



KINGDOM OF MOROCCO

**SHARING MOROCCO'S EXPERIENCE
IN DEVELOPING NUCLEAR TECHNIQUES
IN A SAFE, SECURE AND SUSTAINABLE MANNER**



SAFETY

SCIENCE

TECHNOLOGY

SECURITY



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INTRODUCTION

Since the 1970s, the use of ionizing radiation in Morocco has been promoted and developed progressively in different socio-economic sectors, such as health, agriculture, medicine, industry, energy, environment, water, research and education.

In parallel to this development, the Kingdom of Morocco has continuously upgraded its nuclear legislative and regulatory framework in compliance with the international obligations and standards governing nuclear energy utilizations.

The launching, in 2003, of the Maamora Nuclear Research Centre 'MNRC' and the exploitation of the TRIGA MARK II research reactor since 2009 gave rise to new considerations in terms of nuclear safety and security, development of new applications, training and education, knowledge management, expertise as well as national, regional and international cooperation.

To be fully in compliance with its international obligations, Morocco promulgated in 2014 a new and comprehensive law addressing safety, security and safeguards and creating the Moroccan Agency for Nuclear and Radiological Safety and Security 'AMSSNuR'.

In this context, in 2016, AMSSNuR was established as an independent regulatory body to conduct all core regulatory functions (authorization, review and assessment, inspection and enforcement, communication with stakeholders, development of regulation, etc.) as well as government support, public information and international cooperation.

Globally, the Kingdom of Morocco has developed a strong collaboration network at multilateral and bilateral levels, mainly with International Atomic Energy Agency 'IAEA', African Regional Cooperative Agreement for Research, Development and Training related to Nuclear Science and Technology 'AFRA', Arab Atomic Energy Agency AAEA, Global Nuclear Safety and Security Network 'GNSSN', Regulatory Cooperation Forum 'RCF', Forum of Nuclear Regulatory Bodies in Africa 'FRNBA', Arab Network of Nuclear Regulators 'ANNuR' and several operators and regulators in partner countries.

Being involved in Regional and International Cooperation, Morocco prepared this document with the purpose of sharing its experience in developing Nuclear Techniques in a Safe, Secure and Sustainable manner.

In compliance with the United Nations Sustainable Development Goals, this document highlights the contribution of the nuclear science and technology applications to the development of Human Health, Food and Agriculture, Water Resources, Industry, Environment Monitoring and Protection, Education and Training.

OVERVIEW OF MOROCCO'S NUCLEAR AND RADIOLOGICAL SECTOR

In terms of activities and facilities involving Ionizing Radiation Sources, Morocco's Nuclear and Radiological Sector is dominated by Medical and Industrial applications with more than 80 % of the total volume.

Research and Education activities are also in progress regarding the number of the laboratories and facilities operated by CNESTEN, INRA and other institutions in cooperation with Universities and relevant National and International Stakeholders.

Figure 1: National Status of Ionizing Radiation Sources utilizations

Industry

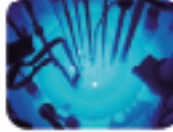
- 400 Radiometric gauges used for quality control in petrochemistry, sugar, factories, cement plants, paper mills
- 13 Non-Destructive Testing Companies (NDT)

Security Control

- More than 40 scanners Installed at ports and airports
- 8 Accelerators for fluoroscopy of trucks and containers during customs checks

Research & Education

- Research Reactor 2 MW
- A dozen research laboratories



Health

- 7200 diagnostic and interventional radiology X-ray units
- 300 scanners
- 42 Linear accelerators for radiotherapy
- 16 HDR brachytherapy Sources
- 2 Gamma Knife Radiosurgery Units
- 23 Nuclear Medicine Centers

Agriculture

- About twenty Veterinary Radiology facilities
- 1 Food Irradiator Units
- 2 Seed Irradiators In project

Radiopharmaceutical industry

- 2 Cyclotrons for the production of Fluorine 18
- 1 Radiopharmaceutical facility for the production of Iodine 131

In general, this sector is in constant development and requires continuous improvements in terms of Regulations, Human Resources Capacity, Education and Training Programs as well as International Cooperation.

NATIONAL LEGAL AND REGULATORY FRAMEWORK FOR SAFETY, SECURITY AND SAFEGUARDS

The development of ionizing radiation sources activities in different socio-economic sectors led the kingdom of Morocco to establish a legislative and regulatory framework in a consistent manner that is compatible with the international obligations, with international standards and guidance.

The Kingdom of Morocco has signed and ratified the main UN international conventions related to Nuclear and Radiation Safety and Security.

In the early seventies, Morocco established the first components of a legal framework governing all activities and facilities using or in possession of ionizing radiation sources. In the eighties, the main components of the regulatory framework were put into force (nuclear safety, radiation protection, nuclear liability).

National Legal Framework

- Law 142-12 on Nuclear and Radiological Safety and Security, and the creation of AMSSNuR (22 August 2014);
- Law 12-02 relating to Civil Liability for Nuclear Damage (7 January 2005);
- Law n° 11-03 relating to Environment Protection (2003);
- Law n° 12-03 on Environmental Impact Studies (12 May 2003);
- Law n° 03-03 relating to the fight against terrorism (28 May 2003);
- Law No. 31-13 on the right of access to information (February 22, 2018);
- Decree No. 2-15-557 of 16 October 2015 implementing the provisions of Title 3 of Law 142-12 on Nuclear and Radiological Safety and Security and the creation of the Moroccan Agency for Nuclear and Radiological Safety and Security (AMSSNuR);
- Decree 2-94-666 of 7 November 1994, relating to the Authorization and Control of Nuclear Facilities;
- Decree 2-97-30 of 28 October 1997, relating to Ionizing Radiation Protection;
- Decree 2-97-132 of 28 October 1997, relating to the use of Ionizing Radiation for Medical purposes;
- Decree n° 2-05-1560 (21 April 2006) for the implementation of the law n° 12-02 on Civil Liability for Nuclear Damage.



This framework designated two regulatory bodies:

- 1- The Ministry in charge of Energy, responsible for the licensing and inspections of nuclear installations and activities.
- 2- The Ministry of Health (through the National Radiation Protection Centre 'CNRP'), responsible for the authorization and inspections of activities and facilities using ionizing radiation sources, in medical, industrial, agricultural, research and other applications.

This legal and regulatory framework has been useful in exercising a regulatory oversight on all activities in Morocco, including construction, commissioning and operation of the Maamora Nuclear Research Centre.

To be fully consistent with its international obligations, Morocco developed a new and comprehensive law addressing nuclear and radiological safety and security and safeguards and proceeded to the Separation of regulatory functions from those dedicated to the promotion of nuclear and radiological applications.

In 2016, AMSSNuR was established as the National Regulatory Authority and developed a strategy to upgrade the national regulatory framework according to the provisions of the Law n° 142-12 and with international Nuclear Safety, Security and Safeguards instruments and treaties, standards and guidance that require the founding of an independent regulatory body.

AMSSNuR

AMSSNuR PRESENTATION

Mission

Established in 2016 by the Law 142-12, AMSSNuR is committed to ensure Compliance of the Radiological and Nuclear Safety and Security of all activities and facilities involving Ionizing Radiation with Morocco's regulatory framework and its international obligations.

Vision

AMSSNuR has established a clear Vision, and Strategic Plan for 2017-2021 to become an Independent, Efficient, Credible and Transparent Regulatory Body.

In 2016, these Strategic Orientations were presented and approved by AMSSNuR's Board of Directors.

Objectives of the Strategic Plan 2017-2021

The following objectives were presented and approved by AMSSNuR's Board of Directors in September 2016:

- Develop and upgrade the existing regulatory framework in compliance with the provisions of the Law 142-12, relevant International Instruments, Standards and Guidance;
- Strengthen the level of nuclear and radiological safety and security of the activities and facilities involving ionizing radiation;
- Implement, in collaboration with the relevant National Departments and Organizations, the National Nuclear Security System and the National Emergency Plan in case of Nuclear Accidents and Radiological Emergencies;
- Establish a transparent and reliable communication policy and strategy;
- Develop and maintain the Human and Organizational Capabilities necessary to Implement AMSSNuR's Strategic Objectives;
- Conduct a proactive Regional and International cooperation programme and monitor the progress in the fields of Nuclear and Radiological Safety and Security.



National Meeting on Emergency Preparedness and Responses

Roadmap 2017-2021

The methodology adopted by AMSSNuR for developing its capacities is based on a stepwise approach and on an open dialogue with all relevant stakeholders.

