Elaboration of an App for calculations of dosimetric quantities aiming at radiological protection

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Abstract. In routine operations of services and standard practices that use ionizing radiation sources, safety is required in relation to the calculations of the variables, according to the operation. The safe distance to operate at, the conversions of units and other important quantities need metrological precision, to avoid any unfortunate unwanted affects. In this sense, this work aims to demonstrate the benefits of an App that can be used free of charge for calculating dosimetric quantities. This App proved to be efficient and accurate in tests, for example, in calculations for Gammaigraphy.

Keywords: App; Dosimetric Quantities; Institute of Radiation Protection and Dosimetry.

1. Introduction
Metrology, defined as the science of measurement, has as main focus to provide reliability, credibility, universality and quality to the measures. Metrology also has, as property, quantifying the quantities, assigning them numerical confidence, both to the instruments and procedures [1].

In metrology, the magnitudes needs to be dependent on fundamental magnitudes of physics, possess a well-established standard and unit and, most importantly, be measurable and traceable to the international Bureau of Weights and Measures (BIPM).

Regarding Ionizing Radiation Metrology (IRM) should be no different. For example, in the dosimetry of ionizing radiation and radioactivity, the quantities in question are activity, kerma in the air and absorbed dose, and in order to establish the degrees of equivalence for a given physical magnitude, the main element to be evaluated is the reference value of a key comparison[2].

However, for radiological quantities, most do not have instruments that measure them and do not have established metrological standards, which would allow traceability to the BIPM [3].

Thus, in daily operations a team working with services where radiation sources are being employed, may come to develop uncertainties in their practices due to differences in the readings of the quantities in the equipment, generating the need for rapid conversion of operating units. Therefore, it is extremely important to know the most accurate value to keep the operation safe, so as to work within the correct limits, so that decisions can be taken in a safe way.

Therefore, in routine operations of services and practices that use ionizing radiation sources, accurate calculations of variables is essential to a safe work environment. Safe distance, unit conversions and other important quantities require metrological accuracy, preferably in an agile way.

In this sense, this work aims to demonstrate the benefit of an App that can be used free of charge for calculating dosimetric quantities, to accomplish precise and efficient calculations. the App Inventor for Android application was used to create the App, which is an open source language made with a command block editor, offered free by the Massachusetts Technological Institute – MIT [4].
2. Methodology
Developed using the Java language, the construction of the App was first modeled in spreadsheet form, where inserting the data of the most common quantities of radiological operation could be calculated.

The results then appear in values with up to four significant digits displayed, providing a margin for taking decision in relation to the work areas, conversion of the values between the dose quantities and the activity of the sources through the date and their respective half-lives.

This App was tested during the practical classes of nuclear gauges and gammography apparatus for radiometric survey, the module "Principles of radiological protection and regulatory control" of the specialization Course in "Radiation Protection and Security of Radiation Sources", offered by the Institute of Radioprotection and Dosimetry (IRD), in partnership with the International Atomic Energy Agency (IAEA).

All the operations were based on the equations of radius of beacon, radioactive decay and dose, using the data of the radionuclides Ir-192, Cs-137 and Co-60.

3. Discussion and Results
The command blocks (Figure 1) were constructed using mathematical operators and logical commands that create instruction layers, where the typing of values previously known by the operator returns the necessary information for use (Table 1).

The modeled equations were:

\[ X = \frac{dX}{dt} = \Gamma \frac{A}{d^2}; \quad D = \frac{\Gamma}{d^2}; \quad A = A_i \cdot e^{-\frac{t}{\tau}}; \quad d = \frac{\Gamma A}{D}; \quad 1 \text{rem} = 10^{-2} \text{Sv} \quad (1) \]

Where:
- A - The activity of the source at the moment of measurement (Ci);
- Ai - Supply Initial activity (Ci);
- \( \Gamma \) - Exposure rate constant (R.m²)/h.Ci);
- d - Distance between source and measurement (m);
- t - Measuring time (second; minute; hour; year);
- \( t_{1/2} \) - Half-life time (second; minute; hour; year);
- \( 1D \) - Effective Dose (Sv);
- X - Exposure rate (R/h).

