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Evaluation and Improvement of Nuclear Security Measures at a Radiological Facility in Morocco

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Abstract

Nuclear security combines both concepts of physical security and security culture within a nuclear facility to protect people, property, society and the environment from harmful effects of ionization radiation. Physical security means prevention, detection, and response to unauthorized removal, sabotage, and/or illegal transfer involving radioactive sources and nuclear material. Nuclear security culture is the human factor within the nuclear field which is considered a principal means to support and enhance nuclear security system. This paper presents a study of nuclear security system already established within a radiological facility considering concepts such as: deter, detect, delay, and response layers. This study focuses on nuclear security culture in order to assess, improve, and complement existing nuclear security practices.

Keywords: Nuclear security, irradiation, ionization, security system, radiological, security culture, Cobalt-60.

I. Introduction

The studied facility, Boukhalef Ionization Station SIBO, which is a part of the Regional Centre for Agronomic Research in Tangier, Morocco, uses a source of cobalt-60 to research how to peacefully apply nuclear energy to agronomy. Today, the capacity of the ionization source is 64,000 Ci, thanks to a recharging operation carried out in collaboration with the International Atomic Energy Agency (IAEA). The IAEA's mission is to research food preservation without chemical additives by adopting ionization techniques, as well as other dosimetry and dosimetric calibration research.

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The SIBO station has a casemate equipped with a gamma radiation source, which generates gamma photons of energies 1.17 MeV and 1.33 MeV, with a maximum capacity of 100,000 Ci. While using this source, the radiation will lead to two safety concerns: radiation exposure and ozone gas. Before the operator closes the casemate door and start irradiation, workers ensure that nobody is inside, because the Co-60 source levels are high enough to cause death within a few minutes. Another concern is the ozone gas emissions which result from the interaction of gamma rays with air during the irradiation of products. When diatomic molecules of oxygen (O_2) absorb radiation from irradiator, they break their connection and separate into two highly reactive atoms which combine with a third molecule of oxygen produce ozone (O_3). Breathing this gas can trigger a variety of health problems including chest pain, coughing, throat irritation, and airway inflammation. It also can reduce lung function and harm lung tissue. Therefore, ventilation is necessary, and scientists recommend researchers to wait a few minutes after irradiation before removing the irradiated products from the casemate.

Since the source of cobalt-60 is classified among category 1 sources, the security requirements applied in the SIBO ionization station are based on the nuclear security performance objectives for radioactive security sources of level A of the IAEA publication No. 11.

In this study, we will focus on improving physical protection measures and nuclear security culture within this radiological installation in order to achieve efficient nuclear security systems.

II. The History of Nuclear Security and Nuclear Security Culture in the Ionization Station SIBO

The nuclear security system was installed in different phases. During the first phase in 2002, only two cameras were installed. The second phase was initiated a few years later to improve existing security system in the site access control system, intrusion detection system, and CCTV system. The main enhancement however, was the installation of a Central Alarm System (CAS) by security specialists in the police control station to monitor the Irradiator Building **[*1*]**. The third phase of development focuses on the physical security measures and the operational security culture revolving around nuclear security at the ionization station SIBO.

III. Nuclear Security Measures at Radiological Facilities

A. Physical Protection Measures

The purpose of a nuclear security system for radioactive material, associated facilities, and associated activities is to protect people, property, society, and the environment from malicious acts that could cause unacceptable radiological consequences **[*2*]**.

Therefore, the key stakeholders should establish a modern security system for protecting radioactive material/sources used in associated facilities and related activities against unauthorized removal. They should also work towards protecting radioactive facilities against sabotage, in addition to ensuring the implementation of rapid and comprehensive measures to locate and recover radioactive material which is lost, missing, or stolen, and to re-establish regulatory control.

These objectives are realized through security measures which should be designed to perform basic security functions: deterrence, detection, delay, response, and security management.

These security measures should be based on a risk informed graded approach, and they should also use the concept of defense in depth after determination of a national threat to radioactive material in use, storage, and transport to/from associated facilities **[*2*]**.

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States should develop security requirements that protect radioactive material from unauthorized removal or loss of control. States should address both security systems and security management to ensure protection **[*2*]**.

