NUCLEAR SECURITY AND RADIOLOGICAL PREPAREDNESS FOR THE OLYMPIC GAMES, ATHENS 2004: LESSONS LEARNED FOR ORGANIZING MAJOR PUBLIC EVENTS

Vassiliki Kamenopoulou, Panayiotis Dimitriou, Constantine J. Hourdakis, Antonios Maltezos, Theodore Matikas, Constantinos Potiriadis, and Leonidas Camarinopoulos*

Abstract—**In light of the exceptional circumstances that arose from hosting the Olympic Games in Athens in 2004 and from recent terrorist events internationally, Greece attributes the highest priority to security issues. According to its statutory role, the Greek Atomic Energy Commission is responsible for emergency preparedness and response in case of nuclear and radiological events, and advises the Government on the measures and interventions necessary to protect the public. In this context, the Commission participated in the Nuclear, Radiological, Biological, and Chemical Threat National Emergency Plan, specially developed for the Olympic Games, and coordinated by the Olympic Games Security Division. The objective of this paper is to share the experience gained during the organization of the Olympic Games and to present the nuclear security program implemented prior to, during, and beyond the Games, in order to prevent, detect, assess, and respond to the threat of nuclear terrorism. This program adopted a multi-area coverage of nuclear security, including physical protection of nuclear and radiological facilities, prevention of smuggling of radioactive materials through borders, prevention of dispersion of these materials into the Olympic venues, enhancement of emergency preparedness and response to radiological events, upgrading of the technical infrastructure, establishment of new procedures for assessing the threat and responding to radiological incidents, and training personnel belonging to several organizations involved in the National Emergency Response Plan. Finally, the close cooperation of Greek Authorities with the International Atomic Energy Agency and the U.S. Department of Energy, under the coordination of the Greek Atomic Energy Commission, is also discussed.**

Health Phys. 91(4):318–330; 2006

Key words: emergencies, radiological; emergency planning; radiation protection; terrorism

INTRODUCTION

SINCE THE 2004 Olympic Games in Athens in 2004 (OG 2004) was the first major athletic event of its kind organized after the terrorist actions of 11 September 2001, security became the predominant challenge Greece had to face among all other issues related to the successful organization of the Games.

In this context, an unprecedented project was initiated by Greece to make the OG 2004 secure. As part of this effort, a comprehensive plan was put in place by the Olympic Games Security Division (OGSD) of the Hellenic Ministry of Public Order to address Nuclear, Radiological, Biological and Chemical (NRBC) threats.

The Greek Atomic Energy Commission (GAEC) played a critical role in this endeavor. According to its statutory role, GAEC is responsible for emergency preparedness, advises the Government on the measures and interventions necessary to protect the public, and acts as the contact point for receiving and communicating information to the emergency response systems. Ever since its establishment, GAEC has participated in the National Emergency Plan for Civil Protection "Xenokratis." Therefore, GAEC was deeply involved in drafting and implementing the nuclear or radiological (N/R) part of the NRBC Threat National Emergency Plan (NEP) for the OG 2004. To cope with its new responsibilities, the response system of GAEC has been significantly enhanced. These upgrades to the response system concern the manpower, the infrastructure (measuring and detection systems, protective equipment, communication systems, dispersion calculation codes, etc.), and the reviewing of internal procedures for assessment and response during a N/R emergency.

In May 2003, a multi-faceted cooperation was initiated when GAEC proposed collaboration between the International Atomic Energy Agency (IAEA) and the Greek Government in the field of nuclear security, to ensure a high level of nuclear security during the OG 2004. As a result, a security project to prevent N/R events was put in place, and official agreements were signed among the major participants in the project, namely the IAEA, the United States Department of Energy (U.S.

* Greek Atomic Energy Commission, P.O. Box 60092, Ag. Paraskevi 15310 Greece.

For correspondence contact Vassiliki Kamenopoulou at the above address, or email at vkamenop@gaec.gr.

(*Manuscript accepted 22 February* 2006)

0017-9078/06/0

DOE) and several National Organizations in Greece. GAEC had the coordination and the overall responsibility for the completion of the project. In parallel, significant national funds were devoted to the project, ensuring continuous technical and scientific support, as well as the training of hundreds of personnel of several organizations involved in the Plan. This cooperative effort greatly contributed to the success and security of the OG 2004.

GAEC is now sharing the experience gained in order to assist other countries in their efforts to secure major public events. For this purpose, the measures taken for the prevention and response in case of a N/R accident or threat are presented here, together with the lessons learned from this unique experience.

Prevention of nuclear/radiological accident or threat

In the framework of the prevention of a N/R accident or threat, several measures have been taken, some of them applicable for only the sensitive period of the OG 2004, and others beyond the OG 2004. Specific details on these measures are provided in the following paragraphs.

Inventory of radiation sources. A quite large number of sealed radiation sources for industrial, medical, educational, and research applications exist in Greece. More specifically, about 740 radiation devices in about 200 industrial facilities are in operation, using radionuclides such as ^{241}Am, ^{137}Cs, ^{60}Co, ^{85}Kr, ^{90}Sr, ^{63}Ni, ^{109}Cd, or ^{55}Fe, with activities varying from 10 kBq to 6.5 TBq. These devices are used as level and density gauges, in quality control, or for other purposes. In industrial radiography, there are about 60 projectors using ^{192}Ir or ^{75}Se sources. A sterilization facility operates with more than 7 TBq of ^{60}Co sources for medical product sterilization, while 40 GBq ^{137}Cs or ^{90}Sr sources are used in blood irradiators at various hospitals. In 14 radiotherapy departments, ^{60}Co systems (200 GBq) have been installed, while ^{192}Ir, ^{125}I, and other sources are used for brachytherapy. Finally, there are more than 1,500 sealed radiation sources in the country that are used for educational and research applications.

As a first line of defense against a radiological accident or incident, GAEC has developed and currently maintains the national inventory for all these sources. This official database has been developed by GAEC in the INGRES Relational Data Base Management System (RDBMS) environment and keeps all relevant information for each sealed radioactive source. More specifically, the following data are kept and updated: radionuclide, activity and reference date of activity, type of source, irradiating system containing the source, source/system manufacturer data, holder's information data (name, address, location of source/system and responsibilities), GAEC's inspection results, and all issued licenses. This database is a part of the National Radiation Protection database, kept by GAEC, according to its statutory role.

