 http://dx.doi.org/10.7733/jnfcwt-k.2013.11.4.293

Borehole Disposal Concept: A Proposed Option for Disposal of Spent Sealed Radioactive Sources in Tanzania

보어홀 처분 개념: 탄자니아의 폐밀봉선원 처분을 위한 제안

Mikidadi Salehe and Chang-Lak Kim*
KEPCO International Nuclear Graduate School, 1456-1, Shinam-ri, Seosaeng-myeon, Ulju-gun, Ulsan, Korea

미키다디 살레히, 김창락*
한국전력 국제원자력대학원대학교, 울산광역시 울주군 서생면 신암리 1456-1

(Received August 23, 2013 / Revised October 7, 2013 / Approved October 29, 2013)

Borehole Disposal Concept (BDC) was initiated by the South African Nuclear Energy Corporation (NECSA) with the view to improve the radioactive waste management practices in Africa. At a time when geological disposal of radioactive waste is being considered, the need to protect ground water from possible radioactive contamination and the investigation of radionuclides migration through soil and rocks of zone of aeration into ground water has becomes very imperative. This is why the Borehole Disposal Concept (BDC) is being suggested to address the problem. The concept involves the conditioning and emplacement of disused sealed radioactive sources in an engineered facility of a relatively narrow diameter borehole (260 mm). Tanzania is operating a Radioactive Waste Management Facility where a number of spent sealed radioactive sources with long and short half lives are stored. The activity of spent sealed radioactive sources range from (1E-6 to 8.8E+3 Ci). However, the long term disposal solution is still a problem. This study therefore proposing the country to adopt the BDC, since the repository requires limited land area and has a low probability of human intrusion due to the small footprint of the borehole.

Keywords: Borehole Disposal Concept, Spent Sealed Sources, Radioactive Waste Conditioning, Repository

처분공 처분 개념은 아프리카의 방사성폐기물관리 방안의 향상을 위해서 남아프리카에너지주식회사(NECSA)에서 처음으로 제시되었다. 초기에 방사성폐기물의 지층처분방안이 고려되었으나, 지하수를 방사성폐기물 오염으로부터 보호하는 방안과 토양과 지하 암석의 균열지대를 통한 방사성 물질의 이동에 대한 조사가 불가피하게 필요했다. 이러한 이유로 처분공 처분 개념이 연구되었다. 처분공 처분 개념은 폐기된 밀봉선원을 상대적으로 좁은 직경(260 mm)의 처분공 시설을 통해 처리 및 처분한다. 탄자니아는 장반감기 및 단반감기의 폐기된 밀봉선원을 방사성폐기물관리시설에 저장하고 있으며 폐기된 밀봉선원의 방사능은 1E-6 Ci 에서 8.8E+3 Ci의 범위로 분포한다. 그러나 영구 처분 문제는 여전히 해결하지 못하고 있다. 본 연구에서는 처분부지 면적이 적고, 이에 따라 인간침입 위험이 줄어드는 처분공 처분개념을 제시하였다.

중심단어 : 보어홀 처분 개념, 폐밀봉선원, 방사성폐기물 안정화, 처분장

*Corresponding Author.
Chang-Lak Kim, KEPCO International Nuclear Graduate School, E-mail: clkim@kings.ac.kr, Tel: +82.52.712.7333

1. Introduction

Radioactive waste management programme has to be prepared in such a way that the safety objective and criteria for the protection of people and the environment against radiation risks arising from disposal facilities is taken as the fundamental requirement for radioactive waste in operation and after closure. A long term management of radioactive waste requires the disposal of the waste in a system that will prevent all forms of contamination and access to human. Such is the Borehole Disposal Concept (BDC). The concept was first developed by the Nuclear Energy Corporation of South Africa (NECSA), and has been accepted and developed further by the IAEA as a safe and secure disposal option as shown in Fig. 1 [1,2].

Tanzania Atomic Energy Commission (TAEC) operates a Central Radioactive Waste Management Facility (CRWMF) in which all un-repatriated radioactive sources and other radioactive wastes are conditioned and stored. However, the long term solution for disposal of the Spent Sealed Radioactive Sources is not yet available. This circumstance triggers a special call for the Borehole Disposal Concept (BDC) establishment in Tanzania, to create a permanent disposal of the radioactive waste available in the country.

