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Protocol for handling contaminated maritime cargo returned to the country

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Abstract: Responding to nuclear and radiological incidents is part of the attributes of the Agency whose mission is nuclear and radiological safety; in the Brazilian case, the National Nuclear Energy Commission (CNEN), an autonomous structure of the Ministry of Science, Technology and Innovation (MCTI), Brazil. In 2022, the Nuclear and Radiological Emergency Response System (SAER) was activated to respond to a finding in a maritime container. The cargo, returned from abroad from a transshipment port, due to the detection of an internal radioactive source, arrived in the country at the Port of Suape, in Pernambuco; It was then analyzed by the CNEN technical team, following regulatory Norms and protocols. After work to remove the container of packed material – metal scrap – the radioactive source was located and identified, in the operation carried out in Caruaru-PE (headquarters of the metal scrap holding company). Immediately, it was collected at the Regional Center for Nuclear Sciences - Northeast (CRCN-NE), in compliance with the country's safety regulations. Qualified and well-trained teams resulted in reliability of the process.

Keywords: Responding to radiological emergencies. Sea cargo. Inspection. Radiological safety.

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Protocolo para manejo de carga marítima contaminada retornada al país

Resumen: Responder a incidentes forma parte de las atribuciones del organismo cuya misión es la seguridad nuclear y radiológica; en el caso brasileño, la Comisión Nacional de Energía Nuclear (CNEN), una estructura autónoma del Ministerio de Ciencia, Tecnología e Innovación (MCTI), Brasil. En 2022 se activó el Sistema de Respuesta a Emergencias Nucleares y Radiológicas (SAER) para responder a un hallazgo en un contenedor marítimo. La carga, devuelta desde el exterior desde un puerto de transbordo, debido a la detección de una fuente radiactiva interna, llegó al país por el Puerto de Suape, en Pernambuco; Luego es analizado por el equipo técnico de la CNEN, siguiendo protocolos de estándares regulatorios. Luego de los trabajos de remoción del contenedor de material embalado – chatarra – fue localizada e identificada la fuente radiactiva, en la operación realizada en Caruaru-PE (sede del holding). De inmediato, fue recogido en el Centro Regional de Ciencias Nucleares - Noreste (CRCN-NE), cumpliendo las normas de seguridad del país. Equipos calificados y bien capacitados dieron como resultado la confiabilidad del proceso.

Palabras clave: Respuesta a emergencia radiológica. Carga marítima. Inspección. Seguridad radiológica.

1. INTRODUCTION

The activity of responding to radiological and nuclear emergencies presupposes a set of techniques and procedures, in use at the National Nuclear Energy Commission (CNEN), as well as practices recommended by the International Atomic Energy Agency (IAEA). Specialized teams, members of the Commission's Technical-Scientific Units, carry out planned emergency actions, which generally result in the identification, characterization and eventual collection and safe storage of radiation sources and radioactive waste. CNEN has the legal responsibility for the safety actions mentioned here, as well as for the storage of the aforementioned waste [1].

In December 2021, CNEN was notified that a maritime cargo being exported from Brazil to Bangladesh (metal scrap in containers), originating in the port of Manaus, had been identified with a source of radioactive emission[1] of 400 microSievert/hour, in the port of Malta, during a transshipment operation [2]. There was suspicion of the presence of the isotope Ra^{226} inside a scrap package. It was then necessary to return the container to the originated country, according to international protocols.

From this moment on, CNEN coordination was carried out with the cargo agent, the maritime operator and the port operator in Suape (municipality of Ipojuca-PE). The Port of Suape was designated as the recipient by the cargo agents, given the fact that the owner of the shipment was a scrap company based in the interior of the State (Caruaru). Subsequently, police and port authorities were also notified, and stablished coordination with them. The protocols followed, in cases of this type, are included in CNEN Norm 3.01 – Basic Radiological Protection Guidelines [3].

[1] Equipment or material that emits or is capable of emitting ionizing radiation or releasing radioactive substances or materials [2].

2. LITERATURE REVIEW

In 1996, a railway incident was recorded in the Czech Republic, when a disused source of Co^{60}, previously used for food irradiation, was stolen from an installation in that country, with destination to Italy [4]. Intercepted by government authorities, the wagon containing the source, full of metal scrap, was returned to its origin and legal responsibilities and actions were imposed.

