Airborne Concentration of I-131 in a Nuclear Medicine Laboratory

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This study measures the airborne radioactivity during the handling of millicurie quantities of I-131 in the liquid and capsule form. The data indicate there is significant airborne activity when bottles containing 100–145 mCi of liquid I-131 are opened, and that the Nuclear Regulatory Commission level for airborne activity of I-131 in restricted areas (9×10^{-9} μCi/ml) is exceeded. However, the airborne activity of I-131 is below the Nuclear Regulatory Commission level for restricted areas when 100-mCi quantities of I-131 in the capsule form are used, or during handling of liquid I-131 in the 20- to 30-mCi range. Thyroid counting is a better method than film badge for monitoring the personnel.

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Iodine-131 is a common radionuclide in a nuclear medicine laboratory. It is used in microcurie quantities for various diagnostic purposes such as thyroid uptakes and scans, liver function studies, etc. Millicurie quantities are used for the treatment of hyperthyroidism and cancer of the thyroid. Iodine-131 is a beta and gamma emitter that concentrates in the thyroid gland. The potential health hazard (*1,2*) to the personnel of the nuclear medicine laboratory from airborne contamination by liquid I-131 has recently been raised by the Nuclear Regulatory Commission (*3*). The purpose of this study is to measure the airborne radioactivity during the handling of millicurie quantities of I-131 in the liquid and capsule forms.

MATERIALS AND METHODS

Iodine-131 in the liquid and capsule form and approximately 100–145 mCi in activity was obtained for this study. The activity was measured, in a dose calibrator, in the 0–200 mCi range. Precautions were taken to ensure that the high activity did not saturate the calibrator's ionization chamber. The instrument was initially calibrated by the manufacturer and checked daily in the laboratory using a standard reference source. The overall precision was better than 1%.

The airborne activity was measured by counting the filter from an air pollution sampler*. This device is a motor-driven vacuum pump with adjustable gauge to measure the air flow. The air is drawn through a carbon-impregnated cellulose filter†, 10 cm in diameter and 2 mm thick. In all experiments the air flow rate was adjusted to 50 cubic feet per minute and the sampler run for 60 min. Only one filter was used for collecting the airborne activity. At the end of 1 hr the filter was taken out of the sampler, cut into small pieces, and packed into a test tube. The activity of the test tube containing the filter was measured with a well scintillation counter for 10 min.

The efficiency of the air pollution sampler with one filter was obtained initially by using two filters back to back and counting the activity of the filters, using the formula:

$$\text{Efficiency (E)} = \left(1 - \frac{B}{A}\right) \times 100,$$

where A = activity of front filter, and B = activity

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of back filter. In our experiment, the calculated efficiency for the sampler using one filter was 78%.

A filter was placed in the air pollution sampler, the cap of the vial containing the capsule or liquid I-131 was opened, and the gases from the vial were permitted to escape into the air. The sampler was placed 4 feet from the vial. In the first set of experiments, the vial containing liquid I-131 was opened for only 10 min and then closed, to simulate a typical situation preparing for treatment of thyroid disease. In the second set of experiments the vial containing liquid I-131 or capsule was kept open for 1 hr and then closed. At the end of each experiment, the vial was again capped as securely as possible and placed in decay bin. At several times the vial with the liquid or capsule I-131 was removed from the decay bin and the above procedure repeated. The volume used for the experiment with liquid I-131 varied from 3–6 ml. Since single 100 mCi capsules of I-131 were not available, five capsules, each containing approximately 20 mCi, were kept in a screw-capped vial. This vial was used to obtain the airborne activity from encapsulated I-131. The filter counts were corrected for efficiency before conversion into activity using the relationship:

$$\text{Corrected filter counts/min} = \frac{\text{filter counts/min}}{\text{efficiency}}.$$

The activity was determined by comparing the counts of a known standard source of I-131 under identical geometrical conditions using the formula:

$$\text{Airborne filter activity } (\mu\text{Ci}) = \frac{\text{corrected filter counts/min} \times \text{standard activity } (\mu\text{Ci})}{\text{standard counts/min}}.$$

