Concentrations of Iodine-131 Released from a Hospital Into a Municipal Sewer

by Ingvar L. Larsen, E. A. Stetar, B. G. Giles, and B. Garrison

Abstract

Samples of wastewater effluent from a local hospital were collected at the point of entry into a municipal sewer system and analyzed for ^{131}I. The effluent contained high concentrations of ^{131}I as a result of excretions from a patient treated with an ablation dose of ^{131}I. External dose rate measurements of the patient over time allowed the calculation of ^{131}I released into the sewer system. Measured concentrations of the effluent corresponded to estimated values based on typical hospital water usage flow releases. These concentrations were used to assess radiation levels and potential contamination of ^{131}I to sewer maintenance crews performing emergency repairs in the sewer downstream from the hospital effluent.

Key words

Radioactive ^{131}I
Ablation dose
Whole body dose readings
Wastewater concentrations
Effluent release

INTRODUCTION

Municipal sewer systems receive a wide variety of radionuclides from both natural and anthropogenic sources. Natural sources include contributions from local water supplies, storm runoff, industrial disposal of chemical waste products, and digested food products in excreta.[1] These radionuclides include ^{40}K, $^{226/228}Ra$, ^{7}Be, and uranium. Anthropogenic sources include fallout radionuclides such as ^{137}Cs; industrial processed contaminated reactor materials such as ^{60}Co and ^{137}Cs; depleted uranium from uranium processing facilities, and medical radionuclides from hospitals.[2,3] Industrial releases into municipal sewer systems of anthropogenic generated radionuclides are regulated through state or federal licensing procedures. Medical radionuclides, however, in the excreta of patients, are exempt from licensing regulations.[1]

Iodine-131 (8.04 d half-life) is one medical radionuclide used for both diagnostic and therapeutic applications. Diagnostic applications typically use ~0.4GBq (10 mCi) while thyroid ablation doses are much higher, typically in the 3-5 Gbq (~100 mCi) range.

RELEASES OF ^{131}I

Patients when treated with ablation doses of ^{131}I are confined in the hospital for a few days to allow external radiation levels to decline to acceptable levels before release. The relatively rapid decline in activity is due primarily to the biological elimination of ^{131}I from the body. As a result of this elimination, considerable amounts of radioactive ^{131}I are discharged within the patient excreta into the local municipal sewer. Elevated concentrations of ^{131}I have been observed in municipal wastewater treatment

Table 1. *Exposure rate measurements on a 20-year-old patient after receiving 3.8gbq (102.6 mCi) of ingested (sodium iodide) ^{131}I ~17:00 4 August 1997. Units are shown in mR/hr.*

Date	Time	Neck		Stomach		Thigh Surface
		Surface	@1 m	Surface	@1 m	
4 August	17:00	110	21.9	275	21.9	40
5 August	17:30	54	5.1	65	5.2	24
6 August	09:00	10	1.1	14	1.3	5

Table 2. *Estimated amount of ^{131}I released from the patient into the sewer after correcting for physical decay*

Date (1997)		^{131}I mCi(Gbq)
From	To	Released
4 Aug 5pm	5 Aug 17:30	70 (2.6)
5 Aug 5:30pm	6 Aug 09:00	17 (0.6)
Estimated total released to sewer:		*87 (3.2)*

plants following the application of ablation doses.[1,4] In Oak Ridge, Tennessee, reported concentrations in grab samples following ablation doses have ranged from 1100 Bq/L (~30,000 pCi/L) in the wastewater treatment plant influent (raw sewage) to 1700 Bq/L (46,000 pCi/L) in the plant's secondary treatment system (aerobic) sludge.[2] Based on hospital estimates, roughly 18.5 GBq (500 mCi) of ^{131}I is released to the Oak Ridge sewer each year.

Although the ^{131}I concentrations observed within the Oak Ridge treatment plant were not considered a significant source of radiation exposure to plant operators, they did raise concerns about potential exposures to individuals performing sewer-line maintenance downstream of the hospital. During transit through the sewer system, the discharged ^{131}I undergoes significant dilution and is further reduced by decay and physical losses. Therefore, the ^{131}I concentrations in the sewer line at and near the point of discharge were expected to be much higher than those observed entering the plant.

To reduce the potential for exposures to workers, a cooperative agreement between the City of Oak Ridge and the local hospital was established to notify sewer-line maintenance crews before the administration of ablation doses of ^{131}I. This agreement in keeping with the practice of ALARA (as low as reasonably achievable), allows routine maintenance activities near the hospital to be rescheduled until ^{131}I activity levels diminish to near background levels. However, under some circumstances, such as line blockages, delaying sewer line repairs may not be possible. Therefore, evaluating the external exposure rates and ^{131}I concentrations to which sewer-line personnel could be exposed during emergency repairs was necessary.

