RADIOACTIVE WASTE DISPOSAL CHALLENGES THAT FACE THE SOUTH AFRICAN NUCLEAR ENERGY INDUSTRY

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ABSTRACT

The consideration of a comprehensive solution to the problem of future final disposal of radioactive waste in South Africa is inextricably tied to the question of formulation of government policy on the management of high level waste, the development and design of an appropriate repository, and the setting aside of adequate funds in order to carry out the above objectives. These are the three critical challenges that face the South African nuclear industry presently. The recently promulgated Nuclear Energy Act (Act No 46 of 1999) vests the authority over the management of radioactive waste and the storage of irradiated nuclear fuel in the Ministry of Minerals and Energy. A possible final high level waste disposal site has been identified at the Vaalputs National Waste Repository, located some 600 km north of Cape Town in the North West Province. The facility presently operates as a low and intermediate level waste storage medium.

Nuclear waste in South Africa is generated by the Koeberg Nuclear Power Station, located some 30 km north of Cape Town, the research-orientated Atomic Energy Corporation, or the AEC, (now known as the South African Nuclear Energy Corporation Limited) near Pretoria, and the mining and medical fraternities country wide.

INTRODUCTION

In March 1987, a Working Group on the Disposal of High-Level Radioactive Waste in South Africa was inaugurated at Pelindaba, Pretoria, under the Chairmanship of Dr JWL de Villiers (1). The Chairman had made the following far-reaching statement:

> '*We do not foresee the Republic of South Africa (RSA) disposing of high-level radioactive waste until early in the next century – say 25 years or even longer, from now. We, however, judge that in common with other countries having nuclear programs, the time has arrived to review the various scenarios that are open to the RSA in this connection. The mandate of this Working Group is to make recommendations regarding the formulation of an integrated national research and development programme regarding the various technical aspects pertaining to the disposal of high level waste in the RSA. This is therefore essentially a long-term project in the true sense of the word. However, when it is borne in mind that it has nearly taken 9 years to get the low-level waste project operational, it is not too early to start looking at the problems pertaining to the disposal of high level waste.'*

Subsequent to the announcement of the above mandate by the Chairman, five select Study Groups were established and charged with the task of researching certain specific aspects of high level waste technology, as well as to develop criteria relevant to the various relevant sub-disciplines. The five Study Groups were:

- Development of a Deep Geological Repository
- Geological Considerations
- Back-End Options
- Storage/Disposal Options
- Environmental Impact

Within a period of one year since the inauguration of the Working Group, a number of formal Reports were subsequently produced and published by the five Study Groups.

However, despite the above gallant efforts, today, more than a decade later, there is still a radioactive waste management policy vacuum in the country.

SOURCES AND QUANTITIES OF NUCLEAR WASTE MATERIALS IN SOUTH AFRICA

The South African nuclear energy sector is quite small in comparison to those of the country's international nuclear state counterparts. Eskom, South Africa's national electricity utility, accounts for more than half of the total electricity generated in Africa, and almost 98% of the country's electricity. It is the world's fifth largest electricity supplier, with a total nominal capacity of 38 000 MW, and sales of more than 165 000 GWh. Eskom's Koeberg Nuclear Power Station (KNPS), a two unit Framatome PWR 1 840 MW_e plant, accounts for only 5% of total electricity generated in the country, while gas turbine plant accounts for 1%, hydro and pumped storage 5%, and coal fired plant, by far the vast majority contributor, for 89%. The above 5% nuclear contribution to the South African national electricity grid should be compared to the current nuclear share figures of approximately 77% for France, 57% for Belgium, and 52% for Sweden. It stands to reason therefore that the quantities of spent fuel stored in South Africa's spent fuel pools, including that from the AEC's research reactor SAFARI, are small in comparison to our European and other international counterparts.

Koeberg Commercial Nuclear Power Station

The Koeberg Nuclear Power Station has been in operation for the past 14 years, since commissioning in 1986. There are currently about 1000 spent fuel assemblies stored in spent fuel pools on site, as a result of the plant's operation. (Slide. 1: Koeberg Spent Fuel Pool). It is estimated that when the plant is decommissioned at its end of life in about 2030, there will be more than 3 000 spent fuel assemblies that will need to be safely transported and stored away at a suitable final storage repository. By far the bulk of South Africa's spent nuclear fuel, and therefore high level waste, arises from the operation of the Koeberg commercial plant. So far, all of the spent fuel generated at Koeberg since commissioning has been kept on site. About three years ago, Eskom management approved plans to extend the interim storage capacity on site by another 25 years, through re-racking, using ultra-high density racks. This decision is being presently implemented, and an operating licence is being sought by Eskom from the National Nuclear Regulator. The re-racking project should provide Koeberg with interim spent fuel storage for approximately 30 – 40 years, depending on fuel management and plant operation strategies adopted. A long term solution is, however, required.

