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BOREHOLE DISPOSAL OF SPENT RADIATION SOURCES: 1. PRINCIPLES.

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Abstract

Large numbers of spent radiation sources from the medical and other technical professions exist in many countries, even countries that do not possess facilities related to the nuclear fuel cycle, that have to be disposed. This is particularly the case in Africa, South America and some members of the Russian Federation. Since these sources need to be handled separately from the other types of radioactive waste, mainly because of their activity to volume ratio, countries (even those with access to operational repositories) find it difficult to manage and dispose this waste. This has led to the use of boreholes as disposal units for these spent sources by some members of the Russian Federation and in South Africa. However, the relatively shallow boreholes used by these countries are not suitable for the disposal of isotopes with long half-lifes, such as ^{226}Ra and ^{241}Am. With this in mind the Atomic Energy Corporation of South Africa initiated the development of the BOSS disposal concept – an acronym for Borehole disposal Of Spent Sources – as part of an International Atomic Energy Agency (IAEA) AFRA I-14 Technical Corporation (TC) project. In this paper, the principles of this disposal concept, which is still under development, will be discussed.

1. REQUIREMENTS OF THE DISPOSAL CONCEPT

The BOSS disposal concept is intended to provide a solution specifically for the disposal of spent sources and therefore must take into consideration the size and number of the sources (i.e. the volume) that needs to be disposed. Several countries world-wide lack a nuclear infrastructure that can control sophisticated disposal facilities. What they need is a disposal concept that is technically feasible and economically viable to implement, taking the equipment at their disposal and their financial situation into consideration. Nevertheless, it is important that the concept should comply with the safety objectives of radioactive waste management [1]. Particular attention should therefore be paid to the design of the repository and its operational requirements. For example, it would be advantageous if waste could be emplaced routinely over the life-span of the repository, that the need for the active maintenance after site closure could be minimized, and that human intrusion (purposefully or inadvertently) is difficult.

2. WASTE CHARACTERISTICS

The main aim of the BOSS disposal concept is to provide a solution for the disposal of both short- and long-life radionuclides, particularly isotopes such as ^{226}Ra and ^{241}Am. Table I list a typical inventory of spent sources from a country for which the BOSS disposal concept would be suitable.

3. FEATURES OF THE DISPOSAL CONCEPT

The conceptual repository for the BOSS disposal concept consists of a standard 165 mm diameter borehole drilled to a depth of 100 m, as shown in Figure 1, with a 150 mm casing. However, wider and deeper (or shallower) boreholes can be drilled if required, depending on site-specific conditions and the sources to dispose. Some guidelines for drilling the boreholes are discussed in [2]. The borehole and screen should be sealed off with a cement plug at the bottom to ensure that the disposal volume remains dry during the operational period. The disposal area can also be fenced in to limit access, and a temporary site office erected if necessary.

The disposal of the waste packages will be limited to the bottom 50 m of the borehole and the rest backfilled with concrete to close the repository and prevent human intrusion. Cement sludge will be poured over the waste package after its emplacement as backfill. A casing constructed from radiation resistant PVC is argued to be the most suitable for the purpose, due to its small mass per unit length and potential shielding power (especially to neutrons). It follows from the preceding discussion that the disposal concept is, by definition, a near-surface disposal concept.

TABLE I A TYPICAL INVENTORY OF SPENT SOURCES FOR WHICH THE BOSS DISPOSAL CONCEPT WOULD BE SUITABLE. (ALL DIMENSIONS REFER TO THE HEIGHT AND DIAMETER OF A CYLINDER.)

Isotope	No. of Sources	Activity per Source (GBq)	Total Activity (GBq)	Dimensions (mm)	Application
^{192}Ir	22	3.700E+03	8,140E+04	3x3	Gammagraphy
^{60}Co	2	3.700E+00	7,400E+00	3.2x3	Level Gauges
^{57}Co	4	1.850E-04	7,400E-04	–	Medicine
^{137}Cs	11	2.775E+00	3,053E+01	6x4	Gamma densitometers
	5	5.550E+01	2,775E+02	6x4	Well Logging
^{241}Am	560	1.850E-04	1,036E-01	60x5	Smoke Detectors
	9	5.550E-04	4,995E-03		
^{226}Ra	6	3.700E-03	2,220E-02	100x35	Calibration
	3	1.110E-04	3,330E-04	70x50	Teaching
^{238}Pu	1	3.700E+00	3,700E+00	20x50	Static Electricity Removal
^{241}Am/Be	5	1.850E+00	9,250E+00	10x10	Humidity gauge

