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Safety Assessment of Low and Intermediate Level Waste Disposal Facility

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1. Introduction

Low and Intermediate Level Radioactive Wastes (LILW) are the byproduct of the use of radioactive materials in medicine, research institutions, industrial use of radioisotopes and the entire nuclear fuel cycle. With increases in global production, accumulation and disposal of LILW due to the growing use of radioactive material, the need for the safe disposal of these categories of waste is obvious in protecting public health and the environment.

In Nigeria, LILW is produced from the use of radioactive materials in the mining, petroleum, medical, research, manufacturing, and the agricultural industries [1]. The wide usage of these materials is expected to drive the inventory of radioactive waste that must be disposed of safely in accordance with international standards. The increase in waste inventory makes the current practice in which disused sources and low-level wastes are stored in small facilities, unsustainable. Near Surface Disposal (NSD) is an option used by many countries for the disposal of radioactive waste containing mainly the short-lived and low concentrations of long-lived radionuclides that make up LILW [2]. Therefore, the construction of a NSD facility in Nigeria for the safe management of LILW now or in the near future is necessary.

To ensure the protection of public health and the environment, a dose constraint of 0.1msv on an individual of critical groups from a radioactive waste disposal facility has been strictly applied by regulatory bodies [4]. In order to help build public confidence, the safety of a NSD facility have to be demonstrated and must answer the burning question "How safe is safe?"

Safety Assessment for Near Surface Disposal facilities has been used to demonstrate safety by evaluating the potential radiological impact of a repository on human health and the environment [2]. The IAEA recommends that Safety Assessment should be an iterative process as accurate data emerges and a robust model is developed to minimize uncertainties and to help build public confidence [3]. This paper demonstrates the safety of a near surface repository by assessing the radiological impact of a hypothetical near surface disposal facility on a receptor meant to represent a person who lives near the facility. To achieve this aim, RESRAD OFFSITE Version 3.2 computer code was used to estimate the total effective dose equivalent (TEDE) from a hypothetical near surface disposal facility via selected pathways.

Generally, safety assessment results are used for regulatory decision making to determine the adequacy of protective actions and to ensure that regulatory criteria are met.

2. Methodology

In order to ensure the long term safety of NSD facilities, the IAEA through the Integrated Safety Assessment Methodology (ISAM) project, presents a coordinated methodology to improve and harmonize the approach to Safety Assessment [3]. Therefore, developing a conceptual model consistent with the ISAM methodology is imperative. This particular assessment has been carried out using the IAEA ISAM approach which is described in Fig. 1.

To achieve the purpose of this study, RESRAD OFFSITE version 3.2 computer codes were employed to calculate the total effective dose equivalent (TEDE) via inhalation, ingestion of plant based food, meat, milk, aquatic foods, soil and drinking water pathway. The software has been significantly improved over the years to make analysis more realistic and reasonably conservative. RESRAD is the industry standard for calculating site cleanup criteria and evaluating the radiological impact of a contaminated site [5]

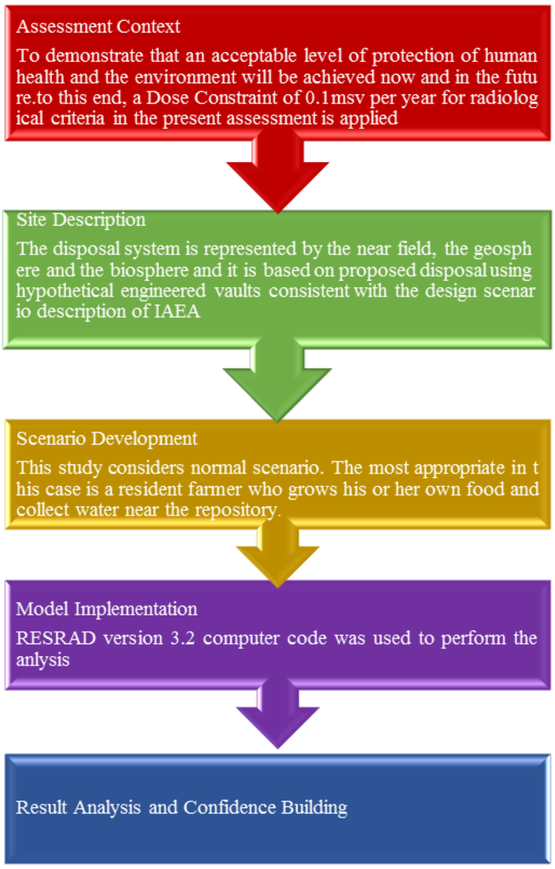


Fig. 1: Key components of ISAM methodology

This paper considers a scenario in which radionuclides leach from the repository after the closure of the facility; this is known as radionuclide migration through the water pathway to an offsite resident. RESRAD models radionuclides migration through the water pathway taking into account horizontal/vertical dispersion, and calculates the radiological impact based on predicted radionuclide concentration. It is assumed that radionuclide reach the accessible environment in three (3) ways [5]

- Released to the atmosphere from the primary contamination.
- Released to surface runoff from the contaminated mixing layer
- Released to groundwater from contaminated mixing layer and from the primary contamination.

Radionuclide Inventory and Site Description

The waste inventory is assumed to contain radionuclides that are commonly used in industry, research and medical applications in Nigeria. Radionuclide inventory and site specific parameters used in this study are presented in Tables 1 and 2.

