Original Article

# Assessment of Radiation Exposure and Radioactivity from the Liquid Discharge in a Nuclear Medicine Facility

**Subhash Chand Kheruka, Sarita Kumari, Manish Ora, Pankaj Tandon[1], Sanjay Gambhir**

*Department of Nuclear Medicine, Sanjay Gandhi Post Graduate Institute of Medical Sciences, Lucknow, Uttar Pradesh, [1]Radiological Safety Division and Central Public Information Officer, Atomic Energy Regulatory Board, Government of India, Mumbai, Maharashtra, India*

## Abstract

**Aim:** Radionuclide imaging and therapies produce radioactive liquid waste that may lead to significant radiation exposure to the general public. The study aims to assess the radiation exposure rate to public sewerage from a modified delay tank facility. We shall also evaluate the exposure rates and overall radioactivity at several points. **Materials and Methods:** After having appropriate permission from the AERB, we measured the radiation exposure from the radionuclide therapy ward. Ward has three isolation beds and a single delay and decay tank of a capacity of 7500 liters. Effluents from the delay tank are processed at the filtration plant of the institute and subsequently released in the public sewerage. We obtained samples from several sites to determine discharged radioactivity. **Results:** A total of 38 patients received 129.4 ± 42 mCi (Range 40- 200) radioiodine therapy during the study. Discharge of the tanks was done two times during the study. The radioactivity discharges into aeration plant were 89.2 and 71.2 mCi that correspond to 440.05 and 351 MBq/m3, respectively. This was diluted by the aeration tank (6 million liters). Finally, at the discharge time, the radioactivity in the discharge was 1.6 and 1.5 MBq/m3, respectively. The highest exposure rates were 14 μSv/h near the delay tank, which rapidly decreased on moving to the surrounding. **Conclusion:** Our study indicates that the addition of the dilution method and close monitoring may significantly reduce the radiation exposure and overall radioactivity release from the facility. Old facilities that do not have space to add up the tank capacity may get a benefit from it. A small change in the practice, such as admitting patients alternate months or providing extra decay time for radioactive waste, may lead to a cost-effective alternative.

**Keywords:** *Delay tank, survey meter, well counter*

## Introduction

The application of radioisotope in medicine is one of the essential peaceful uses of atomic energy. The diagnostic and therapeutic use of unsealed radioisotopes is continuously increasing all over the world. It leads to a considerable production of radioisotope waste and the environmental hazards of handling it.[1] Radionuclide imaging and therapies produce radioactive liquid waste. This may lead to significant exposure to the general public, especially sewage workers.[2-4] Safe storage of all the radioactive wastes must be done till radioactive decay reduces the activity to a safe level. However, low-level radioactivity may be directly disposed into the sewage system.[5]

Radioiodine therapy in thyroid cancer is the most common radionuclide therapy. The success of the treatment depends on the uptake and retention of radioiodine in the residual thyroid tissue or metastases.[6] The urinary system or feces excrete the unretained radioactivity. The total amount discharged during the therapeutic procedure varies according to the protocol used and inpatient or outpatient treatment.[7] Urine and feces of these patients contain significant high radioactivity. As radioiodine is an active biological substance, it has a significant environmental impact. Undue exposure of radioiodine to the general population may harm human thyroid physiology. Driver and Packer found that approximately 55% of the administered activity is excreted with in the first 24-h period following treatment, 22% in the second 24-h period, and 6% in the third 24-h period. Overall, the sewerage system receives approximately 85% of the excreted radioactivity within5 days of administration.[8]



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***Address for correspondence:***
*Prof. Sanjay Gambhir, Department of Nuclear Medicine, Sanjay Gandhi Post Graduate Institute of Medical Sciences, Lucknow, Uttar Pradesh, India.*
*E-mail: gaambhir@yahoo.com*

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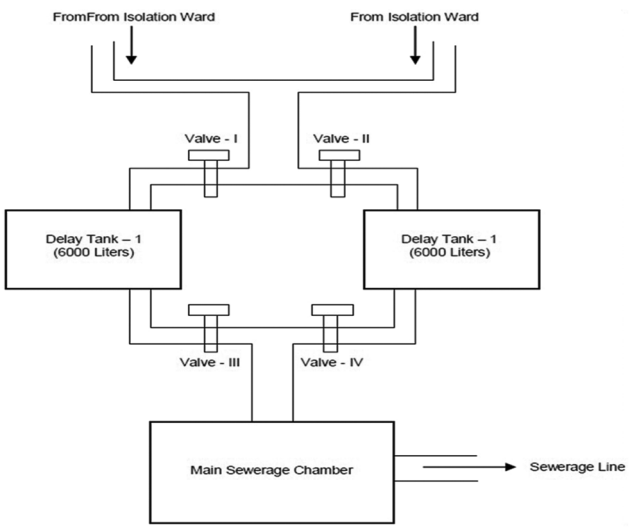


