Skin Dose Assessments using VARSKIN

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Abstract

This paper describes the output of a project to identify a suitable method of compliance with the requirements of IRR99 Regulation 23 “Dosimetry for Accidents”. The assessment of skin doses from contaminated clothing has historically been provided as a service by the Sellafield ADS using Lithium Fluoride (LiF) powder thermo luminescent dosimetry. This is not a legal dosemeter and any dose assessment goes on the dose record as an estimate. There has been little demand for this service for several years, therefore the decision was made to discontinue the LiF process at Sellafield and identify an alternative method for skin dose assessment.

There are several methods of carrying out skin dose assessments. This paper describes one such method and its potential for use on the Sellafield site; the computer code VARSKIN. VARSKIN is a computer code which calculates skin doses; taking into account the isotopes present, source geometry, clothing attenuation and exposure time in order to estimate the dose to the individual. This work was originally carried out using VARSKIN 3; however the paper has been updated to reflect the fact that VARSKIN 4 is now available.

This paper describes how the software can be used in a practical context to assess skin doses received under accident situations, and therefore to determine the further action necessary to comply with IRR99 such as notification of overexposure (if applicable). It details the necessary input information required in order to run a calculation, and the appropriate questions to ask of a contaminated individual. It includes a step-by-step approach towards carrying out a contaminated clothing dose assessment, from the initial event through to identifying the appropriate reporting mechanism, and it explains how to interpret the VARSKIN output into an equivalent dose in mSv.

Key Words

VARSKIN, skin, dose, dosimetry, contamination

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Section 1: Skin Dose Assessments – General

1.A Introduction

The potential for contamination of the skin or clothing should be considered at the risk assessment stage of any work with ionising radiation and appropriate control measures should be in place to control that risk, utilising the hierarchy of control measures as appropriate and only using personal protective equipment as a last line of defence. However, contamination of skin or clothing may occur due to an accident or a breakdown of controls and may result in an un-assessed dose to the skin.

The Personal Dosimetry Management, Nuclear Industry Good Practice Guide [1] recommends skin dose assessments by practical measurement; however this is not always practicable as skin contamination tends to be washed off as soon as it is discovered. Where activity remains on the skin or where the contamination is on clothing which can be removed a thermo luminescent dosemeter (TLD) can be used to measure the dose from the contamination over a fixed period of time and hence assess the dose to the individual. However, where practical methods are not possible the good practice guide lists several methods for the theoretical assessment of skin dose.

This paper describes the methodology for using one of these techniques; the computer code VARSKIN [2].

1.B Statutory Requirements Relating to Skin Dose

Schedule 4 'Dose Limits' of the Ionising Radiation Regulations 1999 (IRR99) [3] contains the following dose limits for equivalent dose to the skin:

Regulation 11 'Dose Limitation'
For employees of 18 years of age or above:
Skin dose limit of 500 mSv in a calendar year, averaged over any 1cm^2 regardless of the area exposed.
For trainees aged under 18 years
Skin dose limit of 150 mSv in a calendar year, averaged over any 1cm^2 regardless of the area exposed.

Regulation 23 'Dosimetry for Accidents'
"(1) Where any accident or other occurrence takes place which is likely to result in a person receiving an effective dose of ionising radiation exceeding 6 mSv or an equivalent dose greater than three-tenths of any relevant dose limit, the employer shall:
…Arrange for the dose to be assessed by an appropriate means as soon as possible, having regard to the advice or the radiation protection advisor (RPA)."

Skin doses are not routinely assessed at Sellafield by use of a dosemeter. In the event of an accident where regulation 23 applies, the guidance in IRR99 states that appropriate means for the assessment of skin dose may include: "*Computation of dose from measured dose rates or contamination levels together with a knowledge of exposure times in the area and distance* *from the place of measurement, depending on the advice from the RPA"* [3], the use of VARSKIN is in accordance with this.

1.C Biological Effects of Radiation on the Skin

The effects of radiation on skin are deterministic, i.e. there is a demonstrable threshold dose for clinical damage, and beyond this threshold the severity of the effect increases with dose. Below the threshold no effects are observed. Deterministic effects only follow exposures to high doses, such as in accident situations, doses under normal working conditions should be controlled far below the threshold dose.

