Radiation Protection in the Operation of the Algerian Nuclear Research Reactor NUR

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ABSTRACT

Research reactors provide important benefits, including research, education, radioisotope production, fuel and materials testing and medical and industrial applications. The potential hazard to the public from most research reactors would be small compared to that from power reactors but the potential hazard to occupational workers may be greater. There is a high interest in studies leading to more precise knowledge of the various components of the radiation environment to radiation exposure and to justification of the regulations, rules and standards for radiation safety in operating such installations. This paper presents the radiation protection status at the 1 MW NUR Algerian nuclear research reactor. We describe here the minimum elements of a radiological control plan necessary to provide an acceptable level of radiation protection for personnel at NUR research reactor and population and environmental exposures in a manner that will maintain exposures as low as is reasonably achievable.

1. INTRODUCTION

Algeria has sufficient uranium resources to produce nuclear energy. On the southwest border with Niger, there is an estimated 56,000 tons of uranium that could be used to produce nuclear fuel. Between 1971 and 1998, the government undertook many activities to exploit uranium. This led to the discovery of deposits in Eglab, Ougarta and southern Tassili. These results were encouraging. However, between 1998 and 2001, the search effort declined progressively and since then, no real prospecting activity has been pursued (OECD and IAEA, 2005). In 1985, the Algerian Government announced that the very first Algerian research nuclear reactor would be built at Draria, on the eastern coast of Algiers (Kessler, 1989). The Argentine nuclear vendor Investigaciones Aplicadas (INVAP) was selected in alliance with a number of local engineering companies. Construction began in 1986. The 1 MW thermal power multipurpose reactor in Algiers named NUR ("luminosity" in Arabic) went critical and was inaugurated in April 1989. It took only 18 months to assemble. Its design is similar to Argentina's RA-6 reactor, but has significant improvements to its human interface capabilities.

Figure 1: The NUR main building

2. Description of the core configurations of the NUR research reactor

Nur is a 1MW pool type reactor located at Draria, 10 km east of Algiers and 200 m above the sea level (figure 1). It has an open water surface and variable core arrangement that uses 19.75% enriched uranium. The reactor core is surrounded by graphite reflector blocks and light water. The latter serves as coolant, moderator, and reflector. Table 1 gives the important NUR core data. In order to facilitate research activities, the reactor is equipped with several vertical and horizontal irradiation beam channels and a neutron radiography facility (figure 2). The reactivity control system of the reactor is made of five Ag–In–Cd absorbing rods: four control and safety rods (C1, C2, C3, and C4) and one fine regulating rod (*F*) (Meftah et al., 2006). There is an auxiliary pool for spent-fuel storage.

