described in earlier 8th NR. The main legislative instruments have been enacted and essential national regulations are in place. An approach of continuous fulfillment of the safety obligations is adopted by Pakistan and priority is given to the most significant safety issues.

Pakistan has, therefore, met the obligations of Article 4 of the Convention.

ARTICLE 5 – REPORTING

Each Contracting Party shall submit for review, prior to each meeting related to in Article 20, a report on the measures it has taken to implement each of the obligations of this Convention.

After signing the Convention on Nuclear Safety, eight (8) National Reports have so far been submitted by Pakistan which were reviewed by the Contracting Parties in the respective review cycle. A special National Report was also submitted by Pakistan to the IAEA in response to the Fukushima Daiichi accident which underwent peer review by the Contracting parties during the Second Extraordinary meeting in August 2012. This is the joint eighth and ninth national report by Pakistan in compliance with Article 5 of the Convention.

Pakistan has, therefore, met the obligations of Article 5 of the Convention.

ARTICLE 6 – EXISTING NUCLEAR INSTALLATIONS

Each Contracting Party shall take the appropriate steps to ensure that the safety of nuclear installations existing at the time the Convention enters into force for that Contracting Party is reviewed as soon as possible. When necessary in the context of this Convention, the Contracting Party shall ensure that all reasonably practicable improvements are made as a matter of urgency to upgrade the safety of nuclear installation. If such upgrading cannot be achieved, plans should be implemented to shut down the nuclear installation as soon as practically possible. The timing of the shut-down may take into account the whole energy context and possible alternatives as well as the social, environmental and economic impact.

Currently, there are six (6) NPP in operation and one in permanent shut down state. The existing nuclear installations are listed in Annexure-I. Following paragraphs briefly describe information about existing nuclear installations in Pakistan. The post Fukushima assessments and implementation of activities related to each nuclear installation are presented in Section 2.4 of the Report.

6.1 Karachi Nuclear Power Plant Unit- 1 (K-1)

K-1 started operation beyond its design life in 2003 after completing large scale refurbishments to meet existing regulatory requirements. K-1 completed its second PSR (PSR-2) in 2014 after a comprehensive re-assessment of overall plant safety. Since then, the OL of K-1 has been extended several times at different intervals depending upon various refurbishments carried out from time to time in order to fulfill the regulatory requirements.

K-1 OL was extended four times for different durations. The first extension was provided to K-1 for three (03) months i.e. from January to March 2017 based upon the assessment made against the qualification criteria of steam generator tube plugging. The next extension was granted to K-1 for a period of six (06) months i.e. from April to September 2017. The request was supported by a report of significant jobs done during last few shutdowns, upgrades made under FRAP and corrective action plan of 2nd PSR e.g. feeder pipes inspection report, test report of cables and tendon gallery and inspection report of reactor building, etc.

The third extension for operation of K-1 was awarded from October to September 2018. This extension was granted to K-1 based on the steam generator condition assessment, feeder pipes inspection, performance of safety related call up cards, Time Limited Ageing Analysis (TLAA) of the intake channel and containment building and implementation of design modifications related to re-routing of primary pressure control cables and installation of active and passive fire suppression system in cable gallery and auxiliary area. In order to carry out Long Shutdown (LSD) activities, KANUPP requested PNRA to extend the OL for shutdown state up to April 2019. After completion of LSD activities and obtaining permission from PNRA, the plant was made critical in May 2019. Another request of K-1 to extend the OL up to 2024 has been received which is under review at PNRA.

During the reporting period, an event occurred at K-1 which resulted in exposure of four (04) radiation workers who received radiation doses that exceed the annual regulatory limit during the post maintenance testing of moderator drain tank outlet valve (MH-V3). In response to PNRA directive, Root Cause Analysis (RCA) was performed by K-1 and the root causes were found to be inadequate adherence to procedure and lack of appropriate

supervision during maintenance. Necessary corrective actions were taken to avoid the recurrence of such events which mainly included revision of procedure for replacement of gasket of MH-valves to enhance supervision level, conduct of risk assessment, and incorporation of lessons learned of this event in training program. This event was reported at IAEA forums of IRS (IRS #8734) as well as INES as level-2 event.

During the year 2018, an event occurred at K-1 NPP in which false alarm was annunciated by temperature detector. Within few seconds, protective channel A also opened on north outlet header temperature (PH7T) high alarm. PH7T was then reading a false value of 600ºF, which is the upper rational limit of the RTD. Smoke was observed close to north primary header (near PH-P1/P3). Considering the safety impact of presence of smoke and opening of protective channel 'A', the reactor was manually shutdown for the fear that smoke may turn into fire. The cause of the minor smoke near PHT header in Boiler Room was the presence of soaked oil in PHT header insulation material. Apparent cause of the event was ingress of seal supply air in the upper oil sump of PH-PM1 motor leading to unwanted oil coming out of it. As a corrective action, spacer between the upper oil sump cover of PH-PM1 motor and its body was removed. This event was reported at IRS (IRS #8825).

During the reporting period, K-1 submitted its final decommissioning plan which was reviewed at PNRA. PNRA also reviewed and accepted the K-1 Off-Site Radiological Emergency Plan (KOFREP) Rev. 05 to conduct Integrated Emergency Exercise 2018 (IEE-2018). In addition, PNRA reviewed and approved the Safety Analysis Report (SAR) of K-1 spent fuel dry storage cask following which the prototype concrete cask was manufactured, tested and qualified.

During the reporting period, K-1 OL was extended by PNRA till August 2021. This extension was granted based upon the assessments made against spent fuel storage bay capacity, fuel channel integrity assessment (FCIA) and third-party assessment report of steam generators. Furthermore, the significant activities were carried out at K-1 including the repair and maintenance of civil structures of diesel generators room & turbine building, development of ageing management program for fueling machine & handling equipment and its implementation and installation of cameras at spent fuel discharge port to monitor the actual condition of discharged spent fuel bundle.

Furthermore, the construction of K-1 Spent Fuel Dry Storage (KSFDS) facility was completed and K-1 started shifting of spent fuel from Spent Fuel Bay to KSFDS using PNRA certified Spent Nuclear CANDU type Fuel Storage Casks (SC-108).

K-1 has been permanently shut-down after completing fifty (50) years of safe operation on 1st August, 2021. Safe decommissioning of K-1 is a challenge for both the operator as well as regulator as it is first nuclear facility to be decommissioned in Pakistan. Currently, K-1 application for decommissioning license is under review at PNRA. The list of codes and standards has been agreed between PNRA and K-1 for review of the application.

6.2 Chashma Nuclear Power Plant Unit-1 (C-1)

Chashma Nuclear Power Plant Unit-1 (C-1) is operating safely since its connection to grid in 2000 after which C-1 conducted its first PSR in 2010 and submitted the report to PNRA. Based on the review of PSR report, the OL of C-1 was revalidated up to December 2020. Similarly, second PSR was conducted in 2020 and based on the PSR report OL of C-1 was revalidated till December 2030. So far, C-1 has completed fourteen (14) RFOs since the start of commercial operation.

During the reporting period, RFO-11, 12, 13 and 14 were carried out at C-1. After getting criticality permission from PNRA, reactor was made critical and subsequently connected to grid. Overall, the plant operated safely during the reporting period within its operating limits and conditions fulfilling all the regulatory requirements.

On July 05, 2019, an integrated trip alarm for SRC heaters and start-up/shutdown feed water pumps appeared in Main Control Room (MCR) of C-1 and pressurizer backup heater bank was observed at tripped state. Afterward, a fire alarm appeared in MCR, indicating fire in one of the rooms of nuclear auxiliary building that housed the breaker cabinets of pressurizer heaters. Later on, fire alarms also appeared in various other rooms in vicinity. 'Standby' emergency was declared and reactor scrammed manually. Consequently, Turbine and Generator also tripped as per design logic. After bringing the situation under control 'Standby' was terminated and plant was maintained at hot shutdown state. The direct cause of event was overheating of power connection which led to melting of breaker rear cover connectors with load side terminal block. The root cause was loose connections due to misalignment of fork type connectors this was a design issue. As a corrective action C-1 removed damaged parts of 380 V bus panel and installed new parts with compatible design. This event was reported to IRS.

6.3 Chashma Nuclear Power Plant Unit-2 (C-2)

C-2 was connected to grid in 2011 and was granted OL by PNRA till 31st December, 2021as per PNRA Regulations PAK/909. C-2 submitted the first PSR reports to PNRA which was reviewed and accordingly operating license of C-2 was revalidated up to 2031.

During the reporting period, RFO-04, 05, 06, 07 and 08 were carried out at C-2. Overall, the plant operated safely within operating limits and conditions, fulfilling all the regulatory requirements during the reporting period.

6.4 Chashma Nuclear Power Plant Unit-3 (C-3)

C-3 achieved initial criticality in October 2016 and was subsequently connected to grid in December 2016. Plant was provisionally accepted by PAEC from vendor in December 2016. During the reporting period, RFO-1, 02, 03 and 04 were carried out at C-3 and after obtaining criticality permission from PNRA, reactor was made critical and connected to grid subsequently. A WANO common site follow-up peer review mission was carried out at C-3. (Details are provided in section 2.2.2 of the report). Overall, the plant operated safely within operating limits and conditions, fulfilling all the regulatory requirements during the reporting period.

6.5 Chashma Nuclear Power Plant Unit-4 (C-4)

C-4 achieved initial criticality in March 2017 and was formally connected to grid for on power tests in July 2017. C-4 was provisionally accepted by PAEC in September 2017. During the reporting period, RFO-1, 02 and 03 were carried out at C-4.

Overall plant operated safely within operating limits and conditions, fulfilling all the regulatory requirements during the reporting period.

6.6 Karachi Nuclear Power Plant Unit-2 and Unit-3 (K-2 and K-3)

K-2 and K-3 are Chinese Advanced NPP (ACP1000). Each Unit is comprised of 1100MWe rating, 3-loops PWR Nuclear Steam Supply System (NSSS) and related auxiliary facilities. China Zhongyuan Engineering Company (CZEC) is the general contractor of the plant.

China National Power Engineering Company (CNPE) is the general subcontractor of design and responsible for nuclear island.

K-2 and K-3 have single-unit layout and double-shell containments. The inner shell is pre-stressed reinforced concrete structure with steel liner, which is capable to withstand the internal pressure in case of a loss of coolant accident and prevents radioactive materials from releasing. The outer shell is reinforced concrete structure, resisting the impact of external events such as aircraft, missiles, tornado and external explosion. As a secondary function the outer containment also act to contain the radioactive material.

PNRA granted construction licenses to K-2 and K-3 respectively in August and November 2015 after safety review of licensing submissions, and ensuring compliance with the applicable safety requirements.

During the reporting period, construction activities of K-2 including assembling and installation of containment building dome liner, installation of reactor pressure vessel, steam generators, construction of containment dome, welding of reactor coolant piping, pre-stressing and grouting activity of inner containment tendons, installation of 132kV overhead transmission line and water intake gate shaft structure was completed. Moreover, placement of pressurizer in the containment building and construction of water intake and outfall tunnels were also completed.

During the reporting period, construction activities of K-3 including construction of containment shell and dome liner, welding of dome liner, welding of Reactor Coolant Piping and construction of K-3 containment building were completed. The following construction activities remained in progress at K-3 including construction of outer containment wall, emergency diesel generator buildings (NU & NV) and installation of equipment hatch in reactor building (NB), lower and upper reactor vessel internals (LRVI and URVI, pre-service inspection (PSI) activities, ultrasonic testing (UT) of Pressurizer surge line welds, UT of inner surface under cladding of most irradiated area of reactor pressure vessel (RPV) and CCTV examination of RPV nozzles and inner cladding.

PNRA granted permission for commissioning to both K-2 and K-3 in September 2019. During the reporting period, major commissioning activities at K-2 including inner containment structural integrity and integrated leakage rate tests, control rod drive mechanism (CRDMs), diesel generator acceptance test, core initial criticality tests etc., were completed.

Upon successful completion of safety review of application for acquiring fuel load permit (FSAR, PSA report and relevant programs and documents etc.), commissioning stage-A tests, availability of necessary manpower and documents, conduct of KNPGS Integrated Emergency Exercise and Physical Security Program (PSP) drill, PNRA issued fuel load permit to K-2 in November 2020. Fuel loading at K-2 was completed in December 2020. The plant achieved its first criticality in February 2021. The plant was connected to grid in March 2021. Upon successful completion of commissioning, K-2 started commercial operation in May 2021.

During the reporting period, Stage-A commissioning tests remained in progress at K-3. Major commissioning activities were completed including Structure Integrity Test (SIT), diesel generator set loading and unloading test, inner containment leak rate test-A type, personnel and equipment hatch and leak tightness test, active injection flow verification test, pressurizer safety valves pressure setting test. The fuel load permit was issued to K-3 by

PNRA in December 2021. Fuel loading at K-3 was completed in December 2021. The plant achieved its first criticality in February 2022 and was connected to grid in March 2022. Upon successful completion of commissioning, K-3 started commercial operation in April 2022.

During the reporting period, PNRA performed regulatory oversight during construction, commissioning and operation activities of K-2 and K-3 during which PNRA carried out continuous surveillance, participated in various exercises, drills, witnessed the commissioning tests and reviewed the commissioning test reports.

Details of safety assessment carried out for NPP are described in Article-14, whereas, the details of design modifications are described in Article-18.

Pakistan has, therefore, met the obligations of Article 6 of the Convention.

ARTICLE 7 – LEGISLATIVE AND REGULATORY FRAMEWORK

1. Each Contracting Party shall establish and maintain a legislative and regulatory framework to govern the safety of nuclear installations.

2. The legislative and regulatory framework shall provide for:

a. the establishment of applicable national safety requirements and regulations;
b. a system of licensing with regard to nuclear installations and the prohibition of the operation of a nuclear installation without a license;
c. a system of regulatory inspection and assessment of nuclear installations to ascertain compliance with applicable regulations and terms of licenses;
d. the enforcement of applicable regulations and the terms of licenses, including suspension, modification or revocation.

7.1 Establishing and Maintaining Legislative and Regulatory Framework

Pakistan has established a comprehensive legislative framework to manage the use of nuclear energy, nuclear safety and radiological protection in the country. In this regard, the first law was promulgated in 1965, called the Pakistan Atomic Energy Commission (PAEC) Ordinance of 1965, which created a Commission for the promotion of peaceful use of nuclear energy and the discharge of corresponding international obligations. Later on, in 1984, PAEC was empowered to oversee nuclear safety and radiation protection as well with the promulgation of Pakistan Nuclear Safety and Radiation Protection Ordinance. In 2001, PNRA Ordinance III of 2001was promulgated which established Pakistan Nuclear Regulatory Authority as the sole national authority having responsibility to supervise and regulate all matters related to nuclear safety and radiation protection in the country.

The Ordinance empowers PNRA to establish and implement regulatory framework to ensure the safe and secure use of nuclear material, radioactive sources and radiation generators in the country. In 2010, the government promulgated the National Command Authority (NCA) Act to provide for the complete command and control over research, development, production and use of nuclear energy and space technologies.

The primary nuclear safety legislation, the PNRA Ordinance, empowers PNRA to issue regulations and perform licensing and authorization of all nuclear installations and associated activities based upon review and assessment of licensing submissions. The Authority is also mandated to perform inspections to verify compliance of regulatory requirements and takes appropriate enforcement actions in case of any non-compliance. In addition, the Ordinance entrusts PNRA to ensure that appropriate measures for physical protection of nuclear installations and nuclear materials are taken and perform effective coordination in case of a nuclear accident or a radiological emergency. PNRA is also empowered to fix the extent of civil liability for an operator in case of a nuclear accident.

The legislation also provides for the composition of the Authority which consists of a Chairman, two full-time Members and seven part time Members representing various stakeholders of PNRA. The operational working of the Authority is managed by various organizational units; with Headquarter in Islamabad and eight regional offices across the country.

7.1.1 International Conventions and Legal Instruments

Pakistan is a party to four international Conventions related to safety and security of nuclear materials and installations. These include “Convention on Early Notification of a Nuclear Accident”, “Convention on Assistance in the case of a Nuclear Accident or Radiological Emergency”, “Convention on Nuclear Safety” and “Convention on Physical Protection of Nuclear Material” and its amendment. Pakistan has also voluntarily committed to implement the Code of Conduct on “Safety of Research Reactors” and Code of Conduct on “Safety and Security of Radioactive Sources”. PNRA is the lead organization and contact point designated by the Government of Pakistan to coordinate with the international community on these Conventions. PNRA plays a pivotal role in fulfilling the international obligations of Pakistan and actively supports the Government in execution of the activities related to these obligations. PNRA, in capacity of designated national warning point, fulfills the obligations of Pakistan under the Conventions on “Early Notification of a Nuclear Accident” and “Assistance in the Case of a Nuclear Accident or Radiological Emergency”.

Pakistan ratified the amendment to the Convention on Physical Protection of Nuclear Material in 2016 and it remained involved in implementation of the obligations of the amendment. In this regard, PNRA promulgated the Regulations on Physical Protection of Nuclear Material and Nuclear Installations (PAK/925) based upon IAEA INFCIRC/525 (Rev.5). PNRA is also implementing obligations arising from Pakistan’s commitment to follow the Codes of Conduct on Safety of Research Reactors and Safety and Security of Radioactive Sources. In this regard, Regulations on the Safety of Nuclear Research Reactor Operation (PAK/923) and Regulations on Security of Radioactive Sources (PAK/926) have been promulgated and implemented.

7.1.2 National Safety Requirements and Regulations

The Regulations, Policies, Regulatory Orders, and Regulatory Guides, issued by PNRA, form the basis for the nuclear regulatory framework of Pakistan. PNRA regulations, policies and orders set basic safety requirements and criterion to be followed by the licensees, whereas, the guides provide acceptable methods for meeting the requirements of the regulations. The methodologies other than those specified in guides may also be adopted by the licensees provided that it can be demonstrated to the entire satisfaction of the Authority that the same or higher level of safety can be achieved.

PNRA Regulations

Section 56 of the Ordinance empowers PNRA to issue regulations. These regulations are mandatory for the licensees to follow and establish the administrative and technical regulatory requirements in the areas of nuclear safety; radiation protection; waste and transport safety; and physical protection.

To date, twenty-two (22) regulations related to different areas of nuclear safety, radiation protection, transport and waste safety, physical protection, and security of radioactive sources have been promulgated which are mainly based on the IAEA Safety Standards. In addition, latest international codes and standards are also consulted during the preparation of the regulations.

List of gazette notified Regulations is given in Annexure-II. The regulations have been placed on PNRA website (https://www.pnra.org) for access of all the stakeholders.

Regulations Promulgated Since the Last Report

Several regulations remained under preparation and revision. However, following fourteen regulations were gazette notified during the reporting period:

a. Regulations on Radioactive Waste Management-(PAK/915) (Rev.1);
b. Regulations on Physical Protection of Nuclear Material and Nuclear Installations (PAK/925);
c. Regulations on Security of Radioactive Sources - (PAK/926);
d. Regulations on Decommissioning of Facilities Using Radioactive Material-(PAK/930);
e. Regulations on Licensing Fee by Pakistan Nuclear Regulatory Authority - (PAK/900) (Rev.03);
f. Regulations on Radiation Protection - PAK/904 (Rev.01);
g. Regulations for the Licensing of Radiation Facilities other than Nuclear Installations - (PAK/908) (Rev.01);
h. Regulations on the Safety of Nuclear Power Plant Design - (PAK/911) (Rev.02);
i. Regulations on the Safety of Nuclear Power Plants Operation - PAK/913 (Rev.02);
j. Regulations on the Safe Management of Spent Nuclear Fuel - (PAK/918);
k. Regulations on Dispute Resolution - (PAK/949);
l. Regulations on Management of a Nuclear or Radiological Emergency – (PAK/914) (Rev-1);
m. Regulations for the Safe Transport of Radioactive Material - (PAK/916) (Rev-01);
n. Regulations on Leadership and Management for Safety – (PAK/921).

PAK/921 will replace PNRA Regulations on “Safety of Nuclear Power Plants-Quality Assurance” (PAK/912) (Rev. 1).

Amendments in Regulations

The amendments are made in order to make minor changes or additions to improve the existing regulations. Such changes are usually based on regulatory experience, licensee's feedback, or promulgation of some new specific requirements in a particular area.

During the reporting period, amendments in the following regulations were made and gazette notified:

a. Regulations on Transaction of Business of Pakistan Nuclear Regulatory Authority - (PAK/901);
b. Regulations on Radiation Protection - (PAK/904).

New Regulations under preparation

The following new regulations are in the process of development:

a. Regulations on Authorization of Organization for Non-Destructive Examination (NDE) of Safety Class Equipment for Nuclear Installation - (PAK/906);
b. Regulations on the Safety of Nuclear Fuel Cycle Facilities - (PAK/917);
c. Regulations for Licensing of Design Organizations - (PAK/927);
d. Regulations on Treatment of Food by Ionizing Radiation - (PAK/931);
e. Regulations on Safety of Research Reactors - (PAK/932).

Regulations currently under revision

PNRA Regulations are usually reviewed, and revised if needed, after every 05 years or earlier on the basis of the following reasons:

a. Obligations of PNRA Ordinance;
b. Obligations of International Conventions;
c. Feedback of Regulatory and Licensing Experience;
d. International Practice and Experience.

The following regulations are currently under revision at PNRA:

a. Regulations for Licensing of Nuclear Installations in Pakistan - PAK/909 (Rev.02)
b. Pakistan Nuclear Regulatory Authority Enforcement Regulations - (PAK/950) (Rev.01)

7.1.3 Policies

During the reporting period, PNRA issued and gazette notified the following policies:

a. "National Safety Policy - (NP-02/2020)" and
b. "National Policy on Safe Management of Radioactive Waste, Decommissioning and Spent Nuclear Fuel in Islamic Republic of Pakistan - (RWP/01/2018)".

7.1.4 Regulatory Guides

During the reporting period, following regulatory guides were issued by PNRA:

a. Radiation Safety in Industrial Radiography (PNRA-RG-904.03);
b. Protection of Patients in Diagnostic Radiology (PNRA-RG-904.05);
c. Format and Content of Radiation Protection Program (PNRA-RG-904.06);
d. Format and Content of Physical Protection Program of Nuclear Installations (PNRA-RG-909.02);
e. Format and Content of Application for Design and FSAR Modification in Nuclear Installations (PNRA-RG-913.02) (Rev.1);
f. Format and Content of Radiation Emergency Plans of Radiation Facilities and Activities (PNRA-RG-914.02);
g. Radiation Protection and Safety in Radiotherapy (PNRA-RG-904.07);
h. Format and Content of Environmental Monitoring Program of Nuclear Installations (PNRA-RG-909.03);
i. Format and Content of Radioactive Waste Management Program of Nuclear Medicine Centers (PNRA-RG-915.01);
j. Format and Content of Radioactive Waste Management Program of Nuclear Installations (PNRA-RG-915.02);
k. Format and Content of Physical Protection Plan for Radiation Facilities having Radioactive Sources (PNRA-RG926.01);
l. Management of Contaminated and Overexposed Individuals in case of Nuclear or Radiological Emergency (PNRA-RG914.03).

Following regulatory guides remained under preparation:

a. Format and Content of Decommissioning Plan of Radiation Facilities (PNRA-RG-930.01);
b. Management of Nuclear Security Events Involving Radioactive Sources (PNRA-RG-926.02);
c. Format and Content of PSI/ISI Program for NPPs (PNRA-RG-909.04);
d. Format and Content of SAR of Radiation Facilities (PNRA-RG-908.02);

e. Preparation of License and Authorization Applications for Radiation Facilities (PNRA-RG-908.03).

7.1.5 Use of Regulatory Guides and Industrial Standards of other Countries

Under the provisions of PNRA Regulations for Licensing of Nuclear Installations in Pakistan (PAK/909), PNRA allows its licensees to use relevant latest US Nuclear Regulatory Commission (USNRC) regulations, in areas where PNRA Regulations are not available. As an alternate, the licensee may choose to follow the latest revisions of the applicable IAEA Safety and Security Standards. In case the nuclear safety and security standards of another country are proposed to be followed, the applicant or licensee is bound to demonstrate to the entire satisfaction of PNRA, that the standards, proposed to be followed, offer the same or better level of safety, security, quality and reliability.

Since the guidance issued by USNRC takes account of internationally recognized industrial standards such as ASME, IEEE, ISO, IEC etc., therefore, these standards can also be used by the licensees. In addition, the industrial standards of the vendor countries such as RCC-M of France or GB of China can also be employed.

7.1.6 Development Process of Regulations

Regulations are developed to set out safety requirements for the applicants and licensees of nuclear installations, radiation facilities, equipment manufacturers and service providers with the aim to perform such activities in a safe manner ensuring protection of workers, public and environment from the harmful effects of ionizing radiation. The development of regulations follows a rigorous process which also includes feedback from all concerned stakeholders including public. The draft regulations are uploaded on PNRA website for comments from the public, licensees and interested parties. This process has been very useful in acquiring feedback of the stakeholders on the draft regulations. The regulations once approved by the Authority are notified in the official gazette of Pakistan and are placed at PNRA website for information and use by all concerned.

7.2 Licensing Process

Currently, there are six (06) operational NPP in Pakistan and one (01) NPP is permanently shut down for decommissioning. In order to regulate nuclear installations and associated activities in accordance with the national regulations, PNRA performs various regulatory functions such as licensing and authorization; review and assessment; and inspection and enforcement.

Under Section-19 of PNRA Ordinance, no person shall acquire, design, manufacture, construct, install or operate any device that contains any radioactive material or produce ionizing radiation unless he is the holder of a license issued by PNRA. PNRA Regulations PAK/909 describes the licensing process which encompasses all stages of the lifetime of nuclear installations e.g. site registration, construction license, permission for commissioning, fuel load permit, Operating License (OL), revalidation of OL, license beyond design life, decommissioning, and removal from regulatory control. At each of these stages, the licensee is required to submit various documents which are reviewed and agreed upon by the Authority before granting an authorization or issuing a license. As per regulatory framework, these authorizations and licenses are issued based on verification of safe design and operational practices. The licenses and authorizations normally impose generic and specific conditions according to the outcome of regulatory processes. PNRA also conducts

licensing of operating personnel for nuclear installations in order to ensure that qualified and trained personnel operate these installations according to national regulations.

7.3 Regulatory Oversight Process

PNRA has a vigorous regulatory oversight process comprising review and assessment, inspection and enforcement. PNRA coordinates with its licensees both at plant and at corporate levels for implementation of regulatory requirements.

7.3.1 Review and Assessment Process

Safety review and Assessment is one of the core functions of PNRA which provides foundations for effective regulatory decision making. PNRA has well established regulatory review process and technically competent staff. Regulations PAK/909 establishes requirements on licensing of nuclear installations and relevant submissions required for different stages of licensing. PNRA performs regulatory review of various submissions such as Site Evaluation Report (SER), Preliminary Safety Analysis Report (PSAR), Final Safety Analysis Report (FSAR) Commissioning Program, PSR Reports, PSA Report and other technical and topical reports submitted at different stages of licensing process.

PNRA performs review and assessment of these submissions through its well established internal Technical Support Organization (TSO). All safety reviews and assessments are performed in the light of regulatory requirements for all the stages of licensing process of NPP from siting to removal from regulatory control. In order to support the review process, safety analysis, audit calculations and on site verifications are also performed. During the review process, queries raised are communicated to the licensee at various stages and accordingly review meetings are held between licensee and regulatory body to resolve the concerns raised during review process. In the end, a safety evaluation report which presents the final outcome of the review and assessment process is developed highlighting important queries raised during review process, their resolution, pending issues and proposed license conditions.

7.3.2 Inspection Process

PNRA performs regulatory inspections of nuclear installations and associated activities to verify compliance with PNRA regulations, industrial codes and standards, license conditions, directives issued by the Authority from time to time and other commitments made by the licensee or applicant. In order to conduct effective regulatory oversight, PNRA has established three Regional Nuclear Safety Directorates (RNSDs) namely RNSD-I (Islamabad), RNSD-II (Kundian) and RNSD-III (Karachi). Resident inspectors from these regional directorates conduct inspections of nuclear installations in their respective jurisdictions as per annual inspection plan. The directorates located at PNRA Headquarter also provide technical support during the conduct of regulatory inspections as and when required. In addition, the regulatory inspections of equipment manufacturers and service providers for nuclear installations are managed through the directorates located at PNRA Headquarter.

7.3.3 Inspection Program

PNRA has established an inspection program to conduct regulatory inspections in all phases of a nuclear installation’s life cycle i.e. construction, commissioning, operation, etc. The regulatory inspections conducted by PNRA inspectors are planned in advance, however, if needed, reactive inspections are also conducted. These inspections may be announced or

unannounced. PNRA inspectors perform inspections according to annual inspection plans, procedures, and checklists. In case of any deficiency or non-compliance of PNRA regulations, license conditions, agreed codes and standards and QA plan or procedures (administrative and technical) observed during inspections, PNRA issues directives to the licensees through inspection reports for implementation of necessary corrective actions within due course of time. A follow-up process is in place to ensure satisfactory implementation of corrective actions in the light of PNRA directives.

Resident inspectors conduct control room inspections and general surveillance of nuclear installations on daily basis. They also carry out periodic inspections of plant systems and processes at a defined frequency, participate in daily meetings of the plants, and also perform control point inspections of selected licensee's activities.

Furthermore, inspections are conducted to verify effectiveness of QA system of the licensees and their contractors and sub-contractors. PNRA also conducts inspections during equipment manufacturing. In this regard, PNRA selects certain points during manufacturing of equipment for carrying out inspections. The inspections cover important manufacturing processes, testing, qualification and performance examinations, ISI activities, and verification of efficacy of QA system of the licensees and their contractors and sub-contractors.

7.4 PNRA Enforcement Process

Section 44 of the Ordinance empowers PNRA for taking legal actions against any person who contravenes any of the provisions of the Ordinance or the rules and regulations made there under or any term or conditions imposed through a license or authorization. Such person shall be punishable with imprisonment for a term which may extend to seven years or with fine which may extend to one million rupees or with both.

Under the Ordinance, PNRA has the mandate to develop and enforce its regulations in the country and take action against violators of the Ordinance and rules and regulations made there under. For the effective implementation of this mandate, PNRA has promulgated Enforcement Regulations (PAK/950) and developed enforcement procedure which describes step-by-step approach for taking enforcement actions. Under the provisions of PAK/950, PNRA has mandate to issue violation, show cause or legal notices to violators and subsequently may conduct hearing before cancellation or suspension of a license or authorization. In case of non-compliance of the orders of PNRA, a complaint is filed in the Court of Law for prosecution.

It is worth mentioning that, as a general policy, the prosecution is used as a last resort when all the other mechanisms described in the procedure i.e. serving of show cause notice and hearing proceedings do not result in a positive outcome. As a result of these enforcement actions, most of the issues are resolved and disposed off in an amicable manner.

Pakistan has, therefore, met the obligations of Article 7 of the Convention.

ARTICLE 8 – REGULATORY BODY

i. **Each Contracting Party shall establish or designate a regulatory body entrusted with the implementation of the legislative and regulatory framework referred to in Article 7, and provided with adequate authority, competence and financial and human resources to fulfill its assigned responsibilities.**
ii. **Each Contracting Party shall take the appropriate steps to ensure an effective separation between the functions of the regulatory body and those of any other body or organization concerned with the promotion or utilization of nuclear energy.**

8.1 Establishment of the Regulatory Body

8.1.1 Legal Basis

Pakistan Nuclear Regulatory Authority (PNRA) was established in 2001 through the promulgation of PNRA Ordinance (Ordinance III of 2001) as a national regulatory authority, independent from the promoters, entrusted with the powers to regulate all nuclear installations and radiation facilities in Pakistan to ensure nuclear safety and radiation protection. Though, the regulatory setup in Pakistan has long been there which evolved over time, passing through various phases until an independent regulatory body was established.

PNRA Ordinance describes the constitution of the Authority, tenure and eligibility of its Chairman and the Members, interface with Government of Pakistan, etc. The Chairman PNRA is the Chief Executive Officer of the Authority and is responsible for ensuring nuclear safety and radiation protection as well as the day-to-day administration of the affairs of the Authority.

8.1.2 Authorities and Responsibilities

PNRA Ordinance consigns the responsibility of regulating all matters related to nuclear safety and radiation protection in Pakistan. It empowers and entrusts PNRA with the responsibility of licensing and authorization of nuclear installations and radiation facilities for the safe and secure use of nuclear material and radioactive sources in the country. PNRA is also empowered to inspect all such installations and facilities to verify that requirements concerning safety and protection are being complied with. In case of non-compliance, PNRA has the mandate to take appropriate enforcement actions. The regulatory jurisdiction of PNRA also covers transportation and disposal of radioactive material and radioactive waste; and import and export of radiation sources. In addition, PNRA is responsible to ensure that such installations and facilities maintain effective preparedness and coordination for managing nuclear and radiological accidents and emergencies.

8.1.3 Organization of PNRA

The organization of PNRA comprises of a Chairman, two full-time Members and seven part-time Members, including representatives from the Ministry of Health, Pakistan Environmental Protection Agency, and Strategic Plans Division (SPD), eminent professionals from the science, engineering and medical sectors and Pakistan Atomic Energy Commission. The Federal Government appoints the Chairman and the Members of the Authority. Chairman PNRA reports to the Prime Minister of Pakistan through SPD which is the secretariat of National Command Authority (NCA).

The organizational structure of PNRA comprises of Executive and Corporate wings, headed by Member (Executive) and the Member (Corporate) respectively. The executive wing is

responsible for performing core functions of the Authority, whereas, the corporate wing is responsible to drive the Authority as an organization and also provides technical support to the executive wing through its technical support centers. The Secretary of the Authority and Director General of Chairman Secretariat both reports directly to Chairman. The latter assists Chairman on matters relevant to the Chairman office, planning future activities of PNRA, and coordination with the government functionaries.

Member (Executive) supervises the activities of the Executive Wing. He is assisted by Director General (Licensing and Authorization) and Director General (Inspections and Enforcement). Director General (Licensing and Authorization) looks after the four Technical Directorates mainly involved in the authorization of nuclear installations and associated activities and have direct interface with the licensees. These include Directorate of Nuclear Safety (NSD), Directorate of Radiation Safety (RSD), Directorate of Transport and Waste Safety (WSD) and Directorate of Physical Protection and Security (PPSD). Moreover, Director General (Licensing and Authorization) supervises the activities of National Radiological Emergency Coordination Centre (NRECC) which is responsible for coordinating the response of various stakeholders to nuclear accidents or radiological emergencies with stakeholders. Director General (Inspections and Enforcement) looks after the three regional directorates and their respective inspectorates. Directorate of Administration and Directorate of Finance also function under the supervision of Member (Executive).

Member (Corporate) supervises the activities of the Corporate Wing. Four Directors General (DGs) are reportable to Member Corporate, namely DG (Regulatory Affairs), DG (Projects and Services), DG (International Cooperation and Human Resource) and DG (Technical Support). DG (Regulatory Affairs) supervises the activities of three Directorates namely Directorate of Regulatory Framework (RFD), Directorate of Monitoring and Evaluation (MED) and Office of Legal Affairs. These Directorates are involved in the supervision of regulatory framework; monitoring performance and evaluation of regulatory effectiveness while legal cell looks after legal matters pertaining to enforcement process of PNRA. DG (Projects and Services) looks after three Directorates namely Directorate of Information Services (ISD); Directorate of Engineering Services (ESD) and Public Sector Development Programme (PSDP) Projects undertaken by PNRA for its capacity building and institutional strengthening to achieve sustainable regulatory effectiveness. DG (Technical Support) supervises the activities of the two technical support centers of PNRA namely Center for Nuclear Safety (CNS) and Safety Analysis Center (SAC) responsible for review and assessment of licensing submissions and the corresponding audit safety analysis and Environmental Monitoring and Dosimetry Labs. DG (International Cooperation and Human Resource) supervises the activities of three Directorates namely Directorate of International Cooperation (ICD) and Directorate of Human Resource Development (HRD) and National Institute of Safety and Security (NISAS) which is used for in-house training of regulatory staff as well as stakeholders. Whereas, Directorate of Establishment functions directly under the supervision of Member (Corporate).

During the reporting period, the organizational structure of PNRA was modified to rename certain organizational units or Directorates and to re-arrange the reporting channel. The revised organizational structure of PNRA is shown at Annexure–III. The functions and responsibilities of Directorates had been described in detail in the previous reports.

8.1.4 Development of Human Resources

PNRA is committed to ensure availability of qualified, knowledgeable, experienced and skilled professionals for regulating nuclear installations and radiation facilities. The Management System Manual (MSM) of PNRA requires that each department should assess and determine its need of necessary human resources to carry out the assigned activities. All PNRA departments send request to the senior management through HRD for fulfillment of their needs of human resources. The senior management takes appropriate steps to induct the necessary manpower according to the results of overall assessment of the expected future requirements of human resources of the organization performed by HRD.

Recruitment is made as per relevant procedures according to applicable pre-set criteria and the management determines the career and succession planning of each individual.

HRD conducts competence need assessment and identifies the training requirements for its manpower. PNRA has adopted a three-pronged approach for the capacity building of its manpower by utilizing in-house training facilities, training facilities of other national institutes and possibilities of training in other countries and at international organizations.

