**NATIONAL STRATEGY AND PLANNING FOR THE SAFE AND SUSTAINABLE MANAGEMENT OF RADIOACTIVE WASTE AND SPENT NUCLEAR FUEL.**

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**Abstract:**

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Nuclear technology applications have been on the increase in Nigeria. The use of radioactive materials in the fields of research, medicine, industry, agriculture, commerce, education and defense; as well as the extraction, processing and combustion of raw materials containing naturally occurring radioactive materials are among the most prominent. Other emerging activities include the development of nuclear reactors for research and electricity generation purposes. These activities generate radioactive wastes, which contain materials that emit ionizing radiation, and have been recognized as a potential hazard to human health and the environment since the beginning of the 20th century. Safe management of radioactive wastes is essential for the protection of human health and the environment, in the present and future. The Nigeria Atomic Energy Commission has developed the National Radioactive Waste Management Policy and the Nuclear Fuel Cycle Policy to express the intent of Government to manage radioactive waste and spent nuclear fuel in a safe, secure and sustainable manner to safeguard public health and the environment. As a follow up to these policies, a set of strategies need to be developed for the management of radioactive wastes arising. The management of radioactive waste involves the reduction to as low as practicable and justifiable, the associated through appropriate processing, containment and eventual disposal of processed waste. The most preferred approach in the management of radioactive waste are ‘delay - decay’, ‘dilute-disperse’ and to concentrate the waste and contain the radionuclides in it by means of a waste matrix and waste container followed by disposal in an appropriate disposal facility designed to provide adequate isolation from the immediate environment. The Policies describe intent; and the Strategy describes “how to” and provides the framework for how Radioactive Waste Management will be performed in the country. It also provides for process development and identifies competencies needed and how they will be provided. It elaborates waste management methods for all waste types and prescribes use for communicating with the public and governmental authorities. In terms of safety, security and environmental protection, one of the main requirements imposed by the Government of Nigeria to all waste generators, is to manage radioactive waste in a manner that protects human health and the environment, now and in the future. The financial requirements for the implementation of the strategic plan for safe, secure and sustainable management of radioactive waste and spent nuclear fuel comes from the Radioactive Waste Management fund.

## **INTRODUCTION**

## A general aim in the management of radioactive waste is to reduce, to as low as practicable and justifiable, the associated risks by appropriate processing, containment and eventual disposal. The main purpose of the paper is to specify the technical means and measures for the safe, secure and sustainable management of radioactive waste and provide a nation-wide framework for the development and implementation of a coherent, integrated and optimized system encompassing all types of radioactive wastes including spent nuclear fuel (SNF) (when spent fuel is considered as waste), disused sealed radioactive sources (DSRS) and Naturally-Occurring Radioactive Materials (NORM) generated in the country. This strategy specifies the administrative, financial and technical arrangements for managing the radioactive waste in Nigeria. The national strategy for the management of radioactive waste and spent nuclear fuel in Nigeria has been developed to be in tandem with the spirit and provisions of the national radioactive waste management policy.

The scope of the national strategy for the management of radioactive waste and spent nuclear fuel (SNF) is intended for all categories of waste from all waste streams available in the country. These are:

-Institutional waste

-Disused Sealed Radioactive Sources (DSRS)

-Reactor operational waste

-Spent nuclear fuel (SNF)

* from research reactor
* power plant reactor

-Decommissioning waste

-NORM waste

## **Overall principles and requirements of the national policy**

The National Strategy for the Management of Radioactive Waste and Spent Nuclear Fuel in Nigeria has been developed to be in tandem with the spirit and provisions of the National Radioactive Waste Management Policy.

**Compliance with the National Policy, Legal and Regulatory Requirement**

The National Strategy for the Management of Radioactive Waste complies with all the legal and regulatory requirements, national as well as international instruments, stipulated in the national laws governing the Radioactive Waste Mana*g*ement in Nigeria. Among those, in terms of safety, security and environmental protection, one of the main requirements imposed by the Government of Nigeria to all waste generators, is to manage radioactive waste in a manner that protects human health and the environment, now and in the future in accordance with the following principles:

**-Protection of Human Health:**Radioactive waste are managed in such a way as to secure an acceptable level of protection for human health.