Radiation causes damage to cells within the human body and those parts of the body with a high turnover of cells, such as skin, react more severely than other parts where the turnover is low. Radiation can cause the ionisation of molecules within the cell, or water molecules can be split to form radicals which attack other critical molecules. Radiation can also kill cells outright by damaging membranes, or it can damage the cell nucleus which contains the DNA genetic code arranged on chromosomes. Damage to the chromosomes can prevent cells dividing so that damaged cells cannot be replenished. It can also cause mutations which are passed on to successive generations when the cells divide.

The deterministic effects of radiation on the skin can be manifested by various effects, including:

- Reddening
- Burns
- Necrosis
- Cancer

The types of incidents that might lead to personal contamination, potentially resulting in biological effects on the skin, are listed in section 1D.

1.D Root Causes of Personal Contamination

The following have been identified in Sellafield management investigations as root causes of personal contamination events

- Accidents – e.g. individual collapsing whilst working in a contaminated area
- Failure of the plant – e.g. leaks
- Failure to follow safe system of work
- Inadequate instructions
- Failure of personal protective equipment (PPE) – e.g. gloves torn
- Incorrect use of PPE – e.g. respirators worn when not clean shaven.
- Cross contamination between individuals whilst undressing at barrier
- Inadequate monitoring of plant or personnel
- Inadequate risk perception/complacency

1.E Information Required when Personal Contamination has Occurred

In order to make an adequate assessment of skin dose and to facilitate any follow-up investigation it is essential to obtain as much information as possible about the circumstances surrounding the contamination event. The following questions should be asked:

- Do they have any injuries or open wounds?
- Is the skin intact?
- Whereabouts on their body is the contamination located?

- Is the contamination on the skin or clothing? What types of intervening clothing were worn (if clothing contamination)?
- Where was the individual working? What were they doing?
- What is the source of the contamination? (to help identify fingerprint/isotopic mix)
- When did the contamination event occur?
- What decontamination has already taken place?
- What was the magnitude of the contamination? What instrument was used to measure it? What is its efficiency?

To aid with the investigation it is also worthwhile to freeze the scene as found, and to obtain a sample of the contaminant if possible.

1.F Welfare of the Contaminated Individual

The individual's welfare is also of the utmost importance. In the event of being contaminated an individual might be anxious or stressed, they may be worried about their exposure to ionising radiation or may be concerned with other factors such as what went wrong, or what to say to their family or their line manager about the event, or simply the fact that they are suddenly the focus of attention could be unsettling for an individual. Good practice would be to ask the individual how they are feeling and whether they have any concerns, and to explain the procedure for assessing the skin dose and why it is important that they provide as much information as possible. Any queries they have should be answered factually and contact details should be provided in case they have further questions to ask at a later date. Referrals for counselling could also be made if appropriate.