Figure 2: Roadmap for developing AMSSNuR's activities



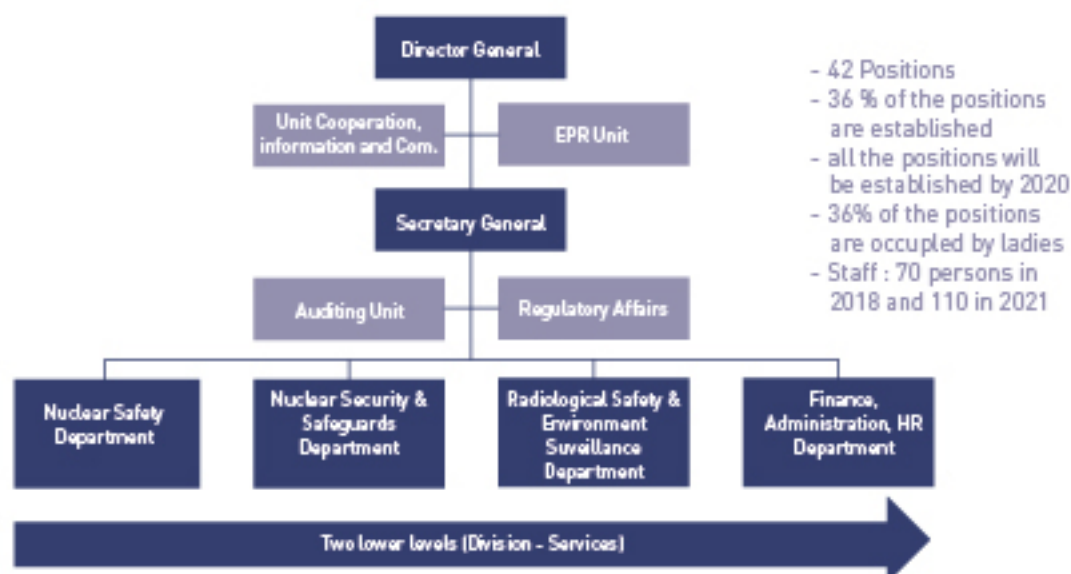
Organization and Human Resources Development

AMSSNuR has adopted an organization (Figure 3), based on 3 core competencies dedicated respectively to (1) Radiological Safety and Protection of the Environment, (2) Nuclear Safety and (3) Nuclear Security and Safeguards.

The fourth department is dealing with support activities (administration, budget, human resources, training, ...).

The organization also includes different Units or services, in charge of developing Public Information, Communication, Cooperation, Emergency Preparedness and Response as well as Audit and Management Control.

Figure 3: AMSSNuR's Organizational Chart



AMSSNuR's Staff

Beside this organization, AMSSNuR developed a Human Resources Development Plan aiming to achieve its Regulatory Functions and all its Activities.

The current staff number is 50 persons and by 2021 it will reach more than 100 staff members.

Regulatory Functions

In compliance with the Law 142-12, AMSSNuR's Strategy is in line with the following regulatory functions:

1. Regulations:

- Prepare and assess Legislative and Regulatory texts in the Nuclear and Radiological fields to be submitted to the Government for approval; and,
- Publish best practices Guidance and Manuals to support the users in implementing relevant national regulations.

2. Authorization and Inspection:

- Manage the Regulatory Control Systems,
- Review and assess all individual applications concerning facilities and activities involving Ionizing Radiation,
- Enforce regulated activities involving Ionizing Radiation, and,
- Establish and implement a state system of accounting for, and control of nuclear material.

3. Government Support:

- Assist the government in establishing national plans for:
- The physical protection of nuclear materials and installations,
- Nuclear and Radiological Emergency Response,
- Assist the Government in the implementation of the legally binding international instruments ratified by the kingdom of Morocco.

4. Public Information:

- Inform the public on regulatory processes safety issues related to Nuclear and Radiological activities,
- Communicate with relevant stakeholders.



Regional Information Meeting of the public and the stakeholders

Activities' Programs

To support its vision and mission, AMSSNuR designed an Integrated Management System covering all its activities including Governance and Decisional and Operational Processes.

Based on the Law 142-12, AMSSNuR's activities are organized in four main Programs dedicated to the development of:

- Core mission and functions,
- Government Support,
- Accompanying Activities,
- Internal Support.

Figure 4: Integration of the AMSSNuR's Activities' Programs and Processes



Detection Exercise

CNESTEN

CNESTEN PRESENTATION

Missions

The National Centre for Nuclear Energy, Science and Technology 'CNESTEN' is a state owned institution with legal and financial autonomy and operating under the supervision of the Ministry of Energy, Mines and Sustainable Development.

CNESTEN was established in 1986 in order to promote, at the national level, the applications of nuclear science and technology for the benefit of scientific and socio-economic development of the country.

Indeed, CNESTEN has been assigned four main missions:

- Developing scientific research in nuclear science and technology;
- Promoting nuclear science and technology applications in social and economic sectors;
- Contributing to the development of nuclear infrastructure for a nuclear power program;
- Acting as a technical support organization to the national authorities in the fields of radiation and nuclear safety & security, safeguards, emergency preparedness & response.

Strategic Objectives

In line with its missions, CNESTEN has established the following strategic objectives:

- Enhancing the utilization of Maamora Nuclear Research Centre 'MNRC' facilities,
- Maintaining a high nuclear safety level,
- Performing R&D to address national societal needs,
- Developing technical support capabilities for the national authorities in terms of safety and security, emergency preparedness, ...,
- Developing financial self-reliance capability,
- Establishing a training and education reference centre at national and regional levels in nuclear science and technology,
- Developing and preserving the human capital and expertise.

Major Programs

According to its strategic objectives, CNESTEN undertakes several scientific and technical programs in various areas of nuclear applications such as:

Health and life Sciences:

- Production of Radiopharmaceuticals (Iodine 131, Tc99m, Cold kits, ..),
- Research in Molecular biology and radiobiology,
- Food and nutrition.

Water & Climate:

- Use of nuclear and isotopic techniques to study water cycle and climate,

Agriculture:

- Assessment of soil erosion and land degradation using fallout radionuclides,
- Use of nuclear tools (RIA) for monitoring reproductive hormones to enhance livestock productivity,

Environment and Natural Resources:

- Contribution of Nuclear Analytical Techniques for pollution assessment in soil, air, river and marine mediums and valorization of natural resources.

Industry:

- Quality control of industrial products and facilities,
- Troubleshooting and optimizing industrial processes using NDT,
- Radioactive sealed sources and radiotracers utilizations.

Nuclear safety and security

Radioactive waste management

Research in Material sciences

Education and training

Maamora Nuclear Research Centre

To fulfill its missions, CNESTEN has established, since 2003, the Maamora Nuclear Research Centre MNRC, the first nuclear facility of Morocco. It was constructed with the cooperation of France and the USA. The IAEA has contributed to the implementation of this important project in terms of training, technical expertise, design and safety reviews.

Located 25 kilometers North of Rabat, the MNRC is a multipurpose nuclear facility which includes a research reactor, 2 MWth power, and several laboratories dedicated to the development of nuclear applications in the fields of health, water, agriculture, environment, industry, safety, security and material sciences.

Nuclear Research Reactor

The TRIGA Research Reactor is currently licensed as a 2 MWth facility as part of the Nuclear Research Centre.

The construction, commissioning and operation of this reactor have been subjected to the system of authorization and inspection by the regulatory authority with the assistance of the IAEA, France, USA....

The safety reviews such as the IAEA INSARR missions confirmed the full compliance of the facility with international standards.

The construction, culminated with the successful completion of full power testing and the operation license delivered by the regulatory body on February 2009.

The Research Reactor offers various capabilities both for fundamental and applied research, as well as for industrial services and products. It has extended CNESTEN capability to fulfill its missions for promotion of nuclear technology applications in Morocco and contribution to the implementation of a national nuclear power program.



Nuclear Research Reactor Building

Utilization:

Since 2009, the reactor is being used in support of many research, commercial irradiation and teaching projects. It has demonstrated its success in the role of providing reliable services to national stakeholders and to the region.

Several socio-economic sectors, such as: health, mining, petroleum, aircraft and electronic industries, benefit from the main programs developed around the reactor:

1- Research and Development:

- Investigation of Mo 99 and other radioisotope production,
- Neutron imaging,
- Materials Science,
- Nuclear data analysis,
- Core physics and thermal hydraulic calculations,
- Instrumentation and control design,
- Safety studies.

2- Products and services

- Production of I-131,
- Analytical analysis (INAA, NAA): soil and ores analysis, environmental monitoring and pollution assessment,
- Investigation of archaeological artefact from museums.

3- Education and training

- Academic education in reactor physics, technology and utilization,
- Training and workshops in reactor physics, operation and management in the framework of AFRA projects;
- Internet Reactor Laboratory project (IRL): The TRIGA reactor of CNESTEN has been recognized by IAEA as the host facility for Africa. The IRL allows virtual real-time access to the CNESTEN TRIGA reactor for African countries for the purpose of education and training.

Technical features

- Steady state power rating of 2 MW(th).
- Fuelled by TRIGA standard, 8.5% uranium content, enriched less than 20%.
- 101 fuel elements and 5 B4C control rods.
- Reactor cooling by natural convection.
- Rotary specimen rack assembly capable of irradiation of 79 samples simultaneously.
- Pneumatic transfer system.
- One central experimental tube (max. flux $7 \times 10^{13}/\text{cm}^2 \text{ s}$).
- Thermal column.
- Three radial beam ports, one tangential.
- Hexagonal and triangular cut outs.
- Education and training facilities for university students and foreign fellows.