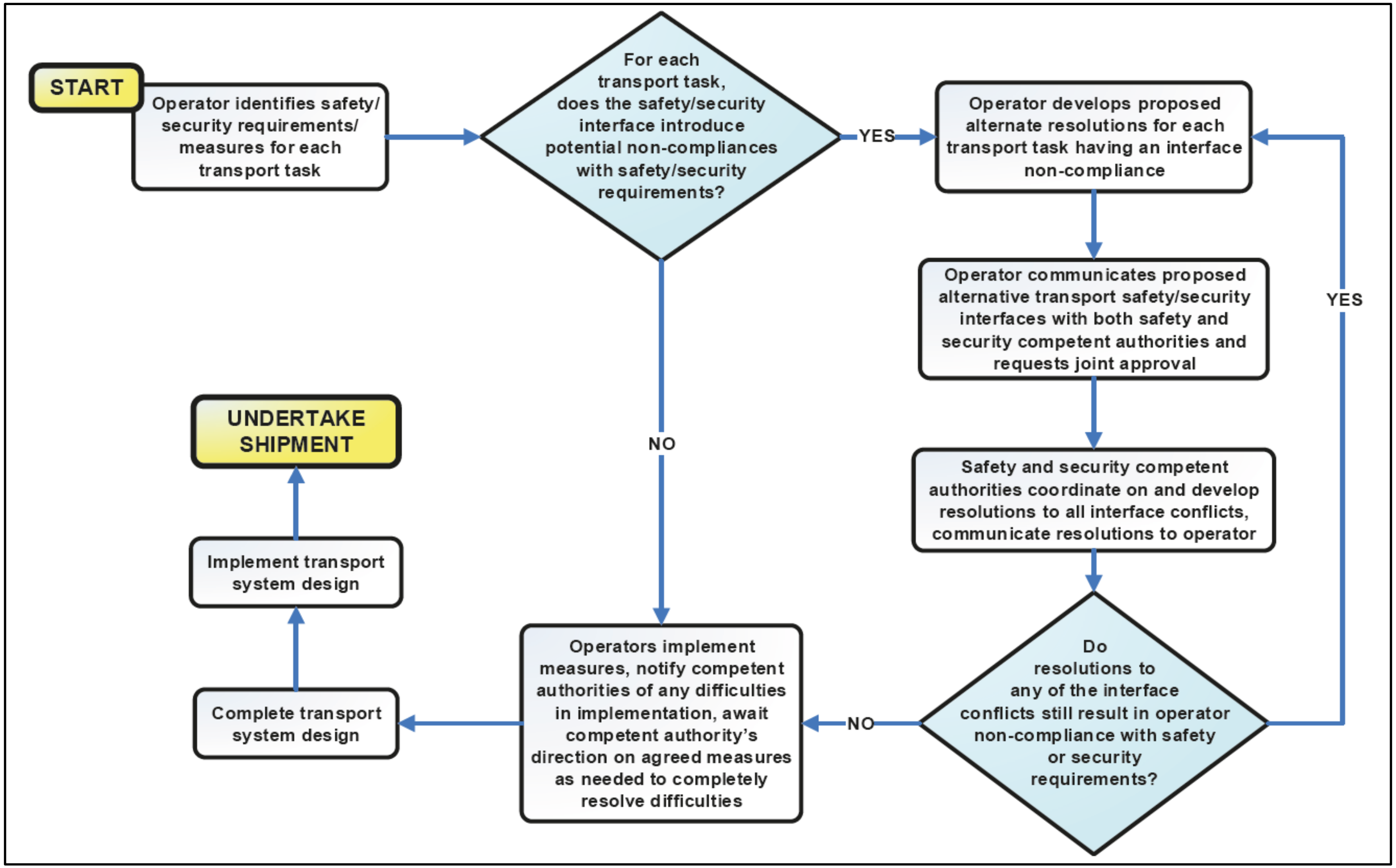
The main activities developed by CNEN are related to the prevention of public exposure to radiation, the prevention of release of radioactive material into the environment, reduction of the probability of events associated with nuclear reactor operations, and also the mitigation of consequences in case of occurrence of related events [5].

