INDAC: A Software Tool to Estimate Effective Doses Following Intakes of Radionuclides

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Abstract. INDAC is a computer application developed by Iberdrola Ingeniería y Consultoría (Iberinco), that allows the user to estimate doses following an intake of radionuclides (inhalation or ingestion). The code uses the methodology of International Commission on Radiological Protection (ICRP) from publication nº 78, that brings together the recommendations of ICRP-60 and the respiratory tract model of ICRP-66. This model has been adopted by the European Union in its recently approved Directive 96/29/EURATOM of 13 May 1996. This Directive is compulsory for all member states before the year 2000. For this reason, the Spanish Nuclear Industry, represented by UNESA, and the regulatory body, the Spanish Nuclear Safety Council (CSN), started a R&D project to develop a computer application that could resolve the new model and then estimates internal doses. The development of such computer application, now called INDAC, was awarded to IBERINCO, a nuclear engineering company. INDAC is the software that the Spanish Nuclear Safety Council (CSN) has approved in order to estimate internal dose in all the Spanish Nuclear Powers Plants

1. Introduction

INDAC (Windows 9X/NT/2000/XP) is a users-friendly application that allows the estimates of internal doses to workers and to the public from acute or chronic intakes, either from inhalation or ingestion. In each case, the program calculates and shows the retention and excretions functions (graphical or numerical), the equivalent dose to each organ and the committed effective dose. The program includes a graphic interface to help the user with the interpretation of dose and retention/excretion functions. INDAC resolve the complete model (Respiratory Tract Model, GastroIntestinal Model and Systemic model) with or without recycling.

INDAC has two operating modes: automatic and manual.

- The AUTOMATIC operating mode may be used only when the application is connected to a PC associated with a Body Radioactivity Counter. The automatic mode has been designed to allow the INDAC application to maintain a "dialogue" with the acquisition and analysis software currently installed in the WBC’s of the Spanish nuclear power plants and dosimetry centres. Following the acquisition and analysis of the spectrum, this software generates a file with the extension .ANS, which contains information on the measurement (personal data, measurement number...) and on the activity measured (in Becquerels) for each isotope detected, along with auxiliary data such as the associated error or LID (or AMD in the case of bioelimination measures). If the dose estimate mode according to ICRP-66 has been selected in the WBC application, then immediately after generating the .ANS file, the INDAC application will process it in order to obtain the dose in accordance with the new models (from ICRP-66 to ICRP-78) and will return control to the acquisition and analysis software for the latter to print out the dose...
report. Consequently, in the automatic operating mode the user will not have to enter any of the INDAC application screens, since all the calculations are performed internally.

- The MANUAL operating mode starts up when the "indac.exe" file is executed, either from Windows Explorer or by clicking on the corresponding icon on the initial Windows screen. This shows the first screen with the initial application menu. In this operating mode the user will have to input the data for performance of the dose calculation.

2. OPERATIONAL METHODOLOGY

2.1. HOW INDAC ESTIMATE DOSE?

Any user of the INDAC application may carry out dose calculations by inputting the WBC or Biossay measurement data from the initial menu of the application, without the need for any password. In this case, all the calculations will be performed using standard input parameter values, as defined in publications 66 and subsequent publications of the International Commission for Radiological Protection (ICRP).

![FIG. 1: Main screen](image)

If no password is used, access to the menus shown as being disabled (grey) on start-up of the application will be restricted. This means, for example, that the aforementioned default values may not be modified, and that there will be no access to the general measurements history file or to the cases under study opened to determine dose on the basis of a set of measures.

By inputting a password it is possible to activate the menus shown as being disabled on start-up of the application. The way in which the password is to be input will be described below.

In this way the user will have access to the options “Measurement database” and “Investigations” on the “File” menu. Once one of the measures has been selected from the general measurements history file and has been associated with an investigation, or if an investigation has been opened directly, all the menus of the application will be activated and any of the parameters used to calculate the dose may be modified. Furthermore, there will be access to the graphic module of the application.
It should be pointed out that even when the user has input the correct password and has opened a dose estimate, certain of the options on the menus will remain deactivated, if they were not applicable in the case in question. For example, if ingestion has been selected as the incorporation path, then the option of seeing the model for activity elimination in the respiratory tract will be deactivated. In other words, only the options applicable to the case under study selected will be activated. Similarly, access to the programme options relating to isotope selection will show only those isotopes (from among the complete list of 25 contained in INDAC) that have been detected in the measures associated with the case under study.