**-Protection of the Environment*:*** Radioactive waste are managed in such a way as to provide an acceptable level of protection of the environment, including natural resources.

**-Protection beyond Nigeria’s Borders*:*** Radioactive waste are managed in such a way as to ensure that the possible effects on human health and the environment beyond national borders will be taken into account.

**-Protection of Future Generations*:*** Radioactive waste are managed in such a way that predicted impacts on the health of future generations will not be greater than relevant levels of impact that are acceptable today.

**-Burden on Future Generations*:*** Radioactive wastes are managed in such a way that will not impose undue burdens on future generations.

**-Minimization of Radioactive Waste Generation:** The generations of radioactive waste are kept to the minimum practicable.

**-Radioactive Waste Generation and Management Interdependencies*:*** Interdependencies among all steps in radioactive waste generation and management are appropriately taken into account.

**-Safety of Facilities:** The safety and security of facilities for radioactive waste management are appropriately assured during each phase of the facility’s lifecycle.

**Legal and Regulatory Requirements**

The national strategy for the management of radioactive waste and spent nuclear fuel operates under the following legislations and regulations:

* Nigeria Atomic Energy Commission (Establishment) Act 46 of 1976
* Nuclear Safety and Radiation Protection Act 19 of 1995 establishing the Nigerian Nuclear Regulatory Authority (NNRA)
* Nigerian Radioactive Waste Management Regulations 2006
* Nigerian Safety Regulations for the Management of Naturally Occurring Radioactive Materials (NORM) Regulations 2008
* Nigerian Transportation of Radioactive Sources Regulations 2006
* Nigeria Environmental Standards and Regulations Enforcement Agency Act 2007
* Petroleum Act of 1962 establishing the Department of Petroleum Resources

**Management Strategy Requirements**

The National Strategy for Radioactive Waste Management complies with the following requirements:

* Spent nuclear fuel considered as a valuable resource,
* Return of spent nuclear fuel (from research or power reactors) to supplier’s countries,
* Return of disused sealed radioactive sources to suppliers or manufacturer’s countries,
* Disposal of radioactive waste in dedicated facilities considered as the final end-point for safe and sustainable long-term management,
* Decay storage followed by authorized discharge to be considered as a possible option for the management of Category I low-level (very short lived) waste,
* Minimization of radioactive waste generation to be considered as a priority,
* Reuse/recycling of radioactive materials to be considered in compliance with exemption and clearance levels,
* Interim storage of spent nuclear fuel in licensed, safe and secure facilities to be considered as an intermediate management step before repatriation to suppliers’ countries or final disposal,
* Interim storage of disused sealed radioactive sources in licensed, safe and secure facilities to be considered as an intermediate management step before repatriation to suppliers’ countries or final disposal.

**Disposal as final end-point for sustainable waste management**

The following constitute the end points for radioactive waste management:

* Near-surface disposal of low-level wastes (LLW) as it arises; near-surface or borehole disposal of disused sealed radioactive source (DSRS) may be considered at the same facility;
* Deep disposal of spent nuclear fuel (SNF) in geologic formation at first opportunity (probably 20-30 years after its production). This also applies to the disposal of intermediate level long lived radioactive waste (ILW-LL)
* Intermediate level short lived radioactive waste (ILW-SL) may go to surface or deep disposal facilities for the purpose of optimizing the use of the facilities. The final choice depends on its nature & volume, properties of the chosen site and the design of the near-surface disposal facility.
* Above ground disposal in engineered facilities for the bulk of the mining waste.
* Remediation of mining and milling tailing are carried out as soon as possible.
* Oil industry radioactive wastes are investigated by the operators of such facilities and reported to the Nigeria Nuclear Regulatory Authority.

The determination of the specific disposal facility to which a specific waste is disposed of are on the basis of a safety case and supporting safety assessment developed by the waste generator/waste management operator and approved by the Nigeria Nuclear Regulatory Authority (NNRA).