In-house professional training

PNRA has established an in-house training facility, namely National Institute of Safety and Security (NISAS) which organizes professional training courses for the regulatory staff and stakeholders. NISAS has an adequate training infrastructure like classrooms and labs equipped with soft panel PWR simulator, physical models of NPP major equipment, radiation protection, physical protection and non-destructive testing equipment for hands on training of the regulatory staff. The institute arranges in-house regulatory specific professional training courses. NISAS has experienced faculty members who are capable of imparting technical and regulatory knowledge at the national as well as international level. Faculty members of NISAS participate as resource persons in different international training courses arranged by IAEA in embarking countries such as Basic Professional Training Course (BPTC) on Nuclear Safety, Human Resource Management, Competence Needs Assessment and Knowledge Management.

Professional training at National Level

PNRA regularly pursues training and re-training of its staff at national institutes for competence development in relevant working areas. These institutes include Pakistan Institute of Management (PIM), Pakistan Welding Institute (PWI), National Center for Non-Destructive Testing (NCNDT), Pakistan Institute of Engineering and Applied Sciences (PIEAS), Karachi Institute of Nuclear Power Engineering (KINPOE), National University of Modern Languages (NUML), Research Society of International Law (RSIL), Secretariat Training Institute (STI), and Pakistan Manpower Institute (PMI). HRD arranges such trainings and maintains the training profiles of the workforce.

Professional training at International Level

PNRA officials also participate in international training courses, workshops, scientific visits, meetings, etc. primarily through the technical cooperation program of the IAEA and bilateral arrangements with other countries. Directorate of International Cooperation (ICD) arranges and coordinates their participation. The reports of participation in international events including recommendations and training material are maintained and used to enhance regulatory effectiveness. HRD keeps record of trainings of all PNRA employees.

8.1.5 Competence Development

Competency development of the regulatory staff is a top priority of PNRA. Therefore, right from its inception, PNRA has focused on the transfer of knowledge and skills of the experienced nuclear professionals to junior staff. A number of steps have been taken over the last few years to strengthen professional capabilities of PNRA staff.

PNRA provides opportunities for coaching and mentoring, on-the-job trainings, scientific visits, attachments with national organizations, regulatory bodies and TSO of other countries and in-house knowledge sharing programs to enhance the technical competence of its staff. Special teams comprising experienced professionals from all Directorates are constituted for specialized tasks such as review of SAR, preparation and revision of regulations, regulatory guides, special inspection activities, etc.

PNRA carried out Competence Needs Assessment (CNA) in 2005 and 2011. In 2020, Competence Needs Assessment was performed again with the updated methodology of IAEA Safety Report 79 and IAEA TECDOC 1757. CNA has helped to identify directorate and individual level competence requirements and competence gaps. Competence development plans have been prepared for each individual to provide the needed trainings

The leadership of PNRA is committed to demonstrate highest level of safety in their actions and decisions. The management at all levels demonstrates leadership attitude for safety in team work, decision making, mutual cooperation, problem resolution, communication within PNRA and communication with interested parties. After its inception, PNRA initiated a Leadership Development Program (LDP) in collaboration with Lahore University of Management Sciences (LUMS) to build-up and maintain leadership capabilities at different levels in PNRA. In order to align PNRA leadership for safety concept with PNRA management System, PNRA has designated a team to reassess the LDP. The team has completed its task and has identified recommendations.

During the reported period HRD completed human resources planning and HR rationalization till 2030.

8.1.6 Financial Resources

Funds of PNRA consist of grants from the federal government, funds collected as license fees and funds through PSDP projects for capacity building. These funds are adequate enough to meet the current financial requirements of PNRA.

8.1.7 PNRA Management System

PNRA management system is a framework comprising of processes and procedures that has been developed in the form of a manual to ensure that PNRA fulfills its functions and responsibilities in order to achieve its Vision, Mission and Goals in a systematic, effective and efficient manner.

PNRA management system is used as an effective tool for the management of organization. It integrates all the elements of management including Vision, Mission, Core Values, Organizational Structure, Tasks and Functions, Leadership and Management for Safety, Policies, Goals, Strategies and Plans; Graded Approach; Resource Management; Conflict Management, Core and Support Processes; Organizational Change; and approach towards Monitoring, Assessment and Improvement; etc.

After five years of issuance of PNRA revised MSM, review of the same was again initiated in 2021 at PNRA. During the review, focus is being given to the changes made in policies, procedures, processes, strategies, plans, goals, etc. The MSM is also being reviewed based on implementation feedback, international experience feedback, change in management, etc. so that these are incorporated in MSM accordingly. The review is currently in progress.

Monitoring and Assessment of Regulatory Processes

MED performs monitoring and assessment of all processes and activities in order to evaluate their effectiveness through an established process prescribed by the MSM at pre-defined frequencies. These include annual progress monitoring of strategic plan, quarterly and annual performance evaluation of all PNRA departments, self-assessment, independent assessment etc. The details of these activities are presented below:

MED monitors all processes and activities by conducting performance review against PNRA Strategic Plan and annual work plans and provides feedback to top management, senior management and relevant departments in the form of quarterly and annual progress report. The activities of PNRA departments planned in the annual work plans are monitored on quarterly basis against progress mentioned in monthly progress reports. The output of the monitoring is communicated to relevant departments for necessary action and senior management for information.

Self-Assessment

Self-assessment is a continuous process and is conducted periodically to identify the weaknesses and to improve the management system, enhance safety culture and effectiveness of the processes and activities. The self-assessment is conducted at the overall organization level and its various departments. All departments are required to conduct their self-assessment on biennial basis. During the reporting period, a number of PNRA departments performed self-assessment on the basis of pre-defined criteria and identified grey areas for improvement.

Further, PNRA conducts internal regulatory audit of all departments to verify the compliance of assigned tasks and functions. At the organization level, PNRA assesses its integrated performance including the effectiveness of regulatory processes and activities and present it to the Government through the annual report. The annual performance assessment is conducted on the basis of twelve (12) Performance Indicators which are described in Annexure-V and are currently being reviewed for revision.

Independent Assessment

PNRA invites international peer review missions for assessing the performance of its processes and activities for independent assessment.

PNRA invited IRRS Mission in 2014 and during the reporting period, progress on status of implementation of the actions on recommendations and suggestions of the Mission was regularly monitored. During the reporting period, Pakistan invited the IRRS follow-up Mission and the same was organized in February-March 2022.

Openness and Transparency of Regulatory Activities

PNRA has developed various mechanisms to ensure and enhance its openness and transparency in decision making. It has a mechanism for obtaining feedback from its licensees through a questionnaire on effectiveness of regulatory processes and

professionalism of regulatory officials. During the reporting period, PNRA received feedback from nuclear installations.

PNRA website is also used to share information about major regulatory decisions and activities with the public. Information about all activities performed during the year is also reflected in detail in PNRA Annual Report. PNRA website is constantly updated with recent information and PNRA's Annual Report is widely circulated within and outside the country.

PNRA encourages public involvement in development of its regulations. During the reporting period, public comments were invited on a number of regulatory documents to involve public in process for development of regulatory framework.

During the reporting period, PNRA continued to maintain effective liaison with Government regarding execution of its national obligations. Regulatory decisions taken during the reporting period were communicated to relevant government organizations. Progress reports on implementation of IRRS Report Action Plan were shared with Government.

PNRA continued to play its role and supported the Government in fulfillment of Pakistan's obligations under relevant international conventions pertaining to nuclear safety, radiological emergencies and physical protection. In this regard, PNRA remained actively engaged in activities related to national obligations under the international Conventions to support the Government of Pakistan.

8.1.8 Use of External Technical Support

PNRA has adequate arrangements for obtaining technical or other expert professional advice or services in support of its regulatory functions, however, such advice is never binding and PNRA remains independent and retains full responsibility for its decision making on safety matters.

PNRA has established strong bilateral relationships with National Nuclear Safety Administration (NNSA), China Nuclear Power Operation Technology Corporation (CNPO) and Nuclear Safety Centre (NSC) of China. The bilateral agreements with these organizations provide a forum for free exchange of information on matters related to nuclear safety. These eminent Chinese institutes are assisting PNRA in the review and assessment as well as regulatory inspections of NPP.

8.2 Separation between Regulatory and Promotional Functions

Legislative framework clearly separates the functions of promotion and regulating nuclear safety and radiation protection in Pakistan. No function or responsibility assigned by the Ordinance to PNRA is related with the promotion of nuclear energy, and none of its functions and responsibilities conflict with its responsibility for regulating nuclear safety and radiation protection.

PAEC or any other organization, responsible for promotion or utilization of nuclear energy or ionizing radiation, does not have any regulatory function. Moreover, Chairman PNRA reports to the Prime Minister of Pakistan through the Strategic Plans Division (SPD) which is the Secretariat of National Command Authority (NCA) headed by the Prime Minister. This feature, among others, ensures the independence of PNRA as a regulatory body. In addition, provision of financial resources directly by the Government further ensures independence of regulatory body in its decision making.

Pakistan has, therefore, met the obligations of Article 8 of the Convention.

ARTICLE 9 – RESPONSIBILITY OF THE LICENSE HOLDER

Each Contracting Party shall ensure that prime responsibility for the safety of a nuclear installation rests with the holder of the relevant license and shall take the appropriate steps to ensure that each such license holder meets its responsibility.

Pakistan has ensured that prime responsibility for the safety of a nuclear installation rests with the holder of the license. Appropriate steps are taken to ensure that the license holder fulfills this responsibility.

9.1 Legislation for Safety

Under the PNRA Ordinance, Government of Pakistan has conferred PNRA with the mandate to protect the workers, public and environment from harmful effects of ionizing radiation by ensuring that the nuclear installations are managed and operated in a safe and secure manner. PNRA is empowered to issue Regulations and ensure their compliance during different phases of the life of nuclear installations i.e. Siting, Design, Construction, Operation, Decommissioning, etc. PNRA Regulations for Licensing of Nuclear Installations, PAK/909, states that the licensee is directly responsible for the safety of nuclear installation. Likewise, Regulations for the Safety of NPP Operation PAK/913 also delineates that the licensee shall have the prime responsibility for safe operation. A National Safety Policy was also issued in 2020 which also reflects the prime responsibility for safety which must rest with the person or organization responsible for facilities and activities that give rise to radiation risks.

In addition, it is explicitly mentioned in all the authorizations and licenses issued by PNRA that the licensee shall retain prime responsibility for safety. The management of the installation is also responsible for providing clear and adequate guidance to its contractors to ensure that safety is integrated into all the activities and any other activity such as production shall not have priority over safety. PAEC, being the licensee of nuclear installations, has overall responsibility for the fulfillment of safety requirements for its nuclear installations and provides necessary resources and support to the respective management for safe operation in accordance with regulatory requirements.

PNRA ensures the compliance of regulatory requirements regarding responsibility of safety through implementation of its regulatory oversight process which consists of authorization and licensing based upon outcomes of review and assessment and inspection and enforcement.

9.2 Responsibilities of PAEC

The responsibilities of PAEC Headquarter with regards to nuclear installations are described below.

9.2.1 PAEC Headquarter

According to the license issued by PNRA, PAEC is the licensee on record for the safe operation of nuclear installations in Pakistan. PAEC has delegated its responsibilities related to the safe operation of the plant to the respective plant management as per PNRA authorization process, with the provision of necessary financial and human resources to meet the requirements for:

a. Safe and continued operation of nuclear installations during the operating life;
b. Safety upgrades and modifications needed for safe operation;

c. Safe design, construction and operation of new nuclear installations.

PAEC has established safety and quality infrastructure at the corporate and nuclear installation levels. At the corporate level, the Directorate of Nuclear Safety (DNS) and Directorate of Quality Management (DQM) are established to disseminate the corporate expectations and to advise the corporate management on safety and quality issues. A Corporate Safety Review Committee (CSRC) has been established to review problems encountered during NPP operation, scientific and engineering issues of safety significance, radiation protection arrangements, physical security plans, emergency preparedness plans, QAP, administrative control and training.

At the nuclear installation level, there are approved organizational structures delineating required authority and independence of each Unit responsible for nuclear safety, licensing and QA related activities. In addition, plants' safety committees advise the management on safety and quality related issues. Representatives of Directorate of Nuclear Safety (DNS) at NPP sites conduct external audits of various plant divisions such as health physics, QA, maintenance, etc. following standard practices of international organizations, and emergency preparedness on regular intervals through an established independent safety oversight program.

In addition, various directorates at corporate level are providing design and engineering support to nuclear installations. This indigenous capability in design and engineering has resulted in enhancing the operational safety of nuclear installations as well as in review and implementation of safety upgrades, as and when required. In order to monitor performance of various functional areas of NPP, corporate headquarters has designated experts namely Corporate Functional Areas Monitors (CFAMs) to look after performance and support and provide guidance to the plants for improvements. The modified PAEC organizational chart showing the corporate directorates is shown in Annexure–IV.

PAEC interacts with PNRA both at the corporate level and at the nuclear installation level. At the corporate level interaction is through Chairman and Members of PAEC to their corresponding counterparts in PNRA. The interaction between the regulatory body and the nuclear installations is through the PNRA licensing directorate at Headquarter and regional directorates at NPP sites.

9.2.2 Karachi Nuclear Power Plant (K-1)

K-1 vision and mission was defined and communicated to all workers so that they put in all efforts in the right direction for continued safe and reliable operation of the plant to ensure safety of workers, public, and environment during its operating phase. The vision of K-1now is to maintain the plant in safe shutdown state while preparation for decommissioning is in progress. This will be achieved through effective implementation of safety and quality policy and by fulfilling configuration control requirements with optimum use of operating experience in all work activities of operations, maintenance and engineering support for continuous improvement. KANUPP (K-1) was permanently shut down in August 2021. After permanent shutdown of K-1, a decommissioning organization was established to look after decommissioning activities under the supervision of Project Director.

9.2.3 Chashma Nuclear Power Generating Station (CNPGS)

CNPGS was restructured considering the requirements of multi-unit site during the reporting period. Currently, CNPGS, headed by a General Manager, deals with four operating Units

(C-1, C-2, C-3 and C-4), a common directorate of technical support and a common training center.

The mission of CNPGS is to generate electricity in a demonstrably safe, reliable and cost-effective manner, for the benefit of society and stake-holders, as well as to consolidate the basis for expansion of the nuclear power program in Pakistan. The vision is to establish a modern, effective and efficient management system within the organization, to enhance the standard of management. CNPGS is earnestly working to achieve its mission and vision.

Technical divisions of C-1, C-2, C-3 and C-4 are responsible for system performance evaluation of structures, systems and components related to safety, safety surveillance during operation and outage, review of safety and technical specification modifications etc. Nuclear safety and operating experience section of technical division is responsible for interfacing with the regulatory authority and performs the function of collecting and utilizing operating experience feedback within C-1, C-2, C-3 andC-4 and manages the corrective action plan. Respective technical division also coordinates the follow-up actions of PSRs as part of the corrective action plan.

Each plant has its own high level safety committee, namely Operational Safety Review Committee (OSRC) which is headed by the respective plant manager. Other members include the deputy plant manager, manager operation, manager health physics, manager QA and manager technical. This committee, among other functions, reviews and assesses changes to approved technical specifications, safety related equipment and systems, tests, new safety issues, violations of approved technical specifications, deficiencies in design or operation that may affect safety, radiological emergency response plan, physical protection plan etc.

9.2.4 Karachi Nuclear Power Project Unit-2 (K-2) and Unit-3 (K-3)

The Safety Division of K-2/K-3 is responsible for addressing safety related issues. This division is also responsible for coordinating the safety review, dealing licensing matters with regulatory body and implementing Configuration Management Plan during construction. A Quality Assurance Division (QAD) ensures quality through the implementation of the QAP. It performs audit of the activities of designer, contractor and sub-contractors and performs QA surveillance during installation, commissioning and operation at site. The licensee is committed to abide by the requirements of the PNRA regulations along with the license conditions and directives of PNRA issued from time to time. The license holder submits the required safety reports and documentation as prescribed in the regulations or required by PNRA in support of a safety case. In addition, the license holder facilitates the regulatory inspections, during all phases of the plant life, which are carried out by PNRA to verify that the requirements of the regulations and conditions of the license are met.

9.3 Technical Support to Operating NPP Units

K-1 management ensures that effective technical support activities are provided as necessary for safety of the plant. The major activities of technical support are performed by Technical Division, Design and Development Division, Control Instrumentation Application Laboratory and Computer Design and Development Division. Roles, responsibilities and programs for each Technical Support Divisions of K-1 are clearly defined and understood by plant personnel. Resources and engineering support are provided for plant life extension plans.

Directorate of Technical Support of CNPGS is composed of eight (08) divisions. Radioactive waste management division assists operating Units in radioactive waste management activities. Technical coordination division assists in performing engineering and safety analysis, preparing design modifications, fuel management and core management activities and RFO planning activities. Information system division establishes and maintains information for the plants. Equipment management division develops and manages the PSI, ISI and AMP. Structure and services division provides supporting activities related to construction and surveillance of structure and buildings. In addition, three maintenance support divisions related to mechanical, I & C and electrical, maintenance assist the plants in major maintenance activities. Directorate of CHASCENT provides training and re-training to operating personnel of C-1, C-2, C-3 and C-4. Besides Operation Training, CHASCENT also provides basic training, maintenance and technical training.

Like CNPGS, a common Directorate of Technical Support has been established at KNPGS to look after maintenance and engineering support to K-2/K-3. Similarly, a common Training Center has been established to meet the training/retraining requirements of licensing personnel and other technical staff.

Corporate technical support is also provided to monitor and prepare for different plant operational as well as improvement activities. PAEC Corporate office sends various technical support teams from time to time to evaluate and assess different on-going activities at NPPs including implementation of Fukushima Response Action Plan (FRAP).

9.4 PNRA Mechanism for Ensuring Discharge of Prime Responsibility of Safety by License Holder

In order to ensure fulfillment of licensee's prime responsibility of safety throughout the entire life cycle of nuclear installations, PNRA performs regulatory review and assessment of licensees' submissions i.e. routine and non-routine submissions, design and technical specifications (TS) modifications, event reports, and other documents required under various regulations, license conditions and directive issued at times. A comprehensive periodic safety review (PSR) of each nuclear installation is also performed prior to operating license revalidation i.e. permitting licensee to continue operation for next 10 years based upon licensee's demonstration for adequate safety and subsequent satisfactory resolution of all regulatory concerns. In addition, regulatory inspections are performed by PNRA which play a pivotal role in effective regulatory oversight of nuclear installations and compliance verification of regulatory requirements. In this respect, PNRA has established an inspection program for nuclear installations that provides basis for regulatory inspections related activities. The three regional directorates of PNRA are responsible for conducting regulatory inspections and taking enforcement actions in case of violations of PNRA Ordinance, applicable regulations, directives or license conditions.

The above-mentioned activities enable PNRA to ensure that licensee fulfills its prime responsibility of safety at nuclear installation. (Please refer to Article 7.3 & 7.4 for furthers details).

9.5 PAEC Mechanism for Maintaining Open and Transparent Communication with Public

Various measures have been adopted by PAEC to maintain open and transparent communication with public. This communication is carried out through PAEC website by posting information about NPP which is updated periodically.

At NPP site, plant management interacts with public residing in nearby areas to share information about NPP and their potential hazards. The education of public regarding protective actions to be taken during emergency situation is also carried out during these sessions.

9.6 Mechanism for Ensuring Effective Onsite Accident Management

PNRA is authorized through section 39(2) of PNRA ordinance 2001 to ensure, co-ordinate and enforce preparation of emergency plans for action to be taken following foreseeable nuclear incidents or accidents that might affect the public and environment.

Emergency plans are submitted to PNRA at the licensing stage of "introduction of nuclear material into the nuclear installation" as per Regulations for Licensing of Nuclear Installations, PAK/909. These plans are reviewed and approved by PNRA. The full scope implementation of these plans is demonstrated by licensee and is witnessed by PNRA inspectors which are one of the contributors towards regulatory decision making regarding above mentioned licensing stage. PAEC corporate office also participates as observer and evaluator, for the independent assessment of such emergency exercises and recommends actions for improvement accordingly.

During the operation phase of NPP, the emergency plans are regularly verified through exercises and drills by licensees to ensure that sufficient resources (human, technical and financial) and infrastructure are available for on-site management of incidents and accidents and mitigation of their consequences. These exercises and drills are carried out under regulatory oversight of PNRA (please refer to Article 11 for further details).

On behalf of Government of Pakistan, PNRA ensures through its regulatory oversight process that license holder has adequate resources and powers for effective on-site management of an incident or accident and mitigation of their consequences.

Pakistan has, therefore, met the obligations of Article 9 of the Convention.

ARTICLE 10 – PRIORITY TO SAFETY

Each Contracting Party shall take the appropriate steps to ensure that all organizations engaged in activities directly related to nuclear installations shall establish policies that give due priority to nuclear safety.

Pakistan has taken appropriate steps to ensure that all organizations engaged in activities directly related to nuclear installations have established policies that give due priority to nuclear safety.

10.1 Regulatory Requirements

PNRA Regulations require that safety shall be the utmost priority in all activities related to Siting, Design, Construction, Commissioning, Operation and Decommissioning of nuclear installations. Regulations PAK/913 requires operator to establish an effective organizational structure for making and implementing policies for safety, allocating adequate resources, enforcing requirements like fitness for duty, monitoring and assessing the performance of operating and supporting functions on regular basis etc. PNRA Regulations PAK/913 further requires that a policy on safety shall be developed and implemented by the licensee and adhered to by all site personnel. This policy shall give the utmost priority to the safety at the installation, overriding the demands of production and project schedules. The policy should promote a strong safety culture, foster a questioning attitude and a commitment to excellent performance in all the activities important to safety and shall encourage questioning attitude. All activities that may affect safety and which can be planned in advance shall be conducted in accordance with established procedures and shall be performed by suitably qualified and experienced individuals. Furthermore, regulations require the operator to establish a system for continuous monitoring and regular review of the safety of the plant and its performance to ensure effective implementation of the safety policy and that lessons are being learned by the licensees from their own experience and from the experience of others to improve safety performance. PNRA require that self-assessment should be an integral part of the performance monitoring and review system of licensee. PNRA Regulations PAK/913 further requires operator to establish, implement, assess and continually improve an integrated management system to ensure that plant is operated in safe manner. PNRA Regulations PAK/921 requires thesenior management of the operating organization to ensure the safety during siting, design, construction, commissioning, operation and decommissioning, or closure, of the facilities.It further requires that equipment and activities meet the regulatory requirements and applicable standards for safety and quality.

Moreover, National Safety Policy based on IAEA Safety Fundamentals describing the commitment of all stakeholders is also developed. As per policy, Pakistan is committed to ensure nuclear safety and radiation protection through an effective and sustainable regulatory regime, striving for continuous improvement and giving overriding priority to safety.

10.2 Measures Taken by PAEC to Implement Arrangements for Priority of Safety

10.2.1 Nuclear Safety Policy of PAEC

Pakistan Atomic Energy Commission (PAEC) is the owner and operator of nuclear installations and has overall responsibility for safety. PAEC has formally established and

implemented a Nuclear Safety Policy from which specific safety rules, procedures and other requirements are derived.

10.2.2 Corporate Safety Oversight Program for NPP

Directorate of Nuclear Safety (DNS) of PAEC is responsible for independent safety oversight of operating NPP and projects. In addition, DNS is also responsible to ensure implementation of corporate safety policies, actions related to safety and to promote and enhance safety practices by conducting safety reviews and inspections of all operating NPP in accordance with Corporate Safety Oversight Program. The safety oversight process focuses on the plants' operational safety and practices for ensuring the safety of workers, public and the environment. Major elements of corporate safety oversight include daily inspections, plants surveillance, periodic safety reviews, follow-up reviews, inspection of RFO's activities and reactive safety oversight.

10.2.3 Priority to Safety in Nuclear Installations

PAEC, being licensee of nuclear installations in Pakistanis committed to give priority to nuclear safety. After Fukushima Daiichi accident, PAEC corporate management formed a task force for safety assessments of nuclear installations in light of the lessons learnt from the Fukushima Daiichi accident and IAEA Nuclear Safety Action Plan. Areas were identified for improvement in terms of availability of equipment and measures to perform safety functions in case of severe accidents, extreme natural hazards and combined effects of severe accidents and extreme natural hazards such as Mobile Emergency Power Sources, Hydrogen Control and Mitigation Systems, Emergency Preparedness and Response etc. PAEC has also allocated financial resources for the implementation of the measures, as identified through FRAP on priority. Considerable progress has been made relevant to the pending actions during the reporting period; however, implementation of some long-term actions remained in progress.

Systems of reporting events such as low-level events and near misses, CAP, equipment health monitoring, and operational experience feedback was further strengthened. WANO peer reviews have been carried out at C-1, C-2 and K-1 in the reporting period. Such activities have added to the improvement of safety at nuclear installations in Pakistan. Detail of international peer reviews is given in section 2.2.2

Under the safety culture program of CNPGS, continuous training on safety culture is arranged and conducted by CHASCENT for all employees of CNPGS. The internal assessment of safety culture is conducted regularly.

K-1

At K-1, the Plant Vision, Mission, Goals and Objectives have been clearly outlined so that all plant personnel remain well aware of their responsibility in ensuring plant safety.K-1 policy statement encompasses complete Nuclear Safety (Reactor Safety, Radiation Safety, Industrial Safety and Environmental Safety) and associated activities.

The policy sets forth the Pakistan Atomic Energy Commission's expectation that individuals and organizations performing regulated activities establish and maintain a positive Nuclear Safety Culture commensurate with the safety and security significance of their actions and the nature and complexity of their organizations and functions. Individuals and organizations bear the primary responsibility for safety and security. The performance of individuals and organizations can be monitored under various programs such as self-assessment, QA and

performance indicator programs with oversights from national and international organizations, and therefore, may be used to determine compliance with requirements and commitments and may serve as an indicator of possible problematic areas in an organization's Nuclear Safety Culture.

Station Instructions (SI) for CAP, Self-Assessment Program (SAP), and Safety Performance Indicators (SPI) are being implemented. Event reporting process has been made easy so that any worker can directly report an event to the CAP Group. After investigation and evaluation, wherever required, necessary corrective measures are taken and feedback is provided to the reporting person. An in-house database of CAP has been developed and is accessible to all the plant personnel through Local Area Network (LAN). Open training sessions and lectures are carried out on CAP and SAP to enhance awareness and acceptance of these programs amongst plant personnel. To further improve safety culture and event reporting attitudes, every year a shield is awarded to the Division having best reporting record and certificates are awarded to one officer and one staff member for best safety suggestion. Focused Self-Assessment (FSA) is carried out on monthly basis to assess the areas in which deficiencies in soft issues are highlighted by the CAP. Necessary actions are developed and tracked to further improve these areas.

Safety is always ensured by systematic implementation of safety culture assessment programs. These programs included Corrective Action Program (CAP), SA (Self-Assessment), OEF (Operating Experience Feedback), PI (Performance Indicator), AMP (Ageing Management Program), In-Service Inspection (ISI), PM (Preventive Maintenance) etc. A number of safety upgrades were implemented as a result of these programs.

Several IAEA and WANO technical missions including a Peer Review Mission were conducted at K-1 during the reporting period. Further details on technical missions are provided in section 2.2.2 of this report.

A number of administrative procedures, which define the organizational arrangements relating to practical implementation of the plant nuclear safety policy, have been issued at K-1.

K-1 completed fifty years of safe operation in August 2021 with "SAFETY FIRST" slogan as its prime responsibility. During the entire length of its operating history, different programs kept in operation to ensure safety of plant, plant personnel and general public.

K-1 has been permanently shut down on 01 August 2021 as planned and deferred dismantling strategy has been selected for K-1 decommissioning. Decommissioning Organization has been implemented and the facility has been renamed as KANUPP-1 Decommissioning Project (KDP). KDP has entered Phase-1 (preparations for safe storage) of decommissioning project. Sufficient manpower of KANUPP has been retained at KDP to execute decommissioning activities safely without compromising the safety culture that was established during plant operation. However, several programs mentioned above are being modified as per current requirements. KDP has joined decommissioning peer group and waste management peer group of COG to learn from Canadian experience in the field of decommissioning.

CNPGS

The Nuclear Safety Policy is being implemented at all operating NPPs under CNPGS at Chashma Site. Management of these NPP bears full responsibility for the safety of the plants

according to the Policy. Plant Manager holds daily work plan meetings to discuss safety issues and ways and means of their resolution. Safety and quality takes precedence over production objectives. Event reporting is encouraged and any plant worker can report events and near misses through a user-friendly reporting system. After evaluation and investigation, wherever required, necessary corrective measures are taken and feedback is provided to the reporting person. An in-house database of low-level events, near misses and corresponding corrective actions has been developed and is accessible to all the plant personnel through Local Area Network. CNPGS has implemented safety performance indicators program to monitor trends of operational safety of the plants in various domains.

Operating experience is carefully examined to detect any precursor signs of possible tendencies adverse to safety and availability of the plant, so that corrective actions could be taken before any serious condition is encountered. Regular reviews of the operation of the plants are conducted to ensure that safety consciousness exists and provisions set forth for enhancing safety are observed. An Operation Safety Review Committee (OSRC) is in place which performs assessment and reviews for safety evaluations of procedures, modifications in procedures, equipment, system or facilities, etc. and investigates any violation of the technical specifications. PSR of plant is performed at regular intervals of ten years in order to ensure plants safety in the light of operating experience and significant new safety information and issues.

During the reporting period, CNPGS safety culture program has been updated in the light of suggestions by PAEC corporate office.

K-2 and K-3

The 'Priority to Safety' is given utmost importance at K-2 and K-3Safety has been ensured in different phases of Siting, Design, Construction, Commissioning and Operation in compliance with the regulatory requirements and international standards through reviews, assessments and inspections A 'Management System for Design and Construction phase of K-2/K-3', in accordance with PNRA Regulations and IAEA Safety Standards, is in place. This MSM is applicable to all safety related structures, systems and components as well as important non safety structures, systems and components.

K-2 and K-3 project organization is established to plan, monitor and control the design and construction activities to meet the safety objectives. Trained manpower has been made available to carry out all activities important to safety. At design stage, the probabilistic safety assessment was performed in addition to the deterministic safety analysis.

Officers of K-2 and K-3 are being trained to foster safety culture by taking into account experience of other nuclear installations.

A dedicated team for safety culture has been set up which will be responsible for coaching, assessment and evaluation of safety culture at K-2/K-3 Project.

10.3 Verification of Safety by PNRA

PNRA regulatory oversight program covers verification of all nuclear safety related activities. PNRA promotes safety culture in nuclear installations by ensuring that it is on the agenda of the licensee at the highest organizational level. PNRA inspection program for nuclear installations covers safety culture inspections in addition to other safety significant areas.

In safety culture inspections, PNRA relies primarily on the notes and reports of inspectors collected during plant visits, reviews of documentation, and interviews with plant personnel. It is supplemented through reviews of event and near misses reports, post event inspections and self-assessment reports of the licensees. PNRA is performing safety culture inspections at operating NPP by utilizing the latest IAEA approach as given in Safety Report Series No. 83 (2016). Such inspections were performed at C-1 during 2019 and at K-1 in 2020. The priority to safety is closely monitored by PNRA during regulatory oversight of NPP.

10.4 Means used by PNRA to Prioritize Safety

The policy of giving priority to safety is rigorously followed by PNRA as a top-down approach for handling nuclear safety related issues. PNRA has developed the regulatory processes in its Management System using the principle to giving priority to nuclear safety in its activities and regulatory decision making. Resources are allocated using the graded approach. Authorization of nuclear installations is focused on satisfactory resolution of all safety related issues pertaining to nuclear safety. During regulatory inspections, control points among the on-going activities of the licensee are selected based on their significance to nuclear safety and experience feedback.

The senior management of PNRA adopted and inculcated specific core values that expect all employees of PNRA to demonstrate consciousness towards nuclear safety.

Pakistan has, therefore, met the obligations of Article 10 of the Convention.

ARTICLE 11 – FINANCIAL AND HUMAN RESOURCES

i. **Each Contracting Party shall take the appropriate steps to ensure that adequate financial resources are available to support the safety of each nuclear installation throughout its life.**

ii. **Each Contracting Party shall take the appropriate steps to ensure that sufficient numbers of qualified staff with appropriate education, training and retraining are available for all safety-related activities in or for each nuclear installation, throughout its life.**

Pakistan has taken appropriate steps to ensure that adequate financial resources are available to support the safety of NPP and that sufficient number of qualified staff with appropriate education and training are available for all safety related activities at each NPP throughout its life. The adequacy of the resources is re-assessed periodically and augmented whenever found necessary.

11.1 National Requirements for Financial Resources

As per regulatory framework, PNRA Regulations PAK/912, PAK/913 and PAK/930 require the licensee to ensure that adequate resources, services and facilities are provided for the safety of the NPP throughout the lifetime.

11.1.1 Financial Resources at Nuclear Installations

NPP are owned by PAEC (Government sector organization) with a clear commitment to provide financial resources required throughout their lifetime. National Electric Power Regulatory Authority (NEPRA) is the electricity tariff determining body in Pakistan. While fixing the unit (kilowatt-hour) price to be paid by the distribution companies to PAEC, it takes into consideration the specific issues related to NPP such as operation and maintenance, RFO, decommissioning costs, storage and disposal of radioactive waste, periodic safety reviews and upgrades, etc. A fund is also maintained to cope with the radiological emergencies for each site.

11.1.2 Resources for Decommissioning and Waste Management

PAEC is committed to carry out decommissioning of its NPP in a safe manner when it becomes necessary. PAEC is also committed to safe and secure management of radioactive waste generated from activities in its NPP according to National Policy on Safe Management of Radioactive Waste, Decommissioning and Spent Nuclear Fuel. PAEC has also ensured provision of adequate financial resources for decommissioning and waste management at NPP. The policy requires that the producer of radioactive waste shall be responsible for safe and secure management of radioactive waste and shall bear the expense for its safe disposal.

Pakistan Atomic Energy Commission (PAEC) is experiencing the decommissioning of a nuclear facility (i.e. K-1) in Pakistan for the first time. All the required resources (funding, technical knowledge, manpower etc.) are being arranged through indigenous efforts. National regulations are being followed in this regard. According to the “National Policy on Safe Management of Radioactive Waste, Decommissioning and Spent Nuclear Fuel – RWP-01/2018”, each nuclear installation shall be responsible to establish and maintain its own decommissioning fund. If a nuclear installation fails to manage financial resources for decommissioning, even in case of premature shutdown, the Government of Pakistan shall

be ultimately responsible for the provision of adequate financial and human resources to cover costs associated for safe decommissioning.

K-1 has described its decommissioning funding and waste management in Final Decommissioning Plan. Decommissioning funding of K-1 is managed from its own savings deposited in decommissioning fund.

CNPGS has also ensured provision of adequate financial resources for decommissioning activities and waste management. CNPGS is also committed to safe and secure management of radioactive waste generated during its activities according to the National Policy. CNPGS also has its waste disposal fund to properly manage disposal activities of operational waste and decommissioning fund to carry out safe and environment friendly decommissioning activities. Waste management activities are being carried out according to PNRA regulation on radioactive waste management, PAK/915.

A Directorate General of National Repository (DGNR) has been established for development of infrastructure for disposal of radioactive waste. Land has been acquired for construction of repository and completion is expected in 2028 at two different locations. PNRA verifies regulatory requirements regarding adequate staffing and qualification of the manpower including contractor's personnel through regulatory oversight.

11.2 National Requirements for Human Resources

PNRA Regulations PAK/913 requires that the nuclear installations are staffed with competent managers and qualified personnel having proper awareness of the technical and administrative requirements for safety and motivated to be safety conscious. Attitude towards safety shall be a criterion for the hiring or promoting of managers. The regulations specify the requirements for academic qualifications, experience at nuclear installations, training and retraining, examination procedures, etc. The regulations also specify the requirements for qualification, training and experience required for issuance of license to operating personnel, validity of license, conditions to be satisfied for renewal of the license and conditions for revoking or cancellation of license. The regulations also require that the licensee shall ensure that the qualifications and training of external personnel performing safety related duties are adequate for the functions to be performed. The regulations also explicitly require that performance-based programs for initial and continuing training shall be developed and put in place for each major group of personnel. The content of each program should be based on a systematic approach. Training programs shall promote attitudes, which help to ensure that safety issues receive the attention that they warrant. PNRA regulations on "Leadership and Management for Safety" (PAK/921), based upon IAEA GSR Part-2, establish detailed requirements regarding leadership and management for safety.

11.2.1 Human Resources, Training and Retraining for Nuclear Installations

PAEC inducts fresh engineers, scientists and technicians every year so that the age profile of the organization remains balanced. Trainings and re-trainings are provided to the operation and maintenance crews of the plants. PAEC employs engineers and scientists possessing high academic qualifications such as Master of Sciences or Bachelors and Master of Engineering in relevant disciplines or other post graduate degrees. Many engineers and scientists have received comprehensive training in relevant fields both in Pakistan and abroad. The plant technicians possess three years diploma after their Secondary School Certificate examination from various institutes in the country.

PAEC has setup several training institutes and centers fully equipped with latest and state of the art facilities, aiming to provide quality education and training to its workforce. Its leading institutes are Pakistan Institute of Engineering and Applied Sciences (PIEAS), Karachi Institute of Nuclear Power Engineering (KINPOE) and CNPGS Center of Nuclear Training (CHASCENT). These institutes not only provide education related to nuclear fields but also contribute towards the Research and Development (R&D) programs of Pakistan.

