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Calculate the Generalized Derived Limits (GDLs) Value of the ^{131}I Isotope when Discharged to the Public Sewer

L. Serrori[1], *M. Salim*[2] *and S. Takriti*[3,*]

[1]National Atomic Energy Authority, Sanaa, Yamen.
[2]physics dept. Damascus University, Damascus, Syria.
[3]Arab Atomic Energy Agency, Tunis, Tunisia.

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Abstract: Generalized Derived Limits (GDLs) indented for use as convenient levels against which the results of environmental monitoring can be compared. GDLs have been calculated in various environmental materials for the radiologically aspect of ^{131}I produced from the nuclear medical center which descharched to the municipals sewage water waste.

The results showed that the ^{131}I concentration was decreased very significant in the sewage waste water. The calculation results noticed that the exposure dose for the workers and humans used the waste water before treatment was higher than after the treatment. The GDLs value was found reasonable for the waste water after the treatment and the sludge.

Keywords: radiation protection, nuclear medicine, iodine-131, sewage waste water.

1 Introduction

Since the discovery of X-rays by Roentgen in 1895 and the radioactivity by Becquerel in 1896, the subsequent developments in the use of radiological and nuclear technologies increasingly in various aspects of life, man has known the risks and damages that may or may result from the use of radioisotopes [1].

The concept of radiation exposure refers to the human receiving a dose of radiation (natural or artificial) as a result of dealing with radioactive materials or the result of being in a place containing radioactive materials, whether intentionally or unintentionally. Where exposure is through radioactive sources in the surrounding environment is called external exposure (External Exposure) or from radioactive substances that enter the body through food, air and water, where it is called internal exposure (Internal Exposure) [2].

Recognizing the dangers of exposure to radiation resulting from the use of natural or industrial sources of radiation, humans have sought to develop means and equipment, procedures and methods to prevent radiation and reduce its negative effects. Therefore, it was necessary to find legislation, laws and science that provide him with protection and safety while using these sources. This understanding of the type and magnitude of these risks did not come at once, but after careful studies, research and follow-up, beginning with the study of what radiation is, its sources, the ways in which it interacts with matter, its physical behavior and the amount of damage it causes [3].

The demand for radioisotopes increased as a result of their increasing use in various applications of radioisotopes in industry, medicine and radioisotope production plants, resulting in a significant increase in radioactive waste to be disposed of. The increased use of radioisotopes has been associated with increased risks to humans and the environment as a result of the disposal of these wastes [4].

In general, environmental discharge is the applied solution used for the disposal of waste containing radioactive materials. Radioactive waste from centers dealing with radioisotopes is often discharged directly into the environment where it is extended, which weakens its activity, but the effect of radiation exposure remains on the pathways of exposure [5]. However, the estimation of the dose resulting from the discharge of radioactive materials into the environment is essential for the assessment of the

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[*] Corresponding author e-mail: stakriti@gmail.com

associated bio-radiological hazards. Consequently, bodies and centers dealing with radioactive materials have devoted considerable attention to setting limits (models, designs) for the discharge of these substances [6]. In other words, the discharge of radioactive isotope waste into public sewerage increases the dose of radiation exposure in a number of different ways, including exposure to sewage treatment plants, radioactive isotope transport to soil irrigated by wastewater, and radioisotope transfer to plantations [7].

Many radioisotopes are used in nuclear medicine for either diagnosis or treatment. Most of these radioactive isotope materials are in closed or open sources (liquid). In nuclear medicine, as in other practices, the benefit to damage caused by the use of radioactive material is outweighed, and the benefits are increased if these materials are treated in sound bases based on radiation protection to minimize the risk for workers and patients alike [8]. Some nuclear medicine centers adopt an internal drainage system for liquid radioactive waste resulting from the treatment of patients. However, this route sometimes leads to radiation exposure of staff in nuclear medicine centers as a result of detection and discharge [9].

