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Personnel internal radiation exposure to iodine-125 in a radioiodination laboratory: Exposure levels and trends

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Background: Monitoring internal exposure of individuals handling significant amounts of iodine-125 (I-125) for iodination is of great importance. These individuals are potentially exposed to external contamination, and internal contamination through inhalation, ingestion and intact skin absorption, to I-125. Considering radiological toxicity of this radionuclide its monitoring in the workplace and workers is necessary for radiation protection purposes. ***Materials and Methods:*** Direct measurement of I-125 in thyroid of individuals, known as a common and reliable method, was applied in the framework of monitoring program. Intakes of I-125 by individuals and the associated effective doses were evaluated using thyroid monitoring results and recommended metabolic models. ***Results:*** The monitoring results of the laboratory personnel for a period of 3 years are given and compared . According to the results , the intakes of I-125 by individuals in the early phase of laboratory operations were higher due to insufficient facilities and experience. Improvements in the radiation protection facilities of the laboratory and personnel including provision of personal respiratory protection devices resulted in significant reduction of I-125 intakes. ***Conclusion:*** According to 3 year results from the implementation of internal exposure monitoring program for personnel producing I-125 labeled compounds, the exposure levels of the personnel have continuously decreased due to improvements in working conditions and increasing of personnel experiences. **Iran. J. Radiat. Res., 2005; 3 (3): 117-122**

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INTRODUCTION

Iodine-125 (I-125), a radionuclide emitting X and gamma rays with energies from 27 to 35 keV and a physical half-life of 60.1 days, is being widely used as a tracer in biological sciences and radioimmunoassay (RIA) diagnostic procedures. This procedure is an in vitro technique within the nuclear medicine practices, that is used for measuring substances in body fluids (mainly blood) whose concentrations are below 10 pg/ml, like certain hormones, enzymes, vitamins, etc. The technique is based on the combination of antibodies and antigens, some of them labeled with a radionuclide, to measure the substance of interest with a radioactivity measuring instrument, mostly a gamma counter[(1)].

Because of high volatility under room temprature, Iodine has a great potential for the contamination of workplaces. Exposure of workers to radioiodines, particularly I-131 and I-125 due to uptake of Iodine by thyroid gland, and associated radiation dose to this organ is of great importance in radiological protection[(2)]. Among individuals occupationally exposed to I-125, those working with radioimmunoassay kits containing I-125 in medical laboratories are not significantly exposed to I-125 contamination, due to the nature of their work and particularly low potential of I-125 release from the source solutions. In contrast, those workers handling solutions of unbound Iodine with high concentrations of activity for the preparation of diagnostic kits are potentially exposed to significant external and internal contaminations due to airborne Iodine in aerosol or vaporized forms. These individuals are potentially exposed to internal contamination through inhalation, ingestion, and intact skin adsorption. Therefore, for keeping radiation exposure of such workers as low as it is reasonably achievable (ALARA), it would be necessary to use well

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equipped laboratories, and that workers are provided with suitable protective means. In addition, enough attention should be paid to training requirements for them.

In the framework of radiation protection programs designed and implemented for this kind of laboratories, individual monitoring for internal exposure to I-125, due to its reliability and accuracy, is a principal requirement, although, regular workplace monitoring for the contamination in air and surfaces plays also an important role, particularly for the detection of probable incidents.

Production of the I-125 RIA diagnostic kits in Iran is being carried out mainly by a laboratory established for this pupose. Protein labeling operations and kits preparation in this laboratory are carried out once every 40 days and the operations continue for nearly 10 days. In each production process, nearly 6GBq of I-125 (carrier-free iodine in NaOH solution) is used.

At the early phase of the production in this laboratory 6 individuals were involved in the operations. During the succeeding years new individuals were employed.

The Iranian National Radiation Protection Department (NRPD), apart from its regulatory function, has the responsibility for providing various radiation protection services, including personnel exposure monitoring, to installations and laboratories carrying out various radiation practices. In the framework of the radiation protection program currently being implemented in the above mentioned laboratory, internal exposure monitoring of the personnel is carried out on a routine basis, following termination of each production operations, that is, once every 40 day. In the case of incidents during operations monitoring will be carried out shortly after the detection of incident. Workplace monitoring for contamination is routinely carried out by the health physics staff of the laboratory and the results are recorded, and investigated if necessary. This paper presents the results of the internal exposure monitoring of the laboratory personnel for a period of 3 years, carried out by measuring I-125 in thyroid. The trend of the personnel exposures during the above period, for indicating the effects of improvements in protection measures on exposure levels, are also presented and discussed.

