RADIOACTIVE WASTE MANAGEMENT AT NARORA ATOMIC POWER STATION IN INDIA

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Abstract

Modern Society creates wastes material, which have to be disposed off in nature without disturbing the ecological equilibrium. Hence effective waste management in all industries is a major concern today. Narora Atomic Power Station (NAPS) generates low and intermediate level liquid, solid and gaseous wastes during it's operation and maintenance. The generation of wastes is controlled at source itself. The wastes are managed by adequate and appropriate treatment before releasing to the environment. Different types of liquid wastes are treated by chemical co-precipitation, ion exchange, evaporation, filtration, and dilution technique. For handling and conditioning of solid wastes, volume reduction techniques such as incineration and baling are employed. The treated wastes are immobilised by incorporation into cement and polymer matrices. Gaseous waste is cleaned by passing through pre-filters and high efficiency particulate (HEPA) filters and diluted with inactive air prior to release to the atmosphere through a 145 m high stack to get further atmospheric dilution. Regular monitoring upto 30 Km. radius is carried out by fully equipped Environmental Survey and Micrometeorological Laboratory which is functioning independently under the Directorate of Health and Safety, Bhabha Atomic Research Centre (BARC), Mumbai. So far, the annual maximum dose to the public around NAPS is reported to be 0.2 to 0.3 % of limit of 1 mSv/year recommended by the International Commission on Radiological Protection (ICRP). A decade of experience has proved that present practices of nuclear waste management at Narora Atomic Power Station are quite safe and effective with respect to ecological equilibrium.

1. INTRODUCTION

The most important objective in radioactive waste management is to isolate the waste from the biosphere and to ensure that man will not receive unacceptable detriments at present and in the future.

NAPS is the fourth nuclear power station having twin units of 220 MW(e) capacity each. It is situated on the bank of the holy river Ganga at Narora which is 140 Km. away form New Delhi, the capital of India. It is the first standardised and totally indigenous PHWR type nuclear power station.

The operation and maintenance of these two units generate low and intermediate level waste of various composition and activity levels. It is necessary to ensure that these wastes are managed and controlled in a perfect manner to comply with the requirements specified by the regulatory body. Radioactive spent fuel is stored in a spent fuel storage bay for adequate duration of time to remove decay heat and then sent to another site for reprocessing the fuel. The spent fuel does not form a part of the radioactive waste treatment and management system at NAPS and hence is not covered here.

Radioactive waste management aims at isolation of the environment from the spread of radioactivity till it decays to innocuous levels. This is achieved by removing most of the radioactivity from the liquid and gaseous waste before discharging to the environment. The concentrated wastes containing the radioactivity thus removed are immobilised and along with the solidified conditioned waste isolated from the environment using a multi-barrier approach such as cement/polymer matrix, the engineered barrier, and the geo-environment.

2. RADIOACTIVE WASTE MANAGEMENT

The waste management facility at Narora Atomic Power Station provides facility for segregation, collection, treatment, storage and safe disposal of liquid and solid radioactive waste. The philosophy of waste management is based on the principle of ALARA (as low as reasonably achievable) taking economic and social factors into account. Three principles governing the management of radioactive wastes are:

(1) Dilution and dispersal of low level waste,
(2) Delay, decay and dispersal of waste containing short lived radio-nuclides, and
(3) Concentration and containment of wastes containing long lived radio-nuclides after conditioning.

The waste management facility is functionally divided into the following four systems:

(1) Liquid effluent segregation system (LESS),
(2) Liquid waste treatment and disposal system,
(3) Solid waste management system,
(4) Gaseous waste management system.

2.1. Liquid effluent segregation system (LESS)

This system is located in the service building and provides for collection and segregation of all the liquid wastes generated in the station at source based on radioactivity levels and chemical nature so as to:

- Minimize cross contamination, and
- To facilitate judicious decisions in respect of management of each category of waste.