The airborne activity in microcuries per milliliter was calculated by using the formula:

$$\text{Airborne activity } (\mu\text{Ci/ml}) = \frac{\text{Total activity of filter } (\mu\text{Ci})}{\text{Total volume of air drawn through the air pollution sampler (ml)}}.$$

Thyroid counts of the person handling radioactive I-131 were obtained using a scanner. The sodium iodide crystal was 3 in. in diameter and 2 in. thick. A flat-field collimator was used, placed 20 cm from the neck or the phantom. All uptakes were done under the same geometric conditions. Net thyroid counts were obtained by subtracting the thigh counts from the thyroid counts. To convert the thyroid counts into activity, a standard cylindrical lucite phantom‡ was used. A known source of I-131 was placed inside the phantom, and source and background counts were obtained for 5 min each. The activity in the thyroid was obtained from the formula:

Activity in the thyroid (μCi) =

$$\text{Activity of the known source } (\mu\text{Ci}) \times \frac{\text{(cpm of the known source} - \text{background cpm) in the phantom}}{\text{cpm from neck} - \text{cpm from thigh}}.$$

RESULTS

The airborne activities during handling of millicurie quantities of liquid and capsule I-131 are summarized in Tables 1, 2, and 3. The thyroid activity of the individual handling the agent is shown in Table 4. Table 5 shows the average film-badge reading of the same person during normal periods and when millicurie quantities of I-131 were handled during the experiment.

DISCUSSION

As can be seen from Tables 1 and 2, airborne contamination is present when vials containing 100–145 mCi of liquid I-131 are opened in the laboratory. The data indicate that airborne contamination when the vial containing liquid I-131 is opened for 10 min is less than when it is kept open for 1 hr. Therefore, it can be concluded that the airborne contamination increases as the time of exposure of the vial containing liquid I-131 is increased. The values obtained by other investigators may vary somewhat, since the airborne contamination from liquid I-131 is affected by the volume, temperature, and the air-handling

TABLE 1. VIALS CONTAINING LIQUID I-131 OPENED FOR 10 MIN ONLY

Day	Activity of liquid I-131 (mCi)	Airborne activity (μCi/ml)
1	144.8	2.29×10^{-9}
4	103.7	5.13×10^{-10}
10	61.3	1.08×10^{-10}
30	10.7	4.94×10^{-11}

TABLE 2. VIALS CONTAINING LIQUID I-131 OPENED FOR 1 HR

Day	Activity of liquid I-131 (mCi)	Airborne activity (μCi/ml)
1	92.7	1.54×10^{-8}
2	85.2	8.00×10^{-10}
11	38.9	6.28×10^{-10}
20	17.5	1.80×10^{-10}
26	10.5	7.93×10^{-11}
40	3.1	1.88×10^{-11}

system of the room. In our case even when 145 mCi of liquid I-131 was kept open for 10 min, the airborne contamination did not exceed the permissible Nuclear Regulatory Commission's limits of 9×10^{-9} μCi per ml; after 1 hr, however, the airborne contamination was 1.54×10^{-8} μCi, greater than permissible NRC limits. It must be emphasized that these values are average values obtained from the air pollution sampler 4 feet away from the source over a period of 1 hr. However, immediately after opening the vial, the atmosphere around the vial may exceed the Nuclear Regulatory Commission's limits.

As can be seen from Table 3, I-131 capsules in very high concentration produced negligible airborne radioactivity. This could be due to absorption of iodine or xenon gas in the sponge or capsule material. While doing the experiment with liquid I-131, we noticed that, as the experiment progressed, wipe tests done on the floor and walls showed a significant increase in the amount of contamination above background. The highest activity increase was found in the filter of the air conditioner.