PIEAS offers MS and PhD programs in Nuclear Engineering, Systems Engineering, Physics, Nuclear Medicine, Radiation Medical Oncology, Mechanical Engineering, Process Engineering, Metallurgy and Materials Engineering and Medical Physics as well as MS in Cyber Security and Computer Sciences. At undergraduate level it offers BS programs in Electrical Engineering, Mechanical Engineering and Computer and Information Sciences.

KINPOE offers Masters Degree Programs in Nuclear Power Engineering, Post Graduate Training Program (PGTP) and Post Diploma Training Program (PDTP) every year. In addition, an In-Plant Training Center (IPTC) fulfills the training and re-training needs of operation personnel of K-1, whereas Mechanical Maintenance Training Centre (MMTC), Electrical and Control Training Centre (ECTC) fulfill these requirements for maintenance personnel.

CHASCENT is a specialized institute of manpower development for nuclear power sector. It primarily focuses on the training of fresh engineers and technicians and is also involved in certification and licensing of plant personnel. CHASCENT also runs one year Post Graduate Training Program (PGTP) for engineers in the design and operations of PWR type plants. Plant technicians are given one year Post Diploma Training (PDT) at CHASCENT.

The organization of the power plants is such that all the managerial and supervisory positions are held by graduate engineers with a minimum of 6 to 10 years' experience in respective fields. The qualification requirement for shift supervisors and shift engineers is a graduate level engineering degree before obtaining necessary licenses.

Qualification and training of operating personnel follow the regulatory requirements of PAK/913 and training program of the plant. PNRA conducts oral and operating examinations for award of licenses to operating personnel. MCR engineers of CNPGS undergo mandatory training on a Full Scope Training Simulator (FSTS) for shift personnel license. The licensed operation engineers receive retraining on FSTS twice every year. The licensed personnel are re-examined internally every year. The field operators also undergo two months retraining every year.

While considering issuance of Fuel Load Permit or allowing commissioning, the availability of appropriate manpower is verified by PNRA. MCR operators including the shift supervisors are required to obtain licenses from PNRA prior to first fuel loading. The shift complement is also verified by PNRA resident inspectors during operation. It is ensured that the nuclear installations maintain a sufficient number of qualified and skilled manpower in all areas necessary for safe operation.

Operation Training Division (OTD) has contributed in development of skill and knowledge of Operation Manpower of existing and upcoming NPP of PAEC. OTD has contributed to development of sufficient manpower for operation of not only CNPGS plants but also for development of K-2/K-3 licensed manpower for operation. Up till now OTD is successfully meeting the regulatory requirement for renewal of license of shift engineers and shift supervisors of CNPGS. Training on enhanced scenarios is also imparted to all retraining

crews of C-1 and C-2. OTD has also developed certified turbine operator, electrical operators and local areas operators by imparting certification training.

OTD has made significant progress for implementation of Systematic Approach to Training (SAT) practices and successfully table top analysis of turbine operator, shift engineer and shift supervisor training needs in which experts from CNPGS participated for improvement of training needs process.

The operations retraining program provides opportunities to MCR crews to discuss MCR logs, nuclear safety culture traits and attributes, event reports, human performance tools and WANO Significant Operating Experience Reports (SOER) on daily basis. As a result, operators share the valuable learning points gained from the different sources of internal and external operating experience to reinforce a strong nuclear safety culture. This has been identified a straining strength in the WANO peer review, 2018.

Maintenance and Technical Training Division (MTT) provides hands on training through "Skill Development Training Program" on different equipment and topics, such as, bearing and its lubrication, improving reliability of mechanical seals for pumps, shaft alignment etc. to maintenance personnel of CNPGS.

CNPGS and Technical Support (TS) personnel are also continuously trained in human performance improvement tools, supervisory and coaching skills. operating experience feedback, plant modifications, QAP, reporting of events, fundamentals of radiation protection, equipment qualification program, WANO PO&C, Foreign Material Exclusion (FME) management, RFO planning, industrial safety, firefighting and nuclear safety culture. Their knowledge and competency is thus continuously updated and ensured for safe and reliable plant operation.

Plant QAD ensures that contractor personnel, equipment, and procedures are properly qualified and adequate to perform the inspection. Shifts staffing policy and schedules have been designed to ensure availability of adequate number of personnel for replacement duties, without resorting to overstay. To ensure a sufficient number of shift engineers and supervisors, qualified candidates are selected to attend the plant operators training program.

At national level, there are thirty-two (32) groups of competent personnel from various organizations which are available for monitoring and supplementing the emergency response organization during management of severe accidents.

Pakistan has, therefore, met the obligations of Article 11 of the Convention.

ARTICLE 12 – HUMAN FACTORS

Each contracting party shall take the appropriate steps to ensure that the capabilities and limitations of human performance are taken into account throughout the life of a nuclear installation.

For safe operation of NPP, the role of plant personnel is vital. The MCR and local areas operators monitor and control the plant systems. The contribution of maintenance and test personnel of plants is also important for ensuring the safe and reliable operation of plant system and equipment. Personnel training, human system interface design, procedures and level of automation influences the reliability of human actions during all the operating conditions of NPP. Location of human system interfaces e.g. alarms, controls, displays provided in control rooms can affect the performance of plant personnel in a positive or negative manner.

Pakistan has taken appropriate steps to ensure that the capabilities and limitations of human performance are taken into account throughout the life of a nuclear installation. PNRA and PAEC recognize that human performance plays an important role in ensuring the safety of a nuclear installation during all phases, i.e. siting, design, construction, commissioning, operation and decommissioning. Accordingly, PNRA has set regulatory requirements for human factors engineering to ensure safe operation of nuclear installations. Subsequently, PAEC has established human performance monitoring program for analyzing events resulting from human errors and to improve human performance for ensuring safe operation of nuclear installations.

12.1 Regulatory Requirements

Reliability of human actions during the operation of plants mainly depends upon the human machine interface design, training program, procedures, workplace environment, staffing and qualification. According to PNRA Regulations PAK/911, attention should be paid by the designer to make the design human friendly to minimize the chances of human errors and their effects. Further, the control rooms of plants shall contain the equipment which provides sufficient information on parameters associated with individual plant systems and equipment to confirm that the necessary safety actions can be initiated safely. Various safety actions are required to be automated so that operator action is not necessary within a justified period of time from the onset of anticipated operational occurrences or design basis accidents. In addition, appropriate information is required to be available to the operator to monitor the effects of the automatic actions.

Sufficient I&C equipment is required to be available, preferably at a single location (supplementary control room) that is physically and electrically separate from the control room, so that the reactor can be placed and maintained in a shut downstate, residual heat can be removed, and the essential plant variables can be monitored should there be a loss of ability to perform these essential safety functions in the control room.

Verification and validation of aspects of human factors is required to be included at appropriate stages to confirm that the design adequately accommodates all necessary operator actions.

The design is required to be aimed at promoting the success of operator actions with due regard for the time available for action, the physical environment to be expected and the psychological demands to be made on the operator. The need for intervention by the

operator on a short time-scale needs to be kept to a minimum. It shall be taken into account in the design that the necessity for such intervention is only acceptable provided that the designer can demonstrate that the operator has sufficient time to make a decision and to act; that the information necessary for the operator to make the decision to act is simply and unambiguously presented; and that following an event the physical environment in the control room or in the supplementary control room and on the access route to that supplementary control room is acceptable.

PNRA Regulations PAK/913 requires that the licensee defines the qualifications and experience necessary for personnel performing duties that may affect safety. Suitably qualified personnel are selected and are given necessary training and instruction enabling them to perform their duties correctly for different operational states of the plant and in the case of an incident or accident, in accordance with the established procedures.

A high level of health and fitness is required for the personnel of nuclear installations. Accordingly, PAK/913 requires that all personnel of the operating organization (licensee) whose duty may affect safety shall be medically examined on their appointment and at subsequent intervals to ensure their fitness for duty and responsibilities assigned to them. Psychological examination is also required for licensed control room operating personnel. In addition, PAK/904 elaborates requirements for health surveillance program of radiation workers. Consideration of human factors aspects is also ensured during subsequent design modifications at NPP.

PNRA evaluates all elements of Human Factors Engineering (HFE) i.e. HFE program management, operating experience review, function requirement analysis and function allocation, task analysis, staffing and qualification. human reliability analysis, human system interface design, procedure development, training program development, verification and validation, design implementation and operation as per requirements of PAK/911, PAK/913, USNRC's NUREG-0800, NUREG-0700 andNUREG-0711.

12.2 Steps Taken by PAEC to Ensure Consideration of Human Factors

K-1 has made several design improvements to enhance human performance and operator oversight in dealing normal as well as abnormal conditions. These include:

a. Efforts to reduce noise in MCR;
b. Installation of protective covers on critical switches to avoid inadvertent operations due to human error;
c. Installation of new Protective Channel Monitoring System (PCM). This system includes installation of new data display, trending, recording, and monitoring system along with all three protective channels instrumentation, analogue and trip signals to provide maintenance aid for the analysis of important systems parameters during problem diagnosing in order to minimize trouble shooting time;
d. Mechanical timers for essential diesel generators were originally installed inside panels are changed to Programmable Logic Control (PLC) based timers for ease of operators;
e. Essential panels' voltages are now made available as per recommendation of WANO-SOER to detect any open phase condition;
f. Provision of operator aids MCR such as Critical Parameter Display System (CPDS) and Safety Parameter Display System (SPDS);

g. Provision of on-line control room parameters and general log on plant network system;
h. Provisions of critical process parameters such as change in primary system inventory, moderator level, reactor power.

FSTS is used for training and qualification of operators at CHASCENT. On the basis of HFE requirements all fidelity related issues are addressed to follow good human factors practices to facilitate the operators. Operators are imparted with rigorous human performance tools training to minimize the chances of error.

Feedback from modifications carried out at C-1 and C-2 against dark panel concept i.e. reduction of undesirable alarms in MCR by changing the alarm logic in order to reduce undue burden on MCR operators were incorporated in design of C-3 and C-4.

At K-2 and K-3 HFE is taken carefully into account in the design of control room system which is composed of Main Control Room (MCR), Remote Shutdown Station (RSS), Technical Support Centre (TSC), Emergency Management Center (EMC) and Local Control Station. The following factors have been considered in the design of Human System Interface (HSI):

a. Taking care of important human actions, reduce the probability of human errors in display and conventional panels;

b. Considering significance, frequency, and sequence of use in the design of consoles/panels layout and displays on Visual Display Units Checking, maintaining, testing of HSI cannot disturb the control and monitor of the plant;

c. Ensuring that the design for human system interface is according to staff configuration under different conditions;

d. Considering periodic testing of protection system actuation and set points for safety related instrumentation in HSI design.

Safety parameters display function (SPDF) and post-accident monitoring (PAM) are integrated in workstations of K-2 and K-3 design. Based on computerized HSI, computerized operating procedures are developed which can help operators to use procedures quickly and conveniently, and satisfy the functional requirements in different operating conditions.

A detailed design review of safety related HMI stations was conducted during Periodic Safety Reviews (PSR) of C-1 & C-2. Walk-downs of control rooms and workplaces were also conducted to evaluate arrangement of controls and displays, movement of operators, viewing angle, alarm arrangement, labeling system, mimics, illumination levels, environment, habitability etc. according to HFE standards. Work load assessment of operators was conducted by using Instantaneous Self-Assessment (ISA) tool. Safety related operating procedures were reviewed to assess their achievability and clarity. Information and control requirements of operators for performing safety related tasks was compared with the information and control available to the operator to validate that sufficient information is available for the operator to perform his tasks.

Since at the time of licensing of C-1 in late 90's, Human Factor Engineering (HFE) program elements and documented analysis as required by NUREG-0711 to develop Chapter-18 of SAR were not available, the same are required to be prepared and submitted to PNRA as a part of C-1 PSR-2 CAP. However, the HFE design activities were performed during the design phase of the plant. Accordingly, C-1 HSI was designed and has been in operation for

more than twenty years and any analysis at this stage is difficult due to limitation in availability of data and relevant expertise. Therefore, safety assessment of HFE of C-1 will be systematically performed with the help of international support to be sought through IAEA.

Through PSA Human Reliability Analysis (HRA), human error probabilities are calculated for the errors that may be due to procedural lapses or operator errors. These inputs are used to improve procedures and operator training on simulator to minimize human errors.

CNPGS has developed Full Scope PSA Level-1 reports and models with updated plant data and configurations including Full Power PSA for Internal Initiators, fire, flood, low power and shutdown and seismic PSA of C-1, C-2, C-3 and C-4 plants as per regulatory requirements.

12.3 Arrangements for OEF in Relation to Human Factors Issues for Nuclear Power Plants (NPP)

The OEF process also identifies and evaluates HFE issues in operating NPPs. The OEF serves as lessons learned from previous experience with related systems. The objective of the OEF is to identify negative features that should not be repeated in new designs and positive features that should be retained. This OEF input is also used to contribute to other review elements of HFE for improvement to avoid the human errors by improving the design, training program and procedures.

PAEC collects the operating experience feedback regarding HFE elements e.g. HMI design, procedures availability, information available, workload. The input is evaluated by the experts and corrective actions are suggested. On the basis of this operating experience feedback, following improvements have been made in C-3and C-4 HFE design:

a. Human Machine Interface (HMI) design of reverse acting controllers has been changed in C-3 and C-4 MCRs. This improvement eliminated the chance of human error due to deficiency in HMI design;
b. Gray background control switches of throttles valves have been replaced by black background control switches in C-3 and C-4 MCRs. This will help operator in differentiating between throttle and discrete valves;
c. Intensity of indicating lights has been increased in C-3 and C-4 MCRs. This improvement will provide the clear indication of equipment status and remove chance of human error due to unclear indication;
d. Provision of training on Loss of Low power AC and DC buses, House load operation and Bypass inoperable system in Full Scope Simulator of C-3 and C-4 MCRs. This improvement will provide hands-on training to the plant operators on above mentioned tasks required to be performed during operation;
e. Addition of new alarms to help MCR operators and local area operators such as Reactor Coolant Pump (RCP) bearing level low in addition to low-low alarm, etc. These alarms will help the operators to avoid reactor trip and equipment damage.

12.4 Verification of Human Factors Considerations by PNRA

PNRA reviews the regulatory submissions and verifies through inspections that the human factors are considered throughout the life of a nuclear installation. Firstly, at the design stage, it is ensured that human factors are considered in the probabilistic safety assessment, design of control rooms, SPDS, safety system bypassed and inoperable status indication system, PAM system, alarm system, full scope training simulator and communication

system. It is also ensured that human factors are considered in development of procedures and training programs. Secondly, during operation stage, regulatory inspections are carried out to verify the work conditions such as lighting, labeling, human machine interface, environmental and habitability issues, etc.

PNRA inspectors witness simulator exercises during training and re-training sessions of operating personnel. They also carry out inspections of operation shift crews to verify compliance with procedures and to assess whether the operator actions are in accordance with the procedures and design intent. Human performance evaluation is also an essential element of safety culture. Inspections and reviews of unusual occurrence reports determine the contribution of human factors in initiation and progression of the event.

While reviewing PSA reports of NPP, it is verified that human factors have been adequately considered and all operator actions are modeled in accordance with actual design. Certain improvements such as provision of Alarm Response Procedures (ARPs) have been made in procedures and training material to minimize operator errors as a result of PNRA review.

Pakistan has, therefore, met the obligations of Article 12 of the Convention.

ARTICLE 13 – QUALITY ASSURANCE

Each contracting party shall take the appropriate steps to ensure that quality assurance programs are established and implemented with a view to providing confidence that specified requirements for all activities important to nuclear safety are satisfied throughout the life of a nuclear installation.

Pakistan has ensured that QAP are established and implemented throughout the life of NPP with a view to provide confidence that specified requirements for activities important to nuclear safety are satisfied.

13.1 Regulatory Requirements

The regulatory requirements for the submission of QAP for site evaluation, construction, commissioning, operation and decommissioning at respective licensing stages, have been stipulated in PNRA Regulations PAK/909.

PNRA Regulations PAK/912 provides basic requirements for establishing and implementing QAP related to the safety of NPP. In addition, various IAEA safety standards are also being followed as part of requirements and guidance for the QAP during various phases of licensing of NPP. These basic requirements apply to overall QAP of licensee, as well as to any other separate QAP submitted at each licensing stage during the life of the NPP. The licensee has to ensure safety in siting, design, construction, commissioning, operation and decommissioning of the NPP. The regulations recognize that all work processes are planned, performed, assessed and improved. These basic requirements apply to all individuals and organizations, including designers, suppliers, constructors, manufacturers and operators of NPP.

QAP is required to provide an inter-disciplinary approach involving many organizational components and is not regarded as the sole domain of any single group. The program is to demonstrate the integration of following principles:

a. Managers provide planning, resources and support to achieve the organization's objectives;
b. Staff performing the work to achieve quality; and
c. Management (at all levels) performing assessments to evaluate the effectiveness of management processes and work performance.

Graded approach based on the relative importance to nuclear safety of each item; service or process is being used.

The management system fulfills the requirements of PNRA "Regulations on Leadership and Management for Safety - (PAK/921)" which are based upon IAEA GSR Part 2.

13.2 Quality Assurance Activities at NPP

PAEC has established a QAP at each NPP in accordance with PAK/912to achieve its safety objectives. The program includes quality policy statement, vision, mission, organizational structure with defined responsibilities and authorities, interfaces, work processes and performance, monitoring and evaluation, reviews and assessments and process control procedures.

13.2.1 Quality Assurance at Corporate Level

Directorate of Quality Management (DQM) is established at corporate level at the PAEC Headquarter to coordinate QA activities in various PAEC establishments, and to have corporate oversight for QA matters. This directorate conducts QA audit of plants, provides guidance to the plants and the corporate management on quality issues and recommends actions for improvements. PAEC has formally issued its nuclear safety policy which encompasses the QA elements such as management's commitment for giving priority to safety over production objectives, compliance with safety regulations and industrial standards for achieving excellence in performance of all activities through highly professional and qualified manpower by utilizing all necessary financial and other resources. PAEC issued its quality policy to ensure safe, reliable and economical functioning of the facilities and work processes.

13.2.2 Quality Assurance at NPP

The NPP in Pakistan have established Quality Assurance Divisions (QAD) staffed with appropriately qualified personnel reporting directly to the highest level of the respective plant management. The QA personnel have been entrusted with necessary authority to ensure the implementation of QAP/MS through surveillance, inspections and audits. Among others QAD have the authority to stop any work or activity which is deviating from the QA requirements. Assessment of QAP/MS is carried out through self and independent assessments. This is done by performing internal and external audits, peer reviews, technical reviews, etc. The purpose of such assessments is to identify weak performance areas. Necessary corrective actions are taken to improve the identified weaknesses.

At K-1, in compliance with the requirement laid down in the Overall Quality Assurance Program (OQAP), the QA activities performed during the reporting period are described in the following paragraphs.

Comprehensive audits were conducted of operation, maintenance, engineering support, chemistry control, health physics, procurement, material management, training and their audit reports were issued. QAD performed inspections and witnessed QA control points during field and control room activities.

During surveillances, deficiencies were highlighted and issued in form of QA finding reports (FRs) and QA Non-Conformance Reports (NCRs) to various Division/Units of the plant. FRs and NCRs were closed out after satisfactory disposition of deficiencies. Procedures of different jobs, change approvals, procurement indents were reviewed from QA point of view. Lectures were delivered to the plant personnel on awareness of QA/QC at training centre.

Findings raised during the external audits by DQM and DOS were implemented and queries raised by DOS and PNRA on "Decommissioning Quality Assurance Program (Phase-1 of KANUPP-1)" were settled down.

The QAD verifies that the work groups clearly understand management expectations to establish and maintain safety culture at K-1. Training and retraining of QA personnel including auditors is a regular activity to maintain and enhance their qualifications and skills.

K-1 QAP for decommissioning was submitted for review and approval by PNRA as part of decommissioning license application.

The QAP of C-1, C-2, C-3 and C-4 encompass all items and activities important to safety and essential for the availability of the plant. The QAD are staffed with adequately qualified and skilled manpower and report directly to respective Plant Manager (PM). In all the activities, QAD emphasize the safety and quality culture.

Through QA surveillance and audit programs, QAD verifies compliance with the established requirements of QAP. Planned as well as general surveillances are carried out of all plant areas within the scope of QAP. Non-Conformance Notice (NCN), System Deficiency Notice (SDN), Non-Conformance Report (NCR), Corrective Actions Report (CAR), and Deficiency Report (DR) are issued during planned or general surveillances and their follow-up is continued for the satisfactory resolution. Internal and external audits are performed according to the audit plans and applicable procedures.

QAD regularly performs inspections and controls the QA activities of contractors through audits and surveillance. Detailed working procedures related to safety and quality undergoes a thorough review by QAD before approval.

According to the Quality Management System (QMS), the contractors and subcontractors are required to execute the quality requirements for procuring items/services. The evaluation of contractors and subcontractors is also carried out as per process defined in QAP to address requirements i.e. supplier evaluation/selection, supplier performance monitoring, etc.

During the reporting period, internal QA audits of different work units of all plants (C-1, C-2, C-3 and C-4) and Directorate of Technical Support (DTS) were performed as per annual QA audit plans. Necessary improvements were made on the basis of QA audit findings. These findings, identified during planned and general surveillances, were issued to relevant work units and their follow-up is being maintained for satisfactory resolution.

Corporate level QA audit of C-1, C-2, and C-4 is also carried out by the Directorate of Quality Management (DQM) audit team. During DQM audit conducted in December 2018, recommendations were made in various areas such as radiation monitoring record of Nuclear Island, procedure adherence and improvements in storage conditions of chemicals and record control, etc. Corporate safety review of C-3 was conducted in April 2019. Total 115 observations were raised in C-3 corporate safety review. Till now 107 observations have been closed and actions on the remaining are in progress.

KNPGS have established a "unified Management System" (MS) for design, procurement, construction, commissioning and operation of K-2 and K-3 in accordance with the requirements of IAEA Safety Standard GS-R-3 and PNRA regulations. The MS covers all activities related to O&M including management, process, implementation, performance and assessment.MS has been implemented by all units of KNPGS in operation and maintenance activities. Non-conformances are dealt according to the severity and safety implications as per procedure. Disposition actions are approved at different levels of the overall QA and regulatory system accordingly.

K-2, K-3 and Directorate of Technical Support (DTS) have established separate QAD which assist Plant Managers and Dir(TS) on QA related matters. K-2 has gone through rigorous review related to operational readiness. Further, IAEA has carried out Pre-OSART of K-2 followed by Pre-Start-up Review (PSUR) by WANO. K-2 has taken concrete measures to improve the deficient areas, highlighted by these independent assessments. K-2 and K-3

perform QA audits of the contractors and sub-contractors to verify compliance with its management system.

During reporting period, QAD K-3 also performed QA audits of its divisions to assess the Operational Readiness of plant prior to Nuclear Fuel loading. WANO pre-startup peer review of K-3 conducted to review 10 plant areas and follow up of action plan is in progress to achieve excellence.

13.3 Quality Assurance Activities of Nuclear Safety Class Equipment Design & Manufacturing Organizations and NDE Service Providers

"Regulations for Licensing of Nuclear Safety Class Equipment and Components Manufacturers" – PAK/907 provide the licensing requirements for manufacturers of Nuclear Safety Class Equipment and Components. The licensee is required to submit QAP, process flow diagrams and manufacturing schedules for selection of inspection control points. The manufacturing activities are performed according to quality plans which describe the processes, testing, examination, reviews and checks in sequential order. Processes are required to be qualified according to the requirements of applicable codes and standards. Mock-ups are also required to be manufactured to qualify the processes. Manpower involved in manufacturing process and testing is qualified according to the requirements of relevant regulations, codes and standards.

PNRA performed numerous control point inspections of safety class equipment manufacturers during the equipment manufacturing of K-2 and K-3 projects to verify the compliance with the requirements of PNRA regulations and to assess the implementation and effectiveness of QAP in compliance with the applicable codes and standards.

During the reporting period, PNRA conducted the QA administrative inspections of safety class equipment manufacturers and NDE service providers for regulatory oversight indifferent areas such as organization and interface, training and qualification, non-conformance control, corrective and preventive actions, procurement control, work control and OEF, design change control, document and record control, calibration control, handling, storage, packaging, preservation, delivery conditions and assessment of safety culture.

After authorization by PNRA to perform NDE activities in nuclear island of NPP, National Center for Non Destructive Testing (NCNDT) has participated in In-Service Inspection (ISI) activities of C-1 RFO-11, 12, 13, & 14, C-2 RFO-04, 05, 06, 07 & 08, C-3 RFO-01, 02, 03 & 04 and C-4 RFO-01, 02 & 03 activities and were witnessed by PNRA to verify the compliance of management system and regulatory requirements.

13.4 Regulatory Oversight of QA Activities

PNRA periodically performs regulatory inspections of overall QA activities of its licensees. During routine and non-routine inspection activities, verification of compliance of QA is also carried out. QA administrative inspections of licensees, contractors and subcontractors performing safety related activities are regularly performed as per defined frequency while comprehensive inspections of specific areas of QA are performed as and when required. During these inspections, PNRA verifies compliance with the requirements of PNRA regulations and the license conditions. The routine inspections at the sites of nuclear installations are conducted by PNRA Regional Directorates at Karachi and Chashma, while the QA administrative inspections at the design organization, manufacturing facilities and

service providers are conducted by Directorate of Nuclear Safety located at PNRA Headquarter.

QA administrative inspection of licensee, main contractor and subcontractor of K-2 and K-3 projects performing safety related activities were carried out by PNRA during the reporting period. The purpose of these inspections was to verify that the project activities are being managed according to the approved Quality Management System, agreed codes and standards and relevant procedures by main contractor and its sub-contractors for the fulfillment of its delegated responsibilities.

PNRA also verifies the implementation and effectiveness of QAP in compliance with the applicable codes and standards by participating in control point inspections during equipment manufacturing of K-2 and K-3 projects.

Pakistan has, therefore, met the obligations of Article 13 of the Convention.

ARTICLE 14 –ASSESSMENT AND VERIFICATION OF SAFETY

Each contracting party shall take the appropriate steps to ensure that:

i. **Comprehensive and systematic safety assessments are carried out before the construction and commissioning of a nuclear installation and throughout its life. Such assessments shall be well documented, subsequently updated in the light of the operating experience and significant new safety information, and reviewed under the authority of the regulatory body;**
ii. **Verification by analysis, surveillance, testing and inspection is carried out to ensure that the physical state and the operation of a nuclear installation continue to be in accordance with its design, applicable national safety requirements, and operational limits and conditions.**

Pakistan ensures that comprehensive and systematic safety assessments and verifications are carried out throughout the life of NPP. Such assessments are well documented and subsequently updated in the light of operating experience and latest developments and are reviewed by PNRA. Verification by analysis, surveillance, testing and inspections is carried out to ensure that the physical state and operation of NPP continue to be in compliance with national regulations and in accordance with its design objectives, and operational limits and conditions.

14.1 Regulatory Requirements

The Ordinance 2001 empowers PNRA to establish requirements for regulating nuclear installations in Pakistan. PNRA has a well-established regulatory framework which requires systematic safety assessments, periodic safety reviews and verification of safety at all licensing stages of NPP.

PNRA Regulations PAK/909 establish requirements on licensing process and documents submission for all stages of nuclear installations starting from site registration to removal from regulatory control. The Regulations PAK/910 establish requirements for detailed site assessment for site registration (further details are provided in Section 17.1 of the report). PNRA Regulations PAK/911 establish design requirements for structures, systems and components important to safety and for preventing or mitigating the consequences of events that could jeopardize safety. These regulations require comprehensive safety assessments including complementary techniques of deterministic safety analysis and probabilistic safety analysis. The regulations also require that at the design stage of a nuclear installation, a comprehensive safety analysis shall be carried out to identify all sources of exposure for evaluation of radiation doses which could be received by workers and the public, as well as potential effects on the environment. Furthermore, measures are required to ensure that the radiation protection and technical safety objectives are achieved, and that radiation doses to the public and to site personnel in all operational states, including maintenance and decommissioning, do not exceed the prescribed limits and are in accordance with ALARA principle.

The safety analysis takes into consideration:

a. All planned normal operation modes of the plant.
b. Plant performance in anticipated operational occurrences.
c. Design Basis Accidents.
d. Event sequences that may lead to a severe accident.

PNRA Regulations PAK/911 establish requirements to ensure robustness of the engineering safety design through the concept of Defence in Depth (DID) barriers to withstand Postulated Initiating Events (PIEs) and measures to mitigate the radiological consequences. These include engineered safety features, onsite accident management procedures, and emergency preparedness and response measures to mitigate radiation exposure if an accident occurs.

PNRA Regulations PAK/913 require the licensee to perform a systematic safety re-assessment of the plant for its entire operational lifetime. In such a re-assessment, operating experience and significant new safety information from all relevant sources also need to be taken into account by performing PSR. The regulations also include the assessment and verification requirements during operation phase, in particular, the assessment and verification of design modifications. It is emphasized that modifications involving plant configuration and the operational limits and conditions shall conform to the requirements set in the Regulations.

The requirements of PSR for revalidation of OL and assessment for licensing beyond design life have also been stipulated in the PNRA Regulations PAK/909.

14.2 Assessment and Verification of Safety and Regulatory Supervision of NPPs

The safety of the plant is continuously assessed and verified during all phases of the plant life. This includes self-assessments, reviews of plant safety performance by the plant operational safety committee, QAD, engineering department, health physics division and relevant operation and maintenance departments. Independent reviews and assessments by corporate safety body and international reviews such as WANO peer review, OSART mission, etc. are conducted. NPPs have established effective systems for recording deficiencies identified during the assessment and verification activities, event analysis, corrective actions and maintaining records for authorization and control of temporary changes to the equipment, procedures, etc. ISI programs are implemented to assess and verify the condition of plant structures, systems and components important to safety at appropriate intervals. All these systems of safety verification take into account the requirements of applicable regulations, codes, standards and international practices.

In addition, all NPPs underwent rigorous safety assessments after the Fukushima Daiichi accident. Pakistan also adopted the IAEA Action Plan on Nuclear Safety to incorporate lessons learned from the Fukushima Daiichi accident.

PNRA performs regulatory review and assessment as one of its core functions which provides foundations for effective regulatory decision making. PNRA has well established regulatory review process and technically competent staff. Regulations PAK/909 establish requirements for licensing of nuclear installations and relevant submissions required for different stages of licensing. PNRA performs regulatory review of various licensee submissions such as SAR, programs and plans, PSR Reports, other technical or topical reports etc., at various stages of the licensing process. In addition, PNRA reviews and approves the safety related design modifications involving plant configuration and the operational limits and conditions to ensure conformance with the design requirements.

PNRA also performs regulatory inspections to verify compliance with the regulatory requirements during all phases of NPP such as Siting, Design, Construction, Installation, Commissioning, Operation and Decommissioning. The inspection plans of each phase are

prepared in line with project schedule under intimation to the licensee. The inspection plans are focused on ensuring that plant construction, equipment manufacturing, installation and commissioning are in conformity with the design intent, and that the operation is within the approved limits and conditions.

14.2.1 Assessment and Verification of Safety at K-1

Safety of K-1 is being assessed and verified through overall QAP, periodic safety reviews, AMP, ISI program, surveillance and testing program, preventive and corrective maintenance program, corporate review, safety performance indicator program and self-assessment program. All safety related change approval or design modification cases are submitted to PNRA after deliberation by K-1 Safety Committee for review and approval before implementation. K-1got extension in OL till the end of September 2018 was mainly based on but not limited to safety assessment and verification of the following:

a. Steam generator tube plugging trend.
b. Feeder pipes inspection.
c. Time limited ageing assessment of the intake channel and containment building.
d. Installation of active and passive fire suppression system in cable gallery and auxiliary area.

The OL was further extended for shut down state till April 2019 to perform mainly steam generator condition assessment including sludge lancing and fuel channel integrity assessment (FCIA).

In continuation of the implementation of FRAP at K-1, significant modifications, safety upgrades, safety assessments and verifications where performed which mainly include:

a. Re-evaluation of seismic capacity of all structures for the revised seismic input of 0.2g.
b. Preparation of procedures to decide when to vent the containment.
c. Construction of 8ft retaining wall around the area enclosing the emergency boiler feed water system equipment and medium pressure injection system.
d. Strengthening of fire water system.
e. Installation of spray header over the bay to further enhance the safety of spent fuel bay.
f. Revision of SAMG based on supporting analysis.
g. Provision of PAM system is in progress.

K-1submittedrevisedFire PSA to PNRA for review and the review process was completed.

A dedicated group is working on ageing management at K-1 which also takes support from external organizations on Ageing Management activities.

During the reporting period, all safety related activities were performed under surveillance by QAD of K-1 and regulatory oversight of PNRA.

<u>The major maintenance activities performed in 2018-2019 include:</u>

i. <u>Reactor Fuel Channel Integrity Assessment (FCIA);</u>
ii. <u>Turbine Generator overhauling job;</u>
iii. <u>Power transformer (GE-T1) overhauled;</u>
iv. <u>Secondary side cleaning with the improved version of locally developed inter tube lancing water equipment and fretting of feeder with instrumentation tubing.</u>

The OL of K-1 was extended till December 31, 2020 based upon the limitation of spent fuel storage capacity. In order to cope with this issue, 04 certified storage casks, each filled with spent nuclear fuel bundles were transferred to KANUPP Spent Fuel Dry Storage (KSFDS) building for creating more space to accommodate fresh fuel at KANUPP spent fuel storage bay.

In December 2020, K-1 OL was extended till issuance of decommissioning license. In August 2021, K-1 was permanently shutdown and is being maintained in safe shutdown till issuance of Decommissioning License.

Fifty years of safe operation vetted the programs implemented for safety of K-1 like overall QAP, periodic safety reviews, Ageing Management Program (AMP), ISI program, surveillance and testing program, preventive and corrective maintenance program, corporate review, safety performance indicator program and self-assessment program. KANUPP Safety Committee continuously reviews all safety maters and approves the changes in safety/safety related systems. During the reporting period, all safety related activities were performed under surveillance by QA division of K-1 and regulatory oversight by PNRA.

14.2.2 Assessment and Verification of Safety at C-1

C-1 is operating safely since commencement of its operation and completed eleventh (11^{th}) twelfth (12^{th}), thirteenth (13^{th}) and fourteenth (14^{th}) RFO during the reporting period. C-1 performs assessment and verification of safety during all operational states under its QAP to ensure compliance with regulatory requirements. Technical support from the designer and vendor is also sought when required. The plant has an Operational Safety Review Committee which performs review and assessment of the safety evaluation, modifications, events reports, plant operations, etc. Independent assessments are carried out in the form of audits, surveillance and internal or external peer reviews. All safety cases for modification are approved by Operational Safety Review Committee before submission to PNRA for approval.

At C-1, a comprehensive program is established for design modification control, which defines roles and responsibilities of the work units involved in the plant modification process. A set of procedures covering all aspects of design modifications, from the initial request, prioritization, safety screening, preparation of the design package supported by relevant analysis (if needed), review and preparation of installation package to the evaluation of impact, testing and commissioning requirements, documentation revision and modification handover, etc. exists. Provision for control of temporary modifications is available in regulatory framework and is carried out through a specific procedure developed by licensee. The activities related to verification of safety are stipulated under the Technical Specifications which include surveillance program, periodic testing, ISI Program, etc. to ensure safety while maintaining high availability and reliability of components.

A dedicated group working on ageing management is in place at CNPGS which also take support from external organizations on Ageing Management activities.

PNRA conducted Pre-RFO inspections to verify radiation protection trainings of manpower hired for RFO activities and same was also verified during daily general surveillances. In addition, Foreign Material Exclusion (FME) and industrial safety issues were verified by PNRA inspectors during general surveillances and control point inspections as well. As per experience feedback, the corrective actions taken by C-1 against degradation of anti-radiation epoxy paint at RX and NX were verified through a dedicated inspection.

Some of the safety improvements made at C-1 are as follows:

i. Installation of moisture barrier at reactor building perimeter and development of program for the provision of ISI of steel liner and moisture barriers.

ii. Expanding the scope of preventive maintenance program for I&C components such as solenoid valves, level switches, limit switches of main feed water and main steam isolation valves etc.

iii. Installation of Passive Autocatalytic Re-combiners at C-1 (as of C-2)

iv. Provision of primary emergency makeup to ensure core cooling in beyond design basis accidents;

Second PSR of C-1 was conducted in 2020 following which PNRA revalidated the operating license of C-1 up to December 2030. As a result of 2nd PSR at C-1, following upgrades were implemented to enhance safety.

i. Condition assessment of WUH cooling tower;

ii. Verification and validation of SAMGs.

During the reporting period thirteenth (13th) and fourteenth (14th) RFO were conducted at C-1. Major activities performed during RFOs are given below:

i. Overhauling of Turbine-Generator;

ii. Cleaning and inspection of Main Condenser-I and 2;

iii. Sludge Lancing of SG-A & B; and

iv. Overhauling of WCP-OI PO and WCP-03PO.