| OldUnits | Equivalence | SI Units |
|----------|-------------|----------|
| Curie (Ci) | 1 Ci = 3.7 x 10¹⁰ Bq | Becquerel (Bq = s⁻¹) |
| Roentgen (R) | 1 R = 2.58 x 10⁻⁴ Ckg⁻¹ | Coulomb per kilogram (Ckg⁻¹) |
| Rem (Sv = Joule kg⁻¹) | 1 rem = 0.01 Sv | Sievert (Sv = Joule kg⁻¹) |
| rad | 1 rad = 0.01 Gy | Gray (Gy = Joule kg⁻¹) |
| mache | 1 mache = 12,802 Bq L⁻¹ | Becquerel per liter (Bq L⁻¹) |

1Effective Dose Estimation for a point source with a minimum of 1 meter.
After completing the compilation process and triggering the command (debug), the software is created as an executable file for Android in apk format (Android executable format), and can be distributed and downloaded for free on the Google Drive page, in link https://drive.google.com/file/d/1dqxFPZ4WBkIwMYdQ-EFhskpMuS8dhRS/view?usp=sharing (Portuguese version) or https://drive.google.com/file/d/1Mq56pRKOJw7fKDCtQ0AFsNF--NZy-eja/view?usp=sharing (English version) (Figure 2).

The installation process may vary based on the operating system of the smartphone. It is possible to connect the smartphone via USB cable to the computer and complete the upload. After that, you must enable the option MTP (media device), searching in the internal memory for the file Safetycalc.apk, remembering that if the package installer is blocked you should select the option "Unknown sources".

Once installed the file can vary its dimensions according to the size of the user's screen,
remembering that the Qwerty keyboard, used on the Android platform, has an "OK" key that allows you to check all the data before performing the desired operation. The App was baptized as "RadioMetroCalc", and presents the following screens (Figure 3).

![RadioMetroCalc App screens](image)

**Figure 3**: "RadioMetroCalc" App screens installed and started with the Qwerty keyboard. Source: the author.

Regarding the insertion of data it is important to remember that the mathematical language in which the platform was conceived uses the dot (.) instead of the comma (,) to describe the decimal numbers. That's why the user can make an error by entering a value greater than expected or simply resulting in an error in the program.

The App was tested during practical classes of nuclear over meters and gammagraphy apparatus for radiometric survey, this tool was made available to the students. According to student Z., the App was of great value for practical classes because "The App improved the speed of work during Gammagraphy practice. The problem was to adapt to the use the Qwerty keyboard, which mimics the conventional keyboard where the numbers are at the top. It is also important to take into account the personal experience of the operator in relation to the units, which must conform, for example, time in months and the half-life time in days".

Thus, with this App, an operator who needs to know the activity of a source, quickly, could calculate it from the data identified by Gammagraphy equipment. For example, equipment that indicates the initial activity of 240 Ci of Ir-192 with half-life of 74.5 days, after five months (150 days), would result in the calculated value of 60 Ci. The result is up to five decimal places (Figure 4).
4. Conclusion
The App was developed according to the observations made in the classroom based on the difficulty of
the class in evaluating different detectors at different scales, which caused measurement errors and in
the conversions and calculations for radiological protection.

The results were taken from the tests performed in the simulated practices in radiological
protection, where radiometric surveys were made with gammagrapy apparatus and nuclear meters,
using detectors with different scales, being Fully effective in the balization of controlled, supervised
and free areas, as well as in the calculation of the activities of the radionuclides of the sources
according to the dates of the labels.

Thus, this App can be used, free of cost, not only for the occupationally exposed individuals
(IOEs), but also for the individuals of the public (definition of areas).

Despite being an open and free App, it presents some graphic limitations, such as the Qwerty
keyboard, and is also best used with prior knowledge for the equations used and to take care with the
conformity of the units. In this sense, some updates are being created for easier use of the mobile App
and enhanced user experience.

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