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FEASIBILITY STUDY FOR THE DISPOSAL OF LOW AND INTERMEDIATE LEVEL RADIOACTIVE WASTE IN CUBA

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Abstract

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The perspective of completing and operating the Juraguá Nuclear Power Station and the development of nuclear applications justifies the need to establish an appropriate low and intermediate level radioactive waste disposal system in Cuba. The design of one option which is consonant with the characteristics of this country is presented in the form of a feasibility study. The study discusses the characteristics of the wastes, the design of the repository, the packaging of the radioactive wastes as well as the siting, conditioning and performance assessment in a preliminary stage. International practice and experience have been considered, as well as the recommendations of the International Atomic Energy Agency [1–4] in the preparation of this study.

1. INTRODUCTION

The production and exploitation of radioisotopes, the use of nuclear techniques in medicine, research and other branches of the economy and the perspective of the construction of a nuclear power plant are fundamental premises for the future development of Cuba. The generation of radioactive waste, which is a direct consequence of these activities, requires the conception, definition, siting and construction of a low and intermediate level radioactive waste (L/ILW) disposal system.

The proposed Juraguá Nuclear Power Plant, the Isotope Centre, the Waste Treatment and Storage Facility and the other facilities to be developed in Cuba are not adequate to store these kinds of waste permanently. To ensure the safest possible storage and disposal of such wastes, a dedicated facility must be developed. This study reviews the main aspects of the proposed Cuban L/ILW disposal system and the assessment of its performance and presents a preliminary outline of the associated waste handling, packaging and transportation system.

2. RADIOACTIVE WASTES: CHARACTERISTICS AND CONDITIONING

The radioactive wastes which may arise from the foreseen operation and maintenance of two WWER-440 reactors of the Juraguá Nuclear Power Station and from nuclear applications in the country have been considered in the present study.

For conditioning, simulated and real low level radioactive wastes were cemented, using Cuban zeolite as an additive. Following cementation, the mechanical characteristics and leach testing of the waste materials thus treated were observed and assessed.

TABLE I. RADIOACTIVE WASTES EXPECTED FROM THE NUCLEAR POWER PLANT (ACCORDING TO THE DESIGN FOR TWO WWER-440 REACTORS)

Activity	Type of wastes	Annual quantity (drums of 208 L)	Principal radioisotopes
Low level	Solidified solids	645	Cs-137, Fe-55, Co-60, Mn-54
	Compacted solids	80	Cs-137, Fe-55, Co-60, Mn-54
	Solids	540	Cr-51, Mn-54, Co-58, Co-60, Zr-95
	Ionic exchange resins	105	Cr-51, Mn-54, Co-58, Co-60, Zr-95
Intermediate level	Ionic exchange resins	78	Cs-137, Fe-55, Co-60, Mn-54
	Solids	470	Cs-137, Co-60, Sr-90

TABLE II. RADIOACTIVE WASTES FROM NUCLEAR APPLICATIONS

Type of wastes	Annual quantity (drums of 208 L)	Principal radioisotopes
Small spent sealed sources	1 to 5	Co-60, Cs-137, Ir-192, Sr-90
Compacted solids	6	H-3, C-14, I-131, P-32, Sr-35
Cemented liquids	25	H-3, C-14, I-131, P-32

Cuba has many zeolite deposits distributed around the country which offer good conditions for the management of radioactive waste [5, 6]. Samples of zeolite from the El Piojillo deposit were selected for the immobilization of real radioactive wastes from research

TABLE III. COMPRESSIVE STRENGTH, SET TIME, ABSORPTION BY IMMERSION AND LEACH CHARACTERISTICS PER SPECIMEN STUDIED

Waste/cement +zeolite ratio	Zeolite/cement ratio	Set time (hours)	Compressive strength (MPa)	Absorption by immersion (%)	Leaching for 28 days ($g/cm^2 \cdot d$)
0.430	1.027	–	41.24	37.30	$2.4 \cdot 10^{-6}$
0.415	0.956	9.50	41.09	38.30	$2.3 \cdot 10^{-6}$
0.400	0.899	9.15	41.25	37.50	$1.1 \cdot 10^{-6}$
0.386	0.832	8.12	43.85	36.10	$2.6 \cdot 10^{-6}$
0.373	0.785	7.00	46.66	34.40	$2.6 \cdot 10^{-6}$
0.362	0.743	6.48	42.24	33.80	$2.1 \cdot 10^{-6}$
0.350	0.702	6.48	44.48	32.30	$2.8 \cdot 10^{-6}$
0.340	0.668	6.16	46.98	30.70	$2.8 \cdot 10^{-6}$
0.620	0	10.00	28.28	23.40	$3.2 \cdot 10^{-6}$

laboratories and of other wastes with the same characteristics as those which would be generated by a nuclear power station. In both cases, the efficiency of this procedure was demonstrated.