Future Facilities

- Neutron Diffraction
- PGAA
- Neutron Tomography.

NATIONAL NUCLEAR PROGRAMS

NATIONAL NUCLEAR PROGRAMS

During the last decades, the Kingdom of Morocco has developed in a safe, secure and sustainable manner, several nuclear programs concerning the applications in human health, nutrition, water, environment, food, agriculture, industry, energy, education and training.

CNESTEN is involved in these programs with different socio-economic operators as well as National Research Institutions, University and foreign partners.

As a regulatory body, AMSSNuR has established a national strategy to enhance the safety, security and safeguards capacity building in accordance with the provisions of the law n° 142-12 and international standards and best practices.

The international cooperation especially with IAEA, AFRA, European Union, USA, France and other countries has provided valuable support for the development of these programs in terms of theme definition, training, equipment and expertise.

Thus, the Kingdom of Morocco wishes through this publication to offer its know-how and share its experience and lessons learnt with interested IAEA Member States.

Human Health

Nuclear medicine and Radiotherapy are the medical techniques that involve the use of radiation or radioactivity to diagnose, treat and prevent various diseases such as infectious and non-communicable diseases.

Innovative technologies in Nuclear Medicine has revolutionized medical diagnosis such as SPECT/CT and PET/CT providing information about the anatomy and function, which would otherwise be unavailable, or would require a more invasive procedure or surgery.

The first applications of nuclear and radiation techniques for medical purposes in Morocco, mainly radiotherapy, were introduced since the fifties of the past century. During the last decades, Morocco enhanced the national capability to address needs related to the prevention, diagnosis and treatment of diseases through the application of nuclear techniques complementary to conventional techniques.

Different national projects have been implemented in order to establish and upgrade radiotherapy and nuclear medicine facilities and capabilities, both in public and private sectors.

Main Indicators

- 80 % of nuclear and radiological activities and facilities are concentrated in medical application;
- 40 000 new patients are treated annually;
- Two Cyclotrons
- 6 PET-SCAN
- Laboratories for the production of ¹³¹I and ⁹⁹Tc
- 29 Radiation Oncology and 22 nuclear medicine Centres;
- 60 % of the facilities are belonging to private operators and 40 % are operated by the public hospitals;
- More than 180 Radiation Oncologists,
- 80 Medical Physicists;
- 90 Radiation Therapists;
- 68 Nuclear Medicine Doctors.

Achievements:

The national program, 2009-2019, for cancer prevention and treatment that aims to strengthen medical research, encourages national institutions to conduct research activities for early cancer diagnosis and personalized therapy.

The number of health care professionals working in radiotherapy and nuclear medicine centres has increased significantly.

For this purpose, CNESTEN and other oncology centres and research institutes have focused on molecular tools to evaluate some biomarkers to be used in the diagnosis and/or as therapeutic targets.

In addition, several academic and clinical degree course programs dedicated to nuclear medicine, medical physics and radiotherapy are being implemented.

The majority of private and public radiotherapy centres are now implementing new treatment techniques such as IMRT, IGRT and VMAT with high precision, improving local tumor control and decreasing acute and late toxicities. Emerging new imaging technologies such as SPECT-CT or PET SCAN are also implemented across nuclear medicine centres.

Furthermore, Morocco has developed capacities in radiopharmaceutical production for nuclear medicine. Two established industrial cyclotrons are producing the most used PET radiopharmaceutical (18-FDG).

In addition, CNESTEN has submitted in 2018 to the Ministry of Health, the registration application for a local production of iodine-131.

As a regulatory body, AMSSNuR pays particular attention to the development of the regulations involving ionizing radiation sources, in particular radiation protection of patients and operators, training, nuclear security, transport of radioactive materials, management of radioactive waste, preparedness and responses in the case of radiological emergencies, etc.

The objective is to ensure a high level of safety and security in compliance with international standards and guidance.

International cooperation

Since 2000, Morocco has been fostering implementation of regional projects through the IAEA and AFRA programs to share resources, knowledge and expertise related to nuclear application for medical purposes.

The National Institute of Oncology in Rabat has been recognized by AFRA/IAEA as a Regional Designated Centre for Oncology since 2003.

Nutrition

The eradication of malnutrition and the improvement of child nutrition are among the objectives of the sustainable Development Goals that Morocco is committed to achieve.

The Moroccan Government, in collaboration with local and international partners, has developed a National Nutrition Strategy 2011-2019 to promote healthy lifestyles, build professional capacity and coordination among partners, and develop nutrition research.

In this context, CNESTEN and Ibn Tofaïl University (ITU) established, since 2006, a Joint Unit of Research in Nutrition and Food (URAC 39) to develop priority research areas in nutrition and food in line with related national and regional health programs. In this regard, several nuclear applications have been developed in collaboration with the IAEA. These techniques are used as a reference to validate conventional methods, determine nutritional status and measure the effectiveness of nutrition national programs mainly:

- Fighting Against Micronutrient Deficiencies,
- Promoting Maternal Breastfeeding,
- Preventing and controlling Non Communicable Diseases.

Main achievements

Capacity building in the use of stable isotopes in nutrition has allowed, during the last seven years, the training of Moroccan scientists, health professionals and students: more than 100 physicians, 20 nurses, 270 Masters and 20 PhD students.

The different projects conducted by the Joint Unit relating to the National Nutrition Programs have provided the following results:



The National Program Against Micronutrient Deficiencies:

- The oil fortification with vitamin A is a success story. Indeed, vitamin A deficiency in children under 5 years was reduced from 41% to 22%,
- The consumption of fortified oil with vitamin A by lactating women who are as well supplemented with vitamin A is an efficient and safe way to improve mother and infant vitamin A status,
- The flour fortification with elemental iron does not give the expected results. The iron deficiency remained constant and high among women and children. There fore, it was recommended to change the type of iron from elemental to iron EDTA which has a better bioavailability,
- The first Moroccan food components table was developed.

The National Program to Promote Maternal Breastfeeding:

- The prevalence of exclusive breastfeeding (EBF) until 6 months is 12.5% estimated by isotope techniques compared to 27.8% determined by questionnaires (conventional technique used usually by the Ministry of Health),
- The exact amount of human milk consumed by Moroccan infants during the six months of breastfeeding was determined for the first time in North African and Arabic countries,
- The zinc concentration in human milk consumed by Moroccan infants was determined.

The National Strategy to Prevent and Control Non Communicable Diseases:

- The determination of the relationship between body mass index (BMI) and fat mass showed that the BMI is not a good indicator of fat mass in Moroccan population,
- The relationship between fat mass and metabolic syndrome was assessed,
- Specific BIA equations to determine fat mass and lean mass Moroccan pregnant women, adolescents, adults and elderly have been established,
- A nutritional guide for people with cancer is under preparation.

The accumulated knowledge in the application of isotope techniques in nutrition and food and the infrastructure implemented at the Joint Unit, are made available to regional countries through the recently selected AFRA Regional Designated Centre to build human capacity, and provides expertise in the application of isotope techniques in nutrition.

Indeed, through the technical cooperation of IAEA, AFRA agreement or/and south- southcooperation, the Joint Unit provided training and expertise to over 30 countries from Africa and Asia and contributes to raise awareness on the role of stable isotope techniques mainly through The African French Leadership Program in Nutrition.

Water & Climate

Nowadays, the sustainability of groundwater resources for drinking water supplies, agriculture, and industry is a prime concern in countries dominated by arid and semi-arid climates such as Morocco. The growing demand for groundwater coupled with impacts from land use and climate change make of sustainability an even more important water management goal. This difficult situation requires application of new technologies to supplement conventional hydrological methods in order to improve water resources management in Morocco and to make sound decisions about water use and protection of water quality.

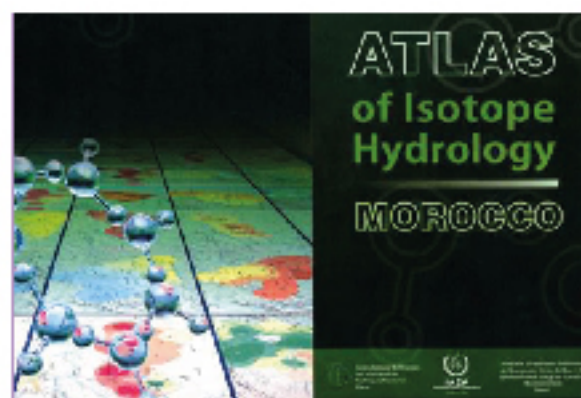
Water managers and policy makers must have a sound understanding of such factors as the location and amount of groundwater recharge and groundwater ages. Isotope methods can be essential for understanding how groundwater systems work in large dry land basins and yield critical insights that standard hydrological or geochemical methods cannot provide. Stable isotopes of the water molecule along with tritium and carbon-14 are effective tracers of the hydrological cycle and have proven to be effective in helping Morocco better understand its water resources and manage them more efficiently.