MATERIALS AND METHODS

For individual monitoring of internal contamination to I-125 both *in vitro* and in vivo bioassay techniques have been applied by several investigators. In applying *in vitro* techniques urine[3] or saliva[4] samples of the individual have been analysed for I-125 contents. However, the most common procedure being applied by the majority of the laboratories for monitoring purpose is in vivo measurement of I-125 (and I-131) in thyroid. Several instruments and counting techniques have been applied by investigators and monitoring laboratories[5-9]. Various aspects of the application of this technique, including in the area of instrumentation and calibration phantoms and methods, was considered by Kramer *et al.*[10-15]. Thyroid monitoring estimates equivalent doses to thyroid more accurately than *in vitro* techniques. For measuring radioiodines in thyroid of individuals two different measurement systems were applied by the Internal Exposure Monitoring Laboratory (IEML) of the NRPD. The first one consisted of a 50 mm diameter by 2 mm thick NaI (Tl) detector (special low-energy X and gamma detector) for measuring I-125, and a 50 mm diameter by 50 mm thick NaI (Tl) detector for measuring I-131, both interfaced to a single channel analyser and scaler. The detector was equipped with a cylindrical lead collimator of 25mm thick, except at the mouth of the collimator, and extended 50 mm beyond the detector surface. The interior surface of the collimator was lined with 1mm thick copper sheet. The collimator was installed on a mobile holder with the ability to be fixed on the neck of the individual on a chair with a head rest. By this means the neck of the individual would be in a fixed position, and the measurement error due to variation in counting geometry related to detector positioning was minimized. The

calibration of the detectors was carried out using an American National Standards Institute (ANSI) neck-thyroid phantom, manufactured according to defined characteristics[16]. This phantom was a plexiglass cylinder of 127 mm diameter and 127 mm height, which had a cylindrical hole for inserting a polyethylene vessel of 30 ml volume as a thyroid simulator. The depth of the vessel inside the phantom is 22 mm, representing the average thyroid depth in the neck of an adult. The distance between the collimated detector and the phantom surface (counting distance) was 50 mm for both detectors. For the calibration of the derectors vessels containing standardized I-125 or I-131 solutions were used. To investigate the variations of counting efficiencies with thyroid depth in the neck a plexiglass cylindrical vessel with dimentions similar to ANSI phantom was applied and filled with water, in which the depth of the polyethylene vessel could have been changed. The details of the instrument operating with above-mentioned detectors and calibrations carried out has been presented elsewhere[17].

In the second system, which is being used currently by the laboratory, both the above mentioned detectors were subsitituted by a single thin-window 50 mm diameter by 50 mm thick NaI (Tl) detector, and it was interfaced to a multichannel analyzer, through required electronic modules. This system provided the possibility of the simultaneous measurement of I-125 and I-131 in the thyroid. This detector was adequately efficient for counting both I-125 and I-131 photons, due to its thin window (for I-125) and thick crystal (for I-131). The recent detector was also calibrated using ANSI phantom described above for measuring I-131 and I-125 in the thyroid. The calibration factor for I-125 measurement with this detector was 0.035 cps. Bq^{-1}. The minimum detectable activity (MDA) of I-125 in thyroid, with a 95% confidence interval and for 5 min counting period, was calculated to be around 10 Bq. The measurement uncertainty due to variation of thyroid depth in the neck was evaluated to be around ±20% for 50mm counting distance, reducing to about ±12% by adopting 100mm counting distance. The application of the instrument with the old and new detectors, for monitoring thyroid of individuals handling I-131 in Radioisotopes Production Laboratory of the Atomic Energy Organization of Iran, and the associated monitoring data for a period of nearly 10 years, has been presented elsewhere[18].

Before the measurement of I-125 in thyroid of individual he/she was requested to take a shower to remove probable skin contamination. During measurement, if a relatively high level contamination was detected by the instrument, the individual was requested to remove the personal cloth and wear a clean laboratory coat. In addition, a smear from the neck surface was taken and counted by the instrument for detecting probable surface contamination. In the absence of surface contamination, the individual was measured again for two or three times. The measured I-125 activity in thyroid of each individual was recorded. In subsequent monitoring of the individual nearly 40 days later the I-125 activity, if remained in the thyroid from previous intake was calculated, by considering an effective half-life of 34 days for I-125, corresponding to a biological half-time of 80day for Iodine in thyroid recommended by the ICRP[19], and subtracted from the new measured thyroidal I-125 content. For estimating I-125 intake resulting from each operation, based on thyroid measurement results, thyroid retentions as a function of time following single intake by inhalation of I-125, recommended by the ICRP[19] for radiological protection purposes, were applied. To calculate the effective dose to individual resulting from I-125 intake the dose coefficient introduced by the ICRP[19, 20] was used. The effective dose coefficients for type F iodine compounds and iodine vapor were 7.3×10^{-9} and 1.4×10^{-8} Sv. Bq^{-1} intake, respectively. The monitoring results were evaluated against an investigation level (IL) equal to one-tenth of 40d intake limit, calculated based on annual effective dose limit recommended by the ICRP (20 $mSv.y^{-1}$)[21], and effective dose coefficients mentioned above. The investigation level for the inhalation of type F iodine compound is 30 kBq and that

for iodine vapor is 15 kBq intake for 40 day time interval.