To determine the ^{131}I concentrations released via patient excreta from the hospital into the municipal sewer system following an ablation dose, samples of the local hospital's wastewater effluent into the municipal sewer system were collected and analyzed.

On 4 August 1997, at 5pm, a patient was administered an oral dose of 3.8 GBq (102.6 mCi) of ^{131}I (as sodium iodide). During the hospital internment, exposure rate measurements were taken on the patient until the measurements diminished to acceptable levels before the patient's release. The measurements were performed using a beta-gamma ionization survey instrument (Keithley model 36150) at the surface of the neck, stomach, thighs and also at one meter distance (Table 1). On 6 August 1997, the patient was released from the hospital in the early afternoon. Since the patient's residency was outside the Oak Ridge area, any additional contributions of ^{131}I to the local sewer from this source would not be anticipated. However, this does not exclude the possibility of other local residents being treated at other hospitals in the Knoxville, Tennessee, area, and contributing an additional source of ^{131}I to the Oak Ridge municipal sewer system. In addition, diagnostic treatments consisting of 0.37 GBq (~10 mCi) of ^{131}I are occasionally administered and the patient allowed to return home without hospital internment. One Oak Ridge resident did receive such a diagnostic dose on 20 August 1997.

LOSSES OF ^{131}I FROM THE PATIENT

The amount of radioactive ^{131}I discharged into the sewer was estimated from exposure readings taken at a distance of 1 meter from the neck and stomach of the patient and corrected for physical decay (Table 2).

Based on these calculations some 2.6 Gbq (~70 mCi) of ^{131}I (after correcting for physical decay losses) were released from the hospital into the sewer within approximately a 24-hour period.

SAMPLE COLLECTION

On 4 & 5 August 1997, wastewater containing pulses of ^{131}I were discharged from the hospital into the local sewer system. Composited samples of hospital waste-water entering the sewer were collected from a manhole near the entry point using an automated ISCO water sampler. Grab samples were collected before the release and intermittently during the first few hours following the release. Grab sample collection times were based on qualitative measurements of increased radiation levels using an end-window G-M probe within the manhole.

SAMPLE ANALYSES

Samples of the collected hospital wastewater and plant influent were transferred to half or one liter Marinelli beakers for ^{131}I analyses. Samples were counted on a high purity germanium detector (HPGe) having a cobalt relative efficiency of 25% and a resolution at 1332 keV of 2.0 keV. The detector, shielded with 10cm of low background lead, is coupled to a Nuclear Data 6700 microprocessor system. Software using a peak search routine, ambient peak background subtraction, nuclide identification, and quantification, was that of the vendor. Calibration of the detector followed the methodology described by Larsen and Cutshall.[5] High activity samples were either diluted with distilled water, or allowed to decay before final analysis. Samples were decay-corrected back to the time of sampling. Corrections for decay-during-sampling compositing were also made similarly to decay-during-counting. That is, a 24-hour composite sample would have an additional ^{131}I decay correction factor of 1.044 to correct for the decay from the beginning of sampling to completion of sampling, in addition for decay corrections to the time of analysis.

Table 3 summarizes the ^{131}I concentrations in the grab samples and composite samples collected at the hospital's discharge point into the city's sewer line. Replicate samples of composited wastewater from the hospital were collected and analyzed.

Quantifying the actual effluent volume flow associated with the ^{131}I release from the hospital during the sample collection period was not done. However, typical flow releases from previous determinations were available (Table 4) and show the order of magnitude of flow volumes anticipated.

RESULTS

Based on grab sampling, the peak ^{131}I concentrations present in the manhole ranged from 0.14 to 2MBq/L (4 to 50 uCi/L). The maximum radiation exposure rates associated with these peak concentrations were approximately 0.02mSv/hour (2 mrem/hour). These radiation levels were transient, lasting only during the passage of the pulse. Between pulses, the radiation levels within the manhole were at background levels. Using the estimated amount of ^{131}I

Table 3. *^{131}I Concentrations in wastewater discharges from the hospital into the municipal sanitation sewer line*

Grab Samples		Date/time	^{131}IBq/L +/- sigma
01	pre dose	4 August noon	Not Detected
02	Grab	4 August 18:45	1.44E05+/-3.30E02
03	Grab	4 August 19:15	8.51E05+/-1.24E03
04	Grab	4 August 20:15	2.01E06 +/-4.11E03
05	Grab	4 August 21:25	5.92E05+/-1.21E03
	Distilled water blank	7 August 7:00	Not Detected
Composite samples			
01A		4 August 5-8 pm	2.35E04+/-8.29E01
01B (replicate)			2.32E04+/-4.74E01
02A		4 August 8-11 pm	6.72E04+/-2.08E02
02B (replicate)			6.59E04+/-2.12E02
02C (replicate)			6.40E04+/-1.97E02
03A		4/5 August 11pm-6am	1.96E02+/-4.14E00
03B (replicate)			2.11E02+/-3.77E00
04A		5 August 6-9 am	2.36E02+/-3.85E00
04B (replicate)			2.03E02+/-3.49E00
05A		5 August 9am-12 noon	7.73E04+/-1.89E02
05B (replicate)			8.07E04+/-2.01E02
06A	-	5-6 August 12 noon	3.77E03+/-2.60E01
06B(replicate)		12 noon	3.88E03+/-3.21E01