In this context, at the end of the 1990s, the Department of Water and CNESTEN established an isotope analysis laboratory, the first of its kind at the national level. This scientific and technical platform has enabled Morocco to:

- Build national capacity for using nuclear and isotopic techniques in water assessment,
- Integrate isotope techniques in the planning, development and sustained management of water resources,
- Make sound decisions about water use and protection of water quality,
- Establish harmonized procedures for isotope and chemical data handling and develop protocols for quality assurance and control,
- Enhance human resources,
- Meet the needs of the scientific community in term of education and research activities.

The main areas treated using isotopic techniques include:

- Determination of "the age of water" which corresponds to the age of the aquifer recharge,
- Identification of recharge zones,
- Understanding the origin of salinity of coastal aquifers,
- Studying the rainwater infiltration rate for artificial recharge of groundwater,
- Development of the use of nuclear and isotopic techniques in agricultural water management,
- Assessment of water quality and investigation of the origin of pollution,
- Estimation of mixing percentages of surface water and groundwater or between different aquifers.



Over the last twenty years, the Department of Water and CNESTEN have worked together to characterize groundwater of the most important aquifers in the country using isotope methods as shown in the figure below.

The results of this endeavor have been published in collaboration with the IAEA in a book entitled "Isotope hydrology Atlas of Morocco".

The accumulated knowledge in isotope hydrology and the infrastructure established are now made available to the countries of the region through the selected AFRA Regional Designated Centre in terms of training human resources and providing expertise and analytical services.

In 2015, CNESTEN has been nominated by IAEA as a Collaborating Center for "Water Resource Assessment and Management" with the goal:

- to conduct research and contribute to the development of new nuclear and isotopic techniques, and
- to support the technical cooperation projects of IAEA at the international level in terms of training, expertise and analytical services.

Main equipments of Isotope Hydrology Laboratory

- Mass spectrometer for the determination of stable isotopic ratios of H, C, N, and O in water, carbonate and organic matter;
- Water equilibration system for the measurement of 18O and 2H in water;
- Gas chromatograph system attached to a mass spectrometer for measurement of isotopic ratios ^{13}C , ^{18}O and ^{15}N in organic matter;
- Laser machine for the determination of stable isotopic ratios of H, and O in water
- Inductively Coupled Plasma Mass Spectrometry «ICP MS» for elemental determinations
- Electrolytic enrichment lines for 3H (40 cells of 500 mL);
- Benzene synthesis line for radiocarbon dating;
- Ultra low level Liquid scintillation counter;
- Ion chromatograph for the measurement of anions and cations in water.

In this regard, a tremendous exchange between the Moroccan scientific community and the African scientific network was made possible. Indeed, through the technical cooperation of IAEA and AFRA, CNESTEN provided, over the last decade, analytical services, training and expertise to over than 30 countries from Africa, Asia and Europe.



CNESTEN participated actively in the IAEA's Coordinated Research Activities. Over the last twenty years, the Coordinated Research Projects carried out focus on:

- Geo-statistical analysis of spatial isotope variability to map the sources of water for hydrology studies,
- Use of environmental isotope tracer techniques to improve basin-scale recharge estimation,
- Quantification of hydrological fluxes in irrigated lands using isotopes for improved water use efficiency,
- Managing irrigation water to enhance crop productivity under water-limiting conditions: A role for isotopic techniques,
- Tritium- ^3He dating and noble gas techniques in water resources management: recharge, infiltration conditions and groundwater balance,
- Use of fallout radionuclides, stable isotopes and conventional techniques to assess soil redistribution, rates and to identify primary sediment source areas at the watershed scale in Morocco,
- Accessible technologies for the verification of origin of dairy products as an example control system to enhance global trade and food safety,
- Isotopes in understanding source of salinity in waters,
- Isotopic Composition of Precipitation in the Mediterranean Basin in Relation to Air Circulation Patterns and Climate,
- Implementation of nuclear techniques to improve food traceability,
- Use of Long-lived Radionuclides for Dating Very Old Groundwater,
- Use of Isotope Hydrology to Characterize Groundwater Systems in the Vicinity of Nuclear Power Plants.

In conclusion, the kingdom of Morocco has built a well-established national capacity for using nuclear and isotopic techniques in water management. These techniques have become an essential tool in all the assessment, development, planning and sustained management of water resources projects.

Environment

Chemical pollution has become a serious problem in both industrialized and developing countries. In this regard, Morocco has established an environmental charter and a national strategy for the protection of the environment and sustainable development.

In this context, nuclear analytical techniques (NAT) have been judiciously employed to assist in solving many of the problems relating to environment preservation.

Since the seventies, national institutions, in collaboration with IAEA, have deployed various nuclear analytical techniques mainly XRF (X-Ray Fluorescence) for trace elements analysis and gamma, alpha and Beta spectrometers for radioelement measurements.

The creation of CNESTEN and the operation of the research reactor have enabled to enhance the national capacity by more powerful techniques such as NAA (Neutron Activation Analysis). The participation of CNESTEN to international inter-comparison programs has allowed producing high level quality analysis results. These techniques contribute to investigate many related pollution problems such as urban air pollution, geochemistry of river basins and marine environment.

1. Urban air pollution

For appropriate air quality management in urban zones, the sources of air particles pollution must be known and identified. NAT (NAA and XRF) are widely used to characterize pollution sources and estimate their respective contributions mainly in the big cities of Morocco. On the other hand, CNESTEN uses these techniques in assessing the impact of this pollution on historical monuments. The cooperation developed with universities from Morocco and Europe in this field allowed the acquisition of new knowledge in cultural heritage preservation by using NAT.

At regional level, CNESTEN contributes to air quality activities by improving monitoring and analytical characterization using NATs.

Main Facilities

- NAA Laboratory: Gamma ray spectrometers, a pneumatic transfer system for short irradiations and sample changer with 20 positions
- X-Ray: Total Reflection (TX-XRF) spectrometer, Wave-length Dispersive X-Ray Fluorescence (WD-XRF), mobile ED-XRF for analysis in situ and X-ray diffraction (XRD) spectrometer,
- AAS Laboratory: spectrometers with Flame, Graphite Oven and VGA (Vapour Generator Analyzer for volatilized elements such as Mercury, Selenium, etc.),
- Radiometric analysis laboratories
Laboratory: Hyperpur Germanium detectors
Silicon Surface Barrier Detectors, Liquid Scintillation ultra low background,
- Sample preparation laboratories,
- Air pollution monitoring laboratory: Fine and coarse particles and TSP samplers, gas emissions analyzers (SO₂, NO_x, O₃, H₂S CO and CO₂)



2. Geochemistry of river basins

NAT play a major role in providing local geochemical background levels of various media in the river basins, establishing regional geochemical standards and assessing the watercourse contamination in terms of anthropogenic contributions of trace metals.

In this context, CNESTEN in collaboration with Academia has established a methodology based on:

- sampling strategy (water, suspended matter, sediments and rocks),
- analysis procedures using NAT tools,
- and measurements of some physicochemical parameters in situ.

The generated geo-database contributes to establishing remediation and risk-based standards necessary for decision makers and planners in sustainable development.

3. Marine Environment

Due to the importance of the Moroccan coast which extends over 3400 kilometers (Atlantic Ocean and Mediterranean Sea), the National Institute of Fishery Research (INRH) undertakes a surveillance programme aiming to preserve marine environment and valorize fishery resources.

Nuclear and related techniques are very useful tools to assess marine contaminants and to provide reliable and complementary data to conventional techniques to decision makers and end-users. In this context, CNESTEN and INRH conducted several projects on marine pollution such as assessment of radioactive and chemical contaminants and biotoxin, radiometric, dating techniques of sediment cores, marine radioecology and development of prediction models.

The NAT related capacities that have been developed in Morocco are made available to regional cooperation through IAEA and AFRA projects. CNESTEN contributes in enhancing human resources by hosting training courses, workshops and fellows, providing lectures, expertise and analytical services, participating to the design of national and regional projects,....

Food & Agriculture

Agriculture has an important and growing effect on the economy of Morocco. It contributes nearly 20% to the gross domestic product (GDP) and employs almost half of the active population.

However, the agriculture sector faces major challenges including natural resource protection, food product conservation, climate change adaptation and mitigation, in addition to animal health, reproduction and improvement. These challenges are taken into account in the national agriculture strategy called "Green Morocco Plan".

Since the sixties of the past century, Morocco, with the support of IAEA, has introduced several nuclear techniques in agricultural research programs undertaken by dedicated Research Centres and Universities mainly the National Institute for Agricultural Research (INRA) and later on by CNESTEN.

Currently, the nuclear techniques are widely used especially in plant breeding, food preservation, plant nutrition and soil fertility, animal health and reproduction, pest management, soil conservation and environment preservation.