Liquid waste received is sampled, monitored and pumped for treatment or dilution and discharge depending on the activity content. All pipelines carrying liquid waste are made of stainless steel and hydrotested at regular intervals to ensure their integrity.

2.1.1. Type and source of liquid waste

The waste management facility is designed to handle the liquid waste of the following nature generated from different sources as mentioned below:

- Potentially active waste (PAW): Showers/washroom and laundry,
- Active non-chemical waste (ANCW): Service area floor drains, decontamination wastes: Lab. washes and rinses, SFSB area, spent resin-handling system,
- Tritiated waste (TTW): Reactor bldg. sump and D_2O upgrading plant,
- Active chemical waste (ACW): Decontamination and laboratory solutions.

A storage capacity of 25×10^5 litres is provided to meet any contingency requirement.

2.1.2. Reduction of liquid waste

In this system, control over waste volume and activity generation is made effective at source. The following measures are used to keep the generation of liquid wastes as low as practicable:

- Provision of close loop operation in spent radioactive resin handling system,
- Operating the reactor so as to avoid fuel failures and discharging failed fuel bundles as soon as possible,
- Reducing leakage from the primary coolant system and other related systems,
- Planning and performing maintenance work with care and with emphasis on precautions to minimize the spread of contamination,
- Taking precautions to minimize the contamination of equipment and tools so as to reduce the need for decontamination,
- Ensuring proper contamination monitoring and usage of appropriate decontamination procedures.
- Reducing the production of secondary wastes by proper selection of waste treatment methods.

2.2. Liquid waste treatment and disposal system

A schematic showing treatment methodology for different streams of liquid waste is shown in Figure 1. The basic philosophy of various treatment techniques used, such as chemical co-precipitation, flocculation and sedimentation is to concentrate and contain as much radioactivity as possible, prior to their discharge in an environmentally acceptable manner. Decontamination by chemical treatment involves co-precipitation using ferro-cyanides, phosphates, hydroxide, etc., in association with scavenger often used for effective removal of fission products (^{137}Cs, ^{134}Cs and ^{90}Sr), corrosion and activation products (^{60}Co, ^{65}Zn). This process gives a decontamination factor (DF) of 10-20 for dissolved radioactivity. For separation of precipitated solid and liquid, a sludge blanket type clarifier is used in which two meter thick sludge blanket is always maintained. This blanket acts as a filtering media also. Hence, when the waste mixed with chemicals is passed through the sludge blanket clarifier, very finely suspended radioactive particles also gets trapped in the sludge blanket giving a high DF of the order of 90-100 for the suspended radioactive particles. This results in very low turbidity (<1 N.T.U.) in the treated waste water.

