ConRAD (Software Application User Guide):

User Guide Instructions

Outline:

This user manual clarifies how to operate the app and website to convert radioactive counts to dose rates based on analytical techniques. The system requires user inputs to return an approximate dose rate for alpha, beta, and gamma radio-emitters. This is intended for users who do not have access to a dosemeter and need fast and efficient dose rates in the lab; **this is not intended to replace calibrated dosimetry devices in critical situations.**

Getting started, installation guide and system requirements:

App: The app is compatible with windows, mac and Linux. When operating the app, to ensure the app can access the isotope dictionary, please ensure that the executable file and the isotopes_data1.json file are in the same folder. To access the user manual from the user interface, ensure the user manual is stored in your PC's downloads folder. Source code built in Python and available upon request.

The software requires user inputs, from what isotope and the corresponding alpha, beta and gamma emission energies (MeV). There is an extensive menu provided, but the software allows users to add custom isotopes through the user interface. The material the radioactive emissions travel through is also user input and there is a list of materials provided for the user to select from, but there is also a custom option where user can input a material density (kg/m^3). The distance between the source and target object (m) is a user input and is typed directly into the interface. The activity of the source (MBq) is input via text input by the user. The area of the radioactive source should be inputted (cm^2) so the alpha dose can be determined. The recorded counts per second (cps) are inputted by the user via text inputs. A cps value for alpha, beta and gamma detected counts should be entered, and if no counts are entered, then 0 counts should be input into the interface. These values should be taken from a calibrated, operating detector to ensure the most accurate dose rates for safety.

User Input	Description	Unit
Isotope	Alpha, beta and gamma emission energies	MeV
Material	Density of material radio emission travels through	Kg/m^3
Distance	Distance between source and target	m
Source Activity	Activity of the source	MBq
Source Area	Area of radioactive source	cm^2
Detected cps	Counts per second for each emission	cps

Table 1: User inputs and corresponding units, and descriptions.

If an estimate is required, always overestimate to ensure safe settings for the user operating in radioactive environments.

These user inputs allow the interface to return a dose rate (μSv/h) for each detected radio-emission: alpha, beta, and gamma.

Website: The website is not compatible with apple phones or tablets but is compatible with mac, Linux and windows on pc and android phones. As above, the software requires user inputs on the chosen isotope's corresponding alpha, beta and gamma emission energies. The interface allows the user to add custom isotopes and energies or choose from the isotope list provided. The website also needs user inputs for: the density of the material the radioactive emissions travel through, this can be chosen from a list of materials or customised; the distance between the source and target object; the area of the radioactive source, so the alpha dose can be determined; the activity of the source and the recorded counts per second at the detector. For the website there is only one counts input assuming you cannot separate the counts for each emission type. Please refer to Table 1 where necessary. The user inputs allow the website to return a dose rate for each emission: alpha, beta, and gamma.

Features and Functionality:

App: When a user inputs a custom isotope, the data will update the dictionary automatically and permanently. To remove an isotope, the user should open the isotopes_data1.json file and delete the isotope which they want removed from the dictionary, re-save the file and re-open the app.

The isotope list is long, so a search bar has been added. If searching for an isotope, starting by typing the first letters of the isotope symbol and not the name (e.g. Technitium-99m is stored as Tc-99m and searching for Technitium-99m will not find the isotope in the menu).

All user inputs must be filled in to work with the software, so if the detected cps are 0, the 0 should be typed into the interface.

When using a custom material density, select the custom option in the drop-down menu first, then this will allow access to the text input for the density.

Website: When a user inputs a custom isotope, the data will update the dictionary automatically but not permanently. The custom isotopes and materials are likely to disappear by the next visit to the site, especially if the page has reloaded.

Both isotope and material lists have a search function. Note that for the isotopes they are stored using element symbols - e.g. Technitium-99m is stored as Tc-99m and searching for Technitium-99m will not find the isotope in the menu.

Trouble Shooting:

App: If the app freezes, close and re-start the app.

All units are on the interface, for optimal accuracy, the user should enter all values in the correct units seen in the interface.

Ensure exe file and isotopes_data1.json are in the same folder and that the user manual is saved in the PC's download folder.

Website: If the website freezes or does not update for whatever reason, restart the page. If this does not work, try clearing the browser cache of waiting for it to clear itself.

Additional Resources:

Analytical Assumptions:

In order to create the equations used for dose rate of alpha, beta, and gamma radiation sources, the following analytical assumptions were made. The same equation was used to determine gamma and beta radiation; therefore, the same assumptions were made. There is a sperate equation and assumptions for alpha sources.