Main Achievements

Soil erosion control and conservation agriculture

Soil erosion is one of the major concerns for Agriculture in Morocco. Nuclear techniques based on the use of fallout radionuclides (FRNs) (eg. ^{137}Cs , ^{210}Pb and ^7Be) were introduced since the end of the nineties to assess soil erosion rates in different regions and to evaluate the efficiency of new agricultural conservation practices.

In the framework of coordinated research projects (CRPs) and regional projects of IAEA, CNESTEN has further developed and completed these techniques by the use of stable isotopes (^{13}C and ^{15}N) to identify primary sediment source areas at the watershed scale.

They are increasingly applied in agricultural fields and watersheds in collaboration with INRA and the High Commission of Water and Combating Desertification (HCEFLCD).

Technical Facilities

At CNESTEN:

- Radiometric analysis laboratories,
- Stable Isotope analysis laboratories,
- NAA, XRF and AAS laboratories,
- RIA laboratories.

At INRA:

- Gamma Irradiation facility (62 kCi).
- Dosimetry and radiation protection Laboratory
- Food Technology, Food Microbiology and Biotechnology laboratories
- Isotope analysis laboratory
- Tissue culture laboratory
- ELISA and RIA laboratories

These achievements have been recognized as a success story by the Joint FAO/IAEA Division of Nuclear Techniques in Food and Agriculture on the occasion of the 12th session of the Conference of the Parties (COP12) of the United Nations Convention to Combat Desertification (UNCCD) held in October 2015 in Ankara, Turkey.

The accumulated knowledge and experience have enabled CNESTEN to make an important contribution to the preparation of an IAEA manual entitled: "Guidelines for Using Fallout Radionuclides to Assess Erosion and Effectiveness of Soil Conservation Strategies" edited in IAEA TECDOC SERIES.

Food irradiation

In 1995, a Gamma Irradiation facility was implemented by INRA in Tangier, north of Morocco, with the support of IAEA and the French Atomic Energy Commission (CEA). The current activity of the radioactive source is 62,000 Ci.

An important research program is conducted in the field of food preservation by irradiation with the objective to establish optimal combination treatments using gamma irradiation and other conventional methods to extend shelf life and improve long-term quality of several food products such as: powder tomato, strawberry, potato, onion, citrus, lentil, faba bean, chicken and red meat.

Crop nutrition and soil fertility

In this field, ^{15}N and ^{32}P labelled tracers were used by INRA to establish fertilization formulae for wheat, rice, sugar cane, cotton, tea, sun flowers and sugar beet. This work allowed to optimize the use of phosphor and nitrogen fertilizers and to improve crop yields.

Other studies were carried out on quantification of Biological Nitrogen Fixation (BNF) in several legumes crops (faba bean, chickpea, lentil, peanut and berseem clover) inoculated by endogenous rhizobia strains. The aim is to enhance productivity and optimize the use of Nitrogen fertilizers.

Currently, CNESTEN is using nuclear and isotopic techniques (^{15}N , ^{18}O , ^2H and neutron probe) for enhancing crop nutrition and water management in Irrigated systems in different regions of Morocco.

Plant breeding

Plant breeding by irradiation is used at INRA irradiation station for several crops to produce new improved varieties by mutation induction. This technique was used on lentil, citrus, date palm, potato, safflower, medicinal and aromatic plants and olive. Several mutants were produced and are in different stages of selection.

Animal health and reproduction

To optimize the livestock productivity of the North Moroccan local goat and "Sardi" local sheep breed of Settat region, nuclear and related techniques based on the use of Radioimmunoassay kits (RIA) and conventional techniques (ELISA) were developed and applied by INRA and CNESTEN for monitoring reproductive hormones of animals such as progesterone, Oestrogen, luteinizing hormone (LH), follicle-stimulating hormone (FSH) and Pregnancy-Associated Glycoprotein (PAG).

This program allowed to establish seasonality of reproduction, puberty, anoestrus postpartum pregnancy and sexual cycle for Sardi sheep breed and North Moroccan local goat.

Sterile Insect Technique

The Mediterranean fruit fly, *Ceratitidis capitata* is a major pest for Citrus and vegetable crops. Losses are incurred directly by fruit damage and indirectly by the quarantine restrictions imposed by other countries to Moroccan vegetables and fruits exportations. The Sterile Insect Technique (SIT) offers an alternative to pesticide uses. With the assistance of IAEA, the National Office for Food Security (ONSSA) is implementing an SIT pilot project in the Souss valley South of Morocco, over 4000 ha of citrus in partnership with Moroccan Private Citrus Growers.

A new facility for the production of sterile flies is planned for the next few years in the framework of a Public Private Partnership (PPP) which will enable to extend the application of this technique to the whole Souss region.

Regional Cooperation

Morocco developed collaboration with several African countries in the field of nuclear applications in the agriculture sector, in the framework of the IAEA and AFRA projects, in terms of training, expertise and analytical services.

Morocco through CNESTEN has been designated in 2012 and 2016 as the Regional Coordinator of the RAF5063 project "Supporting Innovative Conservation Agriculture Practices to Combat Land Degradation and Enhance Soil Productivity for Improved Food Security"

Industry

The applications of radioisotopes are well established throughout the world for troubleshooting and optimization of industrial processes.

Morocco has been using these techniques since their introduction in the seventies mainly in the cement, sugar, petroleum, paper and chemical industries.

CNESTEN has played a major role to enhance the industrial applications by implementing new efficient techniques and building capacity mainly in NDT and the utilizations of radioactive sealed sources and radiotracers.

NDT

In the field of NDT techniques, CNESTEN has acquired a long and valuable experience in terms of training, certification and expertise.

CNESTEN has established a centre for NDT training and certification, in accordance with the Moroccan standard NM.01.1.074 (equivalent to ISO 9712 and EN 473 standards) since 2000.

An average of one hundred domestic and foreign NDT inspectors are trained and/or certified by CNESTEN each year.

This has favored the creation of more than fifty NDT private companies in Morocco.

Main NDT Facilities

- X and Gamma Radiography Laboratories: radiography bunker equipped in particular with (X ray tubes, 192Ir gamma projectors, 60Co projector), a gamma projector specially designed for training, etc..
- Conventional NDT Techniques laboratories (Magnetoscopy, UV interpretation unit, penetrant testing line, ultrasonics testing equipments, ultrasonic testing by immersion unit, Eddy current testing equipments, etc....)
- Advanced NDT techniques laboratory: UT-TOFD and Phased Arrays equipments

CNESTEN is considered as the national reference laboratory in NDT field: it is requested by end users for solving specific problems as well as by private NDT companies to study cases beyond their competence.

Training and field services are delivered to various branches of industry such as chemistry, petro-chemistry, phosphates production and processing, metal industry, transport (air, railways, marine, motorway), energy (thermal power plants, hydraulic, gas production units), food industry, cement industry and civil works (dams, airports, ports, roads...).

CNESTEN is planning to install in 2018 a neutron imaging station around the research reactor to extend existing NDT techniques to other sectors such as aeronautics.



Radioactive Sealed sources and radiotracers applications

Besides NDT activities, CNESTEN has developed a valuable experience in industrial applications of radioactive sealed sources (gamma-scanning, nucleonic gauges) and utilization of radiotracers (diagnosis of industrial processes, sedimentary dynamics,).

These techniques are applied in various industrial plants such as phosphates processing units, petrochemical industry, waste water treatment plants, etc.

The conducted studies concern mainly process & mechanical control: operational conditions diagnosis of distillation columns and other industrial components, determination of Residence Time Distributions (RTD), estimation of dead volumes, leak detection...

On the other hand, CNESTEN is undertaking R&D activities in nuclear instrumentation and related software mainly nucleonic control systems (radiometric gauges) for the measurement of various parameters of industrial products (thickness, density ...), gamma-scanning equipment, reactor instrumentation, etc..

More important, CNESTEN has developed in house capability to maintain most scientific equipment and nuclear installations of Maamora Nuclear Research Centre.

Regional Cooperation

CNESTEN participates in IAEA and AFRA cooperation programs, providing training and expertise, hosting fellows and workshops in the field of NDT and radiotracers applications.

In this respect, several AFRA triangular arrangements are under implementation in the field of NDT as well as radioactive sealed sources and radiotracers applications between Morocco and a number of AFRA MSs with the support of IAEA.

In the same context, CNESTEN has been recognized by AFRA as a Regional Designated Centre (RDC) for Africa in NDT personnel training and certification according to international standards for both French and English speaking African countries.

Energy

The national energy strategy, adopted in 2009, considers nuclear power for electricity generation as an alternative option at the horizon of 2030 in order to meet future electrical needs.

Indeed, since the 1980s, Morocco started considering the nuclear power option, establishing a nuclear legal and institutional framework.