The regulatory body should require operators to implement a security system that meets applicable nuclear security regime objectives. Operators should design a system that can adequately perform security functions in order to deter and prevent malicious acts. While deterrence is not measurable, it is clear that a suitably robust security system can help to deter a malicious act. By implementing a graded approach, such a security system could then be deployed to undertake multiple security measures from prevention of malicious activities to reducing the probability of its occurrence **[*2*]**.

1. Detection

We can achieve the detection measures by different means as visual observation, video surveillance, electronic sensors, accountancy records, seals and other tamper indicating devices, and process monitoring systems.

By implementing a graded approach, the objectives of detection measures could range from immediate detection, assessment, and communication of any unauthorized access to subsequent detection of unauthorized removal through tamper indicators or periodic physical checks **[*2*]**.

2. Delay

Operators should implement delay measures to impede an adversary's attempt to gain unauthorized access, remove radioactive material, or sabotage associated facilities through multiple barriers or other physical means, such as locked doors, cages, tie-downs or the like. A measure of delay is the time, after detection, that is required by an adversary to remove the radioactive material or sabotage the associated facilities. By implementing a graded approach, operators can range the delay measures from providing sufficient delay after detection (to allow response personnel to interrupt malicious acts) to providing delay to allow for timely pursuit following unauthorized removal **[*2*]**.

3. Response

The operator should be required to communicate with law enforcement personnel following detection and assessment to respond in a timely manner. The objectives of response measures could range from immediately interrupting malicious acts to sounding alarm notifications to allow the appropriate authority to investigate the event. The operator should assist the competent authorities as appropriate in their efforts to locate and recover the radioactive material, including cooperation in on-site and off-site responses **[*2*]**.

4. Security Management

Operators should be required to implement security management measures, addressing access control, trustworthiness, information protection, security plan preparation, training and qualification, accounting, inventory, and event reporting. The stringency of appropriate security management measures should vary based on the graded approach **[*2*]**.

B. Nuclear Security Culture and its Characteristics

Nuclear security culture is defined as the assembly of characteristics, attitudes, and behaviors of individuals, organizations, and institutions that supports and enhances nuclear security **[*3*]**.

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The human is an important factor in nuclear security. He or she has a great role and responsibility in all activities of radioactive materials, processes, and management. Therefore, a plethora of individuals and various disciplines and organizations must work together, among them: the State, organizations, managers in organizations, personnel, the public, and the international community. Together, through coordination and dialogue, these stakeholders develop a nuclear security culture.

The greatest influences on individual performance are the beliefs, attitudes, behaviors, and management systems. These layers are the characteristics of nuclear security culture, the proper assembly of which leads to more effective nuclear security.

Security culture model for radioactive sources is based on goals, principles for guiding decisions and behaviors, and beliefs and attitudes. These three layers are broadly applicable to radiological facilities and organizations, including radioactive source users and other entities that handle or store radioactive material. Each of these layers is described in the following sections.

1. Beliefs and attitudes as drivers of people's behavior

Without a strong substructure of beliefs and attitudes about threats, an effective security culture cannot exist. Efforts to instill such beliefs and attitudes must be carefully calibrated to reach everyone working in the facility. The most important assumption for security culture is that there is a real insider and outsider threat. Understanding that a radiological event could have devastating health, environmental, economic, social, and psychological impacts is likely to reinforce the belief that a robust security regime is not only desirable but also necessary **[*4*]**.

2. Leadership behavior as role models

Managerial behavior and proactive security leadership help improve awareness and culture at all levels. Leaders are vital components in dealing with malicious capabilities, unintentional personnel errors, inadequate organizational procedures, and management failures. They are in a position to integrate the security regime for radioactive sources into an organization's security arrangements. Leaders can promote new and different assumptions and patterns of thinking, establish new patterns of behavior, and change the physical environment, mentality, and guiding principles. Culture, therefore, tends to mirror the real intentions, specific actions, and priorities of the management **[*4*]**.

