Peertechz

Open Journal of Thyroid Research

CLINICAL GROUP

OPEN JOURNAL OF Thyroid Research OPEN ACCESS JOURNAL

ISSN: 2640-7981 DOI: https://dx.doi.org/10.17352/ojtr

Research Article

Regulatory approach for dilute and disperse or concentrate and store of the patient's excreta after iodine therapy

Mustafa Majali* and Buthaina Al Ameri

Federal Authority for Nuclear Regulation, Abu Dhabi, United Arab Emirates

Received: 19 January, 2022
Accepted: 04 February, 2022
Published: 07 February, 2022

***Corresponding author:** Mustafa Majali, PhD, CHP, Federal Authority for Nuclear Regulation, Abu Dhabi, P.O. Box 112021, Abu Dhabi, United Arab Emirates, Tel: +971 56 1209496; Fax: +971 2 6516 661;
E-mail: mustafa.majali@fanr.gov.ae

Keywords: Exposure; Occupational exposure; Public exposure; Patients released; Iodine therapy; Radioactive excreta; Dilute radioactive waste; Disperse radioactive waste; Concentrate radioactive waste; Store radioactive waste; Discharge of liquid radioactive effluents; Sewage system; Activity concentration; Discharge of low level liquid radioactive waste

https://www.peertechzpublications.com

Purpose

This study is intended to provide for decision-makers simple criteria for determining which option or approach either dilute and disperse or concentrate and store of the Patient's Excreta after Iodine therapy would be identical to the exemption criteria, the radiation risk is sufficiently low as not to warrant any further control and has no regulatory concern. Additionally, ensure that the selected option would be inherently safe, with no appreciable likelihood of scenarios that could lead to a failure to meet both no concern and no regulatory control.

The disposal of the patient excreta containing radionuclides after Iodine therapy needs special consideration. The criteria and options for the selection of appropriate technology for either discharge of liquid radioactive effluents into the sewer system directly or concentrate and store for decay is a very important regulatory decision due to the exposure raised and costs involved and the potential complexity of technical and environmental considerations. In addition, avoiding contradiction in cost-benefit balances.

Usually, the delay and decay principle could include also concentrating and containing until decay followed by discharging it into the sewage system without further dilution by using less aqueous volume. Occasionally, the principle of delay and decay may be combined with the dilute and disperse principle where a large volume of water may be used to do so.

The "delay- stored" and "dilute- disperse" approaches have been investigated. The production source term (P) was used as a computational model by assuming that the production of the patient excreta is constant and continuous over time. The buildup activity (*A(T)*) during a period (*T*) will depend on the total removal rate (*K*) which is equal to the physical decay rate and any other removal factor if any. In this case, the buildup activity would be increased up to a certain value and reach equilibrium while the activity concentration is most likely to remain the same if not combined with an additional dilution, and would be substantially decreased when the dilute and disperse approach is applied. The decrease in the activity concentration depends on the dilution volume and hence decreasing in the occupational exposure in the facility. Usually, a large amount of diluted volume is available for direct discharge due to mixing it with other liquid effluent or water streams. By the time the effluent reaches the environment, concentrations of the radionuclides would be reduced to acceptable release levels.

Citation: Majali M, Ameri BA (2022) Regulatory approach for dilute and disperse or concentrate and store of the patient's excreta after iodine therapy. Open J Thyroid Res 5(1): 001-004. DOI: https://dx.doi.org/10.17352/ojtr.000012

The presented production source term model can be used effectively for estimating and evaluating the impact of the liquid radioactive effluents discharged into the sewage system either directly following administration of radionuclide by examining the adequacy of the sewage system. Production Model can also demonstrate and support the ICRP and IAEA recommendations which do not recommend providing and installing decay tanks to store excreta. In addition, it can also demonstrate that the concentrate and store approach can increase unnecessary occupational exposures and potential of contamination after delay and store to involved staff and workers without producing any net benefit, in addition to the cost involved. Furthermore, provides the regulatory discussion maker with a straightforward method to ensure that the selected option will be identical to the exemption criteria, the radiation risk is sufficiently low as not to warrant any further control, inherently safe, and has no regulatory concern with no appreciable likelihood of scenarios that could lead to a failure to meet both no concern and no regulatory control.