Therefore, the IAEA has defined a general concept of the effective dose of radioactive material discharge into the environment and the recommended dosage restriction within the IAEA series of radiological protection bulletins [10]. The National Council for the Prevention of Bio-Radiation Hazards (NRPB) clarified the ICRP bulletins. Several studies have been conducted to determine the general limits for the discharge of some radioisotopes such as ^{3}H, ^{32}P, ^{14}C, ^{35}S, ^{51}Cr, ^{54}Mn, ^{57}Co, ^{60}Co, ^{65}Zn, ^{75}Se, ^{125}Sb [11-14].

This work aims to develop a mathematical model to derive (determine) the limit of the discharge of radioactive isotope ^{131}I produced by the Center of Nuclear Medicine in Damascus to the public sewer and then apply this model to the waste of a group of patients to compare the radiation exposure resulting from the collection in the tanks of the center or direct discharge to the public sewer.

2 Experimental Section

2.1 Materials

Iodine ^{131}I is used as a liquid compound of radioactive sodium iodine which is prepared in the hot laboratory. The radioactive fluid is given to patients by mouth (drink) and not by injection, and radioactive substances are prepared in the laboratory of the Center of Nuclear Medicine.

2.2 Instruments Used for Radiation Detection

- Portable FH40G-L, which is a radiation detector for measuring the dose rate in m Sv / h.

- Contamat, FHT 111M portable, a radioactive contamination detector estimated at cm2 / count for α, β and γ.

- Portable nanoASSIST device, a NaI-Tl sodium-iodine crystalline iodine detector.

Several field visits were conducted to the ^{131}I radioisotope treatment unit at the Nuclear Medicine Center to choose the patients who treated by ^{131}I as well as to the sewage treatment plant in Damascus in order to obtain the necessary information on the overall flow rate of the sewage, the distance covered in the underground pipes and the distance covered by the open drainage.

For this study, a group of 9 patients with hypothyroidism was selected. Patients were given 10, 12 and 15 mm of sodium iodine solution labeled with radioactive iodine ^{131}I corresponding to the disease cases as shown in table 1 which note the rate of radiation dose for patients after taking the radioactive material.

The total amount of excretion of urine collected per person on the second day was 2 liters, while the radiative dose was 1 m from the collection vessel 100 mSv/h , but the effective dose on the surface of the vessel containing the subtraction was greater than 500 mSv/h the patient rooms.

The amount of excretion collected from the urine on the third day was 2 liters, while the radiation dose was 1 m 90 mSv/h. The effective dose on the surface of the vessel containing the minus was greater than 500 mSv/h. Also, the amount of subtraction of the person from the urine was collected on the fourth day was 2 liters, the radiation dose was 1 m 50 mSv per hour, while the effective dose on the surface was greater than 500 mSv per hour.

A sample of 10 mL of radioactive waste liquid was taken and radioactivity was measured to determine the concentration of its isotope ^{131}I. It was found that the radioactivity (concentration) is equal to 78 Ci, although the natural background in the location of the hot laboratory was equal to 12 Ci.

The decrease in the radiation dose after measurement for the second and third day is due to the subtraction (urine and sweating) of the patient. The increase in dose value for patients 2 and 4 is due to contamination in hands and / or clothes.

3 Results and Discussion

3.1 Proposed Mathematical Model

In order to derive the permissible limits GDLs for the discharge of the isotope ^{131}I produced by the Center for Nuclear Medicine in Damascus into the sewage network, it must develop an integrated scenario for exposure of people and components of the environment to radioactive materials. For this scenario, the following steps should be taking into an account:

- Choose the form, that's means a bad information scenario is chosen which includes complex cases of use of radioactive waste from the Nuclear Medicine Center.

Table 1: Shows the rate of radiation dose for patients after taking the radioactive material.

Patients	Amount of ^{131}I given mCi	Dose rate (1 day) µ Sv/h	Dose rate (2 day) µ Sv/h	Dose rate (3 day) µ Sv/h	Dose rate (3 day) µ Sv/h
1	150	500	100	15	10
2	150	300	150	40	60
3	150	500	100	20	5
4	150	200	100	30	60
5	100	200	100	20	8
6	100	200	50	10	12
7	100	100	80	10	14
8	80	400	50	10	9
9	100	500	500	40	15

Adoption of methods of radiation exposure, that's means a series of methods of radiation exposure (external and internal) to be considered include breathing (inhalation) and gastrointestinal contamination by drinking contaminated water directly or indirectly when eating and are sometimes well defined. This depends strongly on whether the discharge is one-time or in installments and the extent of its use for several years.

