Estimation of Internal Radiation Doses for Occupational Workers Due to ^{131}I Radionuclide by Using MONDAL Software

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ABSTRACT

Radioactive iodine (^{131}I) is most commonly used radionuclide in nuclear medicine field for diagnosis and therapy purposes. ^{131}I is used in treatment of thyrotoxicosis & thyroid cancer. While administrating patients, occupational workers tends to get exposed to radioactivity. Thus an evaluation of worker effective dose is required to maintain it within 20 mSv/y limit according to ICRP. To assist the evaluation, thyroid radioactivity monitoring program has been chosen for the measurement of effective doses of occupational workers of ^{131}I radionuclide. A software MONDAL-3 has been used to calculate the radionuclide intake, distribution, retention & other biokinetic behavior of the radionuclide. From MONDAL-3 excretion rate at measurement day, activity of intake, effective dose, excretion curves for ^{131}I radionuclide are obtained by using pre measured thyroid activity data of real life occupational worker. By using retention curves, tissue equivalent dose and effective doses upto 50 years have been calculated. The average effective dose of all workers is found to be within regulatory dose limit set by ICRP.

Key words: **: ^{131}I; Thyroid activity; MONDAL-3software.**

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INTRODUCTION

Internal radiation exposure hazards result from radioactive material that gets inside the body when a person breathe it or eat it or when it passes through the skin (1). One of the method of measuring internal radiation dose is through biokinetic modeling of the particular radionuclide that is considered to be the source of radiation. Biokinetic model describes the movement of radionuclide through a biological system in human body. The features that maintain the descripted model are: retention, cumulative activity, absorbed dose and the committed effective dose (2). Ishigure et al. developed MONDAL-3 software for calculation of internal radiation doses i.e. effective dose and organ doses for both occupational workers and members of the public (3). A software named IMPDOS was developed by Miller et al. for modelling, data analysis, activity and dose calculation purposes (4). Jarvis developed a software name LUDEP 1.0 to examine the practical application and radiological implications of a new model of the human respiratory tract based on the International Commission on Radiological Protection (ICRP) biokinetic model (5). Andersson et al. also developed an internal dosimetry computer program, IDAC-Dose 2.1 (6). Previously an intercomparing study was done by IAEA to estimate the total suposure of radionuclides during the three day working period and the corresponding committed effect of ^{131}I (7).

^{131}I is commonly used in Nuclear Medicine (NM) facilities. Since there are no particular direct method to calculate internal radiation exposure for occupational workers, it is difficult to measure particular organ doses due to internal radiation exposure. Thereby it is difficult to comply with the regulatory dose limit 20 mSv per year for occupational worker (8). The purpose of this study was to measure the thyroid activity (in Bq) by using a thyroid probe with NaI(Tl) detector and to calculate organ doses of occupational workers by using MONDAL-3 software.

METHODS

Radiation workers may be exposed to radionuclides in a variety of chemical forms that can be inhaled, ingested, or absorbed through intact skin or open wounds. In NM facilities there are radiation protection programs such as work place monitoring, surface contamination monitoring, (-) personnel monitoring and Areas where intakes of radionuclides are possible, radiation protection programs should also include measurements to estimate the quantity of radioactivity deposited in the body or to establish a basis for judgment that significant intakes (in relation to applicable dose limits) of radionuclides have not occurred. In the thyroid radioactivity monitoring program, workers submit to an in-vivo count of the thyroid. Results are compared to a predetermined level without the need for dose assessment or intake estimation.

In this study, ^{131}I radioactivity in the thyroid gland of occupational workers has been measured. The occupational workers were chosen for this research based on only when they were administrating radioiodine (^{131}I) to the patients for thyroid uptake examination. Any residual activity left from previous administration was subtracted from original measurement. The thyroid ^{131}I radioactivity measurement system of occupational workers is shown in Figure 1.

