Revisiting Goiânia: Toward a final repository for radioactive waste

A range of technical, social, and political aspects are involved in decisions for the final disposal of the 1987 accident's wastes

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On 13 September 1987, a chain of unfortunate events occurred that led to what became known throughout the world as simply the "Goiânia accident":

A shielded, strongly radioactive caesium-137 source was removed from its protective housing in a teletherapy machine in an abandoned clinic in Goiânia, in the Brazilian state of Goiás. The source capsule was subsequently ruptured, and the remnants of the source assembly were sold for scrap to a junkyard owner, who noticed that it glowed blue in the dark. People were fascinated and over a period of days, friends and relatives came and saw the phenomenon. Some grain-sized fragments of the source ended up in the homes of several families, and other fragments came to be dispersed to places throughout the city. By the time the scale of the accident was discovered, and countermeasures were taken, many people had incurred large doses of radiation due to both external and internal exposure. Four of the casualties ultimately died and 28 people suffered radiation burns. Residences and public places were contaminated. The decontamination necessitated the demolition of seven residences and various other buildings, and the removal of topsoil from large areas. In total, about 3500 cubic metres of radioactive waste were generated.

At the time, Brazilian public authorities — assisted by local citizens and national and international volunteers — took remarkable efforts to limit the accident's consequences. People that were exposed to radiation were decontaminated at special centres, and all remaining contaminated objects, from plants to toys to clothing, were handled as radioactive waste and placed in a temporary storage site.

The remains of the broken caesium-137 source were taken to a health care centre maintained by the state of Goiás and placed on a chair. The radiation exposure rates at the time were about 10 sieverts per hour (Sv/h) near the source and 0.4 Sv/h one meter away. Both the chair and the source were shielded with concrete on the first of October 1987.

The typical density of a caesium-137 source for teletherapy, similar to the one involved in the Goiânia accident, is about three grams per cubic centimeter. That would indicate that the source's initial volume was only about 24 cubic centimeters. At the time of the accident, the source's

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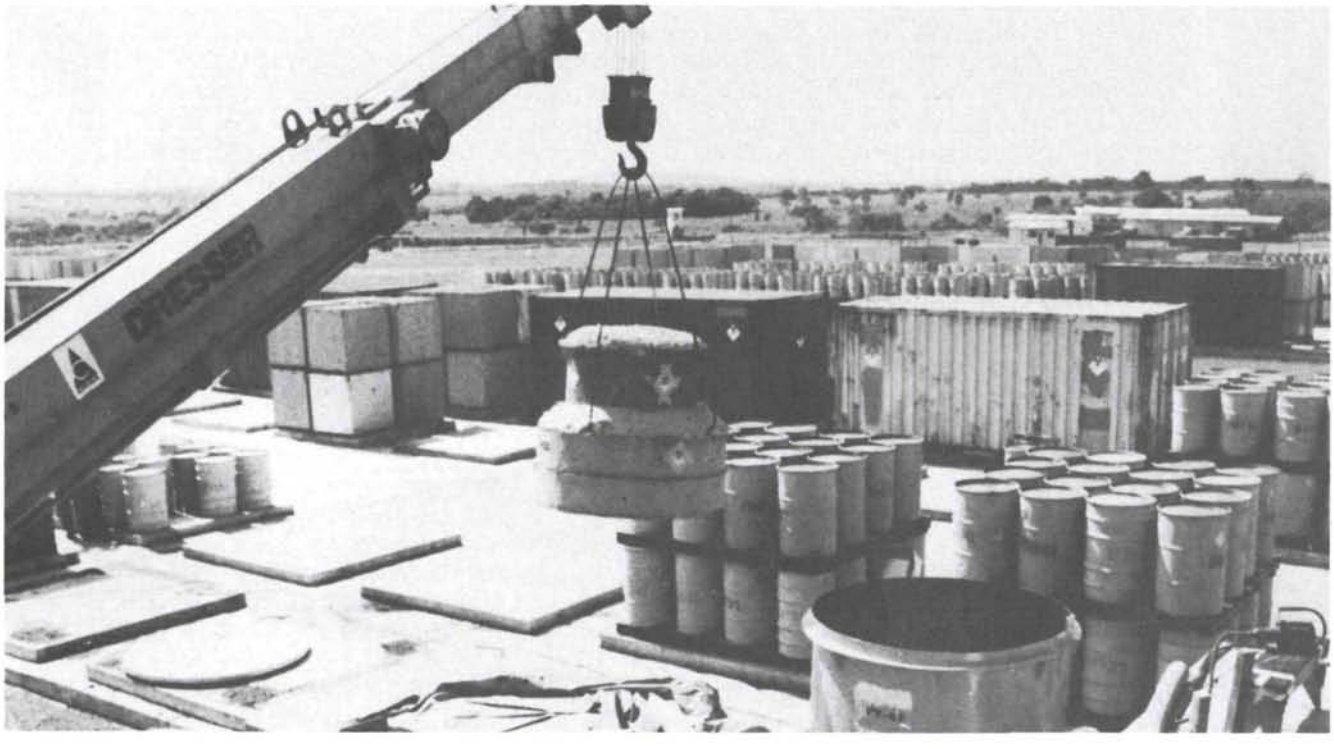
Brazilian authorities found the remains of the small but strongly radioactive caesium-137 source involved in the 1987 Goiânia accident in a sack. They placed it on a chair, and sealed it in concrete. Radioactive wastes generated from the accident amounted to 3500 cubic metres. They were packed in special containers and sent for temporary storage to a site in Goiás. Authorities are in the process of deciding the siting and construction of a final waste repository. (Credit: CNEN)