Before the decision to re-rack was taken by Eskom, four dual-purpose transport and storage casks had been ordered. These were subsequently delivered to Koeberg early in 1996. The casks were intended to be only the first step towards an interim storage spent fuel facility. At that time it was believed that re-racking of the spent fuel pools would not be feasible (2).

In order to address possible public concern regarding the storage of spent fuel at Koeberg in the long-term, and in line with Eskom's overall plans and strategy for the nuclear fuel cycle, Eskom has recently initiated an investigation into the future management of the spent fuel as well as other high level radioactive wastes resulting from operating the nuclear power plant.

SAFARI Research Reactor

The South African Nuclear Energy Corporation Limited is mandated by the Act to operate the South African Fundamental Atomic Research Installation (SAFARI-1) reactor for the purpose of undertaking and promoting research and development in the field of nuclear energy and radiation sciences and technology. The SAFARI-1 research reactor is a 20 MW swimming pool Oak Ridge type reactor, which was commissioned in 1965. For much of its life, the reactor has been operated at only 5 MW until the early 1990's, when the power was increased to 20 MW using improved fuel produced locally at the AEC. It produces radioactive isotopes for medical and industrial use, and finds markets both locally and overseas. A programme for the large scale production of fission ^{99}Mo is operational, and supplies all local markets, apart from providing an extensive export capability.

According to the Corporation, there are about 2 tons of spent fuel elements, of predominantly local origin, that are temporarily stored in dry storage pipes on site at Pelindaba, located some 30 km west of Pretoria. The away-from-reactor pipe storage facility, known as 'Thabana Pipe Store' and commissioned in 1997, is expected to accommodate all of SAFARI's spent fuel elements, thus meeting the reactor's spent fuel needs. Again, a long term solution is evidently needed.

The geology of the selected pipe storage site consists of alternate layers of shale and quartzite of the Transvaal Geological Sequence. A few 100m experimental drill-holes had confirmed that there were no large scale disturbance or concealed structures within the site boundaries. The probability of a large seismic event at the site was considered to be small (2).
Approximately a further 2 tons of SAFARI-1 spent fuel elements of foreign origin have reportedly been shipped away to the country of origin, the United States, over the years. Some quantities of low and intermediate level wastes are also stored in drums on the surface on site at Pelindaba. These arise from SAFARI-1 operations, as well as from hospitals and other medical institutions country wide.

Mining Industry

The South African gold mines produce quantities of low level, as well as long-lived alpha-emitting radioactive wastes. These arise from the extraction of uranium, which is a by-product in the gold mining industry. Since the opening of the first production plant at the West Rand Consolidated gold mine in 1952, about 180 000 tons of U_3O_8 have been produced as a by-product of gold (3). The resulting radioactive wastes are stored on site at the respective mines, predominantly in the Gauteng Province. Most of these wastes will need to be transported and stored away in an appropriate long term storage facility in the future.

Waste rock and tailings account for a very small percentage of the low-level radioactive waste that is generated in the mines annually. The rest comprises mainly plant residues removed during maintenance, typically in the form of sludges, scales, and contaminated steel, rubber, plastics and other materials that cannot be recycled.

Decommissioning Activities

Decommissioning of mines and certain major nuclear facilities at the SA Nuclear Corporation Limited (formerly the Atomic Energy Corporation) have given rise to radioactive wastes. In addition, the future decommissioning of Koeberg and the SAFARI-1 reactor will lead to more radioactive wastes being generated. Again, long-term management plans are required to be put in place timeously in order to be able to deal with these wastes safely and successfully in future.

Research and Medicine

Some radioactive wastes arise from the use of radioactive materials in university research, as well as in the application of radioisotopes for clinical use at medical centres and hospitals country wide.

Military Operations

There may be some quantities of radioactive wastes resulting from military research and operations of the past.

ISSUES TO BE CONSIDERED IN THE FORMULATION OF A NATIONAL RADIOACTIVE WASTE MANAGEMENT POLICY

The fundamental issue of importance in the formulation of a comprehensive policy and strategy for the management of radioactive waste is the protection and safeguarding of human health and the environment, while simultaneously allowing the achievement of sustainable economic development for present and future generations.

Unlike in the UK and elsewhere, South Africa does not have government advisory groups on radiation matters and civil radioactive waste management, such as the UK's Radioactive Waste Management Advisory Committee (RWMAC) and others. It is for this reason that Eskom has found it necessary to assist government in the process of formulation of policy for radioactive waste management in the country.