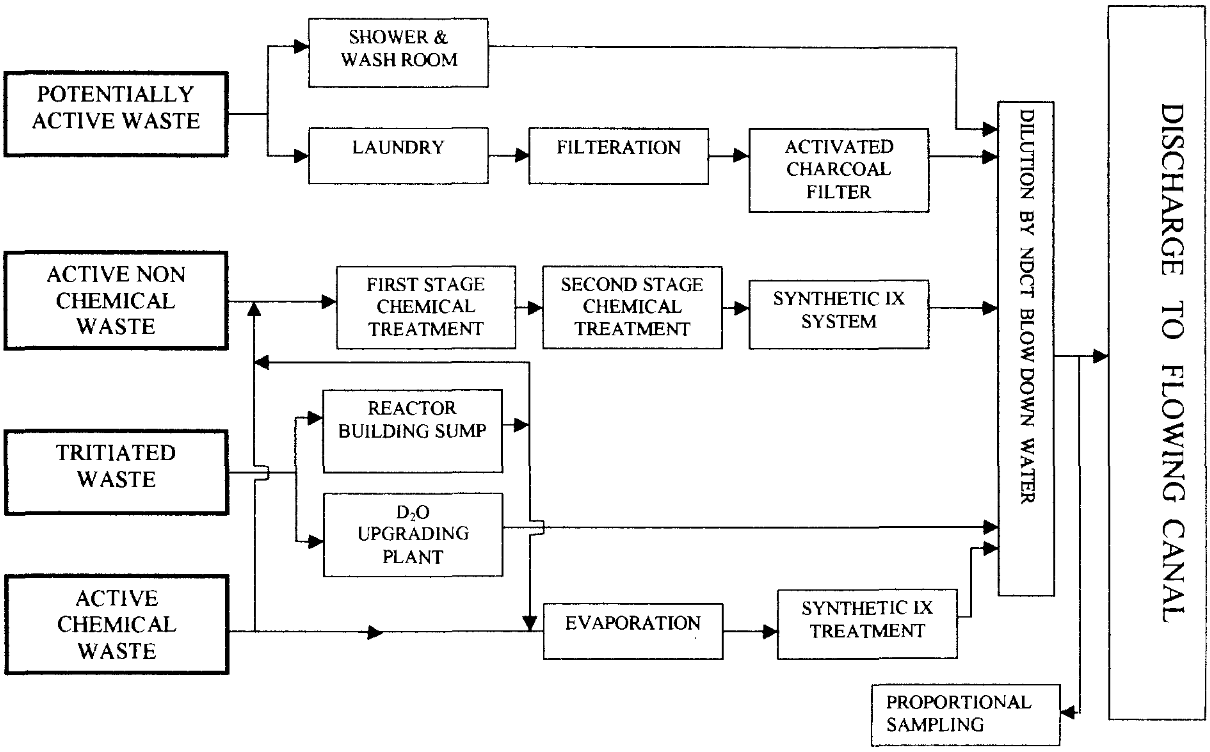

FIG. 1. Liquid waste treatment and disposal schematic.

In case of radioactivity due to ^{131}I the philosophy of delay and decay is adopted. This process, followed by treatment if required for polishing through a synthetic ion exchange system, is used for the liquid waste having gross beta-gamma radioactivity up to 55 $KBqL^{-1}$ which include dissolved as well as suspended radioactivity. If gross beta–gamma radioactivity level is higher, steam evaporation system is envisaged in the design. This system need not to be operated, since higher level of radioactivity is not observed in the liquid waste during normal operation. However, it may be useful in case of any off-normal waste generation. The waste stream like PAW which does not have gross beta-gamma radioactivity or is very low in radioactivity is directly sent to a post-treatment tank. No specific treatment is planned for radioactive tritium except dilution and discharge. In the treatment process almost 98% of the total gross beta-gamma radioactivity (see Figure 2) is removed from the liquid waste and stored as solid waste at the plant site.

Treated waste is stored in a post-treatment tank. Finally, it is re-circulated for homogenization, sampled and after filtration is injected into the condenser cooling water blow down line for dilution. The diluted waste is released to the flowing canals. An on line proportional sampler is provided at the final outlet to check the specific radioactivity level of the diluted waste water being released. Sludge generated from chemical treatment forms a part of the solid wastes.