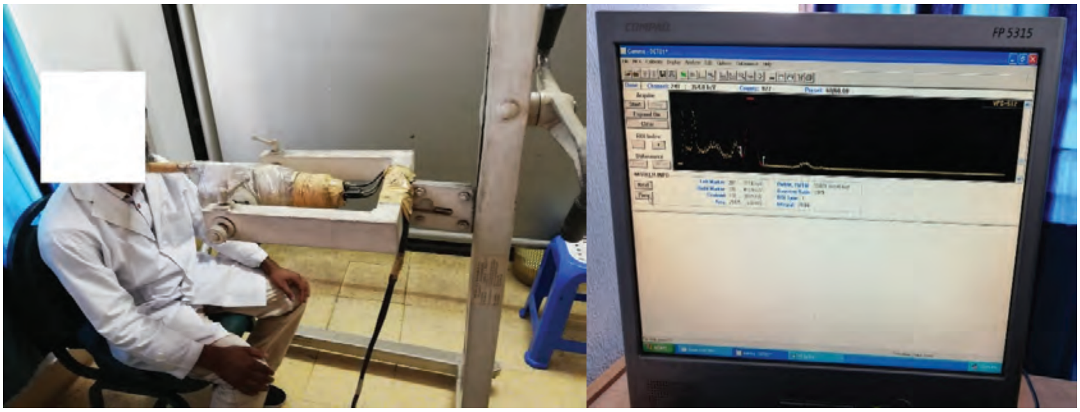
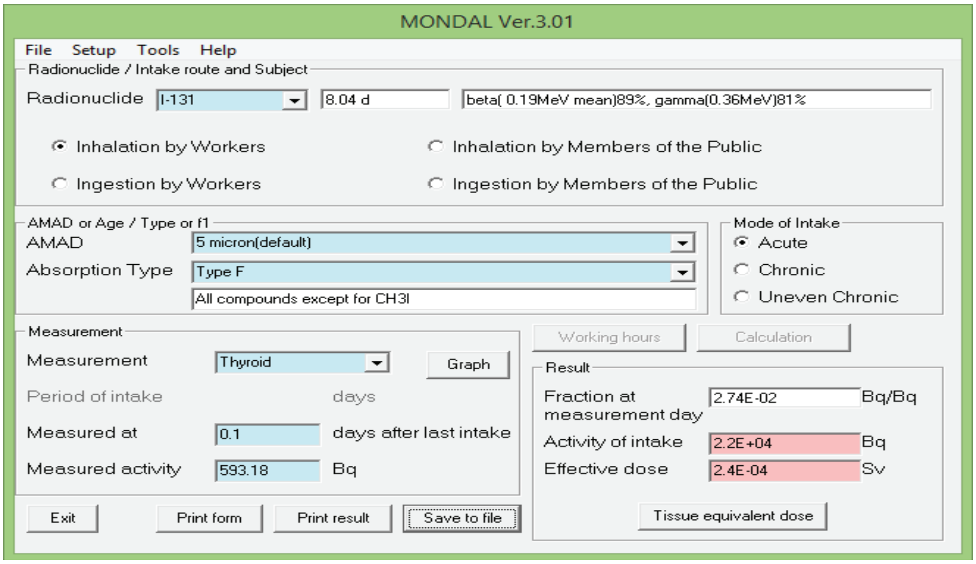


Figure 1: ^{131}I monitoring system to detect thyroid uptake.

At first the activity of thyroid is measured by taking counts per second data of the occupational worker by using single crystal counting probe with a flat field collimator. To calculate thyroid phantom efficiency, the activity of the 10 ml phantom was measured using a dose calibrator (VDC-405) and counts and a counting probe was used to measure the count/second data of the phantom.

fraction at any measurement day, activity of intake, effective dose, tissue equivalent dose & excretion curve. A screen shot of MONDAL-3 software is shown in Figure 2.



MONDAL Ver.3.01

Radionuclide / Intake route and Subject

Radionuclide: I-131 | 8.04 d | beta(0.19MeV mean)89%, gamma(0.36MeV)81%

● Inhalation by Workers
○ Inhalation by Members of the Public
○ Ingestion by Workers
○ Ingestion by Members of the Public

AMAD or Age / Type or f1

AMAD: 5 micron(default)

Absorption Type: Type F

All compounds except for CH3I

Mode of Intake

● Acute
○ Chronic
○ Uneven Chronic

Measurement

Measurement: Thyroid

Period of intake: days

Measured at: 0.1 days after last intake

Measured activity: 593.18 Bq

Result

Fraction at measurement day: 2.74E-02 Bq/Bq

Activity of intake: 2.2E+04 Bq

Effective dose: 2.4E-04 Sv

Figure 2: Input screen of MONDAL-3 software

Measured CPS is then converted into activity. This activity is manipulated in MONDAL-3 software considering data is taken approximately 2 hours after the exposure. After calculation, this software will provide To determine phantom efficiency, the activity of a traceable standard source of the radioisotope of interest is measured using the following formula:

$E = (C - B)/A \text{ X } I_{\Upsilon}$

where E is the efficiency in counts per second (cps) per becquerel (Bq);

C is the measured counts per unit time of the standard source, in cps;

B is the background count rate, in cps;

A is the known activity of the standard source (dps), traceable to a national standardizing laboratory within 5% (1σ, or standard deviation) accuracy, in Bq; and

I_{Υ} is the gamma-ray intensity.

