EVALUATION OF INTERNAL EXPOSURE OF NUCLEAR MEDICINE STAFF USING *IN-VITRO* AND ORGAN DOSE CALCULATION METHODOLOGIES

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ABSTRACT

The manipulation of a wide variety of unsealed sources in nuclear medicine results in a significant risk of internal exposure of the workers. ^{131}I should be highlighted among the most frequently used radionuclides because of its large application for diagnosis and therapy of thyroid diseases. The increasing use of radionuclides for medical purposes creates a demand for feasible methodologies to perform occupational control of internal contamination. Currently in Egypt, there are ~200 nuclear medicine centers in operation but individual monitoring is still restricted to the control of external exposure. In a previous study by Rizk *et al.,* [1], we have developed an *in- vitro* bioassay technique aimed to assessment of the intake due to inhalation of I-131 by workers in 3 Egyptian hospitals. Urine samples from 11 workers were collected after preparation and administration for I-131 and measured with HPGe detection system. In this study, given these bioassay data, we were able to estimate the average organ dose and committed effective doses of the staff working in the hospitals mentioned above over a period of 50 yrs. It would give us some confidence that the dose measure (as evaluated by MONDAL 3.0 software) might yield reasonable predictions for yet other workers (e.g., radiotherapies) and other dose routes. This paper describes the basic structure and validation of MONDAL 3.0 with a practical use of the software. It also shows if any of the workers need routine monitoring.

Keywords: *nuclear medicine, internal contamination, I-131 and Mondal 3.0 software.*

1. INTRODUCTION

Among the most widely used radionuclides in the field of nuclear medicine, the following should be highlighted: ^{99m}Tc, ^{131}I, ^{123}I, ^{201}Tl and ^{153}Sm. The activities manipulated annually in Egypt are in the order of hundreds of millicuries in about 200 nuclear medicine centers in routine operation. Although it is recognized that in nuclear medicine centers external exposure is usually higher than internal exposure, the risks associated with intakes should be estimated in each case and, if necessary, workers involved in the manipulation of unsealed sources should be routinely monitored in order to demonstrate that individual doses are kept as low as possible.

Internal monitoring should also be performed in response to an accidental or suspected inhalation or ingestion intake. In general, the decision to enroll a worker in an internal monitoring program should be based on the likelihood that the individual could receive an intake of radioactive material exceeding a predetermined level, Boli *et al.,* [2], and Dantas *et al.,* [3].

The need for individual or area monitoring for internal exposure will depend on the quantity and type of radioactive material present, the physical and chemical form of the radioactive material, the type of containment used, the operations performed and the general working conditions, Mollan *et al.,* [4]. It can be difficult to determine whether monitoring a worker for intakes of radioactive material is necessary. Such monitoring should be used routinely only for a worker in designated controlled areas where contamination may be present and potential exists for a significant intake to occur (IAEA-Tecdoc), [5] and Kong *et al*., [6]. This work describes an application of the criteria suggested by the IAEA to determine whether an internal monitoring program is needed for nuclear medicine workers and discusses situations where monitoring is necessary and feasible. For this sake**,** Firstly, the measured I-131 urinary excretion is used as input data. Secondly, the time-dependent organ equivalent dose, effective dose and organ absorbed dose are shown. Finally, the effective doses for the possibly contaminated eleven subjects are predicted.

2. BASIC STRUCTURE OF MONDAL SOFTWARE

"MONDAL3" is a PC based software that will help users to estimate intake of radionuclides inhaled or ingested by workers or by members of the public and resulting committed effective dose based on measurement results of individual monitoring such as *in vivo* counting or bioassay measurement. It is developed by the National Institute of

radiological sciences, Japan, intended for the estimation of internal doses based on retention or excretion measurements. Mondal contains the data set for the inhalation or ingestion cases. The calculation method is based on the methodology and parameters applied in ICRP publication No. 78. The software also contains data for radionuclides which were only in the relevant earlier publication of the ICRP No. 54, and data for several radionuclides which are absent also from the new and old ICRP publications.

This software basically consists of a data library for fractions of inhaled or ingested radioactivity retained in a whole-body or a specific organ excreted daily into urine or faeces, hereafter referred as Intake Retention Fraction (IRF).

If single acute intake is assumed, the activity m(t) of intake I, is calculated simply from the IRF value at the measurement day t and the measured activity M. In the case of chronic intake for T days, the values of IRF at the measurement day, t, are m(T+t-1) for the intake at the first day, m(T+t-2) for the intake at the second day and m(T+t-i) for the intake at the i-th day. Hence, an approximate value of intake is calculated in this program from a set of the called values of IRF, m(T+t-1), m(T+t-2), m(T+t-3), …, m(t), and the measured activity, M, by the equation:

$$I = \frac{T \times M}{\sum_{i=1}^{T} m(T+t-i)} \qquad (1)$$

If activity of intake differs from day to day, the measured activity can be expressed approximately in the form

$$M = I_1.m(T+t-1) + I_2.m(T+t-2) + \bullet\bullet + I_i.m(T+t-i) + \bullet\bullet + I_T.m(t) \qquad (2)$$

Where I_i is the activity of intake at the i-th day. If relative values of intake, H_i, are given, Eq.2 becomes

$$M = C.\sum_{i=1}^{T} H_i.m(T+t-i) \qquad (3)$$

For a constant C, An approximate value of the total intake can therefore be expressed as

$$I = \frac{\sum_{i=1}^{T} H_i}{\sum_{I=1}^{T} H_i.m(T+t-i)} \times M \qquad (4)$$

By giving working hours in each day as relative values of daily intake, an approximate value of total intake is calculated from a set of the values of IRF, m(T+t-1), m(T+t-2), m(T+t-3), …, m(t), and the measured activity, M using Eq.4. To determine the tissue equivalent doses and effective doses delivered for various periods after intake, the activity of intake calculated above is multiplied by the dose conversion coefficient (S_v/B_q) given in the ICRP Database of Dose Coefficients, Mahrous *et al.*,[7] and Helal [8].

3. RESULTS AND DISCUSSIONS

Calculation of the committed effective dose equivalent for workers due to the incorporation of radiopharmaceuticals requires specific biokinetic models. Such models are required to interpret results of *in vivo* and *in vitro* bioassay measurements after the intake has occurred.

In a previous study, we have estimated the internal radiation doses due to inhalation of ^{131}I by workers in nuclear medicine units of three Egyptian hospitals. 24 hrs urine samples of 11 workers were weekly collected for 6 weeks. The ^{131}I activity in their samples was measured using Hyper Pure Germanium (HPGe) detector. The hospitals under investigation were: National Cancer Institute (NCI), El-Hussein Hospital and Misr Radiology Center (MRC), Rizk *et al.*, [1].

This study will include a comprehensive organ dose calculation of worker's exposures determined *in vitro* bioassay to provide actual data to evaluate risks associated with the practice of nuclear medicine. Figure 1 shows the form for entering input parameters in the MONDAL 3.0 software.

In tables 1-11 the values of committed effective dose E (over 50 years) are presented as estimated from the results of the measurements in urine.

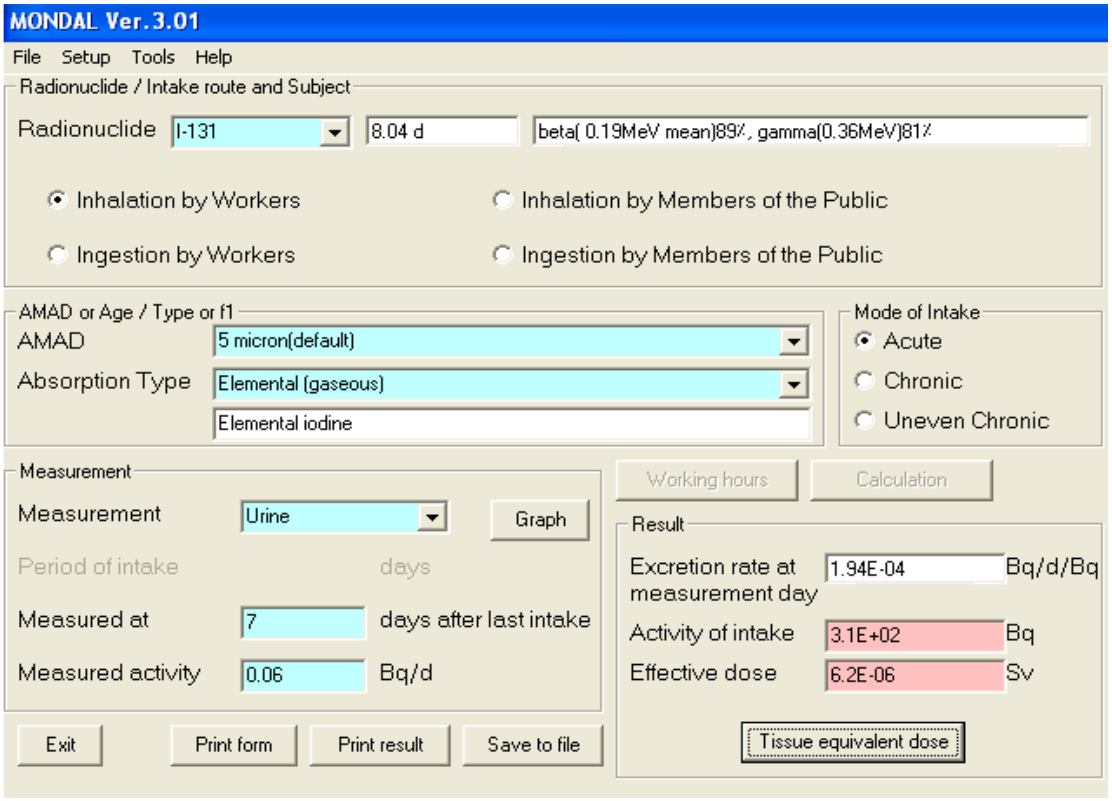
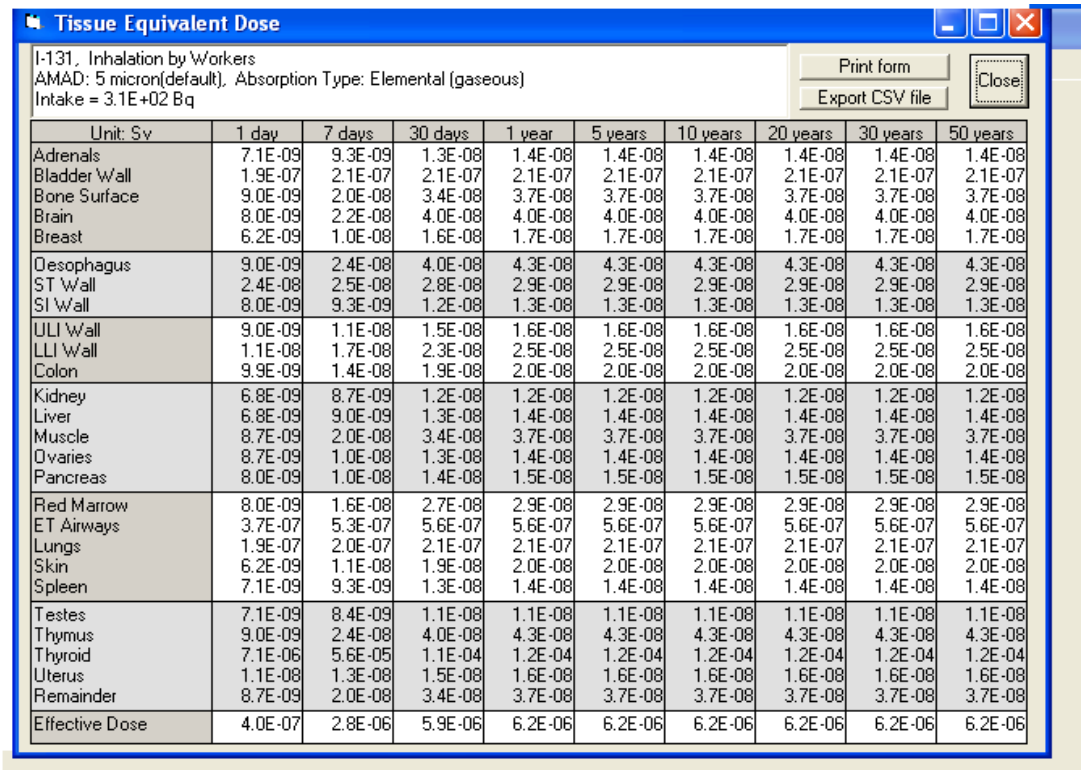