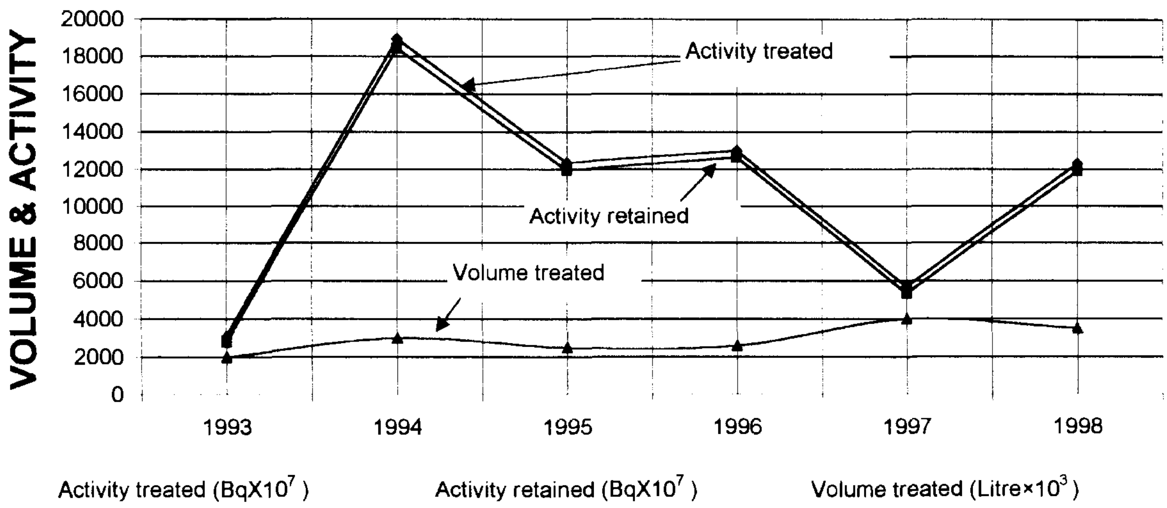

FIG. 2. Performance of chemical treatment system.

2.3. Solid waste management system

2.3.1. Categorization of Solid Waste

In India, solid wastes from nuclear power plants are broadly classified based on surface dose as per the categorization recommended by the International Atomic Energy Agency (IAEA) as follows:

- Category I. Waste with contact surface dose rate ≤ 2 mGy/h,
- Category II. Waste with contact surface dose rate > 2 mGy/h but ≤ 20 mGy/h,
- Category III. Waste with contact surface dose rate > 20 mGy/h.

However, for the purpose of segregation at source, Category-I waste is further divided into two groups:

- Combustible waste,
- Non-combustible waste.

From the point of view of disposal of solid/solidified waste packages, Category III wastes are further sub-divided into two groups:

- Category-IIIA: Waste packages having surface dose rate ≤ 0.5 Gy/h,
- Category-IIIB: Waste packages having surface dose rate > 0.5 Gy/h.

2.3 2. Generation of Radioactive Solid Waste

2.3.2.1. Category I waste

This type of waste largely originates from reactor maintenance/operation and consists of protective clothing, contaminated metal parts, cleaning/packaging materials like cotton, paper and wood etc. Solidified sludge/precipitate generated from chemical treatment for removal of radioisotopes from liquid wastes and exhausted pre-filters and HEPA filters from the ventilation system also form a part of this category of waste. Majority of the waste has a contact field much less than 2 mGy/h which is the upper limit chosen for the purpose of categorization.

2.3.2.2. Category II and III wastes

These types of wastes originate from on line water purification system and consist of filter cartridge and ion exchange resins. Typically this waste has an unshielded radiation field greater than

10 mGy/h. Therefore, additional shielding and greater precautions are required during transportation, handling and storage operation than those required for category-I wastes.

Spent filter cartridges from various purification systems are handled by shielded flasks to protect personnel from radiation during removal and transportation to the radioactive waste storage area.

Spent radioactive ion exchange resins with high radiation levels are produced m primary heat transport system, spent fuel storage bay purification system and moderator system.

2.3.3. Reduction of solid waste

Solid waste production is kept as low as practicable by using measures such as:

- Measurement of solid waste in low background area,
- Pre-fabrication of jobs in inactive areas,
- Restriction on movement of inactive items such as packing materials in active area.
- Recycling of waste,
- Careful planning and performance of maintenance work,
- Careful movement of radioactive material,
- Efficient operation of primary heat transport, moderator, spent fuel storage bay purification systems, liquid and gaseous waste treatment systems,
- Provision of effective contamination control at source,
- Good segregation practice at waste generation point itself.

2.3.4. Treatment and conditioning

A schematic showing treatment and conditioning techniques is shown in Figure 3.

Category I waste consist of combustible waste, non-combustible waste, and compactable waste.