**Waste Management Organization (WMO)**

The Government of Nigeria will consider the need for the establishment of a national Waste Management Organization (WMO)as an autonomous body to be responsible for the management of radioactive waste in the country. The Nigeria Atomic Energy Commission (NAEC)is charged to carry out the duties of Waste Management Organization (WMO)until the WMO is formally established.

The Government of Nigeria has established the Nigeria Atomic Energy Commission charged with the responsibility for the promotion of the development of atomic energy and for all matters relating to the peaceful uses of atomic energy; and also, would be charged with the responsibility for the:

* Site, design, construct and operate national radioactive waste disposal facility/facilities
* Manufacture, acquire, treat, store, transport and dispose of any radioactive substances;
* In collaboration with the stakeholders, define the Radioactive Waste Management policy for the long-term management of radioactive waste for different waste streams;
* Implementation of the national policy on the management of radioactive waste and spent nuclear fuel and regularly inform the Federal Government of the programme’s progress;
* The Commission in conjunction with the competent authority draws up a strategy for the management of radioactive waste and spent nuclear fuel and have the strategy implemented after obtaining approval of the Federal Government.
* Implementation of institutional control of closed disposal facilities, including radiological monitoring and maintenance as appropriate on behalf of Government.

**Strategy Implementation**

*Waste Management Facilities*

Facilities designated and licensed by the Nigeria Nuclear Regulatory Authority for pre-disposal management of radioactive waste and Spent Nuclear Fuel on site as well as a centralized waste treatment and storage facility at national level are required for safe, secure and sustainable pre-disposal management of waste.

Disposal facility to ensure final end point of waste management will be required bearing in mind the waste types and streams.

*Inventory of Radioactive Wastes and Spent Nuclear Fuel, including NORMs*

A comprehensive inventory of all waste streams will be required at the national level by the Waste Management Organization for sustainable management and planning purposes. The individual waste generators should be able to provide correct estimate of waste types in their custody at all times. Estimates should include future arising.

**Technical Steps**

1. On site waste management

All radioactive wastes that are not expected to decay to clearance levels within one year from the time of its generation are transferred from the waste generator to the designated radioactive waste management facilities for proper management.

* Facilities must be licensed to handle Radioactive Waste or spent sources on site
* Initial characterization, segregation and interim storage (decay) are allowed.
* Clearance/discharge, packaging, labeling and identification of waste are done before waste transfer.
* Record keeping and maintenance of log book and inventory are necessary.
* Packaging to comply with transport regulations and Waste Acceptance Criteria of the designated centralized waste treatment and storage facility.

1. Management at the designated/centralized waste treatment and storage facility.

* All waste types received at this facility must comply with already established Waste Acceptance Criteria (WAC) at this facility. Proper record keeping and documentation processes are taken into account.
* Pre- treatment of received waste
* Treatment
* Conditioning
* interim storage
* Long-term storage

The designated/centralized waste treatment and storage facility should be capable of packaging conditioned waste designated for disposal to comply with transport regulations and Waste Acceptance Criteria for the disposal facility or repository.

**Infrastructure Development for Radioactive Waste and Spent Nuclear Fuel Management in Nigeria**

*Current Status of Infrastructure Development for Management of RW and SNF*

There is no infrastructure dedicated to the long-term waste management deployed in Nigeria as at present. However, for the purpose of long-term planning of radioactive waste management infrastructure development, the following have been considered.

Presently there is a Radioactive Waste Management facility at the Centre for Energy Research and Training (CERT) Ahmadu Bello University Zaria developed for temporary storage of Disused Sealed Radioactive Sources and retrieved orphan and legacy sources pending their repatriation, eventual containment, final storage or disposal.

* A Waste Treatment and Storage Facility for treatment and temporary storage of low and intermediate level radioactive waste is being developed at the Nuclear Technology Centre (NTC) Sheda, Abuja to:
  + Serve as a central collection station and processing of institutional wastes generated all over the country through applications of radio-nuclides in Research, Agriculture, Medicine and Industry, including wastes from Research Reactor.
* Management of Radioactive Waste and Spent Nuclear Fuel from power reactors is expected to be carried out at the Nuclear Power Plant site (pending the activation of the Waste Management Organization).