The disposal of the patient excreta containing radionuclides after Iodine therapy needs special consideration. The criteria and options for the selection of appropriate technology for either discharge of liquid radioactive effluents into the sewer system directly or concentrate and store for decay is a very important regulatory decision especially when large activities are applied during therapy. The process of selecting the optimized liquid effluent management option may be complex due to the exposure and costs involved, the potential complexity of technical and environmental considerations, and the need to ensure the adequate performance of any required decay storage arrangements when such approach has been selected.

Usually, the delay and decay principle could include also concentrating and containing until decay followed by discharging it into the sewage system without further dilution by using less aqueous volume. This will include the increase of occupational exposure to workers in the facility during the storage period. Dilute and disperse principle means discharging liquid radioactive effluent to the environment whether after ensuring that the concentrations of the radionuclides are reduced to an acceptable released level or not. Occasionally, the principle of delay and decay may be combined with the dilute and disperse principle where a large volume of water may be used to do so. In both approaches, it is important to avoid unnecessary occupational exposure to either work in a facility or worker in a treatment plant where the final destination is. In addition , avoiding unnecessary exposure to the public or released to the environment.

ICRP [1] and IAEA[1] recommended do not require urine to be stored and no need to provide and install decay tanks where no evidence that this practice produces any net benefit to the population. Meanwhile and where the sewage system is inadequate, the installation of a decay tank system to reduce the impact of the radioactive effluents should be considered [2]. Whatsoever, in light of this contradiction, the regulatory decision is needed to decide whether the ICRP recommendation can be implemented without any furthers obligations or if the sewage system is adequate or not to do so. Therefore, an assessment or case study accepted by the Regulatory Authority should be performed. Such study should take into consideration the volume, frequency, activity, concentration, physical and chemical characteristics of the effluent generated. In addition to ensuring that the optimal approach which fits the purpose is provided.

The "delay and stored" and "dilute and disperse" approaches have been investigated . The available and reliable computational models, as well as, published results have been also used in order to calculate, assess, and compare the doses that could be acquired by involved staff or by a member of the public when either approach has been selected.

According to ICRP publication 94 [1], approximately 55% of administered activity ($A_{admin.}$) is excreted in the first 24-h period following treatment, 22% in the second 24-h period, and 6% in the third 24-h period. A total of 85% of the administered activity is discharged to the sewage system or to the decay tank over 5 days diluted with flushing and washing water volume only. Usually, the patient uses about 50 liters per day for toilet flushing and washing or about 250 liters by the time the effluent reaches the decay tank over 5 days. In case of the continuous treatment process as once a patient is released another patient will take his place, another activity concentration A_V will be added to the stored amount despite the decay being ongoing. Over time, the accumulated activity continues increasing combined with increases in the exposure until reaches a sort of equilibrium. In addition, increasing in the potential for contamination and leakage. When insufficient water volume is applied due to the limited storage capacity, a substantial increase in exposure will be resulted due to a substantial increase in activity concentration.

If we assume the accumulation and production of radioactive effluent is associated with the continuous introduction of radionuclide into the environmental system due to direct discharge or into storage tanks if stored for a while. The production rate ($P=A/t$) is constant and continuous over time (t). The buildup activity $A(T)$ during the period (T) is:

$$A\left(T\right) = \frac{P}{K}(1 - e^{-KT}) \tag{1}$$

Where K is the total removal rate from the system. This removal includes the physical decay (λ) of the nuclide of ($T_{1/2}$) and any other removal factor if any [3].

When KT>> 1, the term (e^{-KT}) goes to zero and the system will reach equilibrium and buildup activity stay constant if it remains subject to the continuous introduction. If we assume that patient excreta (or any release) containing radionuclides is released continuously over the hospitalization period (t), then the source term or production rate has units of activity per time (*i.e. Bq. d*$^{-1}$). In case there is no activity initially present and no

[1] IAEA position statement on release the patients after radionuclide therapy, Ref. K9010241, dated on 23 Feb. 2010.