Furthermore, GAEC performs regular inspections of all these facilities every 2 years, while inspections without prior notification are performed on a random basis. The aim of these inspections is to assess safety and security issues related to radiation protection of workers and members of the public. In each facility, the quality assurance program, the emergency plan, as well as the preventive actions to deter theft of sources or sabotage are also assessed.

Disused and orphan radiation sources. In order to prevent any danger from disused radiation sources, which were installed or had remained unattended in "closed" or bankrupt facilities, GAEC, in collaboration with the National Center for Scientific Research "Demokritos" (NCSR) and the Ministry of the Environment, started in 2002 a program aiming at the collection of these sources. As a result, more than 900 radioactive sources (^{60}Co, ^{137}Cs, ^{90}Sr, ^{241}Am, ^{226}Ra, ^{57}Co, ^{85}Kr, etc.) used in industry, medicine, or research, of total activity about 2 TBq, and 10 radiotherapy sources (^{60}Co and ^{137}Cs) of total activity of 113 TBq have been collected and exported for recycling.

Under the same framework, the waste management facility in the NCSR campus has been significantly upgraded.

Upgrading of the physical protection at selected radiological facilities. Physical protection against unauthorized removal of N/R material and against sabotage of this material is a matter of national as well as of international concern. The ultimate responsibility for establishing and operating an adequate physical protection system for N/R materials and installations rests within the State (Catsaros and Matikas 2004).

Under the auspices of the IAEA and within the framework of the U.S. DOE International Safeguards Threat Reduction Program, in collaboration with the Sandia National Laboratories, the Physical Protection System (PPS) of the research reactor and of all "category A" radiation sources, installed in 22 hospitals and in an industrial sterilization facility, were strengthened. In particular:

a. Greece has only one nuclear research reactor (GRR-1) located in the campus of the NCSR in the Attiki district, approximately 15 km from the center of Athens. GRR-1 is a pool type uranium fueled, light water moderated and cooled reactor with a maximum power of 5 MW (thermal). The reactor core consists of both 93% enriched uranium (HEU) and 19.75% enriched uranium (LEU). The quantity of HEU is slightly less than 5 kg. Accordingly, the reactor is classified as a category II facility for the purpose of physical protection, assuming that the material is not self-protecting. The PPS of GRR-1 had been evaluated in 2001 by a joint U.S. NRC–DOE/NNSA mission and was found to be in general conformity with IAEA standards, INFCIRC/225/Rev. 4 (IAEA 1999a). INFCIRC 225 is an important document that provides recommendations for the physical protection of nuclear material against unauthorized removal during its use, storage, and transport—domestic or international—and provides recommendations for protection against sabotage of nuclear material or facilities, detailing the elements that should be included in a State's system of physical protection. These recommendations also take into account the potential proliferation concerns arising from the unauthorized removal of nuclear material and the potential safety and health consequences arising from the sabotage of nuclear material or facilities. The recommendations provided in INFCIRC 225 use a phased approach and depend on the amount and nature of nuclear material used or stored in the facility. In spite of the fact that the GRR-1 was considered a category II facility for the purpose of physical protection, due to the exceptional circumstances of the OG 2004 in Athens, the PPS of GRR-1 has been upgraded beyond INFCIRC 225 requirements for this type of facility. The new system has been designed in close collaboration with the U.S. DOE in order to obtain improved detection, assessment, and access control capabilities (Fig. 1), according to requirements set by the threat risk assessment. Several upgrades that have been done to the existing PPS include a new perimeter detection system, new Closed Circuit TV (CCTV) system, new main and back-up lighting schemes, and a new security control room. For the implementation of this system, the perimeter has been split into several sectors. The CCTV system utilizes the latest state-of-the-art Charge-Coupled Device (CCD) night-vision cameras for the main perimeter surveillance. All cameras are connected to Central Alarm System (CAS). The new security control room houses all necessary CAS equipment and includes a suitable rack and console. Thin Film Transistor (TFT) monitors are switched upon receipt of alarm activation from the perimeter detection systems. Finally, adequate illumination of the area ensures visual comfort, visual performance and detail discrimination at night time by the security personnel (IAEA 2005; Catsaros and Matikas 2004); and

b. The PPSs of 22 oncology clinics and blood irradiation facilities of 18 hospitals in six Greek cities, and at a large sterilization facility, have been significantly upgraded (IAEA 2005) according to requirements set by Design Basis Threat. The functions of the installed PPSs are the sequential detection, delay and response to an adversary action. The main components of the systems at the medical clinics are:

- balance magnetic switches installed on the entry doors;
- volumetric sensors, microwave and passive infrared complementary technologies to detect unauthorized movement within the clinic;
- penetration sensors to detect penetration of the radioactive source unit;
- dual door locks, each controlled by a separate hospital organization;
- keypads to activate/deactivate the door sensors and the volumetric sensors;
- hardened doors; and
- sirens and visual alarm panels.

The PPS upgrades at the sterilization facility include:

- a multicamera CCTV system with a video motion detection system and video recorder in conjunction with an alarm system;
- glass break detectors at product storage and shipping areas connected to the alarm system;
- secure storage device for source handling tools;
- vehicle jersey barriers in front of the bunker;
- adjustments/improvements of the existing infrared beam system and the addition of new beams;
- improvements at the main entrance and relocation of the reception alarm panel;
- additional motion/microwave detectors for the electrical supply installation room;
- a back up communication system; and
- auxiliary power supply for the security system in case of blackout.

The procedures for responding to adversary actions were also upgraded and communications with relevant law enforcement authorities were tested with drills.

Adequate training, technical support, and follow-up have been provided to the radiation protection experts and to the personnel authorized to use these systems, as well as to response personnel.