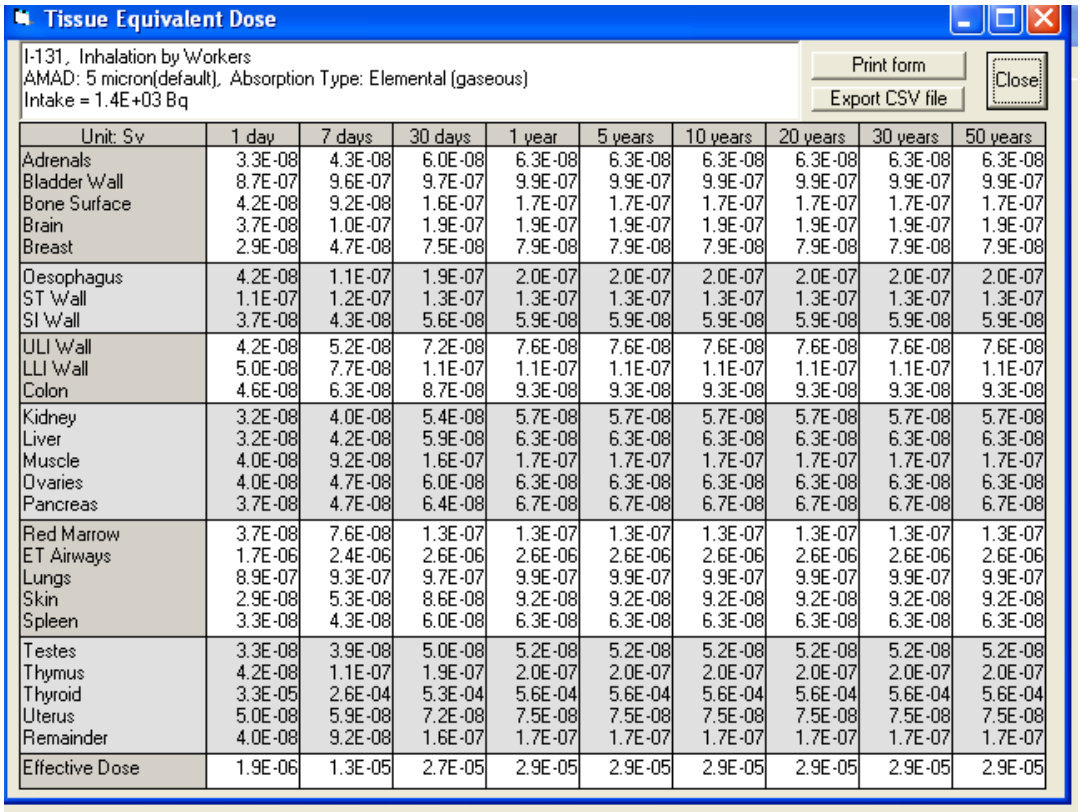
Figure 1: Main screen of MONDAL 3 program

Typical output results from MONDAL 3.0 software are shown in tables (1-11). Tables (1-6) represent the predicted worker' organs dose estimation over 50 years for 6 workers of the NCI.



Unit: Sv	1 day	7 days	30 days	1 year	5 years	10 years	20 years	30 years	50 years
Adrenals	7.1E-09	9.3E-09	1.3E-08	1.4E-08	1.4E-08	1.4E-08	1.4E-08	1.4E-08	1.4E-08
Bladder Wall	1.9E-07	2.1E-07	2.1E-07	2.1E-07	2.1E-07	2.1E-07	2.1E-07	2.1E-07	2.1E-07
Bone Surface	9.0E-09	2.0E-08	3.4E-08	3.7E-08	3.7E-08	3.7E-08	3.7E-08	3.7E-08	3.7E-08
Brain	8.0E-09	2.2E-08	4.0E-08	4.0E-08	4.0E-08	4.0E-08	4.0E-08	4.0E-08	4.0E-08
Breast	6.2E-09	1.0E-08	1.6E-08	1.7E-08	1.7E-08	1.7E-08	1.7E-08	1.7E-08	1.7E-08
Oesophagus	9.0E-09	2.4E-08	4.0E-08	4.3E-08	4.3E-08	4.3E-08	4.3E-08	4.3E-08	4.3E-08
ST Wall	2.4E-08	2.5E-08	2.8E-08	2.9E-08	2.9E-08	2.9E-08	2.9E-08	2.9E-08	2.9E-08
SI Wall	8.0E-09	9.3E-09	1.2E-08	1.3E-08	1.3E-08	1.3E-08	1.3E-08	1.3E-08	1.3E-08
ULI Wall	9.0E-09	1.1E-08	1.5E-08	1.6E-08	1.6E-08	1.6E-08	1.6E-08	1.6E-08	1.6E-08
LLI Wall	1.1E-08	1.7E-08	2.3E-08	2.5E-08	2.5E-08	2.5E-08	2.5E-08	2.5E-08	2.5E-08
Colon	9.9E-09	1.4E-08	1.9E-08	2.0E-08	2.0E-08	2.0E-08	2.0E-08	2.0E-08	2.0E-08
Kidney	6.8E-09	8.7E-09	1.2E-08	1.2E-08	1.2E-08	1.2E-08	1.2E-08	1.2E-08	1.2E-08
Liver	6.8E-09	9.0E-09	1.3E-08	1.4E-08	1.4E-08	1.4E-08	1.4E-08	1.4E-08	1.4E-08
Muscle	8.7E-09	2.0E-08	3.4E-08	3.7E-08	3.7E-08	3.7E-08	3.7E-08	3.7E-08	3.7E-08
Ovaries	8.7E-09	1.0E-08	1.3E-08	1.4E-08	1.4E-08	1.4E-08	1.4E-08	1.4E-08	1.4E-08
Pancreas	8.0E-09	1.0E-08	1.4E-08	1.5E-08	1.5E-08	1.5E-08	1.5E-08	1.5E-08	1.5E-08
Red Marrow	8.0E-09	1.6E-08	2.7E-08	2.9E-08	2.9E-08	2.9E-08	2.9E-08	2.9E-08	2.9E-08
ET Airways	3.7E-07	5.3E-07	5.6E-07	5.6E-07	5.6E-07	5.6E-07	5.6E-07	5.6E-07	5.6E-07
Lungs	1.9E-07	2.0E-07	2.1E-07	2.1E-07	2.1E-07	2.1E-07	2.1E-07	2.1E-07	2.1E-07
Skin	6.2E-09	1.1E-08	1.9E-08	2.0E-08	2.0E-08	2.0E-08	2.0E-08	2.0E-08	2.0E-08
Spleen	7.1E-09	9.3E-09	1.3E-08	1.4E-08	1.4E-08	1.4E-08	1.4E-08	1.4E-08	1.4E-08
Testes	7.1E-09	8.4E-09	1.1E-08	1.1E-08	1.1E-08	1.1E-08	1.1E-08	1.1E-08	1.1E-08
Thymus	9.0E-09	2.4E-08	4.0E-08	4.3E-08	4.3E-08	4.3E-08	4.3E-08	4.3E-08	4.3E-08
Thyroid	7.1E-06	5.6E-05	1.1E-04	1.2E-04	1.2E-04	1.2E-04	1.2E-04	1.2E-04	1.2E-04
Uterus	1.1E-08	1.3E-08	1.5E-08	1.6E-08	1.6E-08	1.6E-08	1.6E-08	1.6E-08	1.6E-08
Remainder	8.7E-09	2.0E-08	3.4E-08	3.7E-08	3.7E-08	3.7E-08	3.7E-08	3.7E-08	3.7E-08
Effective Dose	4.0E-07	2.8E-06	5.9E-06	6.2E-06	6.2E-06	6.2E-06	6.2E-06	6.2E-06	6.2E-06

Table 1: Tissue equivalent dose flowchart of the 1st worker at NCI



Tissue Equivalent Dose

I-131, Inhalation by Workers
AMAD: 5 micron(default), Absorption Type: Elemental (gaseous)
Intake = 1.4E+03 Bq