In this regard, the National Electricity and Potable Water Office (ONEE) has conducted, during the 1983-1993, site and technical-economic feasibility studies for the first Nuclear Power Plant. As a result, a detailed technical report was developed including:

- Selection and qualification of Sidi Boulbra site, south of Casablanca on the Atlantic coast,
- A study of existing nuclear power technologies and their safety, technical and economic performances,
- Electrical grid integration conditions,
- Project management: construction and commissioning phases,
- Fuel cycle aspects.

Many other related issues such as human resources development, legal and regulatory framework, radioactive waste management, ... have been addressed in this report.

In the scope of the national energy strategy, the Department of Energy has set-up, since 2009, a Committee on Nuclear Power and Sea Desalination composed of relevant national organizations representatives.

This Committee was assigned the mission to conduct a global evaluation of the conditions and nuclear infrastructure required to undertake a nuclear power program for electricity generation and seawater desalination. This evaluation was carried out on the basis of the IAEA Milestone approach.

In order to have an external review of the work performed, Morocco requested the IAEA assistance to conduct, in 2015, an Integrated Nuclear Infrastructure Review (INIR).

The INIR team expressed that Morocco has developed a considerable base of knowledge and experience in nuclear activities enabling him to make a knowledgeable decision on introducing a nuclear power program, in line with international standards.

The INIR team has also made recommendations and suggestions aimed at assisting Morocco in making further progress in its nuclear infrastructure development. In this context, an Integrated Work Plan is being implemented, with the support of the IAEA, in order to address these recommendations and suggestions.

At the national level, along with the activities conducted by the Committee, several other institutions and NGO's are involved in the field of nuclear power development in terms of education, communication with the public and international cooperation.

At the international level, Morocco participates in various events and networks related to nuclear power.

Notably, Morocco is member of the International Framework for Nuclear Energy Cooperation (IFNEC) and has, in this regard, hosted its 3rd Ministerial Executive Committee Meeting in Marrakech (2012) and participated as well in several international conferences such as "nuclear power in the 21st Century" organized by the IAEA and Russian Federation, in Saint Petersburg (2013) and Paris Conference on "Access to civil nuclear power" (2010).

Safety, Security and Safeguards

Aware of the vital importance of developing and conducting activities using nuclear and other radioactive materials in compliance with the international standards for safety, international guidance for security and international safeguards obligations, the kingdom of Morocco has, since the early seventies, set up the basis for a legal and regulatory framework and has progressively strengthened and enhanced the national infrastructure for safety, security and safeguards.

In 2014, the government adopted the law 142-12 on nuclear and radiological safety and security and the creation of AMSSNuR which was established in 2016 as the unique regulatory body for Safety, Security and Safeguards.

As a new regulatory body, AMSSNuR developed in 2017 a strategy to upgrade the National Regulatory framework in a transparent and cooperative manner based on a dialogue with all relevant stakeholders (Departments, operators, Technical Support Organizations, Universities and NGOs) and in cooperation with IAEA, UE and other regulatory bodies in several countries.

In this frame, seventeen regulations were identified and seven were elaborated and submitted by AMSSNuR to the Head of the Government.

These first regulations are concerning:

- Licensing and Registration System of Category II facilities and Ionizing Radiation Sources activities;
- Population, Workers and Environment Protection against the risks of Ionizing Radiation;
- Use of Ionizing Radiation for Medical, Forensic, Dental and Veterinary purposes;
- Radioactive Sources Security in use, storage and transportation;
- Safeguards and the Additional Protocol Implementation;
- Safety of Spent Fuel and Radioactive Waste Management;
- Nuclear or Radiological Emergency Preparedness and Response.

The other regulations under drafting and which will be submitted to the Head of the Government are covering:

- Nuclear Safety of Category I Facilities,
- Nuclear Material and Associated Facilities Physical Protection,
- Transport, Import and Export of Nuclear Material, Equipment and related Technologies,
- Agreement granted to Technical Services Providers,
- Training and Qualification in Radiation Safety,
- Training and mission of Medical Physicists,
- Transport Safety of Radioactive Material,
- Technical Inspection aspects,
- Clearance levels,
- Licensing processes for the extraction and processing of Radioactive Ores.



Nuclear and Radiological Safety

The experience gained from the construction and operation of CENM facilities, during the last decades, was very useful in developing national capabilities in terms of regulatory framework, human resources development, education and training, international cooperation and networks.

This allowed Morocco to develop:

- Good skills and practical experience in nuclear and radiological safety;
- Abilities in assessing nuclear and radiological risks, defining appropriate prevention and protection measures, implementing operational programs and measures were developed.

To meet the requirements for safety and the needs of users at the national level, capabilities have been developed to provide the necessary radiation protection technical services, such as dosimetry, calibration, measurements of radioactivity, training, expertise, etc. CNESTEN and CNRP have played an important role in the development and provision of such capabilities.

Training and expertise are provided by CNESTEN at the national level to support AMSSNuR and the users of ionizing radiation upon their request.

As a nuclear safety regulatory body, AMSSNuR has established a national programme aiming at:

- Upgrading the national nuclear safety regulatory framework covering all nuclear facilities and related activities;
- Enhancing nuclear safety culture through education, training, and communication activities;
- Setting up regional and international cooperation with other regulatory bodies.

At the regional and international levels, the kingdom of Morocco contributes to the international efforts to strengthen the safety regime by hosting training courses, workshops, technical meetings and international conferences organized by CNESTEN and AMSSNuR in collaboration with IAEA, UE and other partners.

National Contribution to strengthen regional capabilities

- Organization, in cooperation with the IAEA, of ten editions (21 weeks each) of the PGEC on Radiation Protection and the Safety of Radiation Sources for African French Speaking Countries, since 2002.
- More than 200 African professionals have participated in the PGEC Course.
- Organization, in cooperation with the IAEA, UE and other partners, of more than 20 national and regional workshops, international seminars and conferences
- Hosting the third International Conference on 'Safe Management and Effective Utilization of Research Reactors', Rabat, 14-18 Nov. 2011,
- Contribution to expert missions, consultancy meetings, review missions (INSARR, IRRS, EPREV, ...).

Safeguards

Aware of the importance of fulfilling its international commitments in safeguards, Morocco had deployed the necessary efforts to build its capacity in order to meet the requirements set forth in the Comprehensive Safeguards Agreement and its Additional Protocol. In this regard, Morocco had trained, in cooperation with the IAEA and U.S. DOE, the staff involved in the implementation of the Additional Protocol and the accounting and control of nuclear materials.

Morocco submits regularly the required reports and declarations and hosts the IAEA verification activities.

In addition, Morocco developed a new Draft Law and its implementation regulations, with the support of the EU and US DOE, to establish an export/import control system of dual- use products, in compliance with the international commitments and UNSC Resolutions 1540 and 1977.

Nuclear security

Morocco is engaged in many activities both at the national and the international levels aiming at strengthening its capabilities in nuclear security.

At the national level, Morocco:

- Inserted in the new law the obligations deriving from International guidance and instruments,
- Promoted security culture and information exchange with national stakeholders;
- Established in 2011 a National Training and Support Centre for Nuclear Security, that proved to be active in the organization and conduct of many training events with the support of IAEA and US DOE (6 to 8 training sessions per year for around 200 participants from various national stakeholders),
- Continues to develop and implement, in cooperation with IAEA, its national Integrated Nuclear Security Support Plan (INSSP) in different fields (Legal and regulatory framework, prevention, detection, response and Human Resources Development),
- Strengthened the physical protection, under the GTRI program, of the nuclear materials used in the CEN Maamora and high radioactive sources used in various fields (Medical, industrial...).

Internationally, Morocco is actively contributing to the international initiatives and programs aiming at strengthening the international nuclear security regime. Examples of this active involvement are:

- Hosting, with the support of EU, a regional CBRN Secretariat for the African Atlantic Façade Countries in Rabat, and coordinating the implementation of several CBRN projects, namely on capacity-building,
- Participating actively to the preparation and conduct of the Nuclear Security Summits, held in 2012, 2014 and 2016,

- Being an active member of the Global Initiative to Combat Nuclear Terrorism (GICNT) since 2006 and is chairing, since June 2011, the Response and Mitigation Working Group (RMWG). In this regard, Morocco hosted the Mid-year Implementation and Assessment Group (IAG) Meeting (Marrakech, February 2012) and presented, for consideration, during the GICNT/IAG Meetings (Madrid, February 2013, Seoul, July 2014) and the RMWG meeting (Paris, May, 2014) the draft RMWG "Response and Mitigation Fundamental Document- RMFD-", regarding the establishment of a robust capability for the emergency response to a radiological/nuclear terrorist act.
- Hosting many regional or international training events, workshops or seminars in nuclear security, with international partners (IAEA, USD0E, etc.).

Emergency preparedness and response EPR

Morocco ratified the two conventions on Early Notification of a Nuclear Accident and on Assistance in the Case of Nuclear or Radiological Accident, and built its notification, information exchange and assistance request system with the IAEA.

It developed its national capacities for addressing radiation emergencies, resulting either from an incident or from a nuclear security event through training and exercises.