Nuclear and radioactive techniques are applied to improve industrial processes, such as: measuring solid thickness, liquid flow rates, controlling the quality of metal welding, leak detections, and others. [5]. Events can happen in which such sources are inadvertently discarded together with scrap metal.

The author also mentions that the "most notable event in the area of radiological protection, in Brazil, was the Cs^{137} radiotherapy source accident occurred in Goiânia, in 1987, which forced the review and improvement of the Brazilian regulatory system". Since then, the process of licensing and use of radioactive sources, and definition of responsibilities have been improved. "The process of issuing authorizations in this area has been continuously improved throughout the existence of CNEN" (ALMEIDA, 2005, p. 155 *apud* STAUDE, 2014, p.37) [6].

In terms of safety and protection for the transport of nuclear or radioactive materials, there is a planned flow to be followed by operators and competent authorities; the IAEA (2021) [7] brings standardization of actions, as in figure 1:

Figure 1: Flowchart Oriented aimed for Operators and Regulatory Authorities – Radioactive Transport Safety and Security.



Source: IAEA (2021) [7]

2.1. The occurrence of radioactive sources in metal scrap

The International Atomic Energy Agency mentions the importance of the proposed topic, in terms of professional training. An example is the training course "Control of Radioactive Material Inadvertently Incorporated into Scrap Metal" [8], with reinforcement in this regard.

> "This e-learning addresses the control of radioactive materials inadvertently incorporated into scrap metal and semi-finished products of the metal recycling industries. Radioactivity in scrap metal is detected occasionally at metal recycling sites, and must be detected and removed to avoid injuries, large costs and the creation of radioactive waste" (IAEA, 2022).

The IAEA has established an online tool to record cases of the above mentioned type, in which metal scrap is exported between countries and, inadvertently, a source of ionizing radiation is found among the material to be recycled. This "toolkit", accompanied by online training, is made up of a database of occurrences in several countries, forming an initiative to divulgate this subject and contributing to the BIR - International Recycling Bureau (BIR), an entity that is formed by more than 70 countries [9]. The same article describes an incident involving a source of Cs^{137}, utilized in mining, and was unexpectedly transported as scrap.

In 2010, the IAEA [10], initiated the development of a code of conduct on the transboundary movement of radioactive material inadvertently incorporated into scrap metal and semifinished products from metal recycling industries (Metal Recycling Code of Conduct). The Metal Recycling Code of Conduct was intended to harmonize the approaches of Member States in relation to the detection, management and safe handling of radioactive material that may inadvertently be present in scrap metals and semi-finished products subjected to transboundary movement. The Safety Document describes:

> (a) If there is a history of consignments from specific exporting facilities containing radioactive material, a more thorough investigation for the presence of radioactive material would normally be the case;

> (b) A review of the radiation monitoring report provided by the export facility. If no such report has been provided, a more thorough investigation for the presence of radioactive material should be undertaken than would normally be the case;
>
> (c) A visual inspection of the consignment by an appropriately trained person;
>
> Note: definition of "consignment": a batch of goods destinated for or delivered to someone.
>
> (d) Radiation monitoring at appropriate stages in the movement and processing of scrap metal and the manufacture of semi-finished products where radioactive material might be detected, including entrances and exits of facilities up to and within the melting facility (IAEA, 2014, p. 10).

Kopsik *et al.,* (2005) [11] describe recycled scrap as one of the most traded "commodities" worldwide, representing a multibillion-dollar industry. Many countries monitor radiation in scrap metal at their borders, and some metal processing facilities monitor the material indoors. The authors identify at least three necessary measures to harmonize procedures around the world:

> 1) Protocol: "An internationally acceptable monitoring and response protocol is required" [...] with "collaboration between various government agencies and industry to monitor and eliminate unwanted radioactive materials in scrap metal".
>
> 2) Training: "Training programs are needed" [...] with "optimal location of radiation monitors, detector sensitivities, calibration and maintenance requirements and reports, incident reporting formats, process of handling radioactive materials after detection".
>
> 3) Information exchange: "An international exchange of information is necessary. This can be achieved through the development of a web portal that allows access to scrap industry data" with "the development of a database where countries can report scrap radiation incidents" (KOPSIK *et al.*, 2005, p. 4) [11]

Studies, like described above, motivated the implementation of the database mentioned by Dojcanova (2020) [9], which must be constantly consulted and improved.