The borehole casing stabilizes the borehole; it keeps the repository dry during the operational period while acting as additional barrier to transport of the radionuclides. Backfilling materials will add an additional barrier between the containers and aggressive chemicals, prominently chloride that might initiate corrosion of the stainless steel capsule. The sorptivity nature of the backfilling material makes it act as a chemical buffer to intrinsically limit or reduce the release of radionuclides to the geosphere; it will also form a physical and a hydrological barrier through which leached radionuclides must pass before they are released into the immediate surroundings [3].

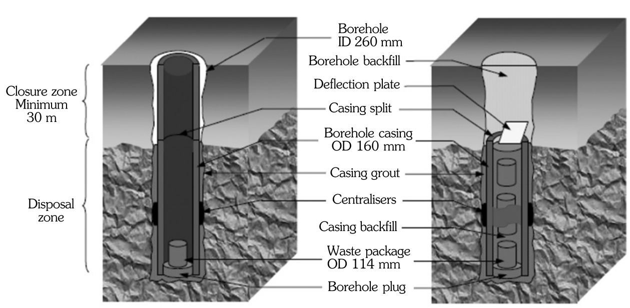

Fig. 1. A Schematic representation of the borehole disposal concept showing emplaced radioactive waste and engineering barriers.

2. Planning for the BDC

Planning for establishment of radioactive waste disposal facility such as a borehole in practice, not only requires a demonstration of compliance with safety and technical requirements, but at the same time consideration of a number of non-technical factors, such as the involvement of stakeholders like public, non-governmental organizations and the balancing of costs and benefits.

2.1 Public participation:

Public participation may be required during the process of environmental impact assessment. The participation process will depend on the approval requirements of a country with regard to environmental impact assessment (EIA) and licensing of the concept. The purpose of involving public is to create awareness and to seek approval for immplimantation of the concept in a selected site. Further sensitization programme on nuclear safety and security and other nuclear related issues of concerns may also arranged.

2.2 Legal and Organizational Framework

The development of a borehole disposal facility should be carried out in compliance with relevant national regulations[4]. However, the Tanzania Atomic En-

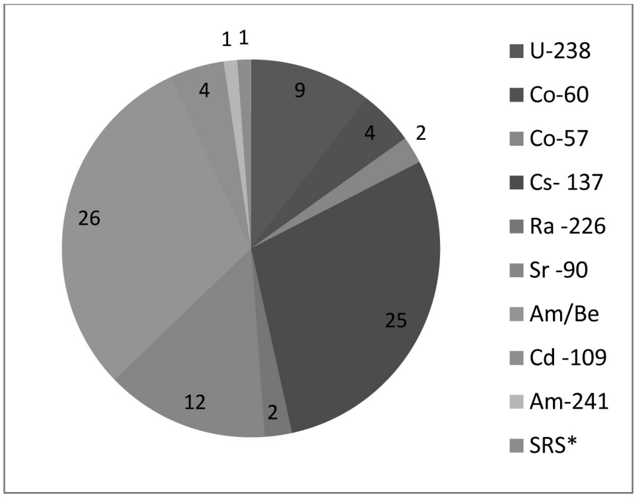

Fig. 2. Number of Sources and Radionuclide type in TAEC (CRWMF).

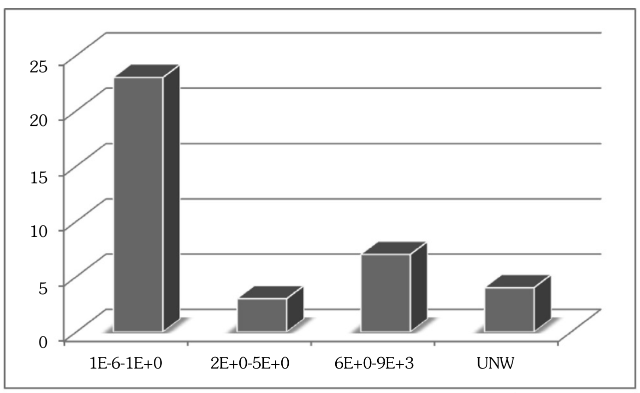

Fig. 3. Activitiy Ranges of the Radioactive Sources against Number of Sources.

