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Radioactive Waste Management Challenges: Nigerian Case Study

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Abstract:
Preceding the publication of the Nuclear Safety and Radiation Protection Act 19 of 1995 (Act) by the Justice Ministry in 1995 (Justice, 1995) and the establishment of the Nigerian Nuclear Regulatory Authority (NNRA) in 2001, radioactive sources had for decades been used for various practices in Nigeria (Ogharandukun, 2017). These early activities involving radioactive sources gave rise to some legacy radioactive waste. NNRA undertook some early actions soon after its inception to ensure the safe management of this legacy radioactive waste. These actions, amongst other outcomes, highlighted the inadequacies of the Nigerian radioactive waste management system. The approval of radiation safety and radioactive waste management regulations enabled the NNRA to enter into national and international cooperative efforts to search for, secure, and create a proper inventory of the radioactive waste in Nigeria and effectively handle and manage it. Implementing the waste management system further highlighted the need for the approval of a national policy on radioactive waste management and the management of disused radioactive sources.

Keywords: *Radioactive sources, radioactive waste, radioactive waste management, nuclear safety and radiation protection, legislative and regulatory framework, biological control of tsetse flies, radiotherapy*

1. Introduction

The use of ionizing radiation sources in Nigeria preceded the present national legal and regulatory infrastructure for nuclear safety and radiation protection. So, they were largely unregulated or had ad-hoc regulatory oversight before establishing NNRA (Ogharandukun, 2017). Amongst others, these were in healthcare delivery, the oil and gas sector, agriculture and water resources, mining, manufacturing, construction, security operations, and education and research.

The establishment of the NNRA in 2001 heralded the implementation of the Act, which gave the NNRA responsibility for nuclear safety and radiological protection regulation in Nigeria. The Act further empowered NNRA to authorize practices, make regulations governing such practices and also to: (Ogharandukun, 2017)

- Perform all necessary functions to enable Nigeria to meet its national and international safeguards and safety obligations in the application of nuclear energy and ionizing radiation, and
- Liaise with and foster cooperation with international and other organizations or bodies concerned having similar objectives

In this regard, Nigeria became a party to the Joint Convention on the Safety of Spent Fuel Management and the Safety of Radioactive Waste Management (JC) in 2007 (IAEA, 2007). Nigeria's obligations under the JC included proper management of radioactive waste and submission of reports of the steps taken in this regard. Nigeria was also committed to achieving and maintaining a high level of safety in radioactive waste management by strengthening national measures and international cooperation, including, where appropriate, safety-related technical cooperation. Nigeria was also to ensure that there were effective defences against potential hazards during all stages of radioactive waste management so that individuals, society and the environment are protected from the harmful effects of ionizing radiation (IAEA, 2007).

1.1. Origins of Radioactive Waste

In the 1980s, the International Atomic Energy Agency (IAEA), in technical cooperation with Nigeria (IAEA, 1990), gave the Federal Ministry of Agriculture some radioactive sources, namely: Cobalt-60 with 15,100 Curie of initial activity and Cesium-137 with 2,381 Curie of initial activity. The sources were to be used in the Biological Control of Tsetse Flies (BICOT) project at the National Veterinary Research Institute (NVRI), Vom, Nigeria. The project aimed to eradicate tsetse flies in Nigeria by breeding and spreading radiation-sterilized insects (the Sterile Insect Technique (SIT)). According to SIT, insects were produced in large rearing plants, sexually sterilized using gamma radiation, and released into the native insect population. When the sterile insects mated with the wild insects, no offspring were produced. This approach was both environmentally friendly and often the only practical means of insect eradication. However, due to various financial and technical reasons, the project was abandoned without proper arrangements for the evacuation and disposal of the radioactive sources. These sources became legacy sources.