- Identify the critical group, means the critical group is usually appointed which is generally from the general public.
- Collection of appropriate rides, which data that includes information on the amount of waste liquid to be discharged, as well as information on the flow of discharged water (containing radioisotope) to the general sewage and the flow rate of the sewage, as well as the distance to the sewage until it reaches the treatment plant in addition to the irregular infringement factors on sewage.
- Application of the threshold dose which is generally accepted by the regulatory authority (1mSv / y).

The illustration of the potential radiation exposure pathways during the discharge of ^{131}I from the Nuclear Medicine Center into public sewage can be shown in figure 1.

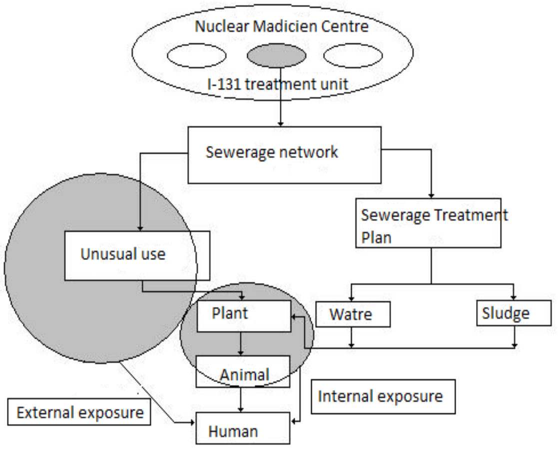

Fig. 1: Radiation exposure pathways for isotope ^{131}I.

The GDLs are calculated from the following equations, which express all the radiation exposure pathways resulting from the discharge of the waste room of the radiotherapy patients at the Nuclear Medicine Center to the general sewer as shown in Figure (1).

The general equation to calculate the GDLs is given in equation (1)

$$\frac{1}{GDLs} = \sum_{i=1}^{i=n} \frac{1}{GDLsi} \qquad (1)$$

It takes into account all exposure paths according to the function *i*.

The GDLs are defined as the sum of the effective dose section D allowed by the general population to the dose from any of the Ei pathways according to equation (2).

$$GDLs = \frac{D}{E_i} \qquad (2)$$

<u>- External exposure</u>

According to Figure (1) external exposure is done through the irregular use of public water and sometimes from sludge. However, radiation exposure to sludge can be neglected, as the sludge remains in the water treatment plant stores for a long period of time compared to the half-life of the isotope used (^{131}I). Accordingly, the dose of radiation exposure to water used before treatment is the only effect according to equation (3).

$$GDLs_{(ext)} = \frac{D}{E_{(ext)}} \qquad (3)$$

This exposure comes from the discharge of the radioisotope from the hospital to the sewer, where the concentration of the radioactive isotope must be calculated at the point of exposure (where use the radioactive materials). While, the equation (4) presents this concentration after taking into account the amount of subtraction resulting from patient rooms per day Qi, hospital discharge rate q_r to the general sewer, the distance traveled x plus the flow velocity of the sewer U.

$$C_{w,tot} = \frac{Q_i}{q_r} \exp\left\langle -\frac{\lambda_i x}{U} \right\rangle = \mathrm{C_t} \qquad (4)$$

It can calculate E_{ext} from equation (5) which gives the amount of exposure dose at distance of 1 meter from the radioactive material. Where a gamma factor $\gamma(fact)$ is given from ICRP tables.