ergy Commission (TAEC) which is the government body responsible for the atomic energy matters in Tanzaina, operates under the atomic energy Act No. 7 of 2003, of which the radioactive waste management issues has been reflected. On the other hand, the general regulations, the Atomic Energy (Protection from Ionising Radiation) Regulations 2004, are comprehensive and largely consistent with the international Basic Safety Standards (BSS) and TEC-DOC 1067. Specific regulation for radioactive waste management (Radioactive Waste Management for the Protection of Human Health Regulation 1999) is also in place.

2.3 Regulatory process

Regulation of borehole disposal should be consistent with the safety requirements of the particular country. In some countries a “license to construct” will first be issued followed by a license for “disposal”. In other countries however, the approval process may be consolidated into one single approval. Notwithstanding the respective licensing regimes, an eventual license is required before disposal of disused sealed radioactive sources in the borehole could take place. In most countries, an Environmental Impact Assessment (EIA) will be required as part of the regulatory approval process. Part of this will entail a public participation process[1,4]

2.4 National Inventory

The United Republic of Tanzania is actively implementing the radioactive waste management activities including the updating and safe storage of the inventory of spent sealed radioactive sources. The disused/ spent radioactive sources which were collected to the CRWMF before September 2009 were conditioned through IAEA– NECSA technical expert and SHARS Mission. The spent Radioactive Sources involves high activity and low activity, as well as long lived and short lived radioactive sources as shown in Fig. 2 & 3. The seven canisters (illicit trafficking sources) suspected to contain U-238 were not conditioned during the SHARS Mission in October 2009 due to the lack of appropriate equipments in the waste facility to verify whether the canisters contain uranium or other materials. Table 1 is the national inventory showing some features of the radioactive sources.

3. Conditioning of Spent Sealed Radioactive Sources

In the BDC system, conditioning is the placing of

Table 1. National Inventory of Spent Sealed Radiactive Sources

Radionuclide	No.of source	Total Activity in Curie (Ci)	Application	Form
^{60}Co	1	1.0 E + 1	Teletherapy	Conditioned
	1	1.8E + 1	Teletherapy	Conditioned
	1	0.5 E + 1	Brachytherapy	Conditioned
	1	2.6 E - 1	Brachytherapy	Conditioned
^{137}Cs	17	0.475E+1	Industrial gauges	Conditioned
	2	1.432E+3	Biological Irradiator	Conditioned
	1	1.583E+3	Biological Irradiator	Conditioned
	1	1.583E+3	Biological Irradiator	Conditioned
	1	8.0 E - 3	Moisture Gauge	Conditioned
	1	8.0E - 3	Moisture Gauge	Conditioned
	1	6.0E - 2	Moisture Gauge	Conditioned
	1	Unkown	Moisture Gauge	Conditioned
^{226}Ra	1	9.46E -2	Brachytherapy	Conditioned
	1	5.0E - 6	Calibration	Sealed
^{90}Sr	7	9.84E - 4	Thickness gauge	Conditioned
	1	2.0 E - 2	Thickness gauge	Conditioned
	1	2.0 E - 2	Thickness gauge	Conditioned
	1	1.0E - 4	Calibration	Conditioned
	1	1.0E - 4	Calibration	Conditioned
	1	1.0E - 6	Research	Sealed
Am/Be	20	3.42E + 0	Moixture gauge	Sealed
	1	8.1E - 10	Moixture gauge	Sealed
	1	8.8E + 1	Moixture gauge	Sealed
	1	8.8E + 1	Moixture gauge	Sealed
	1	1.0E - 2	Moixture gauge	Sealed
	1	1.0E - 2	Moixture gauge	Sealed
	1	4.0E - 2	Moixture gauge	Sealed
		4.0E - 2	Moixture gauge	Sealed
	1	2.0E - 1	Brachytherapy	Sealed
	1	0.5E + 1	Neutron activation Analysis	Sealed
^{109}Cd	1	2.5E - 2	Analytical techniques	Sealed
	1	2.5E - 2	Analytical techniques	Sealed
	1	2.5E - 2	Analytical techniques	Sealed
	1	0.2E - 4	Analytical techniques	Sealed
^{57}Co	1	1.6E - 2	Analytical techniques	Sealed
	1	1.6E - 2	Analytical techniques	Sealed
^{241}Am	1	Unkown	Analytical techniques	Sealed
Suspected Radioactive Sources (SRS*)	1	Unkown	Illicit trafficking	Lead containers
Suspected ^{238}U	9	Unkown	Illicit trafficking	Lead containers