Lagos University Teaching Hospital (LUTH) operated a Theratron 780 Teletherapy Machine manufactured by Atomic Energy of Canada Ltd (AECL) in 1970. The machine had Cobalt-60 sources of about 5017 Curie in 1988. In addition, the hospital also operated an AGAT R1 Teletherapy Machine manufactured by Techsnabexport (Russia/Estonia). The machine also had Cobalt-60 sources of about 4170 Curie loaded in 1990. Additionally, LUTH had Caesium-137 radioactive sources for the treatment of cervical cancer. These were supplied by CIS Bio International of France between 1976 and 1979, with activities ranging from 26.5 milli-Curie to 421.2 milli-Curie. In 2004, due to radiation safety considerations, LUTH was stopped from using radioactive sources for radiotherapy practice. At this point, the disposal of the sources became a challenge as both the management of LUTH and the Federal Ministry of Health claimed that they lacked the budgetary provision for the repatriation of the sources to the respective countries of manufacture, i.e., the Russian Federation, Canada, and France. This was thus a situation of legacy radioactive sources arising from regulatory sanctions. The NNRA had to include these sources in the basket of *Legacy Sources* that needed to be repatriated using external support (Ogharandukun, 2017).

The Grace Hospital, Ibadan (TGH), was not licensed for operation in 2004, but it had a legacy radiotherapy practice using Caesium-137 brachytherapy machines. The practice was carried out with sources lacking documentation and of unknown characterizations. They were, therefore, not traceable to any manufacturer. Uncertainty about the source characteristics meant that they could not be allowed for clinical practice. The situation was further aggravated by the uncalibrated quantity of radiation administered to cancer patients and the possible unintended consequences therefrom. Thus, in 2006, the facility was closed down, and the Caesium-137 sources were decommissioned and taken over by the NNRA for radiation safety reasons. Furthermore, it was impossible to repatriate the sources to any waste management facility overseas. In this regard, the NNRA took possession of the sources and deposited them at the Centre for Energy Research and Training (CERT), Zaria, with which it had an existing Memorandum of Understanding (MOU) (Ogharandukun, 2017).

In the early eighties, more than two hundred sealed radioactive sources, comprising, amongst others, Cobalt-60, Cesium-137, Plutonium-239, Strontium-90, Iridium-192 and Yetrium-90 were brought into the country from the former Soviet Union. They were to be used in various processes of the Ajaokuta Steel Company Limited (ASCL) plant as nuclear gauges (NNRA 2020).

With the failure of the project, the steel plant wanted to dispose of these sources as radioactive waste since they were no longer to be put to any further use and were also not under regulatory control. Thus, in 2006, in one of its initial actions on the matter, NNRA issued authorization to the facility for storage of the sources. NNRA also conducts regular compliance inspections to ensure the safety and security of the sources. The NNRA had confirmed that at least two hundred and eight (208) radioactive sources were at the facility. They had, however, not been characterized as the sources bore Russian inscriptions, which were not easily interpreted. Furthermore, the management of the facility claimed that it had neither the resources to dispose of the sources nor the skills to manage them. The situation was complicated by the fact that the ownership of the facility had changed hands without including the radioactive sources as "liabilities" to the new owners. With this situation, the NNRA requested the IAEA to send a Verified Inventory Mission to Nigeria to establish the correct inventory of the sources and train NNRA staff on the techniques to search for orphan sources (Ogharandukun & Bello, 2009).

2. National Efforts to Locate and Manage Legacy and Orphan Sources

Nigeria did not produce radioactive sources, and all radioactive sources were imported. Thus, sources were grouped into three according to their regulatory control statuses:

- Status A

Radioactive sources imported after May 2001 and fully authorized by the NNRA

- Status B

Radioactive sources imported before May 2001 were not in use but were still in the custody of their original owners. Consequently, they fell under NNRA's regulatory control after its establishment. These are the legacy sources

- Status C

Radioactive sources imported before May 2001 were not in use and whose owners were either unknown or incapable of handling or managing them. Furthermore, no further use was envisaged for them. These were the legacy radioactive waste.

Status C constitutes the core of this work.

Several steps were taken to identify these sources and establish the regulatory infrastructure to properly manage them. Shortly after its inception, the NNRA, in January 2002, requested embassies from the major exporting countries in Nigeria for a list of radioactive sources exported from their countries to Nigeria between 1992 and 2001. Unfortunately, not all the embassies responded, and many of those who responded did not provide helpful information. Furthermore, between 2004 and 2010, annual search parties were dispatched to all steel rolling plants, industrial radiography companies, nuclear well-logging companies, radiotherapy centres, institutions of higher learning, breweries, bottling companies and the yards of scrap metal dealers in the major cities. The result obtained from this effort led to the establishment of a computer based national Regulatory Authority Information System (RAIS). The radioactive waste found in these endeavours was brought under regulatory control and/or also exported to their countries of origin. NNRA deemed the export of radioactive waste to their countries of origin as the best option in the absence of a radioactive waste management facility in the country.