3. Management systems as tools to promote desired patterns of behavior

The management systems integrate characteristics that either relate directly to the security of radioactive sources or are part of the managerial framework, without which security cannot be ensured and maintained. They are designed and shaped by senior management consistent with their vision of an effective security culture and the need for appropriate management tools to facilitate and support this process. At the same time, management systems ensure that health, environment, safety, quality, and economic requirements are not considered separately from security requirements, averting possible negative impacts on security. Characteristics of management systems include visible and effective security policy; the safety-security interface; clear definition of roles and responsibilities; trustworthiness determination; training and qualifications; information security; change management; contingency plans and drills; interface with regulations and other off-site organizations; and record keeping **[*4*]**.

4. Personnel behavior as key to robust and sustainable security

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The ultimate objective of security culture development is a set of desired standards of personnel behavior. Security awareness and culture are driven by personnel beliefs that security avoids malicious radiological events, which may have devastating health, environmental, economic, social, and psychological effects. While security awareness is a low-tier construct applicable to the entire workforce, more rigorous efforts must concentrate on a high-tier culture construct that targets individuals who manage and operate radioactive sources as well as those professionally associated with their use. There are many overlaps between awareness and culture, and they are often used interchangeably, but the latter implies commitment and ownership rather than awareness of possible risks and vulnerabilities. Culture is a more proactive construct than awareness. The behavior of personnel conscious of security culture includes the following characteristics: professionalism and security awareness, compliance, personal accountability, mutual respect and cooperation, and vigilance and reporting **[*4*]**.

5. Goal: more effective nuclear security

The goal of discussing the issues above is establishing an effective nuclear security culture through providing a greater assurance that the entire nuclear security program will accomplish its functions of preventing, detecting, delaying, and responding to theft, sabotage, unauthorized access, and illegal storage or transport **[*3*]**.

IV. Importance of Continual Self-assessment of Nuclear Security Measures

Because the threats are always evolving, it is necessary to continually assess the existing nuclear security systems and improve upon them to ensure they are consistent with the current threat. If personnel understand that their contribution to nuclear security is important, then they will be motivated to implement the nuclear security system effectively and vigilantly, and contribute to its improvement **[*5*]**.

The purpose of self-assessing a nuclear security system is to provide a clear picture of the extent to which the security system is valid, recognizing its weaknesses and strengths.

Self-assessment involves evaluating the key security system in the organization by comparing certain indicators. Indicators serve as gauges, enabling one to compare current performance to reference levels corresponding to optimal nuclear security. This assessment is an evaluation of a nuclear security system through continual technical examination, which allows one to know whether this system performs its functions properly, discover the weaknesses, and troubleshoot damages in real time.

Without harmony between personnel and the security system, an effective security measures cannot exist. Thus, promoting the importance of nuclear security and enhancing nuclear security culture is an ongoing activity.

The self-assessment of nuclear security culture is a tool used to understand the beliefs and attitudes held by personnel that support effectiveness of nuclear security. Self-assessment also allows a competent authority/facility/activity to build on those beliefs and attitudes and to diagnose signs of complacency. The level of nuclear security culture may be difficult to assess as some aspects of culture are not visible. However, by using various methods, including written questionnaires, focus groups, surveys, and oral interviews, one can better understand the existing culture. It is important to recognize that the most accurate feedback is attained from a variety of these assessment methods.

Self-assessment may be conducted at the onset of implementing an enhancement program. Doing so can indicate what specific efforts should be included in the action plan. Afterwards, the culture coordinator

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may regularly implement self-assessments (e.g., every two years) to evaluate results of the existing enhancement program and update the action plan accordingly. Self-assessments, with subsequent development of prioritized action plans that address root causes of difficulties, are essential to maintaining a strong nuclear security culture **[*5*]**.

Security culture self-assessment helps both those directly involved with nuclear security and the rest of the organization by illuminating how culture influences security performance. Effective self-assessment encourages staff to accept ownership of the results and facilitates decisions that foster continuous improvement. Benefits of self-assessment include:

- A deeper understanding of the human factor and nuclear security culture
- A clearer understanding of employees' concerns, needs, aspirations, and motives
- The identification of barriers to and incentives for improvements to security performance
- The identification of barriers to and motives for change
- The clarification of employees' opinions on security-related topics
- An improved capacity to self-assess the organization's security performance and to analyze trends within the site or monitor progress
- The increased prioritization of actions that strengthen the overall organizational culture in areas such as internal communication and human resource management **[*6*]**

Self-assessment of nuclear security culture should complement the currently used methods for evaluating vulnerabilities and nuclear security systems, thus helping management to refine the organization's overall nuclear security arrangements **[*6*]**.