Table III shows the cementation parameters for a solution containing 100 g/L of $NaNo_3$, 12 g/L of $Na_2C_2O_4$, 24 g/L of H_2BO_3, 12 g/L of NaOH and 52 g/L of $Ca(NO_3)_2$ that was used to encase a ^{60}Co source.

3. PACKAGING OF RADIOACTIVE WASTES

Radioactive wastes derived from nuclear applications (radioisotope applications in medicine, research, industry and production of labelled compounds) are conditioned and stored at the Waste Treatment and Storage Facility (WTSF), pending permanent disposal or until radioactivity has decayed to a sufficiently low level for disposal as exempt waste.

Drums of 208 L have been used for conditioning radioactive wastes and small spent sealed sources. A coating, such as epoxy resin, is applied to the inner and outer surfaces of the drums to provide additional protection.

Drums for the immobilization of spent sealed sources are prepared in concrete with the aid of a mould. Before starting to pour concrete, reinforcement bars are placed inside the moulds in order to increase mechanical strength. Compactible wastes are compacted in metallic drums of 60 L, which are then placed in 208 L-drums and covered with a cement mixture.

Liquid radwastes are directly immobilized in 208 L-drums using concrete. Low level radioactive wastes from the nuclear power plant will be immobilized in 208-L metallic drums.

For the transportation and disposal of intermediate level radioactive wastes from the nuclear power plant, reinforced concrete containers are proposed.

These containers were structurally designed using the limit states method. While the concrete mixture is of a high compacity with a characteristic resistance of 20 MPa, the steel has a tensile strength of 300 MPa. These containers will hold four metallic drums for immobilized wastes, and thus be adequate for transportation for the purposes of final disposal.

4. CONCEPTUAL DESIGN OF THE REPOSITORY

The repository designed in Cuba consists of a centralized facility to store the conditioned low and intermediate level radioactive waste from the Juraguá nuclear power plant and from nuclear applications. This design was based on the characteristics of the Cuban nuclear programme, the national policy on the management of radioactive wastes, the local economic, climatic, geological, geographic conditions and the construction experience available in the country.

The designed facility is to be located in a stable geological formation, in rock cavities near the subsurface.

Access to the repository will be by three vertical pits at a distance of 270 m from each other and connected by a ventilation and circulation gallery.

Whereas the central pit will be outfitted with technological equipment and dedicated to the transport of conditioned radioactive waste, the pits on either side will be auxiliary and will serve to ventilate the underground construction. The entire structure will be up to 30 m in depth and contain eight horizontal vaults for the storage of radioactive waste. Of these, three will be for containers of intermediate level radioactive waste, four for metallic drums containing low level radioactive waste, and one for the disposal of any radioactive waste which may arise from accidents. The design contemplates the possibility of storing wastes in the transport gallery. The particulars of the design are described in the literature [7]. The structure of the repository encompasses an underground area of construction of 552 × 300 m, with a storage capacity of 12 150 m^3.

The general layout of the facility is depicted in Fig. 1. The design foresees construction in two stages.

5. COST ANALYSIS

The cost estimate covers the construction of hollow areas, ventilation, electricity, materials and equipment for the repository.

First stage	US $5 000 000
Second stage	4 000 000
Ventilation	50 000
Electricity	300 000
Equipment	350 000
Total	US $9 700 000

Above ground, the design of the repository foresees a control room, a reception room, an administrative building, a ventilation pit room, an auxiliary pit room and an energy building.

The total cost of the design is some US $10 000 000 (including the construction of hollow areas and buildings above ground).