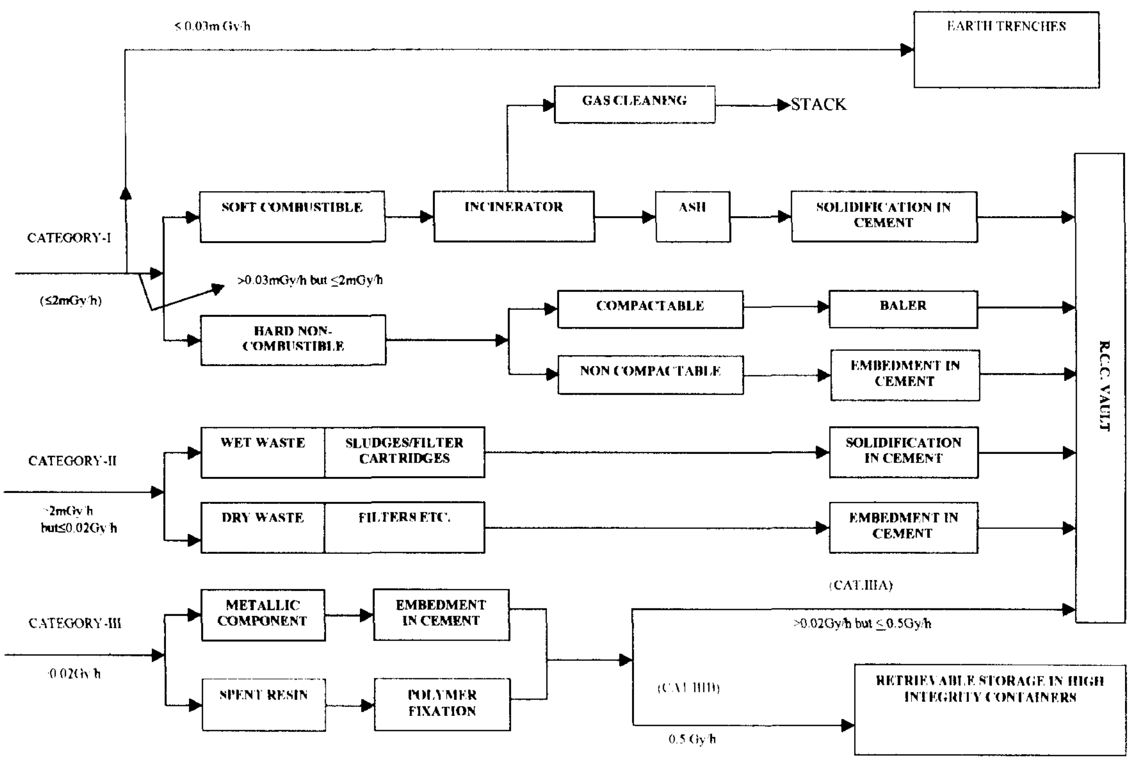

FIG. 3. Solid waste conditioning & disposal schematic.

2.3.4.1. Combustible waste.

It contains mostly paper, cotton, and protective clothing etc. which are incinerated in a pyrolytic type incinerator furnace at a temp. of 850°C to 1000°C to obtain over all high volume reduction factor of the order of 35 to 40 which after immobilisation with cement slurry resulting in a final volume reduction factor of 18 to 20. The incinerator system needs to be operated hardly for four to five days in four months. The gases emanating from the incinerator are released to atmosphere after necessary cooling and cleaning. For gas cleaning, a dry type filtration system with cyclones, bag house filters and HEPA filters (having efficiency 99.9 % for 0.3 micron size particles) is used. At the final out let an on line activity monitor is installed and no radioactivity is allowed to be released to the atmosphere. Ash collected is immobilised with cement and vermiculite that form a monolith in a 200 litres standard drum. The fuel used is liquefied petroleum gas which is a neat and clean fuel system. All the equipment in this system are maintained at slightly negative pressure to avoid any probability of ground level activity release due to leakage from the system if it occurs. An in-built safety feature shuts down the whole system automatically in case of low negative pressure.