At inception, NNRA had the Act as its only instrument. No Regulation was passed until 2003 when the Nigeria Basic Ionizing Radiation Regulations (NiBIRR), 2003 (NNRA, 2003) was approved. NiBIRR prescribed that the safety and security of radioactive sources was the responsibility of the licensee. However, since orphan and legacy sources rarely belonged to licensed owners, NiBIRR required that "… the NNRA shall be responsible for the management of the spent source where the recipient is incapable of returning the source or the license is revoked, or the recipient no longer exists, and the Authority may request to recover the costs incurred from those responsible, where they are known…" Thus, NiBIRR placed responsibility for orphan and legacy sources on the NNRA (NNRA 2003).

2.1. Regulations and Guidance

Exercising the powers conferred on it by the Act, and by virtue of all enabling powers on that behalf, the NNRA set up a Technical Advisory Committee (Committee) for the development of radioactive waste management policy and regulations for Nigeria in July 2004.

The Committee identified all practices and activities generating radioactive waste in the country. It also identified and assessed the various radioactive waste management options, including the prevailing disposal systems. It observed that, whereas the volume and the attendant potential hazards of the radioactive waste were high, their managing and disposal processes were not subject to any specific legislative control. It also observed that information on radioactive waste available at the NNRA was incomplete. The Committee, therefore, agreed that the urgent development and promulgation of an operational radioactive waste management policy and regulations for Nigeria was of priority. In line with its terms of reference, the Committee produced the draft Nigeria Radioactive Waste Management Regulations.

2.2. Nigeria Radioactive Waste Management Regulations (NNRA, 2006)

The draft of the Regulations was developed in 2004, and its principles started guiding the NNRA soon thereafter, even though they were only later approved in 2006.

The Regulations set out the basic technical and organizational requirements for compliance by radioactive waste generators and operators of waste management facilities to ensure the protection of human health and the environment from the hazards of radioactive waste within and beyond national borders. They covered requirements related to collection, characterization, segregation, treatment, conditioning, storage and preparation for transport of radioactive waste arising from facilities where radioactive materials and sources of ionizing radiation were produced, used or handled. The regulations did not deal with radioactive waste arising from technologically enhanced naturally occurring materials. (NNRA 2006).

3. NNRA Missions

In March 2002, NNRA received notification from the Federal Ministry of Agriculture (Ministry) indicating that the facility housing the BICOT project at the NVRI was burnt down in a bush fire. The fire completely destroyed the building housing the Caessium-137 and Cobalt-60 sources used in the project. Inspection findings showed that the sources were still intact. Nonetheless, the NNRA assessment adjudged the situation as a major radiological incident and directed both the facility and the Ministry to repatriate the sources to Canada from where they were originally imported. Both, however, claimed that the cost of the repatriation was not planned for in their budgets.

These radioactive sources constituted public safety and security risks as they were now exposed to the elements following the destruction of their shelter. Also, as no further activities were carried out with the sources and no further use was envisaged for them, they were no longer being attended to or protected by the owner institution. Thus, NNRA felt the urgent need to immediately assume responsibility for them and instituted a program of regular inspection and surveillance over them. Regular inspections were carried out between 2002 and 2007 to confirm the safety and integrity of the sources. With support from the IAEA and the US Department of Energy, the sources were finally evacuated from Vom in 2007. (Ogharandukun and Bello 2009).

3.1. Lagos University Teaching Hospital (LUTH)

Between 2002 and 2003, NNRA conducted radiation safety audits in all five radiotherapy centres in the country. These were cancer treatment centres, four of which used ionizing radiation in the form of radioactive sources. The fifth hospital used radiation generated from a Linear Accelerator (LINAC) machine. The facility at LUTH failed radiation safety regulatory requirements, and its use of radioactive sources for radiotherapy was banned in January 2003 for safety reasons. All the radioactive sources at LUTH thus became legacy radioactive waste in the absence of a national capacity to manage the waste they then constituted.