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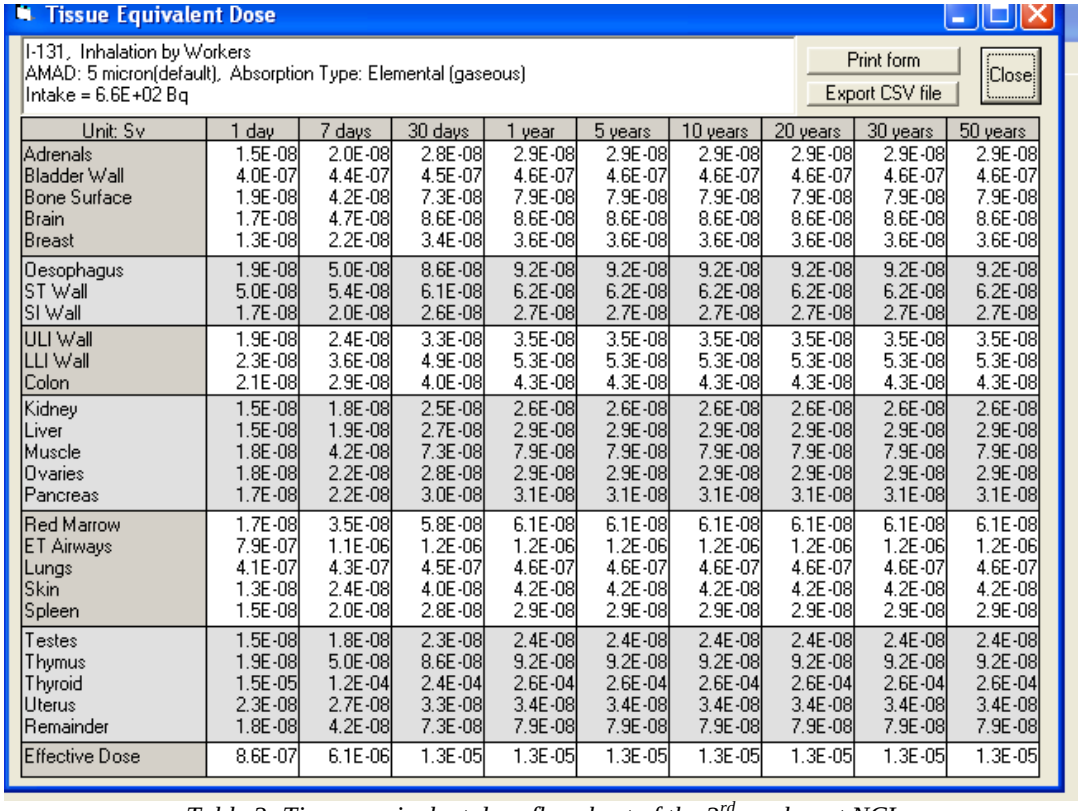
Unit: Sv	1 day	7 days	30 days	1 year	5 years	10 years	20 years	30 years	50 years
Adrenals	3.3E-08	4.3E-08	6.0E-08	6.3E-08	6.3E-08	6.3E-08	6.3E-08	6.3E-08	6.3E-08
Bladder Wall	8.7E-07	9.6E-07	9.7E-07	9.9E-07	9.9E-07	9.9E-07	9.9E-07	9.9E-07	9.9E-07
Bone Surface	4.2E-08	9.2E-08	1.6E-07	1.7E-07	1.7E-07	1.7E-07	1.7E-07	1.7E-07	1.7E-07
Brain	3.7E-08	1.0E-07	1.9E-07	1.9E-07	1.9E-07	1.9E-07	1.9E-07	1.9E-07	1.9E-07
Breast	2.9E-08	4.7E-08	7.5E-08	7.9E-08	7.9E-08	7.9E-08	7.9E-08	7.9E-08	7.9E-08
Oesophagus	4.2E-08	1.1E-07	1.9E-07	2.0E-07	2.0E-07	2.0E-07	2.0E-07	2.0E-07	2.0E-07
ST Wall	1.1E-07	1.2E-07	1.3E-07	1.3E-07	1.3E-07	1.3E-07	1.3E-07	1.3E-07	1.3E-07
SI Wall	3.7E-08	4.3E-08	5.6E-08	5.9E-08	5.9E-08	5.9E-08	5.9E-08	5.9E-08	5.9E-08
ULI Wall	4.2E-08	5.2E-08	7.2E-08	7.6E-08	7.6E-08	7.6E-08	7.6E-08	7.6E-08	7.6E-08
LLI Wall	5.0E-08	7.7E-08	1.1E-07	1.1E-07	1.1E-07	1.1E-07	1.1E-07	1.1E-07	1.1E-07
Colon	4.6E-08	6.3E-08	8.7E-08	9.3E-08	9.3E-08	9.3E-08	9.3E-08	9.3E-08	9.3E-08
Kidney	3.2E-08	4.0E-08	5.4E-08	5.7E-08	5.7E-08	5.7E-08	5.7E-08	5.7E-08	5.7E-08
Liver	3.2E-08	4.2E-08	5.9E-08	6.3E-08	6.3E-08	6.3E-08	6.3E-08	6.3E-08	6.3E-08
Muscle	4.0E-08	9.2E-08	1.6E-07	1.7E-07	1.7E-07	1.7E-07	1.7E-07	1.7E-07	1.7E-07
Ovaries	4.0E-08	4.7E-08	6.0E-08	6.3E-08	6.3E-08	6.3E-08	6.3E-08	6.3E-08	6.3E-08
Pancreas	3.7E-08	4.7E-08	6.4E-08	6.7E-08	6.7E-08	6.7E-08	6.7E-08	6.7E-08	6.7E-08
Red Marrow	3.7E-08	7.6E-08	1.3E-07	1.3E-07	1.3E-07	1.3E-07	1.3E-07	1.3E-07	1.3E-07
ET Airways	1.7E-06	2.4E-06	2.6E-06	2.6E-06	2.6E-06	2.6E-06	2.6E-06	2.6E-06	2.6E-06
Lungs	8.9E-07	9.3E-07	9.7E-07	9.9E-07	9.9E-07	9.9E-07	9.9E-07	9.9E-07	9.9E-07
Skin	2.9E-08	5.3E-08	8.6E-08	9.2E-08	9.2E-08	9.2E-08	9.2E-08	9.2E-08	9.2E-08
Spleen	3.3E-08	4.3E-08	6.0E-08	6.3E-08	6.3E-08	6.3E-08	6.3E-08	6.3E-08	6.3E-08
Testes	3.3E-08	3.9E-08	5.0E-08	5.2E-08	5.2E-08	5.2E-08	5.2E-08	5.2E-08	5.2E-08
Thymus	4.2E-08	1.1E-07	1.9E-07	2.0E-07	2.0E-07	2.0E-07	2.0E-07	2.0E-07	2.0E-07
Thyroid	3.3E-05	2.6E-04	5.3E-04	5.6E-04	5.6E-04	5.6E-04	5.6E-04	5.6E-04	5.6E-04
Uterus	5.0E-08	5.9E-08	7.2E-08	7.5E-08	7.5E-08	7.5E-08	7.5E-08	7.5E-08	7.5E-08
Remainder	4.0E-08	9.2E-08	1.6E-07	1.7E-07	1.7E-07	1.7E-07	1.7E-07	1.7E-07	1.7E-07
Effective Dose	1.9E-06	1.3E-05	2.7E-05	2.9E-05	2.9E-05	2.9E-05	2.9E-05	2.9E-05	2.9E-05

Table 2: Tissue equivalent dose flowchart of the 2nd worker at NCI



Tissue Equivalent Dose

I-131, Inhalation by Workers
AMAD: 5 micron(default), Absorption Type: Elemental (gaseous)
Intake = 6.6E+02 Bq

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Unit: Sv	1 day	7 days	30 days	1 year	5 years	10 years	20 years	30 years	50 years
Adrenals	1.5E-08	2.0E-08	2.8E-08	2.9E-08	2.9E-08	2.9E-08	2.9E-08	2.9E-08	2.9E-08
Bladder Wall	4.0E-07	4.4E-07	4.5E-07	4.6E-07	4.6E-07	4.6E-07	4.6E-07	4.6E-07	4.6E-07
Bone Surface	1.9E-08	4.2E-08	7.3E-08	7.9E-08	7.9E-08	7.9E-08	7.9E-08	7.9E-08	7.9E-08
Brain	1.7E-08	4.7E-08	8.6E-08	8.6E-08	8.6E-08	8.6E-08	8.6E-08	8.6E-08	8.6E-08
Breast	1.3E-08	2.2E-08	3.4E-08	3.6E-08	3.6E-08	3.6E-08	3.6E-08	3.6E-08	3.6E-08
Oesophagus	1.9E-08	5.0E-08	8.6E-08	9.2E-08	9.2E-08	9.2E-08	9.2E-08	9.2E-08	9.2E-08
ST Wall	5.0E-08	5.4E-08	6.1E-08	6.2E-08	6.2E-08	6.2E-08	6.2E-08	6.2E-08	6.2E-08
SI Wall	1.7E-08	2.0E-08	2.6E-08	2.7E-08	2.7E-08	2.7E-08	2.7E-08	2.7E-08	2.7E-08
ULI Wall	1.9E-08	2.4E-08	3.3E-08	3.5E-08	3.5E-08	3.5E-08	3.5E-08	3.5E-08	3.5E-08
LLI Wall	2.3E-08	3.6E-08	4.9E-08	5.3E-08	5.3E-08	5.3E-08	5.3E-08	5.3E-08	5.3E-08
Colon	2.1E-08	2.9E-08	4.0E-08	4.3E-08	4.3E-08	4.3E-08	4.3E-08	4.3E-08	4.3E-08
Kidney	1.5E-08	1.8E-08	2.5E-08	2.6E-08	2.6E-08	2.6E-08	2.6E-08	2.6E-08	2.6E-08
Liver	1.5E-08	1.9E-08	2.7E-08	2.9E-08	2.9E-08	2.9E-08	2.9E-08	2.9E-08	2.9E-08
Muscle	1.8E-08	4.2E-08	7.3E-08	7.9E-08	7.9E-08	7.9E-08	7.9E-08	7.9E-08	7.9E-08
Ovaries	1.8E-08	2.2E-08	2.8E-08	2.9E-08	2.9E-08	2.9E-08	2.9E-08	2.9E-08	2.9E-08
Pancreas	1.7E-08	2.2E-08	3.0E-08	3.1E-08	3.1E-08	3.1E-08	3.1E-08	3.1E-08	3.1E-08
Red Marrow	1.7E-08	3.5E-08	5.8E-08	6.1E-08	6.1E-08	6.1E-08	6.1E-08	6.1E-08	6.1E-08
ET Airways	7.9E-07	1.1E-06	1.2E-06	1.2E-06	1.2E-06	1.2E-06	1.2E-06	1.2E-06	1.2E-06
Lungs	4.1E-07	4.3E-07	4.5E-07	4.6E-07	4.6E-07	4.6E-07	4.6E-07	4.6E-07	4.6E-07
Skin	1.3E-08	2.4E-08	4.0E-08	4.2E-08	4.2E-08	4.2E-08	4.2E-08	4.2E-08	4.2E-08
Spleen	1.5E-08	2.0E-08	2.8E-08	2.9E-08	2.9E-08	2.9E-08	2.9E-08	2.9E-08	2.9E-08
Testes	1.5E-08	1.8E-08	2.3E-08	2.4E-08	2.4E-08	2.4E-08	2.4E-08	2.4E-08	2.4E-08
Thymus	1.9E-08	5.0E-08	8.6E-08	9.2E-08	9.2E-08	9.2E-08	9.2E-08	9.2E-08	9.2E-08
Thyroid	1.5E-05	1.2E-04	2.4E-04	2.6E-04	2.6E-04	2.6E-04	2.6E-04	2.6E-04	2.6E-04
Uterus	2.3E-08	2.7E-08	3.3E-08	3.4E-08	3.4E-08	3.4E-08	3.4E-08	3.4E-08	3.4E-08
Remainder	1.8E-08	4.2E-08	7.3E-08	7.9E-08	7.9E-08	7.9E-08	7.9E-08	7.9E-08	7.9E-08
Effective Dose	8.6E-07	6.1E-06	1.3E-05	1.3E-05	1.3E-05	1.3E-05	1.3E-05	1.3E-05	1.3E-05

