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CRITERIA FOR DESIGNING AN INTERIM WASTE STORAGE FACILITY

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ABSTRACT

The long-lived radioactive wastes with activity above clearance levels generated by radioisotope users in Brazil are collected into centralized waste storage facilities under overview of the National Commission on Nuclear Energy (CNEN). One of these centers is the Radioactive Waste Management Department (GRR) at the Nuclear and Energy Research Institute (IPEN), in São Paulo, which since 1978 also manages the wastes generated by IPEN itself. Present inventory of stored wastes includes about 160 tons of treated wastes, distributed in 1290 steel, 200-liters drums, and 52 steel, 1.6m^3-boxes, with an estimated total activity of 0.8 TBq. Radionuclides present in these wastes are fission and activation products, transuranium elements, and isotopes from the uranium and thorium decay series. The capacity and quality of the storage rooms at GRR evolved along the last decades to meet the requirements set forth by the Brazilian regulatory authorities. From a mere outdoor concrete platform over which drums were simply stacked and covered with canvas to the present day building, a great progress was made in the storage method. In this paper, we present the results of a study on the criteria that were meant to guide the design of the storage building, many of which were eventually adopted in the final concept, and are now built-in features of the facility. We also present some landmarks in the GRR's activities related to waste management in general and waste storage in particular, until the treated wastes of IPEN found their way into the recently licensed new storage facility.

1. INTRODUCTION

A brief history of radioactive waste storage at IPEN.

The safe management of the radioactive waste has been a concern of the operators of the Institute of Atomic Energy (IEA) since the beginning of operation in early 1958. However, this concern was barely reflected in the early technical literature of the IEA, the first reference to radioactive wastes only appearing in 1961, in a report of the Radiation Protection Service: "*Disposal of radioactive waste is presently done by concentration of material. Studies are under way to assess the possibility of burying the radioactive waste materials, which seems to be the best solution for Brazil, because of the availability of large burial spaces.*"[1] No report of such studies was found, nor could we disclose what does mean 'concentration of material'. Perhaps it was the compaction of solid wastes with a hand operated press.[2]

A paper on radioactive effluents was published three years later in the journal 'Department of Water and Sewage of São Paulo'[3]. In that paper and in a report the following year, Rodrigues [4] stated that effluent volumes and activities were small but the planned increase in research activities at IPEN would require the construction of an effluent collection tank to allow monitoring the discharges and to comply with the requirements of sanitary regulations. The author also alerted to the necessity to start to training technicians to operate the future facilities. No evidence could be found that any of the two steps have been taken.

As a matter of fact, the next evidence in the literature of radioactive waste management activities at IEA appears in 1976 [5], forecasting radioactive waste volumes and activities expected for the following decade. One year earlier however, an expert mission from IAEA produced a comprehensive report on the situation of waste management at IEA with advices and recommendations on the steps that should be followed to develop the field in the ensuing period. Unfortunately, no copy of this report is now available.

From 1973 until 1978, the author witnessed the practice of burying the radioactive solid wastes in simple trenches dug in various places of isolated bare lands of the IEA campus, a practice that started many years earlier. The wastes were collected from radioactive laboratories in 40 L kraft-paper bags inside polyethylene bags, and stored in a shielded corner of the Health Physics 'Decontamination Laboratory'. Wastes were stored until a batch with a typical volume of four cubic meters were formed and then buried with no further treatment. Immediately after the bags were unloaded into the trenches, these were backfilled with soil. Trenches were about four meters deep and with enough width to accommodate all bags, allowing about 2 m of soil coverage.

In 1979, a memorandum from the Brazilian Commission on Nuclear Energy (CNEN) prohibited any further burial and urged IEA to initiate plans to start packaging and storing the wastes on site until they could be disposed of in a disposal facility that should be available a few years later. At that time, CNEN was developing the concept of a disposal facility [6] and conducting the site selection studies for the Brazilian Waste Disposal Facility [7]. However, the freezing of the Brazilian Nuclear Program in the eighties stopped the disposal project.