2.2. The standardization in Brazil

The measures of protection and criteria for intervention in emergency situations activities, developed by the Brazilian Nuclear Regulatory Commission are related to the prevention and control of public exposure to radiation, the prevention and control of the release of radioactive material to the environment, reduction of the probability of events associated with nuclear reactor operations, and also the mitigation of consequences in case of occurrence of related events [5].

Norm CNEN, 2014, 3.01 [3], presents, at the regulatory level, fundamental obligations, within the scope of requirements:

> 6.1.1 Whenever justified, protective or remedial actions must be implemented to reduce or avoid radioactive exposure in intervention situations.
> 6.1.3 In interventions, to protect individuals of the public, the intervention levels and action levels for different protective or remedial actions must be observed.
> 6.2.2 During the response to an emergency situation, the justification for the intervention, the levels of intervention and the levels of action pre-established by CNEN may be reconsidered by the groups involved in the intervention, taking into account:
> a) characteristic of the real situation, such as the nature of the release, meteorological conditions and other relevant non-radiological factors;
> b) the probability that protective actions will bring a net benefit, given the uncertainties involved (CNEN, 2014). [3]

The Brazilian public security organizations are responsible for promoting the physical protection of transport and support operations, which applies to the incident described in this document. Coordination with the Brazilian public security organizations was effectively carried out in this case.

3. METHODOLOGY

First, exploratory bibliographical research was accomplished, in specialized literature and in the normative framework, in which the collection of information about cargo with suspicion or evidence of radioactive material inside is dealt with. Norms relating to radiological protection and safety were the basis for the mentioned study.

Theoretical studies were also conducted on the subject, serving as a basis for the research carried out for the problem solution. Team meetings were held in preparation and for responding since the discovery, to the end of the incident, substantiating the action plan itself.

Concerning the standards and norms consulted, the Brazilian Regulatory Body, CNEN, covers:

- supervision of activities related to raw materials and minerals of interest to the nuclear area as well as supervision of radiological protection conditions for respective workers;

- licensing of nuclear and radioactive installations; the regulation and control of the transport, treatment and storage of nuclear and radioactive waste;

- responding to requests for assistance, complaints and emergencies, which deal with sources of ionizing radiation;

- issuance of regulations concerning the broad framework of nuclear and radiological safety, covering licensing and inspections as required for the pertinent activities.

4. PLANNING AND EXECUTION

Information was received by CNEN, from the Cargo Agent, that the Commission for the Protection from Ionizing and Non-Ionizing Radiation of the Government of the Island of Malta had discovered an abnormality in a cargo. Immediate actions and planning have begun, with the opening of an administrative process at the CNEN Research and Development Directorate. Documentation was rapidly gathered, enabling discussions and timely evaluations.

It was a cargo of metal scraps, shipped on December 14^{th}, 2021, from Manaus to Bangladesh. It was detained in Malta, due to the discovery of radioactive material inside the cargo, when passing through a radiation detection portal, during transshipment from one vessel to another.

Planning meetings were held, personally and via videoconferences, between CNEN Headquarters and its affiliated research and inspections Institutes.

A leader of the mission's operational coordination was defined by CNEN, including a sub-coordinator, an assistant, radiation protection supervisors and technicians, transport groups, emergency equipment, and logistics. The CNEN Radioprotection and Nuclear Safety Directorate highlighted instructions to the Emergency Team, such as the necessity to isolate the cargo after unloading, establishing a local radiation protected area, with radiation surveillance and physical protection around the cargo, and landing the cargo at the site in Suape, Brazil, as soon as possible. Instructions included the necessary actions to locate and identify the material immediately after unloading the container. Successful actions undertaken can be consolidated in the Table 2, below:

Table 2: Previous Actions.

1.0	CNEN designated a single interlocutor with the company responsible for receiving the container;
2.0	Directorate of CNEN established contacts at the decision-making level, with the participation of the authority's Deliberative Committee;
3.0	The operational coordination of the Nuclear and Radiological Emergency Response System (SAER) established a detailed work plan, with:
3.1	Definition of SAER team members;
3.2	Immediate assessment of the occurrence;
3.3	Assessment of logistical needs;
3.4	Prediction of the final destination of the material (one of CNEN radioactive waste site facilities);
3.5	Transport forecast of the material to its final destination (armor, vehicle, transport plan, etc.).