Table 3: Tissue equivalent dose flowchart of the 3rd worker at NCI

Tissue Equivalent Dose

I-131, Inhalation by Workers
AMAD: 5 micron(default), Absorption Type: Elemental (gaseous)
Intake = 2.9E+02 Bq

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Unit: Sv	1 day	7 days	30 days	1 year	5 years	10 years	20 years	30 years	50 years
Adrenals	6.6E-09	8.7E-09	1.2E-08	1.3E-08	1.3E-08	1.3E-08	1.3E-08	1.3E-08	1.3E-08
Bladder Wall	1.8E-07	1.9E-07	2.0E-07	2.0E-07	2.0E-07	2.0E-07	2.0E-07	2.0E-07	2.0E-07
Bone Surface	8.4E-09	1.8E-08	3.2E-08	3.5E-08	3.5E-08	3.5E-08	3.5E-08	3.5E-08	3.5E-08
Brain	7.5E-09	2.0E-08	3.8E-08	3.8E-08	3.8E-08	3.8E-08	3.8E-08	3.8E-08	3.8E-08
Breast	5.8E-09	9.5E-09	1.5E-08	1.6E-08	1.6E-08	1.6E-08	1.6E-08	1.6E-08	1.6E-08
Oesophagus	8.4E-09	2.2E-08	3.8E-08	4.0E-08	4.0E-08	4.0E-08	4.0E-08	4.0E-08	4.0E-08
ST Wall	2.2E-08	2.4E-08	2.7E-08	2.7E-08	2.7E-08	2.7E-08	2.7E-08	2.7E-08	2.7E-08
SI Wall	7.5E-09	8.7E-09	1.1E-08	1.2E-08	1.2E-08	1.2E-08	1.2E-08	1.2E-08	1.2E-08
ULI Wall	8.4E-09	1.0E-08	1.4E-08	1.5E-08	1.5E-08	1.5E-08	1.5E-08	1.5E-08	1.5E-08
LLI Wall	1.0E-08	1.6E-08	2.2E-08	2.3E-08	2.3E-08	2.3E-08	2.3E-08	2.3E-08	2.3E-08
Colon	9.2E-09	1.3E-08	1.8E-08	1.9E-08	1.9E-08	1.9E-08	1.9E-08	1.9E-08	1.9E-08
Kidney	6.4E-09	8.1E-09	1.1E-08	1.2E-08	1.2E-08	1.2E-08	1.2E-08	1.2E-08	1.2E-08
Liver	6.4E-09	8.4E-09	1.2E-08	1.3E-08	1.3E-08	1.3E-08	1.3E-08	1.3E-08	1.3E-08
Muscle	8.1E-09	1.8E-08	3.2E-08	3.5E-08	3.5E-08	3.5E-08	3.5E-08	3.5E-08	3.5E-08
Ovaries	8.1E-09	9.5E-09	1.2E-08	1.3E-08	1.3E-08	1.3E-08	1.3E-08	1.3E-08	1.3E-08
Pancreas	7.5E-09	9.5E-09	1.3E-08	1.4E-08	1.4E-08	1.4E-08	1.4E-08	1.4E-08	1.4E-08
Red Marrow	7.5E-09	1.5E-08	2.5E-08	2.7E-08	2.7E-08	2.7E-08	2.7E-08	2.7E-08	2.7E-08
ET Airways	3.5E-07	4.9E-07	5.2E-07	5.2E-07	5.2E-07	5.2E-07	5.2E-07	5.2E-07	5.2E-07
Lungs	1.8E-07	1.9E-07	2.0E-07	2.0E-07	2.0E-07	2.0E-07	2.0E-07	2.0E-07	2.0E-07
Skin	5.8E-09	1.1E-08	1.7E-08	1.8E-08	1.8E-08	1.8E-08	1.8E-08	1.8E-08	1.8E-08
Spleen	6.6E-09	8.7E-09	1.2E-08	1.3E-08	1.3E-08	1.3E-08	1.3E-08	1.3E-08	1.3E-08
Testes	6.6E-09	7.8E-09	1.0E-08	1.0E-08	1.0E-08	1.0E-08	1.0E-08	1.0E-08	1.0E-08
Thymus	8.4E-09	2.2E-08	3.8E-08	4.0E-08	4.0E-08	4.0E-08	4.0E-08	4.0E-08	4.0E-08
Thyroid	6.6E-06	5.2E-05	1.1E-04	1.1E-04	1.1E-04	1.1E-04	1.1E-04	1.1E-04	1.1E-04
Uterus	1.0E-08	1.2E-08	1.4E-08	1.5E-08	1.5E-08	1.5E-08	1.5E-08	1.5E-08	1.5E-08
Remainder	8.1E-09	1.8E-08	3.2E-08	3.5E-08	3.5E-08	3.5E-08	3.5E-08	3.5E-08	3.5E-08
Effective Dose	3.8E-07	2.7E-06	5.5E-06	5.8E-06	5.8E-06	5.8E-06	5.8E-06	5.8E-06	5.8E-06

Table 4: Tissue equivalent dose flowchart of the 4th worker at NCI

Tissue Equivalent Dose

I-131, Inhalation by Workers
AMAD: 5 micron(default), Absorption Type: Elemental (gaseous)
Intake = 1.1E+03 Bq

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Unit: Sv	1 day	7 days	30 days	1 year	5 years	10 years	20 years	30 years	50 years
Adrenals	2.5E-08	3.2E-08	4.5E-08	4.7E-08	4.7E-08	4.7E-08	4.7E-08	4.7E-08	4.7E-08
Bladder Wall	6.5E-07	7.1E-07	7.3E-07	7.4E-07	7.4E-07	7.4E-07	7.4E-07	7.4E-07	7.4E-07
Bone Surface	3.1E-08	6.8E-08	1.2E-07	1.3E-07	1.3E-07	1.3E-07	1.3E-07	1.3E-07	1.3E-07
Brain	2.8E-08	7.6E-08	1.4E-07	1.4E-07	1.4E-07	1.4E-07	1.4E-07	1.4E-07	1.4E-07
Breast	2.1E-08	3.5E-08	5.5E-08	5.9E-08	5.9E-08	5.9E-08	5.9E-08	5.9E-08	5.9E-08
Oesophagus	3.1E-08	8.1E-08	1.4E-07	1.5E-07	1.5E-07	1.5E-07	1.5E-07	1.5E-07	1.5E-07
ST Wall	8.1E-08	8.7E-08	9.8E-08	1.0E-07	1.0E-07	1.0E-07	1.0E-07	1.0E-07	1.0E-07
SI Wall	2.8E-08	3.2E-08	4.2E-08	4.4E-08	4.4E-08	4.4E-08	4.4E-08	4.4E-08	4.4E-08
ULI Wall	3.1E-08	3.8E-08	5.3E-08	5.7E-08	5.7E-08	5.7E-08	5.7E-08	5.7E-08	5.7E-08
LLI Wall	3.7E-08	5.8E-08	8.0E-08	8.5E-08	8.5E-08	8.5E-08	8.5E-08	8.5E-08	8.5E-08
Colon	3.4E-08	4.7E-08	6.5E-08	6.9E-08	6.9E-08	6.9E-08	6.9E-08	6.9E-08	6.9E-08
Kidney	2.3E-08	3.0E-08	4.1E-08	4.3E-08	4.3E-08	4.3E-08	4.3E-08	4.3E-08	4.3E-08
Liver	2.3E-08	3.1E-08	4.4E-08	4.7E-08	4.7E-08	4.7E-08	4.7E-08	4.7E-08	4.7E-08
Muscle	3.0E-08	6.8E-08	1.2E-07	1.3E-07	1.3E-07	1.3E-07	1.3E-07	1.3E-07	1.3E-07
Ovaries	3.0E-08	3.5E-08	4.5E-08	4.7E-08	4.7E-08	4.7E-08	4.7E-08	4.7E-08	4.7E-08
Pancreas	2.8E-08	3.5E-08	4.8E-08	5.0E-08	5.0E-08	5.0E-08	5.0E-08	5.0E-08	5.0E-08
Red Marrow	2.8E-08	5.7E-08	9.4E-08	9.9E-08	9.9E-08	9.9E-08	9.9E-08	9.9E-08	9.9E-08
ET Airways	1.3E-06	1.8E-06	1.9E-06	1.9E-06	1.9E-06	1.9E-06	1.9E-06	1.9E-06	1.9E-06
Lungs	6.6E-07	6.9E-07	7.3E-07	7.4E-07	7.4E-07	7.4E-07	7.4E-07	7.4E-07	7.4E-07
Skin	2.1E-08	3.9E-08	6.4E-08	6.8E-08	6.8E-08	6.8E-08	6.8E-08	6.8E-08	6.8E-08
Spleen	2.5E-08	3.2E-08	4.5E-08	4.7E-08	4.7E-08	4.7E-08	4.7E-08	4.7E-08	4.7E-08
Testes	2.5E-08	2.9E-08	3.7E-08	3.8E-08	3.8E-08	3.8E-08	3.8E-08	3.8E-08	3.8E-08
Thymus	3.1E-08	8.1E-08	1.4E-07	1.5E-07	1.5E-07	1.5E-07	1.5E-07	1.5E-07	1.5E-07
Thyroid	2.5E-05	1.9E-04	3.9E-04	4.2E-04	4.2E-04	4.2E-04	4.2E-04	4.2E-04	4.2E-04
Uterus	3.7E-08	4.4E-08	5.3E-08	5.5E-08	5.5E-08	5.5E-08	5.5E-08	5.5E-08	5.5E-08
Remainder	3.0E-08	6.8E-08	1.2E-07	1.3E-07	1.3E-07	1.3E-07	1.3E-07	1.3E-07	1.3E-07
Effective Dose	1.4E-06	9.8E-06	2.0E-05	2.1E-05	2.1E-05	2.1E-05	2.1E-05	2.1E-05	2.1E-05