2.3.4.2. Non combustible waste

It contains mostly sludge precipitate from chemical treatment of liquid waste and some metallic items. Sludge is solidified and metallic items are embedded in cement and vermiculite.

2.3.4.3. Compactable waste

It contains mostly plastic protective wearing and particulate filters. These are reduced in volume by a factor of 5. This is achieved by in-drum baling of the waste using a hydraulic baling machine having pressurisation capacity of 68.71×10^5 Pa(g).

Category II and III waste consist of filter cartridges, metallic components, and spent resins. The filter cartridges and metallic components are incorporated in cement and vermiculite.

The spent resins are immobilised into polymer matrix to have better isolation from the biosphere. Spent resins contains most of the activity generated in the form of solid wastes and hence needs a special care for it's management. The technique of immobilization of spent resin in polymer has been developed for the first time at NAPS and has been recently put into commercial use. In the process of immobilization, spent resin beeds are physically incorporated into polyester-styrene (isophthalic grade) by making a 200 litres monolith block. The catalyst and accelerator used in this process are benzoyl peroxide and dimethyle aniline respectively. The polymer is found to be a most compatible matrix material for immobilization of spent resins. Compatibility of matrix with waste, chemical and biological durability of immobilised product and thermal/radiological stability of product under storage conditions have been found to be satisfactory. Compressive strength and leach rate of the product are 165×10^5Pa(g) and 2×10^{-4} kg.m. $^{-2}$d^{-1} as against acceptance criteria of 48.54×10^5 Pa(g) and 10^{-3} kg.m. $^{-2}$d^{-1} respectively. Fully remotised operation in a hotcell is carried out for spent resin immobilisation. The various remote handling facilities existing in this system are as follows:

- Rugged duty type with extended reach Master slave manipulators,
- In-cell crane,
- Electrically driven trolley,
- Motorised valves,
- Radiation shielding viewing window,
- Self aligned electrically driven mixer assembly.

2.3.5. Disposal of conditioned waste

All waste are disposed into engineered containers in shallow land burial facility located inside the plant premises only. Depending upon the category of wastes, different modes of storage/disposal containments are used.

2.3.5.1. Earth trenches

These are vermiculite lined trenches (16m × 10m × 2m) having 3 chambers. The waste packets reading upto 0.03 mGv/h are disposed in these trenches. After filling, they are covered with soil giving a mound shape at the top.

2.3.5.2. Re-inforced cement and concrete (RCC) vaults

These are 4m × 4m × 2m concrete vaults located above ground level and have an RCC wall of 0.125 m thickness. All waste packets reading more than 0.03 mGy/h to 0.5 Gy/h are disposed in these vaults. In general, higher radioactive waste will form the bottom layer in the RCC vaults followed by less radioactive waste on top. After filling the vault with waste, cement grout is poured to seal the vault permanently. Further, vaults are closed with top RCC covers and sealed with cement grout. Water proofing is done on the top surface.

2.3.5.3. High integrity containers (HIC)

These are steel lined cylindrical RCC containers as shown in Figure 4. Waste package having more than 0.5 Gy/h surface dose is disposed in high integrity container and sealed completely by welding the top cover and concreting over that. HICs are stacked in single layer in earth trenches and can be retrieved in the future, if so required. It is specially designed to provide higher life span and integrity against any natural calamity. It also provides a shielding of about 2 TVL (tenth value layer).