$$E_{(ext)} = \frac{\gamma(fact) \text{ x } C_{w,tot}}{X^2} \qquad (5)$$

-*Internal exposure*

Internal exposure is, as shown in Figure 1, the water used for irrigation. This leads to the concentration of radioactive isotope in the plant and soil as well as the animal. The use of sludge as fertilizer in agricultural work also leads to the concentration of radioactive isotope in soil and plants. In case of digestion, exposure to agricultural products is calculated according to equation (6). Where the E_{ing} represents the dose from food digestion, while E_{gr} is the ground deposit dose

$$GDL_{(ing)} = \frac{D}{E_{ing} + E_{gr}} \qquad (6)$$

However, the dose E_{ing} is calculated from equation (7), where C is the concentration of radioisotope in plants and soil, while H_e and I_a express the food intake and digestive dose coefficient respectively.

$$E_{(ing)} = CI_a H_{e(ing)} \qquad (7)$$

Where H_e and I_a are taken from the ICRP tables, while the radioactive isotope concentration in the plant is calculated from equation (8) and soil (9). The d_i-filing rate for the radioisotope in the Earth is given by equation (10).

$$C_{pl} = \frac{d_i \alpha \left[1 - \exp\dot{\left(}- \lambda_{E} t_b\right)\right]}{\lambda_{E_v^s}} \qquad (8)$$

$$C_{gr} = \frac{d_i \left[1 - \exp\dot{\left(}- \lambda \; t_b\right)\right]}{\lambda_{E_v^s}} \qquad (9)$$

$$d_i = \dot{C}_{w,i} \, I_W \qquad (10)$$

The ground deposit dose is given by equation (11).

$$E_{gr} = C_{gr} H_{e(gr)} O_f \qquad (11)$$

The above equations have been linked according to a mathematical program to find the maximum radioactivity, which allows it to be discharged into the general sewer after calculating the GDLs.

Several field visits were conducted to the ^{131}I radioisotope treatment unit at the Nuclear Medicine Center to choose the patients who treated by ^{131}I as well as to the sewage treatment plant in Damascus in order to obtain the necessary information on the overall flow rate of the sewage, the distance covered in the underground pipes and the distance covered by the open drainage.

The data necessary for the rate of water consumption in the sections of the Center of Nuclear Medicine and the rate of discharge of the center sewer to the general sewer network was also taken and include:

- The amount of waste liquid to be discharged (800mCi).
- Daily subtraction (20 L).
- The amount of water used by patients per day (2 m3 / day).
- The discharge rate of the medicine center (containing radioactive isotope) to the public sewer (100m3 / day).
- Sewage run speed (350000m3 / day).
- The distance within which the sewer is carried pending the treatment plant (20km).
- Untreated water used for irrigation (50000 m3 / day)

These data are implemented in the above equations in order to find the reasonable parameters of discharging the radioactive water waste to sewage pathway.

Figure 2 shows the values of GDLs derived through external exposure. It is noted from the figure that the values of the isotope concentration decreases with increasing hospital discharge rate, while GDLs increase with decreasing concentration. The convergence point between the two curves (discharge rate of 70 cubic meters per day) is ideal if liquid radioactive waste is to be discharged into the general sewer.

Figure (3) shows the values of GDLs derived through internal exposure where the values of the isotope concentration decreases with increasing hospital discharge rate. GDLs increase with decreasing concentration. The convergence point between the two curves (a variable discharge rate of 55 to 60 cubic meters per day) is ideal if liquid radioactive waste is to be discharged into the general sewer. Here the point of convergence is less than the point of convergence resulting from external exposure.

Figure (4) shows the values of GDLs derived from the proposed model after taking into account all pathways of exposure to radioisotope drained from the Nuclear Medicine Center to the general sewer. It is observed from the figure that the values of the derivative limit increase with decreasing the values of the isotope concentration through all radiation exposure pathways. The point of convergence between the two curves (a discharge rate of approximately 40 cubic meters per day) is ideal if liquid radioactive waste is to be discharged into the general sewer after all exposure pathways are considered. It is also noted that the discharge value of the total exposure is significantly lower than that of external unit exposure and / or internal unit exposure. This may be due to the interference that occurs as a result of inputting all exposure pathways into sequential equations.

In comparing with the values of GDLs recorded in NRPB publications [11-12] for some other isotopes, the values of GDLs derived for isotope ^{131}I in this study are similar in increasing with decreasing concentration. The results of Figure (4) can also estimate the maximum concentration of isotope ^{131}I to be discharged to the public sewer without significant radiation exposure either to the general public or to the water treatment plant.