To ensure the effectiveness and sustainability of the PPS at these sites, the GAEC enforced a relevant regulatory directive concerning inspections and licensing, and a prepaid preventive maintenance/operation guarantee program for a number of years was put in place. In

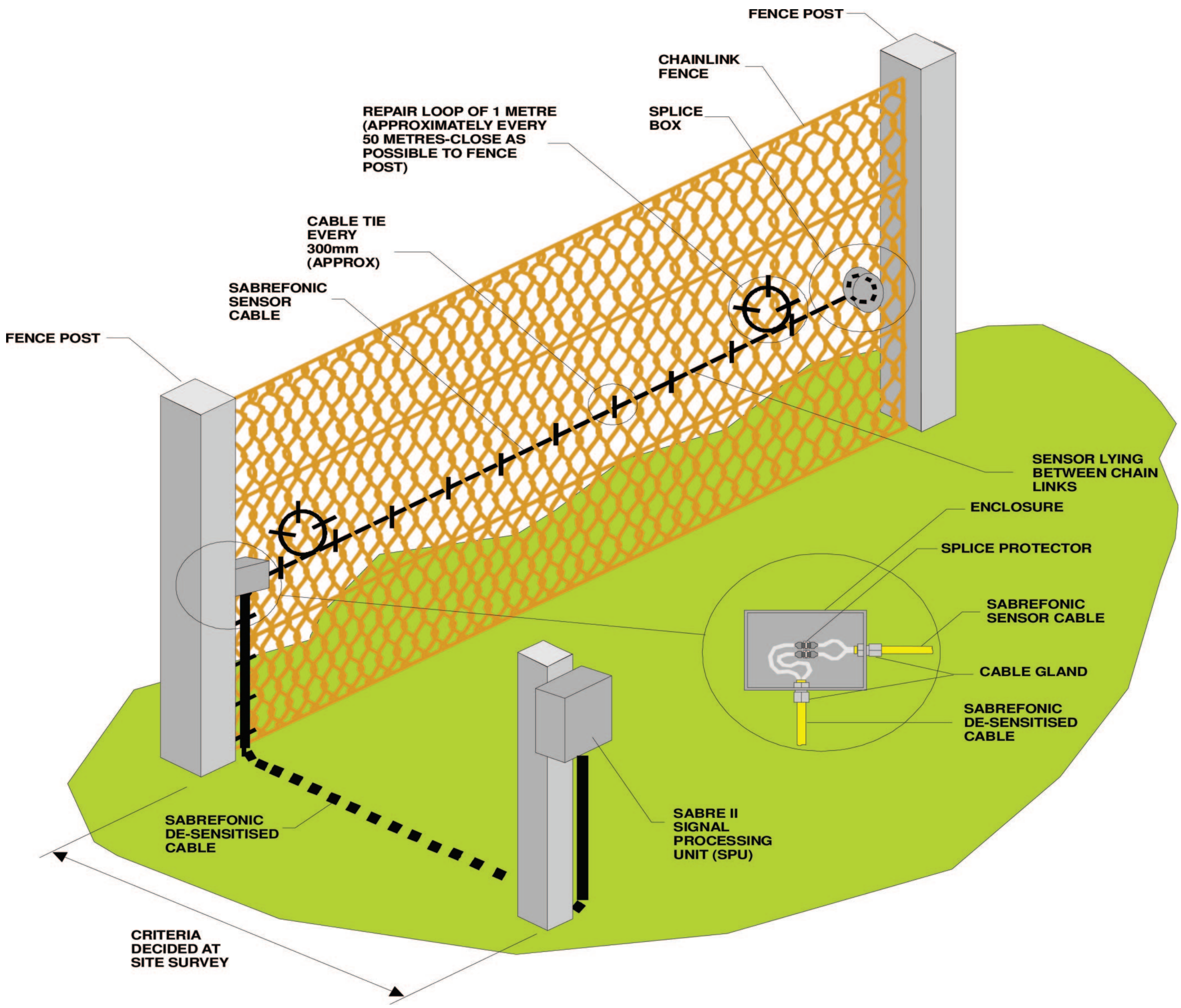

Fig. 1. Schematic of a typical zone/sector configuration.

addition, Greece has adopted the 2003/122/Euratom Council Directive of December 2003 on "the Control of High-Activity Sealed Radioactive Sources and Orphan Sources," which will be brought into force as regulations in the form of a joint Ministerial Order in early 2006. According to these regulations, the GAEC shall ensure re-licensing of the facilities, taking into account among others the sustainability of the PPS of the installations and the adequate relevant training of the staff.

Prevention of illicit trafficking (IAEA 2005). This project had as an objective the prevention of smuggling of radioactive materials into the country. GAEC, in collaboration with the IAEA and Greek Customs, and under the U.S. Second Line of Defense Program, applied state-of-the-art technology at borders in order to detect illicit trafficking of N/R materials. Specifically, 57 portal monitors and 456 pieces of handheld equipment were provided at 32 cargo and passenger entry points to the country, covering seven airports, 12 seaports, and 13 land borders (Figs. 2 and 3).

The hand-held equipment is used for secondary inspection following an alarm by a fixed system, or for the primary control in the minor entry points where fixed systems are not installed. Different kinds of hand-held devices are used: radiation pagers, indicating the presence of radiation, gamma detectors to determine the location of the radioactive source and its intensity, and spectrometers to specify the radionuclide. More specifically, the instrumentation consisted of:

Fig. 2. Radiation detection equipment at the extra-Schengen passengers terminal of the International Airport of Athens.

Fig. 3. Radiation detection equipment at the Piraeus seaport cargo area.

1. Portal radiation monitoring detectors: usually pairs of pillars with one He-neutron detector and two gamma-scintillators per pillar, which are installed at fixed vehicle or passenger/pedestrian crossing points; these systems are supported by alarm panels featuring light and sound alarms;
2. Surveillance unit server, connected to the portal monitoring systems;
3. Gamma radiation pagers, plastic scintillator radiation monitors and radioisotope identifiers; these are handheld gamma and neutron detection units;
4. Workstations consisting of personal computers connected to central alarm stations for receiving all information from the portal electronics, the surveillance cameras and the data downloaded from the radioisotope identifiers; and
5. A central computer system: this is in the process of being installed at GAEC in order to be able to check the signals of the equipment remotely and give the appropriate instructions and in order to keep necessary records and archives.

Written procedures have been provided to the users, complementary to their training program. Also, a special emergency telephone line is devoted for this purpose at GAEC premises. A computer network is under construction that will allow GAEC staff to have a direct connection to the control computer servers at various customs locations. After the first year of operation of the system, GAEC will provide maintenance and troubleshooting of the systems and calibration of the detectors.

Radiation survey at the Olympic venues (IAEA 2005). Aiming at preventing the dispersion of radioactive materials at the Olympic venues, radiation surveys were performed prior to and during the OG 2004. More specifically, extensive radiation surveys to find hidden strong sources in the OG 2004 installations, including the Olympic village, have been carried out one to two days before starting the Games by mobile expert support teams of GAEC staff with IAEA assistance in expertise and instrumentation. The specialized equipment was placed in two emergency response vehicles and in one mobile laboratory equipped with additional sensitive radiation detectors, or was carried by the team members.