To meet the objectives of the national EPR, Morocco has undertaken the main following actions:

- The establishment of the Technical Crisis Centre (TCC) within the MNRC with the support of U.S. / DOE. In case of radiological incident, TCC is making technical assessments of radiological risks or consequences and supports the National Authorities by providing recommendation on protective actions;
- The preparation and conduct of following exercises:
 - A full-scale exercise to test the national response to a transport accident involving radioactive materials (2009),
 - An international exercise, combining table top exercise with field activities, within the framework of the Global Initiative to Combat Nuclear Terrorism (GICNT) (2010 – 2011),
 - A Joint Exercise with Spain "REMEX-2013" on Response and Mitigation (2013),
 - An International Exercise "ConvEx3" (Bab Al-Maghrib), with the participation of 58 States and 10 International Organizations (2013).
 - A bilateral exercise (Spain-Morocco) on response to incident involving radioactive material during maritime transport (2015).

These exercises have been an excellent opportunity for Morocco to adopt a coordinated global approach and operational protocols and to enhance its capacities in terms of information exchange, technical infrastructure and training of a significant number of participants from national institutions involved in the preparation and the response to radiological emergencies.

Radioactive Waste Management

During the last decades, the development of nuclear technology applications in various socioeconomic sectors such as medicine, agriculture, industry and scientific research lead to the generation of different types of radioactive waste that must be managed based on the principle of protecting the public, the environment and to not impose undue burdens on future generations.

According to its mission, CNESTEN established an infrastructure and developed competences to collect, dismantle, treat and secure the disused radioactive sources and waste generated by the various national users.

CNESTEN and AMSSNuR prepare and present regularly the report on the situation of radioactive waste management in the Kingdom of Morocco at the meetings of the Contracting Parties of the Joint Convention on the safety and management of spent fuel and radioactive waste.

During the last sixth meeting, held at the IAEA headquarters in Vienna in May 2018, following the presentation of the national report and the main achievements, it was highlighted that Morocco ensures a high level of nuclear safety and security of radioactive waste and spent fuel management through setting-up global regulatory framework aiming at protecting people, society and the environment now and in the future.

Methods of treatment adopted

- Evaporation for aqueous liquid effluents;
- Compaction for radioactive solid waste;
- Dismantling of disused sealed radioactive sources category 3 to 5 in order to reduce the volume to be stored.

Currently, CNESTEN has collected, conditioned, stored and secured more than 1 000 disused sealed sources including orphan sources.

In compliance with the provisions of the Joint Convention on the safety of radioactive waste and spent fuel management, ratified by the kingdom of Morocco in 2001, and responding to the INIR 'Integrated Nuclear Infrastructure Review' recommendation, AMSSNuR and CNESTEN, in their respective missions as regulatory body and national designated organization for the management of radioactive waste, have prepared a national policy and strategy dedicated for this purpose.

As a regulatory body, AMSSNuR prepared, in concertation with CNESTEN and other stakeholders, regulations on the safety of radioactive waste management, disused radioactive sources and spent fuel.

Regarding research and development activities, CNESTEN established a joint research unit with the Faculty of Sciences of Ben Msik of Casablanca to conduct research in the field of radioactive waste conditioning (spent resin, organic waste and the sludge issued from evaporation of aqueous liquid waste) with cement improved matrix. Other research works are developed with the laboratory of polymers and laboratory of ceramics of the Faculty of Sciences of Kénitra.

EDUCATION & TRAINING ACTIVITIES AND INTERNATIONAL PARTNERSHIP

Human resource development is a key issue for developing sustainable and safe nuclear applications in various sectors such as health, environment, natural resources, agriculture, water, industry, energy, etc.

For that purpose, several national universities are carrying out, since the 1980s, educational programs in nuclear science and technology, through national and international partnership, mainly with the IAEA. Most of the graduates are serving in institutions using ionizing radiation sources so as to meet national needs for developing nuclear applications in a safe, secure and sustainable manner.

For professional training, national institutions used strongly in the first stages of their development the international cooperation framework to develop their capacity: IAEA, AFRA, Bilateral partners.

Cooperation between IAEA and national institutions has progressively evolved from an assistance relation to a partnership relation. Indeed, national experts and consultants are regularly contributing in developing nuclear applications and techniques and nuclear safety and security programmes in different Member States through the IAEA technical cooperation program.

In addition, national institutions are regularly hosting educational and training activities through workshops, training courses, fellowships, etc.

Education & Training programs:

In order to meet national needs in terms of human resources required to contribute through nuclear applications and techniques to national socio-economic development programs, national universities (Rabat, Kenitra, Tetouan, Fes, Casablanca, Settat, etc..) are running different educational curricula and courses (PhD and Masters), covering various professional thematic areas (medical physics, nuclear medicine, radiotherapy, nuclear engineering, human health, radiation protection, dosimetry, materials and radiation physics, etc...). These programs are developed and conducted in partnership with relevant national institutions such as CNESTEN, AMSSNuR, CNRP, INO, INRA,



In this context, different research joint units have been established between university and nuclear institutions on specific thematic areas. It is worth mentioning that CNESTEN has established seven joint units with national universities, and more than 100 PhD and MD students are annually benefiting from CNESTEN knowledge and facilities in which practical and tutorial works are performed.

To ensure sustainable development of nuclear applications and techniques among end-users, national institutions are performing professional programs in different thematic areas.

The national institutions involved in these professional programs are: AMSSNuR, CNESTEN, CNRP, INOs, INRA, IAV, ONSSA, etc. They have dedicated human resources for supervising and performing training activities as well as facilities in which are carried out tutorial courses, hand-on works, practical case studies, etc., in addition to field exercises when appropriate.

On another hand, and based on the IAEA relevant requirements, AMSSNuR launched a study to establish a national strategy for education and training in nuclear safety and security covering all the current and potential applications especially in relation with nuclear power program and involving all the stakeholders.

Professional programs

- NDT,
- EPR,
- Radiation Protection,
- Nuclear Security,
- Human Nutrition,
- Oncology,
- Isotope Hydrology,
- Reactors operations

More than one thousand professional trainees who are benefiting annually from these programs.

National facilities dedicated to E&T activities:

To meet education and professional training needs, the involved national Institutions have established several facilities (research reactor, laboratories, training rooms, calculation centres, ...) fully and/or partially dedicated to activities that include academic and tutorial courses, practical and hand-on works and field exercises, such as:

- Nuclear Research Centre of Maamora including mainly the Research Reactor and specialized laboratories in different nuclear applications and techniques (Health, NDT, EPR, Radiation Protection, Nuclear Security, Isotope Hydrology, Environment, Material science, Agriculture,);
- Rabat Al Irfane laboratories of CNESTEN dedicated to human nutrition and food, visio- conference facility and course rooms dedicated to national and regional training courses such as the Post Graduate Education Course in radiation protection;
- Technical platform of National Institute of Oncology – Rabat and other eighteen Radiation Oncology at national level, which provide clinical training for Radiation Oncologists, Medical Physicists and Radiation Therapists;
- Technical platform for Radiation Protection of CNRP which provide training activities for professionals in radiation protection area;
- Gamma Irradiation Plant of INRA-Tangier in which training and research in plant breeding, pest management and food conservation are regularly undertaken;

- Nuclear physics and instrumentation laboratories of national universities which provide educational programs in nuclear science and applications for MD and PhD students, mainly in Nuclear Engineering, Materials and Radiation Physics, Radiation Protection, Nuclear Security, ...
- AMSSNuR buildings dedicated to training and hosting national and foreign trainees.

The Moroccan Institutions have also invested in the development of the human capacity building in terms of training of trainers, knowledge management, coaching and tutoring.

The International Training Centre of CNESTEN:

In order to extend its education and training capacities and better meet national needs, CNESTEN has set a long term vision for all its E&T activities by establishing an overall strategy to ensure sustainability, efficiency and effectiveness. As a result, a dedicated International Training Centre is in the final stage of construction, and is expected to become operational by the end of 2018.

This International Training Centre is open to regional and international collaboration (IAEA, AFRA, EU, AAEA, the USA, France and other bilateral partners).

Professional National Societies:

Morocco has several professional societies involved in promoting nuclear culture in different topics.

Moroccan Professional NGOs

- COMEND (Moroccan Confederation for NDT)
- AIGAM (Moroccan Association of Nuclear Engineers)
- INMM – Moroccan Chapter (Institute of Nuclear Materials Management)
- INMM- Student Chapter University Ibn Tofail at Kénitra
- AMR (Moroccan Radiation Protection Association)
- GMTR (Moroccan Reactor Technology Association)
- AMPM (Moroccan Medical Physics Association)
- AMMN (Moroccan Nuclear Medicine Association)

Regional and international cooperation: E&T, Expertise, Analytical services

Morocco has signed several Governmental & Institutional Agreements and collaborative arrangements both at multilateral (IAEA, AFRA, AAEA, EU, ...) and bilateral levels (Austria, Canada, France, Germany, Hungary, Portugal, Russia, Spain, USA,...). Partnership with regional and international networks (ANNuR, FNRBA, GNSSN, RFC, ...) is also developed.