14.2.3 Assessment and Verification of Safety at C-2

C-2 is operating safely since commencement of its operation. During the reporting period C-1 underwent fourth (4th), fifth (5th), sixth (6th), seventh (7th) and eighth (8th) RFO. All the routine inspections and tests were carried out to ensure safe operation within the safety margins. PNRA witnessed selected activities and conducted various regulatory inspections during the RFO. During this outage, replacement of main body flange gasket and mechanical seal of Residual Heat Removal Pump-B (SRH-OIBPO) was performed. C-2 was shut down for its 5thRFO in January 2018. Replacement of three stage mechanical seal and oil seal of RCP-A, overhauling of fuel manipulator crane, eddy current testing of steam generator-A tubes were performed. During 6th RFO, in-core nuclear instrumentation distribution cabinet, 3rd stage mechanical seal and oil seal of RCP-B and motor of condensate booster pump were replaced. Leakage from main body of residual heat removal pump was also rectified during this outage.

During the 7th Refueling Outage (RFO-7) of C-2 main activities performed included Turbine-Generator overhauling including associated equipment, replacement of 3rd stage mechanical seal of RCP-A, sludge lancing of SG-A/B, structural inspection of Rx, Nx, WES suction bay, WUH basin and other tanks and FRAP modifications of primary and secondary emergency core cooling make-up.

C-2 has similar modification process as that of C-1 and safety modifications are approved by Operational Safety Review Committee before submission to PNRA for regulatory approval. The activities related to verification of safety are stipulated by the Technical Specifications

which include the surveillance requirements, periodic testing and In-Service Test Program, etc.

PNRA performed a number of reviews and inspections at C-2 based on submitted design modifications and international experience feedback to verify the safety and compliance with regulatory requirements. As a result of these inspections some of the safety improvements are hereunder;

a. Installation of moisture barrier at reactor building perimeter and development of program for the provision of ISI of steel liner and moisture barriers.
b. Shifting of air supply of pneumatic valves from emergency air storage tanks of Compressed Air System (SCA) to their respective air storage tanks.
c. Design Modification for Sludge Lancing and Tele-Visual Inspection of SGs to recover any loose metal parts.

During the reporting period, the first PSR of C-2 was completed following which PNRA renewed its Operating License upto December 31, 2031.

14.2.4 Assessment and Verification of Safety at C-3 and C-4

The design of C-3 and C-4 was assessed at various levels for verification of safety. The designer performed detailed assessment at the first level and it was verified independently by the personnel who were not directly involved in the design. At the second level, the design was assessed and verified by C-3 and C-4 as owner. Modifications in the design followed the same course for approval as for the original design as required by the PNRA regulations PAK/913.

PNRA carried out inspections during installation and commissioning of C-3 and C-4 components and systems. After completion of commissioning tests (stage A), acceptance of Final Safety Analysis Report and other documents stipulated by PNRA Regulations PAK/909, demonstration of implementation of emergency preparedness plan and completion of physical protection measures, fuel load permit was granted to C-3 and C-4 by PNRA.

C-3 and C-4 were granted OL on May 02, 2018 upon satisfactory completion of the safety review which mainly includes Final Safety Analysis Report (FSAR) along with other submissions and verification of safety on site by PNRA.

C-3 and C-4 are operating safely since commencement of their operation. Both of these Units completed their three RFOs. Major maintenance activities performed during the outages include overhauling of turbine, pumps, containment integrated leak rate test, structural integrity test and activities related to ISI. All the routine inspections and tests were carried out for operability and safety margin verifications.

C-3 completed its second (2^{nd}) and third (3^{rd}) RFO during the reporting period. The 2^{nd} Refueling Outage (RFO-2) of C-3 continued from July to September 2019. Major jobs performed during this outage are mentioned below:

i. In-service inspection of Reactor Pressure Vessel (RPV) and Reactor Internals
ii. Replacement of all three stages of Mechanical seal of RCP
iii. Replacement of ex-core power range detector

3^{rd} Refueling Outage (RFO-3) of C-3 continued from November to December 2020. Major jobs performed during the outage are described below:

i. Replacement of all three stages of mechanical seal of RCP

ii. Eddy current testing of tubes of Steam Generator-A
iii. Anti-Condensation heater problem of residual heat removal pump motor (SRH-00I APO) resolved
iv. Overhauling of pressurizer safety valve (SRC-V01 B)

C-4 completed its First (1st), second (2nd) and third (3rd) RFO during the reporting period, Major maintenance activities performed during the outages include overhauling of pumps, overhauling of turbine and ISI of RPV. All the routine inspections and tests were carried out for verifications of operability and safety margin.

C-3 and C-4 are implementing design modification process similar to C-1 and C-2 for the safety related modifications. A comprehensive program is established for design and modification control, which defines roles and responsibilities of the work units involved in the plant modification process. A set of procedures covering all aspects of design modifications from the initial request, prioritization, safety screening, preparation of design package, review and preparation of the installation package to the evaluation of impact, testing and commissioning requirements, documentation revision and modification handover etc. exists. Control of temporary modification is done through a specific procedure which requires safety screening and evaluation similar to the one for the permanent modifications. All safety cases for modifications are approved by the Operational Safety Review Committee (OSRC) before submission to PNRA for approval.

During the reporting period, PNRA performed various safety reviews and inspections at C-3 and C-4 based on submitted design modifications and international experience feedback to verify the safety and compliance with regulatory requirements. As a result of these reviews and inspections some safety improvements were made which are described below:

a. Repairing of moisture barrier at reactor building perimeter and development of program for the provision of ISI of steel liner and moisture barriers
b. Installation of Thermal Fatigue Monitoring System and Establishment of Monitoring Program to assess the degradation of normally stagnant piping systems attached to Reactor Coolant System (SRC) and surge line of reactor coolant Pressurizer due to thermal stratification, thermal stripping and thermal oscillation phenomena
c. Automation of restoration of illumination to area under surveillance of IAEA cameras in RX and FX
d. Installation of smoke detectors in each RCP rooms

In continuation of the implementation of FRAP at CNPGS, significant progress has been made in terms of safety improvement, assessment during the reporting period which mainly included the following:

a. Regulatory review of Probabilistic Seismic Hazard Analysis (PSHA) for Chashma site
b. Re-assessment of important systems such as SRC, safety injection system, I&C cabinets etc. against PGA of 0.32g
c. Pre-requisites are underway regarding modifications for primary emergency makeup to ensure long term heat removal and inventory makeup following Extended Loss of AC Power (ELAP) and loss of Ultimate Heat Sink (UHS) and self-driven pumps and safety related piping and valves.
d. Pre-requisites are underway regarding modifications for Secondary emergency makeup to ensure long term heat removal following ELAP and Loss of UHS and self-driven pumps and safety related piping and valves.

e. Pre-requisites are underway regarding modifications for SFP makeup using portable self-driven pump through Fire water pools as well as fire tenders at all Units of CNPGS.

The activities related to verification of safety are stipulated by the Technical Specifications which include the surveillance requirements, periodic testing and ISI Program etc. PNRA verified the implementation of Surveillance Requirements during RFO along with verification of qualification of ISI activities and verification of Industrial safety and Foreign Material Exclusion (FME) implementation.

14.2.5 Assessment and Verification of Safety at K-2 and K-3

During the reporting period, construction activities at K-2/K-3 remained in progress and regulatory oversight of important activities was carried out by PNRA. PAEC has submitted FSAR for K-2 and K-3 to PNRA along with application for introduction of nuclear material into the reactor core.

During the reporting period, construction activities i.e. assembling of containment building Dome Liner, installation of Reactor Pressure Vessel, Steam Generators and Containment Dome Steel Liner, construction of containment dome, welding of K-2 reactor coolant piping, pre-stressing and grouting activity of K-2 inner containment tendons, installation of 132kV overhead transmission line and water intake gate shaft structure have been completed. Moreover, placement of K-2 Pressurizer in the containment building and construction of water intake and outfall tunnels remained in progress.

During the reporting period, construction of K-2 was completed and permission for first criticality was granted in February 2021. Subsequently, the plant was connected with the grid in March 2021. During the reporting period, construction activities i.e. construction of K-3 containment shell and dome liner, welding of K-3 dome liner has been completed. Moreover, welding of K-3 Reactor Coolant Piping, construction of K-3 containment building, remained in progress.

During the reporting period, the construction of K-3 was completed and fuel load permit was issued by PNRA in December 2021. Currently Stage-B commissioning tests of various systems are in progress under regulatory oversight of PNRA. In addition, QA administrative inspections of the following organizations were conducted by PNRA during the reporting period:

a. Engineering Office and Technical Division of K-2 and K-3;
b. China Nuclear Industry Fifth Construction Company (CNF) at K-2 and K-3 site;
c. Technical Division of K-2/K-3 -2017;
d. Project Engineering Office -2017;
e. China Nuclear Industry Fifth Construction Company (CNF) at K-2 and K-3 site;
f. Experience Feedback Division of CZEC -2019;
g. CNPE for commissioning activities -2019;
h. CNPO for PSI activities -2019;
i. KINPOE -2020;
j. QA administrative inspection of K-2 operational readiness;
k. QA administrative inspection of K-3 operational readiness.

Pakistan has, therefore, met the obligations of Article 14 of the Convention.

ARTICLE 15 - RADIATION PROTECTION

Each Contracting Party shall take the appropriate steps to ensure that in all operational steps the radiation exposure to the workers and the public caused by a nuclear installation shall be kept as low as reasonably achievable and that no individual shall be exposed to radiation doses which exceed the prescribed national dose limits.

Pakistan has taken appropriate measures to ensure that during all activities at NPP such as operation, maintenance, refueling, and implementation of design modifications, etc., the exposure to workers and public is kept as low as reasonably achievable and that no individual is exposed to radiation which exceeds the prescribed national dose limits.

15.1 Regulatory Requirements

PNRA is responsible for controlling, regulating and supervising all matters related to radiation protection. PNRA Regulations PAK/909 require submission of a radiation protection program, radioactive waste management program and radiological environmental monitoring program as part of the pre-requisites for issuance of OL.

The radiation protection objective described in PNRA Regulations PAK/911 states that, it is to be ensured that in all operational states, radiation exposure within the installation or due to any planned release of radioactive material from the installation is kept below prescribed limits and As Low As Reasonably Achievable (ALARA), and to ensure mitigation of the radiological consequences. The safety objectives for design of nuclear installations require that nuclear installations shall be designed and operated so as to keep all sources of radiation exposure under strict technical and administrative control.

PNRA Regulations PAK/913 requires that the licensee shall establish and implement a radiation protection program to meet the objective of PNRA Regulations PAK/911. The regulations also require that implementation of the radiation protection program shall be ensured by the appointment of qualified Station Health Physicist who advises the plant management and shall have authority to participate in establishing and enforcing the safety procedures. The qualification of Station Health Physicist of NPP is also defined in the Regulations PAK/913. The dose limits for radiation workers and public during normal operation are given in PNRA Regulations PAK/904 and are reproduced in Annexure–VI of this report.

Moreover, PNRA regulations require submission of detailed information regarding dose estimation for the RFO, bases for estimation, methodology adopted and procedure followed to optimize radiation doses and to implement ALARA principle. PNRA is also in the continual process to establish guidance documents for licensee so that regulatory expectations to ensure radiation protection are fully met.

15.2 Radiation Protection at NPP

PAEC is committed to take all appropriate steps to ensure that occupational radiation exposure to personnel working at its NPP is maintained as per ALARA principle. Moreover, PAEC is committed to take all reasonably practical steps to achieve the following two safety objectives:

a. The risk of prompt fatality to an average individual in the vicinity (within 2 Km) of an NPP, as a result of an accident at the plant, should not exceed 0.1 % of the sum of

prompt fatalities due to other accidents to which the members of the public are generally exposed.

b. The risk of cancer fatalities to population around NPP (within 15 Km) that might result from the operation of the plant should not exceed 0.1 % of the sum of all cancer fatalities.

The NPPs have developed policies and procedures, for the protection of workers, public and environment from the harmful effects of radiation, in conformance with the PNRA regulatory requirements. It is ensured that in all operational states radiation exposure within the plant or due to any planned release of radioactive material from the plant is kept below prescribed limits and ALARA, and that the measures to mitigate the radiological consequences arising from any design basis accidents are in place. To ensure optimization of radiation exposures to the workers and to implement ALARA principle, administrative dose limits below the regulatory dose limit have been established for each NPP.

At NPPs, monitoring and surveillance of doses to radiation workers is conducted and records are maintained. For environmental monitoring, continuous air sampling and ambient dose level monitoring are performed. Environmental samples of air, water, soil, vegetables, fruits, milk, meat etc., are collected and analyzed for estimation of radionuclide content at frequencies prescribed in the radiological environmental monitoring programs. On-site and Off-site environmental monitoring points are selected at different locations. Environmental Dosimetry using TLDs is also performed to record the cumulative dose level on quarterly basis. PNRA normally reviews the records of sampling and analysis of the licensees, however, independent verification of plant monitoring samples is also conducted. PNRA has also established its own environmental monitoring laboratory for verification of results submitted by the licensee.

At all NPP sites, radiological environmental monitoring is conducted during pre-operational phase, operational phase and emergency phase. The records are maintained and reports are generated on quarterly and annual basis. Radiological environmental monitoring is performed for the following:

a. To determine ambient gamma radiation dose rate in pre-operational phase, operational phase and emergency phase and to assess the public doses contributed by NPP operation
b. To determine level of activity in air, soil, water, vegetables, crops and milk etc. during the three phases and to assess the internal gamma doses to public attributed by NPP operation
c. To meet the surveillance requirement of codes and standards to consolidate the basis for enhancing public confidence in NPPs safe operation

15.2.1 Radiation Protection at K-1

At K-1, radiation exposure is controlled by means of job planning, pre-job briefing, frequent radiation surveys, radioactive contamination control, and regular training to keep the doses well below the regulatory limits. In addition, a Radiation Control Officer (RCO) is designated for radiation intensive jobs with prime responsibility of participating in each activity right from planning to execution. Internal radiation dose is controlled by providing suitable respiratory protection equipment and reducing the airborne contamination level. Internal uptake limits have been defined, which are followed strictly.

Radiation exposure to the public is kept ALARA by controlling the release of radioactive effluents from the plant. This is done by on-line monitoring of the releases, removing the Tritium contents from containment building atmosphere, filtration of gaseous effluent before releasing to the environment, decay and dilution of liquid effluent before its release, collection, processing and safe storage of solid radioactive waste, etc. As a result, both the gaseous and liquid effluent radioactive releases from the plant are well below the Derived Release Limits for K-1.

An environmental monitoring program is in place that includes regular radiation ambient dose rate monitoring at plant periphery and in different areas of Karachi city. This is done by placing TLDs and high volume air sampling system away from the plant. Environmental samples from the vicinity of plant are collected and analyzed. The records show no appreciable change in ambient background dose level and environmental sampling analysis data during the reporting period.

Annual collective doses to the workers during 2016, 2017, 2018, 2019, 2020 and 2021 at K-1 were 1.48 man-Sv, 2.23 man-Sv, 3.830 man-Sv, 2.23 man-Sv, 1.38 man-Sv and 1.41 man-Sv respectively. Annual average individual dose for these years were 2.41 mSv/man, 3.99 mSv/man, 6.36 mSv/man, 3.47 mSv/man, 2.42 mSv/man and 3.20 mSv/man respectively. The graphical representation of these doses is shown in Annexure–VII.

Tritium released through gaseous radioactive effluents during 2016, 2017, 2018, 2019, 2020 and 2021 were 111.843 TBq, 202.977 TBq, 213.304 TBq, 234.445 TBq, 223.284 TBq and 350.522 TBq respectively. Whereas, Noble gases released through gaseous effluents during 2016, 2017, 2018, 2019, 2020 and 2021 were 0 TBq, 0.032 TBq, 0 TBq, 0.132 TBq, 0.148 TBq and 0.00367 TBq respectively. On the average, the cumulative gaseous releases remained less than 1% of annual release limits.

The liquid effluents released to sea during 2016, 2017, 2018, 2019, 2020 and 2021 contained 122.042 TBq, 68.755 TBq, 52.476 TBq, 64.25 TBq, 52.715 TBq and 85.695 TBq of Tritium respectively. Generally, these were less than 0.01 % of annual release limit for Tritium. Gross beta-gamma radioactivity released to sea during 2016, 2017, 2018, 2019, 2020 and 2021 were 0.0056 TBq, 0.0067 TBq, 0.0134 TBq, 0.00938 TBq, 0.00255 TBq and 0.00322 TBq respectively which are less than 1% of annual derived release limit for gross beta-gamma radioactivity. The effluent releases of K-1 are shown graphically in Annexure–VIII.

The ambient dose levels for K-1 for the years 2016, 2017, 2018, 2019, 2020 and 2021 were 87 nGy/h, 75 nGy/h, 75 nGy/h, 74 nGy/h, 72 nGy/h and 71 nGy/h respectively which are depicted in Annexure-IX.

15.2.2 Radiation Protection at C-1, C-2, C-3 and C-4

In order to implement the RPP, CNPGS Units have established the necessary organizational setup headed by Manager Health Physics Division. Health Physicists are responsible for implementing the RPP for handling and monitoring radioactive materials, including sources and secondary source materials. This program conforms to PNRA Regulations and includes:

a. Conformance to working procedures for implementing the radiation protection program
b. Survey of all incoming and outgoing shipments that may contain radioactive material

c. Investigation and documentation of any radiological incident to minimize the potential for recurrence and for reporting these incidents to PNRA in accordance with the regulations
d. Periodic surveys of radiation, contamination and airborne activity
e. Record keeping of occupational radiation exposures and reporting to the PNRA
f. Provision of personnel and other radiation monitoring equipment and their periodic calibration
g. Establishment of access control points to separate potentially contaminated areas from uncontaminated areas and survey of tools and equipment before removal from a controlled area
h. Issuance of Radiation Work Permits (RWP) in accordance with the station radiation control procedures
i. Bioassay program including whole body counting or a urinalysis sampling to measure the uptake of radioactive material
j. An environmental radiological monitoring program to measure any effect of the installation on surrounding environment
k. Dose estimation before maintenance work in contaminated areas
l. Establishment of rubber areas.

C-1

Annual collective doses for C-1 during 2016, 2017, 2018, 2019, 2020 and 2021 were 23.390 man-mSv, 477.261 man-mSv, 400.336 man-mSv 215.45 man-mSv, 188.60 man-mSv and 227.87 man-mSv respectively. Annual average individual dose for these years remained 0.019 mSv/man, 0.273 mSv/man, 0.232 mSv/man, 0.125 mSv/man, 0.123 mSv/man and 0.067 mSv/man respectively. Similarly, maximum individual doses for C-1 during 2016, 2017 and 2018, 2019, 2020, and 2021 were 0.655 mSv, 4.491 mSv, 5.592 mSv, 3.777 mSv, 3.874 mSv and 2.341 mSv respectively. The graphical representation of these doses is shown in Annexure–VII.

At C-1 all liquid and gaseous effluents are monitored before release to the environment. Liquid effluents are released from C-1 into the discharge canal, which falls into the Indus River. For C-1, gaseous effluents released during 2016, 2017, 2018, 2019, 2020 and 2021 were 0.001 TBq, 0.003 TBq, 0.003 TBq, 0.003 TBq, 0.004 TBq and 0.004 TBq respectively. On the average these releases remained less than 1% of annual release limit. Liquid effluent releases for C-1 during the years 2016, 2017, 2018, 2019, 2020 and 2021 were 3.59 TBq, 9.58 TBq, 6.61 TBq, 1.70 TBq, 1.77 TBq and 0.148 TBq respectively. These releases were less than 1% of annual release limit. C-1 effluent releases are shown graphically in Annexure–VIII.

C-2

Annual collective doses for C-2 during 2016, 2017, 2018, 2019, 2020 and 2021 were 526.586 man-mSv, 9.255 man-mSv, 298.590 man-mSv, 250.977 man-mSv, 249.437 man-mSv and 2.689 man-mSv. However, annual average individual dose during 2016, 2017, 2018, 2019, 2020 and 2021 were 0.333 mSv/man, 0.009 mSv/man, 0.206 mSv/man, 0.163 mSv/man, 0.177 mSv/man and 0.005 mSv/man respectively. Similarly, maximum individual dose for C-2 during 2016, 2017, 2018, 2019, 2020 and 2021 were 6.411 mSv, 0.368 mSv, 3.172 mSv, 3.036 mSv, 2.252 mSv and 0.205 mSv respectively. The graphical representation of these doses is shown in Annexure–VII.

Gaseous effluent released from C-2 during 2016, 2017, 2018, 2019, 2020 and 2021 were 0.388 TBq, 0.0148 TBq, 0.00233 TBq, 0.046 TBq, 0.103 TBq and 0.0006 TBq respectively. Liquid effluent released from C-2 during 2016, 2017, 2018, 2019, 2020 and 2021 were 1.88 TBq, 0.589 TBq, 0.450 TBq, 1.27 TBq, 0.724 TBq and 1.15 T Bq respectively. The releases were less than 1% of annual release limits C-2 effluent releases are shown graphically in Annexure–VIII.

C-3

Annual collective dose for C-3 during 2016, 2017 and 2018, 2019, 2020 and 2021 were 0.916 man-mSv, 8.361 man-mSv, 271.798 man-mSv, 248.083 man-mSv, 147.727 man-mSv and 2.012 man-mSv respectively. Annual average individual dose for these years were remained 0.00044 mSv/man, 0.00817mSv/man, 0.1474 mSv/man 0.16 mSv/man, 0.1081 mSv/man and 0.00374 mSv/man respectively. Similarly, maximum individual dose for C-3 during 2016, 2017 and 2018, 2019, 2020 and 2021 were 0.041 mSv, 0.795 mSv,4.172 mSv, 3.212 mSv, 1.801 mSv and 0.072 mSv respectively. The graphical representation of these doses is shown in Annexure–VII.

At C-3, all liquid and gaseous effluents are monitored before release to the environment. Liquid effluents are released from C-3 into the discharge canal, which falls into the river Indus. For C-3, Gaseous effluents released during 2016, 2017, 2018, 2019, 2020 and 2021 were 0 TBq, 0.000994 TBq, 0.00102 TBq, 0.0004 TBq, 0.000017 TBq and 0.0002 TBq respectively. On the average these releases remained less than 1% of annual release limit. Liquid effluent releases for C-3 during the years 2016, 2017, 2018, 2019, 2020 and 2021 were 0.786 TBq, 0.89 TBq, 2.80 TBq, 2.40 TBq, 1.31 TBq and 0.089 TBq respectively. These releases were less than 1% of annual release limit. C-3 effluent releases are shown graphically in Annexure–VIII.

C-4

Annual collective doses for C-4 during 2017, 2018, 2019, 2020 and 2021 were 4.834 man-mSv, 2.586 man-mSv, 262.416 man-mSv, 124.387 man-mSv and 3.568 man-mSv respectively. Annual average individual dose for these years remained 0.009 mSv/man, 0.003 mSv/man 0.144 mSv/man, 0.109 mSv/man and 0.005967 mSv/man respectively. Similarly, maximum individual doses for C-4 during 2017, 2018, 2019, 2020 and 2021 were 0.647 mSv, 0.259 mSv, 7.022 mSv, 1.921 mSv and 0.146 mSv respectively. The graphical representation of these doses is shown in Annexure–VII.

For C-4, Gaseous effluents released during 2017, 2018, 2019, 2020 and 2021 were 0.014 TBq, 0.00939 TBq, 0.000795 TBq, 0.002350 TBq and 0.001090 TBq respectively. On the average these releases remained less than 1% of annual release limit. Liquid effluent released from C-4 during the years 2017, 2018, 2019, 2020 and 2021 were 0.0655 TBq, 4.53 TBq, 1.04 TBq, 0.973 TBq and 0.0000157 TBq respectively. These releases were less than 1% of annual release limit. C-4 effluent releases are shown graphically in Annexure–VIII.

It has been noted that the ambient dose levels at the boundary of Chashma Site were generally close to the level of natural background during the reporting period. The average ambient dose levels at Chashma site during the years 2016, 2017, 2018, 2019, 2020 and 2021 were 122.9 nGy/h, 124.9 nGy/h, 121.4 nGy/h, 101 nGy/h,102 nGy/h and 104n Gy/h respectively (Annexure-IX).

15.2.3 Radiation Protection at K-2

At K-2, radiation exposure is controlled by means of job planning, pre-job briefing, frequent radiation surveys, radioactive contamination control, and regular training to keep the doses well below the regulatory limits. Internal radiation dose is controlled by providing suitable respiratory protection equipment and reducing the airborne contamination level. Internal uptake limits have been defined, which are followed strictly.

Radiation exposure to the public is kept ALARA by controlling the release of radioactive effluents from the plant. An environmental monitoring program is in place that includes regular radiation ambient dose rate monitoring at plant periphery and in different areas of Karachi city.

Annual collective doses for K-2 during 2021 is 4.618 man-mSv and Annual average individual dose for the year 2021 is 0.00748 mSv/man.

15.3 Classification of Areas and Radiation Zones

According to PNRA Regulations PAK/904, the radiation areas are classified into two parts i.e. supervised and controlled areas for the purpose of controlling the occupational exposure. At K-1, controlled area is divided into 4 zones on the basis of dose rates. Zone 1 and Zone 2 contain no radioactive equipment and is kept free of contamination at all times. Zone 3 includes service area for active equipment and materials that are potential sources of contamination. Zone 4 is Radiation Controlled Area (RCA) which is further classified into 3 radiation areas.

The RCA of C-1, C-2, C-3 and C-4are classified into five (05) radiation zones based on dose rates:

a. Zone R1 includes the areas that do not contain radiation sources and their adjacent areas;
b. Zone R2 includes some operating rooms for equipment containing radiation sources, corridors, operating hall in the refueling and storage building, and some equipment rooms with very low activity, etc;
c. Zone R3 includes the areas outside the personnel hatch, emergency hatch and equipment hatch, cable penetration area, and equipment rooms containing lower activity. The thickness of shielding wall between two neighboring equipment is designed to satisfy the dose rate limit of this zone;
d. Zone R4 includes limited entrance areas. Application for permission is required in advance to enter these areas;
e. Zone R5 are normally prohibited areas. Only personnel having Radiation Work Permit (RWP) with prior approval can enter these areas if it is extremely necessary under accident conditions, and they are required to have a careful and approved plan in advance.

15.4 Dose Constraint

For KNPGS, dose constraint limit is 0.26 mSv/year. For CNPGS, dose constraint limit for normal operation, taking into account effluent releases from each Unit, is 0.25 mSv/year. However, dose constraint is being revised to justify compliance with regulatory requirements regarding release limits for CNPGS site and for individual Unit as well.

15.5 Verification of Implementation of Radiation Protection Program

Performance of the NPP is continuously monitored to verify compliance with radiation protection requirements. In this regard, PNRA performs regulatory inspections and reviews various reports of the licensees to verify compliance with radiation protection and radiological environmental monitoring programs. The regulatory inspections in the area of radiation protection are an essential part of annual inspection plan of PNRA Regional Directorates. During these regulatory inspections, various aspects of implementation of radiation protection program are verified which includes; development and implementation of ALARA plans for activities involving radiation exposures, compliance with the procedures, provision of personal protective gear to workers, availability and accuracy of personal and area monitoring equipment, radiation dose records for radiation workers and records of radioactive releases from NPP. It has been observed during the reporting period, that the doses to radiation workers remained well below the regulatory limits and the average dose received by an individual remains less than a fraction of the annual dose limit. Similarly, in the entire operating history of NPP in Pakistan the gaseous and liquid effluent releases have been well below the derived release limits. The licensee report the ambient dose levels at NPP to PNRA quarterly and annually. PNRA has observed that the ambient dose levels at the boundary of K-1, K-2, C-1, C-2, C-3 and C-4 are generally close to the level of natural background.

Pakistan has, therefore, met the obligations of Article 15 of the Convention.

ARTICLE 16 - EMERGENCY PREPAREDNESS

i. **Each Contracting Party shall take the appropriate steps to ensure that there are on-site and off-site emergency plans that are routinely tested for nuclear installations and cover the activities to be carried out in the event of an emergency. For any new nuclear installation, such plans shall be prepared and tested before it commences operation above a low power level agreed by the regulatory body.**

ii. **Each Contracting Party shall take the appropriate steps to ensure that, insofar as they are likely to be affected by a radiological emergency, its own population and the competent authorities of the States in the vicinity of the nuclear installation are provided with appropriate information for emergency planning and response.**

iii. **Contracting Parties which do not have a nuclear installation on their territory, insofar as they are likely to be affected in the event of a radiological emergency at a nuclear installation in the vicinity, shall take the appropriate steps for the preparation and testing of emergency plans for their territory that cover the activities to be carried out in the event of such an emergency.**

Regulatory framework and national arrangements are in place to respond to nuclear or radiological emergencies in the country. Emergency Preparedness and Response (EPR) arrangements are documented in emergency response plans which include both on-site and off-site emergency response measures to deal with the consequences of potential accident conditions at NPP and their impact on the public residing in surrounding areas. These plans also integrate National Nuclear and Radiological Emergency Response Plan (NRERP) established under the Nuclear Emergency Management System (NEMS) to respond to a nuclear or radiological emergency having impact at national level.

16.1 Emergency Plans and Programs

16.1.1 Regulatory Requirements

Under the Ordinance, PNRA is empowered to ensure that EPR arrangements are in place at its licensed facilities and are documented in relevant on-site and off-site emergency plans. PNRA "Regulations for Licensing of Nuclear Installation(s) in Pakistan-(PAK/909)" and "Regulations on Management of a Nuclear or Radiological Emergency-(PAK/914)" set the requirements for NPPs to establish and demonstrate EPR arrangements before introducing nuclear material into NPP.

Based upon IAEA GSR Part 7, PNRA has recently developedrevision-1 of the Regulations PAK/914 which establishes detailed requirements including general, functional and infrastructure requirements for EPR. These Regulations require the licensees to establish an emergency management and response system commensurate with the potential hazards associated with facilities and activities which mainly include the following arrangements:

a. Identification of potential emergency situations, notification and activation of relevant response organizations;
b. Taking mitigatory measures to normalize the situation;
c. Providing information to the public;
d. Taking urgent protective measures for public;
e. Protecting emergency workers and helpers;
f. Managing the medical response and agricultural countermeasures;

g. Managing radioactive waste and non-radiological consequences;
h. Analyzing the nuclear or radiological emergency and the emergency response.

These regulations also require the licensees to establish emergency response organization, develop plans and procedures, maintain readily-available equipment related to emergency response centers and facilities, conduct training courses and exercises and ensure quality assurance in all activities related to EPR.

As per regulatory requirements, licensees are bound to clearly specify and assign, in advance, the roles and responsibilities of all stakeholders/parties for preparedness and response for a nuclear or radiological emergency. The responsibilities of all the parties including decision makers are defined in respective emergency plans and a coordination mechanism is established for implementing the decisions both at on-site and off-site areas. PNRA reviews and approves the emergency plans and ensures that the plans are demonstrated regularly through emergency exercises.

PNRA Regulations PAK/914 (Rev.1) also requires the licensee to perform a comprehensive safety analysis to identify all sources of exposure and to evaluate radiation doses that could be received by workers at the facility and the public as well as potential effects on the environment. Full range of postulated events are required to be considered, including emergencies involving a combination of a nuclear or radiological emergency with a conventional emergency such as an earthquake, tsunami, fire etc. It is required that the nature and extent of emergency arrangements for preparedness and response shall commensurate with the potential magnitude and nature of the hazards associated with the facility or activity. PNRA has defined criteria for hazard categorizations of facilities and activities in PNRA regulations which are in line with IAEA requirements and guidelines. The assessment of hazards is described in Safety Analysis Report and emergency plans of the NPP. The plans also describe the functions and interfaces of safety and security organizations and their integration in case of nuclear or radiological emergency.

The Regulations require that on-site and off-site emergency response are effectively managed and coordinated. Clear command and control system for the response to nuclear or radiological emergencies both at on-site and off-site areas are in place and tested regularly. As per regulatory requirement and for effective coordination in response to an emergency, on-site and off-site Emergency Control Centre (ECCs) are required to be established by the facility and the local government respectively. Organizational interfaces among all major response organizations are required to be defined.

The Regulations require the licensee to take, all appropriate measures to save lives during emergency situations. The arrangements need to be made for taking appropriate actions for the protection of emergency workers, alerting permanent, transient and special population groups, taking urgent protective actions, protecting supplies of food and water, imposing restrictions on the immediate consumption of locally produced food and milk, monitoring and decontaminating evacuees, caring for evacuees, alerting special facilities; the control of access and the restriction of traffic. It is required to identify Emergency Planning Zones (EPZ) and distances for which arrangements shall be made for taking urgent protective actions and other response actions. The generic criteria for taking urgent protective actions and other response actions are defined in the Regulations. The reference levels for emergency and existing exposure situations are described in National Nuclear and Radiological Emergency Plans which are further supported by Operational Intervention Levels (OILs) defined in the emergency response plans of each facility.

The instructions for warning and informing public in EPZ are required to be provided in local languages. Accordingly, predefined statements in national and local languages are prepared and made part of emergency plans.

PNRA regulatory requirements are in line with IAEA safety standards which demonstrate an effort to harmonize the national EPR arrangements with international arrangements. The regulatory requirements related to EPR are being revised based on IAEA General Safety Requirements on "Preparedness and Response for a Nuclear or Radiological Emergency-GSR Part 7".

16.1.2 National Emergency Management Infrastructure

West Pakistan National Calamities (Prevention and Relief) Act of 1958 provides for the maintenance and restoration of order in areas affected by calamities, and relief against such calamities. This Act was mainly focused on organizing emergency response.

The institutional and policy arrangements were further strengthened by promulgation of the National Disaster Management Ordinance 2007 (NDMO) in the aftermath of the 2005 earthquake. Under NDMO, Government of Pakistan established a National Disaster Management Commission (NDMC) headed by the Prime Minister under National Disaster Management Act, 2010.

The National Disaster Management Act, 2010 established NDMA to serve as the focal point and coordinating body to facilitate implementation of disaster management. All stakeholders including government departments, agencies and Armed Forces work through and form a part of NDMA in all stages of Disaster Risk Management.

PNRA has the mandate to ensure, co-ordinate and enforce preparation of emergency plans for actions to be taken by relevant authorities following foreseeable types of radiological emergencies that might affect the public.

PDMA and DDMA have been established respectively at the provincial and district levels of the country. The NDMA has formulated a National Disaster Response Plan (NDRP) after extensive cross-sectored consultations. NDRP seeks to upgrade the country’s ability to cope with all conceivable disasters. To achieve this purpose, complete range of disaster management activities from preparedness to response have been addressed. The formulation outlines a framework for emergency response at different levels of the government structure; identifies roles and responsibilities of various stakeholders, and lays down coordination mechanism for activities involving the United Nations, Non-Governmental Organizations (NGOs), civil society organizations, public and private sector and media to harness the full national potential for efficient disaster management. Details on functions and responsibilities of national, provincial and district level disaster management authorities and other stake holders are given in the NDRP.

In case of a nuclear or radiological emergency, the licensee is responsible to implement response actions at the site while local government implements the protective measures in offsite areas. The responsibilities of the licensees in case of nuclear or radiological emergencies and coordination with District and Provincial Governments and other off-site organizations are defined in respective onsite and offsite emergency plans.

NDMA is supported by organizational set-ups at provincial and district levels by PDMA and DDMA respectively. At the district level, the District Coordination Officer (DCO), the leading officer of the DDMA has been empowered to take decisions in consultation with the Site

Emergency Director of the facility. Additionally, under the NRERP, necessary coordination and liaison is maintained with all the stakeholders including:

a. Strategic Plans Division (SPD);
b. Pakistan Nuclear Regulatory Authority (PNRA);
c. Pakistan Atomic Energy Commission (PAEC);
d. National, Provincial, District Disaster Management Authorities (NDMA, PDMA and DDMA respectively);
e. Federal and Provincial Ministries and local response organizations;
f. Armed Forces.

Under the National Command Authority (NCA) Act 2010, the existing National Emergency Management Infrastructure is being further strengthened with the establishment of national Nuclear and Radiological Emergency Response Plan (NRERP). The NRERP is under review and will be finalized with the consultation of all stakeholders.

On occurrence of an incident or an accident, emergency response plans will be implemented by respective NPP and recommendations for public protective actions will be made from ECC to district government / DDMA for implementation in off-site areas, while keeping corporate offices of PNRA and PAEC informed. The Department of Safety established at PAEC headquarters notifies Nuclear and Radiological Emergency Support Center (NURESC) established under NEMS regarding emergency level/status, it's up/down gradation, response actions and coordination requirements with other national organizations. For the consequence management of nuclear or radiological emergency, national capabilities are in place, covering areas of emergency response, scientific and technical support in the form of Hazard Assessment and Advisory Team (HAAT), Radiological Assistance Groups (RAG), Aerial Survey and Support Team (ASST), Radiation Emergency Medical Response Teams and fixed environmental radiation monitoring Labs at NPP sites along-with Mobile Radiation Monitoring Labs (MRML). In addition to these, fixed environmental radiation monitoring labs at PINSTECH (PAEC) & PNRA HQs Islamabad and MRML in other big cities are functioning to cater for the need of environmental radiation monitoring and in case of a nuclear or radiological emergency.

The emergency management is overseen by NRERP Oversight Committee (OSC), comprising senior decision makers and technical experts. This committee facilitates critical decisions related to emergency response, accident management, and accident consequences including recovery and restoration phase of an emergency.