RESULTS AND DISCUSSION

The results of internal exposure monitoring of individuals who have worked in radioiodination laboratory for a period of 3 years are given in tables 1 to 3. As shown in the tables, the range of periodical intakes resulting from 10 operations in each year, the total annual intake, and the annual effective dose, for each individual, as well as the mean values for all individuals are presented. As indicated in table 1, during the working period 2001-2, four individuals were actively involved in the labeling operations. During this period, the internal contaminations of the laboratory personnel resulting from the operations were relatively significant, although, lower than the investigation level and far below the annual limit on intake. For a few months before this period, exposures higher than those given in table 1 and even exceeding investigation level have been occurred for a number of personnel, particularly the individual who performed labeling operations. These levels of personnel contaminations at the early phase of operations were mainly due to insufficient ventillation through the fume hood, inadequate number of personnel and experience for doing the operations.

To reduce personnel exposures, a number of corrective actions were carried out in the laboratory. The operation of the fume hood was improved. Respiratory protective devices capable of adsorbing Iodine in both particulate and vapor forms were provided and the individuals were requested to carefully apply protective measures, including wearing thick

Table 1. Internal exposure of laboratory personnel during the period 2001-2002.

worker	Range of 40d intake (kBq)	Total annual intake (kBq)	Effective dose (μSv)
A	0.31-55.76	218	1591
B	0.66-4.08	17	127
C	0.93-18.36	55	399
D	5.87-23.55	125	913
Mean	1.94-25.44	104	757

Table 2. Internal exposure of laboratory personnel during the period 2002-2003.

worker	Range of 40d intake (kBq)	Total annual intake (kBq)	Effective dose (μSv)
E	<MDA-6.64	12.53	91
F	0.14-2.19	10.29	75
G	<MDA-6.96	14.2	104
A	<MDA-5.76	22.40	163
H	<MDA-1.21	2.27	17
I	<MDA-2.09	7.27	53
J	<MDA-3.51	8.91	65
C	<MDA-3.84	12.73	92.70
D	0.36-19.66	47.74	348
B	0.05-1.92	5.27	38
K	0.13-1.35	4.64	34
L	<MDA-2.99	10.05	73
Mean	<MDA-4.84	13.20	96

Table 3. Internal exposure of laboratory personnel during the period 2003-2004.

worker	Range of 40d intake (kBq)	Total annual intake (kBq)	Effective dose (μSv)
F	0.08-0.85	4.57	33
G	<MDA-0.80	3.11	23
H	<MDA-0.19	0.64	5
I	<MDA-0.63	2.29	17
J	<MDA-0.30	0.72	5
M	<MDA-0.45	1.81	13
C	<MDA-9.03	20.11	147
B	<MDA-1.61	5.10	37
L	0.42-5.63	13.30	97
N	<MDA-0.39	1.66	12
P	<MDA-0.67	3.11	23
Mean	<MDA-1.87	5.13	37

gloves and disposable cloths when handling source solutions. In addition, the automation of production process, and planning for doing the operations by more individuals, were also carried out. Such corrective actions resulted in significant reduction in personnel exposures.

The monitoring results for the period 2002-3, as given in table 2, indicates a reduction factor of around 7 in mean annual effective dose of personnel compared to 2001-2 period. In addition, the periodical I-125 intakes following a number of operations for most individuals during that period have been lower than MDA value. The monitoring results for the period 2003-4, as shown in table 3, also indicate more reductions in annual effective doses of the personnel and the most individuals have had contaminations lower than MDA value following a number of operations. Although, there are numerous reports on the instrumentation and methods for the determination of thyroidal content of radioiodines, a few reports are available on the evaluation of exposure doses of individuals working in RIA kits production laboratories[5, 22]. Sumerling *et al.*[22] have reported and discussed the monitoring data for a group of workers engaged in the commercial production of RIA kits. The estimated annual intakes of I-125 for the workers of interest, taking I-125 activities handled by the workers per annum into account, are comparable to data given in our work, although working conditions in different laboratories should be cosidered.