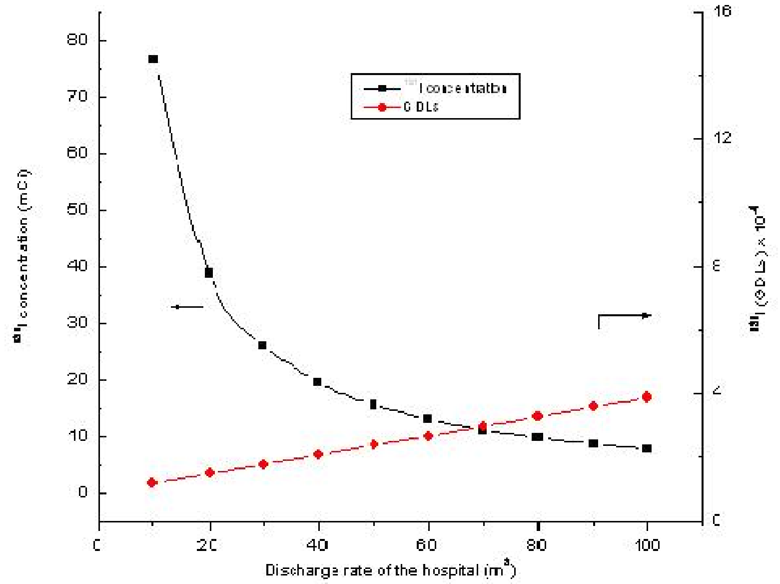

Fig. 2: GDLs values for external exposure of ^{131}I discharge to the sewer.

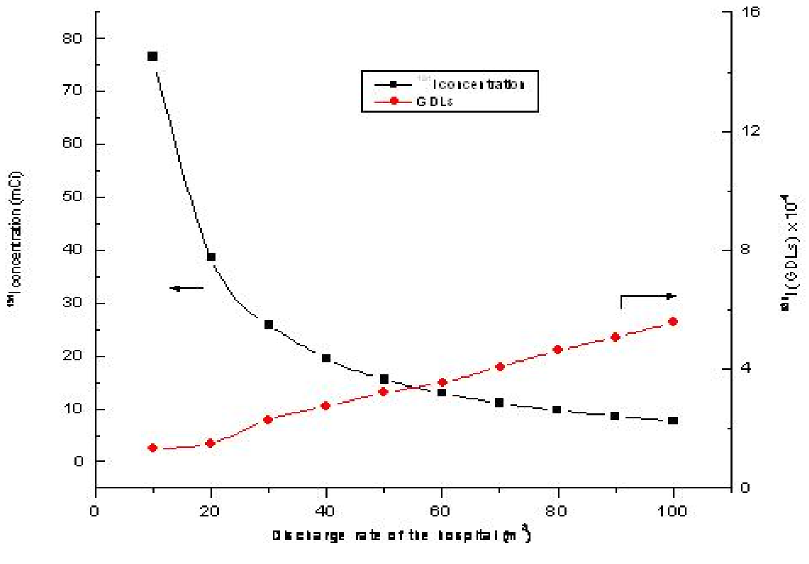

Fig. 3: GDLs values for internal exposure of ^{131}I discharge to the sewer.