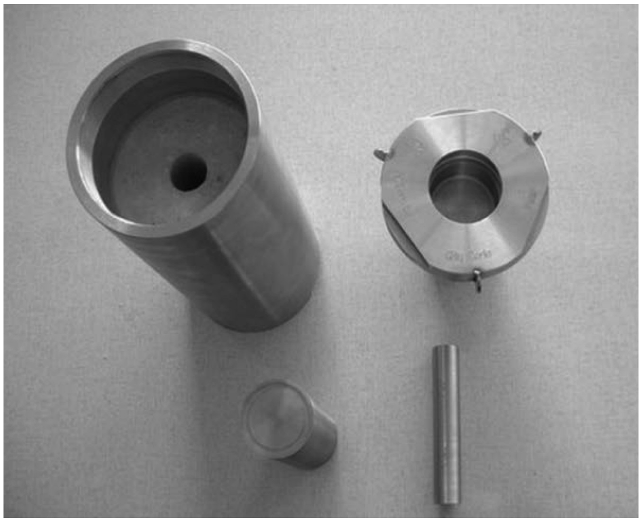

Fig. 4. Disposal container and lid (top row) and two sizes of capsule with lids in place. The scale may be judged from the diameter of the container, which is 114 mm. Note also the precastconcrete buffer that lines the inside of the container.

one or more spent SRS within a 316 L stainless steel capsule that is subsequently seal welded as shown in Fig. 4. Prior to 2001, some capsules for radium conditioning were made from 304 stainless steel, which is similar to 316 L, but with slightly inferior properties with respect to localized corrosion. Capsules are 3 mm thick and currently manufactured in one length and two diameters to accommodate different physical sizes of source.

Conditioning provides: a) Conversion of the Spent SRS to a special form radioactive material (in the sense of the IAEA transport regulations); b) Proper documentation for the Spent SRS; c) Physical protection from damage and radionuclide release; d) A standard sized package that is more easily handled. All this, greatly facilitates, and improves the safety of, subsequent transportation, storage and disposal [5,6].

Packaging is the placing of a stainless steel capsule (containing one or more Spent Sealed Radioactive Sources) into a stainless steel disposal container which is cylindrical, 114 mm outside diameter, 250 mm long, 6 mm thick and made from type 316 L stainless steel. The purpose of packaging is to convert the conditioned Spent Sealed Radioactive Sources into a disposal package [6,7]. As with conditioning, packaging will be carried out in either the conditioning unit or in the BDC portable hot cell. The BDC design allows only one capsule per container. It is possible that this could increase in future.

A disposal container will be prepared to receive its capsule by first labelling it indelibly so that it, and its contents, can be identified uniquely. Also, the concrete buffer insert is cast into place: capsules are made in two diameters and the insert will be designed to fit whichever one is appropriate. If the portable hot cell is being used, the disposal container is then posted into the cell.

Following packaging, the disposal container will be transferred to the borehole. The conditioning unit has an overhead crane that extends from the working area to the adjacent borehole. In container filling/storage zone, the disposal container can be placed on the crane and then run out of the conditioning unit so that it hangs directly over the borehole from where it can be emplaced. This will allow a containerized SRS to be lifted quickly from its temporary shield then, with the operators standing at a distance, moved directly to the borehole and lowered into it.

4. Conceptual Design and Safety Approach

Development of borehole concept may take several time starting from siting, designing, construction, operational management and closure. The decisions will be made on the basis of the information available at the time and the confidence that can be placed in that information. On the other side, the legal frame work of the country will influence the decisions to develop the facility as well as the availability of a suitable host geology.