The waste is assumed to occupy an area of 2500m^2, be 1m thick, uniformly mixed with the soil and be covered by 5m thick of clean soil. With no engineered barriers, degradation was conservatively assumed to begin at time t=0 and a first order released mechanism was used. Also, default values for the Dose Conversion Factor based on ICRP 103 for each radionuclide was used.

Input parameters were selected to produce an unfavorable result from literature review while default parameters were applied appropriately.

Table 1: Radionuclide Inventory

Radionuclides	Half-life (yr.)	Radionuclides concentration (Bq/yr)
H-3	12.34E+00	1000
C-14	5.70E+03	10
Co-60	5.27E+00	1
Cs-137	30.06E+00	1
I-129	1.57E+07	0.1
Nb-94	0.36E+00	1
Ni-59	31.78E+00	1000
Ni-63	1.00E+02	1000
Pu-239	2.40E+02	1
Sr-90	28.81E+00	10
Tc-99	2.11E+05	10

Table 2: Site specific parameter

Parameters	Value
Distance to surface water (m)	450
Precipitation amount m/yr	1.2
Water consumption (l/yr.)	730
Distance from center of contamination to well (m)	300

3. Results and Discussion

The goal of any disposal design option be it trench, vault or landfill, that is based on a near surface disposal concept is to provide an acceptable level of safety during the operational, closure and post closure stages. In this work, the radiological impact in terms of the dose delivered to a receptor via selected pathways located close to a near surface repository is assessed. Although the maximum total effective dose equivalent (TEDE) of 0.0786msv/yr. based on conservative input parameters does not exceed a dose constraint of 0.1msv/year, simulation results show that C-14, H-3, I-129, Tc-99, Nb-94 and Pu-239 are the important radionuclides that contribute to dose levels via the pathways. Fish ingestion and drinking water pathways are the most significant in which dose is delivered to the receptor See Fig. 2 and 3 for more details.

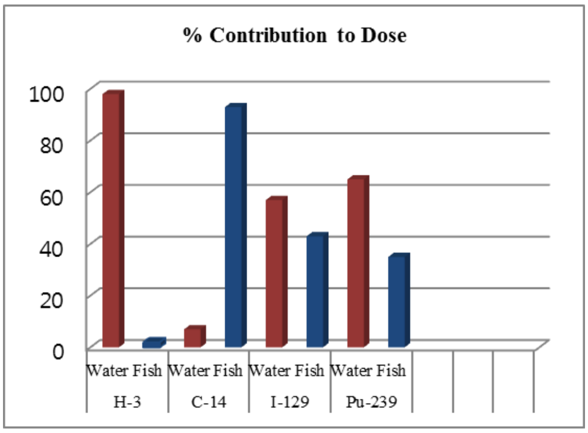
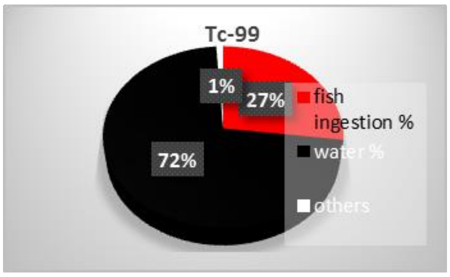


Fig 2: RESRAD output result showing fish and water ingestion pathways for H-3, C-14, I-129 and Pu-239.

Sensitivity analysis was carried out to study the independent influence of the following parameters on the predicted dose; length of waste parallel to aquifer flow, waste inventory, distance of contamination from well, and the thickness of contaminated zone. Sensitivity result shown in Table 3 testifies to the importance of the input parameters and by extension, the site characteristics to the dose levels. Sensitivity results have been used in a graded manner by regulators and operators to focus scarce resources and attention where greatest benefit can be derived.



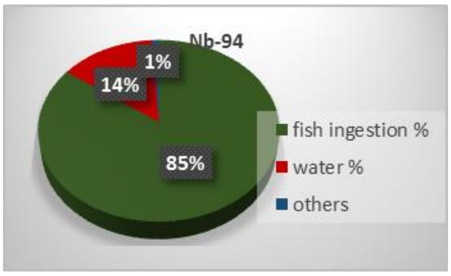


Fig. 3: RESRAD output results for Tc-99 and Nb-94. Approximately 1% of the dose is delivered through ingestion of milk, meat, soil and inhalation

Table 3: Sensitivity Result

parameter	Parameter value	Time of peak dose (yr.)	Maximum dose msv/yr.
Length parallel to aquifer flow	500 250 [b] 125	120 105 95	0.0424 0.0786 0.1782
Thickness of contaminated zone	2 1[b] 0.5	105 105 105	0.1639 0.0786 0.0381
Distance parallel to aquifer from contamination to well	600 300 150	105 105 105	0.0786 0.0786 0.0786
Waste inventory activity	Upper* Baseline Lower**	105 105 105	0.7857 0.0786 0.0007857

**Upper limit: radionuclide concentration was increased by a power of 10*
*** Lower limit: radionuclide concentration was reduced by a power of 10*

In Nigeria, the current practice in which LILW from disused radioactive sources are kept in storage facilities is not only inconsistent with international best practices but is becoming impracticable. For this reason, a decision to construct a near surface disposal facility for LILW seems essential.

In order to ensure the protection of public health and the environment, a Near Surface Disposal Facility must meet the radiological protection criteria of 0.1msv/yr of the predicted dose set out by regulatory bodies. Safety which is the first priority in the management of waste must be demonstrated at all stages to help build public confidence. Equally important is making an informed decision regarding site characterization, waste inventory criteria, disposal design and other important parameters to ensure that the dose constraint is not exceeded.

REFERENCES

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