The efficiency was measured by using a standard ^{131}I source (measured with dose calibrator) in thyroid phantom. From the experimental data, it was found that CPS value of the thyroid phantom was 414.0667 & phantom activity is 9.9 μCi or 366300 Bq. So the phantom efficiency is,

$$\text{Phantom efficiency} = \frac{414.0667-2}{366300\times0.85}$$

$$= 0.00132 \text{ Bq}^{-1}$$

$$=0.132\%$$

Minimum Detectable Activity:

The minimum detectable activity (MDA) is the smallest amount of radioactivity that can be detected with a 95% confidence limit. The following formula based on NCRP Report 58 (NCRP, 1984) is used to calculate an MDA value (9):

$$\text{MDA} = \frac{4.65\xi\,\overline{B}+2.71}{ET}$$

Where, B is total background counts collected during time ‘T’;

E is the efficiency in cps/Bq; and

T is the time in seconds.

$$\text{So, MDA} = \frac{4.65\xi\,\overline{120}+2.71}{0.132\text{X}60} = 6.774\text{Bq}$$

The standard deviation can be estimated in the following equation:

$$S = \sqrt{\frac{\sigma_{i=1}^{n}(N_i-N_A)^2}{n-1}}$$

Where, S is the standard deviation;

n is the number of either background or standard source measurements;

N_I is the count rate of each individual measurement; and

N_A is the average of n measurements of N_i.

RESULTS

Table 1 shows the calculation of measured activity and effective dose for the inhalation by worker of ^{131}I (Type-F or fast acting) for individual CPS value.

Table 1: Calculation of activity and annual effective dose for corresponsive sample cps value

Data no.	Counts per Second (cps)	Activity ± σ (Bq)	Effective Dose (Sv)
1.	0.467	353.79± 0.0265	1.4E-04
2.	0.750	568.18± 0.0384	2.3 E-04
3.	0.583	441.67± 0.0001	1.8E-04
4.	0.683	517.42± 0.0231	2.1E-04
5.	0.617	467.42± 0.0079	1.9E-04
6.	0.433	328.03± 0.0343	1.3E-04
7.	0.600	454.55± 0.0040	1.8E-04
8.	0.783	**593.18± 0.0460**	2.4E-04
9.	0.567	429.55± 0.0036	1.7E-04
10.	0.650	492.42± 0.0155	2.0E-04
11.	0.450	340.91± 0.0304	1.4E-04
12.	0.517	391.67± 0.0150	1.6E-04
13.	0.550	416.67± 0.0075	1.7E-04
14.	0.417	315.91± 0.0380	1.3E-04
15.	0.717	543.18± 0.0309	2.2E-04
16.	0.733	555.30± 0.0345	2.2E-04
17.	0.500	378.79± 0.0189	1.5E-04
18.	0.533	403.79 ± 0.0114	1.6E-04
19.	0.700	530.30 ± 0.0270	2.1E-04
20.	0.400	**303.03 ± 0.0419**	1.2E-04

For different measured activity various number of tissue equivalent doses are calculated by using MONDAL software. Table 2 shows the tissue equivalent doses for 593.18 Bq thyroid activity of occupational worker due to 131I (Type- F). It can be noted that, after 1 year tissue equivalent doses and effective dose remains same upto 50 years.

Table 2: Tissue equivalent doses for 593.18Bq thyroid activity of occupational worker