For gamma and beta sources, we assume:

- The radioactive isotope is a point source.
- Surface area of the detector is factored into counts per second value from the detector.
- The μ in the absorption coefficient (μ_m/ρ_m) is valid to use in the Beer-Lambert Law for gamma and beta radiation.
- That Ionactive is a reliable source with accurate information [7]

For alpha sources, we assume:

- Using only very low energy alpha particles (non-relativistic)
- Using the Continuous Slowing-Down Approximation (CSDA): [1]
    - Assuming continuous energy loss
    - Neglecting stochastic variations between different particles of the same energy
    - Neglecting angular deflection of the particles
    - The rate of energy loss at every point along the track is assumed to be equal to the total stopping power
- Assume even distribution of particles throughout source which also spread out evenly
- Assume the energy of the alpha particles deplete with the trend discussed in source [9]. This same trend is also exhibited in sources [5] and [6].
- An average initial source energy is used for this calculation, so if a source has greater variation in different energy values, the resulting dose rate may be less accurate.

Isotope assumptions:

ConRAD has the capacity to use any radioactive isotope from the periodic table of elements as well as allowing the user to enter their own isotope information. This information provides the energy emissions at the source to be used in the calculation equations. While there are many available options for the emissions of these radionuclides, the most commonly used and extensive is the Radionuclide and Radiation Protection Data Handbook 2002 [4], colloquially known as the Delacroix tables. This set of data tables provides the top three highest emissions of each radiation type, of every radionuclide and the probability of these emissions. All data is collected through experimental data and in reference to an isotope activity of 1 MBq.

The data from the Radiouclide and Radiation Protection Data Handbook 2002 was transformed into dictionary to be used in the ConRAD software with the following assumptions:

- Provide an average energy for gamma and beta emissions and an array of the top three energies of alpha emissions.
- If there is only one energy at an 100% emission rate. The energy stated is the energy.
- If there is only one energy at a <100% emission rate. The energy stated is the energy as any counts we are getting are of that energy.
- If there is only one energy at a >100% emission rate. The energy stated is the energy as any counts we are getting are of that energy.
- If there are two or more energies and a total emission probability of 100%. Calculated as average energy using the following equation:

$$(e_1 \cdot p_1) + (e_2 + p_2) + (e_1 + p_2)$$

- If there are two or more energies and the total emission probability is not equal to 100%. Average energy is calculated using the following:

$$\frac{(e_1 \cdot p_1) + (e_2 \cdot p_2) + (e_3 + p_3)}{p_1 + p_2 + p_3}$$

- If there are 'Electrons' included. These are included with the beta emissions.
- If there are beta and electrons within the table. Only the beta emissions are considered as the electron emissions should be negligible in comparison.
- Alpha energies are also calculated using the above equation where two or more emission energies are considered.
- Always rounded values up, even if a value of 10.1 rounds to 11.
- Some sources in the Delacroix have a '% omitted'. These values have been ignored.
- If the emission is stated to be <1%. Assumed to be 1% emission probability.

Bibliography

[1] E. S. Agency, "Cooperation of Space Standardization," 2025. [Online]. Available: https://ecss.nl/item/?glossary_id=44 .

[2] A. N. HABTE, "CALCULATIONS OF STOPPING POWER AND RANGE OF ALPHA PARTICLES OF SEVERAL ENERGIES IN DIFFERENT MATERIALS," June 2011. [Online]. Available: https://etd.aau.edu.et/server/api/core/bitstreams/6c122e08-068c-475e-9399-e4ad032563fd/content.

[3] C. E. K. S. N.L. Hansson, "Alpha dose rate calculations for UO2 based materials using stopping power models," January 2020. [Online]. Available: https://www.sciencedirect.com/science/article/pii/S2352179120300107 .

[4] J. P. G. P. L. C. H. D. Delacroix, "RADIONUCLIDE AND RADIATION PROTECTION DATA HANDBOOK 2002," 2002. [Online]. Available: https://www.hep.ucl.ac.uk/~saakyan/phas0052/Radionuclide_Data_Handbook.pdf.

[5] "RANGE OF ALPHA PARTICLES," 6 Sept 2011. [Online]. Available: https://www-f9.ijs.si/~studen/sola/emfjod/vaje/literatura/alpha_2011.pdf.

[6] A. M. H. Hiwa Mohammad Qadr, "Alpha- particle stopping powers in air and argon," November 2017. [Online]. Available: https://www.researchgate.net/publication/326658273_Alpha-_particle_stopping_powers_in_air_and_argon.

[7] "Formula for calculating dose rates from gamma emitting radioactive materials," 2025. [Online]. Available: https://ionactive.co.uk/resource-hub/guidance/formula-for-calculating-dose-rates-from-gamma-emitting-radioactive-materials.

[8] NIST, "Appendix: Significance of Calculated Quantities," [Online]. Available: https://physics.nist.gov/PhysRefData/Star/Text/appendix.html.

[9] M. N. A. S. M. e. a. Rezaie, "Parameterization of 241Am and 230Th alpha particle energy in dependence on distance traveled in air.," (2012). [Online]. Available: https://doi.org/10.1007/s10967-012-1706-1.