**Figure 1: Delay tank layout for 131I isolation ward as per the National Regulatory Body guidelines**

All efforts should be made to decrease the remote possibility of radioiodine exposure to the general population. Patients receiving High dose radioiodine therapy (HDRI) remain hospitalized for several days in individual isolation rooms. The patient must not expose any individual to levels higher than the dose limit.[9] Specially designed storage tank stores excreta. The regulatory authority predefines controlled disposal with appropriate monitoring. As per the current regulatory requirement in India, the nuclear medicine department giving high-dose radionuclide therapy should have a delay and decay tank [Figure 1].[10] As per the Atomic Energy Regulatory Board (AERB) guidelines, all the radioactive wastes from the nuclear medicine facility should follow the following rules.[11]

1. At the time of discharge from the ward, radiation exposure from the patient should not exceed 50 μSv/h at a 1-m distance
2. Radioactive waste of isolation ward at the time of release into the public sewerage system should not be more than 22.2 MBq/$m^3$
3. No hospital is permitted to release more than 37GBq (1Ci) of radioactive liquid waste in 1 year into public sewerage.

The delay and decay tank unit uses two tanks of the same capacity. There is the release of waste from the tanks alternatively. This leads to a significant reduction in the release of radioactivity.[12] However, building and maintaining these facilities involve a lot of economic and logistic burden, especially a small laboratory giving high-dose therapy only to small numbers of patients. The study aims to assess the radiation exposure rate to public sewerage from a modified delay tank facility. In this study, we would evaluate the exposure rates and overall radioactivity at several points from the delay tank, pipelines, and the room nearby the delay tank.

## Materials and Methods

### The current facility

The current nuclear medicine facility was built more than 30 years before and had a single delay and decay tank of a capacity of 7500 L [Figure 2]. We have a three bedded isolation ward. After complete filling of the tank (nearly 4 weeks), the effluent is sent to the aeration tank of the institute before the patient for the next week is admitted. However, this facility does not fulfill the waste disposal criteria as per the AERB guidelines. The AERB approved a pilot study to seek the radiation safety from the modified facility.

### Dilution available and Mechanism for ensuring the dilution before discharge

Aeration tanks receive the discharge of effluents from the delay tank Figure 3. It has a massive capacity of 6 million liters and receives liquid waste from all over the institute. After a weighting period of a few days, the contents of the tank are sent to the filtration plant. Before filtration, there is a mixing of chemicals into the diluted contents. From the filtration area, it reaches a postfiltration tank and subsequently released in the public sewerage.

### Patient admission

This study was conducted for 2 months, May–June 2019. Thyroid cancer patients were admitted to the ward and given a high dose of 131I-sodium iodine solution. The patient remained in the isolation ward until the level of radiation fall to 50 μSv/h/mt.

### Sampling method

One milliliter of sample was drawn directly from the decay tank every week. Effluent volume was calculated by the depth of the effluent at the time of sampling. The sample was measured using a Captus 3000 well counting system Capintec, Inc. 7 Vreeland Road, Florham Park, NJ 07932. The total radioactivity was calculated by count per second and volume. Once the tank was near filled (end of the 4$^{th}$ week), the last sample was drawn from the tank. Once the radioactivity was released from the tank, the sampling done form the aeration plant (dilution tank) just before the the post treatment tank. After a hold up in the post treatment tank the content is [Figure 3].

### Radiation-level measurement

A radiation survey meter (Technical Associate Model: TBM 15 D; Technical Associates, Canoga Park, CA, USA) measured radiation exposure. It was measured in μSv/h every week on the surface of the delay tank (closed), delay tank (open), at the time of discharge, pipeline area, nearby room, and aeration dilution tank.