**Long Term Planning for Radioactive Waste Management Infrastructure Development in Nigeria**

*Strategy Framework*

The strategy framework statement specifies the waste management options to be adopted, the waste management end points and the development and implementation of site/waste stream/category specific waste management strategy in Nigeria.

*Waste Management Options*

The main waste management options to be adopted in Nigeria are:

* Return of spent sources including *spent nuclear fuels (from Research and power Reactors)* to suppliers
* Interim storage of radioactive waste prior to clearance, discharge, predisposal management or disposal
* Clearance
* Authorized disposal/discharge;
* Authorized re-use or transfer to another user;
* Regulated storage and
* Regulated disposal;

Arrangements are being made ensuring that contractual agreements for the supply of sources and fuel rods cover the return of same to the supplier after they are declared spent by agreed authorities.

In the case of authorized disposal/discharge, re-use/transfer to another user and clearance, the following category specific factors specified by the regulatory bodies:

* Pre-treatment and treatment requirements;
* Conditions and criteria for disposal / discharge / re-use / transfer to another user and clearance; and
* Criteria and condition verification methodology.

*Waste Classification Scheme*

The following classification schemes are adopted in the pre-disposal management operations and control:

* Exempt Radioactive Waste (ERW): This waste contains small concentrations of radionuclides that do not require provision for radiation protection.
* Very Short-Lived Radioactive Waste (VSLRW): Waste that can be stored for decay over a limited period of up to a few years and subsequently exempted from regulatory control specified and approved by the regulatory authority.
* Very Low-Level Radioactive Waste (VLLRW): Waste that is of low activity but contains some radionuclides that are long lived.
* Low Level Radioactive Waste (LLRW): Waste that has activity concentration higher than VLLRW and contains radionuclides whose half-lives does not exceed 30 years.
* Intermediate Level Radioactive Waste (ILRW): Waste that contains long-lived radionuclides that may not decay to an activity concentration that is acceptable for near surface disposal within reasonable period.
* High Level Radioactive Waste (HLRW): Waste that has requirement for heat removal and possesses concentration of alpha emitters that exceed the limitations of VLLRW. SNF falls within this category.

*Radioactive wastes are characterized according to the following properties:*

1. Physical (solid, liquid, gaseous, sealed sources, medical waste)
2. Chemical composition (liquid aqueous, liquid organic)
3. Radiological (activity concentrations, half-lives)
4. Biological (organic matter)

*Radioactive Waste Processing*

Radioactive wastes that are not removed under regulatory control (exempted/cleared) will be processed for further consideration. There are three major steps involved in radioactive waste processing and are be observed at all waste management facilities.

* *Pre- treatment of radioactive waste*

Pre-treatment activities include collection, characterization, segregation, chemical adjustments and decontamination. For this initial step, waste streams are expected to segregate at the place of generation and adequate waste identification and classification be performed to comply with the waste acceptance criteria of a designated waste treatment and storage facility.

* *Treatment of radioactive waste*

This involves operations that provide for safety and/or economy by changing the characteristics of waste type. The basic treatments applicable are volume reduction, removal of radionuclides and change of composition. Treatment of waste is only allowed to be done at a designated waste treatment and storage facility.

* *Conditioning of radioactive waste*

This involves those operations that convert the processed waste into a form suitable for handling, transport, storage and disposal. The operation may include immobilization of the waste in a matrix, placing it into a container and providing additional packaging.

*Waste Management End-Points*

The main waste management end-points correspond with the waste management options and may be regarded as the outcome of a specific waste management option. Regulated disposal requires continued regulation of the disposal site for a predetermined duration after which the site will be placed under institutional control.

