Utilisation of the IAEA BDC Scoping Tool and AMBER Modelling for Post Closure Safety Assessment for a Proposed Borehole Repository of Disused Sealed Radioactive Sources in Ghana

Paul Essel*, Eric T. Glover, Eric Akortia, Yaw Adjei-Kyereme, Gustav Gbeddy, A.M.A Dawood, Emmanuel A. Aberikae, Evans M. Ameho

Radioactive Waste Management Centre (RWMC), Radiation Protection Institute (RPI), Ghana Atomic Energy Commission (GAEC), P.O. Box LG 80, Legon-Accra, Ghana

*Corresponding Author's email: yawpaul72@gmail.com : IAEA-CN-318_#13

1. Introduction

The use of radioactive materials in various sectors of the Ghana economy over the past six decades has resulted in the generation of disused sealed radioactive sources (DSRSs) that need to be managed safely to ensure the safety of human health and the environment. The DSRSs that contain high radioactivity concentration of long-lived radionuclides need to be disposed of in facilities, such as the deep geological repository to provide high level isolation.

Ghana, however, has a small inventory of DSRSs for which such disposal option is not cost-effective. The Ghana Atomic Energy Commission (GAEC) therefore intends using the International Atomic Energy Agency (IAEA) developed Borehole Disposal System (BDS) which is more effective and efficient in terms of safety and cost for disposal of the limited volume of DSRSs in storage.

The BDS uses intermediate disposal depth (minimum,30m) incorporated with multiple passive engineered and natural barriers to offer safe and secure isolation of DSRSs for thousands of years. These include an inner stainless-steel capsule that contains the wastes, an inner cement containment barrier, and an outer stainless-steel container in addition to an outer backfill cement, besides the surrounding geosphere (Fig 1).

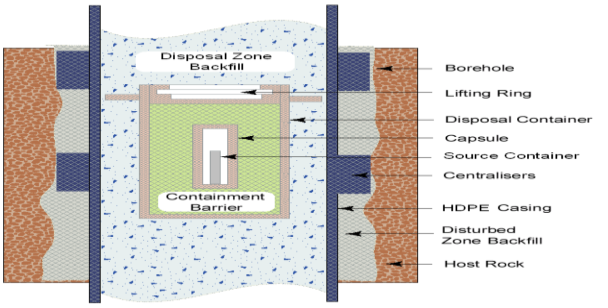

Fig. 1: *An Illustrative section through the Disposal Borehole*

In conducive geochemical subsurface environment, these barriers provide an effective containment and long-term safety by isolating the wastes from the biosphere. The disposal depth besides the small footprint of the borehole enhances the safety and the security function.

A post-closure radiological safety assessment is carried out to demonstrate and evaluate the safety of the disposal facility before a licence is issued for implementation. IAEA BDC Screening Tool and AMBER software developed by Quintessa Limited were used to assess the suitability of the borehole site. This is based on the hydrogeological and geochemical characteristics of the proposed site. Input data for both the IAEA BDC Screening Tool and the AMBER Modelling were derived from site-specific and generic information. A total of 13 waste packages will be required to dispose the inventory of DSRSs made up of Co-60, Sr-90, Cs-137, Ra-226, Am-241and Cf-252 in the borehole disposal facility (BDF).

The 26cm diameter disposal borehole to be constructed is to be drilled to a depth of 150 m deep and fitted with 10mm thick HDPE pipe of 14cm internal diameter. In the disposal zone, the 13 waste packages will occupy a space of approximately 14m with a 0.5 m thick 'plug' of backfill slurry emplaced at the base of the borehole.

2. Methodology

The post closure safety assessment (PCSA) of the Ghana BDF utilised the IAEA BDC Screening Tool and the AMBER Modelling software.

2.1. IAEA BDC Screening Tool

The IAEA BDC Screening Tool (Fig. 2) was used to evaluate the containment provided by the capsule and the disposal container as well as the containment barrier and backfill in the post-closure period. The tool has been used to calculate the duration of each of the cement grout degradation stages based on the hydrogeological and geochemical conditions considered in the PCSA. The failure times for the disposal container and waste capsule for the Design Scenario are given in Table 1.