The equipment used included:

- a backpack-based spectral gamma scanner consisting of a large sodium iodine (NaI) detector, a multichannel analyzer (MCA) and an HP 200LX (Hewlett-Packard Company, 3000 Hanover Street, Palo Alto, CA 94304-1185) computer; the system was equipped with spectral review software allowing a quick overview of results and location-spectrum correlation using voice recorder and time stamp features;
- four sensitive neutron search detectors;
- an electrically cooled germanium detector;
- a highly portable gamma spectrometer;
- a high-volume plastic scintillation detector placed on the roof of a vehicle;
- portable plastic scintillation detectors;
- radiation pager alarms; and
- radionuclide identification devices.

The measurements were used as background signals for the surveys performed during the Games (Fig. 4).

N/R control at OG 2004 venue entry points (IAEA 2005). Radiation detection at the entry points of the major Olympic venues was performed continuously,

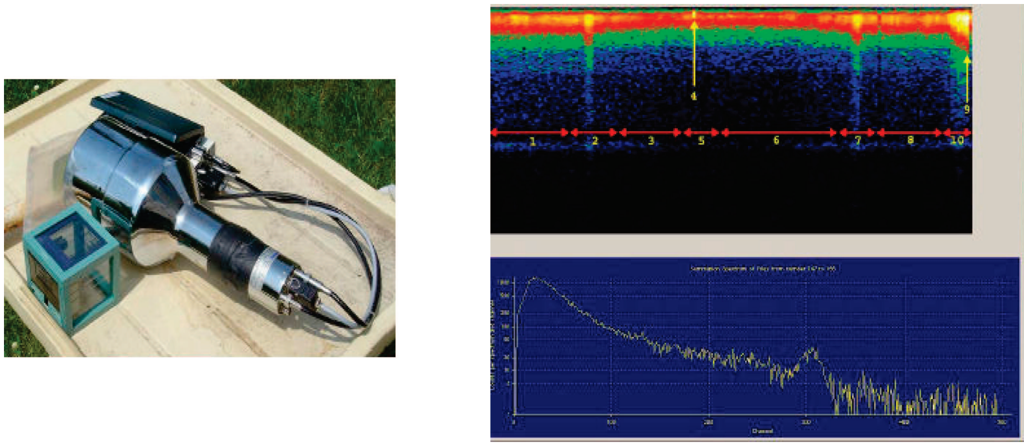

Fig. 4. Portable gamma spectrometry system and a corresponding spectrum.

in order to detect attempts to bring N/R materials into the venues. This was achieved by permanently placing radiation pagers on the metal detectors at the gates of the venues and below the moving belt of the x-ray inspection systems, as well as by providing radiation pagers or personal radiation detectors to the security officers. In total, 181 detectors and 32 identification systems were used for this purpose. Prior to the OG 2004, GAEC staff with IAEA support pursued the positioning and on-site testing of the portable venue equipment in the prioritized venues and concurrently gave hands-on training to officers at the venues. During the big events, the officers were assisted by GAEC scientific staff and an IAEA expert.

The number of innocent alarms that occurred, as was expected, was due to the presence of persons that had undergone nuclear-medicine examinations or treatments. For this reason, prior to the OG 2004, each person that had undergone a nuclear-medicine examination or treatment was provided with a specific certificate issued by the medical department. In the certificate, the patient personal data, the type of examination/treatment, the radionuclide, the administered activity, as well as the days that the isotopes would remain in the body of the patient were recorded. This certificate was valid for a certain period of time, depending on the examination/treatment.

When a person entering the venue triggered a radiation alarm, the security officers performed a secondary detection/measurement, in order to exclude the possibility of false alarm (Fig. 5). In case of alarm confirmation, the person had to undergo further investigation with the identification system in order to determine the radionuclide. If neutrons were detected, the incident was of high importance, so that the police officers and the GAEC were immediately informed for further actions. If only gamma radiation was detected, the dose rate was measured at a 1-m distance from the person. In case the dose rate was greater than 0.1 mSv h^{-1}, the event was considered as a serious one, so the police officers and the GAEC were again immediately informed for further actions. In case of rates lower than 0.1 mSv h^{-1}, the person was asked whether he or she had undergone a nuclear-medicine examination or treatment and to present the relevant certificate. In possession of a certificate, the person was permitted to enter the venue. Under all other circumstances, the police officers and the GAEC were immediately informed for further actions.

Fig. 5. Secondary inspection by security officer at the entrance of an Olympic venue. 1,2: Radiation detection equipment.

Emergency preparedness and response in case of a N/R event

GAEC participation in the NEP for NRBC threats. The NRBC NEP, issued by the OGSD, covered the six Olympic cities and in particular the Olympic venues and training installations, administrative buildings, hotels, hospitals, customs, airports, and other transport systems.

GAEC participated in drafting the part of the NEP concerning the N/R threats. The NEP provided two kinds of actions against a terrorist attack: (a) police actions to respond to the attack under the command of police and military forces, and (b) mitigation of the consequences and casualties under the co-ordination of the General Secretariat for Civil Defense (GSCD) where uniformed (police, fire brigade, etc.) and other civil services were involved.

The organizational structure for analyzing, decision making, and responding to an event had four distinct levels:

- Political level;
- Strategic level;
- Operational level; and
- Tactical level.

The political level deals with decision making in case of a major crisis, where Ministers and high ranking military, police, and coast guard or fire brigade officers are involved.

The strategic level deals with the decision making during the management of the crisis, the evaluation of information, the initiation of on-scene actions, and co-ordination of the high rank military, police, and coast guard or fire brigade officers involved.

The operational level deals with the coordination and support of the police forces operating on-scene and for the management of consequences and casualties under the GSCD.

The tactical level refers to on-scene actions. Police actions are under a police or a coast guard commanding officer, while actions concerning the management of consequences and casualties are under a fire brigade commanding officer.

The main national authorities involved in the implementation of the NEP were the Hellenic Police, the Hellenic National Intelligence Service, the Coast Guard, the Fire Brigade, the GSCD, several Ministries including the Ministry of National Defense, the Ministry of Health, the Ministry for Environment, the Ministry of Rural Development and Food, the Ministry of Transportation and Communications, the Ministry of Justice, and several non-uniformed national services such as the GAEC, the GSCD, the Hellenic Center for Infectious Diseases, the National General Chemistry Laboratory, the National Meteorological Service, the National Food Control Organization, the National Center for Emergency Care, and the Medical Jurisprudence Laboratory of the University of Athens.