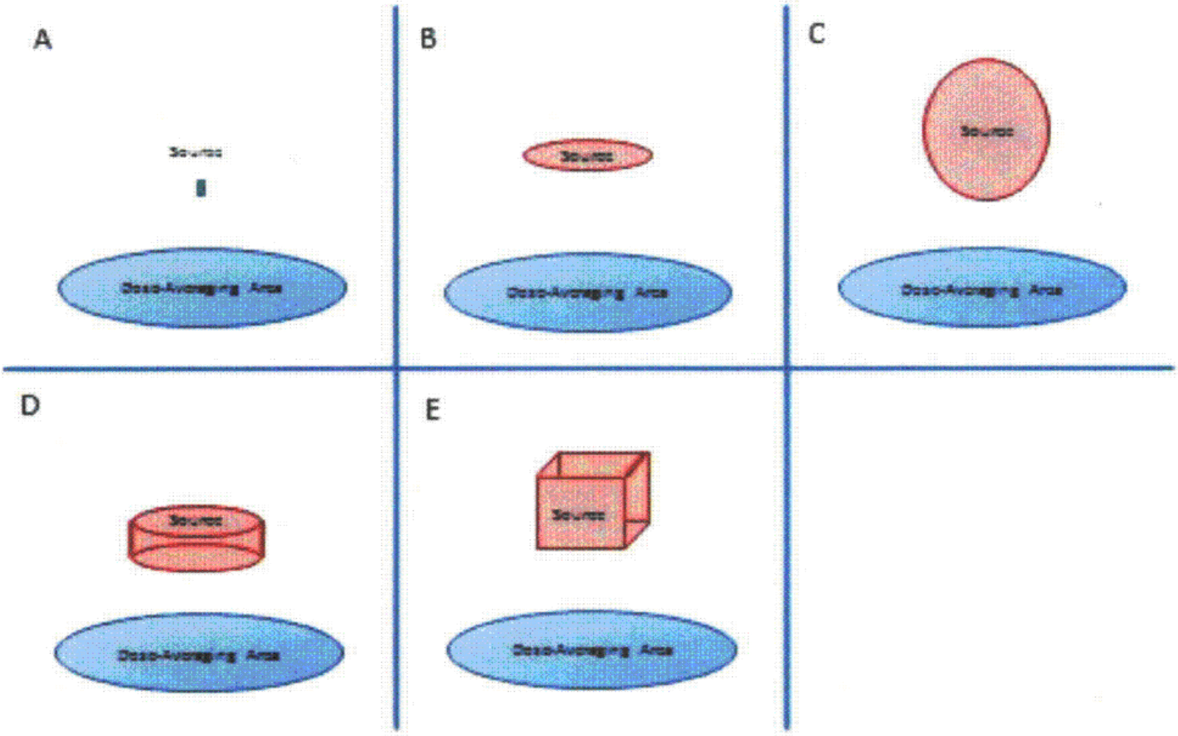
Section 2: VARSKIN dose assessment methodology

2.A Alpha Contamination

If alpha contamination is reported on the skin or clothing, the shallow dose equivalent from alpha radiation may be considered to be negligible. An alpha particle will penetrate tissue to a depth less than the 0.07 mm recommended for practical dose assessments. This depth generally corresponds to the interface between the epidermis and dermis layers of the skin.

2.B Step 1 - Obtain Information:

- Information Required:
    - Duration of exposure
    - Activity
    - Identity of the substance
    - Source geometry [Figure 1]
    - Intervening clothing worn – thickness and density [Figure 2]
- If detailed information not available use pessimistic assumptions e.g.
    - Point source Geometry
    - Sellafield worst-case isotopic mix
    - 40% ^{90}Sr, 40% ^{90}Y, 20% ^{137}Cs
- Or, carry out sampling of substance to accurately identify isotopic mix.



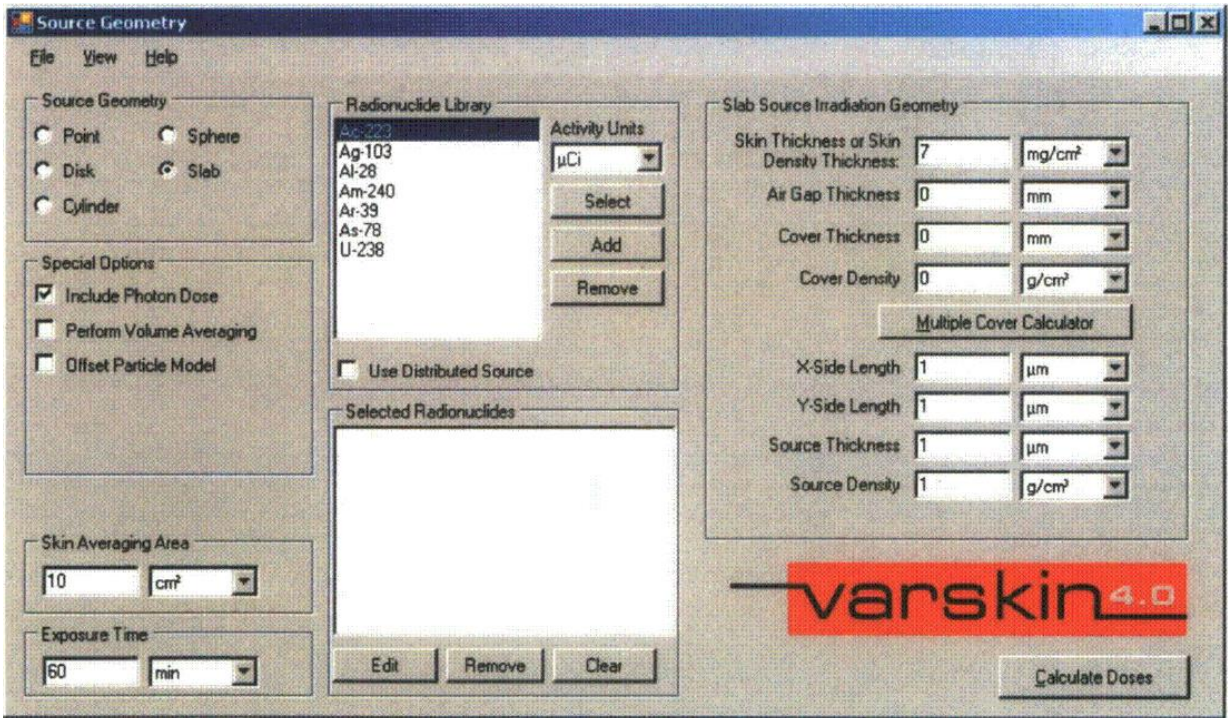
[Figure 1. Schematic representations of source geometries [2]]