V. Study Conducted in Tangier to Improve Both Physical Protection and Nuclear Security Culture

In order to improve physical protection and nuclear security culture within the Ionization Station SIBO, we have created a team to carefully study nuclear security. We started by making a simple map that contained the nuclear security system already established within the facility on which we based our theoretical study. It mentioned different areas which could be considered vital, and we took numerous measurements including the height and width of the walls, hardness of doors, effectiveness of detection systems, response time, and many others key notes were written in a special document for future discussion.

We had also established a few potential scenarios for removal of the radioactive sources or sabotage of the facility. The scenarios have been replicated in reality to help us to have a clear vision about the effectiveness of the security system and discover its strengths and weaknesses. Some example scenarios include:

- Calculated the time it would take an adversary to reach the door of the ionization station from the main door of regional center with different routes
- Calculated the time it would take to break the door to enter the ionization station if the adversary hasn't been detected, considering whether the adversary has access inside the station
- In addition, we calculated the time it would take to get from the ionization station doors to the casemate which contain the source taking into consideration the various paths and whether the adversary would have access or if they must break doors to achieve their goal
- Calculated how long it would take the response forces to deter the adversary in each attempt

To assess the effect of human factor in nuclear security within this facility, we asked to each team member to present ideas that could help improve nuclear security. These presentations had been shared in meetings which were held every 15 days.

In the following section we will share the results and recommendations of the study involving nuclear security system as well as nuclear security culture.

VI. Results and Recommendations

The primary physical protection objective is preventing unauthorized individuals from getting access to radioactive material and stealing it from the facility. The use of penetration delay barriers securing the material buys time for the guards to call for assistance and contain or delay adversaries until the arrival of the response force **[*7*]**. The ionization station needs strong and sufficient fences to deter any attempted theft or sabotage. In this study we started with the wall which surround the facility and some area which contain glass windows. After obtaining all measurements and reviewing likely scenarios, we recommended barbed wire affixed to the entire wall that surrounds the regional center of agriculture, rather than limiting it to the wall surrounding the radiological plant. This measure can provide an absolute security efficiency. We also found that it would be better to replace all glass windows with barred ones, which would be stronger and higher off the ground.

Regarding security guards, we had proposed to install another new permanent guard post in addition to the old one. This post would be managed by two security officers, with a crossing barrier to reinforce external security.

In addition to layers and fences, prevention measure would be implemented to deter adversaries. Among prevention measures we had proposed:

- A pointing system that tracks the presence of staff and trainees, recording the date, time and type of check-in (entry / exit)
- A paper registry which bears the name of any individual (staff, trainees, visitors,..) who has accessed the interior of the installation and a scanned copy for not losing the information
- Installing extra external lighting lamps along the fenced perimeter to give clear vision and deter any attempt of intrusion during the night

The detection features are vital, so we suggested additional means of detection, to determine the entry control effectiveness, and assess intrusions:

- Installing a walkthrough metal detector at the entrance of the ionization station that can detect gamma radiation and neutron radiation (weapons, explosives...)
- Adding surveillance camera in areas considered blind spots in the facility
- Changing the current analogical surveillance cameras to IP cameras in order to improve image quality.

Delay comes just after detection; in this regard we suggested replacing the turnstile door with a barred turnstile which offers a high level of security for a single person crossing and an access control system.

On the other hand, it is imperative to take into consideration the human factors in order to succeed the security system. Below are propositions to strengthen the nuclear security culture within the studied station.

A. Performance Measurements

Surveys are important for self-assessment because they establish a baseline for tracking changes over time. Therefore, we set up a survey in order to assess everyone's involvement.

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B. Task Management

The management system defines a set of activities related to the set of services (IT, analysis, verification, validation, decision-making, etc.). The aim of this system is to give flexibility in carrying out tasks, consistent work and a well-developed management system which prioritize security.