Nevertheless, IEA initiated the project of the treatment facility in 1980 and in the end of 1982 it started operation. The facility consisted of a fenced 0.15 ha flattened land, with a building for compaction of wastes, and two 30 m^3 concrete slabs over which the resulting 200L-drums of compacted waste were to be stacked until they could be transported to the disposal site. All solid wastes generated during the 1979-1982 period have been kept in a temporary storage room and treated in the new facility.

The compaction building housed a small shielded storage space; a 10 ton hydraulic bailing press with its upper plenum connected to an air exhaust fan and filtration system, with HEPA and activated charcoal filters; a shower for personnel decontamination; and spaces for storage of empty drums and an area for loading and unloading operations.

Although the facility had been built at a time when CNEN had not yet issued its regulations neither for licensing installations nor for radioactive waste management, the manager of the recently created Waste Management Department at IEA, then rechristened Nuclear and Energy Research Institute (IPEN) submitted a Safety Report and applied for a license. A formal license has never been issued and at the end of 1982 the facility was commissioned any way. Figure 1 shows the facility some time after the start of operation.

It was soon realized that the canvas that covered the drums over the concrete platforms created an accelerated corrosion environment for metallic drums, trapping moisture during the day and condensing the water vapor on their surfaces at night. The commission of an industrial storage shed to store the treated wastes took two years and in 1985 it started up.

Figure 1 – View of the waste treatment and storage facility in early 80’s.

Since IPEN played an active role in the so called ‘parallel nuclear program’, the volume of wastes generated by its facilities and by radioisotope users increased during the 80’s, peaking in the next years after the Goiânia accident. To cope with the large waste volume, another shed was built to house untreated wastes. Figure 2a shows the site by the end of the decade. The shed at left stored untreated wastes and the shed at right stored the waste packagings ready for final disposal.

Figure 2b shows the storage shed by the end of the 90’s. The generation of wastes during the 90’s, mostly related with increased radioisotope production and operation of pilot plants for uranium purification and conversion, resulted in the depletion of storage capacity, driving the GRR to store part of the treated wastes in the shed for untreated.

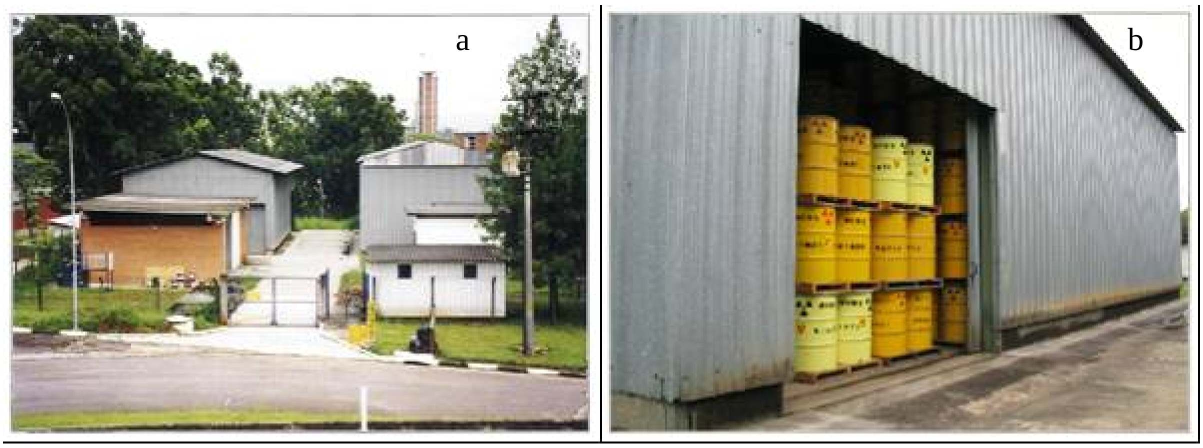

Figure 2 – Views of the treatment and storage facility in late 90’s.