Table 5: Tissue equivalent dose flowchart of the 5th worker at NCI

Tissue Equivalent Dose

I-131, Inhalation by Workers
AMAD: 5 micron(default), Absorption Type: Elemental (gaseous)
Intake = 1.3E+03 Bq

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Unit: Sv	1 day	7 days	30 days	1 year	5 years	10 years	20 years	30 years	50 years
Adrenals	3.1E-08	4.0E-08	5.6E-08	5.9E-08	5.9E-08	5.9E-08	5.9E-08	5.9E-08	5.9E-08
Bladder Wall	8.2E-07	9.0E-07	9.1E-07	9.2E-07	9.2E-07	9.2E-07	9.2E-07	9.2E-07	9.2E-07
Bone Surface	3.9E-08	8.6E-08	1.5E-07	1.6E-07	1.6E-07	1.6E-07	1.6E-07	1.6E-07	1.6E-07
Brain	3.5E-08	9.5E-08	1.7E-07	1.7E-07	1.7E-07	1.7E-07	1.7E-07	1.7E-07	1.7E-07
Breast	2.7E-08	4.4E-08	7.0E-08	7.4E-08	7.4E-08	7.4E-08	7.4E-08	7.4E-08	7.4E-08
Oesophagus	3.9E-08	1.0E-07	1.7E-07	1.9E-07	1.9E-07	1.9E-07	1.9E-07	1.9E-07	1.9E-07
ST Wall	1.0E-07	1.1E-07	1.2E-07	1.3E-07	1.3E-07	1.3E-07	1.3E-07	1.3E-07	1.3E-07
SI Wall	3.5E-08	4.0E-08	5.2E-08	5.5E-08	5.5E-08	5.5E-08	5.5E-08	5.5E-08	5.5E-08
ULI Wall	3.9E-08	4.8E-08	6.7E-08	7.1E-08	7.1E-08	7.1E-08	7.1E-08	7.1E-08	7.1E-08
LLI Wall	4.7E-08	7.2E-08	1.0E-07	1.1E-07	1.1E-07	1.1E-07	1.1E-07	1.1E-07	1.1E-07
Colon	4.3E-08	5.9E-08	8.2E-08	8.7E-08	8.7E-08	8.7E-08	8.7E-08	8.7E-08	8.7E-08
Kidney	2.9E-08	3.8E-08	5.1E-08	5.4E-08	5.4E-08	5.4E-08	5.4E-08	5.4E-08	5.4E-08
Liver	2.9E-08	3.9E-08	5.5E-08	5.9E-08	5.9E-08	5.9E-08	5.9E-08	5.9E-08	5.9E-08
Muscle	3.8E-08	8.6E-08	1.5E-07	1.6E-07	1.6E-07	1.6E-07	1.6E-07	1.6E-07	1.6E-07
Ovaries	3.8E-08	4.4E-08	5.6E-08	5.9E-08	5.9E-08	5.9E-08	5.9E-08	5.9E-08	5.9E-08
Pancreas	3.5E-08	4.4E-08	6.0E-08	6.3E-08	6.3E-08	6.3E-08	6.3E-08	6.3E-08	6.3E-08
Red Marrow	3.5E-08	7.1E-08	1.2E-07	1.2E-07	1.2E-07	1.2E-07	1.2E-07	1.2E-07	1.2E-07
ET Airways	1.6E-06	2.3E-06	2.4E-06	2.4E-06	2.4E-06	2.4E-06	2.4E-06	2.4E-06	2.4E-06
Lungs	8.3E-07	8.7E-07	9.1E-07	9.2E-07	9.2E-07	9.2E-07	9.2E-07	9.2E-07	9.2E-07
Skin	2.7E-08	5.0E-08	8.0E-08	8.6E-08	8.6E-08	8.6E-08	8.6E-08	8.6E-08	8.6E-08
Spleen	3.1E-08	4.0E-08	5.6E-08	5.9E-08	5.9E-08	5.9E-08	5.9E-08	5.9E-08	5.9E-08
Testes	3.1E-08	3.6E-08	4.7E-08	4.8E-08	4.8E-08	4.8E-08	4.8E-08	4.8E-08	4.8E-08
Thymus	3.9E-08	1.0E-07	1.7E-07	1.9E-07	1.9E-07	1.9E-07	1.9E-07	1.9E-07	1.9E-07
Thyroid	3.1E-05	2.4E-04	5.0E-04	5.2E-04	5.2E-04	5.2E-04	5.2E-04	5.2E-04	5.2E-04
Uterus	4.7E-08	5.5E-08	6.7E-08	7.0E-08	7.0E-08	7.0E-08	7.0E-08	7.0E-08	7.0E-08
Remainder	3.8E-08	8.6E-08	1.5E-07	1.6E-07	1.6E-07	1.6E-07	1.6E-07	1.6E-07	1.6E-07
Effective Dose	1.7E-06	1.2E-05	2.5E-05	2.7E-05	2.7E-05	2.7E-05	2.7E-05	2.7E-05	2.7E-05

Table 6: Tissue equivalent dose flowchart of the 6th worker at NCI

From the above tables, the effective doses incline to a constant value after one year of acute intake. Figure 2 shows the predicted results of retention and effective dose in all parts of GI tract through inhalation of ^{131}I radionuclide for 6 workers in NCI after one year of intake.

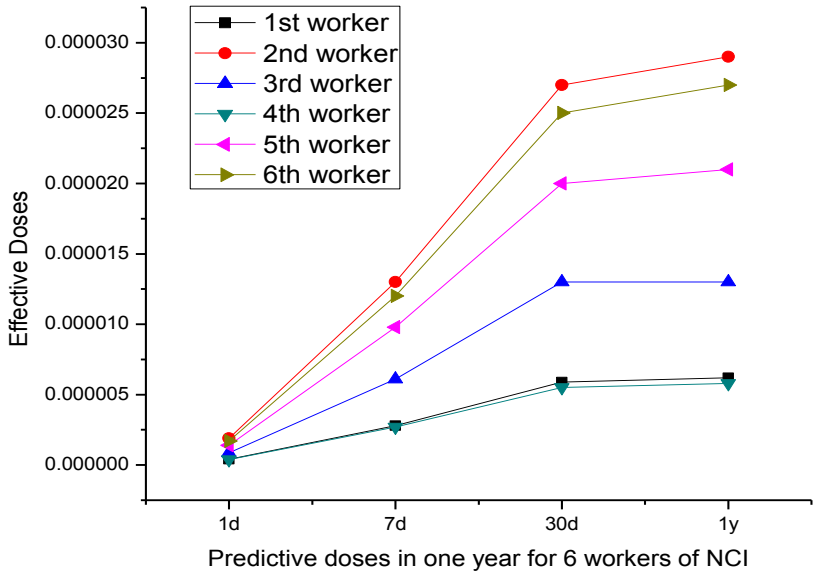

Figure 2: the predictive effective doses in one year of various body organs of 6 workers of NCI

From the above figure: the 2nd worker received the highest dose, then the 6th, 5th and the 3rd one. Both 1st and the 4th workers show very close values. The effective dose of these 6 workers are ranged from: 0.00038 µSv to 0.0019 µSv at the first day, from 0.0027 µSv to 0.012 µSv at 7 days, from 0.0055 µSv to 0.027 µSv after 30 days and finally, from 0.0058 µSv-0.029 µSv after 1 year of exposure to I-131, assuming an acute intake by inhalation and AMAD type of 5 µ (default value). Tables 7& 8 are the predicted worker' organs dose estimation over 50 years for 2 workers of the El-Hussein hospital.

Tissue Equivalent Dose

I-131, Inhalation by Workers
AMAD: 5 micron(default), Absorption Type: Elemental (gaseous)
Intake = 6.0E+01 Bq

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Unit: Sv	1 day	7 days	30 days	1 year	5 years	10 years	20 years	30 years	50 years
Adrenals	1.4E-09	1.8E-09	2.5E-09	2.7E-09	2.7E-09	2.7E-09	2.7E-09	2.7E-09	2.7E-09
Bladder Wall	3.7E-08	4.0E-08	4.1E-08	4.2E-08	4.2E-08	4.2E-08	4.2E-08	4.2E-08	4.2E-08
Bone Surface	1.7E-09	3.9E-09	6.6E-09	7.2E-09	7.2E-09	7.2E-09	7.2E-09	7.2E-09	7.2E-09
Brain	1.6E-09	4.3E-09	7.8E-09	7.8E-09	7.8E-09	7.8E-09	7.8E-09	7.8E-09	7.8E-09
Breast	1.2E-09	2.0E-09	3.1E-09	3.3E-09	3.3E-09	3.3E-09	3.3E-09	3.3E-09	3.3E-09
Oesophagus	1.7E-09	4.6E-09	7.8E-09	8.4E-09	8.4E-09	8.4E-09	8.4E-09	8.4E-09	8.4E-09
ST Wall	4.6E-09	4.9E-09	5.5E-09	5.7E-09	5.7E-09	5.7E-09	5.7E-09	5.7E-09	5.7E-09
SI Wall	1.6E-09	1.8E-09	2.4E-09	2.5E-09	2.5E-09	2.5E-09	2.5E-09	2.5E-09	2.5E-09
ULI Wall	1.7E-09	2.2E-09	3.0E-09	3.2E-09	3.2E-09	3.2E-09	3.2E-09	3.2E-09	3.2E-09
LLI Wall	2.1E-09	3.3E-09	4.5E-09	4.8E-09	4.8E-09	4.8E-09	4.8E-09	4.8E-09	4.8E-09
Colon	1.9E-09	2.7E-09	3.7E-09	3.9E-09	3.9E-09	3.9E-09	3.9E-09	3.9E-09	3.9E-09
Kidney	1.3E-09	1.7E-09	2.3E-09	2.4E-09	2.4E-09	2.4E-09	2.4E-09	2.4E-09	2.4E-09
Liver	1.3E-09	1.7E-09	2.5E-09	2.7E-09	2.7E-09	2.7E-09	2.7E-09	2.7E-09	2.7E-09
Muscle	1.7E-09	3.9E-09	6.6E-09	7.2E-09	7.2E-09	7.2E-09	7.2E-09	7.2E-09	7.2E-09
Ovaries	1.7E-09	2.0E-09	2.5E-09	2.7E-09	2.7E-09	2.7E-09	2.7E-09	2.7E-09	2.7E-09
Pancreas	1.6E-09	2.0E-09	2.7E-09	2.8E-09	2.8E-09	2.8E-09	2.8E-09	2.8E-09	2.8E-09
Red Marrow	1.6E-09	3.2E-09	5.3E-09	5.6E-09	5.6E-09	5.6E-09	5.6E-09	5.6E-09	5.6E-09
ET Airways	7.2E-08	1.0E-07	1.1E-07	1.1E-07	1.1E-07	1.1E-07	1.1E-07	1.1E-07	1.1E-07
Lungs	3.7E-08	3.9E-08	4.1E-08	4.2E-08	4.2E-08	4.2E-08	4.2E-08	4.2E-08	4.2E-08
Skin	1.2E-09	2.2E-09	3.6E-09	3.9E-09	3.9E-09	3.9E-09	3.9E-09	3.9E-09	3.9E-09
Spleen	1.4E-09	1.8E-09	2.5E-09	2.7E-09	2.7E-09	2.7E-09	2.7E-09	2.7E-09	2.7E-09
Testes	1.4E-09	1.6E-09	2.1E-09	2.2E-09	2.2E-09	2.2E-09	2.2E-09	2.2E-09	2.2E-09
Thymus	1.7E-09	4.6E-09	7.8E-09	8.4E-09	8.4E-09	8.4E-09	8.4E-09	8.4E-09	8.4E-09
Thyroid	1.4E-06	1.1E-05	2.2E-05	2.4E-05	2.4E-05	2.4E-05	2.4E-05	2.4E-05	2.4E-05
Uterus	2.1E-09	2.5E-09	3.0E-09	3.1E-09	3.1E-09	3.1E-09	3.1E-09	3.1E-09	3.1E-09
Remainder	1.7E-09	3.9E-09	6.6E-09	7.2E-09	7.2E-09	7.2E-09	7.2E-09	7.2E-09	7.2E-09
Effective Dose	7.8E-08	5.5E-07	1.1E-06	1.2E-06	1.2E-06	1.2E-06	1.2E-06	1.2E-06	1.2E-06