A – Point source
B – Disk
C – Sphere
D – Cylinder
E – Slab

Table 2-2. Suggested Values for Cover Thickness and Density		
Material	**Thickness (mm)**	**Density (g/cm^3)**
Lab Coat (Plastic)	0.1	0.036
Lab Coat (Cloth)	0.4	0.9
Cotton Glove Liner	0.3	0.3
Surgeon Glove	0.05	0.9
Outer Glove (Thick)	0.45	1.1
Ribbed Outer Glove	0.55	0.9
Plastic Bootie	0.2	0.6
Rubber Shoe Cover	1.2	1
Coveralls	0.7	0.4

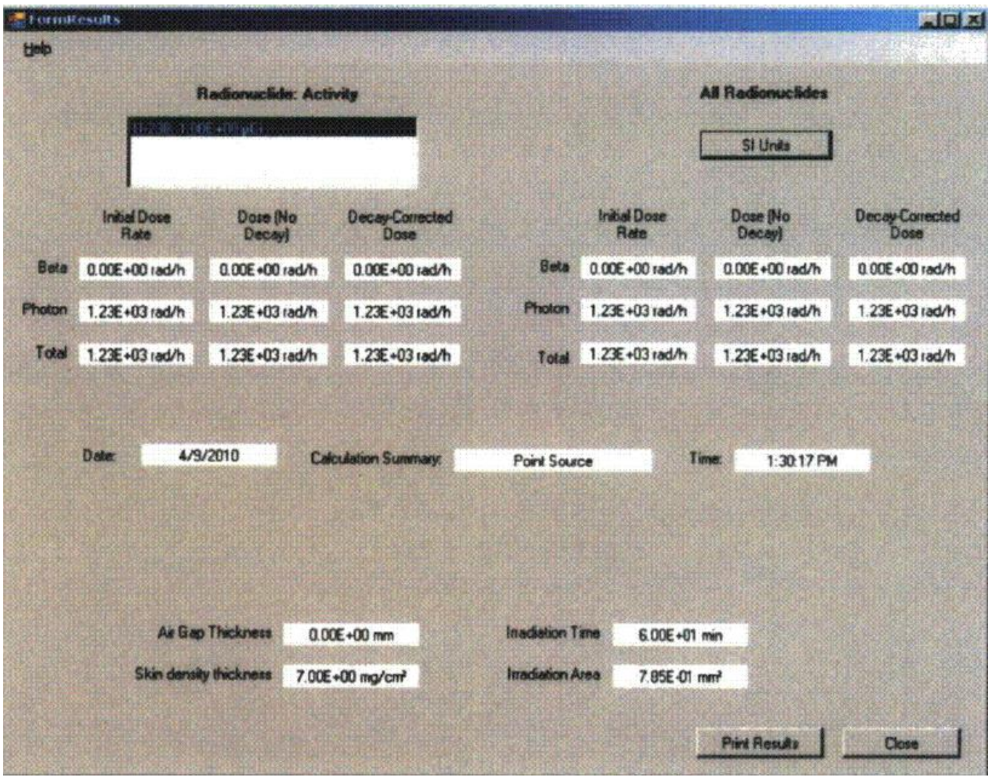
[Figure 2. Typical clothing data [2]]

