Upgrading the Physical Protection System (PPS) To Improve the Response to Radiological Emergencies Involving Malevolent Action

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Abstract

Experience in many parts of the world continues to prove that movements of radioactive material outside of the regulatory and legal framework may occur. The aim of this article is to discuss a proposed physical protection system for improving the protection of radioactive sources used for medical purposes.

Introduction

The threat from criminal activities can include bomb threats, bombings, sabotage, vandalism, physical attacks, kidnapping, hostage-taking, theft of radioactive or fissionable material, or other criminal acts potentially resulting in an actual or perceived radiation emergency. Experience shows that the public's perception of the risk posed by the threat may be more important than the actual risk. Consequently, an important part of a security program is providing the public, ideally in advance of an attack, with timely, informative (understandable) and consistent information on the true risk.[1].

Many factors can lead to loss of control of radioactive sources, including ineffective regulations and regulatory oversight; the lack of management commitment or worker training; poor source design; and poor physical protection of sources during storage or transport. The challenge is to address this wide range of risks with effective actions. [2]. Effective physical protection requires a designed mixture of hardware (security devices), procedures (including the organization of the guards and the performance of their duties) and facility design (including layout) [3]. One of the most important aspects of managing a radiological emergency is the ability to promptly and adequately determine the threat and take appropriate actions to protect members of the public and emergency workers.

Objective

This article is focused on the study of the current status of the physical protection system (PPS) for a radioactive source used in a tele-therapy unit in a public hospital. Hazard assessment is calculated and Design Basis Threat (DBT) is proposed. The process utilizes a performance-based system to design and analyze PPS effectiveness for the protection of the radioactive

source. We also analyze how this design improves the response to radiological emergencies involving malevolent action.

Methodology

The ultimate goal of a Physical Protection System (PPS) is to prevent the accomplishment of overt or covert malevolent actions. Typical objectives are to prevent sabotage of critical equipment, deter theft of assets or information from within the facility, and protect people. A PPS must accomplish its objectives by either deterrence or a combination of detection, delay, and response [4]. In attempting to address the threats from malevolent acts involving radioactive sources, it is clear that radiological sources of certain magnitudes and types are more attractive to those with malevolent intent than others [5]. The present study involves the steps A-F discussed below for the proposed PPS.

A- Asset and Site Assessment:

A ^{60}Co source with an activity of 7494 Ci (277.27 TBq) as of March, 1999 is used by a Tele-therapy Unit in a public hospital for the treatment of patients. The working hours are 9.00 am to 2.00 pm daily. Fig.(1) illustrates the layout of the hospital including the main gates.

The hospital gates are: Gate 1 is for employees and a clinical unit, closed at 2.00 pm; Gate 2 is for patients, open 24 hours. Gates 1&2 are the main gates; Gate 3 is emergency gate, open 24 hours; Gate 4, is for the hospital's receivables; Gate 5 is for external treatment (medical investigation unit), closed at 1.30 pm; and Gate 6 is for the family medical care unit, closed at 6.00 pm.