3.2. The Grace Hospital, Ibadan (TGH)

In 2004, NNRA identified TGH, a private centre which had a radiotherapy practice using Caesium-137 sources for brachytherapy. Inspection findings showed that the activity of the sources used in the practice could not be established as they had no calibration certificates or any technical documents related to them. Thus, the sources were not traceable to any manufacturer. Furthermore, the situation was compounded by the uncalibrated quantities of radiation administered to cancer patients and the possible attendant consequences that could emanate therefrom. The uncertainties about the sources meant that they could not be allowed for clinical practice. The NNRA 2006, therefore, closed down the facility. The sources were decommissioned and taken over by the NNRA and deposited at CERT under the terms of an existing MOU between the two institutions.

3.3. NNRA "Search and Secure" Program

In 2003, a "Search and Secure Program" was instituted by the NNRA. The program targeted major scrap yards, scrap metal recycling plants, warehouses of airports and seaports, bottling companies, tobacco companies, sugar processing plants, road construction companies and textile mills, amongst others.

The searches were both visual and by instrumentation using radiation detectors. At all the locations, printed copies of the missing materials and other images of sample sources were circulated, and contacts were advised to report such findings to the nearest State Security Office or Police Station. Most searches yielded no material of interest, and electronic surveys yielded no radiation reading above the background.

4. International Cooperation to Locate and Manage Legacy and Orphan Sources

Nigeria became a party to the JC in 2007 (IAEA, 2007). By the provisions of JC, each contracting party would submit a national report to each review meeting of contracting parties. This report addressed the measures taken to implement each of the obligations of the JC and highlighted safety issues in Nigeria's quest for the proper management of radioactive waste.

In keeping with the objectives of the JC, Nigeria was committed to achieving and maintaining a high level of safety in spent fuel and radioactive waste management by strengthening national measures and international cooperation, including, where appropriate, safety-related technical cooperation. As all radioactive sources in Nigeria were imported, NNRA realized early on that international cooperation would be vital in the location, handling and repatriation of legacy radioactive waste. Thus, NNRA forged close international partnerships that assisted with the handling and repatriation of legacy radioactive waste. Thus, further efforts to address the issue of legacy radioactive waste involved entering into multilateral cooperation on the one hand with the IAEA and, on the other hand, with the United States Department of Energy (US-DOE). Cooperation with the US-DOE was under its Global Threat Reduction Initiative (GTRI) program. Additionally, NNRA entered into an understanding with CERT, which operated the only radioactive waste storage facility in Nigeria. Several efforts were undertaken under this cooperation. (Ogharandukun and Bello 2009).

At the inception of the NNRA in 2001, Nigeria was already a member of the IAEA. So, there were already opportunities for cooperation with the IAEA under its membership terms. However, bilateral cooperation with specific countries requires entering into cooperation agreements with such states. Thus, with the approval of Mr. President and under the guidance of the Attorney General of the Federation and Minister of Justice, the USA and Nigeria, on 11th March 2005, signed a Bilateral Cooperation Agreement on the Upgrading of Nuclear Security at various nuclear facilities in the country. Under this agreement, several nuclear facilities were identified for a security upgrade, and some legacy radioactive sources would be evacuated from the country. The facilities included the radiotherapy centres at the Eko Hospital (EKO), Lagos, University College Hospital (UCH), Ibadan, Ahmadu Bello University Teaching Hospital (ABUTH), and Zaria, all of which used Cobalt-60 radioactive sources for cancer treatment. Also covered by the Agreement was the nuclear research reactor at CERT. Under these international frameworks, it was possible to carry out a number of activities.

4.1. IAEA Verified Inventory and Orphan Source Mission (Ogharandukun & Bello, 2009)

As an active member of the IAEA, the Nigerian government invited the IAEA, which sent a Verified Inventory and Orphan Source Mission to Nigeria. The mission which was from 27th - 30th August, 2007, was to:

- Establish a strategic plan for a Verified Inventory of Sealed Radioactive Sources and assist in locating Orphan Sources
- Investigate companies and industries in Nigeria that may have Sealed Radioactive Sources in an effort to place them under regulatory control
- assess the available radiation detection equipment available for the task
- assess the National Radioactive Source Storage Facility's capabilities for storing Disused Radioactive Sources
- Evaluate the physical security of IAEA Categories I and 2 Sources in the Country and consider possible security upgrades of these facilities.
- Discuss any knowledge of possible orphan sources in the country. Visit such known locations for orphan and legacy sources and evaluate the security of such sources.