In 2006, two regulatory inspections identified non-conformities in the storages, and inspector’s reports [8] urged changes in building characteristics and storage methods. Although the IAEA recommendations for waste store buildings [9] include the type of construction adopted in the former storage sheds, the regulatory agency inspectors demanded masonry construction for a new storage building. Besides this, the availability of a final repository was unpredictable at that time and so IPEN was forced to invest in a new storage building to meet regulatory requirements and to extend storage capacity on site. Some of the main demands by regulators were: replacement of the galvanized steel cladding construction by masonry structure; coating of the floor with an easy to clean smooth surface flooring; and rearrangement of the drums to leave sufficient space between stacks of drums to allow inspection of packagings. Results of the studies undertaken to design the new building are reported below.

2. REQUIREMENTS FOR THE WASTE STORAGE FACILITY

2.1 - Applied regulations and legal requirements

Federal Law 10308 [10] defines three kinds of storage for radioactive wastes: initial, intermediate and final. Initial storages are those constructed and operated by the licensees of radioactive installation. Radioactive wastes from initial storages are discharged to the environment after delay/decay, or are otherwise transferred to intermediate storages. Intermediate storages are centralized facilities built and operated by CNEN, aimed at storing the longer-lived wastes until they are disposed of in the 'final storages', which are repositories whose construction and operation are also CNEN's responsibility.

The storage facility at GRR-IPEN is double purpose: it functions as an initial storage for the untreated wastes generated by IPEN facilities or wastes received from generators outside IPEN, and as an intermediate storage for treated wastes. Consequently, storage structure is split in the two separated, although contiguous, corresponding building areas.

The regulatory requirements for initial and intermediate storages fall in one of the following five general functions of a radioactive waste storage structure:

1. Protecting the wastes against degradation by the elements;
2. Preventing the inadvertent or malicious access to the wastes by unauthorized individuals;
3. Protecting the workers and public individuals against the radiation emitted by the wastes;
4. Preventing the dispersal of the wastes by animals or other natural forces;
5. Protracting the control over the wastes.

The requirements for design, construction and operation of initial and intermediate storage facilities, to perform those functions, are established in the regulation CNEN-NE-6.05 – "Radioactive waste management in radioactive installations" [11]. This regulation will be superseded in the near future by two new regulations that are in the approval phase, the 'Management of low- and intermediate-level radioactive wastes' and the 'Licensing of radioactive waste storage facilities'. No substantial changes in the requirements are expected however. By the time this paper is written the old and outdated CNEN-NE-6.05 is still in force and its requirements shall apply.

The regulation states that: "The storage facility must be designed, built and operated as to:

a) confine the radioactive materials safely;
b) prevent the release of radioactive materials to the environment;
c) possess the means for monitoring radiation levels;
d) be located far from working areas;
e) possess the means to prevent unauthorized individuals to entering the storage area;
f) have radiation risk symbols and warnings posted at visible places;
g) have non-porous, easily decontaminable flooring and walls;
h) be shielded against radiation to the outside;
i) possess a ventilation, exhausting and filtration system;
j) be equipped with barriers against the entrance of animals;
k) have a controlled environment to prevent the natural degradation of packagings;

l) have a clear separation between controlled and exempt areas;
m) have a floor drain and storage tank capable of holding spills or decontamination liquids;
n) withstand the effects of foreseeable natural destructive events;
o) have written procedures for emergency situations and accidents;
p) be equipped with means for loading and unloading of waste containers;
q) have foundations capable of supporting the weight of all packages;
r) be provided with smoke detectors and fire-fighting equipment;
s) have storage capacity for the total amount of wastes."

A discussion about each of these requirements is outside the scope of this paper, although all demands have been implicitly considered in the concept. The relevant points in the design of the storage are discussed below. Unless otherwise stated, the assumptions and results apply for both the treated waste and untreated waste storage rooms.