Source: CNEN Emergency Team

To plan the overall operations, these actions were complemented with meetings with the assigned personnel from the Port of Suape.

Coordination with the State of Pernambuco Civil Defense was essential, as well as with the Port Security Authority, formalizing the necessity for escort by the Federal Road Police, for the road transport: Ipojuca-Caruaru and, later, Caruaru-Recife.

In Caruaru-PE, was located the headquarters of the scrap company, the place of origin of the cargo. It was the recommended location for the source rescue operation (container opening), in safe and controlled conditions. The identified material would then go to Recife-PE, for storage at the Regional Center for Nuclear Sciences – Northeast (CRCN-NE) – Intermediate Radioactive Waste Deposit.

The designated land transport was configured as follows:

Route 1

Origin: Governador Eraldo Gueiros Port, Industrial Complex (Port of Suape)

Destination: Road BR 104, km 64, Caruaru-PE

Route 2

Origin: Road BR 104, Km 64, Caruaru-PE

Destination: CRCN-NE/CNEN Intermediate Radioactive Waste Deposit (Recife-PE). Figure 2, below, shows the assigned land transportation routes:

Figure 2: Route between Suape and Caruaru.

Source: Google Maps (2022)

The Norm CNEN-NN-3.01 was the basis for the preparation of the SAER Initial Assumptions (IA), as described in the Table 3, below:

Table 3: Initial Actions (IA).

IA-1	The information sent by the freight forwarder and Maltese authorities was the starting point for the work plan: 1. monitoring for dose rates at "hot points" on the surface of the container; 2. identification of the Ra-226 nuclide; 3. possible conclusion that there was no contamination on the external surface of the container. Remark: CNEN team carried out measures to verify these above-mentioned three points when receiving the container.
IA-2	The CNEN team always considered, conservatively, that the operation was about rescuing a dangerous source;
IA-3	Initially we adopted the operational intervention protocol of 100 microSv/h to isolate areas;
IA-4	It was planned that possible radiation doses for all the team members involved in the operations, would comply with the criteria of Norm CNEN-NN-3.01 [3].

Source: CNEN Emergency Team

Regulatory position of the Norm CNEN 3.01/006:2011, – Protection Measures and Intervention Criteria in Emergency Situations [5] – complements the Norm CNEN 3.01, in terms of its requirement "6.1.3", regarding interventions to protect individuals from the public. Relevant protective measures include "shelter, evacuation, and administration of stable iodine, which can be complemented by additional actions, such as access control, respiratory protection and decontamination" (CNEN, 2011) [5].

The operations were also conducted having as reference the International Atomic Energy Agency (IAEA) document EPR-Method-2003, in particular the action guide "recovery from a hazardous source outside regulatory control" (IAEA, 2003) [12].

All the members of the CNEN Emergency Team, all well trained, certified, and experienced, pertain to the Institute of Radioprotection and Dosimetry (IRD), based in Rio de Janeiro, and the Regional Center for Nuclear Sciences – Northeast, based in Recife. With expertise in collecting orphan sources[2] and other types of assistance, the referred

[2] Radioactive source that is not under regulatory control, either because it was never under control, or because it was abandoned, lost, misplaced, stolen or transferred without due authorization (CNEN, 2020) [13]

professionals made use of their expertise in dealing with technical, administrative, logistics and public protection tasks.

The teams traveled to the Port of Suape in three vehicles; A radiometric survey was carried out to characterize the background radiation[3], in the area planned for the unloading the container, prior to the disembarkation. If "hot spots" (with radioactive emissions) were found, which could affect the container monitoring work, the unloading area would be cleaned or the place changed.

Clarification was provided to the regular workers of the Port of Suape, regarding CNEN protocols. At the time, national port parameters were sent to CNEN by those agents, for example, situations that cover maritime "frequent exporters".

Disembarkation at the Port of Suape took place on June 23rd, 2022, at 01:30 AM. On the same day, CNEN Emergency Team arrived into the port. It was planned for the same day, unloading the container from the ship, identifying the source presence in the container, transportation in convoy, identification and segregation in Caruaru and subsequently the source transportation to CNEN waste facilities at Recife.