In order to implement NRERP and facilitate EPR activities, a Nuclear and Radiological Emergency Support Center (NURESC) has been established with following main functions:

a. Act as national focal point for receipt of information on any nuclear or radiological emergency and oversee consequence management activities at national level;
b. In case of nuclear emergencies arising at NPP, NURESC would augment the capabilities of response organizations by providing advanced radiation detection system and arrange additional support for implementing off-site protective measures;
c. Coordination with the nuclear facilities to ensure communication of requirements of offsite assistance to concerned DDMA and arrange assistance required from the armed forces;
d. Augments the resources of other stakeholders in managing nuclear emergencies;

e. Render technical expertise and assistance to other national agencies, especially NDMA in managing nuclear and radiological emergencies;
f. Provides technical input to NRERP Oversight Committee for public communication related to nuclear and radiological incidents or accidents;
g. Maintains close contact with NDMA and act as liaison point for off-site emergencies;
h. Facilitates capacity building of stakeholders to strengthen emergency preparedness and response;
i. Maintains database of stakeholders and resources.

16.1.3 PNRA Roles and Functions related to Emergency Preparedness and Response

Pakistan is a State Party to the Convention on Early Notification of a Nuclear Accident and Convention on Assistance in the case of a Nuclear Accident or Radiological Emergency. In Pakistan, PNRA is the national competent authority as well as point of contact for notification and coordination with IAEA and other State Parties under both the Conventions. For fulfillment of obligations under these Conventions and the Ordinance, PNRA has established National Radiation Emergency Coordination Centre (NRECC) which acts as National Point of contact under these Conventions. Main functions of NRECC during a nuclear or radiological emergency are:

a. Notification and information exchange with licensee, response organizations, government and IAEA;
b. Assessment and prognosis of the situation by using in-house tools, deployment of PNRA Radiation Monitoring Teams (RMTs), collection and analysis of environmental samples during an emergency;
c. Coordination with and provision of advice and assistance to Government, off-site response organizations through NRERP and other Member States under IAEA Response and Assistance Network (RANET);
d. Provision of public information through press releases, briefings and updates on PNRA website and responding to queries raised by national and international organizations.

NRECC is supported and equipped with communication system, radiation detection equipment, personal protective equipment, Mobile Radiological Monitoring Labs (MRMLs) and technical support team comprising of experts from various directorates of PNRA. A network of Radiation Monitoring Teams (RMTs) equipped with radiation monitoring, personal protective and communication equipment and MRMLs comprising of trained scientists and technicians have been established by PNRA which are geographically located at major cities and NPP sites across the country. These include Islamabad, Chashma, Karachi, Peshawar, Multan and Quetta. The purpose of these teams is to provide technical assistance to local and national response authorities and to perform independent assessment of any situation involving accidental radiation exposures, if needed.

As per regulatory requirements and approved emergency plans, the licensee is required to keep NRECC informed about any protective measures being taken at onsite area or recommended for implementation at off-site. Multiple implementation procedures related to PNRA Response Plan for Nuclear and Radiological Emergencies are approved.

NRECC receives information about radiation incidents and emergencies occurring worldwide through IAEA. These events are usually related to events at nuclear facilities, overexposure of workers or members of the public, theft or loss of radiation sources, contamination or spill

of radioactive material, malfunction of equipment, etc. NRECC analyzes the information received, identifies the lessons learnt and implement these lessons for improvement of radiation safety in the country. PNRA also shares the information of incidents occurring worldwide with the relevant licensees.

NRECC was modernized and upgraded under a project of Public Sector Development Program (PSDP) in line with the decision of the Government of Pakistan to increase share of nuclear power in electricity generation. Under this project, capabilities of NRECC were improved for technical assessment of emergency situation, reliable communications, timely notification and sharing of information and effectively advising the Government and relevant organizations who shall implement protective measures in case of a nuclear accident or radiological emergency.

16.1.4 Implementation of Emergency Preparedness Measures by the Licensees of NPP Classification of Nuclear and Radiological Emergencies

As per regulatory requirements, the licensees classify the emergencies into four classes for taking interventions to protect the workers and public as per PAK/914 (Rev. 01).

a. **General emergencies** at facilities in hazard category I or II involving an actual or substantial risk of release of radioactive material or radiation exposure that requires urgent protective actions off the site. Upon declaration of this class of emergency, actions shall be promptly taken to mitigate the consequences to protect people within the Precautionary Action Zone (PAZ) or Urgent Protective Zone (UPZ) as appropriate.
b. **Site emergencies** at facilities in hazard category I or II involving a major decrease in the level of protection for those on the site and near the facility. Upon declaration of this class of emergency, actions shall be promptly taken to mitigate the consequences, to protect people on the site and to make preparations to take protective actions off the site if this becomes necessary.
c. **Plant emergencies** at facilities in hazard category I, II or III involving a major decrease in the level of protection for people on the site. Upon declaration of this class of emergency, actions shall be promptly taken to mitigate the consequences and to protect people on the site. Emergencies in this class can never give rise to an off-site hazard.
d. **Standby** at facilities in hazard category I, II or III involving an uncertain or significant decrease in the level of protection for the public or people on the site. Upon declaration of this class of emergency, actions shall be promptly taken to assess and mitigate the consequences and to increase the readiness of the on-site and off-site response organizations, as appropriate.

The details of the initiating conditions and actions to be taken during these emergencies are defined in the emergency plans and procedures.

Main Elements of Emergency Plans of NPP

All the operating NPP have developed on-site and off-site emergency plans. These emergency plans describe on-site and off-site response organizational setups, classification of emergencies, assessment and declaration of emergencies, emergency facilities, on-site and off-site notification systems, emergency planning zones and distances, generic criteria, Reference Levels & OILs, environmental dose measurement and assessment facilities, application of protective measures, recovery operations, termination of emergency, public

information, records and reports pertaining to exercises and drills, etc. Emergency plans also give brief details of plant systems, demography and regional climatology. The on-site and off-site emergency response organizations of all NPPs are described in the emergency plans covering the role of each responsible person during an emergency situation. Emergency facilities like ECC, auxiliary ECC, communication facilities, radiation monitoring system, Post Accident Monitoring System (PAMS), medical facilities, decontamination facilities, etc. are described in the respective emergency plans.

Moreover, PAEC Emergency Response Coordination Center (PERCC) has been established at PAEC Headquarter. This center operates round the clock. PERCC coordinates response activities in case of emergencies at nuclear installations and is a focal point for receiving notification of emergency at PAEC facilities processed and forwarded to the relevant authorities. Under the NRERP, PERCC coordinates with NURESC for response activities including measures to minimize the radiological exposure risk to the general public and the environment. This Center is equipped with state-of-the-art facilities; including high quality diverse communication channels.

There are two types of response organizations called on-site emergency response organization and off-site emergency response organization. The on-site response organization consists of Site Emergency Director and different type of emergency support and advisory groups. Off-site response organization consists of head of local government and all supporting departments. Functions of these response organizations are defined in emergency plans. Positions have been assigned to all those who will perform response functions in case of a nuclear accident or radiological emergency. Organizational coordination and interfaces among all major response organizations have been established.

The effectiveness of emergency plan is demonstrated in an integrated exercise before the commencement of operation of a NPP and periodically repeated with a pre-defined frequency during the operation phase as per regulatory requirements. The plans are updated in the light of experience gained from the exercises and drills, if required.

The initial assessment of the accidents and determination of associated emergency class is specified in relevant plant procedures to be exercised by the on-duty shift supervisor under intimation to the Site Emergency Director (SED). After the situation comes under control and the plant is brought to a safer mode, shift supervisor terminates the emergency with the authorization of SED.

During the reporting period, a common on-site emergency plan was established at CNPGS. Earlier, each unit had a separate onsite emergency plan and all units had a joint procedure for interface during a nuclear emergency defining communication links between ECC and MCR in case of emergency at C-1, C-2, C-3 and C-4. In case of emergency at any one Unit, the respective SS notifies all other Units and the same class of emergency is declared at CNPGS. Consequently, all the Units perform actions in accordance with their respective emergency plans and procedures.

According to Emergency Plan of CNPGS Emergency Response Organization' (CERO) is responsible for initiation and completion of recovery operation and is regarded as Recovery Organization while Technical Support Centre (TSC) is meant to provide technical support to the MCR crew in case of emergency at each Unit. All CERO and TSC are activated by SS in case of emergency.

CNPGS off-site Emergency Plan is endorsed both by the district as well as provincial governments for the implementation of protective measures in off-site areas. The CNPGS "Off-Site Emergency Plan" identifies off site organizations defines its scope and functions. It also identifies various protective measures to be implemented by the off-site response organizations for public safety during the course of emergency at CNPGS under the supervision of District Co-ordination Officer (DCO) Mianwali. Communication and co-ordination with the district is tested through different exercises and drills.

Karachi Nuclear Power Generating Station (KNPGS) has two operational units (K-2 and K-3) and one unit (K-1) is permanently shutdown for decommissioning. KNPGS has a common on-site and off-site plan. The on-site emergency plan covers on-site emergency preparedness and response arrangements. The off-site emergency plan is duly approved by Provincial Disaster Management Authority (PDMA) Sindh. The off-site plan describes the response actions required to be taken to protect public in case of emergency at KNPGS. PDMA Sindh has constituted and notified Karachi Radiological Emergency Response Committee (KRERC) for timely implementation of off-site response measures to protect the public. Standard Operating Procedures (SOPs) are also in place on specific response actions in line with KNPGS offsite emergency response plan.

At CNPGS and KNPGS, a team of multi discipline reserve force (Operation, Maintenance, and Health Physics Divisions etc.) is formed for assistance during any emergency situation. Interface procedure is in place at KNPGS to implement measures during emergency at any unit.

Emergency Facilities and Equipment at NPP

As per regulatory requirements, emergency facilities and equipment are available for response to any nuclear or radiological emergency at all operating NPP in Pakistan. Each Unit is supported by Emergency Control Room (ECR), Technical Support Center (TSC) with trained manpower, on-site and off-site ECC, communication facilities, SPDS, PAM systems, radiation monitoring systems, on-site and off-site medical facilities, personnel and equipment decontamination facilities etc. The use of such facilities and equipment is continuously tested through conduct of emergency exercises and drills.

16.1.5 Training and Exercises

Training and Exercises conducted at NPP

Emergency preparedness arrangements are being maintained at each operating NPP to ensure that emergency response actions as required under various conditions will be performed effectively within the required timeframe. The maintenance of emergency preparedness is achieved through training and retraining, conduct of exercises and drills, maintenance of emergency facilities and equipment and review and evaluation

The NPP conduct periodic trainings for on-site and off-site response organizations to ensure that emergency response personnel are aware and have sufficient expertise and competence to perform their functions in case of a nuclear or radiological emergency.

At NPP, two types of emergency exercises are conducted i.e. Partial Emergency Exercises (PEE) and Integrated Emergency Exercises (IEE). Both CNPGS and KNPGS conduct partial on-site, partial off-site and integrated emergency exercises once in three (03) years. During partial on-site emergency exercises, on-site response arrangements are tested including emergency class assessment, on-site communication and notification arrangements, search

and rescue of injured and contaminated victims and provision of on-site medical treatment, environmental monitoring, post-accident sampling and analysis, off-site projected dose assessment, recovery to normalization of situation and on-site interface arrangements etc.

During IEE, in addition to the aforementioned on-site measures, the off-site response arrangements are also tested which generally include the following:

a. Notification, activation and coordination with off-site ECC and response organizations;
b. Implementation of protective measures including announcements, evacuation, sheltering, Potassium Iodide (KI) tablets distribution, access control etc. in potentially affected areas;
c. Sample press releases, briefings, medical management of the victims at off-site designated hospitals, demonstration of public screening and decontamination at the evacuee centre etc.

During the reporting period, the emergency exercises at KNPGS and CNPGS have been conducted as per schedule. The frequency and execution dates of the emergency exercises and drills performed at KNPGS and CNPGS are shown in Annexure–X. PNRA inspectors and representatives of PAEC Corporate office witnessed the exercises and made recommendations to the licensee for further improvements.

Training and Exercises conducted by PNRA and other Organizations

PNRA organizes various training courses and workshops on emergency preparedness and response to train its own staff, licensees and off-site response organizations. Some of these activities are arranged in coordination with other national organizations and IAEA under TC projects.

During the reporting period, PNRA organized fifteen (15) local training courses on emergency preparedness and response. The aspects covered during these training courses included regulatory oversight, emergency management system, hazard assessment, public communication, medical response, response to malicious acts, etc. Participants from PNRA, various organizations, hospitals, research institutions, NPP, rescue services, and police, participated in these training courses and were provided with trainings on various aspects of preparedness and response to nuclear and radiological emergencies. PNRA supported other response organizations by providing its technical assistance in conducting training courses regarding response to an event involving nuclear or radioactive material.

A national workshop was also organized in coordination with the IAEA on revised safety requirements "Preparedness and Response for a Nuclear or Radiological Emergency-GSR Part 7" at PNRA Headquarter, Islamabad. PNRA also conducted national workshops on activation and deployment of National Assistance Capabilities (NAC) registered in IAEA Response and Assistance Network (RANET). Further, a National Workshop on RANET including a field exercise for Field Assistance Team (FAT) was also arranged.

PNRA also conducts various emergency exercises to test its own preparedness and response arrangements during different types of emergency situations. These exercises include; Communication Test Exercise (COMTEX) and Mobile Radiological Monitoring Laboratory (MRML) field exercise. COMTEX exercises are conducted, thrice a year, to check availability and reliability of communication channels established with licensees and other relevant national organizations whereas MRML field exercises are conducted,

biannually, to test the procedures and operation of field response teams in different emergency scenarios. Such field exercises are sometimes conducted in different cities, in coordination with and support of regional directorates of PNRA and by involving regional field response teams and PNRA licensees. The exercises conducted during the reporting period are listed in Annexure X.

Being Contracting Party to the Convention on Early Notification of a Nuclear Accident, and to the Convention on Assistance in the Case of a Nuclear Accident or Radiological Emergency, Pakistan participates in various IAEA ConvEx exercises to test its:

a. Communication and notification arrangements;
b. National response arrangements for nuclear or radiological emergency;
c. Provision of international assistance under RANET.

During reporting period, Pakistan participated in various IAEA ConvEx exercises including five (05) ConvEx-2b under RANET (Details of exercises in which Pakistan participated are provided in Annexure X).

A comprehensive NRERP Integrated Training System (ITS) is in place to strengthen emergency preparedness and response capabilities of stakeholders. It ensures that uniform training standards are implemented, besides dovetailing available technical and scientific expertise and resources at different tiers in a cross-cutting manner. Training is being imparted in the form of courses, workshops, table top exercises and field drills to emergency responders, technical experts and other relevant stakeholders. Major areas of the training include hazard assessment and protection strategy, emergency operation management, accident management, radiation monitoring, accident consequences management, decontamination, waste management, recovery and public awareness, emergency notification, public communication and media management.

During the reporting period, following trainings have been conducted:

i. NEMS Training course at Pakistan's Centre of Excellence for Nuclear Security (January 2017);
ii. NEMS Orientation Course at CNPGS (September 2017);
iii. NEMS Orientation Course at K-1 (October 2017);
iv. NEMS Radiation Equipment Training Course at PNRA (February and July 2018);
v. Hands on training on NEMS equipment for Radiation Monitoring Teams (RMTs) at RNSD-III, Karachi (October 2018);
vi. Radiation Portal Monitor (RPM) Operator Training Course at Pakistan Centre of Excellence of Nuclear Security (November 2018);
vii. NEMS Communication Exercise between NURESC and CNPGS (September 2018);
viii. NEMS table top exercise for Aerial Survey and Support Team (ASST) and Radiological Assistance Groups (RAG)" (January 2019);
ix. NEMS equipment course at PCENS, Chakri (February 2019).

16.1.6 Regulatory Review and Control Activities

PNRA has developed a specific mechanism to regulate emergency preparedness and response arrangements at nuclear installations. This mechanism is based on review and evaluation of emergency plans and regulatory inspections including evaluation of emergency exercises and drills.

Review of Emergency Plans

PNRA Regulations require licensees to submit emergency response plans for review and assessment starting from initial stage of licensing. The emergency plans are submitted as part of preliminary safety analysis report of an NPP to ensure the compatibility of proposed emergency plans for both on-site areas and EPZ, with plant design features, site layout, and site location, access routes, surrounding population distributions, land use etc. Later on, detailed plans are submitted to the PNRA along-with FSAR. PNRA reviews and approves the plans against regulatory requirements prior to issuance of fuel load permit. First criticality of NPP is allowed only after successful demonstration of complete emergency preparedness and response arrangements in an emergency exercise. During the 8th review cycle, onsite emergency plan of C-3, C-4 and revised on-site emergency plans of K-1were reviewed and approved by PNRA. However, during the 9th review cycle, combined on-site emergency plan for all units at CNPGS remained under review at PNRA. Emergency plan of K-2/K-3 was reviewed and approved by PNRA.

Evaluation of Emergency Exercises

PNRA evaluates the conduct of periodic emergency exercises and record of trainings as part of regulatory oversight. During this evaluation, it is ensured that the licensee has demonstrated arrangements in place to cope with or minimize radiological consequences in case of an emergency. At least one month prior to the conduct of an exercise, licensee submits emergency exercise scenario for review and approval of PNRA. A team from PNRA Headquarter and respective regional office evaluates the exercises.

On the basis of the evaluation results and experience feedback of emergency exercises and drills, PNRA issues reports describing recommendation for improvements in emergency plans, procedures and practices. A follow-up system exists to ensure the compliance verification of recommendations.

16.1.7 International Cooperation in Emergency Planning and Preparedness

Pakistan is participating in a number of international activities under the auspices of IAEA in the area of emergency preparedness and response.

As a Contracting Party to the Convention on Early Notification of a Nuclear Accident and Convention on Assistance in the Case of a Nuclear Accident or Radiological Emergency, Pakistan is committed to exchange information and consider provision of assistance in case of a nuclear accident or radiological emergency in line with the provisions of the Conventions. The contact points for IAEA are Permanent Mission of Pakistan to the IAEA whereas; PNRA is National Point of Contact and National Competent Authority under the Early Notification and Assistance Conventions. Pakistan participates in IAEA ConvEx exercises which are conducted to test the accuracy, availability and accessibility of contact points, adequacy of response time and capability to exchange information through USIE website.

Response and Assistance Network (RANET)

IAEA Response and Assistance Network (RANET) is an integrated system established under the International Convention on Assistance in the Case of a Nuclear Accident or Radiological Emergency and is meant to provide international assistance to Member States to minimize the radiological consequences of accidents. Being the State Party to the Convention, Pakistan has registered its NAC in four functional areas in the RANET since

2008, which have been revised in 2018. At present, Pakistan is offering assistance in seven functional areas. PNRA is the national contact point under this network. Considering the revised functional areas of assistance, PNRA has also identified various experts from different fields to contribute in RANET. During the reporting period, the NACs registered with RANET have been revised and were updated in IAEA RANET in April 2018. National SOPs for provision and seeking RANET assistance are in place.

As mentioned above, a national workshop was conducted to test the deployment and response capabilities of NAC registered with RANET. RANET members from PNRA, PAEC and representatives from national organizations having roles and responsibilities in the deployment of NACs participated in the national workshop. During the reporting period, a request for assistance was received from Lebanon through IAEA USIE following which an offer of assistance (field assistance in radiation survey and external based support in environmental monitoring) was uploaded on USIE in August 2020.

16.2 Communication with Public about Emergency Planning and Emergency Situations

Pakistan has adopted a two-pronged strategy for implementation of public awareness program. First, as part of implementation of offsite emergency plans, the licensees are implementing site specific public awareness programs in areas around nuclear installations. Assistance from other local organizations such as local governments, educational institutions, etc., is being sought for providing awareness about emergencies and response of the public. Secondly, for the use and awareness of first responders and public, PNRA has prepared and distributed pamphlets and booklets regarding nuclear and radiation emergencies in English as well as in national language. Some of them are "Instructions for General Public during Radiation Emergencies" and "How to Use TLDs" The brochures are prepared both in English language and national language i.e., Urdu.

The CNPGS "Off-Site Emergency Plan" identifies off site organizations, defines its scope and functions. It also identifies various protective measures to be implemented by the off-site response organizations for public safety during the course of emergency at CNPGS under the supervision of local government authorities. Communication and coordination with these authorities are tested through different exercises and drills.

According to its Public Awareness Program (PAP), KNPGS creates awareness to various groups of the public directly in national and local languages. This awareness includes emergency response measures to be taken once emergency is announced. The public queries and concerns on nuclear emergency are addressed directly by health physics personnel. Earlier K-1 and now KNPGS has been conducting integrated emergency exercises periodically and in some portion, public are involved in such exercises to test the effectiveness of emergency plan and PAP.

Further details of activities regarding communication with public are described in section 2.2.9 of the report.

Pakistan has, therefore, met the obligations of Article 16 of the Convention.

ARTICLE 17 – SITING

The Contracting Parties shall take the appropriate steps to ensure that appropriate procedures are established and implemented:

- **i. for evaluating all relevant site-related factors likely to affect the safety of a nuclear installation for its projected lifetime;**
- **ii. for evaluating the likely safety impact of a proposed nuclear installation on individuals, society and the environment;**
- **iii. for re-evaluating as necessary all relevant factors referred to in sub paragraphs (i) and (ii) so as to ensure the continued safety acceptability of the nuclear installations;**
- **iv. for consulting Contracting Parties in the vicinity of a proposed nuclear installation, insofar as they are likely to be affected by that installation and, upon request providing the necessary information to such Contracting Parties, in order to enable them to evaluate and make their own assessment of the likely safety impact on their own territory of the nuclear installation.**

The objective of siting and site evaluation for nuclear installation is to protect the public and the environment from the consequences of radioactive releases during normal operation and accident conditions. Site characteristics that may affect the safety of the NPP and characteristics of the natural environment in the region that may be affected by potential radiological impacts during normal operational states and accident conditions are observed and monitored throughout the lifetime of the NPP. The site evaluation process provides adequate input to the design and safety assessment. The following main aspects are considered in the evaluation of suitability of a site for a NPP:

a. Effects of external events (natural or human induced) occurring in the region of a particular site;
b. The characteristics of a site and its environment that could influence the transfer of radioactive material to public and the environment;
c. Population density, population distribution and the possibility of implementing emergency measures.

PNRA regulatory framework ensures that licensees have adequately investigated the sites with regard to all relevant site characteristics that could be significant to safety.

It is ensured that licensees have developed and implemented adequate procedures for evaluating (initially and periodically) all relevant site related factors likely to affect the safety of NPP for its projected lifetime.

17.1 Regulatory Requirements

Requirements for site evaluation of a NPP are provided in Regulations PAK/909 and PAK/910.

Regulations PAK/909 require provision of NOC from relevant departments of the federal, provincial or local governments prior to site registration for NPP. The applicant has to establish an adequate QAP to control the effectiveness of the execution of site investigations and assessments, and engineering activities performed in different stages of the site evaluation.

For example, before site registration, the applicant has to submit an Environmental Impact Assessment (EIA) report to Environmental Protection Agency (EPA). EPA conducts public hearing to provide the public with adequate, reliable information of the planned project that is of significant importance in creating public trust and acceptance.

A Site Evaluation Report (SER) is submitted to PNRA for site registration in order to ensure that the plant complies with the national rules and regulations regarding environment protection, land and water use, etc. In the evaluation of the suitability of a site for a NPP, various aspects are considered such as external events (natural origin or human induced) occurring in the region of the particular site, the characteristics of the site and its environment that could influence the exposure pathways, population density, population distribution and other characteristics of the external zone that may affect the possibility of implementing emergency measures.

PNRA Regulations on the Safety of Nuclear Installations – Site Evaluation (PAK/910) specify the specific site related requirements which are described in the following sub-sections.

17.1.1 Specific Requirements for Evaluation of External Events

The characteristics of the natural and human induced hazards as well as the demographic, meteorological and hydrological conditions of the NPP site are monitored over the lifetime of the plant. The site characteristics are assessed on the basis of historical evidences, recorded data, site surveys, detailed investigations and analyses in line with international practices and proven engineering techniques. Generally, site specific data (recorded data) are used. Where site specific data is not available, data derived from historical information or data of similar site is used in the evaluation of the suitability of a site for a NPP.

The following external events of natural origin occurring in the region are:

a. Earthquakes and surface faulting;
b. Meteorological phenomena including cyclones, tornadoes;
c. Flooding caused due to tsunami, failure of water control structures;
d. Geotechnical hazards including soil liquefaction, subsurface stability.

These evaluations are used to establish design bases for NPP. Seismic activities, ground water, and meteorological conditions are continuously monitored by instruments installed at NPP sites.

17.1.2 External Human Induced Events

Human induced events (i.e. fire, explosion, missile generation, aircraft crash) are assessed at proposed sites for NPP. Events associated with nearby land, river, sea or air transport (e.g. collisions and explosions) are also considered. The potential for aircraft crashes on the site is assessed with account taken, to the extent practicable, of characteristics of future air traffic and aircrafts to be used. Activities in the region that involve the handling, processing, transport and storage of chemicals having a potential for explosions or for the production of gas clouds capable of deflagration or detonation are identified and considered in the design.

Potential natural and human induced events that could cause a loss of function of systems required for the long-term removal of heat from the core are identified such as the blockage or depletion of a reservoir or cooling tower, ship collisions, oil spills and fires.

17.1.3 Site Characteristics and the Potential Effects of the NPP in the Region

According to the Regulations PAK/910 (Rev.1), licensees of NPP perform assessment on the possible effect of the proposed NPP on individuals, the society and environment and the feasibility of implementing emergency plans. The site and the design for the NPP are examined in conjunction to ensure that the radiological risk to the public and the environment associated with radioactive releases is acceptably low. Programs for meteorological measurements at appropriate elevations and programs for investigation and measurements of the surface and groundwater hydrology to determine the dilution and dispersion characteristics for water bodies are established at NPP sites. Following studies are carried out to determine the dispersion of radioactive material to the population:

a. Atmospheric Dispersion of Radioactive Material;
b. Dispersion of Radioactive Material through Surface Water;
c. Dispersion of Radioactive Material through Groundwater;
d. Population Distribution.

Mechanisms of hazard monitoring are in place at these sites which include seismic instrumentation and meteorological instrumentation station for monitoring of wind and temperature distribution. Furthermore, there is close interaction with the national authorities regarding information on tsunami, flooding and precipitation. The sites are declared as no fly zones and close interaction exists with the concerned aviation authorities for implementation of such arrangements.

The NPP are designed, installed and operated with such stringent standards that the adverse impacts are taken care of in an inherent way.

During the consideration of NPPs sites at Karachi and Chashma, the environmental assessments were integrated with feasibility studies of respective designs to avoid any major adverse impact on the environment. To fulfill the requirements of the EPA Act, the information about the site, project development, plant features and operation was provided in EIA Report. EPA guidelines regarding air emissions, liquid effluents and solid wastes are to be followed by the proponent.

Radiological environmental monitoring programs are in place at KNPGS and CNPGS to analyze the effect of controlled radioactive discharges in the environment during plants operation. Environmental TLDs have been installed for ambient dose rate measurement. Soil, water, milk, grass and fish sampling is done and analyzed from the surroundings of sites. In addition, air borne samples are also collected and analyzed.

The analysis result shows no significant impact of operation of Chashma NPP Units 1-4 and K-1 on the respective environments. K-1 and Chashma NPP Units 1-4 also submit annual reports on environmental monitoring to PNRA.

Measures taken to address the factors affecting the safety of the nuclear installation related to loss of infrastructure and site access following an event are described under section 2.3 of the report.

17.2 Evaluation of NPP Sites

Pakistan has two NPP sites i.e. Karachi and Chashma. Karachi site has three NPP units out of which one unit (K-1) is permanently shutdown, while K-2 and K-3 are in operation. Chashma site has four operating NPP namely C-1, C-2, C-3 and C-4. The design and

operation of these NPP have demonstrated that integrity of all SSC is ensured against all potential hazards considered in siting. PAEC is in process of identifying new NPP sites in line with the Government of Pakistan Energy Security Plan to increase the nuclear energy share in energy mix.

17.2.1 Karachi Site

Karachi site is located along the coastline of the Arabian Sea. It is about 22 Km North-West of Karachi port and 1155 Km in South-West of Islamabad. The regulatory requirements regarding size of the exclusion area, low population zone and population center distance have been fulfilled with respect to each plant individually. The licensee is committed to demonstrate that the simultaneous operation of multiple reactors at site will not result in cumulative radioactive effluent releases beyond the allowable regulatory limits. The impact of all relevant site related factors on plant and the impact of plant on individuals, society and the environment has been evaluated and reassessed.

Karachi site was reevaluated in 2012 to find any potential hazard including earthquake, Tsunami, flooding etc. by following the IAEA Specific Safety Guide SSG-9, various structural elements present in the region were critically studied and PGA was re-estimated. Safety and safety related SSCs of K-1 were assessed against 0.2g instead of the original design basis of 0.1g.

PNRA also directed the licensee to re-evaluate the seismic potential of Murray Ridge situated about 75 Km from the site. Licensee submitted a report regarding seismic potential and Tsunami analysis of Murray Ridge and historic instrumental seismicity along with other geophysical and drilling data which indicates that no tsunami event occurred along Murray ridge in recent and distant past. Whereas, other potential sources related to Karachi site i.e. Makran subduction zone and triple junction were identified and also evaluated with special emphasis. It can be concluded that site is safe against earthquake and tsunami hazards.

Karachi site has been enlisted with Tsunami Early Warning System (TEWS) of Pakistan Meteorological Department (PMD) for dissemination of tsunami warnings. A recent study to analyze the seismic hazard along with tsunami potential, as per new IAEA guidelines, for Karachi site has now been completed. The results are similar to those obtained from earlier studies conducted for earthquake and tsunami potential. Since the Karachi site is not close to any forest or fire source therefore possibility of external fire is ruled out.

K-2 and K-3 site is about 1.5 Km in the North-West of existing Karachi NPP (K-1).The site was evaluated against tsunami, earthquake and all relevant natural and manmade hazards.K-2 and K-3 have been designed for 0.3g. Factors, such as population distribution in the area, future growth and industrial development, have also been given special attention. Comprehensive technical reports for all siting factors such as tsunami hazard analysis from potential sources were provided. Licensee has performed preliminary studies by using Next Generation Attenuation (NGA-2008) relationships to determine PGA values for K-2 and K-3 site. Considering Fukushima experience, licensee has been asked to perform PSHA for the site to take all possible earthquake scenarios for the site. PSHA study for Karachi site been submitted to PNRA and is under regulatory review.

17.2.2 Chashma Site

Chashma site is situated on the left bank of the Indus River about 32 km South of Mianwali district and 280 km South-West of Islamabad. Four NPP (C-1, C-2, C-3 and C-4) at

Chashma site are in operation. The major site studies include demographic and geographic studies, nearby industrial transportation and military facilities, meteorological hazards, hydrological, geological, seismotectonics and geotechnical evaluations as per regulatory requirements. The requirements for size of the exclusion area, low population zone and population center distance have been fulfilled with respect to each plant. Furthermore, the licensee is committed to demonstrate that the simultaneous operation of multiple reactors at site will not result in total radioactive effluent releases beyond the allowable regulatory limits.

Design basis Safe Shutdown Earthquake (SSE) value of 0.25g has been adopted for all Units at the site. Similarly meteorological parameters and flooding have been taken into consideration in the design which provide sufficient margin against these hazards. The phenomena of surge, seiche flooding and tsunami are not relevant for the Chashma site. The floods due to other natural causes as well as those due to multiple failures of upstream dams have also been analyzed and the site has been evaluated as safe against peak flood level. The maximum possible water level expected at the CNPGS site is 201.03 meters Mean Sea Level (MSL), whereas the minimum finished ground level in the plant area is 203 meters around the safety related structures to cater for wind induced effects during flooding, free board etc. For additional margin, flood protection gates for important buildings have been installed.

17.2.3 Re-evaluation of Site Related Factors

The OL for NPP is granted for a period of upto ten (10) years. For the license revalidation, comprehensive re-assessments of site related factors and the effects of external events on the safety of the facility are carried out in the light of national and international standards. In this regard, PSR is performed by the licensee based on IAEA standards. The assessment of safety factor relating to siting covers meteorology, hydrology, geology, seismology, population and use of land. Karachi site was reevaluated after Fukushima Daiichi accident to find any potential hazard including earthquake, tsunami, flooding etc.

In the light of lessons learned from Fukushima accident and international experience feedback, PNRA required licensee to update and re-evaluate relevant site related factors like earthquake potential, tsunami potential and other hydrological and meteorological factors etc. The licensee invited IAEA Site and External Event Design (SEED) review and advisory Mission to review PSHA studies conducted for Chashma site. After inclusion of SEED recommendations, the licensee has submitted the revised PSHA report of Chashma site to PNRA. In addition, PSHA for K-2 and K-3 has been submitted to PNRA and is under review. PNRA also required licensee to monitor the current status of potential earthquake sources around the Plant site.

PNRA also required licensee to update dam break studies for Chashma site using latest available tools and determine the water elevation at Chashma site. Accordingly, CNPGS completed studies to analyze the combined effect of earthquake and flooding due to dam break. The studies revealed that the existing design basis is still valid and provide sufficient safety margin.

Assessment for NPP accidents consequences taking into account the simultaneous accidents at multi-units as well as combined effects of external events has been completed under FRAP. Areas For Improvement (AFI) were identified in terms of additional equipment needed, personnel training and measures to be taken in case of severe accidents, extreme natural hazards and their combined effects. Considering new seismic potential, site access

studies have been completed. CNPGS is planning to construct a 2-lane seismically qualified bridge on CJ link canal to ensure site access in case of multi-unit failure and loss of infrastructure following an event. Work on design of this proposed bridge has been completed and it is now at implementation stage. For CNPGS (multi-unit site), a joint procedure for interface during a nuclear emergency among all the Units is in place which defines communication links between ECC and MCR. In case of emergency at any one Unit, the respective MCR shift supervisor will notify to all other Units and the same class of emergency will be declared. Consequently, all the Units will perform actions in accordance with their respective emergency plans and procedures which are harmonized at station level.

The Safe Shutdown Earthquake (SSE) for K-1 site has been re-evaluated based on new IAEA methodology, and found as 0.2g. The same has now been set as the DBE for K-1 site and all the important buildings and systems have been evaluated for this new DBE. Seismic retrofits where necessary, have been provided. Design basis tsunami height using Japan Nuclear Energy Safety (JNES) organization code in worst hypothetical case is found as 2.84m, while Pump House (P/H) is at 2.74m. However, none of the equipment installed at pump house has been credited for usage during severe accident due to natural hazard. The expected landslide generated tsunami height has also been calculated and found as 3.24m whereas the ground level of K-1 site is 12m above MSL. K-1 and K-2/K-3 sites are safe against submarine landslide generated tsunami. Water recession during tsunami has been analyzed and found maximum probable water recession (net depression) is -4.80m from MSL in worst case scenario with 10% safety margin at the Hawks bay coast near K-1 site. The safety of K-1 intake structure could be compromised if the worst case scenario of wave recession occurred but the probability is very low. As per topographic survey and hydrologic study carried out for K-1 site, the existing drains are sufficient to drain out discharge. However, refurbishment work of existing rain drainage system has been completed.

The maximum water level expected at K-2/K-3 site due to flooding is about 9.13 m. All safety related structures are located above the high flood level. The finish grade level in the plant area is about 12.30 m.

17.3 Consultation with other Contracting Parties

Pakistan is signatory of the Convention on “Early Notification of a Nuclear Accident” and the Convention on “Assistance in the Case of a Nuclear Accident or Radiological Emergency”. The nuclear plant sites are far away from the international borders, which rules out the possibility of any trans-boundary implications. However, in case of an accident, Pakistan will respond according to the obligations under these Conventions with the international community.

Pakistan has, therefore, met the obligations of Article 17 of the Convention.

ARTICLE 18 - DESIGN AND CONSTRUCTION

Each Contracting Party shall take appropriate steps to ensure that:

i. **the design and construction of a nuclear installation provides for several reliable levels and methods of protection (defence in depth) against the release of radioactive materials, with a view to preventing the occurrence of accidents and to mitigating their radiological consequences should they occur;**
ii. **the technologies incorporated in the design and construction of a nuclear installation are proven by experience or qualified by testing or analysis;**
iii. **the design of a nuclear installation allows for reliable, stable and easily manageable operation, with specific consideration of human factors and the man-machine interface.**

Pakistan has taken appropriate steps to ensure that the design and construction of NPP provide methods of protection (defence in depth) against the release of radioactive materials to prevent the occurrence of accidents and mitigate their radiological consequences and that the technologies incorporated in the design and construction of a nuclear installation are proven by operating experience or qualified by recommended testing and analysis.

18.1 Regulatory Requirements

The Regulations PAK/911 establishes requirements to ensure safety of the design of NPP. It requires that the design management for a NPP shall ensure that the SSC important to safety have the appropriate characteristics, specifications and material composition so that the safety functions can be performed to ensure safe and reliable operation of the plant throughout the design life in order to prevent accidents for achieving the prime objective of protection of workers, public and the environment. Moreover, feedback obtained from relevant operational experience of operating plants and results of relevant research programs are required to be incorporated in the design where applicable.