2.2 – Storage capacity

Although some operational details, such as for instance drum spacing, influence the dimensions of the storage building, the intended storage capacity is the main parameter and it depends mainly on the waste volume already existing and on two key assumptions about future capacity requirements: the date when a final disposal facility will be available to start receiving wastes, and the rate at which new waste will be generated until that date. Whatever is the capacity of the storage for treated wastes, the untreated waste storage room will be constructed with the same area because the first is expected to accommodate the largest volume at any time and the second can function as a backup for the first or may swap functions in future decisions.

2.2.1 – Inventory of treated wastes

At the start of the project, the total number of 200 L drums stored at IPEN was about 1290 drums and there were 52 steel boxes each one with capacity for 1,6 m^3, containing paper for recycling, contaminated with Cs-137 from the Goiania Accident, that reached recycling factories in São Paulo State, before the accident was detected. Table 1 gives the yearly number of stored packages.

Table 1 – Number of 200 L drums of treated wastes produced annually and stored at IPEN

Year	compactable	non compactable	total	Year	compactable	non compactable	total
1983	56	1	57	1997	0	5	5
1984	59	2	61	1998	44	25	69
1985	38	1	39	1999	0	0	0
1986	40	0	40	2000	7	0	7
1987	48	2	50	2001	12	0	12
1988	106	88 + 52 boxes	194	2002	16	62	78
1989	66	11	77	2003	25	39	64
1990	77	30	107	2004	3	17	20
1991	30	30	60	2005	16	22	38
1992	48	0	48	2006	4	0	4
1993	33	31	64	2007	7	0	7
1994	24	0	24	2008	0	0	0
1995	35	27	62	2009	6	0	6
1996	9	26	35	2010	41	0	41

2.2.2 – Deadline for final disposal in Brazil

At the time this study started, Brazil had no schedule for construction of a final disposal site. However, the Brazilian policy for radioactive waste disposal has recently been changed by events in other area. The Brazilian Institute for the Environment and Renewable Natural Resources (IBAMA) issued the license for construction of the unit 3 of Angra Nuclear Power Plant with the precondition that final disposal for low- and intermediate-wastes were available before the date of issuance of the operation permit [12]. This establishes a deadline for the completion of a repository in 2014. However, as is CNEN which bears the responsibility for final disposal, it is debatable whether IBAMA can force the nuclear utility to provide a final repository.

Considering that the demand for disposal services will still remain small for a long period and that capital costs for a disposal facility is very high, it is reasonable to assume that disposal availability can be postponed to between ten and twenty year from now. As a conservative assumption about the capacity of the storage, twenty year was adopted as the operation time.

2.2.3 – Future waste generation rate

The annual volume of radioactive waste generated by IPEN facilities or received from generators outside IPEN was consistently decreasing in the last decade and seams to stabilize around an average of 20 drums per year. The decrease was a consequence of better operational and administrative measures in relation to waste management, and the consequence of a decrease in the activities that generates radioactive wastes. Figure 3 shows the trend in waste generation.

This trend will probably be reversed if the plans to produce Mo-99 by fission in a new reactor go ahead. These plans are part of the rebirth of the Brazilian Nuclear Program, the expansion of the radiopharmaceutical industry at IPEN, and the implementation of a multi-purpose nuclear reactor nearby São Paulo. Forty drums per year were adopted as a round, reasonably conservative value for the next two decades.