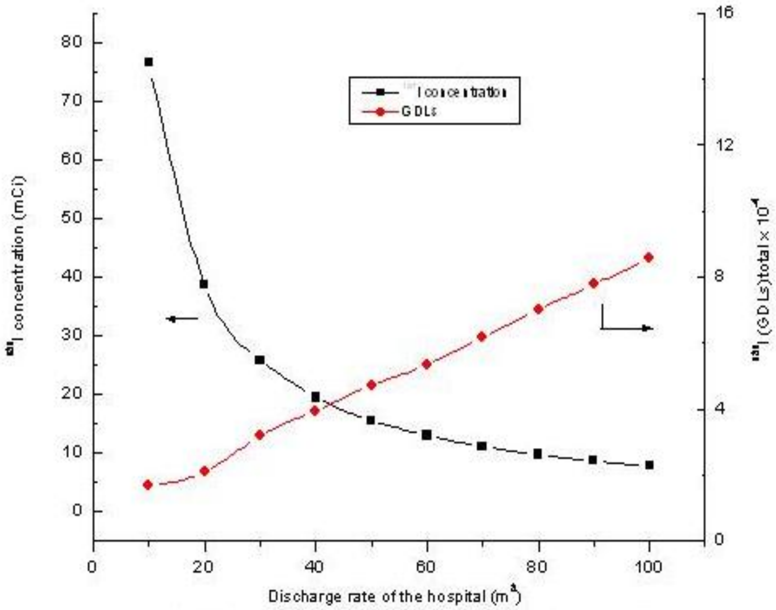

Fig. 4: GDLs (total) values derived from the proposed system.

4 Conclusions

It is noted that with a discharge rate of 60 cubic meters of hospital water to the public sewer can be discharged 800 mCi (dose given to patients), where the concentration drops to 15 mCi and the value of GDLs acceptable. In other words, radiation exposure is minimal as the effective dose is 1 mSv / year.

Based on the results of this mathematical model, the effluent from the radioactive iodine unit at the Nuclear Medicine Center can be discharged into the general sewer instead of being stored in the center's tanks for a period of time based on radioactive dissociation without significant radiation exposure to the general public.

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References

[1] ADAS (Agricultural Development Advisory Service). The Safe Sludge Matrix. Guidelines for the application of sewage sludge to agricultural land. ADAS; April 2001, 3rd Edition., 2001.

[2] J. Brown and J. R. Simmonds: a dynamic model for the transfer of radionuclide through terrestrial food chains. Chilton, NRPB-R273, 1995.

[3] S. Pearce KI,Nair and C. Colins, A computer code for the prediction of the time dependent of ^{35}S by crops. Barnwood, Nuclear Electric, TD/RPB/REP/0017, 1991.

[4] ICRP, Human respiratory tract model of radiological protection. ICRP Publication 66. Ann ICRP.,**24(1-3)**, 1994.

[5] ICRP, Recommendations of the International Commission on Radiological Protection. ICRP, Publication 60. Ann ICRP., **21(1-3)**, 1991.

[6] ICRP, Age-dependent doses to members of the public from intake of radionuclides: Part 5.compilation of ingestion and inhalation dose coefficients. ICRP Publication 72.Ann ICRP., **26(1)**,1996.

[7] NRPB, Public exposure: guidance on the 1990 recommendation of ICRP. Doc NRPB.,**4(2)**, **27-41**, 1993.

[8] J. G. Titley, A. D. Carey, G. M. Crockett et al., Investigation of the sources and fate of radioactive discharges to public sewers. London, Environment Agency. R&D Technical Report P2888., 1990.

[9] J. R. Simmonds, G. Lawson and A. Mayall, Methodology for assessing the radiological consequences of routine releases of radionuclides to the environment. Luxembourg. EC, EUR 15760., 1995.

[10] R. Northrop, B. Carnow , R. Wadden et al., Health effects of aerosols emitted from an activated sludge plant. IN Waste Water Aerosols and Disease, Proceedings of a symposium. Cincinnati,

Environmental Protection Agency. Publication EPA-600/9-80-028, 1980.

[11] NRPB, Statement by the National Radiological Protection Board: 1990 recommendations of the International Commission on radiological Protection. Doc NRPB., **4(2)**, 1-5, (1993 a).

[12] NRPB, Public exposure: guidance on 1990. Recommendations of ICRP. Doc. NRPB., **4(2)**, 27-41, 1993 b.

[13] NRPB, Generalized derived constraints for radioisotopes of strontium, ruthenium, iodine, caesium, plutonium, americium and curium.,**11(2)**,1-41, 2000 a.

[14] NRPB, Generalized derived limits for radioisotopes of polonium, lead, radium and uranium. Doc NRPB., **11(2)**, 42-71, 2000 b.