Requirements regarding management of the design changes/modifications are established in Regulations PAK/911 (Rev-2). Moreover, it also requires that the adequacy of design, including independent verification or validation of design tools, design inputs and outputs. Verification, validation and approval shall be completed before implementation of the design.

PNRA regulates the construction activities of NPP in accordance with approved design. In this context, PNRA inspection program provides guidelines for regulatory oversight.

18.2 Implementation of Defence in Depth (DID)

Regulations PAK/911 require that implementation of the concept of DID shall provide a series of levels of defence (inherent features, equipment and procedures) aimed at preventing accidents and ensuring appropriate protection in the event when prevention fails. PAK/911 also requires that the overall safety concept of DID is maintained and the design shall be such as to prevent as far as practicable:

a. Challenges to the integrity of physical barriers
b. Failure of a barrier when challenged
c. Failure of a barrier as a consequence of failure of another barrier

In striving to realize the objectives of its Nuclear Safety Policy, PAEC is committed to design, construct, operate and decommission its NPP with appropriate barriers and engineered safety features to prevent or minimize potential radioactive releases. In order to ensure the

safety of NPP, a multi-barrier concept is applied based on the DID principle in the design and operation of NPP. All SSC of NPP are designed in consideration of internal and external hazards.

K-1 has given due consideration to the concept of DID in implementing actions to meet challenges from severe accidents in wake of Fukushima Daiichi accident.

During second PSR of C-1 and first PSR of C-2, re-evaluation of plant design in relation to application of DID was carried out as per IAEA SRS 46. Review of DID of C-1 identified non-availability of integrated configuration management, probabilistic safety assessment and severe accident analysis, health reports of some of the SSCs, incorporation of updates in revised PSI/ISI program, analysis to ensure SSCs are protected against high trajectory missiles. Whereas, C-2 DID review revealed the missing information regarding improvements in the design and site evaluation based on current national and international practices and operating experience, design assessment of some areas based on output of other safety factors, impact of mitigative strategies on design and changes in design basis documents based on non-safety related design modifications, TS modifications and FSAR modifications. In this regard, necessary corrective actions are being taken.

The design of C-3 and C-4 has given due consideration to the DID principle. Provision of these features in C-2 is primarily based on the severe accident analysis, PSA and international experience feedback.

PNRA has a mechanism for review and assessment of regulatory submissions for issuance of the authorization to licensee. Further, PNRA carries out regulatory inspections during construction, commissioning and operation through regional offices at site.

18.2.1 Implementation of Design Measures for Preventing and Mitigating Accidents

Nuclear installations are adequately designed and constructed for preventing, controlling and mitigating the consequences of anticipated operational occurrences, faulted conditions and design and beyond design basis accidents. Following features have been considered in the design of operating NPP at CNPGS and K-2/K-3:

a. The reactor coolant pressure boundary is designed to have an extremely low probability of abnormal leakage and gross rupture. If any leakage of the reactor coolant takes place, it is promptly detected and isolated to prevent an accidental situation. It is also designed to permit periodic inspection and testing to assess the pressure boundary integrity and leak-tightness;
b. The reactor core is designed to assure that power oscillations, which can result in conditions exceeding specified acceptable design limits, are not possible or can be readily suppressed;
c. The emergency core cooling system is designed to provide adequate emergency core cooling following any loss of reactor coolant at a rate such that any fuel damage that could impair continued effective core cooling is prevented;
d. In case of loss of offsite power, there is provision of house load operation. Cooling through natural circulation up to certain level is also considered. Redundant emergency power sources are also available to accomplish safety functions in case of loss of offsite power. Consideration of station black out (complete loss of power scenario) for prolonged period is also taken into account;
e. The reactor containment is designed so that if any accident occurs, the radioactive material released from the reactor coolant pressure boundary is confined and

reduced over a long period. A system is installed in the containment to control the concentration of any combustible gas as it accumulates inside the containment. The safety features including the containment spray system are considered to lower the pressure inside the reactor containment and to remove radioactivity from containment atmosphere;

f. The reactor protection system is designed to sense abnormal conditions and maintain the reactor in a safe state by automatically initiating the operation of the reactor shutdown system and the engineered safety features. The reactor protection system is designed with redundancy, diversity, and independence to assure that no single failure of any equipment or channel of the system results in loss of the intended safety functions;
g. The SPDS is installed in MCR so that challenge to major safety parameters or functions is promptly recognized. The MCR is designed so that even if any accident occurs, the operator can safely remain inside the MCR to take the necessary post-accident actions. It is also possible in the separate ECR to monitor the essential operating parameters, the radioactivity inside and outside the reactor containment, the radiation releasing passage, and the radioactivity around the nuclear installation in order to sense the accident conditions and to take appropriate actions;
h. Mitigating features for severe accidents such as cavity flooding system, PARs, fast depressurization of containment, large dry containment, thickened containment base-mat, etc., are provided at all nuclear installations;
i. Provision of alternate water and power sources for long term removal of decay heat has been ensured;
j. The ECC are established to assess, coordinate and respond to any radiological emergencies including release of radioactive material.

In addition, new power plants (K-2 and K-3) have been constructed considering insights from VDNS principle-1 are equipped with following additional design features:

a. Provision of double containment along with filtered ventilation system;
b. Passive systems for cooling of containment and secondary side;
c. Provision of water storage for core cooling within the containment (in-containment refueling water storage tank).

18.2.2 Implementation of Design Modifications

During the reporting period, following modifications have been implemented at CNPGS NPP Units:

a. Primary and secondary emergency make-up using portable diesel driven pumps;
b. Hook-up arrangements for connection of medium voltage diesel generators to provide additional source of power supply with 6 kV safety bus bars;
c. Hook-up arrangements for connection of medium voltage diesel generators with emergency diesel generators fuel supply system;
d. Emergency makeup of SFP in case of a beyond design basis event;
e. Hook up arrangements for primary and secondary emergency make up using FLEX (portable diesel driven) pumps;
f. Hook up arrangements and installation of interface box for connection of medium voltage diesel generators to provide additional source of power supply with 6 kV safety bus bar;

g. Design modification of spacer grid guide vanes of fuel assemblies to avoid the phenomena of their deformation and tearing of grid;
h. Segregation of essential and non-essentials loads on 220V AC UPS (SPV mitigation);
i. Auto availability of ultimate heat sink cooling tower fans on Loss of Power (LOP) and Safety Injection (SI) signals;
j. Installation of additional smoke detectors in Reactor Coolant Pump (RCP) motor rooms;
k. Reducing mesh size of Chemical and Volume Control System (SCV) filters;
l. Hook up arrangement for connection of medium voltage diesel generator with emergency buses EMA and EMB.

18.2.3 Review and Regulatory Controls

In order to enhance safety, the licensee perform modifications in safety and safety related structures, systems and components (SSCs) and approved regulatory documents prior to implementation from time to time on the basis of operating experience feedback and to fulfill regulatory requirements. Licensee submits these modifications to PNRA for review and approval as per PNRA regulations and condition of operating license. Moreover, the licensee is required to submit an annual report containing a brief description of modifications, including a summary of the safety evaluation of each modification. Moreover, licensee also maintains a list of changes made in the approved regulatory documents which identifies the changes and their dates of approval.

18.3 Incorporation of Proven Technologies

Regulations PAK/911 require that wherever possible, SSC important to safety shall be designed according to the latest or currently applicable regulations; shall be of a design proven in previous equivalent applications; and shall be selected to be consistent with the plant reliability goals necessary for safety.

For all NPP, it is ensured that technologies incorporated in design are proven by experience or validated by testing and analysis.

Technologies used in design of NPP are proven based on operation experiences. Both C-3/C-4 and K-2/K-3 designers have mastered nuclear safety codes, advanced 3-D designs, simulations validation and professional calculation analysis workstations which are used to build PWR nuclear design. Different tests were performed to ensure higher levels of nuclear safety in the design which include reactor hydraulic integral test, CRDM seismic test, cavity flooding system test, digital I&C equipment, etc.

K-2/K-3 is an advanced 1100 MWe NPP, designed on the basis of design experiences, construction, commissioning and operation of existing NPP. K-2/K-3 is a standard designed 3-loop PWR with high safety features. The design characteristics of K-2/K-3 mainly includes, combination of deterministic and probabilistic approaches and engineering judgment taking latest experience feedback and PSA results as reference. Improvements are made to increase the safety of the plant like, double shell containment, seismic safety through standard design of 0.3g, passive technologies for residual heat removal and containment heat removal, specific features to cope with severe accident etc.

18.4 Design for Reliable, Stable and Manageable Operation

In order to maximize the safety, reliability and stability of NPP in Pakistan, the MCR, the SPDS, the auxiliary control rooms and ECC are designed so that the results of analysis and evaluation of human factors are reflected therein. Details are provided under Article-12.

Pakistan has, therefore, met the obligations of Article 18 of the Convention.

ARTICLE 19 - OPERATION

Each Contracting Party shall take the appropriate steps to ensure that:

i. **the initial authorization to operate a nuclear installation is based upon an appropriate safety analysis and a commissioning program demonstrating that the installation, as constructed, is consistent with design and safety requirements;**
ii. **operational limits and conditions derived from the safety analysis, tests and operational experience are defined and revised as necessary for identifying safe boundaries for operation;**
iii. **operation, maintenance, inspection and testing of a nuclear installation are conducted in accordance with approved procedures;**
iv. **procedures are established for responding to anticipated operational occurrences and to dents;**
v. **necessary engineering and technical support in all safety-related fields is available throughout the lifetime of a nuclear installation;**
vi. **incidents significant to safety are reported in a timely manner by the holder of the relevant license to the regulatory body;**
vii. **programs to collect and analyze operating experience are established, the results obtained and the conclusions drawn are acted upon and that existing mechanisms are used to share important experience with international bodies and with other operating organizations and regulatory bodies;**
viii. **the generation of radioactive waste resulting from the operation of a nuclear installation is kept to the minimum practicable for the process concerned, both in activity and in volume, and any necessary treatment and storage of spent fuel and waste directly related to the operation and on the same site as that of the nuclear installation take into consideration conditioning an disposal.**

Pakistan has taken appropriate steps to meet the intent of Article 19 of the Convention. Authorization for initial operation is issued based on appropriate safety analysis, safety review and assessment of commissioning program and other documents demonstrating that the plant construction, installation and commissioning is consistent with design and safety requirements. Operational limits and conditions are derived from safety analysis, commissioning tests and operational experience to identify safe boundary for operation, and are updated as necessary. All activities are performed according to the approved procedures.

Technical assistance on safety matters remained available for K-1 from Canada under the auspices of IAEA. Designer and vendor support is also available for all NPP at Chashma site. Engineering and technical support is available at all the plants from sister organizations within PAEC. OEF process remained in place to collect and analyze operating experience and to take appropriate actions. Experience was also shared with the international community at various forums such as IAEA OSART, Nuclear Events Web Based System (NEWS), WANO, COG, etc.

The generation of radioactive waste resulting from the operation of a nuclear installation is kept to the minimum practicable both in activity and in volume.

19.1 Regulatory Requirements

PNRA issues licenses to NPP according to Regulations PAK/909. The licensing process mainly includes, site registration, issuance of construction license and issuance of OL.PAK/909 enlists the documents to be submitted at each licensing stage for regulatory review and approval. PNRA Regulations PAK/913 establishes regulatory requirements for safety of NPP during commissioning and operation. PNRA Regulations PAK/912 (being replaced by PAK/921) set the requirements for QA during commissioning and operation. The licensee is required to establish an overall QAP that covers all safety related activities.

Initial Authorization

Authorization to operate a NPP is granted by PNRA in steps. After construction and equipment installation by licensee, commissioning program is submitted to PNRA for review and approval. PNRA selects control points for regulatory inspections and communicates the hold points to the licensee for proceeding from one stage to next stage of the commissioning. The regulatory inspections are performed on selected commissioning tests to verify the design intent and compliance with safety requirements. Furthermore, the commissioning reports submitted by the licensee are reviewed by PNRA and upon satisfaction, permission for proceeding to the next commissioning stage is granted.

After approval of commissioning program, licensee is allowed to perform pre-operation test which includes cold and hot performance tests. During this phase, FSAR is submitted, which demonstrates that the plant conforms to the safety requirements and the design is according to safety standards. Based on the satisfactory safety review of FSAR and compliance of other regulatory requirements, the licensee is allowed to introduce nuclear material into the reactor core, perform initial start-up tests at different power levels during and after fuel loading, which include fuel loading, subcritical tests, initial criticality and low power tests. Upon satisfactory completion of commissioning, trial operation after attaining full power and submission of updated FSAR and other documents, an OL is issued. The OL is valid for a period of up to ten (10) years subject to certain license conditions. Before expiry of OL, application for revalidation of OL is submitted by licensee along with latest PSR reports required by PAK/909. For the case of relicensing beyond design life, PAK/909 prescribes ~~d~~detailed requirements. The required documentation for the purpose includes updated PSR report and revised FSAR along with all updated licensing submissions as per PAK/909.

19.2 Operational Limits and Conditions

The Operational Limits and Conditions (OLC) are developed to ensure that plant is operating in accordance with design assumptions and intent. K-1 Operating Policies and Principles (OPP) are based on Canadian practice that set operational limits and conditions derived from the safety analyses, tests, and operational experience. During the reporting period, the OPPs were revised on the basis of design modifications carried out in response to re-licensing beyond design life and implementation of FRAP.

C-1 developed technical specifications based on standard Technical Specifications (TS) i.e. NUREG-0452 whereas, the technical specifications of C-2, C-3 and C-4 are developed on the basis of NUREG-1431. TS include safety limits, limits on safety system settings, limits and conditions for normal operation and transient operational states, and surveillance requirements. The TS are based on actual plant design, safety analysis as well as operational experience.

Technical specifications for K-2 and K-3 are based on NUREG-1431 including insights from French experience. These include safety limits, limits on safety system settings, limits and conditions for normal operation and transient operational states, and surveillance requirements. In addition, these include technical requirements for operation and surveillance requirements for additional passive safety features installed at the plant to mitigate design extension conditions.

In the event, where the operation of the plant deviates from the established operational limits and conditions, licensee is required to undertake review and evaluation of safety limit violations and notify to the Authority in accordance with the established event reporting system. These operational limits and conditions are revised as and when required, based on changes in safety analysis, changes in regulatory requirements or implementation of design modifications in safety systems or limits. Modifications in TS may also be made based on operating experience feedback, if approved by PNRA.

Operating limits and conditions are reviewed and approved by PNRA at the time of grant of permission to introduce nuclear material into the reactor core. During the lifetime of the NPP, any changes in OLC are subject to regulatory review and approval of PNRA.

19.3 Procedures for Operation, Maintenance, Inspection and Testing

PNRA Regulations PAK/913 requires the licensee to develop operating instructions and procedures for normal operation and procedures for all maintenance, testing, surveillance and inspection tasks. PAK/913 further requires to establish comprehensive administrative procedure which contains the rules for the development, review, validation, approval, modification and their distribution. Further, Regulations PAK/913 requires that the procedures and reference material shall be clearly identified and readily accessible in the control room and other operating locations.

PNRA Regulations PAK/921 also requires that each process or activity that could have implications for safety shall be carried out under controlled conditions, by means of following readily understood, approved and current procedures, instructions and drawings. These procedures, instructions and drawings are required to be validated before their first use and shall be periodically reviewed to ensure their adequacy and effectiveness. Individuals carrying out such activities shall be involved in the validation and the periodic review of such procedures, instructions and drawings.

All operation, maintenance, inspection and testing activities at NPP are carried out in accordance with written, validated and approved procedures. The revision and updating of plant procedures is a continuous process at K-1, K-2 and at all Units of CNPGS, and any revision of these documents is carried out by involving relevant personnel and disseminated to the operating personnel and other relevant entities.

PNRA ensures the adherence of plant procedures by the relevant plant personnel during regulatory inspections of operation and maintenance activities conducted by Regional Nuclear Safety Directorates from time to time. Moreover, the revision and validity of all types of procedures are verified during the periodic inspections of operation and maintenance divisions of the plant.

It is further ensured that approved procedures are in place at all NPP to manage and control both permanent and temporary modifications in SSC. All the plants have established administrative procedures for updating documents after modification, installation and testing.

within the stipulated time. Responsibilities for the revision of all documents (such as drawings, procedures, safety analysis report, OLC, system description, training material including simulator training, vendor equipment manuals and spare parts lists) are clearly identified to ensure that up-to date procedures are used during operation, maintenance and testing of the equipment and systems.

19.3.1 Procedures for Operation

Procedures for normal operation of the plant are kept updated to reflect as built conditions of the plants. These procedures ensure that the plant is operated safely within the design envelope. The procedures for C-3 and C-4 were validated during the commissioning tests with the involvement of plant operating personnel. Plant personnel engaged in operation are trained and re-trained in the use of these procedures.

The operating procedures of K-2 and K-3 are also validated and plant personnel are being trained in the use of these procedures.

19.3.2 Procedures for Maintenance and Inspections

Maintenance, testing, surveillance and inspection programs are in place at all plants since the commencement of operation. The procedures are developed in line with the programs taking into consideration the design data, equipment specifications, QA requirements, human factors considerations and ALARA principle. The procedures are subject to revision within the time period specified in each document or as and when needed.

19.4 Procedures for Responding to Operational Occurrences and Accidents

PNRA Regulations PAK/913 also require the licensee to develop and validate operating procedures for anticipated operational occurrences and design basis accident and further requires development of procedures for the management of accidents more severe than the design basis accidents using the event-based/ symptom-based approaches, as appropriate.

The EOP were designed to restore and maintain safety functions, and place the plant in a safe shutdown condition.

At K-1, EOP have been reviewed and validated through table top and walk-through exercises after Fukushima Daiichi accident and were revised using revised safety analysis results. Revised EOP for earthquake has also been issued. For extreme weather condition, guidelines in the form of technical manuals have been issued. The operators are being trained for EOPs through class room lectures, tabletop exercises, walk-downs, MCR and field activities at K-1.

C-1 and C-2 initially received event based EOP from the vendor. According to the licensing requirement and international practice, currently duly verified and validated set of EOP also known as symptom based EOP are in place at all CNPGS Units.

SAMGs provide guidance to operators and designated support staff for use in the event that accident conditions progress beyond the mitigation capabilities described in the EOP (e.g., fuel damage is imminent or has occurred). SAMGs have been revised in the light of lessons learned from Fukushima NPP accident.

Moreover, the Fukushima accident introduced the concept of FLEX equipment which will be used in accordance with guidelines known as FLEX Support Guidelines (FSGs). The listing of FSGs has been finalized. All the modifications related to hook-up connections of FLEX equipment were implemented at the plants. FSGs for use (staging, operation, and 6kV Bus

preparations) of MV DGs have been developed, while remaining will be developed upon availability of the remaining FLEX equipment (i.e. FLEX Pumps).

19.5 Engineering and Technical Support

NPPs have their own engineering departments for technical support, whereas, engineering support is also available from other organizations within PAEC. Although for CNPGS NPP, the support from the designer and vendors is also available, efforts are also being made at all NPP to acquire necessary engineering and technical support from national and international organizations. Technical assistance on safety matters remained available for K-1 from Canada under the auspices of IAEA in certain areas.

Following major activities are carried out:

a. Fuel Channel Integrity Assessment (FCIA) of selected 11 fuelling channels;
b. Sludge lancing and ISI in all six (06) steam generators;
c. Steam Condenser tubes cleaning, inspection and replacement (~ 6000 tubes);
d. Thickness measurement of feeder pipes and inspection of feeder flanges and supports;
e. Miscellaneous ISI activities as per ISI program.

During plant operation, K-1 received the technical support of COG in different safety matters. Now, K-1 that has been permanently shut down enrolled for the membership of Waste Management Peer Group (WMPG) and is in the process for getting the membership of Decommissioning Peer Group (DPG) both under COG.

Engineering support of vendor and designer is available for all Chashma NPP under lifetime support agreement. Similar support from the designer of K-2/K-3 is also being arranged for KNPGS. In addition, support from vendor country organizations for maintenance, ISI, RFO, etc., are also available., Directorates of Technical Support are established at both CNPGS and KNPGS sites which provide support to all operating plants at sites in the areas of engineering, maintenance, radioactive waste, procurement, etc. In addition, support from PAEC corporate office is also available for various aspects including financial, human and technical.

19.6 Reporting of Incidents Significant to Safety

Requirements for reporting incidents important to safety, accidents and abnormal events to the regulatory body are specified in PNRA Regulations PAK/913which require immediate notification of significant events. Detailed event report in a prescribed format is required to be submitted by the licensee within 60 days of the events. These reports are analyzed by PNRA to review event details and to identify any additional corrective action which needs to be taken by the licensee. Root Cause Analysis (RCA) is normally an essential part of the detailed event reports.

PNRA is the contact point for the IAEA IRS and Nuclear Events Web Based System (NEWS) of INES. During the reporting period, an event occurred at K-1 which involved overexposure of workers due to leakage of heavy water moderator from bonnet gasket of moderator storage tank outlet valve. The event (rated at INES Level 2) was reported to IRS (No. 8734) and INES. According to root cause analysis report, about 1589 kg spilled heavy water of moderator system was collected from reactor building floor. Among the workers involved in valve isolation and heavy water collection, four (04) individuals exceeded the annual

regulatory dose limit of 20mSv. The doses received by the overexposed workers were 20.8 mSv, 24.2 mSv, 30.9 mSv and 36.2 mSv respectively.

No event exceeding INES level 1 occurred at C-1, C-2, C-3 and C-4 during the reporting period.

During the reporting period, an event of INES Level 0 occurred at all C-series plants and was reported to INES. During this event, CNPGS faced severe grid fluctuations during operation due to country wide power breakdown which resulted in tripping of all units. Both offsite power sources (220 kV and 132 kV) were lost and both Emergency Diesel Generators (EDG) of C-1, C-2 and C-4 started automatically and successfully connected to provide power to emergency buses. While one of the EDGs of C-3 could not start on auto and it had to be manually started after some time. Hot shutdown condition was finally maintained at C-1, C-2, C-3 and C-4.

Another event occurred at C-1 in July 2019 was reported to IRS (No. 8979). Before the event, C-1 was operating at 325 MWe when an integrated trip alarm for SRC heaters and startup and shutdown feed water pumps appeared in Main Control Room (MCR) and one of the pressurizer backup heater banks was observed at tripped state. Afterwards, a fire alarm appeared in MCR, indicating fire in one of the rooms of nuclear auxiliary building that housed the breaker cabinets of pressurizer heaters. Later on, fire alarms also appeared in various other rooms in their vicinity. Standby emergency was declared and reactor was manually scrammed. After bringing the situation under control the standby emergency was terminated and the plant was maintained at hot shutdown state.

19.7 Operational Experience Feedback

PNRA Regulations PAK/913 also require the licensee to establish an operating experience feedback program to learn from events at the plant and events in the nuclear industry and other industries worldwide. The program shall cover reporting, collection, screening, analyzing, trending, documenting and communicating operating experience at the plant in a systematic way. Events with significant safety implications shall be investigated to establish their direct and root causes including causes relating to equipment design, operation, maintenance or human and organizational factors. The investigation shall, where appropriate, result in clear recommendations to the plant management, which shall take appropriate corrective action without undue delay. Information resulting from such evaluations and investigations shall be fed back to the plant personnel. PAK/913 further requires the licensee to maintain liaison with support organizations (manufactures, research organizations, and designers) involved in the design, construction, commissioning, and operation of the plant for sharing feedback and obtaining advice in the event of equipment failure or other events.

K-1 interacts with COG, WANO and IAEA networks to exchange OEF information. Information received from these networks is screened for relevancy and applicability at K-1 by OEF Section and disseminated to relevant divisions and sections for review and follow-up actions. If the information is found applicable, it is incorporated through changes in procedures, systems or equipment, etc., in order to prevent recurrence of event. Important OEF is discussed in weekly management meeting and actions are recommended for their implementation at K-1. A number of changes in plant systems and procedures have been carried out on the basis of operating experiences. To deal with internal low level and significant events, K-1 has established an Event Identification, Investigation and Corrective

Action (EIICA) Program. Low level and significant events are recorded, evaluated, and investigated under the umbrella of EIICA program and necessary corrective actions are formulated and implemented to prevent recurrence. Bi-annual and annual trending of events is carried out to identify areas for improvement. Lessons learned are retrieved and disseminated to OEF coordinators.

KNPGS interacts with WANO, IAEA, and CNPGS etc. to exchange OEF information. Information received is screened for relevancy and applicability at KNPGS by OEF section and disseminated to relevant divisions and sections for review and follow-up actions. If the information is found applicable, it is incorporated through changes in procedures, systems or equipment, etc., in order to prevent occurrence of similar event. KNPGS has carried out self-assessment of recommendations of significant operating experience report (SOERs) issued by WANO from the applicability and implementation point of view. Important national and international OEF is discussed in daily management's morning meeting for lesson learned and measures required at KNPGS.

KNPGS has developed integrated Corrective Action Program (iCAP) which is being implemented through software in-line with the similar program of CNPGS. Events are being reported, recorded, screened, analyzed and corrective actions identified in the report are being also tracked and followed-up through this software.

All plants of CNPGS and KNPGS use Plant Condition Reports (PCR) system for collection of information about low level events. The information collected is screened and trended for identification of vulnerable areas of the plant. LAN based CNPGS and KNPGS Operating Experience Reports (COER AND KOER) are used for collection of information about all types of events, suggestions and lessons learned. All COER and KOER are categorized according to their significance in the domains of nuclear, radiological, industrial safety, economic impact etc. Depending upon significance, Apparent Cause Analysis (ACA), Root Cause Analysis (RCA) and Condition Evaluation Report (CER) are initiated to find causes and corrective actions to prevent recurrences. For significant events, "Event Analysis Call-up Form (EACF)" is in place which requires event analysis to find causes and formulate corrective actions in order to prevent recurrences.

All events are coded for trending to identify adverse trend. Internal operating experience information is disseminated to all relevant work units within the plants for effective utilization of information. Significant events are evaluated for reporting to PNRA, IAEA and WANO. The criteria of reporting to IAEA are as per requirements of "IAEA Service Series No. 19, IRS Guidelines" and to WANO are as per requirement of "Operating Experience Program Reference Manual".

NPP are continuously striving to strengthen the operator training program by considering the feedback gained from in-house and international experience. All NPP have a system of analyzing national and international operating experience feedback which includes analysis of events at national level and events reported through the IAEA, WANO, QNPC, SNERDI, CNPO, etc. on various safety related issues as well as best practices. In addition, plants have access to the IAEA IRS and Nuclear Events Web based System (NEWS). Technical divisions of the plants are responsible for collecting and analyzing the operating experience from within the installations while DTS is responsible for OEF from other installations (including non-nuclear installations) operating in the country.DTS also utilizes international experience feedback to identify necessary actions. Evaluation of operating experience feedback regarding domestic and international events is carried out as per plant procedures.

The operating experience of management issues, unexpected degradation, design weaknesses, external hazards not considered earlier, etc., is shared through peer reviews conducted within and outside Pakistan under auspices of IAEA, WANO, COG, etc.

As result of lessons learnt from operating experience, necessary modifications are carried out to the plants, personnel training programs and FSTS.

PNRA verifies the licensee's programs to collect and analyze operating experience through reviews of licensee event reports and by inspections. PNRA is the contact point to the IAEA IRS and Nuclear Events Web Based System (NEWS) and the licensee's relevant personnel have access to these systems. PNRA encourages the licensee to benefit from relevant international operating experience at other nuclear installations to enhance safety and reliability. PNRA oversight also includes verification of licensee's program of recording and reporting near misses and utilization of these near misses to take timely corrective action so that they may not lead to significant event at the plant and at the other similar nuclear power plants within the country. The results and evaluation of the recorded near misses are mostly helpful in revising the plant procedures and practices.

PNRA believes that effective use of OEF is essential to maintain and improve safety of nuclear installations. Along with licensee, the same activity has been performed by PNRA to support its functions, responsibilities and missions. The theme and intentions of learning and implementation of lessons extracted from previous events are to adopt a safety conscious approach so that recurrence of such events is controlled. Working on this theme, PNRA started a formal program of evaluation of international OEF received at PNRA from nuclear industry around the globe including INES, IRS and information received from other regulatory bodies of the world. The program comprises evaluation of international OEF and issuance of reports on biannual basis along with its dissemination to relevant stakeholders including operators of NPP.

19.8 Management of Spent Fuel and Radioactive Waste on the Site

During the reporting period, Pakistan has issued a "National policy on safe management of radioactive waste, decommissioning and spent nuclear fuel in Islamic Republic of Pakistan (RWP-01/2018)" which describes the national commitment for safe management of radioactive waste including Disused Sealed Radioactive Sources (DSRS) and spent nuclear fuel. Further, Regulations PAK/915 establishes requirements for safe management and disposal of all type of radioactive waste from NPP. PAK/915 requires licensee to keep the generation of radioactive waste in terms of both activity and volume to the minimum practicable by suitable design, operation and while opting decommissioning strategy. The NPP manage radioactive waste in accordance with the radioactive waste management programs approved by PNRA. Waste generation at NPP is kept to a minimum by appropriate classification, segregation, characterization, treatment, conditioning and reuse and recycling of material. Procedures are in place for processing of radioactive waste to reconcile the objectives of safety and retrieve-ability from the storage to disposal facility.

Radioactive Waste Storage Area (RAWSA) at K-1 is a designated facility for collection of radioactive waste from radiation facilities and K-1. It comprises of a shelter (40 ft X 120 ft) for storage of radioactive waste. There are trenches for storage of contaminated hard waste, spent resin tanks and DSRS. Radioactive Waste Management Program (RWMP) is based on PNRA Regulations PAK/915.

As per final decommissioning plan, K-1 will be decommissioned in three phases i.e. Phase-I (preparation for SAFSTOR), Phase-II (storage-with-surveillance) and Phase-III (Decontamination & Dismantling). In general, the radioactive waste will be generated during Phase-I and mainly in Phase-III. The RWMP is equally implementable during the Phase-I & Phase-II of decommissioning as these two phases do not include any major activities. However, RWMP will be revised before the initiation of Phase-III of decommissioning.

In the original design of C-1, spent resin was stored in holdup tanks which had capacity for 10 years resin generation. The process has been modified to solidify the stored resin resulting in enhancement of storage capacity of spent resin. Liquid Radioactive Waste Solidification Building (LR) is being used for solidification of liquid waste concentrate. Spent resin is being stored in hold up tanks which had capacity for 10 years resin generation. Solidified Radioactive Waste Storage Building (SR) and Low Level Solid Radioactive waste Storage Building (RS) are available for storage of solidified radioactive waste generated from Chashma site.

CNPGS has established modular extended storage building at Chashma site for Low Level Waste (LLW) storage purpose. This design envisages over packed LLW solidified drums in concrete containers with concrete grouting which will then be stored in extended storage building. The storage building will cater for storage needs of Chashma site. In future, one more extended storage building for storage of over packed LLW solidified drums in concrete containers with concrete grouting is expected to cater for storage needs of Chashma site.

Discharges to the environment are kept minimum possible and within the permissible levels authorized by PNRA. Environmental monitoring is performed according to established monitoring program and procedures and approved by PNRA.

PNRA requirements for the licensing of spent nuclear fuel storage facilities are covered in the Regulations PAK/909. According to national policy (RWP-01/2018) the spent nuclear fuel is safely managed by PAEC. PAEC has planned to shift spent fuel from wet storage at fuel bay to on site dry storage facilities. Following activities were performed at national level during reporting period:

a. Enhanced regulatory framework for the safe management of spent nuclear fuel through establishment of regulatory process for certification of spent fuel storage casks; revision of Regulations for Licensing of Nuclear Safety Class Equipment and Components Manufacturers – (PAK/907). PNRA established regulatory framework for the safe management of spent nuclear fuel by promulgation of Regulations on Safe Management of Spent Fuel – PAK/918 which covers regulatory requirements related to spent fuel storage facilities (wet & dry), spent fuel storage casks and their certification;
b. PAEC has opted to utilize indigenous resources to manage spent fuel in dry environment. K-1 completed the construction of its spent fuel dry storage facility and spent fuel from K-1 Spent Fuel Bay (SFB) is being transferred, in the certified casks, to dry storage facility due to limitation of storage capacity at SFB. Furthermore, site for CNPGS spent fuel dry storage facility has been registered and construction work is in progress at the site. The design certification of associated cask for KNPGS dry storage facility is completed while design certification of casks for CNPGS dry storage facility is in progress;
c. Organized various training courses and workshops to build and enhance the capacity of designers, operators and regulators in the development and assessment of design

documents of casks and facilities; analysis in the areas of structural, thermal, shielding, criticality; testing of prototypes, evaluation of testing and manufacturing facilities. Moreover, PNRA and PAEC officials participated in various relevant international events arranged by IAEA.

Chashma Spent Fuel Dry Storage Facility

At NPP of Chashma site, spent fuel storage facilities are integral part of each plant to meet under water storage requirement for fifteen (15) reloads plus one (01) full core. Due to limited storage capacity of underwater spent fuel storage pools at plants, the spent fuel will be placed in dry concrete storage casks and stored in the dry storage facility at CNPGS site. The construction of Spent Fuel Dry Storage Facility has been started on allocated site already registered by PNRA. The facility is designed to store spent fuel generated from lifetime operation of C-1, C-2, and C-3 and C-4.

19.9 Safety Performance Evaluation

The K-1 Safety Performance Indicators (SPI) Program comprises of a comprehensive framework of performance indicators. After three development phases, eighty-nine (89) specific safety performance indicators identified in the main framework of K-1. The SPI are reported on six-monthly basis and have a quarterly, half-yearly, annual and biennial monitoring interval as appropriate to the SPI. Since the SPI reports are issued half-yearly, thus SPI having a Quarterly or half-yearly monitoring interval appear in each report. The Annual SPI are reviewed in the second report of the year while biennial are discussed in the second report every alternate year. Before the issuance of SPI report, a management meeting is held during which all the red and yellow SPI are discussed in detail and the responsibility and target date for completion of the analysis are assigned. Status of the previously assigned analysis and corrective actions are also discussed. The tracking of investigations and corrective actions is then done by station CAP group. K-1 also participates in the WANO Performance Indicators Program and regularly submits performance indicators data on quarterly basis. K-1 safety performance indicator program remained implemented till the permanent shutdown of plant for decommissioning. Efforts are underway to develop SPI for decommissioning.

CNPGS Units (C-1, C-2, C-3 and C-4) and KNPGS Unit (K-2) have adopted WANO performance indicators program and have shared performance indicators data elements with WANO on a quarterly basis. The existing programs consist of collecting, trending, exchanging, and disseminating performance data for complete set of WANO performance indicators, covering critical safety and operational aspects of the plant. CNPGS Units (C-1, C-2, C-3 and C-4) and KNPGS Unit (K-2) have also developed SPI programs to monitor operational safety of station. Homogeneous target values are set for all four Units of CNPGS based on operational history of these Units. However, for K-2 being the newly commissioned unit, SPIs targets are set by the corporate office for first phase, based on operational history of CNPGS plants. The SPI programs are based on the guidelines of WANO and IAEA. The SPI trends are reported in respective technical reports of that Unit. KNPGS unit K-3 has started its commercial operation in April 2022, thus reporting of SPI data of K-3 would be started from third quarter of 2022.

Corporate Office of PAEC have also developed Operational Safety Performance Indicators (OSPIs) for monitoring performance of all operating NPP units.

Pakistan has, therefore, met the obligations of Article 19 of the Convention.