C. Effective Communication

Effective communication is a main tool to develop the security of each organization. To improve communication, we focused on some points as follows:

- Holding more meetings that can encourage team members to communicate effectively and make each person participate in discussions about their current missions, priorities and objectives. The meetings can be held weekly and briefly where each person has 2-3 minutes to present their work. Special attention should be paid to identifying problems and possible solutions.
- Including videos to keep people moving since they keep everyone informed of major (and even minor) changes and events in the business.
- Build an anonymous suggestion box, since each person is different and therefore communicates differently. Some staff feel comfortable proposing ideas face to face while others prefer making contributions anonymously.

VII. Conclusion

Because of the weight and size of the container (5 tons), the theft of the Co-60 source is highly unlikely, but sabotage remains a potential concern, however. Following the terrorist attacks in the U.S. on September 11, 2001, there is concern that the source is vulnerable to attack by commercial aircraft. This study was done in order to reduce risks associated with variant threats that can target the facility and the radioactive source of Co-60. The results were very satisfying especially for nuclear security culture to improve and strengthen nuclear security in the studied station. Such improvements can also deter insider threats and therefore reduce threats induced or facilitated by these insiders.

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IX. Authors' Bios

Halima Jemmal
Halima Jemmal is a Ph.D. student in the nuclear sciences field at the University of Ibn Tofail in Kenitra, Morocco. Jemmal received a bachelor's degree in physical sciences from the University of Moulay Ismail in Meknes, Morocco, and a Master's degree in nuclear sciences and techniques at the University of Ibn Tofail in Kenitra. Jemmal is a member of WIN Africa (Women in Nulear Africa) and INMM (Institute of Nuclear Materials Management). Recently, Jemmal attended WINS Academy courses and received a certificate in nuclear security for scientists, technicians, and engineers, as well as a certification from WINS (World Institute for Nuclear Security) as a Certified Nuclear Security Professional (CNSP) with specialization in Foundation.

Dr. Abdelmajid Choukri
Dr. Choukri is a professor of nuclear physics at the University of Ibn Tofail in Kenitra, Morocco. Choukri has a Ph.D. in nuclear sciences from Mohammed V University at Rabat. He was formerly responsible for two laboratories, was formerly the secretary general of the Moroccan Radiation Protection Association, and is currently a member of INSEN (International Nuclear Security Education Network), WINS, and INMM.

Dr. Choukri has been a research professor for 30 years. He taught courses in general physics and specialty courses in the field of nuclear physics including courses on nuclear physics, radiation protection, nuclear energy and nuclear security. Dr. Choukri managed several programs in undergraduate and master cycles and supervised numerous master and PhD theses in the field of applied nuclear science.
He has published more than one hundred articles in international journals and more than two hundred oral and poster presentations in international congress. Dr. Choukri has done expert consulting for nuclear security meetings for the International Atomic Energy Agency (IAEA).

Dr. Mohammed Mouhib
Dr. Mohammed is an expert consultant in nuclear energy, nuclear safety and security, dosimetry and radiation protection, construction of irradiation facilities and irradiator management. Dr. Mohammad has a Ph.D. in nuclear physics and is an engineer in energy and industrial processes. He also specializes in radioactive materials transportation and energy efficient/environment conscious construction.

Dr. Mohammed has over twenty-eight years of experience and several scientific and technical publications resulting from his careers in research and management

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of facilities and production. He has written many research articles on food irradiation, wastewater irradiation techniques, sterilization of medical products, and dosimetry.

Dr. Mohammed is a lecturer in irradiation technology and nuclear safety at Irradiator SIBO in collaboration with security services in Morocco. He has supervised several doctoral and master's theses on nuclear techniques, the environment, and quality by establishing quality systems for industrial process namely with APPI France, and energy efficiency at RSE orientations in collaboration with several universities. Dr. Mohammed is a member of the Moroccan delegation to the IAEA General Conference representing the Ministry of Agriculture (national consultant). He is also the course director on aromatic and medicinal plants in collaboration with the IAEA as well as a member of several professional associations in development of new training actions and business models such as CSR, KMS, Hancho, BSC, and BPR.

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