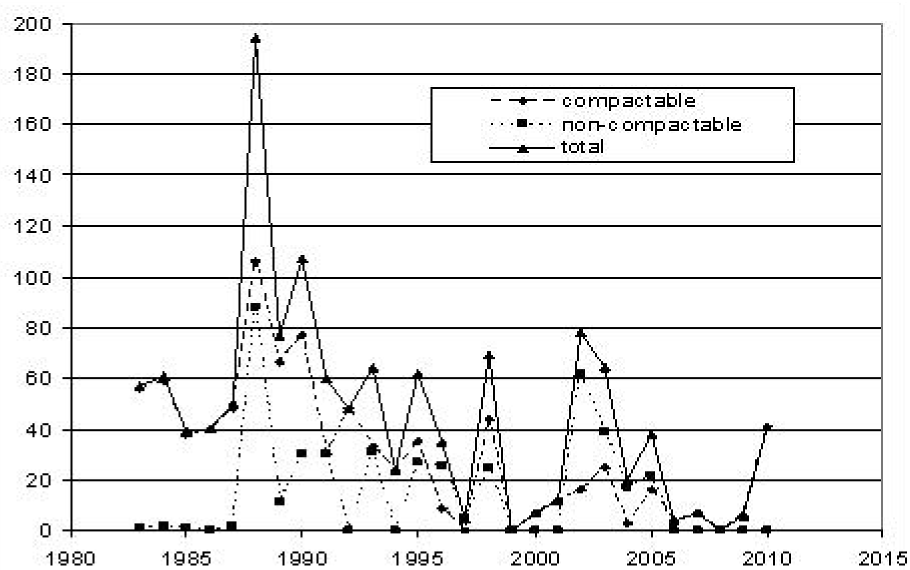

Figure 3 – Trend in radioactive waste generation at IPEN.

The assumptions are conservative but in the event that a larger storage capacity is necessary the buildings will have flexibility for rearrangement of spaces, and further treatment and volume reduction of some wastes will provide for additional capacity without the necessity of expanding the storage room.

2.3 – Operational aspects

2.3.1 – Loading and unloading equipment

Treated wastes will continue to be moved and stacked on pallets with four drums, using the existing gas-propelled forklift truck, which has a capacity to moving 2.5 tons at the ground level and 0.7 tons at the highest mast operation level.

The alternative concept of using a crane was rejected because: 1) investment costs for a crane is high; 2) drums are not expected to be moved after being positioned in the storage except for transportation to final disposal; 3) dose rates during loading and unloading operations are low enough to allow for using instead, already existing equipment. The existing forklift truck is capable of moving treated waste packagings and all usual untreated wastes and pieces of equipment.

The former wooden pallets must be replaced. Recycled plastic pallets is the choice because of the better performance at reasonable cost, showing longer service life, lower porosity, waterproofness, cleanliness, and higher resistance to decontamination solutions. The use of cage pallets is considered unnecessary because in GRR’s experience the risk that a pallet being carried be accidentally dropped is very low.

2.3.2 – Space between stacks

The easy and quick access to every waste package in the storage room, for inspection or in case it is necessary to replace a damaged or leaking drum, is the point in question here. Damaged packages must be replaced as soon as possible to reduce the risk of accidents. Periodic inspection of packages is necessary to the early detection of problems, although no requirement in this aspect exists in the regulatory text in effect as of 2011, the draft of the regulation that will supersede the current CNEN-NE-6.05 requires easy access for identifications and inspection of packages.

In GRR’s experience, improperly segregated wastes containing damp rags or vials with corrosive liquids are at times mixed into the compactable solid wastes what causes severe corrosion of the drums, despite stringent rules and frequent warnings against laboratory personnel discarding vials with liquids in the solid radioactive waste bins. The periodic inspection of the drums is necessary to keep low the risk of spills or that a damage package put the drum stack in peril of falling down.

An arrangement of packages in columns as shown in Figure 4a allows for more than 90% of drums’ surfaces to be seen directly. The space between the stacks necessary and sufficient for the inspection is about 0.7 meters. This spacing creates a very compact arrangement, which requires less storage space while allows for the periodic inspections of all the packages.

An alternative arrangement of the stacks in rows, as shown in Figure 4b, allows for the forklift to drive among the stacks, providing easier access to stored drums in case one must be replaced or relocated. This placement would require less rearrangement of the other packages and, as the advocates of this system claimed, the doses to personnel would be lower, although less than 60% of most drum's surface could be seen during routine inspection.