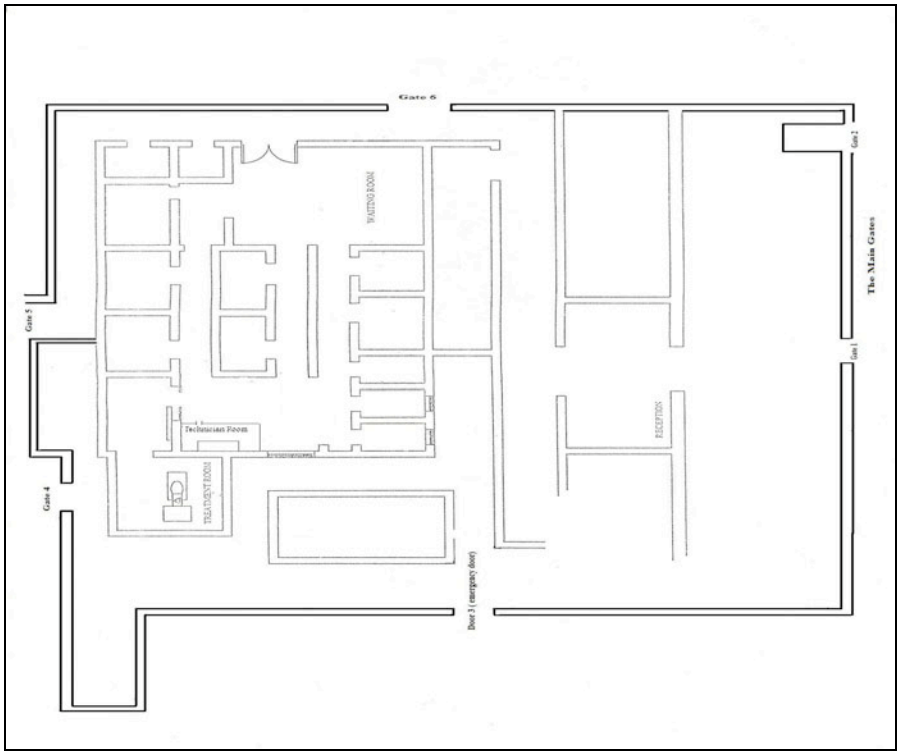

Fig. 1 Lay out of a Public Hospital and the Room for the Tele-therapy Treatment

B- Current Status of the Security System:

A concrete fence of height 2.5 meters defines the external boundaries of the hospital. The room for the tele-therapy unit is covered with windows supported by steel. There is only a monitoring camera in the main hole (waiting area in the first floor); the recorded video is monitored by security personnel. All the entrance gates are opened and connected to each other (you can enter to the hospital's utility from any gate). There is one access to the tele-therapy room, and the door is locked manually. *The functions of PPS in the hospital are thus initially dependent mainly on the initial response of the security guards; in the event of intrusion, they call the police for help, through the police office is located 500 m away from the hospital. Thus, upgrading the PPS is necessary to cover the main three functions (detection, delay, and response) for ensuring the security and safety of the radioactive source.*

C- Risk Assessment and Action Level

The risks are assessed on the assumption that the source or material of interest is not being managed safely or kept securely. A fire or destructive accident could lead to removal of the protecting shield of the radioactive material. The decommissioning of the tele-therapy unit could lead to the same risk if someone would try to remove the radioactive material from the head (protecting shield) of the tele-therapy unit for shipping [1]. Because similar sources worldwide number in the millions, the security measures should be directed at those sources that pose the greatest risks. With this in mind, the IAEA in October of 2003 developed a new categorization system for radioactive sources [6], to ensure that the sources are maintained under a control commensurate with the radiological risks. This categorization system is based on the potential for radioactive sources to cause deterministic effects, i.e., *health effects which do not appear until threshold value is exceeded and for which the severity of effect increases with the dose beyond the threshold*. An amount of radioactive material is considered "dangerous" if it could cause permanent injury or be immediately life threatening if not managed safely and contained securely [1]. The risk factor is calculated through the following equations**:**

For all materials (individual source):

$$D_{f1} = \frac{A}{D} = \sum \frac{A_i}{D_{1,i}} \text{ ---------- (1)}$$

Where D_f is the risk factor, (its value ranges from < 0.01 to > 1000.0).
A_i is the activity (TBq) of each radionuclide over which control could be lost during an emergency/event.
$D_{1,i}$ is constant for isotopes, and is citied in appendix 8 of ref. [1].

For dispersible material:

$$D_{f2} = \frac{A}{D} = \sum \frac{A_i}{D_{1,i}} \text{ ---------- (2)}$$

Where A_i is the activity (TBq) of each radionuclide i that is in a dispersible form over which control could be lost during an emergency/event.
$D_{2,1}$ is constant for isotopes, and is citied in appendix 8 of ref. [1].

Table (1) illustrates the D_{f1} and D_{f2} values of the Co-60 source used in the hospital and the associated risk. From the calculation of A/D value, the source is categorized as category 1 as described in reference [6].

Table (1): The calculated D_{f1} and D_{f2} Values and their associated risk

Activity TBq	D_{f1} Value	D_{f2} Value
277.27	9242.6	9.242
Associated Risk	***Very dangerous to the person:*** This amount of radioactive material, if not managed safely and kept securely, could cause permanent injury of a person who handless it or is otherwise in contact with it for a short time (minutes to hours). It could possibly be fatal to be close to unshielded material for a period of hours to days.	***Dangerous to the person*****:** This amount of radioactive material, if not managed safely and kept securely, could cause permanent injury of a person who handles it or is otherwise in contact with it for some hours. It could possibly — although it is unlikely — be fatal to be close to this amount of unshielded material for a period of days to weeks.