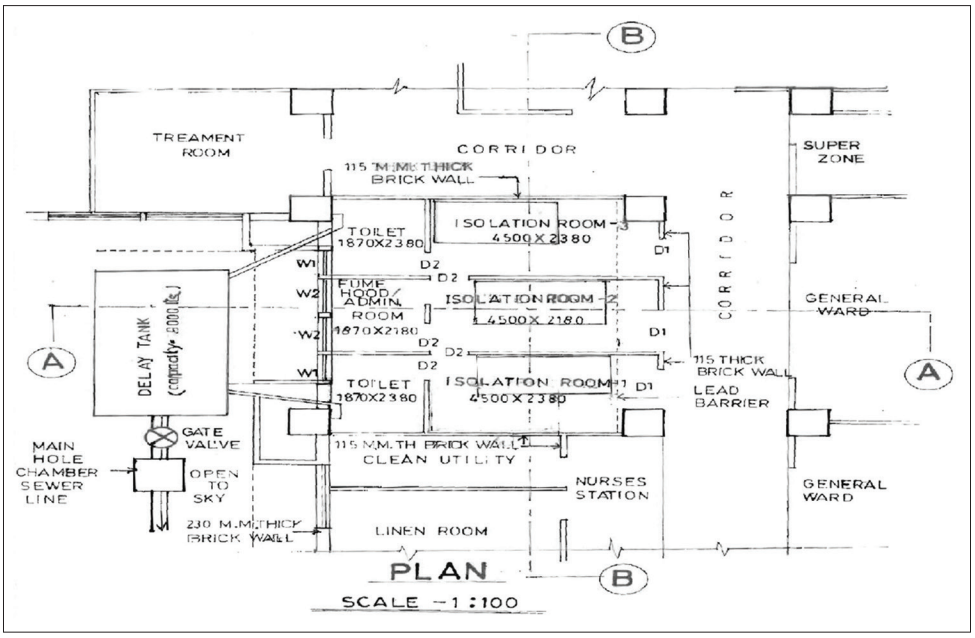


**Figure 2: Diagram showing the existing isolation ward and delay tank facility**

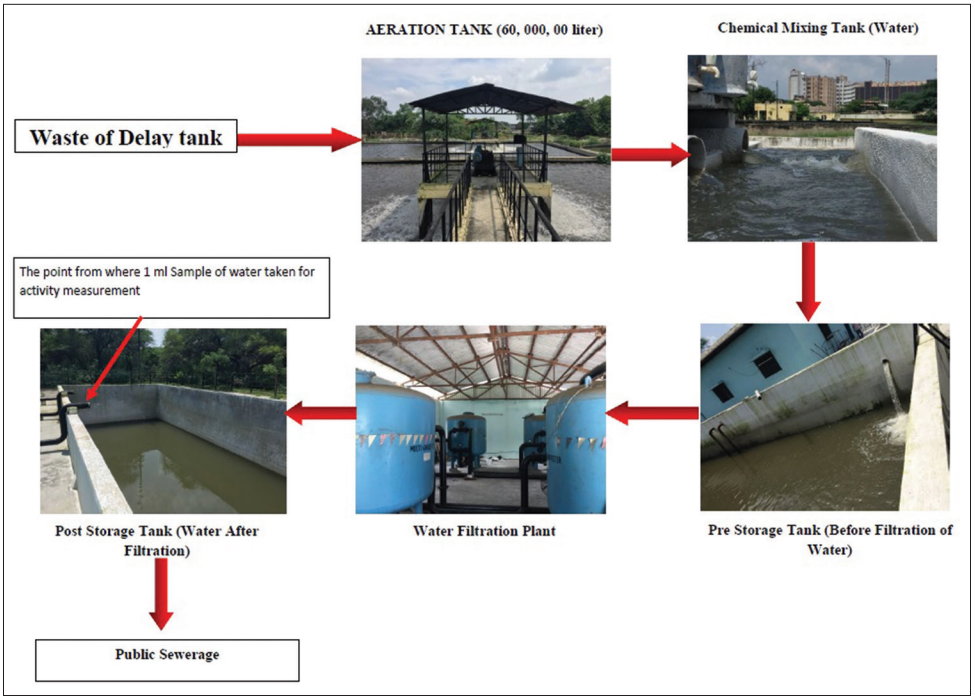


**Figure 3: Systematic diagram showing the treatment of the radioactive waste released from the nuclear medicine isolation ward before draining into the public sewerage system**

## Results and Discussion

### Patient

A total of 38 patients (26 females) received high-dose radioiodine therapy during the study. The dose of the radioiodine was 129.4 ± 42 mCi (range 40–200 mCi). Patients were under isolation for 2.1 ± 1.8 days (1–5 days).