Organs	1 day	7 days	30 days	1 year	5 years
	Unit Sv				
Adrenals	2.8E-07	3.7E-07	5.0E-07	5.4E-07	5.4E-07
Bladder Wall	7.1E-06	7.8E-06	7.8E-06	8.0E-06	8.0E-06
Bone Surface	4.3E-07	9.1E-07	1.4E-06	1.5E-06	1.5E-06
Brain	4.3E-07	1.0E-06	1.7E-06	1.8E-06	1.8E-06
Breast	2.6E-07	4.3E-07	6.5E-07	6.9E-07	6.9E-07
Oesophagus	4.8E-07	1.1E-06	1.8E-06	1.8E-06	1.8E-06
ST Wall	1.4E-06	1.5E-06	1.6E-06	1.6E-06	1.6E-06
SI Wall	3.2E-07	3.7E-07	4.8E-07	5.0E-07	5.0E-07
ULI Wall	4.1E-07	5.0E-07	6.5E-07	6.9E-07	6.9E-07
LLI Wall	4.8E-07	8.0E-07	1.0E-06	1.1E-06	1.1E-06
Colon	4.3E-07	6.3E-07	8.2E-07	8.7E-07	8.7E-07
Kidney	2.6E-07	3.2E-07	4.5E-07	4.8E-07	4.8E-07
Liver	2.6E-07	3.7E-07	5.0E-07	5.2E-07	5.2E-07
Muscle	4.3E-07	9.1E-07	1.4E-06	1.5E-06	1.5E-06
Ovaries	3.2E-07	3.9E-07	5.0E-07	5.2E-07	5.2E-07
Pancreas	3.2E-07	4.1E-07	5.6E-07	5.8E-07	5.8E-07
Red Marrow	3.7E-07	7.4E-07	1.1E-06	1.2E-06	1.2E-06
ET Airways	7.1E-05	1.0E-04	1.0E-04	1.0E-04	1.0E-04
Lungs	8.9E-07	1.3E-06	1.7E-06	1.8E-06	1.8E-06
Skin	2.8E-07	5.0E-07	7.6E-07	8.0E-07	8.0E-07
Spleen	2.8E-07	3.7E-07	5.0E-07	5.4E-07	5.4E-07
Testes	2.6E-07	3.0E-07	3.9E-07	4.1E-07	4.1E-07
Thymus	4.8E-07	1.1E-06	1.8E-06	1.8E-06	1.8E-06
Thyroid	2.6E-04	2.1E-03	4.3E-03	4.5E-03	4.5E-03
Uterus	4.1E-07	4.8E-07	5.8E-07	6.1E-07	6.1E-07
Remainder	4.5E-07	9.3E-07	1.5E-06	1.5E-06	1.5E-06
Effective dose	1.4E-05	1.1E-04	2.1E-04	2.4E-04	2.4E-04

In Fraction vs Days curve in Fig. 3, fraction rate decreases with the increase of days. That means absorbed dose decreased time. The nature of the curve remains identical for all particle size with slight difference in their fraction rate.

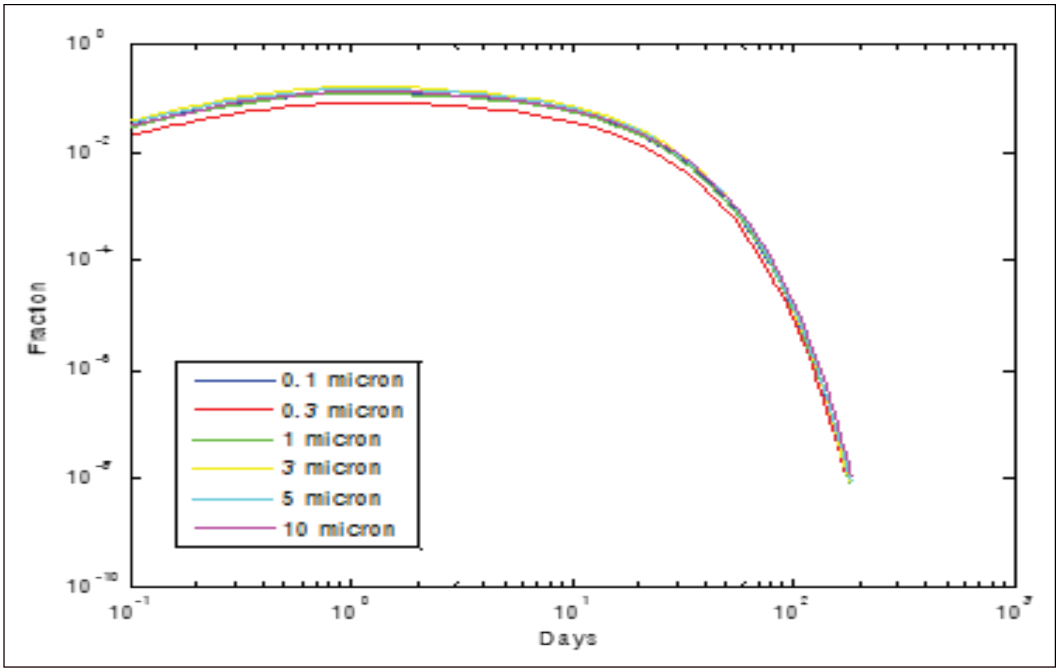


Figure 3: Inhalation by workers excretion curves for 593.18Bq Thyroid (Type F) activity of ^{131}I

In terms of thyroid activity in Figure 4, the nature of the curves for maximum (593.18Bq), minimum (303.03 Bq) and mean (448.105 Bq) thyroid activities remains constant with slight fraction rate difference.