4.2. US-DOE Mission 19th - 25th April, 2008 (Ogharandukun & Bello, 2009)

Under the auspices of the GTRI and IAEA, a multilateral team comprising US-DOE and the IAEA undertook a Mission to Nigeria from 19th to 25th April, 2008. The objective of the mission was to explore areas of possible assistance especially on recovery and/or securing vulnerable high-risk nuclear and other radioactive material that may pose risk or which may be put to malicious uses. The mission was also to assess such affected facilities to provide security upgrades for them.

As part of its initial priority, the Joint Mission and the NNRA visited ASCL on 23rd April 2008. The visit was to verify the status of the legacy sources at the facility and to explore options for their removal. The visit took advantage of the recommendations of the Verified Inventory and Orphan Source Mission by the IAEA in August 2007.

4.3. IAEA Technical Experts' Mission to ASCL, 21st - 26th July 2008

A team of experts comprising representatives of the IAEA, Open Joint Stock Company, Russia, Nuclear Corporation of South Africa (NECSA), Los Alamos National Laboratory (LANL) USA and the NNRA undertook a Mission to ASCL from 21st - 26th July 2008. It was to characterize and establish a complete inventory of the disused radioactive sources at ASCL. At the end of the mission, the report will be compared with the information at the IAEA. A decision on what technical and necessary applicable solution would then be taken. (Ogharandukun and Bello 2009)

4.4. US DOE - Global Threat Reduction Training Workshop, 17th - 21st November 2008 (Ogharandukun & Bello, 2009)

The National Search and Secure Training Workshop on Orphan Radioactive Sources was organized by the US-DOE in conjunction with the NNRA. It was to provide search and secure training on locating orphan radioactive sources using various radiation detection equipment. The training involved classroom lectures and practical field exercises to enhance the overall knowledge and skills of the participants in searching for and securing orphan radioactive sources. Amongst others, the training modules covered how to:

- Perform a verified inventory and locate orphan sources
- Organize a search team and implement a search
- Use radiation detection equipment
- Characterize unknown radioactive sources and
- Package and transport found orphan radioactive sources

Twenty-five (25) participants drawn from Nine (9) organizations in Nigeria attended the training course. The resource persons who took the participants through the lecture presentations and practical exercises were from Argonne National Laboratory, USA, Los Alamos National Laboratory, USA and Canberra Industries.

The training workshop consisted of classroom lectures and field trips for practical exercises aimed at increasing the overall knowledge and awareness of the trainees on issues relating to search and secure program of orphan sources, and to prepare each trainee to search for, locate and identify orphan sources. In addition, the participants were familiarized with the requirements for packaging and transportation of sources to secure storage. (Ogharandukun and Bello 2009)

5. Inventory of Legacy Radioactive Sources (IAEA, 2007)

At the end of these expert missions and NNRA regular and enforcement inspections, an inventory of legacy radioactive sources was established. The updated list of radioactive waste in 2020 showed that the waste was collected at two major locations, namely:

- Radioactive Waste Management Facility (RWMF) CERT, Zaria, and
- ASCL Temporary Storage.

These are shown in tables 1 and 2.

S/N	Radionuclide	Qty	Activity Range (Ci) (23 – 11 – 2020)	Activity Aggregate (Ci) (23 – 11 – 2020)
1.	Sr-90	23	0.00035 – 0.034	0.1155
2.	Cs-137	8	0.00466 – 0.091	0.2058
3.	Co-60	10	0.00002 – 712.63	831.773
4.	Ir-192	1	0	0
5.	Cs-137	3	Not Available	Not Available
6.	Co-60	42	Not Available	Not Available
7.	Ra-226	36	Not Available	Not Available
8.	Fe-55	2	Not Available	Not Available
9.	Ir-192	7	Not Available	Not Available
10.	Am/Be	2	Not Available	Not Available
11.	Cf-252	1	Not Available	Not Available
12.	Am-241	2	Not Available	Not Available
13.	U-233	1	Not Available	Not Available
14.	Eu-152	1	Not Available	Not Available
15.	Co-57	1	Not Available	Not Available
16.	Contaminated Containers	9	Not Available	Not Available