Borehole disposal facility should be sited, designed and constructed so that, when closed, the post-closure safety of the facility will not depend on actions that would need to be taken after the closure. This allows the facility to comply with the requirements concerning passive safety. The requirement to provide for safety by means of passive design features means that for the post-closure period there should be no need for active management of a borehole disposal facility once this phase is reached. For boreholes of an intermediate depth (i.e. boreholes where the waste is placed more than 30 m below the surface), the natural and engineered characteristics of the closed disposal system should be sufficient, on their own, to ensure the safety of the waste and the protection of people and the environment.

In the case of near surface boreholes (where waste is less than 30 m below the surface), institutional control to reduce the risk of human intrusion may also be an element of the safety case. Near surface boreholes are not likely to be suitable for waste that would pose unacceptable risks associated with human intrusion or security [8,9]. The national inventory provided indicates that, there are at least 95 Spent Sealed Radioactive sources in the CRWMF. However, some of these SSRSs have not yet conditioned. With this number of SSRSs, the 30 m Borehole Disposal might be the appropriate size for the country at the moment.

4.1 Site Location and Description

The site for the facility is located at the Tanzania Atomic Energy Commission's site, Block J Njiro-Arusha Municipal in Arusha Region as shown in Fig. 5. The area lies within latitude: 3° 23' South, longitude: 36° 40' East and latitude 3.367° South, longitude 36.683° East [10]. Altitudes throughout the region vary widely, but much of it ranges from 900 to 1,600 metres (3,000 to 5,200 ft) in elevation.

The Region has moderate, salubrious temperatures. The average annual temperature is 21°C in the highlands and 24°C in the lowlands. Arusha region has two types of rainfall patterns: Monomodal and bimodal. The southern Districts nomally enjoy monomodal rainfall which usually starts in November and end in April. The

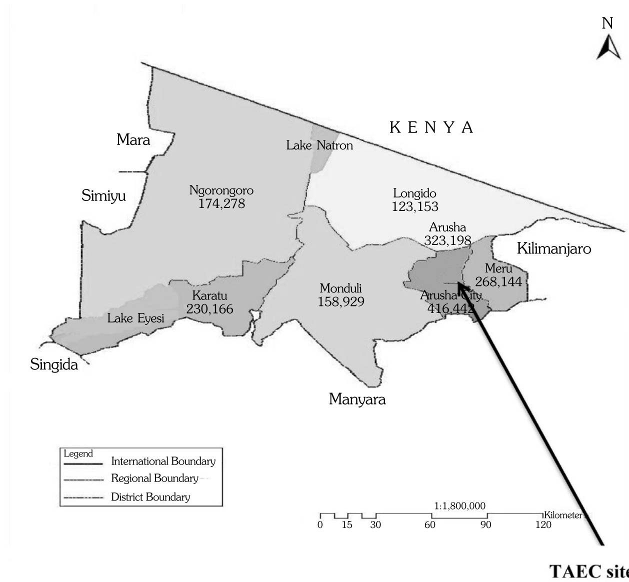

Fig. 5. Arusha Municipal Map.

rainfall in these Districts is usually reliable, ranging from 800-1000 mm.

The other districts like Arusha Municipal, Arumeru, Monduli, Ngorongoro and Simanjiro usually get both short and long rains. The short rains normally start in October and end up in December, while the long rains start in February and end up in June. The lower areas of Arusha Municipal where site (TAEC) is located is mainly Semi-arid, occupied by small farmers and pastoralists [11].

Soils have been classified by colour, i.e. grey, brown and red brown. Brown soils cover large areas in the central part of the region and west of Arusha municipality. The south-eastern areas are characterized by grey/brown and red/brown soils. The south-eastern areas are characterized by grey/brown and red/brown soils. Soil erosion is particularly severe in the heavily settled central part of the region and in the areas heavily utilized by stock. Generally soil erosion is widespread throughout the region. There are four natural vegetation zones-woodland bushlands, wooded grasslands, bushed grasslands and open grasslands, all of which cover 80% of the region[12].