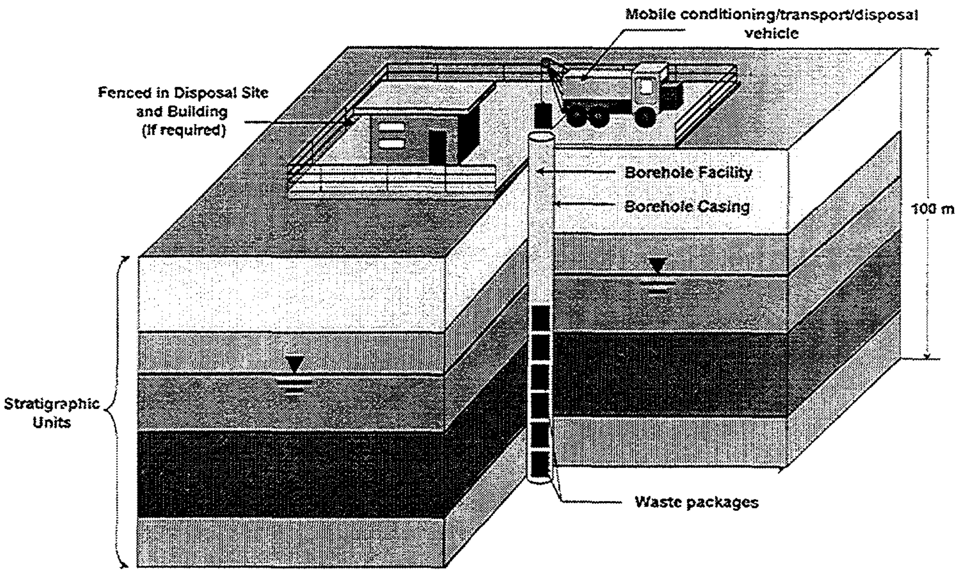

FIG. 1. Schematic presentation of the repository area of the BOSS disposal concept.

4. DESIGN OF THE DISPOSAL WASTE PACKAGES

The nature and construction of the waste packages can play a very significant role in the safety of the BOSS disposal concept, especially as an engineered barrier, but also to handle and transport the packages.

A large proportion of spent sources consists of radium needles. These needles are tubes of platinum, platinum-iridium, or (more rarely) gold, which contain soluble salts of radium [3]. Since the needles often tend to leak [4], the IAEA recommended that they be encapsulated, using the techniques described in [2] and [4]. The capsules recommended for this purpose are tubes with an outside diameter of 21.23 mm, length of 110 mm and wall thickness of 2.77 mm, constructed from Type 304 stainless steel [4].

The approach followed in developing the BOSS disposal concept was to set a reference waste package design. There is little doubt that ^{226}Ra is the most demanding isotope to provide for in a disposal concept for spent sources. A waste package suitable for ^{226}Ra should therefore also be suitable for the other isotopes of importance, such as ^{60}Co, ^{137}Cs, and ^{241}Am. With this in mind, each of the stainless steel capsules containing the ^{226}Ra needles will be placed in a cementatory waste form within another Type 304 stainless steel container with outside diameter 114.3 mm, length 250 mm and wall thickness of 3.04 mm, as illustrated in Figure 2.