Through this partnership, national institutions involved in nuclear applications and their regulatory aspects are active in hosting education and training activities, performing consultancy and expert missions as well as providing analytical services for the benefit of the Member States, mainly in the African region.

CNESTEN's Regional Recognitions

- AFRA Regional Designated Centre in Education and Training in Radiation Protection (2011)
- AFRA Regional Designated Centre for Environmental Isotope Hydrology (2010)
- IAEA Collaborating Center for Water Resource Management (2015)
- AFRA Regional Designated Center for Human Nutrition, Joint Unit of CNESTEN-University Ibn Tofailon Food and Human Nutrition
- AFRA Regional Designated Centre (RDC) for Non Destructive Testing (2016)
- IAEA Internet Reactor Laboratory (IRL) for Africa (2017)

INO's Regional Recognitions

- Regional Designated Centre for Clinical Radiotherapy and Medical Physics (2002)

Beyond developing national capacity in nuclear science and technology and also in safety and security, the national institutions are sharing their experiences through the IAEA/AFRA regional cooperation programmes as well as the triangular relationship with partners and donor's countries to African Members States.

Under these thematic fields, national institutions are taking a leading position in hosting IAEA/ AFRA training events as well as fellowships, mainly from African Member States. Currently, hundreds of professionals are trained per year.

Furthermore, the Moroccan Institutions are actively involved in hosting more than forty national, regional and international events per year in different thematic areas, mainly through IAEA/AFRA/AAEA, UE and DOE/USA partnership, so as to contribute in enhancing regional and international capabilities and sharing knowledge and expertise among the participation of hundreds of professionals from the region and worldwide.

It is worth mentioning that IAEA and CNESTEN signed in 2017 a Practical arrangement to further strengthen this South-South cooperation for the benefit of the developing countries through the relevant IAEA programs and projects.

On the other hand, AMSSNuR established a regional cooperation programme with FRNBA, ANNuR, RCF and GNSSN aiming at developing the national safety and security capacity building and to share the national experience with African and Arabic countries.

As a new regulatory body, AMSSNuR established a regional cooperation programme with FRNBA, ANNuR, RCF and GNSSN aiming at developing the national safety and security capacity building and to share the national experience with African and Arabic countries.

Through this cooperation programme, AMSSNuR is working to strengthen its presence in regional and international cooperation networks such as FRNBA, RCF, GNSSN and its relations with the IAEA, EU and partners US, Canadian, German, Russian, Chinese, French and others.

IAEA & AFRA Programmes

- 6 national projects,
- 25 regional projects
- 5 interregional projects
- 15 IAEA Coordinated Research Projects

UE Cooperation Programme

- 5 to 6 Integrated actions with European universities and institutions.

Bilateral Cooperation Program

- Organization of 6 to 10 national and regional workshops per year
- Training more than 10 weeks-men per year
- Technical and scientific visits

Abbreviations

Acronym	Title
AAEA	Arab Atomic Energy Agency
AFRA	African Regional Cooperative Agreement for Research, Development and Training related to Nuclear Science and Technology
AIGAM	Moroccan Association of Nuclear Engineers
AMSSNuR	Agence Marocaine de la Sûreté et la Sécurité Nucléaires et Radiologiques
AMMN	Moroccan Nuclear Medicine Association
AMPM	Moroccan Medical Physics Association
AMR	Moroccan Radiation Protection Association
ANNuR	Arab Network of Nuclear Regulators
CEA	Commissariat à l'Energie Atomique
COMEND	Moroccan Confederation for NDT
CNESTEN	Centre National de l'Energie, des Sciences et des Techniques Nucléaires
CNRP	Centre National de la Radio-Protection
EPR	Emergency preparedness and response
FNRBA	Forum of Nuclear Regulatory Bodies in Africa
GICNT	Global Initiative to Combat Nuclear Terrorism

Abbreviations

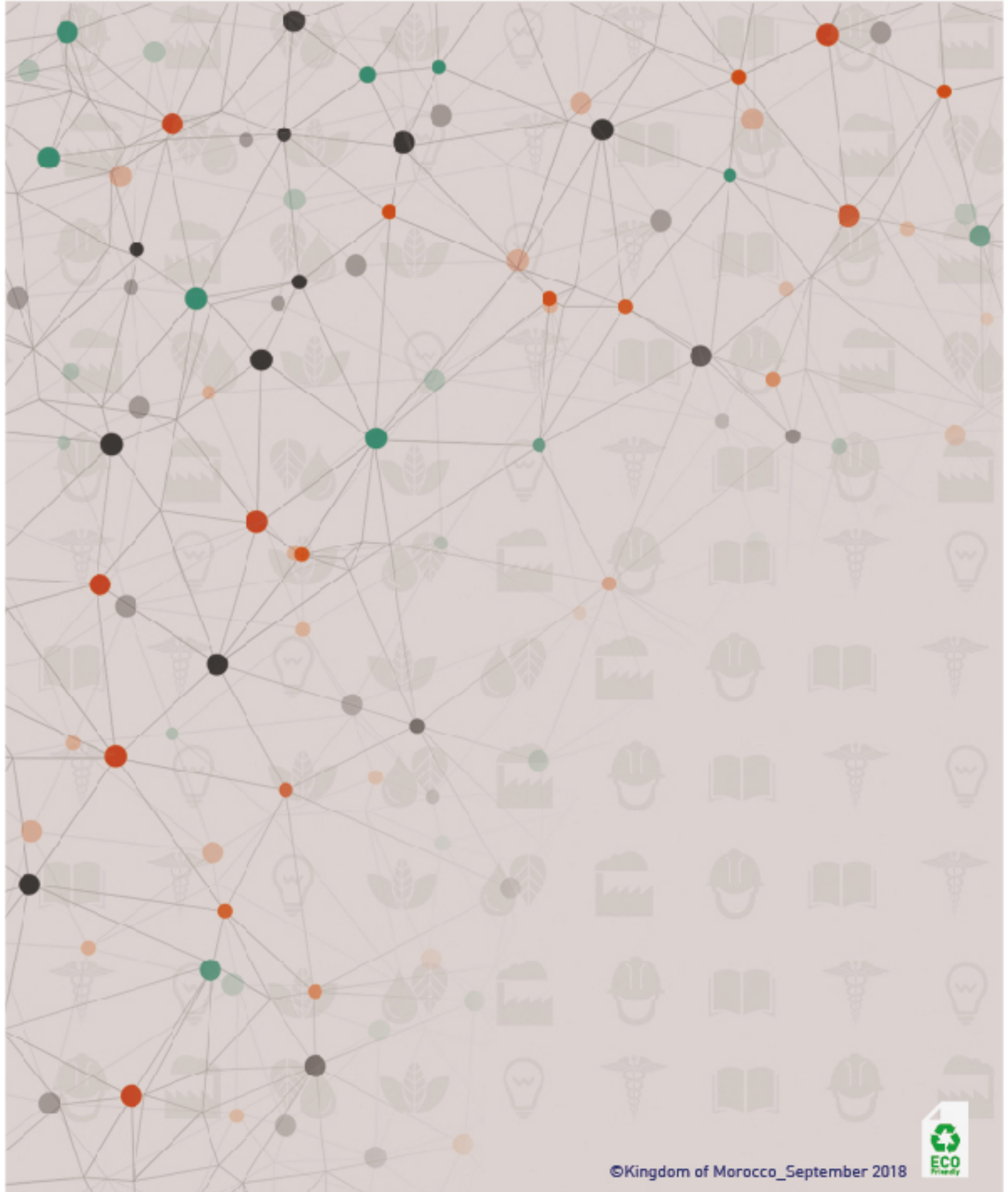
Acronym	Title
GMTR	Moroccan Reactor Technology Association
GNSSN	Global Nuclear Safety and Security Network
IAEA	International atomic Energy Agency
IFNEC	International Framework for Nuclear Energy Cooperation
INIR	Integrated Nuclear Infrastructure Review
INRH	Institut National de la Recherche Halieutique
INRA	Institut National de la Recherche Agronomique
INO	Institut National de l'Oncologie
INMM	Moroccan Chapter (Institute of Nuclear Materials Management)
ITU	Ibn Tofail University (Kénitra, Morocco)
MEMDD	Ministère de l'Energie, des Mines et du Développement Durable
MNRC	Maamora Nuclear Research Centre
ONEE	Office National de l'Electricité et de l'Eau Potable
ONSSA	Office National de l'Electricité et de l'Eau Potable
PGEC	National Office for Food Security

Abbreviations

Acronym	Title
RCF	Post Graduate Educational Course
RCF-Morocco	Regulatory Cooperation Forum
RDC	Moroccan Research Centre for Forestry
RMWG	Regional Designated Centre
SIT	Response and Mitigation Working Group
TCC	Sterile Insect Technique
VMAT	Technical Crisis Centre







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