D- Threat Assessment and Design Basis Threat (DBT)

The *Design Basis Threat* for sources must consider the attributes and characteristics of potential insider and/or external adversaries who might attempt to damage or seek unauthorized removal of radioactive sources, against which the PSS is designed and evaluated. The use of a design basis threat assessment methodology is recommended by the IAEA as the best method to design the security measures for specific sources [5]. For our case, the risk involving radioactive source is therefore considered to be quite high. An analysis was performed for the possible consequences of unauthorized acquisition of these radioactive sources from the hospital. This analysis showed that, the nature and form of the ^{60}Co sources are in such that the radioactive material could be easily dispersed via an explosion or otherwise destructive device. On that basis, the specific design basis threat is the possible acquisition of a tele-therapy source by an insider in the hospital or by people who enter the hospital as patients or contractors. Based on the vulnerability analysis for a specific source, an assessment of the risk can be made. The level of this risk will determine the security measures required to protect the source. The higher the risk, the more capability will be required from the security systems [5].

Four security groups are defined based on these fundamental protection capabilities. They provide a systematic way of categorizing the graded performance objectives required to cover the range of security measures that might be needed, depending on the assessed risk. In our case, the security level required was considered to be equivalent to the performance requirements in Security (Group A) in which measures should be established to deter unauthorized access, and to detect unauthorized access and acquisition of the source in a timely manner. These measures should be such as to delay acquisition until response is possible [6].

E- Suggested PPS and Design Criteria

In designing the PPS, we take into consideration a feature-based design and a performance-based design. On the base of the worst case of threat, a proposed PPS was designed. Figs. 2&3 show the suggested access and their locations. This system incorporates the three key functions (detection, delay and response). It also has the capability to verify the various roles of the proposed system: **in-depth protection, balanced protection, and timely detection/response.** The PPS was applied in two protection zones (control room and treatment room) and in the Entrance (door no.2 and the emergency door, as well as the exists of the hospitals).

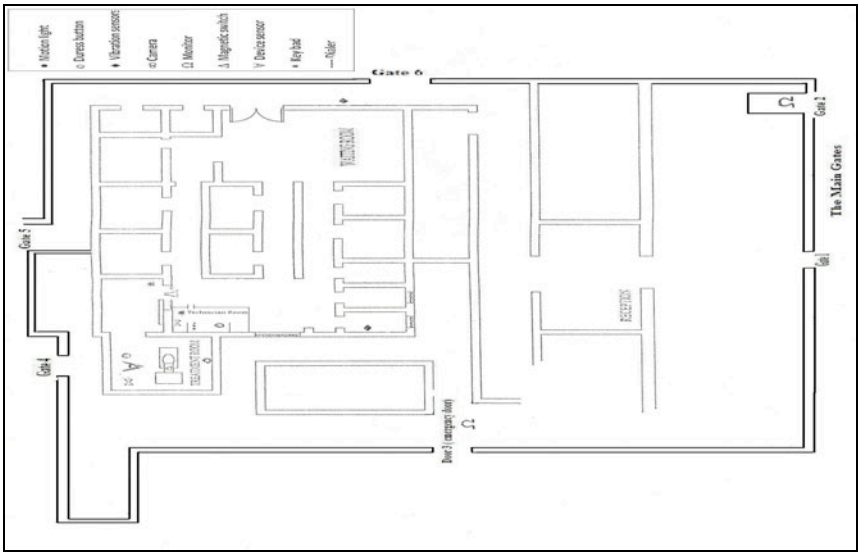

Fig.2 The Suggested Access with their Locations in the Hospital

Fig.3 The Locations of the purposed Equipments in the Tele-therapy Unit

I- Detection Function:

Zone 1: Vibration sensor, Glass break sensor, Duress button, Motion light, Cameras and Dialer.
Zone 2: Balanced magnetic switch (door-device), Microwave sensor, Passive Infra Red (PIR) sensors, Duress button, Sources sensor, Camera and Motion light**.** These functions are attached with *alarm assessment* for all sensors and connected to Video monitors and Sirens in three positions (door 2, door 3" emergency door" and security room). The measures of effectiveness for the detection function are the probability of sensing adversary action, the time required for

reporting and assessing the alarm, and nuisance alarm rate [3]. The proposed system can provide: Timely Detection, Balanced Detection, and Protection in Depth.