### Radioactivity of the liquid discharge

The tank was emptied two times after the completion of 1 month. Figure 4 shows the radioactivity measured in the tank every week. As expected, there was a gradual increase in radioactivity from week 1 to 4. It was discharged at the start of the 5$^{th}$ week, just before the patients for the 2$^{nd}$ month admitted. Total radioactivity discharges into aeration plant were 89.2 and 71.2 mCi that correspond to 440.05 and 351 MBq/m$^3$, respectively. It was well above the regulatory limit of 22.2 MBq/m$^3$. The activity was further diluted by the aeration tank (6 million liters) using the dilution method

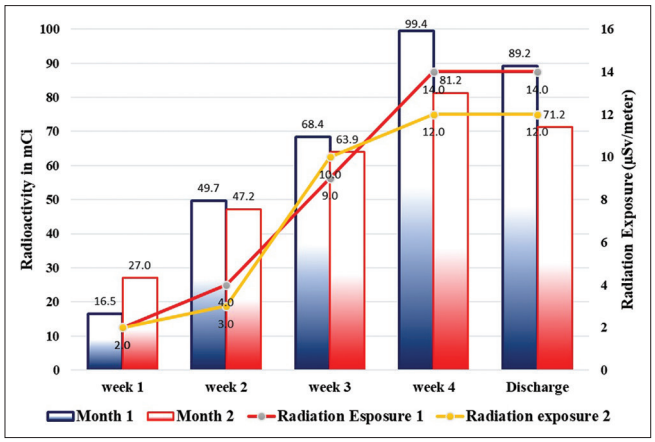


**Figure 4: Primary *y*-axis (bar chart) showing activities in mCi from both months (every week and at the time of discharge). Secondary *y*-axis (line chart) showing corresponding radiation exposures**

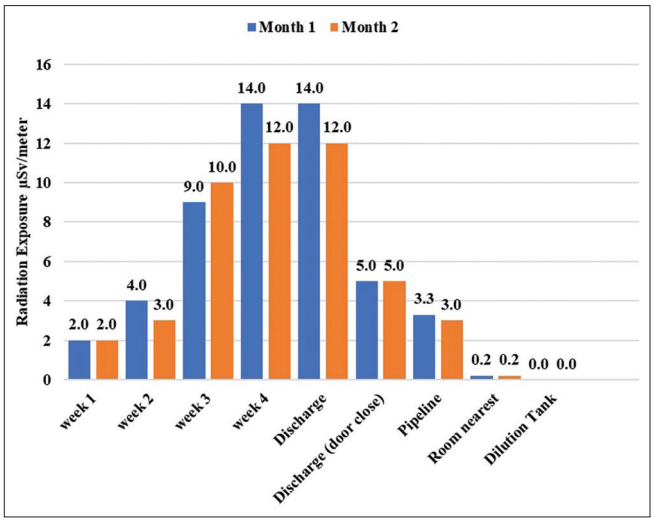


**Figure 5: The bar chart represents radiation exposure levels at the various sites in the delay tank and dilution tank facility**

and continued physical decay of the radioactivity. Finally, at the discharge time, the radioactivity in the discharge was 1.6 and 1.5 MBq/m$^3$, respectively.

### Radiation exposure from the delay tank

As expected, the exposure rate increased from week 1 to 4 as an overall increase (2–14 µSv/h and 2–12 µSv/h in both months, respectively). The highest exposure rate was 14 µSv/h when the delay tank opened to take the sample, which decreased (5 µSv/h) after closing the tank. The exposure rates decreased between 58.3% and 64.2% after closing the tank. It was due to attenuation by the wall and door of the delay tank. The pipeline connected to the delay tank was 3.3 µSv/h. The nearest room (~4 m away) had minimal radiation exposure to 0.2 µSv/h. It may be explained by the inverse square law, where an increase of distance from the radioactive source resulted in a decrease of exposure by the radioactive source. The results indicate that the delay tank facility gave a significant amount of public exposure close to the tank. Radiation exposure in the region of the dilution tank was not measurable [Figure 5].

After completion of the study, we submitted the results to the AERB. The AERB approved the study and issued the license for high-dose radionuclide therapy. Our study indicates that the dilution method and close monitoring significantly reduce the radiation exposure and overall release of the activity from the facility. The addition of the dilution method also allows more time for physical decay. Those facilities that could not add a dilution facility, an additional decay may be applied. It may be done by admitting patients alternate months and providing an extra decay time for radioactive waste. It could decrease radioactivity release by ~ 94%. We have not compared our delay and decay facility results with the standard facility design. We could not find a similar study from India to compare our findings. The results from this study may not apply to facilities with higher radionuclide utilization or with a smaller dilution facility.

## Conclusion

At present, as per the National Regulatory Body, the delay and decay tank is a mandatory requirement for the use of high-dose radionuclide therapies. However, if appropriate engineering methods are applied, an alternative arrangement could be made. In our study, we were able to achieve a significant reduction in the level of radioactivity before releasing it into the public sewerage system. Thus, we suggest an added dilution method or extended delay, and decay method may be considered as a reasonable alternative by the competent authorities.

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### Conflicts of interest

There are no conflicts of interest.

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