As it has been already mentioned, GAEC participates in the NEP for Civil Protection "Xenokratis," and is responsible for Annex P of this Plan, related to N/R emergencies. In addition, during the OG 2004, GAEC participated in the NEP, coordinated by the OGSD, 24 hours per day, 7 days per week, for a period of 3 mo.

According to the NEP, GAEC participated in the operational and the tactical levels, under the co-ordination of the GSCD for the management of consequences and casualties in case of a N/R event.

At the operational level, GAEC had a permanent representative in the Crisis Management Support Team (CMST) of the GSCD. This Team operated 24 h a day in three shifts. CMST is an advisory multidisciplinary team consisting of experts in NRBC threats, representing the national services involved in the NEP. According to the NEP, the CMST performs an initial assessment of the NRBC threat, based on the preliminary information received, and then provides recommendations accordingly to the higher governmental level. Reassessment of the situation might be performed depending on the information updates that the CMST continuously receives. Moreover, the CMST communicates continuously the relevant information to the appropriate teams. The CMST supports and advises on technical and scientific matters the person-in-charge on the scene of the event.

At the tactical level, GAEC had ready in its premises the Response Team (RT) and the Support Team (ST), each of them composed of 6 members (mainly scientists). These teams were available 24 hours a day in three shifts and for a period of 3 mo.

The RT operates both in the hot and the warm zones, having as duties the on-scene monitoring, zone determination, identification and measurement of radiological contamination, provision of radiation protection recommendations, radioactive source recovery, dosimetry, and decontamination supervision. It should be underlined that the GAEC RTs are the only non-uniformed teams operating inside the hot zone.

The ST provides assistance to the CMST and mainly to the RT, by collecting information, performing calculations, organizing additional teams, and providing any assistance required.

GAEC's preparation. According to its statutory role, GAEC, prior to the OG 2004, had successfully intervened in several emergencies concerning N/R accidents or recovery of N/R materials, gaining a significant experience in emergency-response issues. However, GAEC had no experience in emergencies resulting from N/R terrorist threats, this being the case for most similar organizations internationally. For this purpose, and in order to accomplish its tasks and duties as described in the NEP, GAEC developed and implemented a series of actions aiming to upgrade its emergency response system. In this context, the technical advice and recommendations provided by scientists from Commissariat à l'Energie Atomique (CEA; France) that visited the GAEC twice under the auspices of IAEA, were valuable.

The main activities were as follows.

(a) Establishment of an internal emergency plan documenting all the procedures to be followed in case of an emergency. This document contains:

- the responsibilities of the GAEC's teams;
- administrative information concerning the GAEC premises and vehicles and the supporting or back-up infrastructure used for the purpose;
- step-by-step analytical procedures of the actions to be performed after receiving the first alarm for each team involved;
- technical procedures to be followed, based on two possible scenarios: an event with dispersion of radioactive material and an event with a lost radioactive source. These procedures are based on the IAEA relevant documents as well as on the national radiation protection legislation (Greek Radiation Protection Regulations 2001) describing specific tasks, such as:

1. procedures for the definition and use of hot,[†] warm,[‡] and cold zones[§] on the scene—this process is based on values coming from Appendix 5 (IAEA 2004);
2. quality control of the measuring devices (IAEA 1999b);
3. individual monitoring (IAEA 1999b);
4. checking team-members' protective clothing (IAEA 1999b);
5. recommendations for individual protection (IAEA 1999b);
6. procedures for the entrance in the hot/warm zone (IAEA 2000);
7. search and identification of the contamination (IAEA 1999b);
8. control for individual contamination (IAEA 1996, 1999b);
9. plume survey (IAEA 1999b);
10. localization and recovery of a lost source (IAEA 2000);
11. soil, water and air sampling (IAEA 1999b, 2000, 2003);
12. removal of radioactive wastes (IAEA 2000, 2003);
13. intervention and action levels and measures to be taken for the radiation protection of the public in case of a N/R threat (IAEA 1997a, 1997b);
14. follow up of the individual decontamination process (IAEA 2000); and
15. thyroid monitoring (IAEA 1999b).

- technical fiches to complete,
- list of the equipment, quality control procedures, and basic descriptions of each piece of equipment,
- a useful bibliographical list, and
- phone numbers and address of the personnel involved.

(b) Infrastructure upgrading: According to the NEP, GAEC had to be ready to respond and face three simultaneous events with N/R components. To fulfill its obligations under the NEP, GAEC had to upgrade its infrastructure with additional equipment. In this context, GAEC proceeded to the provision, collection, checking, calibration or classification of:

- a mobile laboratory fully equipped with a series of portable equipment such as detectors, spectrometers and protective equipment. This vehicle contains additionally a radiochemical lab, an HPGe spectrometer, and a plastic detector of high volume placed on its roof and connected to a laptop computer;
- measuring and detection systems: a series of instruments for rapid detection (plastic scintillators with audio signals and pagers), dosimeters for dose assessment (survey meters, contamination monitors for alpha, beta, gamma) and portable spectrometers (NaI and HPGe) for radionuclide identification;
- protective equipment of different types, in order to respond to events of any severity, like coveralls, gloves, masks, shoes, casks, respiratory devices, etc.;
- independent communication systems, in order to permit its staff to communicate independently of the general communication network, if needed;
- specialized vehicle with the possibility of stabilizing and carrying shielded radioactive sources (with shieldings of different type, like boxes made of lead, sheets of lead, lead bricks and pellets);
- auxiliary equipment;

[†] The hot zone represents the control zone immediately surrounding the nuclear or radiological incident, which extents far enough to prevent acute radiation effects to personnel outside this zone. According to IAEA Guidelines, the hot zone is an area with an exposure rate equal to or greater than 100 μSv h^{-1}.

[‡] The warm zone is a transition area between the cold and the hot zones, with an exposure rate equal to or greater than 10 μSv h^{-1}, but less than 100 μSv h^{-1}. In this area, gross decontamination of persons, equipment, and hot zone support takes place. In the warm zone operate civil and military medical teams and paramedics, and law enforcement units (police, coast guard).

[§] The cold zone represents the control zone at a distance from a nuclear or radiological incident, with an exposure rate less than 10 μSv h^{-1}, that contains the command post and such other support functions necessary to control the incident (law enforcement, ambulance services).