4.1. Port inspection and container inspection in Caruaru-PE

The operation began on June 23rd, 2022, at 5:00 AM. After carrying out radiological monitoring, with external mapping of the container and identification of the presence of the radioactive material, the container was transported by road to Caruaru-PE.

Upon arrival at Caruaru, a search, monitoring, identification, characterization and segregation of the radioactive material was carried out.

Professionals from both CRCN-NE, close to the stablished emergency operations center, and The Institute of Radioprotection and Dosimetry, located in Rio de Janeiro, the CNEN unit which centralizes the SAER. The team was made up of technologists, researchers

[3] Background radiation: radiation present in the environment, normally below permissible levels [13].

and technicians, with a total of 14 professionals (8 from CRCN-NE and 6 from IRD). The Figure 3, below, shows the initial assessment of the containment at the Port of Suape.

Figure 3: Container undergoing the Emergency Team assessment.

Source: CNEN Emergency Team

The materials used were: 14 personal radiation detectors (PRD), of three models; 2 dosimeters to assess precisely radioactive doses; 2 radionuclide identifiers; 1 meter (dose rate) and 1 telescopic radiation detection probe. As Personal Protective Equipment: coveralls, full-face masks, combined filters, gloves, boots, overshoes and surgical masks. Four vehicles were used for displacement of personnel. Accessory materials were made available, such as a shielding set, masking tape, etc.

5. FINDINGS AND DISCUSSIONS

The container was transported for evaluation in Caruaru, after identifying the radioactive source in Suape, as already mentioned. Radiometric survey was previously carried out in Caruaru (before the container arrived), to characterize the background radiation, especially in the area planned for opening the container and searching for the radioactive material (the same protocol was carried out at the port). Figure 4 shows the team at the location.

Figure 4: Emergency Team in Caruaru-PE.

Source: CNEN Emergency Team

A set of shielding devices were made available for the initial storage and subsequent road transport of the source. Depending on its volume, weight and local dose-rate, additional shielding could be necessary.

With the container positioned in the scrap company's yard, the operation began. After 18 object removals with a mechanical winch shovel – each removal being monitored – the emission source was identified using a radiation detector, protected and positioned like a pendulum, in the claw that removed the materials (figures 5 and 6). The detector warned when the emission source was found, which was confirmed by a technician, who was positioning a long telescopic radiation detector (figure 7). After removal, the material was segregated, and the source was then found; identifiers were used to measure the radiation levels and compare to the dose values previously obtained, confirming Ra^{226} emission. The source was characterized as for industrial use. It was then placed into a container (figure 8) and road transported to the CRCN-NE.

Figures 5 and 6: Arrow indicating the packed detector, attached to the winch claw; and measurements made with the extended telescopic detector.

Source: CNEN Emergency Team

Figure 7: Dose rate verification operation during container unloading (positioning rod with detector).

Source: CNEN Emergency Team

Figure 8: The R-226 Source encapsulation.

Source: CNEN Emergency Team

6. CONCLUSION

The activity of responding to radiological and nuclear emergencies, vital for the country's security, finds support in global and national Norms. At an international level, the IAEA is the body issuing protocols and sharing good practices to its Member States. CNEN rules all Brazilian nuclear and radiological activity in terms of safety.

The Teams from the two CNEN Institutes that carried out the emergency tasks described in this document, with support from other Brazilian Security organizations, complied with approved procedures, resulting in a standardized process that brought safety and security to all the direct and indirect involved persons and the public. The innovation concept, obtained through a remote pendulum for radiation verifying method, must be herein emphasized.

The event, addressed in this study, was originated in the detection from a maritime transshipment of containerized cargo, exported from Brazil to Bangladesh. The detection occurred in Malta, and from then on, approved protocols were activated to return the cargo and safely perform all the described activities herein. Lessons learned from the described actions remained in the adequate coordination, information and cooperation of public organizations.

Centralized coordination and dialogue, detailed planning, the transmission of accurate information to those involved and the organization of professionals into thematic groups were amongst the major success factors of the very well accomplished mission.

Remark: The direct and root causes involved in dispatching of a non-detected radioactive source of Ra^{226}, as well as all potentially involved doses, may be discussed in another paper. This paper is intended to describe only the safe operations for the rescue and to place the source in a Brazilian official radioactive waste site, with no registration of incidents.

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CONFLICT OF INTEREST

All the authors declare that they have no conflicts of interest on this subject.

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