4.2 Preparation of the Conceptual Design and Safety Assessment for BDC in Tanzania

The purpose of having the Borehole Disposal facility in Tanzania is to dispose spent sources using a borehole disposal concept. The conceptual design of the facility should therefore contribute to the general aim of the safety concept for near surface disposal systems. Fundamental aspects to take into consideration in the design of the facility are:

- The dimensions of the borehole should allow for the disposal of spent sources in suitable waste packages;
- The design of the borehole should take into consid eration the operational requirements, e.g. waste em placements should be able to take place as a matter of routine over the period during which it operates;
- The design should minimize the need for active maintenance after site closure and compliment the natural characteristics of the site to reduce environ mental impact; and
- Human intrusion (advertent and inadvertent) should be difficult.

Conceptually, the disposal concept comprises a borehole drilled down to a depth of several tens of metres.

The borehole will be constructed using the percussion drilling method. As shown in Fig. 6, it is a 260 mm (26 cm) diameter borehole through the weathered zone that is telescoped to 209 mm diameter in the hard rock zone. A 255 mm casing will be fitted through the weathered zone to keep loose material from falling in. A 158 mm PVC casing will be fitted to the bottom of the borehole, where it will be driven through a wet cement plug.

Due to possible corrosiveness of the water/soil, the borehole casing will be a PVC casing. PVC casings are comparable in terms of cost and availability with carbon steel casings. To ensure that the disposal volume is dry during the operational period, a bottom plug is provided. The disposal area can be fenced off to limit access, and a temporary site office can be erected. The borehole will not be fitted with a cap; the top 3 m will be filled with topsoil to conceal the location of the borehole. The concrete backfill will also serve as a plug.

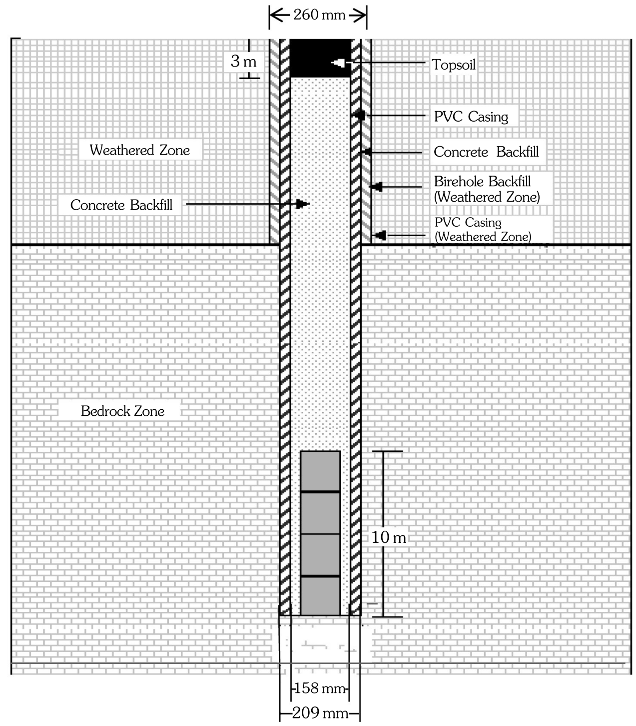

Fig. 6. The conceptual design of the borehole that will be used for the disposal of spent sources.

4.3 Exposure Scenarios for Safety Assessment of the BDC

The purpose of the safety assessment is, amongst others, to evaluate the borehole disposal concept under specific site and land use conditions. The site conditions for the BDC involves the implementation of the borehole disposal concept in unsaturated condition in a semi-arid environment. The land use condition for the BSC site described in this case, considers the continuation of current land use patterns, which is characterised by small farms, agricultural activities and animal keeping to the extent supported by the local climate. With this condition as part of the assessment context, it will be possible to follow a simplified approach to scenario generation and justification. The following three exposure scenarios were consequently defined for the BSC assessment:

· Member of public (farmer) with an abstraction well (variants on distance of well from disposal borehole and unsaturated zone);
· Member of public (farmer) with plan to dig the water borehole (variants on unsaturated zone); and
· Member of public (animal keeping).