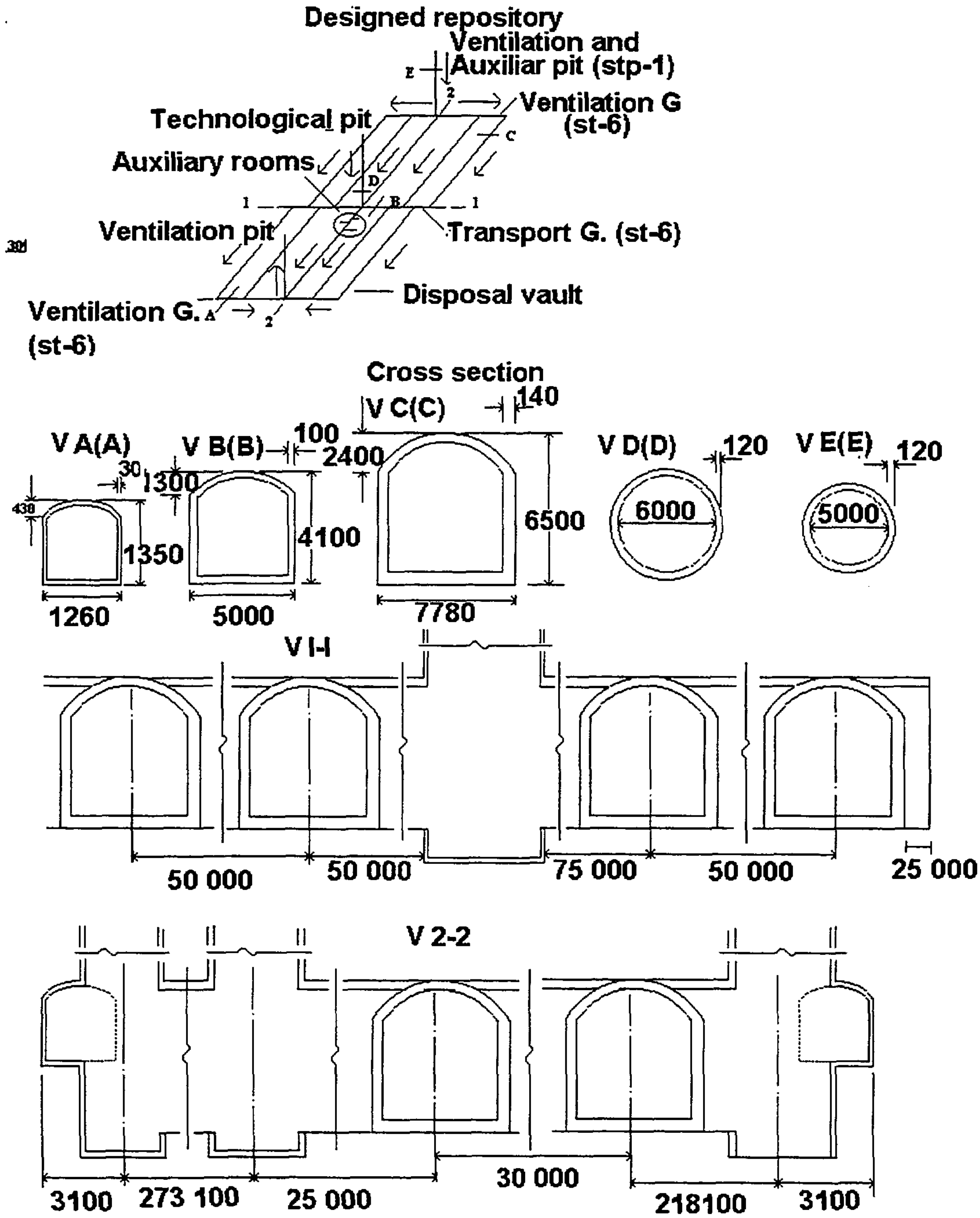

FIG. 1. Layout of designed repository.

6. REPOSITORY SITING

The following selection criteria were established. The siting should be in a stable geological medium, with high mechanical resistance (geological criterion), sufficiently removed from rivers, ditches, dams, streams and not subject to flooding. The underground water movement should be minimal or non-existent. Rocks should have very low filtration coefficients (hydrogeological and hydrological criteria) and the possibility of the occurrence of an earthquake should be very low. The maximum earthquake values for the project (100 years) and for design (10 000 years) should be V and VI, respectively, in accordance with the

MSK intensity scale (seismological criterion). In addition, the site should have a low population density, be relatively removed from important population centres and not be a focus of important social and economic activities. Its relief characteristics should be favourable and in particular, the area should not feature abrupt changes in morphology (topography criterion).

For siting, the process illustrated in the Figure 2 was developed, as described in earlier reports [8].