activity was 50.9 tera-becquerel (TBq), or 1375 curies. The total radioactive wastes that were generated from this source, after being ruptured, amounted to almost 150 thousand times more than its initial volume and had an overall activity between 47 and 49.6 TBq, or between 1270 and 1340 curies.

Over the past 5 years, Brazilian authorities have been engaged in a comprehensive decision-making process for the siting and construction of a permanent repository for the radioactive wastes from the Goiânia accident. This article presents a summary of some important aspects of that process, which has involved activities ranging from preparing environmental impact assessments to holding public hearings and debates. Issues that were addressed concerned not only technical considerations, but social, political, and ethical aspects as well.

Selecting the repository site

Wastes from the Goiânia accident are temporarily stored in a site near the village of Abadia de Goiâs, about 23 kilometres from the center of Goiânia. The site is made of six concrete platforms, each 60 by 18 square metres, upon which the wastes are placed.

Brazilian regulations concerning the disposal of radioactive wastes require that they be confined to protect human beings and to preserve the environment for the short- and long-term. The regulations conform with internationally recognized concepts of sub-surface disposal for radioactive wastes, namely those recommended by the IAEA. The Brazilian Comissão Nacional de Energia Nuclear (CNEN) took these concepts and legal requirements into account in determining the site-selection procedures for the final disposal of the radioactive wastes from the Goiânia accident.

By way of summary, the procedures covered several stages:

- They defined the entire state of Goiâs as a "region of interest" and took into account technical, socio-political, and economic aspects.
- Regional studies were done to identify preliminary areas, and to eliminate unfavourable ones. Detailed maps were analyzed and factors that were considered addressed each area's demography, mineral zones, geographical contours, hydrological conditions, ecosystem, seismicity, and biological reserves, as well as whether the area included national or state parks or Indian reservations. In all, 189 preliminary areas were identified.
- Preliminary areas were further evaluated for the selection of potential areas. Analyses were based on physiographic and geological aspects using detailed maps to eliminate areas on the basis of lithological and tectonic studies. Eighteen potential areas were then selected.
- Three candidate sites were selected following "in loco" examination of the potential areas. Studies employed a methodology covering aspects of geology, land and property use, aquifer depths, soil characteristics, and transportation requirements. The three candidate sites are 400 meters, 74 kilometers, and 100 kilometers away from the temporary storage site.

The three candidate sites were presented to the government of the state of Goiâs for the final site selection. It was expected that the nearest site might be selected to minimize the probability of an accident during the transport of heavy and large volumes of radioactive wastes. Governmental authorities in Goiâs considered the sites in the context of this important transportation factor, as well as civic growth trends for Goiânia. Thereafter, they jointly decided with CNEN to start the environmental impact assessments in the area nearest the temporary storage site.

Criteria for waste disposal

Criteria for the disposal of low- and intermediate-level radioactive wastes have been issued in a number of countries. *(See table.)* It is well recognized, however, that there are difficulties in applying radiation protection criteria for the long-term disposal of radioactive waste. The principles of justification, optimization, and individual dose limitation are interpreted in different ways by national authorities, mainly when they are dealing with radioactive waste disposal. Criteria for the limitation of individual dose, for example, range from 0.10 to 1.0 mSv per year. Criteria for the institutional control of a sealed repository also vary from country to country.