2.C Step 2 - Input data into VARSKIN and run calculation



[Figure 3. Geometry input screen – slab model shown [2]]

2.D Step 3 - Interpret VARSKIN Results:



[Figure 4. Screen shot of VARSKIN Output]

The output screen summarises the input details. i.e;

- Geometry
- Radionuclides,
- Cover thickness
- Irradiation Time
- Irradiation Area

The output of most interest will usually be the Total Decay-Corrected Dose.
(Where the irradiation time is significantly shorter than the half life(s) this will be the same as the initial dose). The VARSKIN output is the absorbed dose in Grays; this is a measure of the energy deposition in any medium by any type of ionizing radiation. The Gray is defined as the absorption of one Joule of ionizing radiation by one Kilogram (1 J/Kg) of matter.

This needs to be converted into dose equivalent; a measure of the dose to a tissue or organ designed to reflect the amount of harm caused. It is defined as the product of the absorbed dose delivered by a type of radiation averaged over a tissue or organ and the appropriate radiation weighting factor. The unit of equivalent dose is the Sievert (Sv), equal to 1 J/kg.
Dose equivalent (Sv) = Absorbed Dose (Gy) x Q x N

- Q is a quality factor which reflects the ability of a particular type of radiation to cause damage. The Quality factor is dependent on the density of ionization caused by the radiation; a beta particle produces about ten thousand ion pairs per millimetre of track in tissue. For Beta radiation the quality factor is assigned a value of 1.

- N is a modifying factor which might take account of such factors as absorbed dose rate and fractionation. At present ICRP (International Commission on Radiological Protection) has assigned a value of N = 1.

Therefore, for Beta Radiation the absorbed dose in Grays has the same numerical value as the Equivalent dose in Sieverts, i.e.

Dose equivalent (Sv) = Absorbed Dose (Gy) x 1 x 1
Where Q = 1 and N = 1.

Therefore, for Beta radiation: **Dose equivalent (Sv) = Absorbed Dose (Gy).**
I.e. The output dose from VARSKIN in Grays has the same numerical value as the dose equivalent in Sieverts.

2.E Step 4 – Take further action:
The final dose calculated should then be compared against the reporting levels to identify the appropriate action to be taken. In any circumstances the individual should be kept informed of the outcome of the dose assessment and provided with appropriate information about any associated health implications.

Table 1: Action to be taken, by magnitude of skin dose

Skin Dose (averaged over 1cm^2) likely to be:	Action to be taken
> 25 mSv	Sellafield requirement for dose to be assessed and recorded on individual's dose record.
> 150 mSv (three-tenths of dose limit)	As above Legal requirement (IRR99 Reg23) for dose to be assessed and recorded on individual's dose record.
> 500 mSv (dose limit)	As above Overexposure under IRR99 Reg25. Reportable to regulators. Radiation employer and appointed doctor to be informed. Investigation to be carried out.

Section 3: Conclusions

Significant contamination events requiring assessment of skin dose are infrequent at Sellafield therefore any method of skin dose assessment would not be used regularly and would require user familiarisation for each instance of its use. VARSKIN is advantageous as it is simple to use and requires minimal training, a user can become re-familiarised with it in a short space of time and would not need significant refresher training to maintain competency as a VARSKIN user.

VARSKIN operates quickly and it only takes a short period of time to calculate a result. This is beneficial in being able to make a fast assessment of the severity of the exposure, to enable decisions to be made regarding the most appropriate course of action. It also allows for information to be provided to the contaminated individual within a relatively short timescale, to alleviate concern or to provide informed advice about the potential risks to the individual from the contamination. VARSKIN is used in similar institutions to Sellafield and has been widely recommended as a suitable tool for carrying out skin dose assessments.

As a result of the work undertaken for this paper, VARSKIN software is now installed at Sellafield for carrying out skin dose assessments, and RPAs and dosimetry personnel have been trained in its use.