CONCLUSION

In conclusion the exposure levels of the personnel have continuously reduced, due to a number of reasons including corrective actions on protection facilities, provision of adequate ventillation through fume hood, automation of production process, the use of disposable clothings and respiratory protection device by the personnel, the use of more personnel for doing laboratory activities, as well as the provision of the required training for the personnel.

REFERENCES

1. Wang CH, Willis DL, Loveland WD (1975) Radiotracer methodology in the biological, environmental, and physical sciences. Englewood Cliff, N.J.: Prentice-Hall, Inc.
2. Hall EJ (1988) Radiobiology for the radiologist. J. B Lippincott; Philadelphia.
3. Johnson JR (1978) Summary of bioassay and thyroid monitoring results following an accidental exposure to I-125. *Health Phys,* ***34:*** *106-107.*
4. Nishizawa K (1985) Quantitative measurement of I-125 with NaI(Tl) scintillation survey meter. *Radioisotopes,* ***34:*** *78-82.*
5. Bartolini P and Ribela MTCP (1988) Results of a thyroid monitoring survey carried out on workers exposed to I-125 in Sao Paulo, Brazil. *Health Physics,* ***55:*** *511-515.*
6. Berdell E, Sayeg JA, Wald N, Wechsler (1972) In vivo measured effective half-life of I-125 in human thyroid. *Phys Med Biol,* ***17:*** *365-373.*
7. Burns PA and Peggie JR (1980) An Iodine-125 thyroid measurement method. *Phys Med Biol,* ***25:*** *445-452.*
8. Kivinitty K, Nasman P, Leppaluoto J (1984) Accumulation of I-125 in the thyroid glands of laboratory workers. *Health Phys,* ***46:*** *234-236.*
9. Lambert JP (1981) Report for minor I-125 exposure in a research laboratory. *Health Phys,* ***40:*** *746-748.*
10. Kramer GH, Burns C, Meyerhof DP (1993) The Canadian national calibration reference centre for in vivo monitoring: Thyroid monitoring. Part 1: The national inter-comparison programme. *Canadian J Med Radiat Technol,* ***24:*** *157-160.*
11. Kramer GH and Meyerhof DP (1994) The Canadian national calibration reference centre for in vivo monitoring: Thyroid monitoring. Part 2: Source of errors in thyroid monitoring of occupationally exposed personnel. *Canadian J Med Radiat Technol,* ***25:*** *21-24.*
12. Kramer GH and Meyerhof DP (1994) The Canadian National Calibration Reference Centre for in vivo Monitoring: Thyroid monitoring. Part 3: A basic calibration procedure for thyroid monitoring. *Canadian J Med Radiat Technol,* ***25:*** *61-63.*
13. Kramer GH and Meyerhof DP (1994) The Canadian National Calibration Reference Centre for in vivo Monitoring: Thyroid monitoring. Part 4: Optimising a counting system that uses a single channel analyser. *Canadian J Med Radiat Technol,* ***25:*** *100-103.*
14. Kramer GH and Meyerhof DP (1994) The Canadian national calibration reference centre for in vivo monitoring: Thyroid monitoring. Part 5: Minimising placement error in a thyroid monitoring system. *Canadian J Med Radiat Technol,* ***25:*** *125-128.*
15. Nishizawa K and Maekoshi H (1990) Thyroidal I-125 monitoring system using an NaI(Tl) survey meter. *Health Phys,* ***58:*** *165-169.*
16. American National Standards Institute (1973) Thyroid radioiodine uptake measurements using a neck phantom. ANSI N44.3.
17. Sohrabi M, Alirezazadeh N, Aliabadi M (1996) Design and performance charateristics of a thyroid counter for

radioiodines monitoring. In Proc. of 9th Conf. of the International Radiation Protection Association (IRPA).
18. Alirezazadeh N., Garshasbi H., Karimi Diba J. (2003) Internal exposure monitoring of 131I-Radiopharmaceuticals production workers in Iran. *Radiat Prot Dosim,* ***104:*** *173-176.*
19. International commission on radiological protection (1998) Individual monitoring for internal exposure of workers. Elsevier science, Oxford and New York. ICRP Publication 78.
20. International Commission on Radiological Protection (1994) Effective dose coefficients for ingested and inhaled particulates. Dose Coefficients for Intakes of Radionuclides by Workers. Pergamon Press, Oxford. ICRP Publication 68.
21. International commission on radiological protection (1991) Recommendations of the international commission on radiological protection. pergamon press, Oxford. ICRP Publication 60.
22. Sumerling TJ, Neville RWJ, Wrigglesworth PM (1983) Determination of Iodine-125 intakes in a group of radiopharmaceutical production workers by means of thyroid radioactivity measurements. *Radiat Prot Dosim,* ***5:*** *209-217.*