Table 7: tissue equivalent dose of the 7th worker of El-Hussein hospital

Tissue Equivalent Dose

I-131, Inhalation by Workers
AMAD: 5 micron(default), Absorption Type: Elemental (gaseous)
Intake = 7.3E+02 Bq

Print form | Export CSV file | Close

Unit: Sv	1 day	7 days	30 days	1 year	5 years	10 years	20 years	30 years	50 years
Adrenals	1.7E-08	2.2E-08	3.1E-08	3.2E-08	3.2E-08	3.2E-08	3.2E-08	3.2E-08	3.2E-08
Bladder Wall	4.5E-07	4.9E-07	5.0E-07	5.1E-07	5.1E-07	5.1E-07	5.1E-07	5.1E-07	5.1E-07
Bone Surface	2.1E-08	4.7E-08	8.1E-08	8.8E-08	8.8E-08	8.8E-08	8.8E-08	8.8E-08	8.8E-08
Brain	1.9E-08	5.2E-08	9.5E-08	9.5E-08	9.5E-08	9.5E-08	9.5E-08	9.5E-08	9.5E-08
Breast	1.5E-08	2.4E-08	3.8E-08	4.0E-08	4.0E-08	4.0E-08	4.0E-08	4.0E-08	4.0E-08
Oesophagus	2.1E-08	5.6E-08	9.5E-08	1.0E-07	1.0E-07	1.0E-07	1.0E-07	1.0E-07	1.0E-07
ST Wall	5.6E-08	6.0E-08	6.7E-08	6.9E-08	6.9E-08	6.9E-08	6.9E-08	6.9E-08	6.9E-08
SI Wall	1.9E-08	2.2E-08	2.9E-08	3.0E-08	3.0E-08	3.0E-08	3.0E-08	3.0E-08	3.0E-08
ULI Wall	2.1E-08	2.6E-08	3.7E-08	3.9E-08	3.9E-08	3.9E-08	3.9E-08	3.9E-08	3.9E-08
LLI Wall	2.6E-08	4.0E-08	5.5E-08	5.9E-08	5.9E-08	5.9E-08	5.9E-08	5.9E-08	5.9E-08
Colon	2.3E-08	3.2E-08	4.5E-08	4.8E-08	4.8E-08	4.8E-08	4.8E-08	4.8E-08	4.8E-08
Kidney	1.6E-08	2.0E-08	2.8E-08	2.9E-08	2.9E-08	2.9E-08	2.9E-08	2.9E-08	2.9E-08
Liver	1.6E-08	2.1E-08	3.0E-08	3.2E-08	3.2E-08	3.2E-08	3.2E-08	3.2E-08	3.2E-08
Muscle	2.0E-08	4.7E-08	8.1E-08	8.8E-08	8.8E-08	8.8E-08	8.8E-08	8.8E-08	8.8E-08
Ovaries	2.0E-08	2.4E-08	3.1E-08	3.2E-08	3.2E-08	3.2E-08	3.2E-08	3.2E-08	3.2E-08
Pancreas	1.9E-08	2.4E-08	3.3E-08	3.4E-08	3.4E-08	3.4E-08	3.4E-08	3.4E-08	3.4E-08
Red Marrow	1.9E-08	3.9E-08	6.4E-08	6.8E-08	6.8E-08	6.8E-08	6.8E-08	6.8E-08	6.8E-08
ET Airways	8.8E-07	1.2E-06	1.3E-06	1.3E-06	1.3E-06	1.3E-06	1.3E-06	1.3E-06	1.3E-06
Lungs	4.5E-07	4.8E-07	5.0E-07	5.1E-07	5.1E-07	5.1E-07	5.1E-07	5.1E-07	5.1E-07
Skin	1.5E-08	2.7E-08	4.4E-08	4.7E-08	4.7E-08	4.7E-08	4.7E-08	4.7E-08	4.7E-08
Spleen	1.7E-08	2.2E-08	3.1E-08	3.2E-08	3.2E-08	3.2E-08	3.2E-08	3.2E-08	3.2E-08
Testes	1.7E-08	2.0E-08	2.6E-08	2.6E-08	2.6E-08	2.6E-08	2.6E-08	2.6E-08	2.6E-08
Thymus	2.1E-08	5.6E-08	9.5E-08	1.0E-07	1.0E-07	1.0E-07	1.0E-07	1.0E-07	1.0E-07
Thyroid	1.7E-05	1.3E-04	2.7E-04	2.9E-04	2.9E-04	2.9E-04	2.9E-04	2.9E-04	2.9E-04
Uterus	2.6E-08	3.0E-08	3.7E-08	3.8E-08	3.8E-08	3.8E-08	3.8E-08	3.8E-08	3.8E-08
Remainder	2.0E-08	4.7E-08	8.1E-08	8.8E-08	8.8E-08	8.8E-08	8.8E-08	8.8E-08	8.8E-08
Effective Dose	9.5E-07	6.7E-06	1.4E-05	1.5E-05	1.5E-05	1.5E-05	1.5E-05	1.5E-05	1.5E-05

Table 8: tissue equivalent dose of the 8th worker of El-Hussein hospital

The time dependence of the organ absorbed dose after acute inhalation of I-131 is shown in Fig. 3.

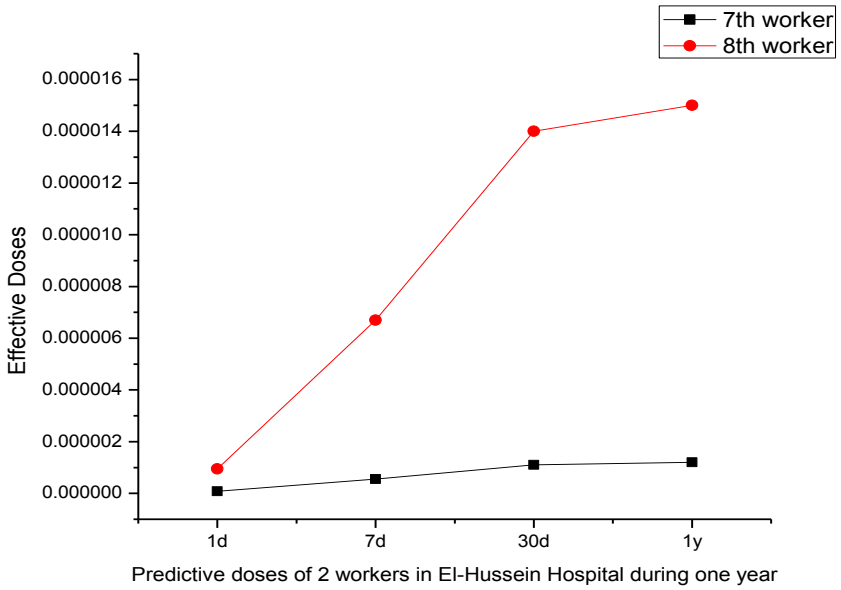


Figure 3: The predictive effective doses in one year of various body organs of 2 workers of El_Hussein hospital.

From the above figure, the 8th worker has received higher doses than the 7th worker. The highest organ absorbed doses are in the bladder wall (5.0E-07 Sv), ET Airways (1.3E-06 Sv), lungs (5.0E-07 Sv) and thyroid (2.7E-04 Sv), after an acute inhalation of I-131 at 30 days after incorporation.

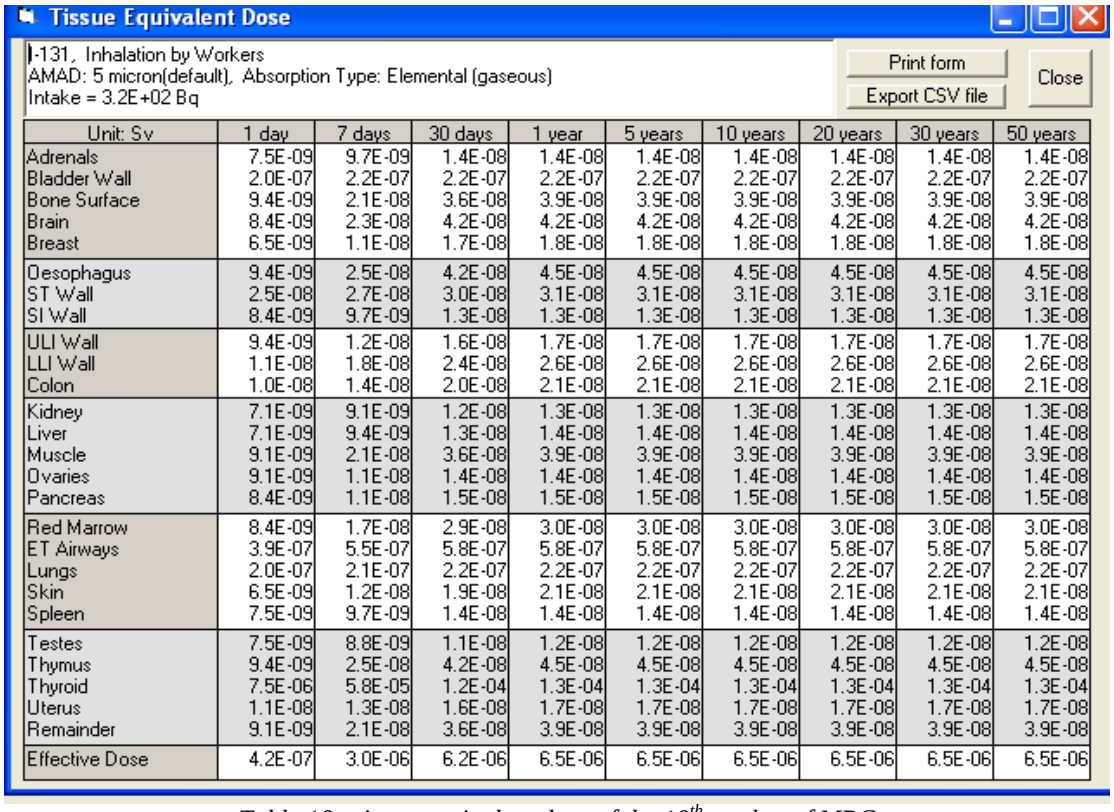
Tissue Equivalent Dose

I-131, Inhalation by Workers
AMAD: 5 micron(default), Absorption Type: Elemental (gaseous)
Intake = 1.2E+03 Bq