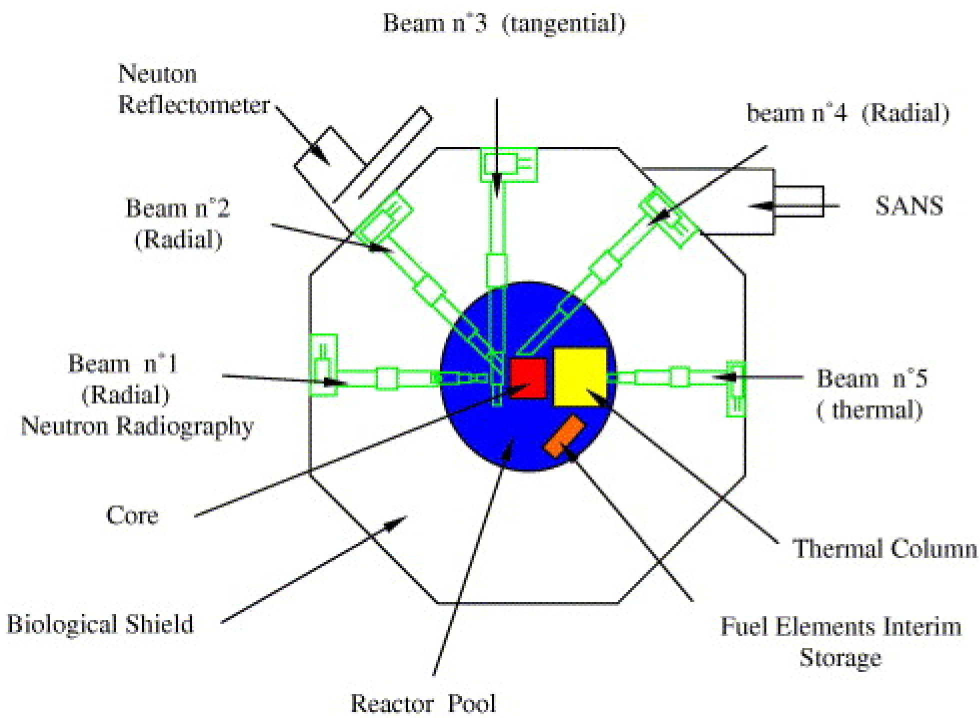

Figure 2: Top cross-sectional view of the Nur reactor.

Table 1. NUR Technical data

Technical Data	
Reactor Type	Pool
Diameter	3 m
Height	10 m
Thermal Power, Steady (MW)	1.00
Max Flux, Thermal (n/cm2-s)	8.9E12
Max Flux, Fast (n/cm2-s)	2.0E12
Moderator	Graphite
Coolant	Light water
Natural Convection Cooling	Yes
Forced Cooling	220 m^3 /h
Coolant Velocity in Core	30 cm/sec
Reflector	Graphite, Light water
Reflector Number of Sides	4
Control Rods Material	Ag,In,Cd
Control Rods number	5
Horizontal Channels	5
Horizontal Use	Neutron radiography
Core Irradiation Facilities	1
Reactor building ventilation system	Underpressure 10mm of H_2O
Filters	carbon-activated filters for normal and emergency conditions

3. NUR - a versatile and reliable tool serving Algeria for many years

Algeria was not a signatory to the Nuclear Non Proliferation Treaty at the time of inaugurating this research reactor. The reactor itself is of little direct significance to weapons proliferation, in partly dues to its limited capacity, and because the reactor was subject to a site-specific safeguards agreement with the IAEA. One important point of the arrangement with the contracting party, the Haut Commissariat à la Recherche of Algeria (today replaced by the Commissariat a l'Energie Atomique, COMENA) was the participation, right from the beginning of the project, of over 50 Algerian professionals and technicians and a number of Algerian firms, involved in the project.

The design concept of NUR reactor is based on the requirements of a reactor of versatile utilization. The reactor has been mainly designed for the following purposes:

- Neutron radiography for research and industrial purpose
- Laboratory scale production of radioisotope for medical and industrial uses
- Basic and applied research in reactor physics and nuclear engineering
- Beam port for neutron scattering experiments and neutron radiography
- Materials testing
- Activation analysis
- Materials irradiation
- Training of scientific and technical personnel

NUR reactor features a hot-cell and circuit to handle irradiated samples by pneumatic transport, several neutron beam extraction channels, and a supplementary control console - 'slave' to the main console - by means of which the reactor can be operated by personnel in training.

4. Safety

Reactor safety is complemented with a network of radiation detectors located in contamination-risk areas, plus a fire-detection and manual and automatic fire-extinguishing systems. Auxiliary services such as water supply, compressed air, electrical energy system, communications system, workshops, physical security system and labs are also available. The whole reactor is housed in a steel containment building in which the air is maintained at slightly less than atmospheric pressure (10 mm H_2O). In the unlikely event of any release of radioactive material from the reactor, the building automatically seals to prevent any contamination of the environment. In the event of any condition exceeding safe operating limits, the reactor protection system would automatically shut it down. This is done by the release of the cadmium control arms which drop between the fuel elements to absorb all of the free neutrons. A number of cooling systems with back-up safety mechanisms installed in the reactor would operate if there were any likelihood of its fuel overheating.

5. Reprocessing

In 1995, Algeria begun to construct a nuclear fuel reprocessing plant and associated facilities with the assistance of China next to the Essalam research reactor (located at Ain Oussera at 90 km south–west of Algiers) (Spector et al., 1995) (Albright and Hinderstein, 2001). This is a part of the second phase of a nuclear cooperation agreement with Algeria.

6. Waste Disposal

Next to the reprocessing plant are two storage tanks used for storing high-activity liquid waste. The facility consists of two sections and is made of heavy concrete and contain hot cells. The first section contains five tanks, set in reinforced concrete and brick. The second section is a liquid storage building containing six storage tanks. This area expanded the liquid waste storage capacity of the site to twice its original size.