ANNEXURE–I: EXISTING NUCLEAR POWER PLANTS (NPP)

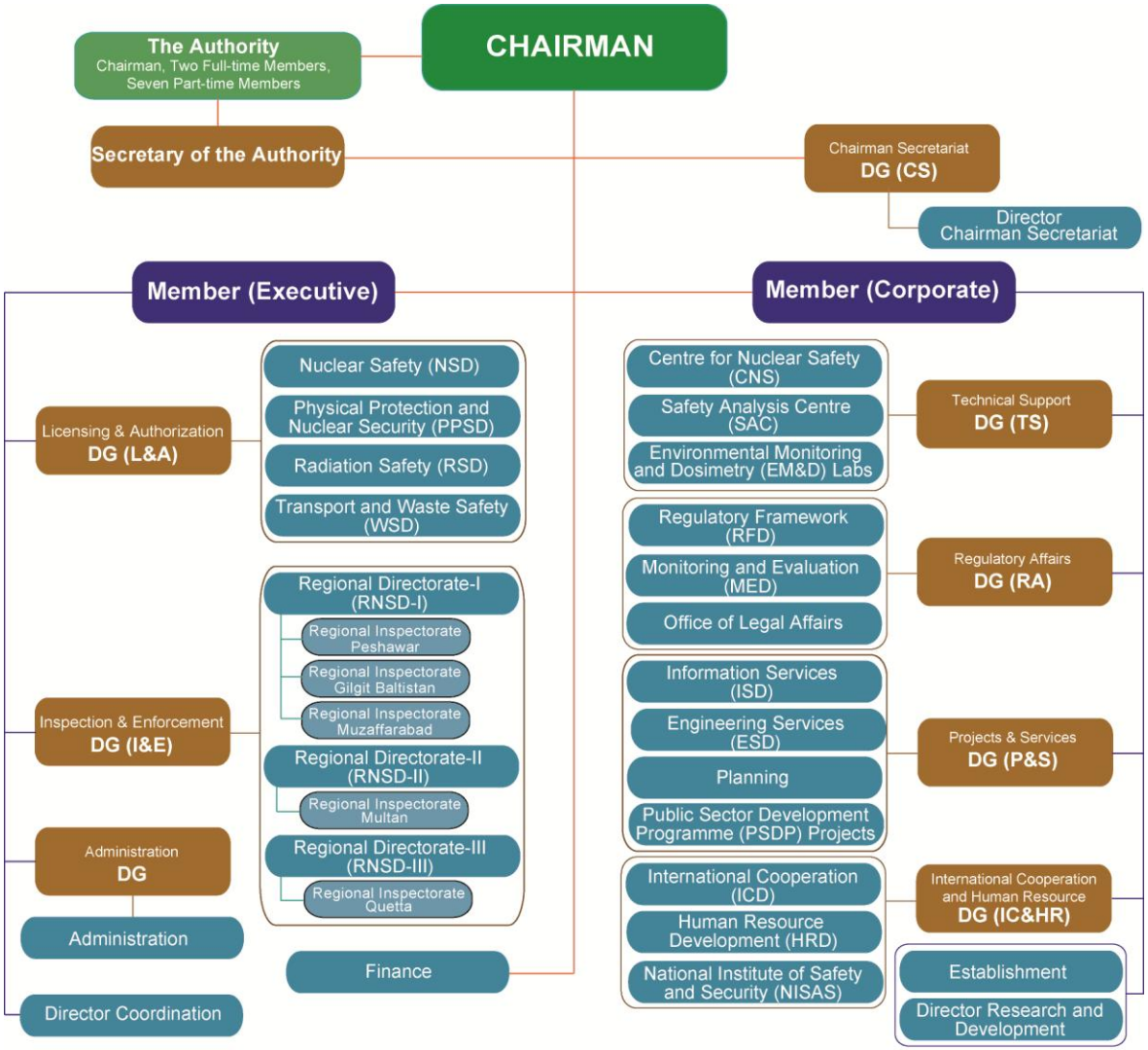
	K-1	C-1	C-2	C-3	C-4	K-2	K-3
Status	Permanent shutdown	Operating	Operating	Operating	Operating	Operating	Operating
Location	Karachi, Sindh	Chashma, Punjab	Chashma, Punjab	Chashma, Punjab	Chashma, Punjab	Karachi, Sindh	Karachi, Sindh
Type	CANDU	PWR	PWR	PWR	PWR	PWR	PWR
Capacity (gross)	137 MWe	325 MWe	340 MWe	340 MWe	340 MWe	1100 MWe	1100 MWe
First fuel loading	July 1971	November 1999	February 2011	May 2016	March 2017	December 2020	December 2021
Connection to Grid	1971	June 2000	March 2011	October 2016	July 2017	March 2021	March 2022

ANNEXURE–II: LIST OF ISSUED REGULATIONS

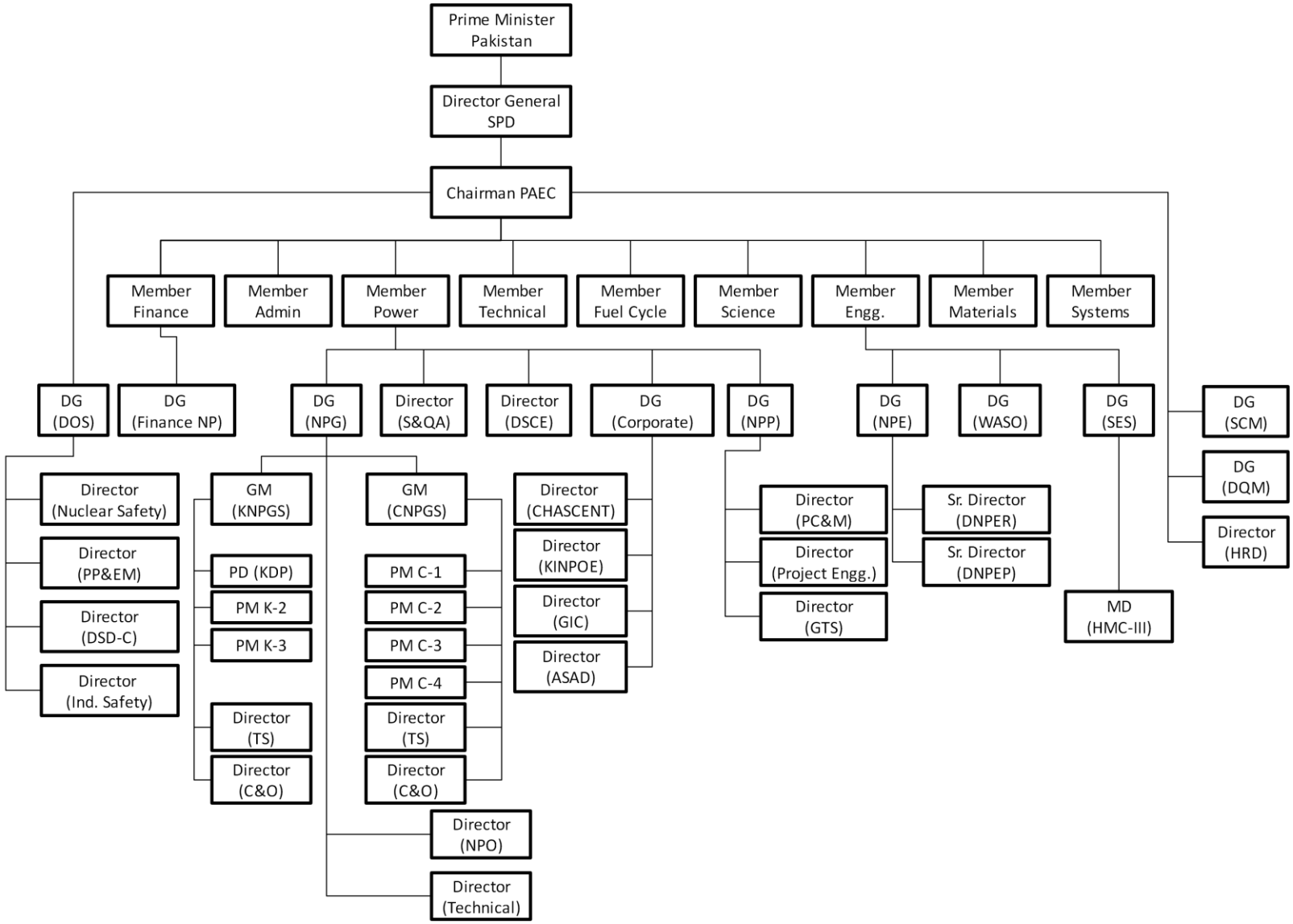
Sr. No.	Title	Latest Version
1.	Pakistan Nuclear Safety and Radiation Protection Regulations–1990	Mar 01, 2012
2.	PNSRP (Treatment of food by ionizing Radiation) Regulations–1996.	Mar 07, 1996
3.	Regulations on Licensing Fee by Pakistan Nuclear Regulatory Authority – (PAK/900) (Rev. 3)	Jun 15, 2020
4.	(Amendment in) Regulations on Transaction of Business of Pakistan Nuclear Regulatory Authority – (PAK/901)	May 03, 2018
5.	Regulations on Radiation Protection –(PAK/904) (Rev. 1)	Oct 17, 2020
6.	Regulations for Licensing of Nuclear Safety Class Equipment and Components Manufacturers –(PAK/907) (Rev.1)	May 03, 2018
7.	Regulations for the Licensing of Radiation Facilities other than Nuclear Installations –(PAK/908) (Rev. 1)	Dec 31, 2019
8.	Regulation for Licensing of Nuclear Installations in Pakistan –(PAK/909) (Rev.1)	Jun 29, 2012
9.	Regulations on the Safety of Nuclear Installations – Site Evaluation–(PAK/910)	Sep 01, 2008
10.	Regulation on the Safety of Nuclear Power Plants Design – (PAK/911) (Rev.2)	Dec 31, 2020
11.	Regulations on the Safety of Nuclear Power Plants-Quality Assurance–(PAK/912)	Will be repealed after issuance of PAK/921
12.	Regulations on Safety of Nuclear Power Plants-Operation – (PAK/913) (Rev.2)	Dec 31, 2020
13.	Regulations on Management of a Nuclear or Radiological Emergency–(PAK/914)	Sep 01, 2008
14.	Regulations on Radioactive Waste Management – (PAK/915)(Rev.1)	Jul 12, 2019

15.	Regulations for the Safe Transport of Radioactive Material – (PAK/916) (Rev.1)	At printing stage
16.	Regulations for the Safe Management of Spent Nuclear Fuel - (PAK/918)	Feb 01, 2020
17.	Regulations on Leadership and Management for Safety – (PAK/921).	At printing stage
18.	(Amendment in) Regulations on the Safety of Nuclear Research Reactor(s)Operation - (PAK/923)	Dec 31, 2015
19.	Regulations on Physical Protection of Nuclear Material and Nuclear Installations - (PAK/925)	Jul 12, 2019
20.	Regulations on Security of Radioactive Sources - (PAK/926)	Oct 09, 2018
21.	Regulations on Decommissioning of Facilities Using Radioactive Material-(PAK/930)	Dec 31, 2016
22.	Pakistan Nuclear Regulatory Authority Enforcement Regulation - (PAK/950)	Dec 23, 2010
23.	Regulations on Dispute Resolution – (PAK/949).	Dec 31, 2019

ANNEXURE–III: ORGANIZATIONAL CHART OF PAKISTAN NUCLEAR REGULATORY AUTHORITY



ANNEXURE–IV: ORGANIZATIONAL CHART OF PAKISTAN ATOMIC ENERGY COMMISSION



ANNEXURE–V: PNRA PERFORMANCE INDICATORS

Indicator 1.	Ensure that acceptable level of safety is being maintained by licensees
Indicator 2.	Ensures that regulations and guides are in position and understood by licensees
Indicator 3.	Strives for continuous improvement of its performance
Indicator 4.	Take appropriate actions to prevent degradation of safety and to promote safety improvements
Indicator 5.	Take appropriate steps for human resource development and has competent and certified regulatory staff
Indicator 6.	Ensure legal actions are taken in case of violation of regulatory requirements
Indicator 7.	Performs its functions in a timely and cost-effective manner
Indicator 8.	Ensure that a well established Quality Management System exists
Indicator 9.	Ensures that adequate resources are available for performing its functions and Technical Support Centre is available for specialist assistance when required
Indicator 10.	Performs its functions in a manner that ensures confidence of the operating organization
Indicator 11.	Performs its functions in a manner that ensures confidence of the general public
Indicator 12.	Performs its functions in a manner that ensures confidence of the Government.

Grading Scale for Performance Indicators

Green	Satisfactory
White	Minimally acceptable
Yellow	Needs improvement
Red	Unsatisfactory
Pink	Not acceptable

ANNEXURE–VI: DOSE LIMITS FOR EXPOSURES INCURRED FROM PRACTICES

ANNUAL DOSE LIMITS FOR RADIATION WORKERS

Organ or Tissue	Dose Quantity	Dose Limit (mSv)
Whole body	Effective dose	20*
Lens of the eye	Equivalent dose	20
Extremities (hands and feet) or Skin (average dose over 1 cm^2 of the most highly irradiated area).	Equivalent dose	500

* In special circumstances, an effective dose of up to 50mSv in a single year provided that the average dose over five consecutive years does not exceed 20mSv/year.

ANNUAL DOSE LIMITS FOR APPRENTICES AND STUDENTS (16 to 18 years of age)

Organ or Tissue	Dose Quantity	Dose Limit (mSv)
Whole body	Effective dose	6
Lens of the eye	Equivalent dose	20
Extremities (hands and feet) or skin (average dose over 1 cm^2 of the most highly irradiated area).	Equivalent dose	150

ANNUAL DOSE LIMITS FOR PUBLIC

Organ or Tissue	Dose Quantity	Dose Limit (mSv)
Whole body	Effective dose	1*
Lens of the eye	Equivalent dose	15
Skin	Equivalent dose	50

* In special circumstances, an effective dose of up to 5mSv in a single year provided that the average dose over five consecutive years does not exceed 1mSv/year.

ANNEXURE–VII: OCCUPATIONAL EXPOSURES AT NUCLEAR INSTALLATIONS (2016-21)

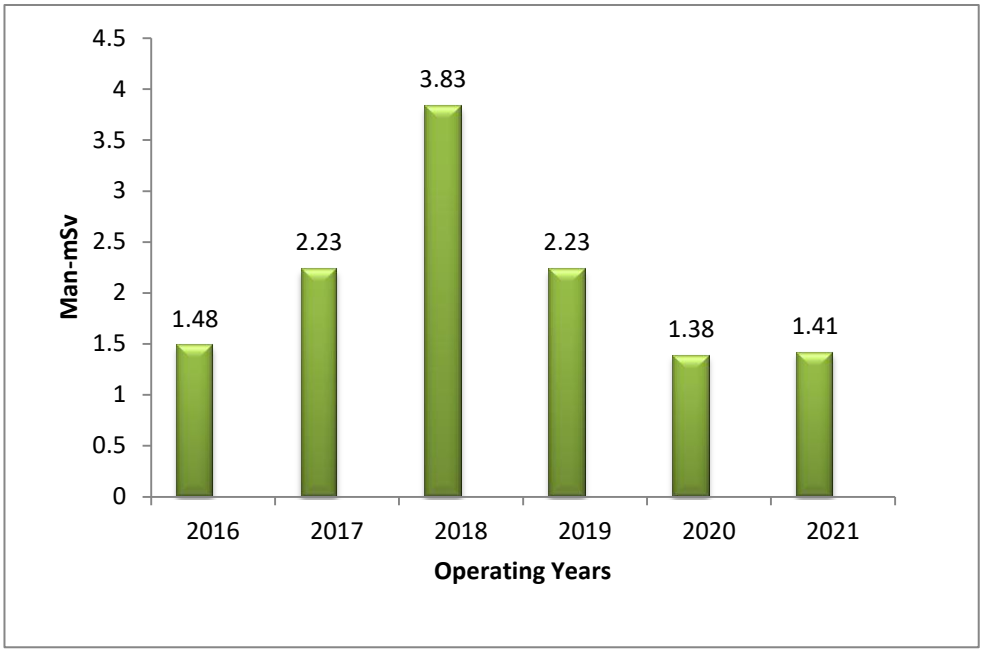


Figure 1: Annual Collective Dose at K-1

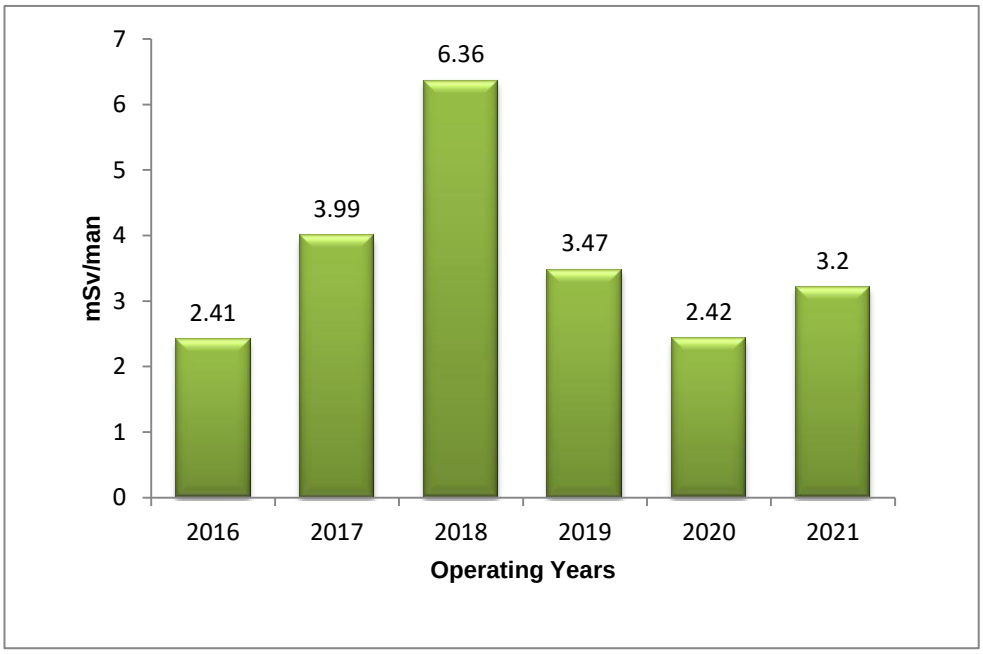


Figure 2: Annual Average Individual Dose at K-1

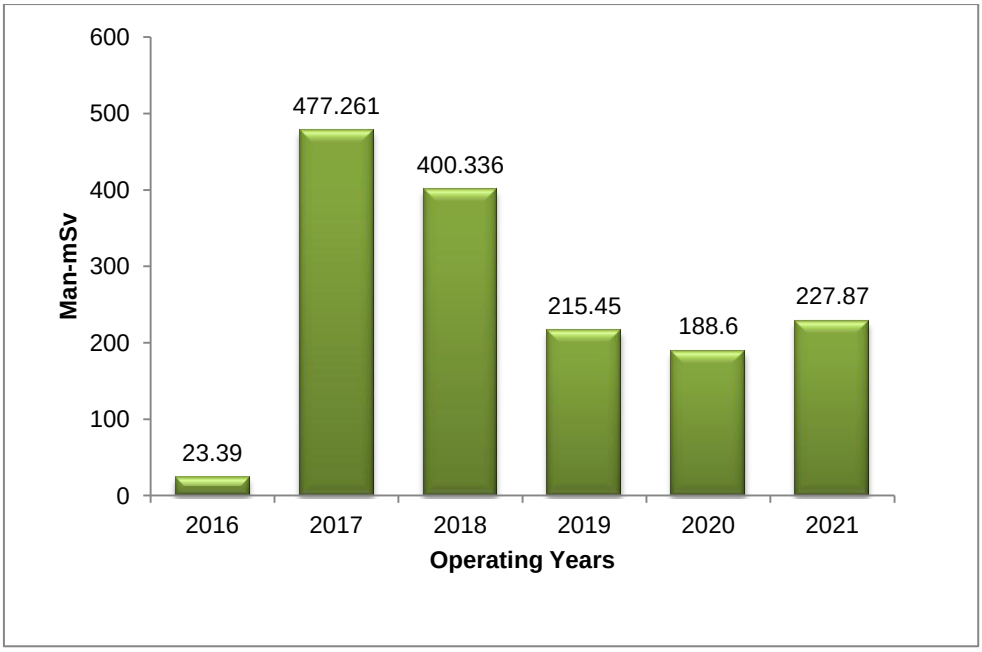


Figure 3: Annual Collective Dose at C-1

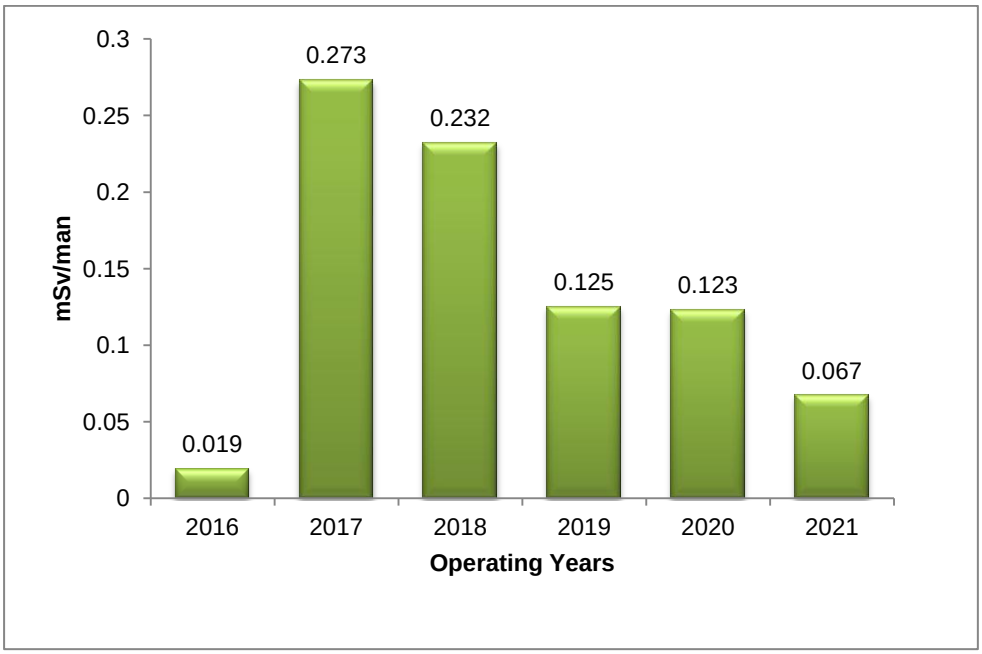


Figure 4: Annual Average Individual Dose at C-1

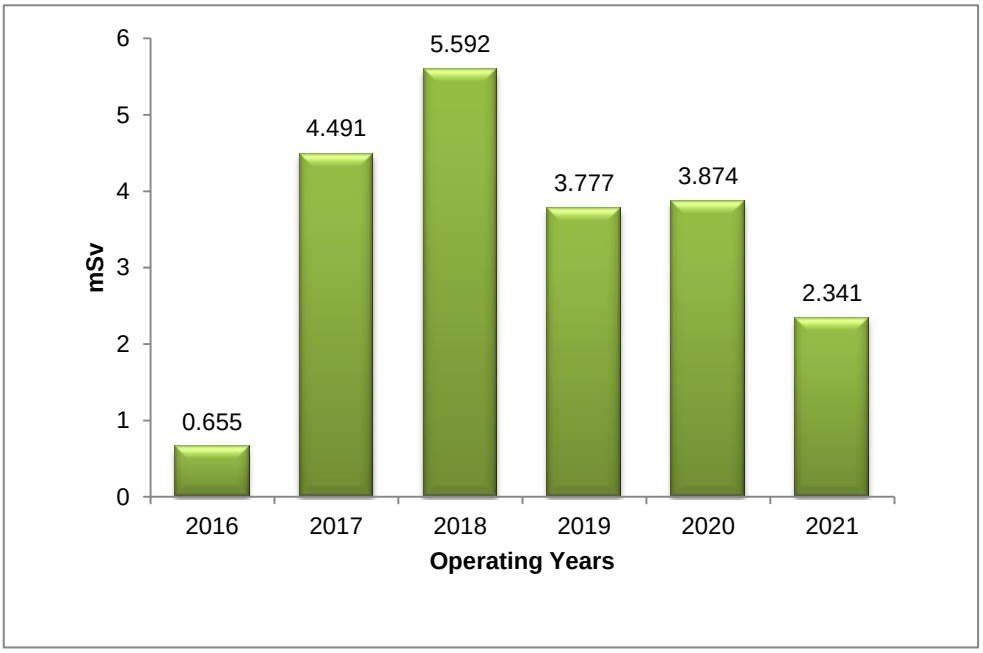


Figure 5: Maximum Individual Dose at C-1

Figure 6: Annual Collective Dose at C-2

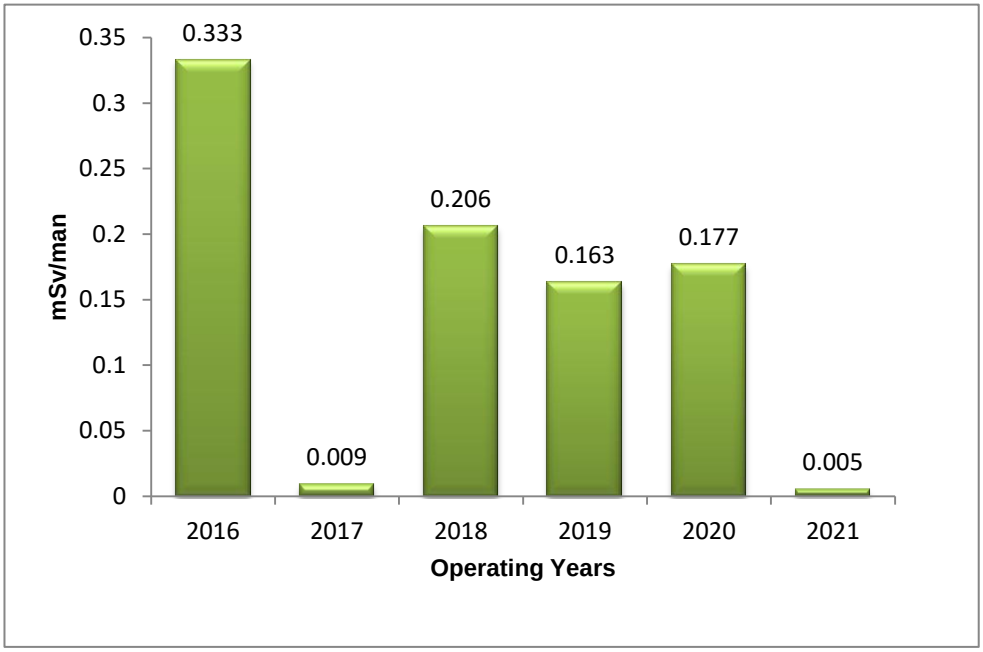


Figure 7: Annual Average Individual Dose at C-2

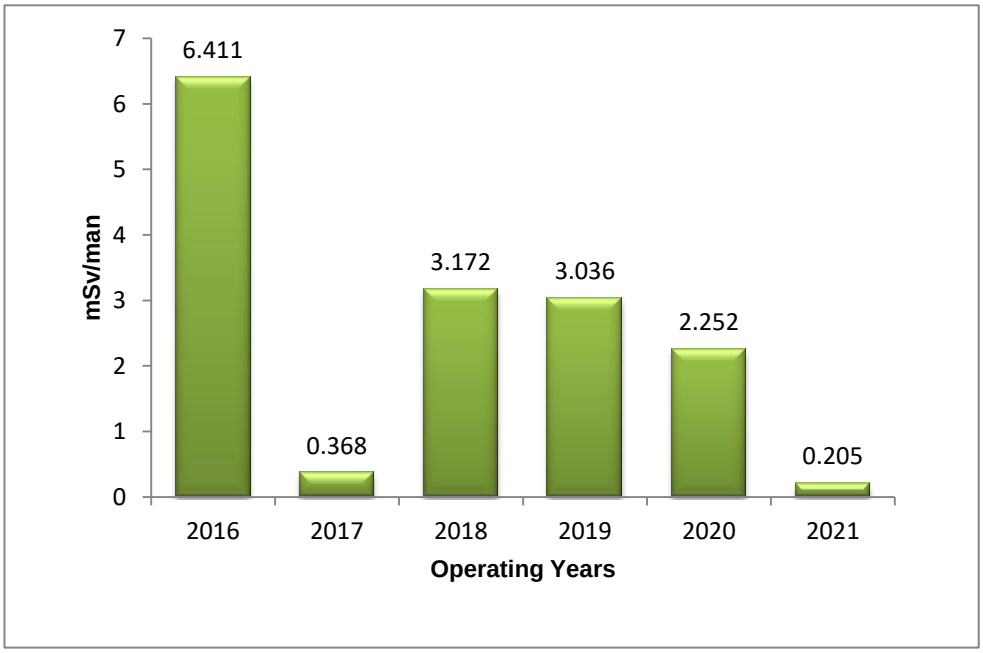


Figure 8: Maximum Individual Dose at C-2

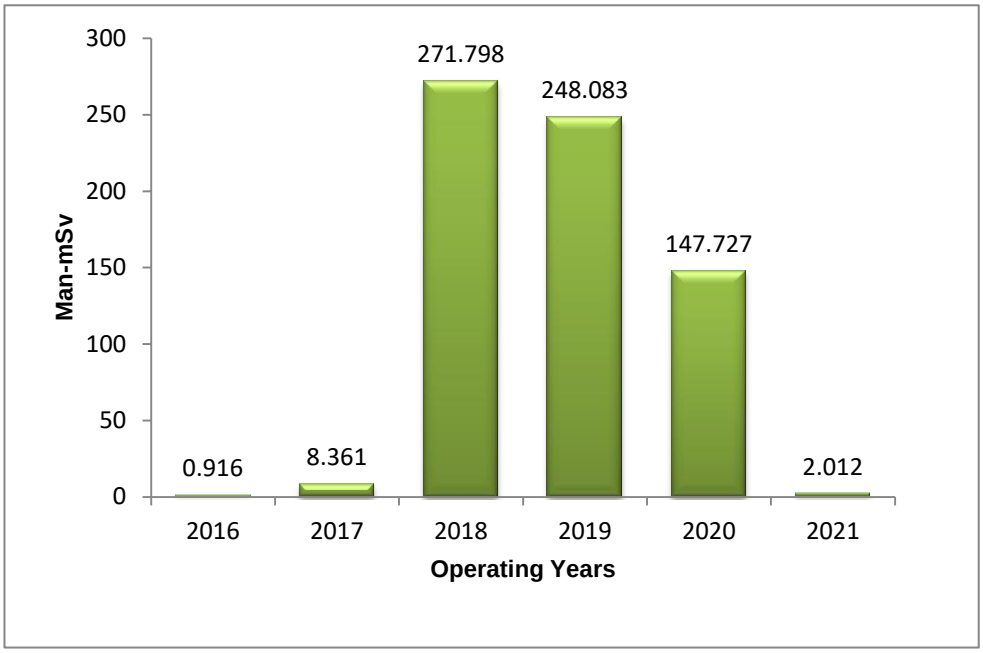


Figure 9: Annual Collective Dose at C-3

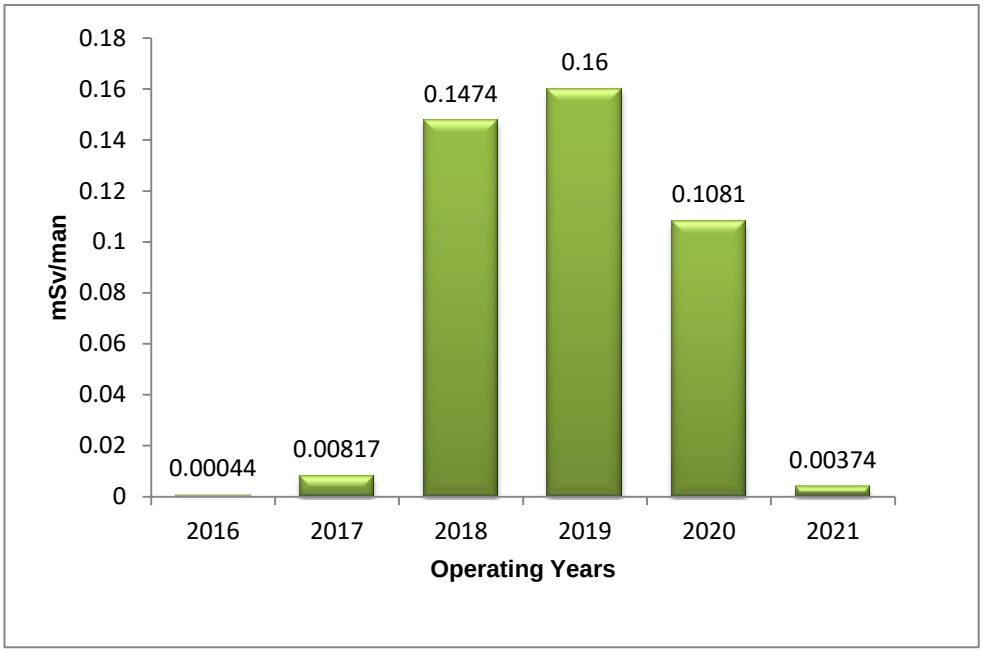


Figure 10: Annual Average Individual Dose at C-3

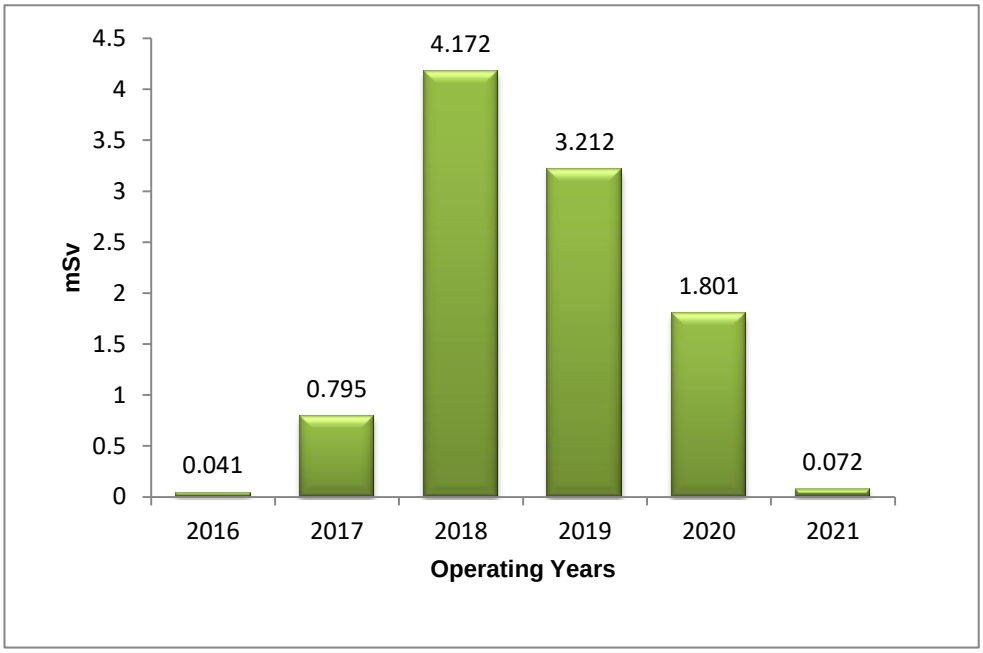


Figure 11: Maximum Individual Dose at C-3

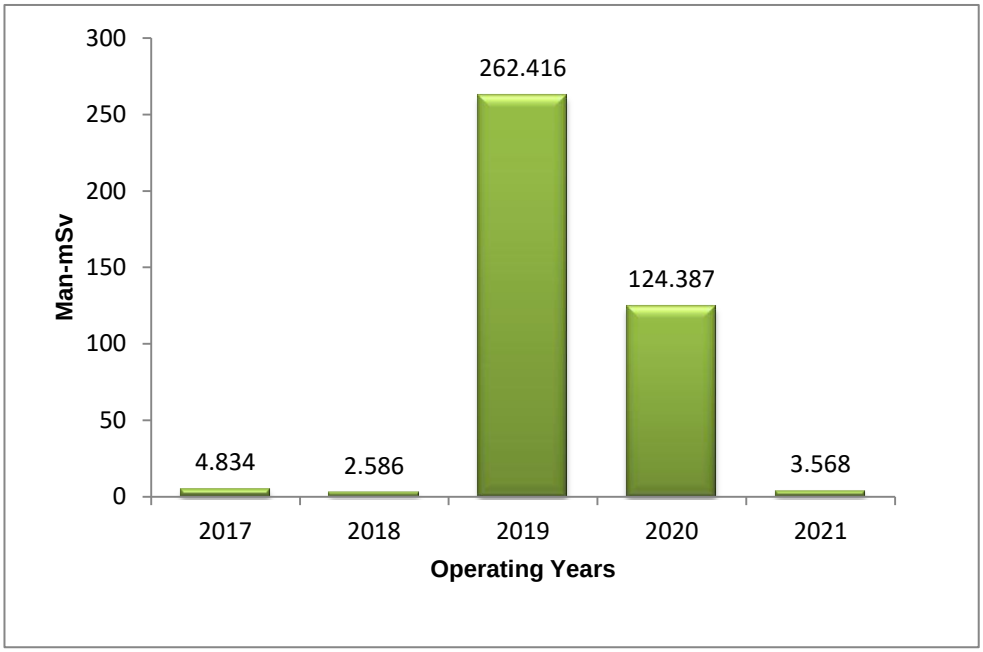


Figure 12: Annual Collective Dose at C-4

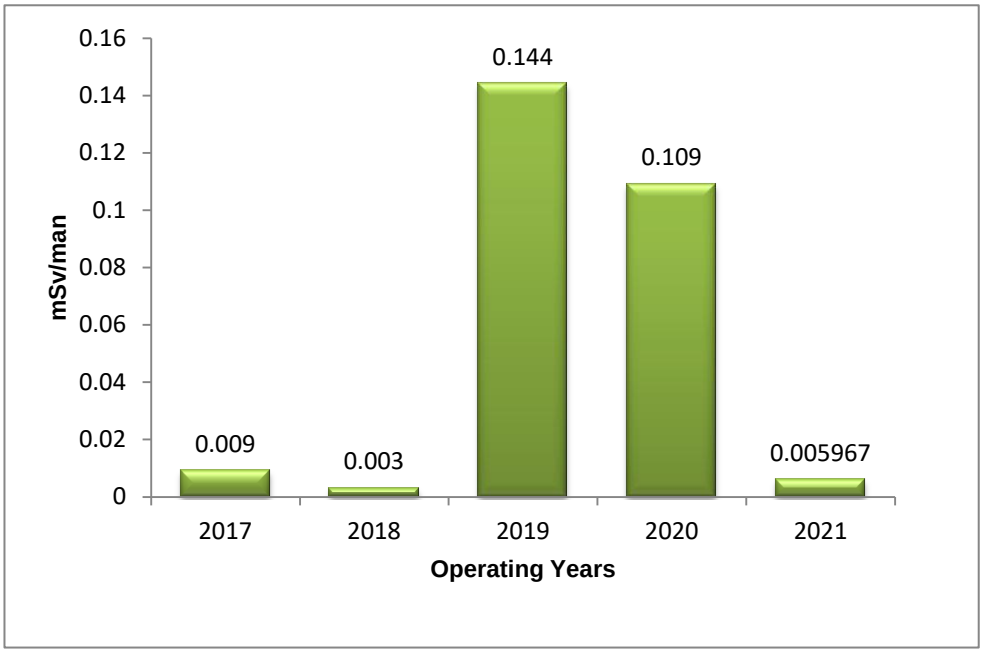


Figure 13: Annual Average Individual Dose at C-4

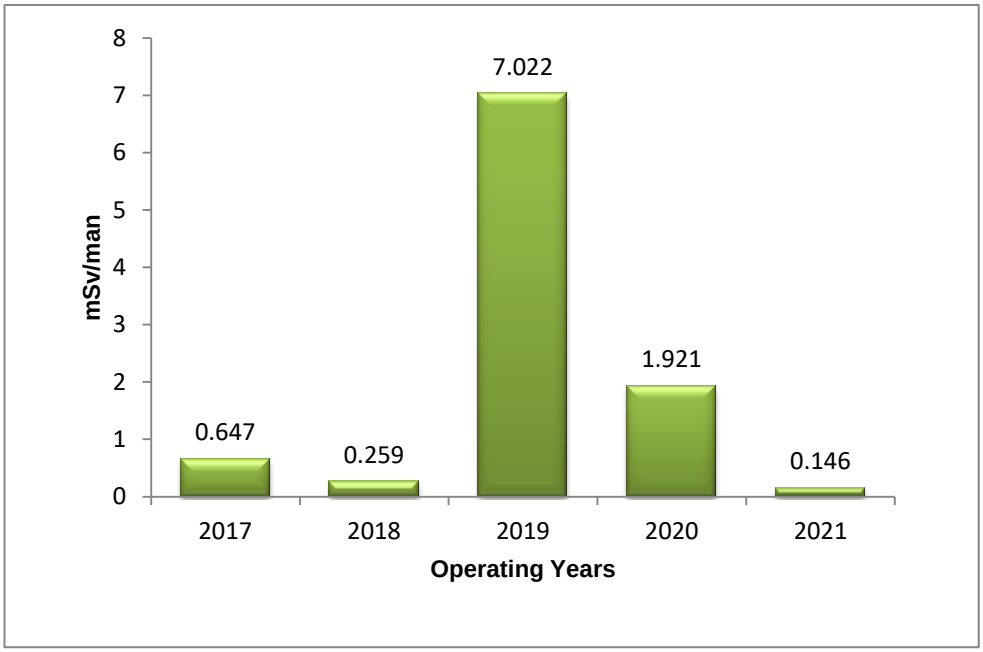


Figure 14: Maximum Individual Dose at C-4

ANNEXURE–VIII: EFFLUENT RELEASES FROM K-1, C-1, C-2, C-3 AND C-4 (2016–21)