Citation: Majali M, Ameri BA (2022) Regulatory approach for dilute and disperse or concentrate and store of the patient's excreta after iodine therapy. Open J Thyroid Res 5(1): 001-004. DOI: https://dx.doi.org/10.17352/ojtr.000012

other removal factors, then the accumulated or buildup activity ($A(T)$) during the period (T=∞) is:

$$A\left(T\right)=\frac{P}{\lambda}=1.44\times A\times\frac{T_{\frac{1}{2}}}{t} \quad (2)$$

In the presence of continuous introduction of radionuclides whether into storage tanks or to the environment, the evaluation point can be indicated by the ratio of release rate and half-life of released radionuclide from a single source. If the duration of the discharge is greater than half-life, the accumulated activity will decrease and versa visa. This amount will be diluted with flushing and washing water volume (V). So, the activity concentration A_V is:

$$A_V=\frac{A(T)}{V} \quad (3)$$

In a medical facility that has more than one iodine therapy room discharging the Patient's Excreta to decay tanks. The accumulated activity will be multiplied by the number (n) of rooms. In addition to excreting only 85% off ($A_{admin.}$) over hospitalization period. Over time, double amount of administrated radioactivity will be accumulated in decay tanks as a result of the patient stay for 5 days [$A(T)=1.44\times1.6\times0.85\times A_{admin}=1.96\ A_{admin}$]. Subsequently, double of the exposure to involved workers. The resulted exposure actually is depending on the amount of diluted water which is most likely insufficient to ensure not exposed the workers. The dose rate at distance (d) from the stored activity concentration in tanks is:

$$D=\frac{\pi A_V\Gamma(1-e^{-\mu x})}{\mu}\times\ln\left[\frac{r^2+d^2}{d^2}\right] \quad (4)$$

On the other hand, if this amount is discharged directly to the sewer system, it will be mixed with the other liquid effluent or sewer stream. Eventually, the effluent reaches the environment or to the treatment facility with an additional substantial dilution that would reduce the concentrations of the radionuclides significantly even reach the acceptable levels if combined with sufficient dilution depending on the adequacy of the sewer system.

When there is (n) number of iodine patient rooms directly discharging to the same effluent or to the environment. The production rate would be subject to dilution process in several points along its pathway until reach final destination starting from toilet flushing point, through medical facility effluent, to other mixing and dilution points within sewage system along its journey. The fate of ^{131}I discharged to the sewers has been modeled and quantified by Punt, et al. [4]. Approximately one-third of the iodine activity will be retained in the sewage system during flow periods and therefore, additional reduction on the discharged amount would be experienced too where only (0.66) of discharged radioactive iodine (i.e. $A_{discharge}=0.85\ A_{admin.}$) reach the final destination. In this case, the final activity concentration (A_{final}) would be accumulated over time in a treatment facility or environment once mixing with additional (V_{Sewage}) would be:

$$A_{final}=1.44\times\frac{2}{3}\times\frac{T_{\frac{1}{2}}}{t}\times n\times\frac{A_{discharge}}{V_{Sewage}} \quad (5)$$

In presence of an adequate sewage system, the (V_{Sewage}) almost would be quite sufficient to achieve the safe discharge requirements. The adequacy of the sewage system whether in the main discharge point at the facility in a treatment facility or to the environment can be examined easily by using equation (5).

Discussion

In order to test the provided model. if the average of the administered activity from a single treatment is about 7.5GBq in the conservative scenario for continuous process repeated every 5 days, the accumulated activity in the delay tank after a while will be about 15GBq. The released amount of activity was already diluted with 250 liters of liquid from flushing and washing for each patient. The activity concentration (A_V) will be constant (about 25MBq per liter) over time. In order to calculate the possible exposure, equation (4) may be used. In this case, additional information about tank specifications, engineering design, and liquid characteristics is required. Alternatively, the volume can be divided into several segments and thereafter calculate the dose resulting from each segment or by approximation to point source at the point of interest where the representative person could be existing. I do so, the calculated dose rate at one meter from point sources equals 1.15mSv/h in the delay tank adjacent area in the worst scenario. Also, the occupationally exposed workers may be existing closer to the sources, hence receiving more exposure . Moreover, the additional costs of providing, installing, and maintaining delay tanks, as well as, establishing a proper acceptable control and measures. It has been estimated that with no additional dose reduction intervention, the annual increase in the radiation dose to facility maintenance works up to 1.5mSv. Also, it was extrapolated that £5 million had been necessary to save 1 mSv of dose [2].