In Brazil, an individual dose limitation equivalent to 0.3 mSv per year has been adopted. This corresponds to a caesium-137 concentration of about 87 Bq/g, based on landfill scenarios and pathways used by the IAEA in obtaining derived exempt concentrations for its recommendations. However, these scenarios and pathways are generic ones, and a site-specific environmental model needs to be developed for evaluations before adopting a definitive value for exempt concentrations of radioactive waste. In the case of the Goiânia waste, it is not expected that the value adopted in Brazil (87 Bq/g) will change significantly as far as exemption is concerned. However, decisions being taken now could be changed.

The Goiânia wastes now stored at the site in Abadia de Goiâs have been categorized into five groups. *(See table.)* The volume and average concentrations of each group were determined based on information derived from the way the wastes were packaged, and assuming an average specific mass of about 1700 kilograms per cubic meter.

Considering each group's average concentration, Brazilian experts calculated the time it would take for each waste group to decay to a concentration level lower than or equal to 87 Bq/g. They calculated that the required time for all the radioactive wastes to become innocuous from the radiological standpoint is less than 360 years. The wastes having the highest average concentration would have to be kept confined for that entire time period but this group accounts for only about 1.5% of the total waste volume. The largest group, which accounts for almost half of the total waste volume, already has an average concentration lower than 87 Bq/g, and technically could be considered exempt from regulatory control.

For the present time, the wastes in the second and third groupings, which together account for about 40% of the waste volume, have been reencapsulated in cylindrical concrete containers. An improvised shield also has been reencapsulated in a larger metallic drum.

Radioactive caesium-137 wastes temporarily deposited in Abadia de Goiâs.

Waste group	Volume (cubic meters)	Percent of total volume	Average concentration (Kilobequerel per kilogram)	Decay time (years)
5	51	1.5	3.21×10^5	356
4	429	12.8	1.43×10^4	221
3	578	17.2	1.45×10^3	122
2	769	22.9	3.2×10^2	57
1	1534	45.6	26.9	0

Note: The decay time is the number of years required to reach a concentration of or below 87 Bq/g, which is the exemption level established in Brazil for these wastes

Criteria for radioactive waste disposal adopted or being adopted by selected countries

	Dose (1 mSv/year)	Control (years)	Comments
France	1.00	300	an average alpha concentration of 370 Bq/g was derived based on an individual dose of 1 mSv/year
Germany	0.30	none	safety analyses must be based on conservative assumptions
Brazil	0.30	undefined	optimization is required
United States	0.25 (whole body) 0.75 (thyroid) 0.25 (any other organ)	unclear	an annual dose of 0.50 mSv to the whole body and an institutional control period of 100 years can also be required
Sweden	0.10	1×10^4	disposal of low- and intermediate-level wastes in a bedrock cavern repository near Forsmark
Switzerland	0.10	none	no requirement to estimate collective dose or to analyze cost/ benefits
United Kingdom	0.10	300	optimization required; the assumed annual risk of death from radiation exposure of 1 mSv/year is 10^{-5}

Notes Dose refers to the limitation of individual dose equivalent which is usually based on realistic transport models. Control refers to institutional control after the sealing of the repository.
Source Data partially drawn from "The Development of Criteria for Radioactive Waste Disposal", by K P Wagstaff, Radioactive Waste Management Criteria, INFO-0158, Canadian Radiation Protection Association Workshop, Toronto, Ontario (1985)

Ongoing discussions

The decision-making process to build the final repository for the Goiânia accident's radioactive wastes has involved a large number of explanatory talks and debates with professional associations, community groups, academic societies, and others. These discussions are continuing in Goiânia and elsewhere.

In all cases, the talks are not restricted to technical aspects, but include ethical and sociopolitical considerations as well. Such aspects are important considerations because of the need to strike the necessary balance for solving the problem on a permanent basis. The repository will have to last for more than three centuries.

Before a final decision is taken, much remains to be done. In accordance with Brazilian legislation, an environmental impact assessment now is being done, and a summation of the studies will then be submitted for public hearings. Federal, state, and municipal approvals are necessary to build any new installation such as the Goiânia waste repository.

Despite the intrinsic difficulties involved, the many rounds of talks, debates, and public hearings associated with this process are of paramount importance for the acceptability of the Goiânia waste repository. In the final analysis, scientists and engineers are not necessarily better equipped than any other segment of society, in terms of ethical values or social and political experiences, to decide such matters on their own. ❐