Print form | Export CSV file | Close

Unit: Sv	1 day	7 days	30 days	1 year	5 years	10 years	20 years	30 years	50 years
Adrenals	2.7E-08	3.5E-08	4.9E-08	5.1E-08	5.1E-08	5.1E-08	5.1E-08	5.1E-08	5.1E-08
Bladder Wall	7.1E-07	7.8E-07	7.9E-07	8.1E-07	8.1E-07	8.1E-07	8.1E-07	8.1E-07	8.1E-07
Bone Surface	3.4E-08	7.5E-08	1.3E-07	1.4E-07	1.4E-07	1.4E-07	1.4E-07	1.4E-07	1.4E-07
Brain	3.0E-08	8.3E-08	1.5E-07	1.5E-07	1.5E-07	1.5E-07	1.5E-07	1.5E-07	1.5E-07
Breast	2.3E-08	3.9E-08	6.1E-08	6.4E-08	6.4E-08	6.4E-08	6.4E-08	6.4E-08	6.4E-08
Oesophagus	3.4E-08	8.9E-08	1.5E-07	1.6E-07	1.6E-07	1.6E-07	1.6E-07	1.6E-07	1.6E-07
ST Wall	8.9E-08	9.6E-08	1.1E-07	1.1E-07	1.1E-07	1.1E-07	1.1E-07	1.1E-07	1.1E-07
SI Wall	3.0E-08	3.5E-08	4.6E-08	4.8E-08	4.8E-08	4.8E-08	4.8E-08	4.8E-08	4.8E-08
ULI Wall	3.4E-08	4.2E-08	5.8E-08	6.2E-08	6.2E-08	6.2E-08	6.2E-08	6.2E-08	6.2E-08
LLI Wall	4.1E-08	6.3E-08	8.8E-08	9.3E-08	9.3E-08	9.3E-08	9.3E-08	9.3E-08	9.3E-08
Colon	3.7E-08	5.1E-08	7.1E-08	7.6E-08	7.6E-08	7.6E-08	7.6E-08	7.6E-08	7.6E-08
Kidney	2.6E-08	3.3E-08	4.4E-08	4.7E-08	4.7E-08	4.7E-08	4.7E-08	4.7E-08	4.7E-08
Liver	2.6E-08	3.4E-08	4.8E-08	5.1E-08	5.1E-08	5.1E-08	5.1E-08	5.1E-08	5.1E-08
Muscle	3.3E-08	7.5E-08	1.3E-07	1.4E-07	1.4E-07	1.4E-07	1.4E-07	1.4E-07	1.4E-07
Ovaries	3.3E-08	3.9E-08	4.9E-08	5.1E-08	5.1E-08	5.1E-08	5.1E-08	5.1E-08	5.1E-08
Pancreas	3.0E-08	3.9E-08	5.3E-08	5.5E-08	5.5E-08	5.5E-08	5.5E-08	5.5E-08	5.5E-08
Red Marrow	3.0E-08	6.2E-08	1.0E-07	1.1E-07	1.1E-07	1.1E-07	1.1E-07	1.1E-07	1.1E-07
ET Airways	1.4E-06	2.0E-06	2.1E-06	2.1E-06	2.1E-06	2.1E-06	2.1E-06	2.1E-06	2.1E-06
Lungs	7.2E-07	7.6E-07	7.9E-07	8.1E-07	8.1E-07	8.1E-07	8.1E-07	8.1E-07	8.1E-07
Skin	2.3E-08	4.3E-08	7.0E-08	7.5E-08	7.5E-08	7.5E-08	7.5E-08	7.5E-08	7.5E-08
Spleen	2.7E-08	3.5E-08	4.9E-08	5.1E-08	5.1E-08	5.1E-08	5.1E-08	5.1E-08	5.1E-08
Testes	2.7E-08	3.2E-08	4.1E-08	4.2E-08	4.2E-08	4.2E-08	4.2E-08	4.2E-08	4.2E-08
Thymus	3.4E-08	8.9E-08	1.5E-07	1.6E-07	1.6E-07	1.6E-07	1.6E-07	1.6E-07	1.6E-07
Thyroid	2.7E-05	2.1E-04	4.3E-04	4.6E-04	4.6E-04	4.6E-04	4.6E-04	4.6E-04	4.6E-04
Uterus	4.1E-08	4.8E-08	5.8E-08	6.1E-08	6.1E-08	6.1E-08	6.1E-08	6.1E-08	6.1E-08
Remainder	3.3E-08	7.5E-08	1.3E-07	1.4E-07	1.4E-07	1.4E-07	1.4E-07	1.4E-07	1.4E-07
Effective Dose	1.5E-06	1.1E-05	2.2E-05	2.3E-05	2.3E-05	2.3E-05	2.3E-05	2.3E-05	2.3E-05

Table 9: tissue equivalent dose of the 9th worker of MRC



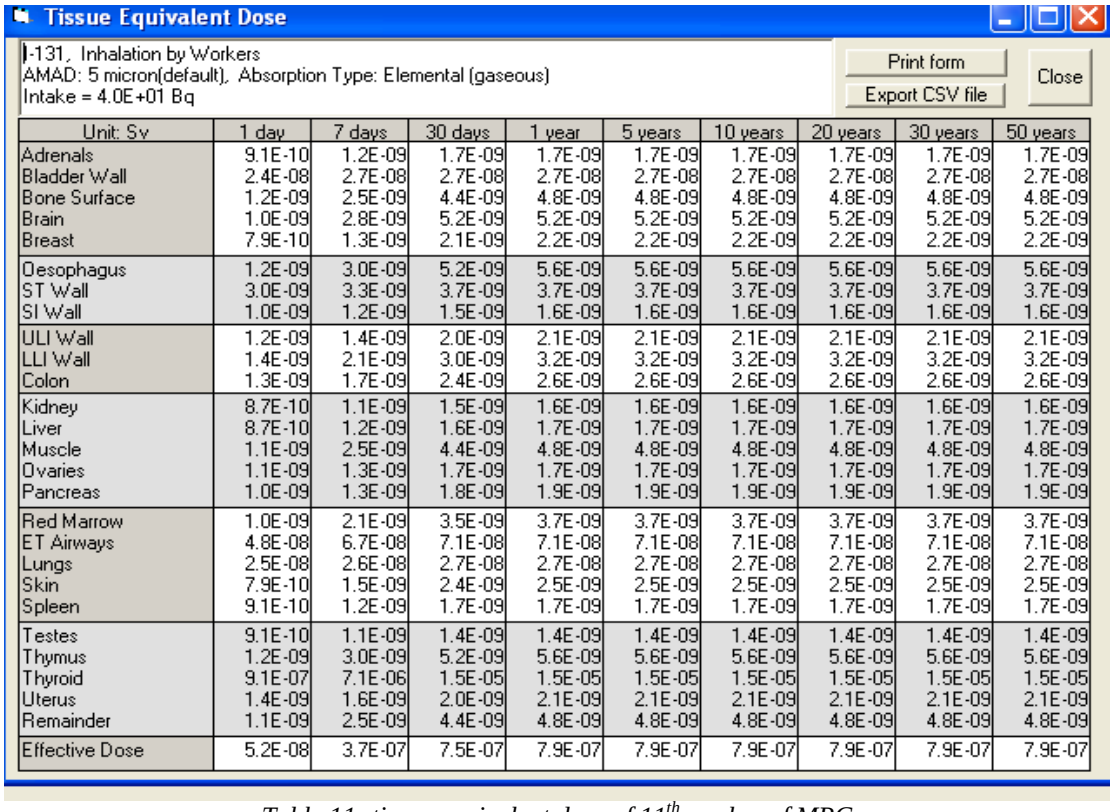
Tissue Equivalent Dose

I-131, Inhalation by Workers
AMAD: 5 micron(default), Absorption Type: Elemental (gaseous)
Intake = 3.2E+02 Bq