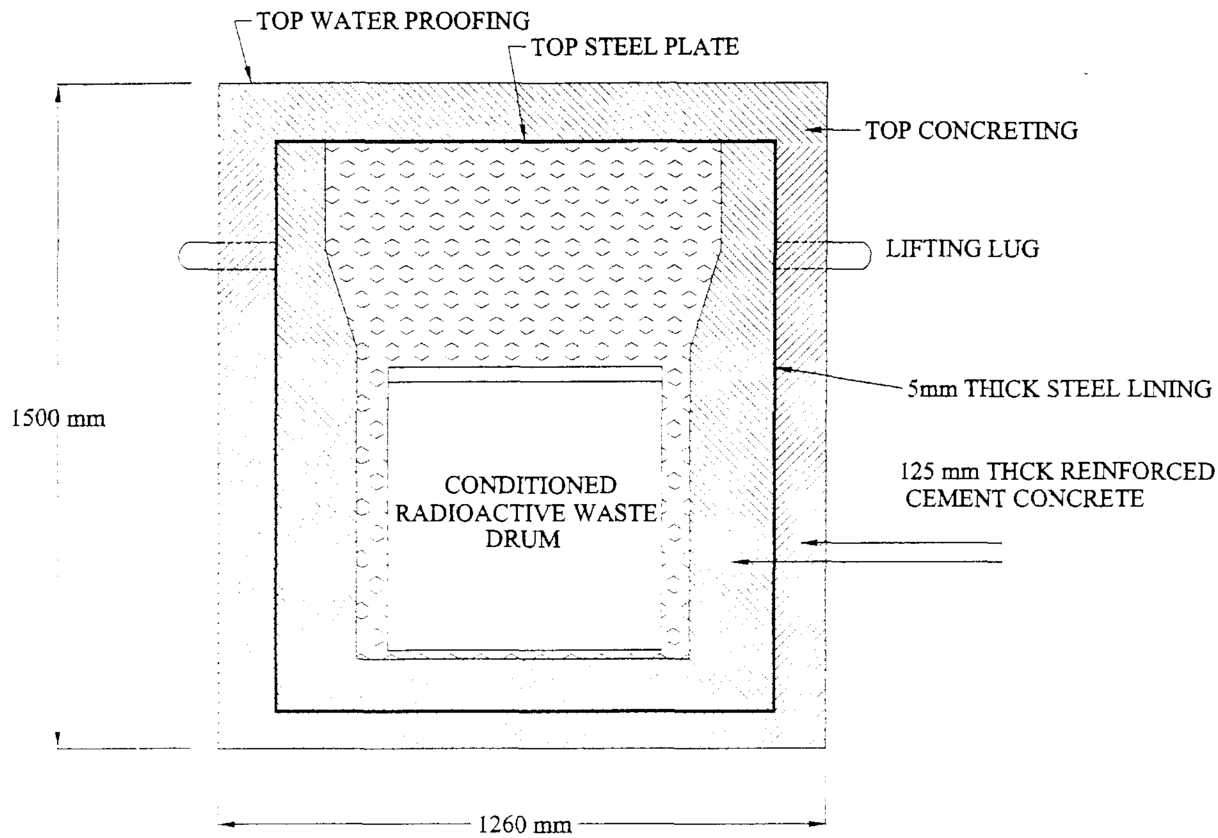

FIG. 4. High integrity container.

2.4 Gaseous waste management

An extensive ventilation system consisting of pre-filters and HEPA air filters as indicated in Figure 5 collects potentially active exhaust air from areas such as reactor building, spent fuel handling and storage area, the decontamination centre, and the heavy water management area. The exhaust flow is further diluted with inactive exhaust air from service building and monitored for noble gases, tritium, iodine and active particulate before being released to the atmosphere through a 145 m high stack. Signals from iodine, wide range gamma and particulate monitors are recorded in control room. Tritium monitoring is carried out by laboratory analysis of bubbler samples. Activity releases are maintained well below technical specification limit.

3. SAFETY ANALYSIS OF WASTE MANAGEMENT FACILITY

Detailed safety analysis of waste management facility at NAPS has been carried out by BARC. An institutional control of 300 years on the solid waste repository has been assumed for the purpose of analysis. Using a unidirectional model with axial dispersion and taking into consideration the total loss of engineered containers and further sinking of above ground storage to sub-surface levels during a catastrophe, the analysis indicates the following.