II- Delay Function:

The effective source access delay system includes the two elements:

II-1- Physical Barriers

Zone 1: Hardened doors in the 3 entrances, Key control systems for three doors, and Steel on the Windows.

Zone 2: High security hardened door with keypad and lock (password – key) and another hardened door with key.

II-2- Protective Force

■ 2 well -rained Guards are to be present in the Radiotherapy Dept. (Patrolling- closed doors-monitoring).

■ 2 well trained Guards are to be present at Door 2& 3 (Quick response- evaluation of the situation – Quick communication).

■ A police officer is to be present at Door 3 .

The measure of the delay effectiveness is the time required by the adversary (after detection) to bypass each delay element [5].

III- Response:

The response function consists of the actions taken by the response force to prevent adversary success. Response, as it is used here, consists of interruption. Interruption is defined as a sufficient number of response force personnel arriving at the appropriate location to stop the adversary's progress. It includes communicating to the protection force of accurate information about adversary actions and the deployment of the response force. The effectiveness measure of this function is the probability of deployment at the adversary location and the time between receipt of a communication of adversary action and the interruption of the adversary action (response force time RFT) [4].

Development of the response may be established through the following steps:

- Developing of Memorandum of Understanding (MOU) for security and police officers,
- Effective training of security officer,
- Implementation of the authorized security devices to permit fast response,
- Documentation of all procedures.

F- Measuring the Effectiveness of the Proposed PPS

A Computerized EASI Model [4] was used to calculate the probability of interruption (P_I). It is a simple calculation tool that quantitatively illustrates the effect of changing physical protection parameters along a specific path. It uses detection, delay, response, and communication values to compute the probability of interruption P_I. In this model, input parameters representing the physical protection functions of detection, delay, and response are required. Communication likelihood of the alarm signal is also required for the model. Detection and communication inputs are in the form of probabilities (P_D and P_C respectively) that each of these total functions will be performed successfully. Delay and response inputs are in the form of mean times (T_{delay} and RFT respectively) and standard deviations for each element. All inputs

refer to a specific adversary path [4].

Table (2) describes the path of an adversary and the expected P_D values, the delay times, Response Force Time and the calculated P_I.

Table (2): The Calculated Probability of interruption as the function of the PPS Effectiveness

Response Force Time (in Second): 300 sec. Standard deviation: 90			
Probability of Guards communication: 0.95			
Worst path Segments	***P_D***	***Delay Time (Sec.)***	***Standard deviation***
Penetrate site Boundary	0	10	3.0
Cross hospital property	0	10	3.0
Enter Main Door	0	5	1.5
Cross Main Lobby	0	5	1.5
Penetrate Door to Room	0.9	60	18.0
Cross Rad. Treatment Room	0.9	90	27.0
Remove Source & Pack	0.9	360	108
Cross Rad. Treatment Room	0.9	30	9.0
Exit Door to Room	0.7	10	3.0
Exit Emergency Room	0.8	10	3.0
Cross hospital Property	0	5	1.5
Exit Site Boundary	0	5	1.5
Probability of Interruption: 0.9			

Conclusion

The ultimate goal of a Physical Protection System (PPS) is to prevent the accomplishment of overt or covert malevolent actions.

This Study covers the use of a systematic and measurable approach to the design of a PPS. It emphasizes the concept of detection, followed by delay and response.

The proposed performance-based Physical Protection System (PPS) appears to have the capability of defeating adversaries for which it is designed.

Verification of timely detection for intrusion is one of the principles in the proposed system based on use of the included sensors, signal lines, and alarm displays.

The study is considered as base guidelines for the application of PPS in any radioactive facilities.

References

1- EPR-METHOD (2003) Emergency Preparedness and Response Method for Developing Arrangements for Response to a Nuclear or Radiological Emergency Updating IAEA-TECDOC-953.
2- El Baradei, M. (IAEA Director General), Address at the International Conference on Security of Radioactive Sources, Vienna, 11–13 Mar. 2003.
3- IAEA INFCIRCL 225/ rev.4 Corrected, "The Physical Protection of Nuclear Materials and Nuclear Facilities" June 1999.
4- Design and Evaluation of Physical Protection Systems, Mary Lynn Garcia.

5- IAEA-TECDOC-1355 Security of radioactive sources Interim guidance for comment, June 2003.
6- IAEA-TECDOC-1344 Categorization of radioactive sources Revision of IAEA-TECDOC-1191, Categorization of radiation sources July 2003.