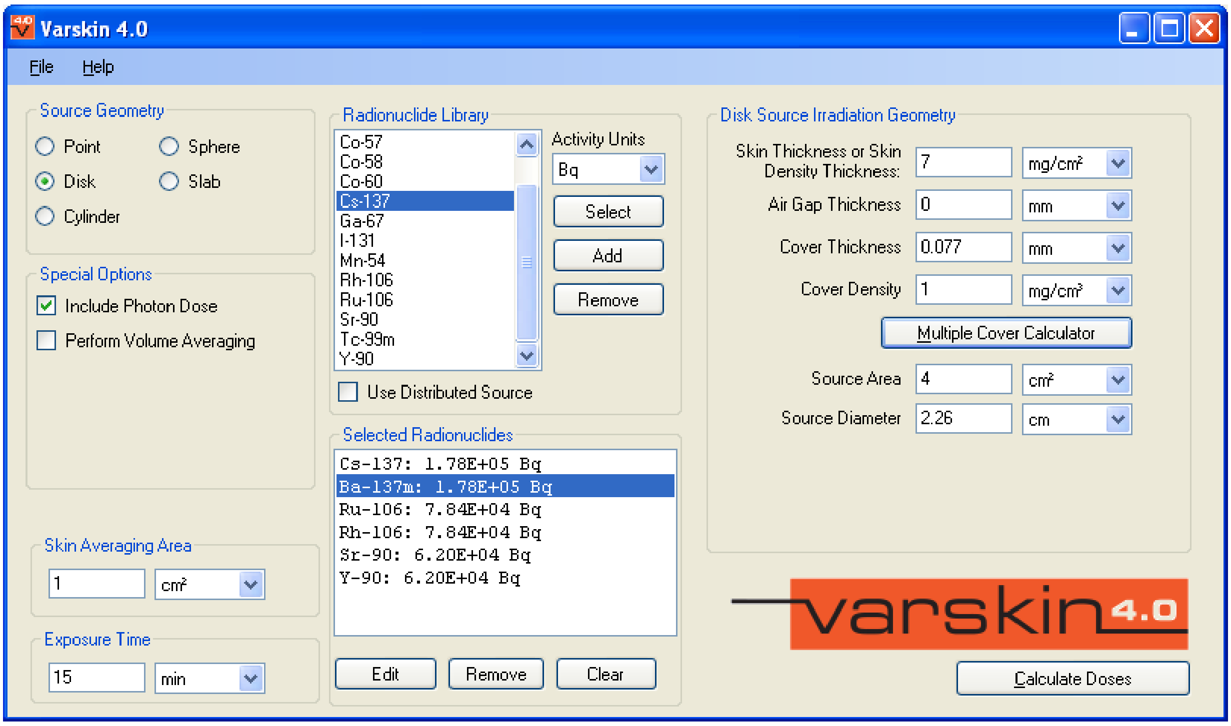
References

[1] IRPCG, 2011, Personal Dosimetry Management - A Nuclear Industry Good Practice Guide
[2] DM Hamby et al, 2011, VARSKIN 4: A Computer code for skin contamination dosimetry, US Nuclear Regulatory Commission
[3] Work with ionising radiation, Ionising Radiation Regulations 1999, Health and Safety Executive