- development of a technical library containing all recent publications relevant to N/R safety and security; and
- procurement, adaptation and testing of dispersion calculation codes. Two codes for dispersion of radioactive materials after a dirty bomb explosion have been used, namely Lasair (Bundesamt fuer Stralenschutz, Ingolstaedter Landstrasse 1, 85764 Oberschleissheim, Neuherberg, Germany) and Hotspot (Lawrence Livermore National Laboratory, University of California, 7000 East Avenue, Livermore, CA 94550). These codes present some differences, since their calculations are based on different mathematical models. Using the codes, an estimation of the trajectory of the radioactive plume can be obtained, as well as the radioactivity deposited per unit area and the corresponding dose according to the specific radionuclide involved, the quantity of the explosive and the meteorological data. Lasair takes also into consideration the geographical morphology of the area. In addition, maps of the Attiki region have been electronically introduced to the system, so as to overlap the calculated plume on the map of the affected area. In order to cover an explosion in a nuclear power plant, the Hysplit calculation code (ARL, U.S. National Oceanic and Atmospheric Administration, Silver Spring, VA 20910) is used for a quick estimation of the situation, before running more sophisticated codes. GAEC is connected with the National Meteorological Service in order to get the meteorological data on a continuing basis.

(c) Additionally, in order to cope with the specific needs related to the OG 2004 emergency period (3 mo), GAEC hired additional temporary auxiliary staff composed of medical and radiation physics post-graduate students. Special training has been provided to these students, who, however, were not supposed to enter the hot or warm zones under any circumstances.

Apart from the infrastructure devoted to emergency response, all specialized laboratories of GAEC and their personnel were prepared to participate as deemed necessary. These laboratories were: the environmental radioactivity laboratory for performing measurements of environmental samples, the telemetric network for monitoring of the environmental radioactivity all over the country, and the individual monitoring laboratory for external and internal radiation.

Moreover, in order to cover the whole country, GAEC mobilized during the critical period of OG 2004 its network of collaborating laboratories belonging to universities or research institutes. Specialized equipment and training was provided to these laboratories.

Cooperation

This project was a large-scale cooperative project between several organizations at international and national levels. Apart from the major partners already mentioned, GAEC undertook additional collaborations under the framework of Cooperation Agreement between the IAEA, GAEC and the OGSD, a Declaration of Intent was signed between U.S. DOE, GAEC and the Greek Customs, and a Memorandum of Understanding between GAEC and the Greek Customs.

Intensified links were put in place with European and International Organizations, Emergency Response Systems and Data Bases [European Community Urgent Radiological Information Exchange (ECURIE), IAEA Illicit Trafficking Data Base, Emergency Notification and Assistance Technical Operations Manual (ENATOM), etc.], and a national network of collaborating laboratories in Greek Universities or Research Centers was created to provide training, equipment (tens of hand held detectors) and additional manpower, so as to be able to comply with an emergency in another location away from Athens.

Through the OGSD, links with more than 50 national organizations were established. Extensive cooperation in the area of intelligence between the partners helped the radiological emergency system become more efficient and effective.

In order to accomplish its tasks within the NEP, GAEC has also signed Memorandums of Understanding with the Services involved in the NEP, such as police, fire brigade, airport authorities, customs, etc.

Finally, GAEC's staff participated in several committees, working groups, meetings, exercises and visits related to emergency response and planning.

Education and training

Aiming at the creation of a mechanism for training the persons involved in the NEP to pursue their duties effectively, three axes have been followed:

1. Under the auspices of IAEA, experts from the CEA, France, provided training in emergency-response issues to the GAEC, creating a nucleus for the dissemination of such knowledge in the country;
2. Customs personnel were trained at the Hammer training facility in Richland, WA, in the U.S. Additionally, the Pacific Northwest National Laboratories provided training to more than 400 persons in Greece; and
3. Organization and participation in national training programs.

In the context of the third axis, GAEC provided training on radiation protection, prevention, detection, emergency preparedness and response for the staff of the national authorities involved. Within this frame, relevant courses, seminars, exercises, and drills addressed to first responders, first-line officers, and members of scientific and technical supporting teams were organized by GAEC in cooperation with the military and civil services involved. The organization of the training programs included more than 3,000 personnel belonging to the fire brigade, International Airport of Athens, OGSD, customs, radiological installations, network of collaborating laboratories, and the first responders, medical physicists and medical personnel of the main hospitals. During these events, GAEC provided education and training targeted to respond to N/R threats.

More specifically, two-week courses on NRBC threats were provided to approximately 500 participants belonging to the police and fire brigade services, first-line officers from airports and customs, staff of the OGSD, the National General Chemistry Laboratory, and the Hellenic Center for Infectious Diseases Control (KEEL).

Other training activities included three-day courses in the use of N/R detectors for the detection of radiation sources, which were attended by approximately 450 police officers; courses on illicit trafficking of radiation sources organized at the customs offices around Greece, which were attended by approximately 400 first line officers during the course of a month; one-week courses on emergency response in case of radiological accidents or events, which were attended by approximately 50 radiation protection and dosimetry experts; and one-week courses on emergency response in case of radiological accidents or events, which were attended by approximately 50 experts from GEAC.

In addition, radiation protection courses were organized for first responders in case of radiological accidents or events including fire brigade, police, hospitals medical staff, medical physicists and the staff of collaborating scientific laboratories network. Approximately 600 responders attended these courses over the course of two months.

Finally, a number of awareness courses were provided by GAEC and the IAEA to the personnel of hospitals, industry and the GRR-1, related to the physical protection of their respective installations.

Emergency Response exercises: GAEC staff participated in several exercises, either internally or at the national level, organized by the Ministry of Public Order and OGSD. Two major national exercises organized by OGSD took place in the wider Attica region of Athens, namely "Blue Odyssey 2004" and "Hercules Shield," where the organizational schemes and the whole emergency plan were tested. The first exercise was carried out at Olympic Games virtual timing and the scenario included a nuclear security component introduced by GAEC, which took an active part in the exercise. The scenario considered the accidental discovery of an orphan source and related detection response activities. The experience gained was useful in the upgrading of the existing radiation detection response procedures and adapting them to Olympic Games conditions. Very important was the testing of the communication channels between the participating organizations. During the second national exercise, the organizational schemes and the whole emergency plan were tested. This was a table top exercise, having a radiological component related to an expressed threat of explosion of a dirty bomb placed on a ship in Piraeus harbour. Participation in international exercises included the DACIA 2003 organized by North Atlantic Treaty Organisation (NATO) in Romania and, after the OG 2004, the IAEA CONVEX-3 to test the International Joint Radiation Emergency Management Plan (IAEA 2004), etc.