7. Radiological impact assessment on the population in the vicinity of NUR reactor

The meteorological data relevant to the Algiers region and provided by the National Office of Meteorology, covers a period of 15 years and consist of 122 663 hourly observations of wind speed and direction as well as atmospheric stability class [Office National de Météorologie, 1988].

In the framework of the environmental impact studies of the NUR reactor, a study assessed, on the basis of a Gaussian dispersion model, the impact of atmospheric releases from the reactor in normal operation mode (Messaci 2007). One of the important meteodiffusive assessed parameters is the annual averaged atmospheric dilution factor (ADF) (expressed in $s.m^{-3}$). The maximum impact point has been located at a distance ranging from 300m to 1 km from the release point which corresponds to 10 to 30 times the height of the reactor stack. Furthermore, the area located at the south of the reactor is by far the most exposed one (ADF $\approx 1.5 \times 10^{-5}$ $s.m^{-3}$), 1 to 2 orders higher than that of the other sectors.

8. Radiation protection in and around NUR reactor

COMENA is the Regulatory Body and the Operating Organization designated by the Algerian Government as having legal authority for conducting the regulatory process, including issuing authorizations, regulating nuclear radiation, radioactive waste and transport safety. In accordance with the IAEA (IAEA, 2004) and the ICRP 60 (ICRP 60, 1991) international recommendations, COMENA issued a code of conduct to achieve and maintain a high level of safety for the NUR nuclear reactor. The objective of this code of conduct is achieved by proper operating conditions, the prevention of accidents and, should accidents occur, the mitigation of the radiological consequences, in order to protect workers, members of the public and the environment against radiation hazards.

As far as radiation protection and safety in and around NUR reactor are concerned the role of COMENA is to:

- require that radiation doses to workers and the public, including doses from releases to the environment, be within prescribed international dose limits and be as low as reasonably achievable, social and economic factors being taken into account
- provide guidance, as international consensus develops, on the protection of the environment from the harmful effects of ionising radiation
- establish criteria for intervention in emergencies, and require that adequate emergency plans be in place
- establish and implement effective quality assurance programmes with a view to providing confidence that

specified requirements for all activities important to nuclear safety are satisfied throughout the life of the research reactor

- carry out a comprehensive and systematic safety assessment and periodic safety reviews. These include all technical, operational, personnel and administrative aspects of safety related operations. The assessments and reviews are well documented, subsequently updated in light of operating experience and significant new safety information and reviewed

The system of protection against radiation at NUR reactor includes:

- Control of personal dose using portable devices (TL, electronic dosimeters)
- Ambient neutron detectors
- Control of surface contamination
- Control of the concentration of gas and radioactive dust in air.

The radiological protection instrumentation includes:

- Detection of fuel elements leakage $^{88, 89}Rb$, $^{134, 137, 138}Cs$ on particulate air monitors and $^{85, 88}Kr$ and $^{133, 135, 138}Xe$ on gaseous air monitors
- Detection of $^{131, 132, 133, 134, 135}I$, noble gases and aerosols
- Fixed radiation monitors (area gamma and neutron monitors with local alarms)
- Various types of portable monitors (gamma survey meters and neutron dose equivalent meters)
- surface contamination monitoring (direct and indirect measurement of surface contamination made with portable instruments for alpha and/or beta/gamma contamination)
- Foot and hand contamination monitors

The general services and facilities include:

- Clean and dry compressed air
- Fire detection
- Manual and automatic fire extinguishing system
- Electric power system
- Stand-by power system for illumination and power supply
- Emergency power illumination system
- Closed TV circuit
- Internal telephone network
- Loudspeaker system

9. Conclusion

In order to achieve the fundamental safety objective to protect workers and people and the environment from the harmful effects of ionizing radiation, a comprehensive safety analysis has been carried out at NUR reactor to identify all sources of exposure and to evaluate radiation doses that could be received by workers and the public, as well as potential effects on the environment. The neighborhood of the NUR reactor is monitored, as well. So far, no influence on the outside environment has been found out. Neither any accident has occurred at the NUR workplace with the radiation consequences.

10. REFERENCES

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