In formulating policy, it will be necessary to define present and future obligations resulting from international Agreements and Treaties that South Africa has embraced, in particular those that the country has acceded to since the democratisation of the state in 1994. Some of these are the IAEA Comprehensive Safeguards Agreement, the Non-Proliferation Treaty (1991), the All Africa Nuclear Free Zone Treaty of 1994, the International Nuclear Safety Convention, the Vienna Joint Convention on the Safety of Spent Fuel Management and the Safety of Radioactive Waste Management, etc.

In 1997, the National Nuclear Regulator (formerly known as the Council for Nuclear Safety, or the CNS) submitted proposals to the Department of Minerals and Energy regarding their views on what the policy should be. Their Proposal Document (4) was divided into two sets of Principles which listed a series of items that required consideration in formulating policy, viz. Fundamental Principles and Supporting Principles. It also addressed certain 'generic measures' that are required for the implementation of these Principles.

The Fundamental Principles, on the one hand, stated that radioactive waste shall be managed in such a manner that:

- generators of radioactive waste are responsible for the costs of managing the waste, that is, the so-called '*polluter pays principle*';
- possible effects on human health and the environment, within as well as beyond our national boundaries, will be taken into consideration;
- predicted impact on the health and well-being of future generations will not be greater than the impact that is presently considered acceptable;
- it will not impose undue burden on future generations;
- it will fit into an appropriate national framework including clear allocation of responsibilities and provision for independent regulatory functions;
- the generation of the radioactive waste shall be kept to the minimum levels possible;
- interdependencies among all steps in radioactive waste generation and management shall be taken into consideration;
- the safety and integrity of radioactive waste management facilities shall be appropriately assured at all times

The Supporting Principles, on the other hand, tabulated a range of guidelines with regard to legal, safety, financial, organisational, social, economic, political, as well as environmental considerations.

Furthermore, the Proposal called for the formation of a national Radioactive Waste Management Agency (RWMA), which would act on behalf of government to carry out the state's mandate over a wide range of radioactive waste management issues. Finally, the Proposal advocated that the CNS would be the Regulatory Authority over the management of radioactive waste.

The responsibility of government to lead the debate and discussions in the formulation of a national policy on radioactive waste management is enshrined in the White Paper on Energy Policy, which was released by the Minister in December 1998, after a lengthy process of consultation with stakeholders. The following is the provision contained in the White Paper regarding the management of radioactive waste:

> '*The Department of Minerals and Energy will investigate all aspects of the management of radioactive waste in South Africa, and will make recommendations in regard to the safe management and disposal of such waste, following a process which is subject to structured participation and consultation of all stakeholders'*.

It is anticipated that the state will accordingly most likely convene a Consultative Forum within the first half of this year, in order to collate all stakeholder viewpoints and ideas on the issue of policy formulation on the management of radioactive waste in South Africa.

VAALPUTS NATIONAL NUCLEAR WASTE STORAGE SITE

International experience indicates that a lead time of approximately between 30 and 40 years is required for the preliminary investigation, concept design, final design, public acceptance, construction, commissioning, licensing and operation of a deep repository for the final disposal of spent fuel and other high level wastes.

The Vaalputs site, covering approximately 10 000 hectare and located some 600 km north of Cape Town, inland from the west coast of South Africa, was acquired by the Atomic Energy Corporation in 1983, subsequent to the passing by Parliament of the 1982 Atomic Energy Act. Numerous in-depth studies were undertaken by the AEC (1) between 1986 and 1988 in order to qualify Vaalputs as a suitable site for radioactive waste disposal. An operating licence, under which Vaalputs may receive low and intermediate level radioactive waste from Koeberg Nuclear Power Station, was eventually issued by the CNS, the Regulatory Authority. The facility commenced operation in this mode in 1986.

From a *demographics* point of view, the Vaalputs site is suitable for this purpose because the rural area surrounding the site is sparsely populated (a 1985 survey indicated that a rural population of about 100 people lived within a 20 km radius). From a *geological* point of view, the site is also suitable, since the underlying bedrock consists of granite, which is a part of the Namaqualand Metamorphic Complex (NMC). The NMC may be sub-divided into a series of tectono-stratigraphic and metamorphic domains and subprovinces as follows:

- the 2 000 to 1 730 Ma Richtersveld Subprovince
- the Bushmanland Subprovince which underwent high grade metamorphism some 1 000 Ma ago
- the West Coast Subprovince with its Pan African (700 – 420 Ma) structural and metamorphic overprint.