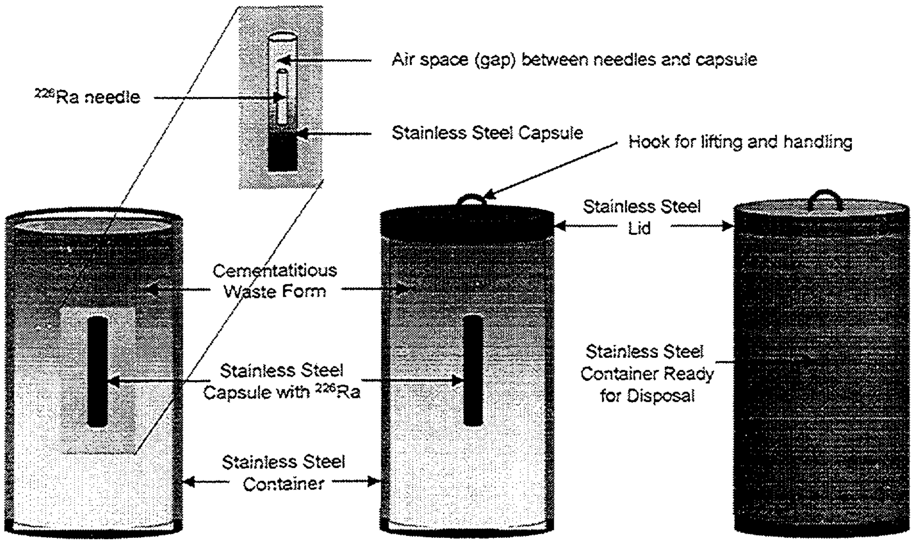

FIG. 2. Various stages in the preparation of waste packages proposed for the disposal of spent sources in the BOSS disposal concept.

Once the waste package is closed and without any leaks, it is ready for disposal, as depicted in Figure 3. This means that each waste package will be separated from it's neighbour by a cement layer of 750 mm in the borehole. A single package and its backfill will therefore occupy a length of 1 m in the borehole, so that 50 waste packages can be disposed off in a borehole with the standard dimensions proposed for the BOSS disposal concept. The inventory and the site characteristics, as derived from the waste acceptance criteria for the disposal facility will however, determine the exact number.

There are a number of reasons for proposing stainless steel as the container material and cement as waste form for the reference design in the BOSS disposal concept. Stainless steel is more resistant to corrosion than carbon steel and passivated by high-pH conditions. The general corrosion and pitting corrosion rates are therefore expected to be low, so that the containers do not need a protective coating. Crack corrosion cannot be excluded, however, particularly in groundwater with a high chloride content. It is estimated that stainless steel will in general corrode at a rate of 0.3–1.0 $\mu m\ y^{-1}$ [5] under the alkalic and anaerobic conditions of a repository [6].

The cement, on the other hand, will act as a barrier, first between the container and aggressive chemicals (primarily chloride) and then the capsule and the chemicals, thereby reducing the initiation of corrosion on the capsule. The cement will also provide a physical barrier through which leached radium must pass before being released into the geosphere. It may at the same time provide a chemical buffer, which may limit the release of radium intrinsically [6].

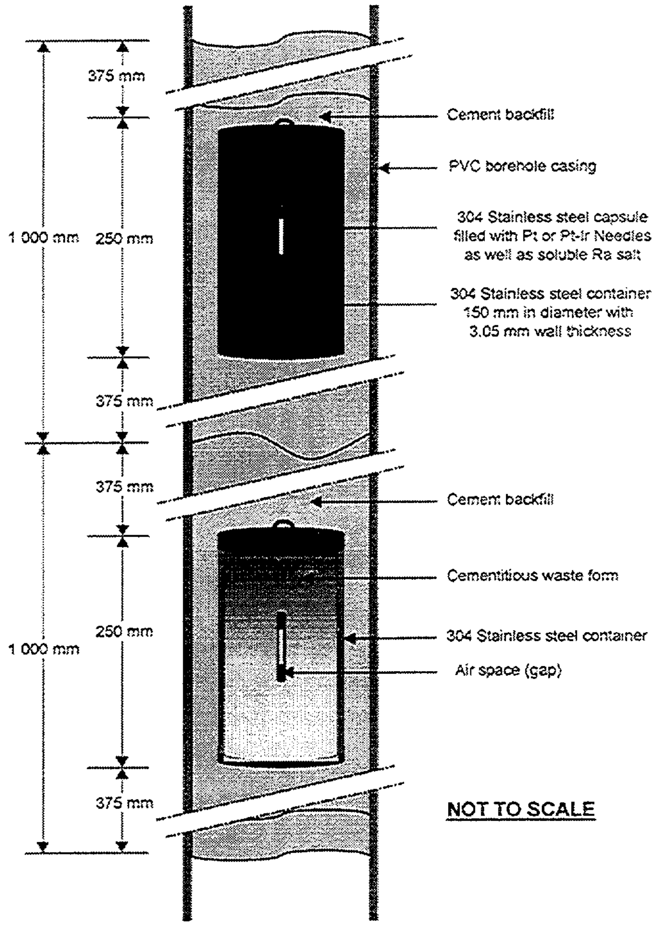

FIG. 3 Schematic depiction of the in situ placement of waste packages with the BOSS disposal concept.

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