released from the patient into the sewer system over the first 24 hours (~70 mCi or 2.6 G Bq), and an estimated mean flow of 3E05 L/d, an overall ^{131}I concentration of 8.7E03 Bq/L (2.6E09Bq/3E05 L) or 2.3E05 pCi/L would be anticipated. This estimated value based on an overall assumed mean flow for the discharge day is within the range of the observed composited samples. Typically, higher concentrations would be anticipated with lower volume discharges, and conversely, lower concentrations with higher volume discharges during this period.

CONCLUSIONS

An ablation treatment dose of ~3.8 Gbq (102.6 mCi) of ^{131}I in a patient at a local hospital, resulted in ^{131}I releases of approximately 3.2 Gbq (87 mCi) entering the sewer system over a 40-hour period. Measured aqueous concentrations of ^{131}I in grab samples were taken at the point of the hospital's discharge into the local sewer system. These samples revealed concentrations as high as 2MBq/L (5.4E07 pCi/L). Time integrated composited samples ranged from ~2E02 to ~7E04 Bq/L (~5E03 to ~2E06 pci/L), depending on liquid flow discharges coupled with patient excreta releases. These released concentrations diminish with time and dilution and eventually enter the wastewater treatment plant.

Table 4. *Typical effluent flow volumes from the hospital wing into the sewer*

	Liter/Day x 10^3	Liters/Minute
Minimum Flow	76	53
Mean Flow	300	220
Normal Peak Flow	490	340
Maximum Peak Flow *	600	420

**Maximum peak flow duration typically ranges from 1 to 2 hours near noon and normal peak flow occurs during early morning through late afternoon.*

Table 5. *Wastewater treatment plant flow proportional time integrated volume influent and ^{131}I concentrations*

Date 6am-6am	Influent Volume, Liter/d (x 10^6)	Influent ^{131}I Bq/Liter*
4-5Aug	18.9	0.36+/-0.04
5-6	15.9	NS*
6-7	17.4	17.50+/-0.36
7-8	17.0	3.58+/-0.18
8-9	17.8	1.25+/-0.16
9-10	15.9	1.16+/-0.08
10-11	16.3	0.10+/-0.06
11-12	16.3	1.00+/-0.10
12-13	17.4	NS*
13-14	16.3	NS*
14-15	18.2	NS*

** NS No Sample*

Flow-proportional, time-integrated influent ^{131}I water concentrations collected at the treatment plant are listed in Table 5. A complete continuous record was not available, but the influent concentrations correspond to the treatment period and illustrates the decrease over approximately a 5-day period.

The purpose of the sampling effort was to assess the radiation levels and concentrations of ^{131}I to which sewer crew workers performing emergency repairs following an ablation dose might be exposed. The maximum radiation levels observed, which were associated with the peaks of the I-131 pulses entering the system, were 0.02 mSv/hour (2 mrem/hour). This exposure rate is assumed to be the "worst-case" level to which sewer workers would be exposed while performing repairs immediately down-stream from the hospital. Based on the concentrations of ^{131}I measured in the sewer line (up to 120,000 dpm/ml), the potential for contamination of worker clothing, tools, equipment, and the soils surrounding the sewer line is high. Therefore, in the event repairs must be done downstream from the hospital following an ablation dose, the City of Oak Ridge will ensure that a trained health physicist is present to monitor radiation contamination levels and assist in decontamination as needed.

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About the Authors

Ingvar L. Larsen has over 35 years of experience in the use of radionuclides with regard to understanding and quantifying environmental processes—the determination of contaminant pathways, transport rates, and accumulation areas. In addition, he has developed instrumental methods for quantifying radionuclide concentrations in various matrices.

I.L. Larsen
Teledyne-Brown Engineering, Inc.
2508 Quality Lane
Knoxveille, TN 37931-3133
Phone: 865/690-6819
E-mail: Lauren.Larsen@tbe.com

Elisabeth Stetar is a certified health physicist and consultant in the areas of regulatory compliance, environmental monitoring, and dose assessment. She has extensive experience in decontamination applications and the evaluation of the impact of radionuclides discharged into sanitary sewers.

Bruce G. Giles holds a BS degree in environmental health and is an employee of the City of Oak Ridge, Tennessee, serving as the environmental and regulatory compliance coordinator.

Beverly Garrison has served as a medical technician in the area of radiology.