On the opposite, in case of direct discharging. The final activity concentration (A_{final}) if we assumed that there is one source introducing the radionuclides from single and repeated treatment procedures over time. The accumulated activity would be about 10GBq at any time during the year from single procedures. This amount will be diluted with (V_{Sewage}) which almost equals hundreds or thousands of cubic meters over the production duration (i.e.5 days). If sewage volume is in order of hundreds of cubic meters during this period, the activity concentration in the final destination will be within a range less than 100 *Bq* per gram when applying equation (5). This activity concentration surely meets the clearance and exempted levels. If the sewage volume increased, the number of production sources will be increased too. Also, if these conditions have been met at the facility itself, then the clearance and exempted levels will meet at the facility discharge point. Nevertheless, in order to estimate the volume of the effluent that would achieve the exemption criteria, the radiation risk is sufficiently low as not to warrant any further control and has no regulatory concern. Equation (5) can be used as follows :

Citation: Majali M, Ameri BA (2022) Regulatory approach for dilute and disperse or concentrate and store of the patient's excreta after iodine therapy. Open J Thyroid Res 5(1): 001-004. DOI: https://dx.doi.org/10.17352/ojtr.000012

$$A_{final} = 1.44 \times \frac{2}{3} \times \frac{T_{\frac{1}{2}}}{t} \times n \times \frac{A_{discharge}}{V_{Sewage}} \leq Exemption\ level$$

The exempted level or clearance level may be in terms of volume (ml, L) or in terms of weight (g, kg). it is important to carefully obtain sufficient information on effluent characteristics such as density (ρ). Usually, the density of wet wastewater is about (1.0 to 1.03g/cm^3) and may reach up to (1.2 to 1.4g/ cm^3) for dry or heavy sludge.

For example, Patient excreta are exempt from sewer discharge regulations in the United States. Several studies have measured I-131 in sewage sludge. The results of several investigations indicate that most of the I-131 entering Water Pollution Control Plants (WPCPs) are discharged in the effluent eventually. Therefore, these studies suggest that the occurrence of I-131 in sewage may be common. Paula S, et al. [5] measured the Iodine-131 concentrations in sewage sludge collected at few WPCPs. The I-131 concentrations in the collected sample ranged from 0.027 to 0.41Bq/g in WPCP with an average flow rate of 4.9ML per day, and 0.139 to 0.214Bq/g in another WPCP with an average flow rate of 3.2ML per day, while ranging from 20-149Bq/g in another one with a flow capacity of 6.8ML per day subject to seasons fluctuations [5]. Also, other studies reported that the specific activities of I-131 in sewage sludge are generally ranged from 0.004 to 2.5Bq per g in dray sample [5]. If these flow rates are applied for the production rate theoretical model with the average administered activity of 5.5GBq of I-131, for 5 hospitalization days and assuming continuous treatments. The calculated activity concentrations would be about 0.3-0.5Bq per ml. with consideration of the density of dry sludge. These calculated activity concentrations are within the majority of the reported and published data. However, this proposed model is based on theoretical assumptions, not an empirical ones. Therefore, further field investigations and tests are still recommended.

Additionally, an analysis of possible exposure pathways indicated that negligible human exposure resulted from the Iodine-131 released [6]. Radiological Protection Institute of Ireland (RPII) report [7-14] concluded that the direct discharge to sewer does not lead to any significant exposure, has no additional cost burden or other identifiable disbenefits. Hospital plumbers may receive elevated exposure, while the annual dose for Sewer workers, Sewage Treatment workers, and others was less than 10μSv. These conclusions are supporting that the dilute and disperse approach is desirable for managing the patient excreta since no occupational exposure is raised to workers in the sewer system or treatment plant.