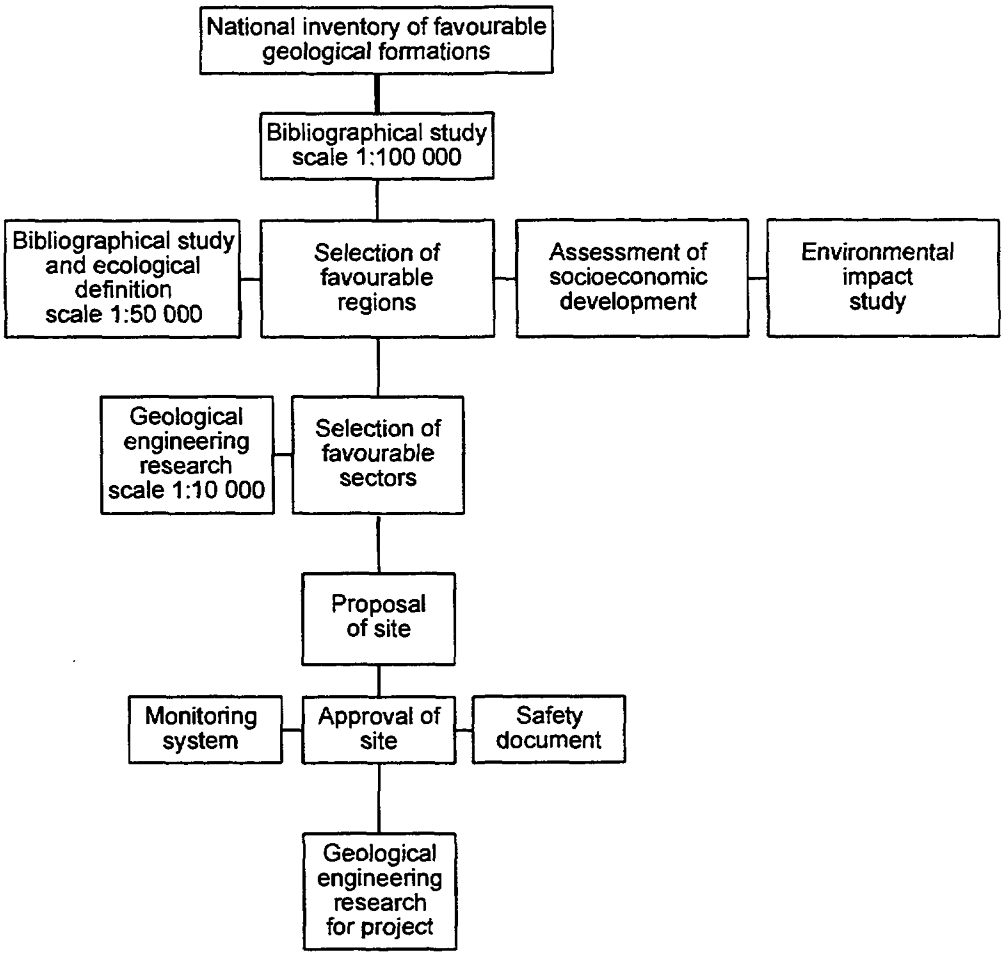

FIG. 2. Flow chart of siting process.

Different formations of hard rocks, salt and clays were found in the national inventory on the basis of information contained in archives, data gained through surveys and reconnaissance visits.

6.1. Evaluation process

Six igneous formations were identified in different regions of the country as well as eleven caverns, two mines, one argilite formation in the Matanzas province and two salt formations.

6.2. Selection of favourable formations

After a geological reconnaissance and geological and geophysic tests performed in the identified regions, the choice was narrowed to eight favourable formations. These were further characterized and six of them were disqualified, as they did not conform to the previously established criteria. The following sectors were retained for further research:

1. Granite rock of the Central Region,
2. Granite rock of the Oriental Region.

The sector of the Central Region was analyzed in terms of seismology, geology, hydrology and hydrogeology, topography, climate, economical and social aspects and extreme occurrences (meteorological events, fall of aircraft, detonation of explosive charge).

6.3. General characteristics of selected sector

The sector is located in a granitic formation in the Central Region of the country. The underground waters flow into a large river, and the surface of this area drains easily. The site has favourable hydrological conditions, the aquifer is poor and the water table lies at depths of 10 m to 20 m below the surface. The seismic studies of the site define as V the design basis earthquake (for a recurrence period of 100 years) and VI the maximum design basis earthquake (for a recurrence period of 10 000 years) according to the MSK intensity scale. The tectonics of the site are favourable and very simple. The sector has no high elevations and lies at an altitude of 40 m to 70 m. The area selected is not densely populated.

The performance assessment of the disposal system is in a very preliminary stage. The methodology used includes a characterization of the system (near field, remote field and biosphere), the analysis of scenarios, analysis of consequences and analysis of uncertainties.

The system design foresees a facility located in a granitic rock cavity at the near surface where natural and artificial barriers will be used. These barriers are:

- conditioned wastes in cement or bitumen
- metallic drums
- concrete container (for intermediate level wastes)
- natural zeolite as filler
- monolithic concrete as shore up in the vaults of disposal
- granitic rock as geological medium.

The near field will be characterized by means of geological, hydrogeological and environment surveys which are currently under way. The GTM-1 code(Geophere Transport Model, release-1) is being used for the analysis of consequences.

7. CONCLUSIONS

1. A design for a system of disposal for low and intermediate level radioactive wastes derived from nuclear applications and the proposed Juraguá nuclear power plant was carried out.
2. A feasibility study was conducted for a centralized repository in Cuba.
3. The methodology for the siting process was established, which allowed to define the general characteristics of the site sector selected.

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