The following constitutes the end points for radioactive waste management:

* Near-surface disposal of low-level wastes (LLW) as it arises: near-surface and/or borehole disposal of disused sealed radioactive source (DSRS) may be considered at the same facility.
* Deep disposal of spent nuclear fuel (SNF) in geologic formation at first opportunity (probably 20-30 years after its production). This also applies to the disposal of intermediate level long lived radioactive waste (ILW-LL).
* Intermediate level short lived radioactive waste (ILW-SL) may go to near surface or deep disposal facilities for the purpose of optimising the use of the facilities. The final choice depends on its nature & volume, properties of the chosen site and the design of the near-surface disposal facility
* Above ground disposal in engineered facilities for the bulk of the mining waste.
* Remediation of mining and milling tailing are carried out as soon as possible
* Oil industry radioactive wastes are investigated by the operators of such facilities and reported to the Nigeria Nuclear Regulatory Authority. If Radioactive Waste Management is needed, oil industry will buy in expertise.

The determination of the specific disposal facility to which a specific waste is being disposed of is on the basis of a safety case and supporting safety assessment developed by the waste generator/waste management operator and approved by the Nigeria Nuclear Regulatory Authority.

*Development of Waste Stream and Site-Specific Radioactive Waste Management Strategy*

The development and implementation of the waste stream and site-specific radioactive waste management strategy by any waste management generator/operator adopts the following scheme:

* Identification of nature of Radioactive Waste and site-specific radioactive waste stream/categories and associated waste management issues.
* Consideration and listing of realistic options for the long-term management of specific radioactive waste management streams/categories.
* Systematic evaluation of the merits and disadvantages of each option (multi-­attribute analysis) covering cost-effectiveness, technological status, operational safety, social and environmental factors.
* Identification of the Cost-Effective Best Available Technology Ensuring Safety (CEBATES)
* Acceptance of CEBATES as waste stream/category specific strategy

The strategy so developed is being reviewed by the National Committee on Radioactive Waste Management (NCRWM) to ensure consistency with this Policy and Strategy Framework and approved by the Nigeria Nuclear Regulatory Authority before its implementation.

*Time Schedules - Significant Milestones and Time Frames for Implementation of the National Plan for Radioactive Waste Management*

Based on the scenario for nuclear infrastructure development, it is planned that the following time lines applies for the development of waste disposal facilities:

* Near-surface disposal facility needs to be operational about five years after the start-up of the new research reactor (about 2025). It shall close when the fourth NPP has been decommissioned by about 2100.

The process of selecting sites for long-term waste management involves a comprehensive public participation process.

**Long-Term Planning of Infrastructure Development for Spent Nuclear Fuel Management**

* *Strategy framework*

The strategy framework statement specifies the spent fuel management options to be considered and eventually adopted, the spent fuel management end points and the development and implementation of site-specific spent fuel management strategy in Nigeria.

* *Fuel management options*

Nigeria does not have spent nuclear fuel presently; however, the only expected source of spent fuel will be from the miniature nuclear reactor facility in CERT (NIRR‐1) and from any other nuclear facilities that will be established in future. The NIRR‐1 fuel was supplied under a Project Supply Agreement (PSA) between the IAEA, China and Nigeria. It is expected that the manufacturers takes back the spent core assembly at the end of its life‐time.

According to the Requirements of the National Policy for Radioactive Waste Management, Spent Nuclear Fuel from the power reactors are considered as a valuable resource. Consequently, priority is given to returning Spent Fuel to the suppliers’ countries. In this respect, the Government initiates investigations into the best long-term option taking into account the development in the field and the provisions of the National Energy Policy.

*Fuel Management End-Points*

If the repatriation of spent fuel to the country of origin is not possible, long-term storage of spent fuel assemblies adequately encapsulated during at least 30 years i.e., by 2050, followed by disposal in a deep geologic repository would be the preferred option. This facility should remain open until 30 years after last reactor has closed.

*Time Schedules - Significant Milestones and Time Frames for Implementation of the National Plan for Spent Nuclear Fuel Management*

Based on the scenario for nuclear infrastructure development, it is planned that the following time lines applies for the development of waste disposal facilities:

Deep geologic repository for Spent Nuclear Fuel and high-level wastes is needed when fuel has been decay cooled for at least 30 years.

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