From these scenarios it is clear that two critical groups or receptors are of concern. The first two considers a present day farmer and the other a negative social development to a more traditional animal keeping life style. In addition to these three land-use based scenarios, a fourth scenario is added for consideration, namely: inadvertent human intrusion.

The next step for safety assessment will be started from the development of the necessary conceptual models for the consequence analysis.

4.4 Staged Construction of Borehole Disposal

The increase in number of the road construction projects, mining activities and the discovery of natural gas in the Southern deep sea of Tanzania, recently has contributed much to boost the use of the Sealed Radioactive Sources imported to the country for gauging and well logging purposes. The number has been realized through the importation licenses issued to the road construction companies, mining and oil/gas exploration companies and the recently national inventory of the sealed radioactive sources conducted by Tanzania Atomic Energy Commission (TAEC) which is the National Authority responsible for the Atomic Energy Matters in the Country. The operation of the disposal facility with the first borehole is needed as alrealy as possible to ensure safety management of the sealed radioactive sources in Tanzania. Then, based on the monitoring of the radioactive waste arising, additional boheholes in the disposal facility would be installed step by step.

5. Conclussion

The size of the BDC described in this paper was suggested according to the current inventory of the Disused Radioactive Sources existing in Tanzania. However, due to presence of the large number of Sealed Radioactive Sources currently used for the different practices in the country, the need for more rooms to accommodate more boreholes in the future is inescapable.

The BDC for the disposal of disused sealed radioactive sources was developed with the specific aim of solving an existing problem in a number of countries, Tanzania being one of them. It is foreseen that the technology developed for the borehole disposal concept could be used and safely implemented by any country possessing small volumes of high specific activity radioactive waste.

The design includes a multi-barrier system that provides chemical and physical isolation and containment. It also provides defense-in-depth, so that should one or two barriers not perform as anticipated, the other barriers will provide the necessary containment. The BDC provides direct and cost effective access to suitable geology, using readily available construction materials and technologies. The repository requires limited land area and has a low probability of human intrusion due to the small footprint of the borehole.

TAEC should build up comprehensive knowledge on repository siting and safety assessment and intiate searching for the appropriate site and safety assessment for the BDC.

REFERENCES

[1] A.M.A. Dawood, Borehole Disposal Concept for Radioactive Waste Disposal–the GAEC Project (2012).
[2] B. NEL, Design for the Borehole Disposal Concept, South African Nuclear Energy Corporation (NEC-

SA) Report, GEA-1623 (2004).

[3] IAEA, Borehole Disposal Facilities for Radioactive Waste, Specific Safety Guide SSG-1 (2009).

[4] IAEA, Safety Considerations in the Disposal of Disused Sealed Radioactive Sources in Borehole Facilities, IAEA- TECDOC-1368 (2003).

[5] L. Prests, Disposal of Disused Sealed Radioactive Sources in Borehole, 2242-C-University Sao Paulo-0548-900 (2007).

[6] IAEA, BOSS: Borehole Disposal of Disused Sealed Sources, IAEA-TECDOC-1644 (2011).

[7] I.E. STEYN, NNR Review Report on the Borehole Disposal Investigation, National Nuclear Regulator Report, BDC-006-NTW (2005).

[8] P. Martin and R.A. Akber, "Radium Isotopes as Indicators of Adsorption-Desorption Interactions and Barite Formation in Groundwater", Journal of Environmental Radioactivity, 46, pp. 271-286 (1999).

[9] IAEA, Management of Spent High Activity Radioactive Sources(SHARS), IAEA-TECDOC-1301 (2002).

[10] A.S. Macheyeki, "Fault Kinematics and Tectonic Stress in the Seismicallyactive Manyara–Dodoma Rift Segment in Central Tanzania –Implications for the East African Rift", Journal of African Earth Sciences, 51, pp. 163–188 (2008).

[11] URT Government Report, Arusha Regional Social Economic Profile, RC Office Arusha (1998).

[12] A.E. Howard, A Brief Introduction to the Geology and Mining Industry of Tanzania, SIKA Resources INC, Canada (2011).