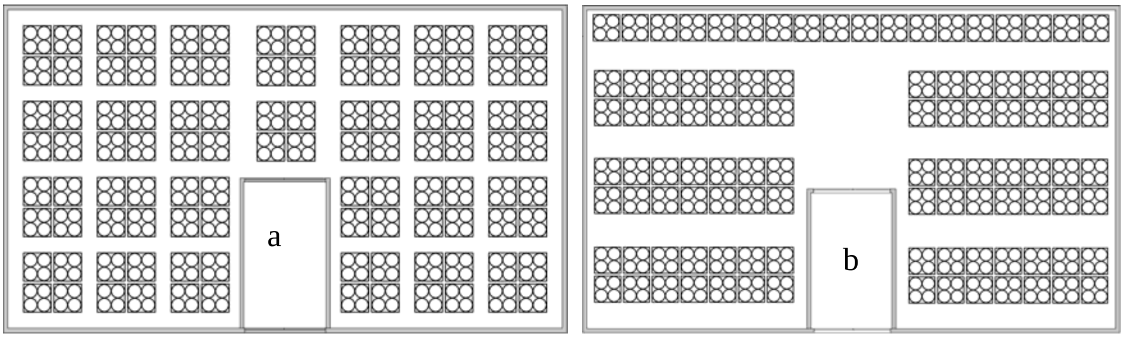

Figure 4 – Alternatives of placement of stacks in the storage room.

To decide on the best arrangement was a more laborious task, considering these contradictory arguments. There is no possibility of instant access to every package without compromising the storage capacity or without excessively enlarging the storage building. To remove any drum from the stacks with little rearrangement of other packages is only possible if aisles about five meters wide are left between adjacent stacks, because the forklift truck can only pick up loads in the front side. A radiation protection optimization approach was tried, using expected exposure data from Dellamano [13], without success because the outcome depended on the frequency at which operations to remove packages from the storage would be required during the working life of the storage and, consequently, the expected committed collective dose of these operations. Although the frequency at which radiation doses incurred in these operations, that would justify a row arrangement, was unrealistically high, there was no agreement on this issue and the decision was left to the management staff which decided on the row placement, with about two meters wide corridors – a conservative albeit more expensive design than the column placement.

2.3.3 – Arrangement of packages

Packagings will be stacked in five layers, each one consisting of a pallet and four drums. Steel boxes are stackable without pallets and are roughly the same size of each pallet-drum module. The weight of the upper drums will be supported by the lower layers.

Packages were stored in the former storage room following the criteria of putting packages first in the back of the building and proceeding forward to the door, as treated waste packages were produced. The guidelines for the emplacement of the existing packages in the new storage room are: heaviest packages close to the floor; high dose rate packages at the center of the store; and packages eligible to retreatment and further volume reduction in more accessible rows.

The weight of waste packagings varies between about 150 kg and 600 kg for 200 L drums and from 1.5 to 2 tons for boxes. The boxes contain recyclable paper bales, the lightest drums contain low density compacted wastes, and the heavier drums contain radium needles encapsulated in barites concrete. Therefore, boxes and heavy drums are to be placed in the first layers of the stacks.

The dose rate at the surface of the waste packagings varies from near 2 mSv/h down to values close to the background. Since the beginning of operation of the facility, this upper limit had been established for waste packagings taking the exposure rate limits of transport regulations as the criteria. These limits were used to guide package design and to limit waste activities in each drum. Packages with low dose rates contain mainly alpha and beta emitters. The emplacement of the high dose rate packages near the center of the store takes advantage of the shielding effect of the other packages to reduce external doses.