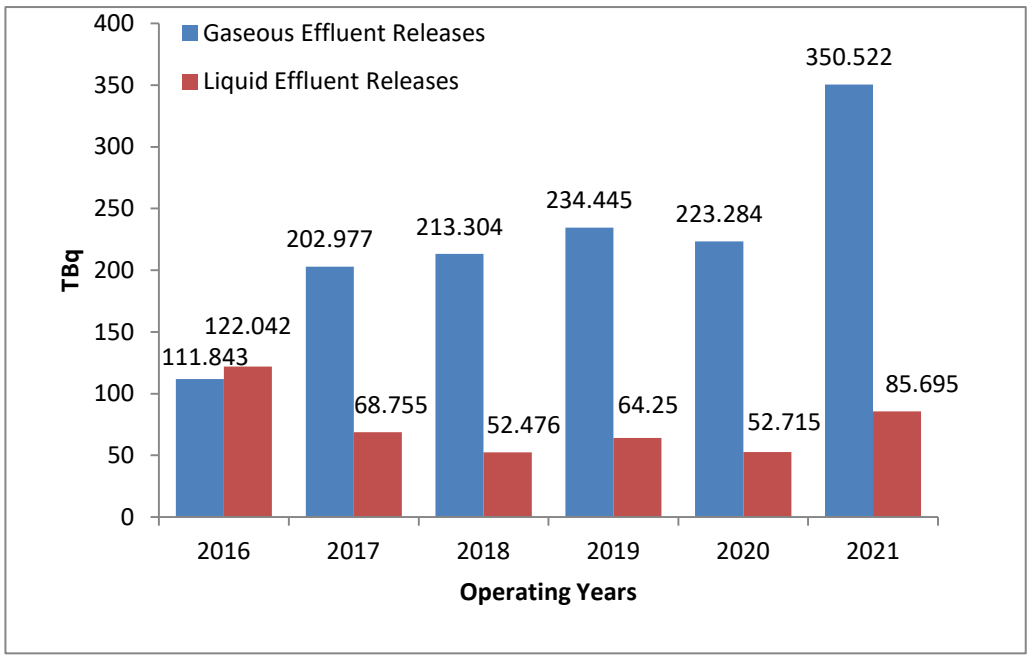


Figure 15: Tritium Released Through Gaseous and Liquid Effluents at K-1

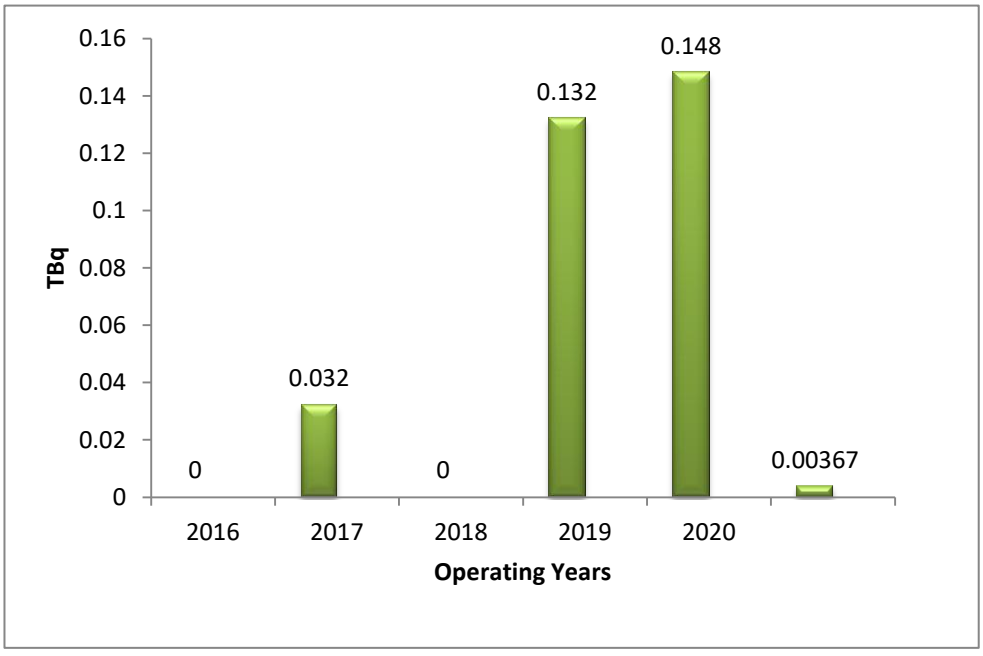


Figure 16: Nobel Gases Released Through Gaseous Effluents at K-1

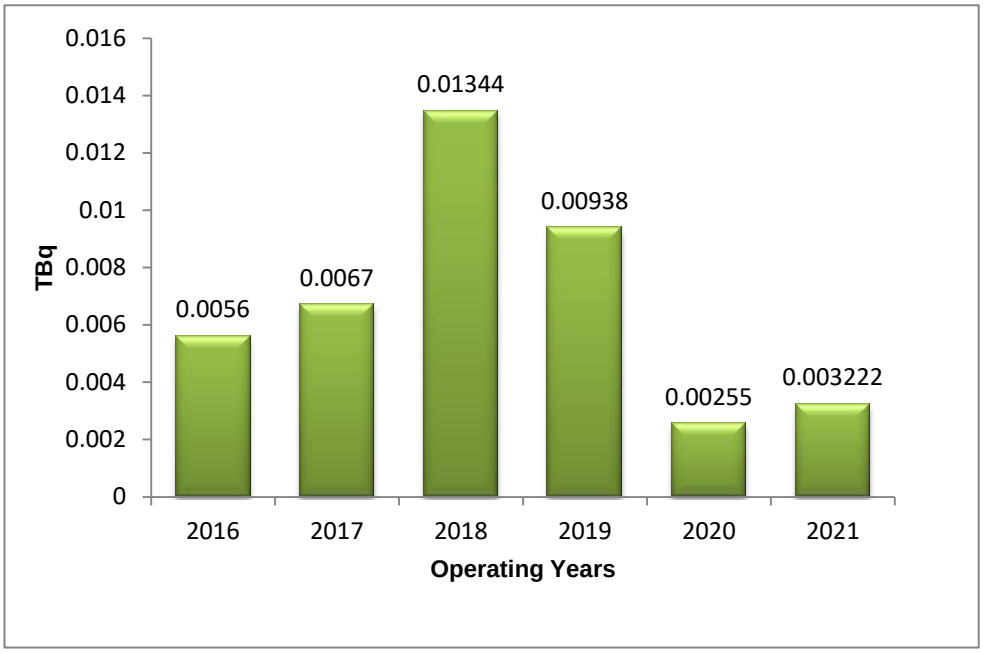


Figure 17: Gross Beta Gamma Released Through Liquid Effluents at K-1

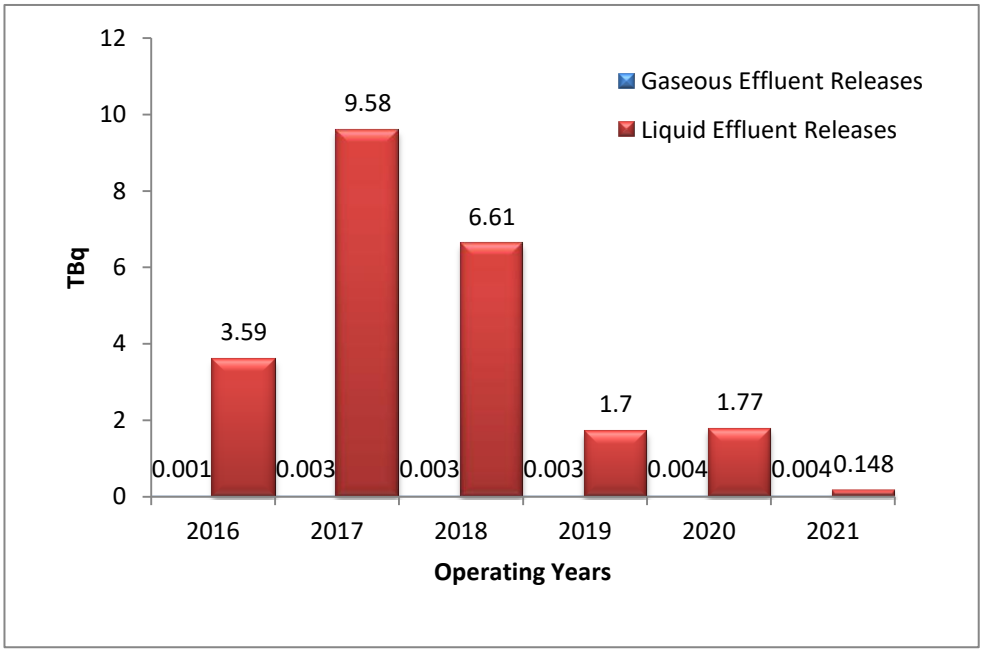


Figure 18: Effluent Releases at C-1

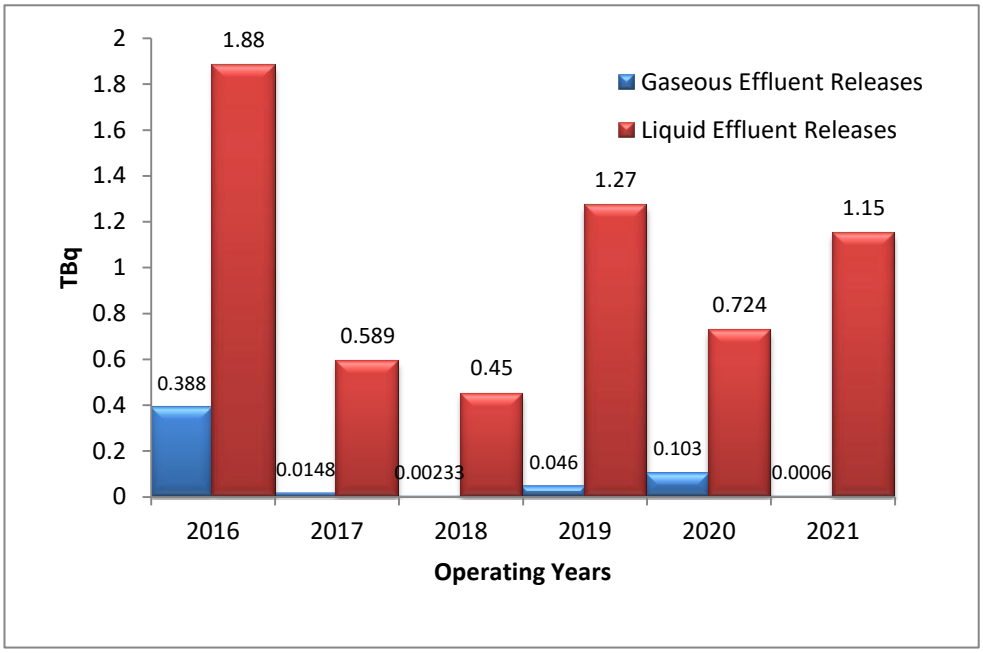


Figure 19: Effluent Releases at C-2

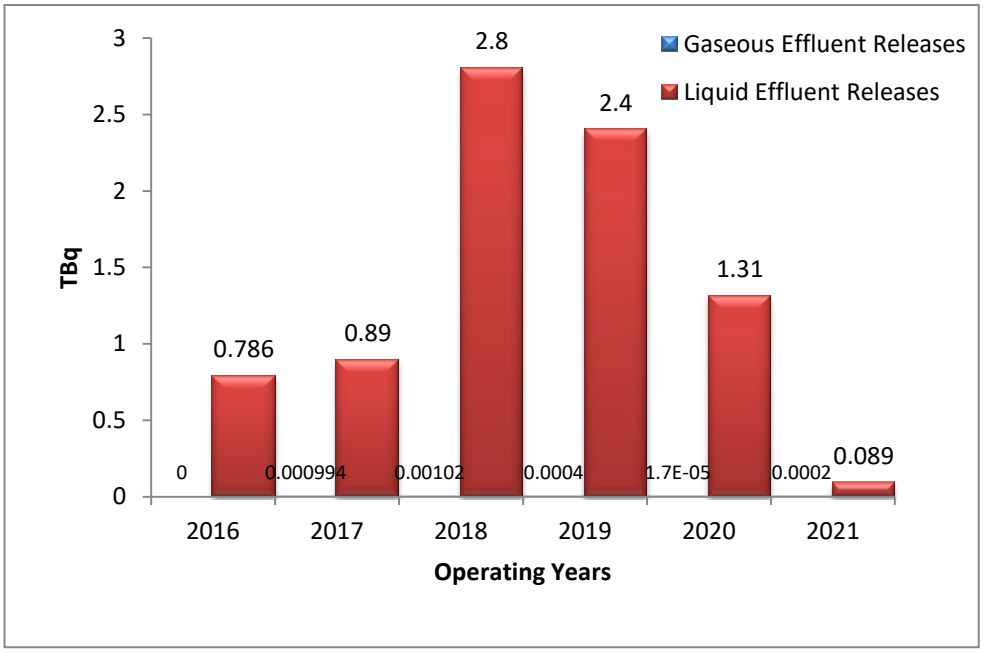


Figure 20: Effluent Releases at C-3

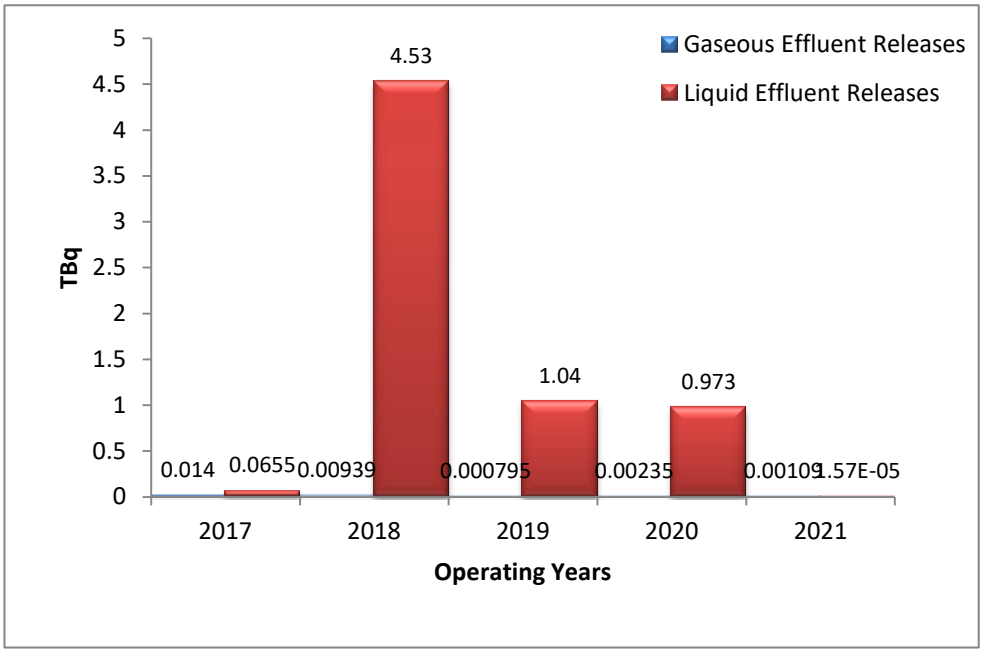


Figure 21: Effluent Releases at C-4

Note:- Gaseous effluent releases are not visible in figures 18-21 due to difference in order of magnitude with liquid effluent releases.

ANNEXURE–IX: ANNUAL AVERAGE AMBIENT DOSE LEVELS AROUND NUCLEAR INSTALLATIONS (2016-21)

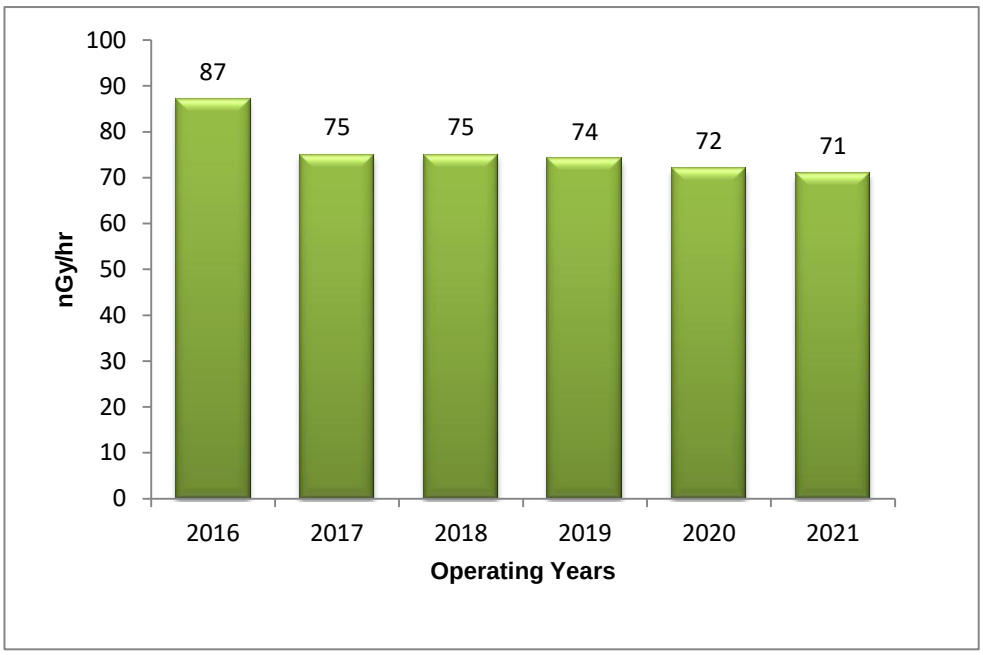


Figure 22: Ambient Radiation Levels around K-1

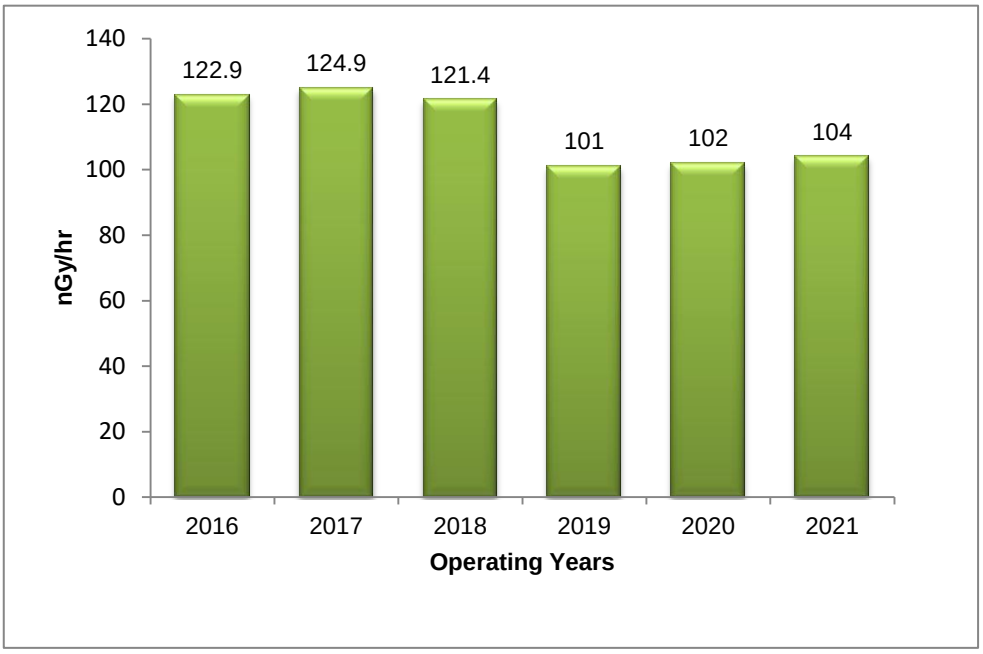


Figure 23: Average Ambient Dose Levels around CNPGS

ANNEXURE–X: FREQUENCY OF VARIOUS EMERGENCY EXERCISES AND DRILLS

Types of Emergency Exercises and Drills		Frequency
K-1		
1.	Decontamination of contaminated injured person	Half yearly
2.	Assembly area air sampling	Quarterly
3.	Emergency class announcement	Quarterly
4.	Notification of emergency to K-1Emergency Response Organization (KERO)	Yearly
5.	Healthiness of VHF communication sets and response of relevant personnel at emergency facilities	Quarterly
6.	Assembly Emergency Response Team (ERT)	Yearly
7.	Environmental monitoring and sampling activities	Quarterly
8.	Emergency assembly drill	Yearly
9.	Onsite emergency exercise	Yearly
10.	Integrated (on-site and off-site) emergency exercise	Once in two years
CNPGS		
11.	Communication drill	Quarterly
12.	Off-site projected dose assessment drill	Bi-Annual
13.	Search and rescue operation drill	Bi-Annual
14.	Medical treatment and personnel decontamination drill	Bi-Annual
15.	Fire fighting drill	Annual (with On-site PEE/IEE)
16.	On-site Partial Emergency Exercise (PEE)	Year next to year of IEE
17.	Off-site PEE	Year next to year of On-site PEE

18.	Integrated Emergency Exercise (IEE)	Once every three years
19.	Environmental radiation monitoring drill	Bi-Annual
20.	Emergency class assessment drill	Quarterly
21.	Post-accident sampling and analyses drill	Bi-Annual
22.	Environmental decontamination drill	5 – Years
K-2/K-3		
23.	Communication drill	Quarterly
24.	Off-site projected dose assessment drill	Bi-Annual
25.	Search and rescue operation drill	Bi-Annual
26.	Medical treatment and personnel decontamination drill	Annual
27.	Fire fighting drill	Quarterly
28.	On-site Partial Emergency Exercise (PEE)	Year next to year of IEE
29.	Off-site PEE	Year next to On-site PEE
30.	Integrated Emergency Exercise (IEE)	Once every three years
31.	Environmental radiation monitoring drill	Annual
32.	Emergency class assessment drill	Quarterly
33.	Post-accident sampling and analyses drill	Bi-Annual

ANNEXURE-XI: EMERGENCY EXERCISES PERFORMED AT K-1, CNPGS AND NRECC

1. Emergency Exercises Performed at K-1

Sr. No.	Time of Exercise	Type of Exercise
1.	September 2016	Integrated Emergency Exercise
2.	May 2017	Site Emergency Exercise
3.	March 2018	Integrated Emergency Exercise
4.	September 2018	K-1 Standby Emergency Exercise following a warning of Tsunami from National Tsunami Warning Centre (NTWC)
5.	November 2019	K-1 Site Emergency Exercise
6.	October 2020	KNPGS integrated emergency exercise
7.	November 2021	Joint Safety-Security Plant Emergency Exercise

2. Emergency Exercises Performed at CNPGS (C-1, C-2, C-3 and C-4)

Sr. No.	Time of Exercise	Type of Exercise
1.	April 2016	CNPGS Integrated Emergency Exercise
2.	December 2016	C-4First Fuel Load Permit On-site Exercise
3.	November 2017	CNPGS Partial On-Site Exercise
4.	December 2018	CNPGS Partial Off-Site Exercise (Tabletop)
5.	April 2019	CNPGS 9th Integrated Emergency Exercise
6.	December 2020	CNPGS 9th Partial Emergency Exercise

3. Participation of Pakistan in IAEA ConvEx Exercises

Sr. No.	Time of Exercise	Type of Exercise
1.	February 2016	ConvEx-2a
2.	March 2016	ConvEx-1a

3.	April 2016	ConvEx-1c
4.	June 2016	ConvEx-2b
5.	September 2016	ConvEx-1b
6.	February 2017	ConvEx-2a
7.	March 2017	ConvEx-1a
8.	April 2017	ConvEx-1c
9.	August 2017	ConvEx-1b
10.	December 2017	ConvEx-2b
11.	March 2018	ConvEx-2a
12.	April 2018	ConvEx-1a
13.	October 2018	ConvEx-1b
14.	October 2018	ConvEx-2b
15.	November 2018	ConvEx-2c
16.	January 2019	Convex-1a
17.	March 2019	Convex-2b
18.	June 2019	Convex-2a
19.	July 2019	Convex-1b
20.	October 2019	Convex-2d
21.	March 2020	Convex-1b
22.	May 2020	Convex-2a
23.	October 2020	Convex-1a
24.	December 2020	ConvEx-2c
25.	March 2021	Convex-2b
26.	April 2021	Convex-1b
27.	May 2021	Convex-2a

28.	October 2021	Convex-3

4. Exercises Conducted by NRECC

Sr. No.	Time of Exercise	Type of Exercise
1.	February 2016	COMTEX
2.	June 2016	COMTEX
3.	October 2016	COMTEX
4.	October 2016	MRML
5.	December 2016	MRML
6.	February 2017	COMTEX
7.	June 2017	COMTEX
8.	August 2017	MRML
9.	October 2017	COMTEX
10.	November 2017	MRML
11.	January 2018	Un-announced MRML
12.	February 2018	Un-announced MRML
13.	February 2018	COMTEX
14.	May 2018	MRML
15.	June 2018	COMTEX
16.	October 2018	COMTEX
17.	December 2018	MRML
18.	February 2019	COMTEX
19.	May 2019	MRML
20.	June 2019	COMTEX
21.	October 2019	COMTEX
22.	January 2020	MRML
23.	February 2020	COMTEX

24.	February 2020	MRML
25.	October 2020	COMTEX
26.	April 2021	COMTEX
27.	June 2021	MRML
28.	October 2021	COMTEX

ANNEXURE–XII: LIST OF ABBREVIATIONS

AFI	Area for Improvement
ALARA	As Low As Reasonably Achievable
AMP	Ageing Management Program
ASME	American Society of Mechanical Engineers
C-1	Chashma Nuclear Power Plant Unit-1
C-2	Chashma Nuclear Power Plant Unit-2
C-3	Chashma Nuclear Power Plant Unit-3
C-4	Chashma Nuclear Power Plant Unit-4
CANDU	Canada Deuterium Uranium
CAP	Corrective Action Program
CFAMs	Corporate Functional Areas Monitors
CERO	CNPGS Emergency Response Organization
CHASCENT	Chashma Center of Nuclear Training
CJ	Chashma-Jhelum
CNA	Competence Need Assessment
CNPGS	Chashma Nuclear Power Generating Station
CNPE	China National Power Engineering Company
CNPO	China Nuclear Power Operation Technology Corporation
CNS	Convention on Nuclear Safety
COER	CNPGS Operating Experience Report
COG	CANDU Owners Group
COMTEX	Communication Test Exercise
ConvEx	Convention Exercise
CPHGC	China Power Hub Generation Company

CRDM	Control Rod Drive Mechanism
CSRC	Corporate Safety Review Committee
CZEC	China Zhongyuan Engineering Company
DBE	Design Basis Earthquake
DCO	District Coordination Officer
DDMA	District Disaster Management Authority
DG	Diesel Generator or Director General
DID	Defence-in-Depth
DNS	Directorate of Nuclear Safety
DOS	Directorate General of Safety (PAEC)
DQM	Directorate of Quality Management
DSRS	Disused Sealed Radioactive Sources
DTS	Directorate of Technical Support
ECC	Emergency Control Center
ECR	Emergency Control Room
EDG	Emergency Diesel Generator
EIA	Environmental Impact Assessment
EIICA	Events and Issues Identifications and Corrective Action Program (generally called CAP)
ELAP	Extended Loss of AC Power
EMA	Emergency Bus A
EMB	Emergency Bus B
EOP	Emergency Operating Procedures
EPA	Environmental Protection Agency
EPP	Emergency Preparedness Plans
EPR	Emergency Preparedness and Response

EPZ	Emergency Planning Zones
EX	Electrical Island
FCIA	Fuel Chanel Integrity Assessment
FP	Full Power
FR	Finding Report
FRAP	Fukushima Response Action Plan
FSAR	Final Safety Analysis Report
FSG	FLEX Support Guidelines
FSTS	Full Scope Training Simulator
FW	Fire Water
GoP	Government of Pakistan
HFE	Human Factors Engineering
HLO	House Load Operations
HMC-3	Heavy Mechanical Complex -3
HMI	Human Machine Interface
HRA	Human Reliability Analysis
HRD	Directorate of Human Resource Development
HSI	Human System Interface
IAEA	International Atomic Energy Agency
ICCC	Instrumentation Control and Computer Complex
IEC	International Electro-technical Commission
I&C	Instrumentation and Control
I&E	Inspection and Enforcement
IEE	Integrated Emergency Exercise
IEEE	Institute of Electrical and Electronic Engineers

INES	International Nuclear and Radiological Event Scale
IPP	Independent Power Producers
IRRS	Integrated Regulatory Review Services
IRS	International Reporting System for Operating Experience
ISI	In-Service Inspection
ISO	International Organization for Standardization
K-1	Karachi Nuclear Power Plant (Unit-1) (Previously known as KANUPP)
K-2	Karachi Nuclear Power Plant (Unit-2)
K-3	Karachi Nuclear Power Plant (Unit-3)
KDP	Karachi Decommissioning Project
KINPOE	Karachi Institute of Power Engineering
KM	Knowledge Management
KNPGS	Karachi Nuclear Power Generating Station (KDP, K-2 and K-3)
KOER	KNPGS Operating Experience Report
KOFREP	K-1 Offsite Radiological Emergency Plan
KRERC	Karachi Radiological Emergency Response Committee
KSC	K-1 Safety Committee
KSFDS	K-1 Spent Fuel Dry Storage
LAN	Local Area Network
LDP	Leadership Development Program
LER	Licensee Event Report
LLW	Low Level Waste
LSD	Long Shutdown
LUMS	Lahore University of Management Sciences
MCR	Main Control Room

MOV	Motor Operated Valve
MRML	Mobile Radiological Monitoring Labs
MSL	Mean Sea Level
MSM	Management System Manual
NAC	National Assistance Capabilities
NaOCI	Sodium Hypochlorite
NB	Reactor Building
NCA	National Command Authority
NCNDT	National Center for Non-Destructive Testing
NCR	Non Conformance Report
NDE	Non Destructive Examination
NDMA	National Disaster Management Authority
NDMC	National Disaster Management Commission
NDMO	National Disaster Management Ordinance 2007
NDRP	National Disaster Response Plan
NDT	Non Destructive Testing
NEMP	National Environmental Monitoring Program
NEMS	Nuclear Emergency Management System
NEPRA	National Electric Power Regulatory Authority
NEWS	Nuclear Events Web Based System
NOC	No Objection Certificate
NGO	Non Governmental Organization
NISAS	National Institute of Safety and Security
NKI	Northern Karachi Interconnection
NNSA	National Nuclear Safety Administration

NPP	Nuclear Power Plants
NR	National Report
NRECC	National Radiological Emergency Coordination Centre
NRERP	National Nuclear and Radiological Emergency Response Plan
NSC	Nuclear and Radiation Safety Centre
NSD	Directorate of Nuclear Safety
NTDC	National Transmission and Dispatch Company
NUML	National University of Modern Languages
NURESC	Nuclear and Radiological Emergency Support Center
NX	Nuclear Island
OEF	Operating Experience Feedback
OL	Operating License
OLC	Operational Limits and Conditions
O&M	Operation and Maintenance
OPP	Operating Policies and Principles
OSART	Operational Safety Review Team
OSPI	Operational Safety Performance Indicators
OSRC	Operational Safety Review Committee
OTD	Operation Training Division
PAEC	Pakistan Atomic Energy Commission
PAM	Post Accident Monitoring System
PAP	Public Awareness Program
PAR	Passive Autocatalytic Re-combiner
PDMA	Provincial Disaster Management Authority
PDTP	Post Diploma Training Program

PEE	Partial Emergency Exercise
PERCC	PAEC Emergency Response Coordination Center
PGA	Peak Ground Acceleration
PGTP	Post Graduate Training Program
PIEAS	Pakistan Institute of Engineering and Applied Sciences
PIE	Postulated Initiating Events
PM	Preventive Maintenance
PMD	Pakistan Meteorological Department
PNRA	Pakistan Nuclear Regulatory Authority
PO&C	Performance Objective and Criteria
PSA	Probabilistic Safety Analysis
PSAR	Preliminary Safety Analysis Report
PSDP	Public Sector Development Program
PSHA	Probabilistic Seismic Hazard Analysis
PSI	Pre-Service Inspection
PSR	Periodic Safety Review
PWR	Pressurized Water Reactor
QA	Quality Assurance
QAD	Quality Assurance Division
QAP	Quality Assurance Program
QMS	Quality Management System
QNPC	Qinshan Nuclear Power Company
R&D	Research and Development
RAG	Radiological Assistance Group
RANET	Response Assistance Network

RCA	Radiation Controlled Area
RCC-M	Design and Construction Rules for Mechanical Components of PWR Nuclear Island (French Code)
RCP	Reactor Coolant Pump
REM	Radiological Environmental Monitoring
RFO	Refueling Outages
RNSD	Regional Nuclear Safety Directorate
RNSI	Regional Nuclear Safety Inspectorate
RPP	Radiation Protection Program
RPV	Reactor Pressure Vessel
RTD	Resistance Temperature Detector
RWMP	Radioactive Waste Management Program
SA	Self-Assessment
SAFSTOR	Safe Storage
SALTO	Safe Long Term Operation
SAMG	Severe Accident Management Guidelines
SAP	Self Assessment Program
SAR	Safety Analysis Report
SCSA	Safety Culture Self-Assessment
SED	Site Emergency Director
SEED	Site and External Event Design
SER	Site Evaluation Report
SFP	Spent Fuel Pool
SG	Steam Generator
SI	Station Instruction
SIT	Structure Integrity Test

SNERDI	Shanghai Nuclear Engineering Research and Design Institute
SOER	Significant Operating Experience Report
SOP	Standard Operating Procedure
SPD	Strategic Plans Division
SPDS	Safety Parameters Display System
SPI	Safety Performance Indicators
SRC	Reactor Coolant System
SRH	Residual Heat Removal System
SRS	Sealed Radioactive Sources
SSC	Structures, Systems and Components
SSE	Safe Shutdown Earthquake
STI	Secretariat Training Institute
TC	Technical Cooperation
TEWS	Tsunami Early Warning System
TLD	Thermo Luminescent Dosimeter
TS	Technical Specifications
TSC	Technical Support Committee
TSO	Technical Support Organization
UHS	Ultimate Heat Sink
UPS	Un-interrupted Power Supply
USNRC	US Nuclear Regulatory Commission
UT	Ultrasonic Testing
VDNS	Vienna Declaration on Nuclear Safety
VHF	Very High Frequency
V&V	Verification and Validation

WANO	World Association of Nuclear Operators
WES	Essential Service Water