Conclusion

The production rate term is a simple model that can be used to estimate the discharged activity to the final effluent destination as a fraction of the administered activity. The estimated discharged activity and its relevant resulted exposure are mainly depending on the dilution volume. Also, it is easy to obtain and determine the adequacy of the sewage system that can achieve exempted criteria, ensure no radiation risk, and warrant no regulatory concern. Furthermore, it can apply and manage of discharge of low-level liquid radioactive waste generated in other medical activities, educational, research, and Industrial Facilities. In the presence of appropriate sewage infrastructure, it would be better to dilute and disperse the waste activity in a continuous sewage system rather than concentrate and store for decay in order to avoid unnecessary occupational exposure to workers at the facility during the storage period. In addition to reducing the potential of occupational exposure due to contamination also. Moreover, achieve the best cost-benefit balance. The dilute and disperse approach is desirable for managing the patient excreta containing radionuclides since no occupational exposure is raised to workers in the sewer system or treatment plant at no additional costs. In addition, consentient with ICRP, IAEA recommendation and RPII conclusions where they recommended that do not require to urine to be stored and no need to provide and install delay tank.

References

1. ICRP (2004) Publication 94, Release of Patients after therapy unsealed radionuclides, Elsevier Lt. **Link:** https://bit.ly/32ZfoHz

2. IAEA-TECDOC-1714 (2013) Management of Discharge of Low Level Liquid Radioactive Waste Generated in Medical, Educational, Research and Industrial Facilities, IAEA, Vienna. **Link:** https://bit.ly/3grEOAO

3. Bevelaqua J (2009) Contemporary Health Physics, Second Edition. **Link:** https://bit.ly/3rrcmoF

4. Punt A (2006) Assessment of Radioiodine Discharges to Sewer. Royal Society of Chemistry- 10th International Symposium, Oxford Press.

5. Rose PS, Swanson RL (2013) Iodine-131 In Sewage Sludge from A Small Water Pollution Control Plant Serving a Thyroid Cancer Treatment Facility. Health Phys 105: 115-120. **Link:** https://bit.ly/3otSsaP

6. Prichard HM, Gesell TF, Davis E (1981) Iodine-131 Levels in Sludge and Treated Municipal Wastewaters Near a Large Medical Complex. Am J Public Health 71: 47-52. **Link:** https://bit.ly/3rrAHe8

7. Punt A, Kruse P, Smith K (2010) Review of Best Practice in relation to Iodine-131 Ablation Discharges to Sewer, Final Report. **Link:** https://bit.ly/3rv2YRg

8. European Commission (1998) Radiation Protection following Iodine-131 Therapy.

9. Federal Authority for Nuclear Regulation (FANR) (2013) Basic Safety Standards for Facilities and Activities involving Ionizing Radiation other than in Nuclear Facilities (FANR-REG-24), Version 1, Abu Dhabi, UAE. **Link:** https://bit.ly/3rsg3dV

10. IAEA (2009) SR-63, Release of Patients after Radionuclide Therapy, IAEA, Vienna. **Link:** https://bit.ly/3smRgaB

11. IAEA-TECDOC-1000 (1998) Clearance of materials resulting from the use of radionuclides in medicine, industry and research. **Link:** https://bit.ly/3oqecob

12. IAEA-TECDOC-1638 (2010) Setting Authorized Limits for Radioactive Discharges: Practical Issues to Consider, IAEA, Vienna. **Link:** https://bit.ly/3B1gz5C

13. Punt A, Wood M, Rose D () Radionuclide discharges to sewer -A field investigation, Science Report – SC020150/SR2, Environment Agency, England and Wales.

14. NHCPS, Nuclide Safety Data Sheet Iodine-131. **Link:** https://bit.ly/3GtHrwj

Citation: Majali M, Ameri BA (2022) Regulatory approach for dilute and disperse or concentrate and store of the patient's excreta after iodine therapy. Open J Thyroid Res 5(1): 001-004. DOI: https://dx.doi.org/10.17352/ojtr.000012