Follow up

During the 3-mo period (July–September 2004) and according to the representative of GAEC in the CMST archive, 11 events have been reported. For four of them the emergency plan was fully activated, for three of them partly, and for the remaining four, there was no activation of the plan. Only one event presented a "radiological" component, since the monitors in the Olympic Village entry were activated when an athlete carrying an old compass with a radioactive dial passed through. The majority of the other events concerned the existence of suspicious powder in parcels in various post offices throughout Greece.

Concerning the physical protection systems installed at the radiological facilities, during the OG 2004 period, there were 10 innocent alarms due to entry without proper deactivation of the corresponding alarm system or use of a wrong alarm code by the operators. The security companies contacted the specific sites immediately and, following the existing procedures, the incidents were easily resolved. Moreover, besides the regular maintenance, only one intervention was necessary due to a software error from one system.

For security reasons, the research reactor GRR-1 remained shut down during the OG 2004. After the completion of the Games, the GRR-1 resumed normal operation. However, the upgraded physical protection system continued to provide enhanced security to the research reactor. A revision of the Design Basis Threat after the OG 2004, concerning the security measures of GRR-1, determined that the threat had been significantly lowered after the Games. It was then decided that it was no longer necessary for military personnel to guard the GRR-1, and furthermore, the number of guards at GRR-1 could be reduced.

The alarms received at the customs offices were, as it was expected, mainly innocent alarms due either to trucks carrying materials with natural radioactivity or due to passengers that had undergone diagnostic or treatment procedures using a radionuclide. It is worth mentioning the fact that the passengers that were called for a secondary inspection were not at all embarrassed, but on the contrary, presented a sentiment of confidence and cooperation with the officials in charge.

Lessons learned after the OG 2004

Lessons learned from organizing the nuclear and radiological security of the 2004 Athens Olympics are categorized in three major aspects (Camarinopoulos 2005): organizational aspects, technical aspects, and training. It should be pointed out that while planning the emergency measures related to radiological security, one must have in mind that the effects of dispersion of radiological materials are mostly psychological and economic and not massive loss of life. Despite this fact, there is a substantial probability that decision makers will cancel a major event, such as the Olympic Games, in case of a radiological incident.

Organizational aspects.

- Close coordination and cooperation between all partners is critical;
- Strong political leadership from a lead agency in the host country is necessary to move the project forward;
- International and local expertise must be combined in the design and implementation of such a project;
- The combined threat (radiological, chemical and/or biological) should be accounted for in the emergency planning and response, as well as in training;
- The existence of adequate, trained and well informed personnel with clear assignment of responsibilities is a prerequisite. Moreover, efforts should be made to keep well-trained personnel in place and assure the dissemination of knowledge;
- Time is always a crucial factor that must be seriously taken into consideration for all activities (e.g., planning, contract negotiations, purchase of equipment, acceptance tests, installation, training, etc.);
- When introducing or implementing structural changes in the facilities or the procedures, the stakeholders and the personnel involved must be well informed and their opinion must be seriously taken into consideration;
- Even if the goal is a near-term event such as the Olympics, it is important to plan for long-term use and benefits from the systems. It is crucial to develop a plan for the sustainability of the system over time and the transition of full ownership and operation to the host country. Moreover, the use of the equipment after the event must be investigated (redistribution, leasing, etc.); and
- Intelligence illicit trafficking information provided by the IAEA to the Greek authorities proved to be a critical element in the evaluation of the overall terrorist threat to the Olympic Games, particularly under conditions characterized by the limited time available for decision making.

Technical aspects.

- During major events, both the threat level and the consequences of threat activity may be significantly higher than the norm. For that reason, the adequacy of the normal security systems, even if they meet current international recommendations, should be reassessed;
- When installing physical protection systems in radiological installations like hospitals, special emphasis must be attributed to assure the functionality of the system without disturbing the proper duties of the staff (e.g., the operation of both access control and alarm systems proved highly impractical);
- Potential adverse consequences of threat sabotage are reduced by shutting down critical installations during the critical period of the event (e.g., a reactor);
- Countries that have entered into bilateral cooperation agreements, installed and effectively used equipment, and have broadly enhanced border security can assist, through regional leadership, other countries in benefiting from such installations and from the experience acquired;
- Special provisions must be taken for the prevention and handling of false and innocent alarms and their possible consequences;
- In case of an alarm, the key point is to quickly localize the person at the check point, not in the crowd;
- Radiation detection can be integrated with standard security equipment;
- The optimum positioning of the detectors at the entrance of the venues is: one pager at the belt of the security officer, one pager under the moving belt of x-ray inspection systems to avoid interferences and one pager on the non-active side of the magnetic portal used for metal detection; and
- Speed and effectiveness in quickly detecting an anomaly is strongly enhanced if naturally occurring radioactive material (NORM) spectra for the region are catalogued and an overview software tool and expertise to handle/evaluate many spectra are available.

Training. Training is crucial; it is impossible to overestimate the importance of training. Equipment alone cannot help if people do not know how to use it effectively. Initial training as well as ongoing refresher training is necessary to ensure that the system works. The most important recommendations concerning this issue are:

- Foster cooperative teamwork, which is essential since experts with different backgrounds contribute to the project;
- Create a comprehensive, phased plan, taking into account different stages and different categories of staff (specialty, tasks, etc.);
- Provide timely and convincing information to address concerns on radiological, chemical and biological agents;
- Provide theoretical and practical training on radiation, instrument usage and procedures, scheduled well in advance;
- Provide timely documentation;
- Adhere to established plans, in order to bring everything together at the right time: equipment, procedures, training facilities, materials, trainers and trainees;
- Conduct exercises demonstrating the cooperation of different authorities, based on a national response plan and small-scale exercises for the personnel within a single authority; and
- Include instrument training materials into the purchase orders.

Sustainability and the post-OG 2004 period

Greece attributes great importance to the sustainability of this project so as to assure in the future continuously and globally a high level of radiological protection (including safety and security) in the country. For this reason, the Greek Government contributed to the program significant national funds. All Greek authorities involved have the appropriate personnel and technical infrastructure to support the program.