As stated before, some packagings can undergone further treatment – for instance, segregation of shorter and longer half-lived waste bags that were compacted together. A study of the clearance of these wastes, using the methodology of optimization of the radiation protection [13], showed that a significant number of drums could be reworked to reduce the volume of the stored wastes. However, the decision depends, among other things, on the availability of resources for expenditures with construction and operation of the necessary equipment. In any case, all eligible drums should be stored as to facilitate their retrieval from the building.

2.4 – Control of gaseous discharges

CNEN-NE-6.05 requires ventilation, exhausting and filtration systems in the store room (item 'i' of the requirements list in section 2.1 above). This requirement was maintained in the draft of the new regulation. It is debatable, however, whether forced ventilation and filtration systems should or should not be installed in a store for solid, drummed wastes. These systems are expensive and present drawbacks because they need passive safety operation and a low frequency maintenance program.

Under normal operating conditions, no radioactive gases or aerosols are expected to be produced by the treated wastes, except perhaps radon and radon progeny from radium needles or radium bearing solid wastes. In the event these air contaminants leak from the drums it is expected that they constitute a fraction of the amount emitted from naturally occurring sources. However, gases and aerosols can be generated under accident conditions and the question becomes to investigating whether accident scenarios that can occur would produce relevant quantities of air contamination to require control of discharges.

The store for untreated wastes is more susceptible to produce air contamination under normal or accident conditions because the packages are usually much less robust and wastes in gaseous and liquid forms will be stored there. Considering that the functions of the two storage rooms must be interchangeable, the ventilation, exhaust and filtration systems were included in the concept of both. Two other considerations aided in favor of installing the air cleaning systems: first, the literature shows examples of radioactive waste store rooms in other countries being equipped with air handling system [14, 15, 16, 17]; second, the concept of the new storage is to keep waste packages clean. In the former storage sheds, dusty, humid air of the region quickly created a layer of dirt on the surface of the drums.

Basically, the gaseous discharge control system is composed of an exhaust fan that aspirates the air from the interior of the building and discharges it to the exterior through a filter bank. Change rates were determined according to the experience in other countries, for instance, the Nuclear Ventilation Group of the British Nuclear Fuel Limited [18]. According to guidance in AECP-1054 [19] of United Kingdom, for controlled areas of low potential hazard, which was used as a reference document to filling the gap in Brazilian regulations, the fan must provide two air changes per hour.

The exhaust and filtration system design includes one air extraction grille with local filtration and one air inlet point in the opposite side of the building for each storage room. The filter bank is composed of three filters in series: one pre-filter for coarse and one for fine dust particles complying with Class G and Class F of Brazilian Standards [20] respectively, and one high efficiency particulate air filter that complies with Class A of those standards. A bag-in bag-out system for replacement of the filters is desirable for cleanliness but it is not mandatory because no high activity contamination is expected. Operational experience of GRR indicates that the Class G filters must be replaced once each six months, Class F filters each two years and Class A each six years. However, this is a simple estimate and manometers must be installed to monitor the pressure drop across each filter and indicate when they should be replaced.

The building envelop must present some degree of air tightness to aid in keeping underpressure inside to assure that any contaminated air passes through the filtration system. It was assumed that minus 5 mm water gauge pressure is sufficient to maintain an inward air movement. To keep the internal space isolated, an isolation chamber is requires at the entrance of the building. It must be large enough to accommodate the forklift truck in the access door. The building also requires ceiling, fixed windows and special doors. The specification of these items is given below.

2.6 – Control of liquid discharges

CNEN regulation requires that the store of radioactive waste have a floor drain and storage tank with capacity to hold spills and decontamination liquids.

Under normal operation conditions, no liquid discharge is expected in the store because treated wastes are all solid or solidified and untreated wastes will be solely stored in the building. However, in the event of leakage of liquid wastes, the accidental release of radioactive material to the environment must be avoided and so the storage rooms were designed as to collect any spill or decontamination liquids into holding tanks. Furthermore, an analysis of accident scenarios in the facility indicated that an unusually strong storm could partially break the roof and let rainfall gets in. In this case it would be necessary to hold the water that flushed the packages in a holdup tank, to allow monitoring the presence of any radioactivity before discharging to the sewage system, mainly to demonstrate that no relevant release has occurred.