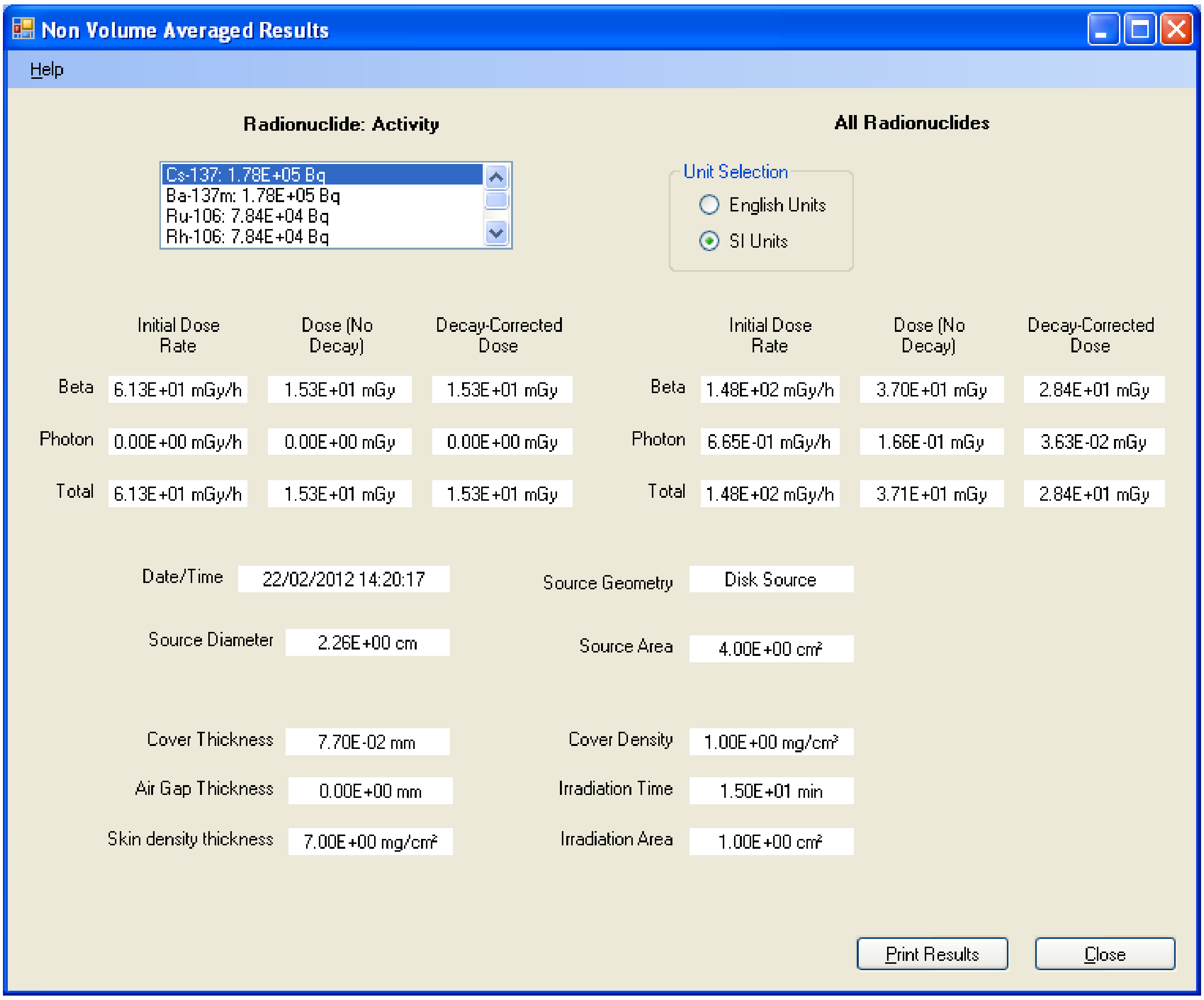
[Appendix 1] Worked Example of a VARSKIN Calculation

- Following a task to carry out decontamination of filter housing, health physics checks of an individual revealed that the right sleeve of their coverall was contaminated to 31000 cps beta by probe. The probe efficiency was 7.5%, therefore activity can be estimated as:
  31000/7.5 *100 = 413333 Bq
- The coverall had been worn for 15 minutes.
- The contamination was assumed to consist of an isotopic mix of 15% ^{90}Sr, 19% ^{106}Ru and 43% ^{137}Cs based on the waste stream of the plant where the event occurred. Daughter isotopes have also been included in the calculation.
- The following assumptions were made:

- There was no air gap between the contaminated coverall and the skin.
- The same skin location was exposed for the duration the contaminated coverall was worn, i.e. no movement of coverall against the skin.
- The contamination on the coverall was averaged over an area of 4 cm^2 (estimate based on witness evidence that supports the contamination being a uniform deposit rather than a single spot). Therefore the disk model was used.
- The coverall has a density thickness of 7.7 mg/cm^2.
- The VARSKIN calculation [Figure 5 and 6] indicated a skin dose of 28.4 mSv.



[Figure 5. VARSKIN input information for worked example]



[Figure 6. VARSKIN output for worked example]