The activity absorbed in the thyroid gland of the person handling the liquid I-131 is higher than anticipated by air contamination alone. As shown in Table 4, the maximum activity in the thyroid gland of this worker, handling 145 mCi of liquid I-131, is 0.17 μCi. The maximum predicted activity in the thyroid gland (assuming all the I-131 to be inhaled, absorbed, and concentrated in the thyroid gland) is 1.6×10^{-3} microcurie. This was calculated as follows (*4*):

$$\text{Average minute respiratory volume} = \text{tidal volume (500 ml)} \times \text{the respiratory rate (12/min)}.$$
$$= 6{,}000 \text{ ml/min.}$$

Assuming the person is in the room for 1 hr, the formula to calculate the total activity of I-131 inhaled is:

$$\text{Total activity of I-131 inhaled } (\mu\text{Ci}) = \text{airborne contamination } (\mu\text{Ci/ml}) \times \text{minute respiratory volume (ml/min)} \times \text{total stay in the room (min)}$$
$$= 2.29 \times 10^{-9} \times 6000 \times 60$$
$$= 8.24 \times 10^{-4}\ \mu\text{Ci}$$

Assuming the individual conducting this experiment inhaled 8.24×10^{-4} μCi of I-131, and exhaled none, on each of two successive days the experiment was carried out, the maximum concentration of I-131 inhaled would be only 1.6×10^{-3} μCi. This is less than 1% of the 0.17 μCi amount actually observed in the thyroid gland of this person. There are several possible explanations. The first possibility is a significantly higher concentration of airborne I-131 immediately around the vial, which the investigator may have inhaled when opening the vial. The second possibility may have been due to absorption of I-131 through the skin of the handler. A third but less likely possibility is accidental ingestion of I-131.

An interesting relationship was observed between the amount of radioactive I-131 handled and the amount of I-131 present in the gland of the person performing the experiment. As can be seen from Table 4, as expected, the thyroid concentration of radioactive iodine decreases as the amount of radioactive I-131 handled decreases.

The activity in the thyroid glands of other technicians in the nuclear medicine laboratory who routinely handle 10–20 mCi of I-131 was measured and was found to be no greater than 7 nCi. It is difficult to measure such quantities with our system. Measurement of nanocurie quantities of I-131 needs much more elaborate equipment.

The film-badge records for the individual performing the experiment were analyzed. Table 5

TABLE 3. VIALS CONTAINING CAPSULE I-131 OPENED FOR 1 HR

Day	Capsule activity (mCi)	Airborne activity (μCi/ml)
2	84.0	0
9	45.8	3.99×10^{-11}
20	17.4	1.43×10^{-11}

TABLE 4. THYROID ACTIVITY OF THE INDIVIDUAL HANDLING MULTIMILLICURIE QUANTITIES OF LIQUID I-131

Day	Activity handled (mCi)	Thyroid content (μCi)
1	144.8	.17
4	103.7	.15
10	61.3	.09
12	50.8	.06
30	10.7	.02

TABLE 5. BIWEEKLY AVERAGE FILM-BADGE READINGS OF THE PERSON HANDLING I-131

Type of badge	Normal period	I-131 handling period
Wrist badge readings (mR)	16	72
Whole-body badge readings (mR)	14	46

shows a three- to fourfold increase in gamma radiation dose to both the wrist and whole-body film badge of the worker involved in I-131 experiments. The film badge did not show any beta radiation.

CONCLUSION

Laboratories using 100 mCi quantities of liquid I-131 should monitor both the laboratory area and laboratory personnel. Laboratory areas should be monitored by wipe testing and/or pollution sampling. The laboratory personnel should be monitored by film badges and thyroid counting. Monitoring by means of film badges, however, has inherent limitations (*5*), and we feel that for the monitoring of laboratory personnel for low-level I-131 radiation, thyroid counting is better. There is a significant amount of I-131, undetected by film badges, found in the thyroid gland of the worker handling the 145 mCi doses of liquid I-131. The 0.17 μCi observed in the thyroid gland is less than the maximum permissible thyroid burden, 0.7 μCi (*6*). In view of the recent developments regarding the biologic effects of low level radiation, however, this may be significant. This is evidenced by the NRC's trend from Maximal Permissible Dose (MPD) to allowable limits As Low As Reasonably Achievable (ALARA) (*7*).

FOOTNOTES

* Atomic Products Air Pollution Sampler, Model No. 086-004, Long Island, N.Y.

† Atomic Products Carbon Impregnated Cellulose filter, No. 090-2133 Cl, Long Island, N.Y.

‡ Abbott Laboratories, North Chicago, Ill.

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