Even with a conservation accident scenario without taking any credit of engineered containment and assuming the site fully submerged under water and relatively high input, source term of $3.33 \times 10^{8}BqL^{-1}$, the concentration of isotopes at 200 m and 500 m distance from the source is negligible.

Hence, it can be concluded that the characteristics of the conditioned wastes, the geo-hydrological condition, together with the engineered barriers will render the waste disposal/storage site at Narora Atomic Power Station safe and acceptable.

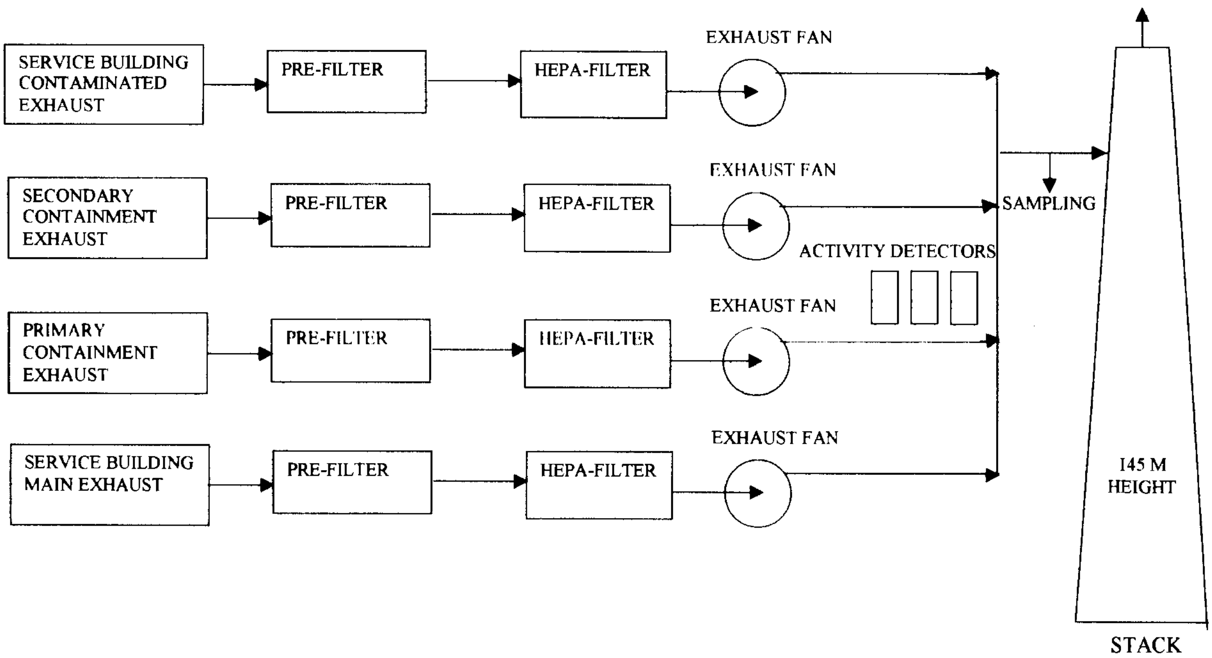

FIG. 5. Gaseous effluent management schematic.

4. ENVIRONMENTAL MONITORING

Around solid waste disposal area regular monitoring of underground water is being done by a series of monitoring bore wells to check the integrity of waste management facility. For assessment of environmental impact, a fully equipped environmental survey and micrometeorological laboratory is established at each nuclear power plant which is functioning under the Directorate of Health and Safety of BARC, an independent agency. So far, none of nuclear power plant has shown any significant environmental impact on its surroundings. The maximum dose to the public at any nuclear power plant in India is 1 to 2 % of the limit of 1 mSv/year recommended by the ICRP. Here it is to be noted that contribution of dose due to NAPS to the public is only 2 to 3 μSv/year which is in addition to 2 mSv/year getting from natural sources. Hence a decade of experience have proved that present practice of nuclear waste management at NAPS is quite safe and effective with respect to ecological equilibrium.