Another possibility for the users to access to the different menus of the application is to introduce the password and don't select any investigation. So, the users can see the different menus with all the list of radionuclides: H-3 (H2O), Cr-51, Mn-54, Fe-59, Co-58, Co-60, Zn-65, Sr-89, Sr-90, Zr-95, Ru-103, Ru-106, Ag-110m, Sb-124, Sb-125, I-131, Cs-134, Cs-137, Ba-140, Ce-141, Ce-144, U-234, U-235, U-238, Pu-239, Pu-240, Pu-241, Am-241.

In order to estimate the dose, the users have to introduce the next information:

- Define Time of Intake
- Intake pathway: Ingestion or Inhalation
- Personal Data (Last name, age, sex, …)
- Measurement date and number identification
- Nuclide and activity (Becquerels)
- Absorption type (F/M/S) for inhalation or fI for ingestion. Not all the isotopes have all the types of absorption available to them, since the International Commission on Radiological Protection has determined that certain nuclides are absorbed in the blood only at a given rate. For certain nuclides the user will not be able to adopt types of absorption not contemplated by the Commission in its publication number 68. Furthermore, the INDAC application has some types of absorption stored by default for each nuclide, such that if the user skips the “Absorption type” column and goes on to another, the field will automatically be filled in with S, M or F.

Once all the data have been input, INDAC is able estimate the effective dose (mSv) and the equivalent dose (mSv), and a dosimetry report is generated.

2.2. ADVANTAGED OPTIONS

When the user introduces the password, several options are available:

2.2.3. Type of Intake
• “Acute”: the Intake of the activity is considered to have occurred instantaneously, or over such a short period of time that it may be considered to have been an isolated case.

• “Chronic”: the user is determining that the incorporation has occurred over a prolonged period of time (“prolonged” being understood as a period that is not negligible with respect to the dose integration period). If the user simply selects “Chronic”, the interval of Intake taken will be the entire dose integration interval (normally 50 years). Nevertheless, the user may perform a more realistic assumption and define the interval of incorporation by clicking on the “Define interval” button.

2.2.3. Group of people and Morphology

The “Group of people” option will allow the user to select the age group to which the individual under study belongs. If this population group is not changed, then by default the individual in question will be male and belong to the “Worker” category.

Each of the population groups will be defined in accordance with the standard model defined in ICRP-23.

The user can modify the respiratory parameters, depending on the age group selected, for each type of physical activity: Sleep, Rest, Light exercise, Heavy exercise.

2.2.4. Physical Activity

The “Level of activity” screen will show by default the standard time values used in different exercises or physical activities, as defined by the International Commission for Radiological Protection.

There are four types of physical activity defined by the Commission for any individual: Sleep, Rest (sitting), Light exercise and Heavy exercise.

These level of activity parameters serve for the case of inhalation of an aerosol, since their modification determines a change in the rate of pulmonary ventilation and in other respiratory parameters, this ultimately implying a different distribution of the activity inhaled in each of the regions of the respiratory tract. The way in which the initial distribution of particles changes in the different regions of the respiratory tract may be appreciated by clicking on the “Show regional deposition...” button.
The “Regional deposition” screen shows the fractions of activity deposited initially in the different regions of the respiratory tract, in percentage terms. These regions are defined in ICRP-66, and anatomically correspond to the different organs of the respiratory tract:

ET1: nose and anterior nasal passages.
ET2: posterior nasal passages, pharynx and larynx.
BB: trachea, main bronchia (first fork in the respiratory passages, or 1st generation of the pulmonary system) and bronchia (up to the 8th generation of the pulmonary system).
bb: bronchioles (approx. from the 9th to the 15th generation of the pulmonary system).
AI: alveoli (from the 16th to the last generation of the pulmonary system, the latter normally being the 18th-20th).

2.2.3. Particle Size

Initially the default value will always be displayed, this being 5 micra in the case of professionally exposed workers. The user may change the size of the particle inhaled to a different value (in the range 0.0001 to 100 micra), deleting the value of “5.00E+00” and inputting a new value.

2.2.4. Models

This functionality consists of viewing the scheme of compartments applicable to each isotope selected and incorporation path. As a result, only the corresponding options will be activated in each case. For example, in the case of incorporation by ingestion, the “Respiratory Tract model” option would be deactivated since it is not applicable. The models than the users could see are Respiratory Tract Model, GastroIntestinal Tract Model and Systemic Model.
By clicking twice in the graphical representation of an activity transfer, a new screen appears with the names of the origin and destination compartments for activity transfer. The "Current value (1/d)" box shows the value (in d⁻¹) of this transfer rate currently stored in the database.

2.2.3. Retention and excretion functions

The users can consult the values of retention and excretion functions for any of the radionuclides included in the INDAC Data Base. The values are shown in numerical format or in graphical format.