Actually, the NEP of the OG 2004 is under revision. For this purpose, all the participating organizations are collaborating not only to form the new plan, but to assure the compatibility of their respective internal plans.

The equipment that was distributed to the Olympic venues (181 pagers and 32 identifiers) has been redistributed to the green line officers (police and coast guard).

Furthermore, GAEC contributes continuously with its know-how to ensure smooth future operation of the systems. More specifically, GAEC has undertaken the responsibility for the continuous training of the custom officers, law enforcement officers, and first responders; for the provision of additional equipment to various authorities and institutions; as well as for the maintenance of the equipment used in customs and the calibration of all radiation detectors.

Internally, GAEC kept the entire infrastructure for its own emergency needs. The internal plan used during the Olympic Games has been slightly modified and now constitutes its internal emergency plan. Special measures have been taken for public information and the continuous training of its staff.

CONCLUSION

Greece demonstrated its commitment in assigning the highest priority to security issues and in particular to nuclear and radiological security by organizing successful Olympic Games in Athens in 2004. These Games were indeed among the most secure in the history of modern Olympics. Our wish is to see other countries enhancing nuclear security while preparing to host major public events, and we believe that this unprecedented cooperation project provides a model for this purpose.

Acknowledgments—The authors wish to thank the following organizations for their support and cooperation: International Atomic Energy Agency, U.S. Department of Energy, Ministry of Development, Ministry of Public Order and in particular the Hellenic Police and the Fire Brigade, Ministry of Economy and Finances and in particular the Office of Customs and Excise, General Secretariat of Public Defense, and the network of collaborating laboratories of GAEC (Environmental Radioactivity Laboratory of NCSR "Demokritos," Nuclear Technology Sector of the National Technical University of Athens, Nuclear Technology and Nuclear Physics Laboratories of the Aristotle University of Thessaloniki, Nuclear Technology Department of the University of Patras, Nuclear Physics and Medical Physics Laboratories of the University of Ioannina, Radioactivity Measurements Laboratory of the Research and Technology Institute of Crete, Laboratory of Analytical and Environmental Chemistry of the Technical University of Crete, and Nuclear Technology Laboratory of the Demokrition University of Thrace).

The authors express their gratitude in particular to those who most contributed to the success of this endeavor: Anita Nilsson, Head of the IAEA/NSNS Office of Nuclear Security; Pantelis Ikonomou, IAEA/NSNS Program Coordinator for Greece; Rolf Arlt, Senior Nuclear Instrumentation Specialist IAEA/Nuclear Security Equipment Laboratory; Mauri Riihonen, Nuclear Security Expert IAEA/NSNS; Richard Hoskins, IAEA Senior Nuclear Security Officer; Carlos Nogueira De Oliveira, IAEA Emergency Preparedness and Response Expert; and Jean-Pierre Gayral and Thierry Pelletier, IAEA Experts, CEA/France; Spenser Abraham, U.S. DOE Secretary; Paul Longsworth, U.S. DOE/NNSA Deputy Administrator; Ioanna Iliopulos, Director, U.S. DOE International Radiological Threat Reduction Program; Elly Melamed, Deputy Director, U.S. DOE Office of Second Line of Defense; Russell Hibbs, U.S. DOE International Safeguards Division; William Rhodes, Sandia National Laboratories; Chip Johnson, Los Alamos National Laboratory; Dick Pappas, Pacific Northwest National Laboratory; Ministers of Development Dimitrios Sioufas and Apostolos Tsohatzopoulos; Ministers of Public Order George Voulgarakis and Michael Chrysohoidis; Secretary General of Research and Technology Ioannis Tsoukalas; General Sotirios Tsenes, Director of Olympic Games Security Division; P. Fourlas, Head of the General Secretariat of Public Defense; Vassilios Manolopoulos, Customs General Director of the Ministry of Economy and Finances; Dimitris Pardos, Director of the 33rd Division of Customs of the Ministry of Economy and Finances; Michael Antonopoulos-Domis, Director of the Institute of

Nuclear Technology—Radiation Protection of the NCSR "Demokritos;" and Nicolas Catsaros, Head of the Greek Research Reactor GRR-1.

Special thanks are addressed to the permanent and temporary staff of GAEC who provided their scientific and technical skills and worked long hours to implement this Program, assuring its success. Finally, the authors express their warm thanks to George Yadigaroglu, Member of GAEC Administration Board for his valuable comments and suggestions on the text.

REFERENCES

Camarinopoulos L. Nuclear security at major public events: lessons learned from the 2004 Athens Olympic Games. In: Nuclear security: global directions for the future. Proceedings of an International Atomic Energy Agency Conference. Vienna: International Atomic Energy Agency; IAEA-STI/PUB/1232; 2005:147–155.

Catsaros N, Matikas Th. The Greek research reactor: physical protection beyond INFCIRC/225. In: Proceedings of the INMM 45th Annual Meeting, Orlando, Florida, 18–22 July 2004.

Greek Radiation Protection Regulations. Ministerial Order No 1014, Official Gazette of the Greek Government No 216B; 2001.

International Atomic Energy Agency. Assessment and treatment of external and internal radionuclide contamination. Geneva: IAEA; IAEA-TECDOC-869; 1996.

International Atomic Energy Agency. Method for the development of emergency response preparedness for nuclear or radiological accidents. Geneva: IAEA; IAEA-TECDOC-953; 1997a.

International Atomic Energy Agency. Generic assessment procedures for determining protective actions during a reactor accident. Geneva: IAEA; IAEA-TECDOC-955; 1997b.

International Atomic Energy Agency. The physical protection of nuclear material and nuclear facilities. Geneva: IAEA; IAEA-INFCIRC/225/Rev. 4 (Corrected); 1999a.

International Atomic Energy Agency. Generic procedures for monitoring in a nuclear or radiological emergency. Geneva: IAEA; IAEA-TECDOC-1092; 1999b.

International Atomic Energy Agency. Generic procedures for assessment and response during a radiological emergency. Geneva: IAEA; IAEA-TECDOC-1162; 2000.

International Atomic Energy Agency. Method for developing arrangements for response to a nuclear or radiological emergency. Geneva: IAEA; IAEA-EPR-METHOD; 2003.

International Atomic Energy Agency. Joint radiation emergency management plan of the International Organisations. Geneva: IAEA; IAEA-EPR-JPLAN; 2004.

International Atomic Energy Agency. Restricted report, based on the archives of the Greek Atomic Energy Commission. Geneva: IAEA; 2005.

■ ■