Print form | Export CSV file | Close

Unit: Sv	1 day	7 days	30 days	1 year	5 years	10 years	20 years	30 years	50 years
Adrenals	7.5E-09	9.7E-09	1.4E-08	1.4E-08	1.4E-08	1.4E-08	1.4E-08	1.4E-08	1.4E-08
Bladder Wall	2.0E-07	2.2E-07	2.2E-07	2.2E-07	2.2E-07	2.2E-07	2.2E-07	2.2E-07	2.2E-07
Bone Surface	9.4E-09	2.1E-08	3.6E-08	3.9E-08	3.9E-08	3.9E-08	3.9E-08	3.9E-08	3.9E-08
Brain	8.4E-09	2.3E-08	4.2E-08	4.2E-08	4.2E-08	4.2E-08	4.2E-08	4.2E-08	4.2E-08
Breast	6.5E-09	1.1E-08	1.7E-08	1.8E-08	1.8E-08	1.8E-08	1.8E-08	1.8E-08	1.8E-08
Oesophagus	9.4E-09	2.5E-08	4.2E-08	4.5E-08	4.5E-08	4.5E-08	4.5E-08	4.5E-08	4.5E-08
ST Wall	2.5E-08	2.7E-08	3.0E-08	3.1E-08	3.1E-08	3.1E-08	3.1E-08	3.1E-08	3.1E-08
SI Wall	8.4E-09	9.7E-09	1.3E-08	1.3E-08	1.3E-08	1.3E-08	1.3E-08	1.3E-08	1.3E-08
ULI Wall	9.4E-09	1.2E-08	1.6E-08	1.7E-08	1.7E-08	1.7E-08	1.7E-08	1.7E-08	1.7E-08
LLI Wall	1.1E-08	1.8E-08	2.4E-08	2.6E-08	2.6E-08	2.6E-08	2.6E-08	2.6E-08	2.6E-08
Colon	1.0E-08	1.4E-08	2.0E-08	2.1E-08	2.1E-08	2.1E-08	2.1E-08	2.1E-08	2.1E-08
Kidney	7.1E-09	9.1E-09	1.2E-08	1.3E-08	1.3E-08	1.3E-08	1.3E-08	1.3E-08	1.3E-08
Liver	7.1E-09	9.4E-09	1.3E-08	1.4E-08	1.4E-08	1.4E-08	1.4E-08	1.4E-08	1.4E-08
Muscle	9.1E-09	2.1E-08	3.6E-08	3.9E-08	3.9E-08	3.9E-08	3.9E-08	3.9E-08	3.9E-08
Ovaries	9.1E-09	1.1E-08	1.4E-08	1.4E-08	1.4E-08	1.4E-08	1.4E-08	1.4E-08	1.4E-08
Pancreas	8.4E-09	1.1E-08	1.5E-08	1.5E-08	1.5E-08	1.5E-08	1.5E-08	1.5E-08	1.5E-08
Red Marrow	8.4E-09	1.7E-08	2.9E-08	3.0E-08	3.0E-08	3.0E-08	3.0E-08	3.0E-08	3.0E-08
ET Airways	3.9E-07	5.5E-07	5.8E-07	5.8E-07	5.8E-07	5.8E-07	5.8E-07	5.8E-07	5.8E-07
Lungs	2.0E-07	2.1E-07	2.2E-07	2.2E-07	2.2E-07	2.2E-07	2.2E-07	2.2E-07	2.2E-07
Skin	6.5E-09	1.2E-08	1.9E-08	2.1E-08	2.1E-08	2.1E-08	2.1E-08	2.1E-08	2.1E-08
Spleen	7.5E-09	9.7E-09	1.4E-08	1.4E-08	1.4E-08	1.4E-08	1.4E-08	1.4E-08	1.4E-08
Testes	7.5E-09	8.8E-09	1.1E-08	1.2E-08	1.2E-08	1.2E-08	1.2E-08	1.2E-08	1.2E-08
Thymus	9.4E-09	2.5E-08	4.2E-08	4.5E-08	4.5E-08	4.5E-08	4.5E-08	4.5E-08	4.5E-08
Thyroid	7.5E-06	5.8E-05	1.2E-04	1.3E-04	1.3E-04	1.3E-04	1.3E-04	1.3E-04	1.3E-04
Uterus	1.1E-08	1.3E-08	1.6E-08	1.7E-08	1.7E-08	1.7E-08	1.7E-08	1.7E-08	1.7E-08
Remainder	9.1E-09	2.1E-08	3.6E-08	3.9E-08	3.9E-08	3.9E-08	3.9E-08	3.9E-08	3.9E-08
Effective Dose	4.2E-07	3.0E-06	6.2E-06	6.5E-06	6.5E-06	6.5E-06	6.5E-06	6.5E-06	6.5E-06

Table 10: tissue equivalent dose of the 10th worker of MRC



Tissue Equivalent Dose

I-131, Inhalation by Workers
AMAD: 5 micron(default), Absorption Type: Elemental (gaseous)
Intake = 4.0E+01 Bq

Print form | Export CSV file | Close

Unit: Sv	1 day	7 days	30 days	1 year	5 years	10 years	20 years	30 years	50 years
Adrenals	9.1E-10	1.2E-09	1.7E-09	1.7E-09	1.7E-09	1.7E-09	1.7E-09	1.7E-09	1.7E-09
Bladder Wall	2.4E-08	2.7E-08	2.7E-08	2.7E-08	2.7E-08	2.7E-08	2.7E-08	2.7E-08	2.7E-08
Bone Surface	1.2E-09	2.5E-09	4.4E-09	4.8E-09	4.8E-09	4.8E-09	4.8E-09	4.8E-09	4.8E-09
Brain	1.0E-09	2.8E-09	5.2E-09	5.2E-09	5.2E-09	5.2E-09	5.2E-09	5.2E-09	5.2E-09
Breast	7.9E-10	1.3E-09	2.1E-09	2.2E-09	2.2E-09	2.2E-09	2.2E-09	2.2E-09	2.2E-09
Oesophagus	1.2E-09	3.0E-09	5.2E-09	5.6E-09	5.6E-09	5.6E-09	5.6E-09	5.6E-09	5.6E-09
ST Wall	3.0E-09	3.3E-09	3.7E-09	3.7E-09	3.7E-09	3.7E-09	3.7E-09	3.7E-09	3.7E-09
SI Wall	1.0E-09	1.2E-09	1.5E-09	1.6E-09	1.6E-09	1.6E-09	1.6E-09	1.6E-09	1.6E-09
ULI Wall	1.2E-09	1.4E-09	2.0E-09	2.1E-09	2.1E-09	2.1E-09	2.1E-09	2.1E-09	2.1E-09
LLI Wall	1.4E-09	2.1E-09	3.0E-09	3.2E-09	3.2E-09	3.2E-09	3.2E-09	3.2E-09	3.2E-09
Colon	1.3E-09	1.7E-09	2.4E-09	2.6E-09	2.6E-09	2.6E-09	2.6E-09	2.6E-09	2.6E-09
Kidney	8.7E-10	1.1E-09	1.5E-09	1.6E-09	1.6E-09	1.6E-09	1.6E-09	1.6E-09	1.6E-09
Liver	8.7E-10	1.2E-09	1.6E-09	1.7E-09	1.7E-09	1.7E-09	1.7E-09	1.7E-09	1.7E-09
Muscle	1.1E-09	2.5E-09	4.4E-09	4.8E-09	4.8E-09	4.8E-09	4.8E-09	4.8E-09	4.8E-09
Ovaries	1.1E-09	1.3E-09	1.7E-09	1.7E-09	1.7E-09	1.7E-09	1.7E-09	1.7E-09	1.7E-09
Pancreas	1.0E-09	1.3E-09	1.8E-09	1.9E-09	1.9E-09	1.9E-09	1.9E-09	1.9E-09	1.9E-09
Red Marrow	1.0E-09	2.1E-09	3.5E-09	3.7E-09	3.7E-09	3.7E-09	3.7E-09	3.7E-09	3.7E-09
ET Airways	4.8E-08	6.7E-08	7.1E-08	7.1E-08	7.1E-08	7.1E-08	7.1E-08	7.1E-08	7.1E-08
Lungs	2.5E-08	2.6E-08	2.7E-08	2.7E-08	2.7E-08	2.7E-08	2.7E-08	2.7E-08	2.7E-08
Skin	7.9E-10	1.5E-09	2.4E-09	2.5E-09	2.5E-09	2.5E-09	2.5E-09	2.5E-09	2.5E-09
Spleen	9.1E-10	1.2E-09	1.7E-09	1.7E-09	1.7E-09	1.7E-09	1.7E-09	1.7E-09	1.7E-09
Testes	9.1E-10	1.1E-09	1.4E-09	1.4E-09	1.4E-09	1.4E-09	1.4E-09	1.4E-09	1.4E-09
Thymus	1.2E-09	3.0E-09	5.2E-09	5.6E-09	5.6E-09	5.6E-09	5.6E-09	5.6E-09	5.6E-09
Thyroid	9.1E-07	7.1E-06	1.5E-05	1.5E-05	1.5E-05	1.5E-05	1.5E-05	1.5E-05	1.5E-05
Uterus	1.4E-09	1.6E-09	2.0E-09	2.1E-09	2.1E-09	2.1E-09	2.1E-09	2.1E-09	2.1E-09
Remainder	1.1E-09	2.5E-09	4.4E-09	4.8E-09	4.8E-09	4.8E-09	4.8E-09	4.8E-09	4.8E-09
Effective Dose	5.2E-08	3.7E-07	7.5E-07	7.9E-07	7.9E-07	7.9E-07	7.9E-07	7.9E-07	7.9E-07

Table 11: tissue equivalent dose of 11th worker of MRC

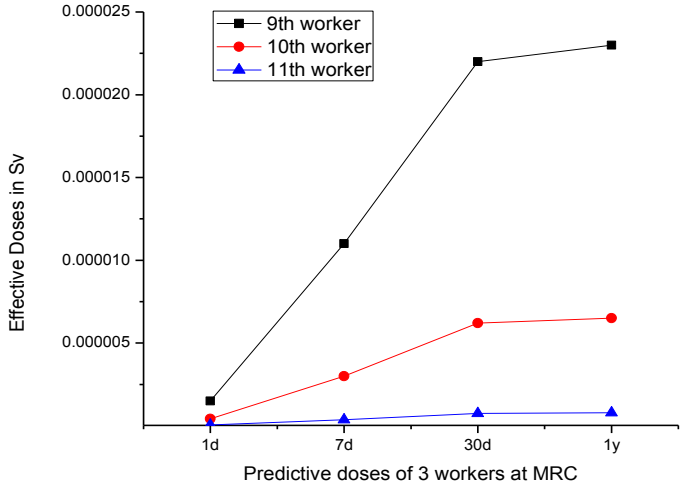


Figure 4: Predictive effective doses of 3 workers at MRC in one year

Again, from figure 4, great variations in organs doses absorbed by the 3 workers of Misr Radiological Center have been observed. The highest dose goes to worker no. 9, followed by worker no. 10 and finally the lowest dose goes to the 11th worker.

In this work, the time-dependent organ equivalent dose and effective dose after an acute intake of ^{131}I are calculated by applying the model of Mondal 3.0. Moreover, the 24-h-urine samples of eleven persons who were possibly contaminated were applied. From the fact that the measured results were within the natural level of the excretion rate of ^{131}I, it is concluded that no additional ^{131}I intake can be detected. Thus, no excess health effects related to the toxicity of ^{131}I are expected for those monitored subjects besides the background exposure to the natural level of ^{131}I.

4. CONCLUSION

In this paper, the basic structure of MONDAL 3.0 was presented in addition to an example of its application to practical use. The effective dose equivalent is a quantity which may be suitable for estimating risks of different procedures in nuclear medicine, radiology, and other applications involving ionizing radiation. The software has been tested in the frame of national exercise. Tables from 1-11 shows the results of Mondal 3.0 software in terms of effective dose of the 11 workers under investigation.

This small study looked at the questions of 1) how much internal exposure a worker' organs receive, on average, while preparing and administering a diagnostic dose of ^{131}I. 2) Does the worker need routine monitoring?

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