In addition to the above factors, the site is *topographically* elevated above the surrounding plateau, so that there is no water catchment area that could potentially cause floods. Finally, the site is practically a desert, with little or no rain.

As has already been mentioned, under its operating licence, Vaalputs is intended for disposal of low and intermediate level wastes resulting mainly from Koeberg operation. The spectrum of radionuclides found in the waste is typical for wastes that arise from PWR's, and includes ^{3}H, ^{14}C, ^{54}Mn, ^{60}Co, ^{90}Sr, ^{99}Tc, ^{110}Ag, ^{129}I, ^{134}Cs, ^{137}Cs, ^{144}Ce and transuranium radionuclides.

The wastes are received from Koeberg in 200 litre metal drums and in concrete containers which usually incorporate a steel liner. The drums and containers are transported over a distance of 600 km by road on a custom designed truck. The wastes contained in steel drums are in the form of lightly compacted paper and other contaminated rubbish, while wastes that need solidification and shielding such as chemical treatment sludge, evaporator concentrates, filters and ion-exchange resins are placed in concrete containers.

Currently, these wastes are disposed of in two trenches, one (Trench A01) containing low level waste in steel drums (Slides 2, 3: Metallic Drums in Trench A01), and the other (Trench B01) the intermediate waste in concrete containers. The trenches, located about 400 m apart, are excavated in a clay-rich layer of about 20 m thickness overlaying the granite bedrock. Each trench is 100 m long, 20 m wide at the bottom, and 7,7 m deep.

In Trench A01 the metallic drums are stacked horizontally, while in Trench B01 the cylindrical concrete containers are placed on top of each other.

However, it has become evident over the years that more in-depth technical studies need to be carried out at Vaalputs, in order to qualify the site as a suitable high level waste location. Four test holes were drilled by the AEC earlier on (HLD1 – HLD4), to depths of 750m for the HLD1 and HLD3 test holes, a depth of 250m for HLD2, and to a depth of 1 000 m for the last test hole, HLD4. Corresponding experimental logs, presenting a graphical display of *petrophysical data* versus the *lithological data* of the test hole soil samples, were recorded.. The lithological data gives a detailed geological description of the substrata (eg Stoffkloof Megacrystic Granite) by depth, whereas the petrophysical data gives corresponding graphical display information with regard to rock characteristics such as K-Gamma (%), U-Gamma (ppm), Th-Gamma (ppm), magnetic susceptibility, resistivity, temperature, and density. Results logged for HLD4 had indicated that the bedrock had good characteristics, with no evidence of cracks or other adverse features.

Eskom is presently considering drilling four more test holes in the vicinity of HLD4, in order to confirm the promising rock characteristics revealed by this test hole. Should the results be encouraging, the government and Eskom would likely consider embarking on the lengthy process of conducting further vigorous tests and eventually developing Vaalputs as a national high level waste repository. To this end, Eskom has initially set aside a fund of nearly R400-million (approximately US $67-million) for the management and disposal of Koeberg high level radioactive waste.

CONCLUSION

South Africa has a young and small nuclear energy sector, in comparison to her European and other international counterparts. However, the country is now well on its way to developing a policy for radioactive waste management as mandated by the White Paper on Energy Policy. The effort by Eskom to investigate a suitable site for the final disposal of Koeberg and other spent fuel and high level waste is now in progress, in consideration of the long lead time that is required for the eventual commissioning and operation of a deep final repository.

The Vaalputs site is licensed to receive low and intermediate level radioactive waste from Koeberg, which is transported over a distance of 600 km by road. Further experimental tests and analyses need to be conducted on the site characteristics, in order to reach a critical decision regarding the suitability of the bedrock for high level waste disposal as well.

REFERENCES

1. PD TOENS, "Working Group on the Disposal of High-Level Radioactive Waste in South Africa. Final Report on Investigations Carried out by the Five Study Groups", (PIN-1127 B/R), November 1988

2. PJ BREDELL et al, Atomic Energy Corporation of South Africa, "Spent Fuel Management in South Africa", IAEA Regular Advisory Group Meeting on Spent Fuel Management, Vienna, 9 – 12 September 1997.

3. DG WYMER, Chamber of Mines of South Africa, "Nuclear Regulation of South African Mines: An Industry Perspective", IAEA Conference on Safety Regulations on Uranium Mining and Waste Management, Vienna, 14-17 September 1998.

4. COUNCIL FOR NUCLEAR SAFETY, Pretoria, South Africa, "Proposals Regarding the Principles and Implementation Strategy to be Adopted for the National Radioactive Waste Management Policy", 1997.