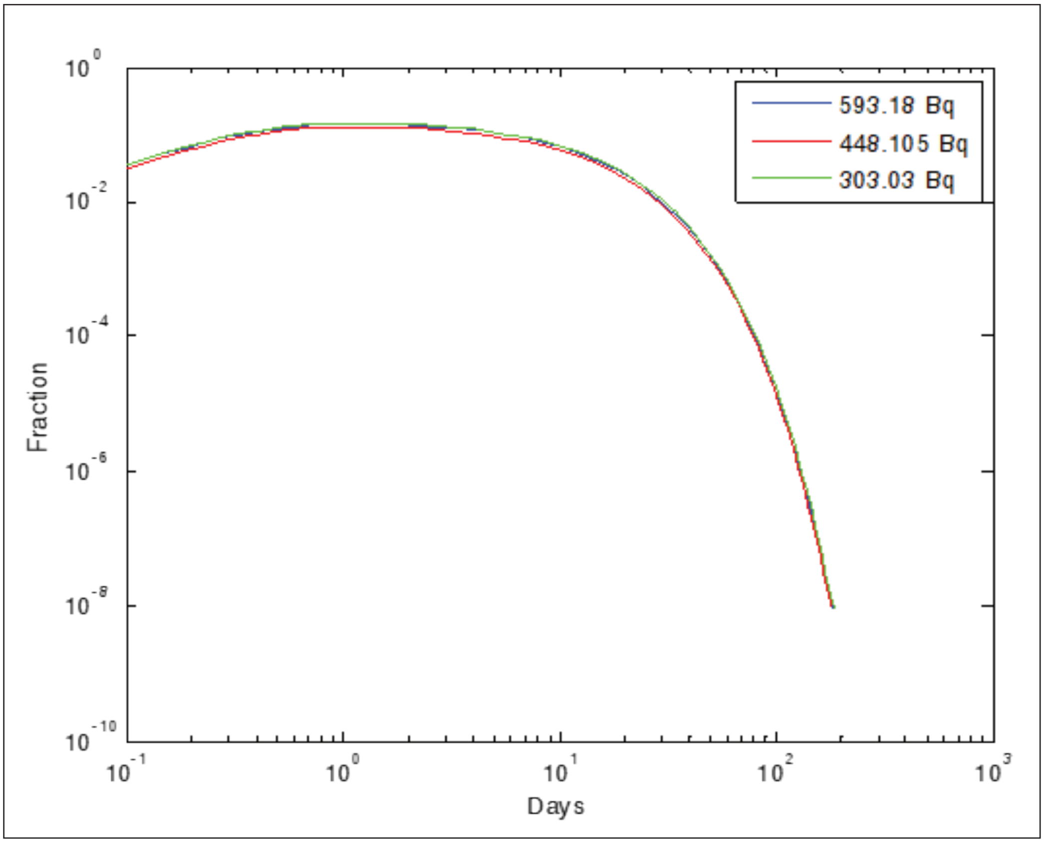


Figure 4: Inhalation by workers excretion curves for maximum, mean and minimum thyroid activity

DISCUSSION

This study is based on the analysis and evaluation of the effective dose and tissue equivalent dose of ^{131}I. Calculation of the internal dose and analysis of the effect of dose in workers are evaluated graphically. It is a regular monitoring and evaluation procedure to ensure that workers do not get exposed to excess dose than the recommended limit of ICRP. This research shows that the effective doses of the occupational workers range from 1.2×10^{-4} Sv to 2.4×10^{-4} Sv in a year. Since ICRP's regulatory dose limit for occupational worker is 20mSv/y, the average effective dose for the particular activities is well within the regulatory dose limit. From the minimum detectable activity calculation it is found to be 6.774Bq, which is below the measured thyroid activity data. So it can be inferred that the system is quite effective for the experiment with low standard deviation.

From the result, it can be seen that effective dose might change due to AMAD (Activity Median Aerodynamic Diameter), absorption type or sample type. This whole research is conducted based on acute mode of intake. This study enables estimation of the intake activity, excretion rate, effective dose and tissue equivalent dose for particular radionuclides. While using thyroid probe to measure body radioactivity, the distance between body and counting probe must always be constant. Practical application of the result acquired is to protect occupational workers, prevent acute (short-term) effects, minimize risk of long-term effects, verify adequacy of workplace controls and demonstrate regulatory compliance.

CONCLUSION

This study suggests that a routine monitoring program for internal exposures should be implemented for most nuclear medicine workers in order to demonstrate that individual doses should be as low as possible.

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