Table 1: Inventory of Radioactive Waste (IAEA, 2007)

	Source	Qty	Activity Range (Ci)
i.	Cs -137	22	1.78 - 1.00
ii.		180	0.19 - 0.01
iii.		1	0.01
iv.	Co - 60	4	0.22 - 0.01
v.	Co - 60	20	0.01
vi.	Pu - 239	5	0.35

Table 2: Inventory of Legacy Radioactive Waste (ASCL), Ajaokuta (IAEA, 2007)

6. Decommissioning and Repatriation of Some Legacy Radioactive Wastes

With the identification and decommissioning of this legacy radioactive waste, the stage was then set for their evacuation from their locations to either a central national facility or back to the countries of their origin.

The repatriation exercise took place between 4th - 19th July, 2007. The collection, evacuation and transportation of the sources within the country and their ultimate repatriation out of the country were carried out under a joint project between the IAEA and the US-DOE. Under the coordination of the NSC, a task force was set up comprising members of the Nigeria Police, the Department of State Security, the Defence Headquarters, the Nigeria Customs Service, the Nigeria Immigration Service and the NNRA. The task Force worked with the international team set up by the IAEA for the project. The exercise achieved the removal of a total weight of about 35 tons (including source shielding and transport containers) (Ogharandukun & Bello, 2009).

6.1. Temporary Storage of Legacy Radioactive Wastes

CERT had a radioactive waste storage facility built by the Nigerian government and supported by the IAEA with equipment. In 2006, CERT applied to NNRA for a licence to operate its Waste Management Facility. A licence was granted to CERT for conditioning only Low-Level Waste (LLW) and Intermediate Level Waste (ILW) and for temporary storage of the same. Furthermore, NiBIRR required that the NNRA would be responsible for the management of spent radioactive sources where the recipient (licensed or otherwise) was incapable of returning the source, the license is revoked, or the recipient no longer exists, and the Authority may request to recover the costs incurred from those responsible, where they are known. Therefore, in 2007, NNRA signed an MOU with CERT for the temporary storage of legacy and orphan radioactive sources, which would be paid for by the NNRA until the owner could make it. With the MOU between NNRA and CERT with respect to the use of its radioactive waste management facility and other related matters, CERT would, amongst others, support the NNRA with the temporary storage of legacy radioactive waste at its facility. The NNRA would provide CERT with appropriate financial, operational, and technical assistance with respect to radioactive waste management regulations, amongst other requirements. In this regard, NNRA transferred some decommissioned radioactive sources to CERT for temporary storage.

7. Observations and Conclusions

NNRA ensured that legacy and orphan sources and radioactive waste found around the country during search activities were transferred to the CERT Waste Management Facility for temporary, secured storage. The disused sources and radioactive waste that the supplier/manufacturer overseas accepted to take back were repatriated to that supplier/manufacturer. This was the only viable option for managing disused radioactive sources and radioactive waste in Nigeria, as there was no radioactive waste management facility in the country capable of treating radioactive waste.

Additionally, the Federal Government has yet to approve the National Policy on Radioactive Waste Management and Management of Disused Radioactive Sources. The enactment of this policy would be a major regulatory tool to strengthen the national regulatory framework for nuclear safety and radiological protection regulation.

8. Recommendations

- The Federal Government of Nigeria may wish to approve the establishment of a Waste Management Organization and a Centralized Radioactive Waste Management Facility.
- Furthermore, the government should approve the Draft National Policy on Radioactive Waste Management and Management of Disused Radioactive Sources, which captures the various options available with regard to radioactive waste management.
- The government should provide adequate resources for the management of existing legacy and orphan sources located in several locations around Nigeria and
- NNRA should include in its authorization requirement the provision of a financial guarantee for end-of-life management of radioactive sources.

9. Data Availability

All data, models, and code generated or used during the study appear in the submitted article

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