Table 1: Disposal Container and Waste Capsule Failure Times

Geosphere	*Disposal Container Failure Time (y)*	*Waste Capsule Failure Times (y)*		
		Small Capsule	*Medium Capsule*	*Large Capsule*
Anaerobic	*14548*	*21540*	*21540*	*21540*
Aerobic	*5198*	*7575.5*	*7575.5*	*7575.5*

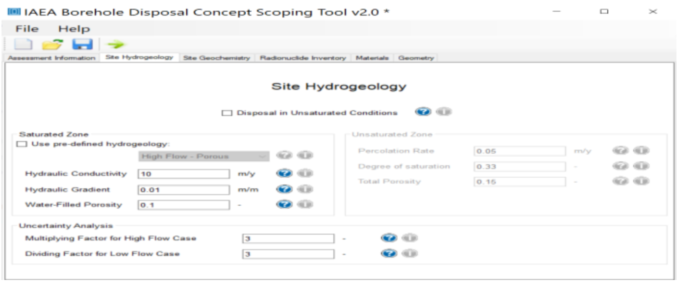

Fig. 2: Graphical user interface from the BDC scoping tool

Site-specific hydrogeological and geological data were used in the scoping tool. Activities of the radionuclides to be disposed were derived from the DSRSs inventory. Results calculated were given in a traffic light system (Fig. 3) indicating the safety status of the disposal system. Maximum dose rate and the time when it happened were also produced. Besides, this tool also provided data on failure time for the source capsule and the disposal container as well as cement degradation time (Fig.3) that were further implemented in AMBER Modelling.

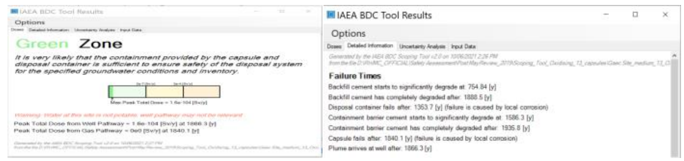

Fig. 3: Assessment Results from IAEA BDC Scoping Tool

2.2. AMBER Modelling

The AMBER software tool (Fig.4) was used to implement the assessment model. In implementing the models and data in AMBER, the aim was to minimise the number of input files that needed to be created and thereby reduce the probability of input errors, facilitate checking and updating, and avoid the replication of data needed by all or most calculation cases (e.g., decay rates and dose coefficients). This was achieved through the use of a series of "literal" parameters as switches to allow variant cases to be easily set up from a common "source" file. Literal parameters used include: TypeScenario – is set to 'Design', and 'Defect; and TypeGeosphere – is set to, 'Anaerobic Porous', Anaerobic Fractured with reducing conditions based on geochemical results from the site.

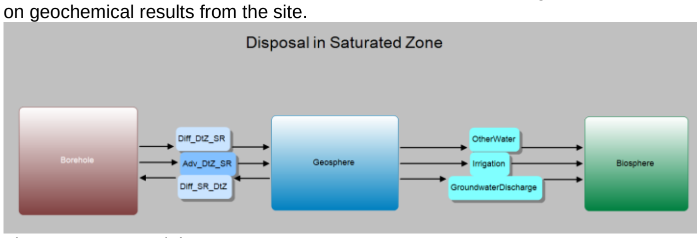

Fig. 4: AMBER Model

3. Results and Discussion

Results from the IAEA BDC Scoping Tool (Fig. 3) indicated that the containment provided by the capsule and disposal container alone was sufficient to ensure safety. From the AMBER modelling, the total peak dose at the end of the institutional control period is 2.2E-12 mSv/y (Fig. 5a). From Fig. 5b, the peak dose from all the disposed radionuclides from the worst-case defect scenario is less than the dose constraint of 0.3 mSv/y.

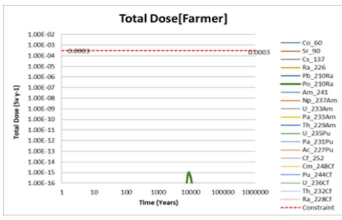

Fig. 5a: Total Dose (Design Scenario)

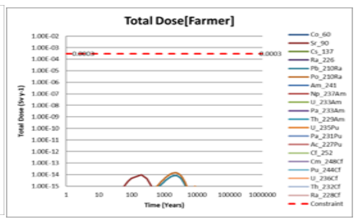

Fig. 5b Worst Case Defect Scenario

The assessment indicates that Ghana's current inventory of DSRSs can be safely disposed of using the IAEA developed borehole disposal system.

4. Conclusions and Acknowledgements

The IAEA BDC Scoping Tool indicated that the borehole and its components were able to provide satisfactory safety to the disposal system. Nonetheless, results on failure times were utilized in AMBER calculations. Calculated results from AMBER Modelling showed that based on the Scenarios considered, the BDF when implemented at the proposed site will meet the safety criteria set by the regulator. The authors would like to thank Mr. Richard Little for his immense support. Special thanks to the IAEA for financial support.