To define tank capacity, scenarios of heavy rainfall entering the store was used as criteria. In the postulated accident, 50 m^2 of roof is broken and allow for the maximum one day average precipitation of the isohyet of IPEN’s region (80 mm) to flow into the storage room during one hour. The damage area was defined taking into account the typical size of roofing tiles. This scenario results in holding tanks with capacity of 4 m^3 for each storage room, inside the building.

2.7 – Building structure, components and materials

<u>Structure</u>:

The storage is composed of two single storey rectangular contiguous rooms with overall plan dimensions of approximately 25 m x 14 m, with no internal partitions, rising to an eaves height of approximately 5.5 meters. Reinforced concrete columns in the perimeter provide support to the roof structure and lateral stability to the building. Exterior walls are of concrete blocks masonry, finished with mortar and plaster. Additional shielding walls, for instance reinforced concrete walls, are not required for the wastes existing at present or that are expected in the future.

Roof:

The roof is of symmetrical double pitch form and comprises commercial insulated metal cladding on steel purloins which span between the portal beams. Roof draining must be achieved by gutters discharging into downspouts to the exterior of the building envelope.

Ceiling:

The suspended ceiling system will be constructed with plaster cardboard tiles, hung with a metal grid fitted to the roof structure. This system was selected because of its light weight, smooth finishing, heat insulation properties, cleanliness, easy of repair, and because it allows to maintain the underpressure in the building.

Floor:

The ground floor comprises a reinforced concrete ground bearing slab finished with an epoxy resin. The slab and floor finish must have capacity to support the applied loads placed on it during the life time of the building. The applied load will have three components – the dead load, which includes the weight of the structure of the floor, the additional static load of the stored packages and the dynamic load of the forklift truck plus the payload. The project criterion is the dynamic load of the operation of the forklift truck with its maximum payload. The maximum load value is 5,800 kg over the forklift truck's load-axle – 3,280 kg of the equipment plus a payload of 2.5 tons.

Flooring:

The floor finishing must be an industrial epoxy resin floor coating, which provides a hard wearing, chemically resistant, slip resistant, non-dusting surface, with a minimum of 3 to 5 millimeters thickness. This coating is deemed suitable for the working environment of the store building.

Walls:

The walls must be painted with acrylic paint in the exterior and with epoxy-based paint in the interior to comply with the CNEN-NE-6.05 requirement of an impervious and ease to clean and decontaminate wall surface finishing.

Doors:

The building entrance and the isolation chamber must be fitted with air sealed doors, large enough to allow for the operation of the forklift and to provide a secure access to the stored wastes, while keeping the interior space isolated. The passageway must have about 3 m x 3 m. Heavy-duty industrial doors used in walk-in freezer warehouses assure good seal, high speed operation, and security. The external door can be a horizontal sliding door and the internal door can be a sectional overhead door. These two door types are adequate to the building and isolation chamber geometry.

Windows:

The building will be fitted with fixed windows that cannot be opened and whose function is limited to allowing light to enter while avoiding the interference of wild life in the store. The number, size and position of the windows will be determined as to provide a good lighting and, at the same time, prevent them to be used as an unauthorized access to the building.

Figure 5 shows pictures of the interior of the two storage rooms as they were built and are under operation.

Figure 5 – Views of the interior of storage rooms – treated wastes at left, untreated at right.

3. FINAL REMARKS

Although the issues addressed in the above text are neither deemed to cover all relevant aspects of the design of a radioactive waste interim storage facility nor to be examined from the best angle or have led to definitive conclusions, many of the approaches taken in this work resulted in concepts that were actually adopted in the project that eventually resulted in the new GRR storage facility.

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