IAEA-CN-96-17P
XA0203815

EFFECT OF XCOM PHOTOELECTRIC CROSS-SECTIONS ON DOSIMETRIC QUANTITIES CALCULATED WITH EGSnrc

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The EGSnrc [1] Monte-Carlo code system incorporates improved low energy photon physics such as atomic relaxations and the implementation of bound Compton cross-sections using the impulse approximation [1]. The total cross-section for photoelectric absorption however, still relies on the data by Storm and Israel(S&I) [2]. Yet, low energy applications such as brachytherapy (e.g. ^{125}I) require up-to-date low-energy photoelectric cross-section data. In this paper, we study the dosimetric effects of a simple implementation of NIST XCOM-based [3] photoelectric cross-sections [4] in EGSnrc. This is done by calculating mass energy-absorption coefficients, absorbed dose from point sources, kilovoltage x-ray beams and ion chamber response.

In the EGS code system, the PEGS4 routine reads the photoelectric and pair cross-sections for elements from a file (pgspepr.dat) and provides numerical fits for compounds which will be used by EGSnrc. We updated the photoelectric cross-sections of the pgspepr.dat file with the XCOM total photoelectric absorption cross-sections from NIST [4]. After validation of this new implementation, we studied its effects on a number of dosimetrically relevant quantities. Firstly, we calculated mass energy-absorption coefficients by scoring energy transferred in a thin slab of water and air using the DOSRZnrc user code. Secondly, we calculated inverse-square corrected absorbed dose distributions from point sources in water by using an internally developed user code, KERNELph. Thirdly, we studied the differences in free-air ion chamber response calculations. Ion chamber response is defined as the dose to the cavity of an ionization chamber, D_{gas}, positioned with its effective point of measurement at a reference point divided by air-kerma measured free-in-air at the same point. The ion chamber response was calculated using monoenergetic photon beams of energy 10 keV to 200 keV.

The comparison of the Storm & Israel photoelectric cross-sections with the XCOM cross-sections shows significant differences between the two datasets. Figure 1 shows that for dosimetrically important low-Z elements, these differences can be up to 5%. The influence of these differences can be seen in Figure 2 which compares the ratio of mass energy-absorption coefficients (and hence collision kerma) for water as calculated by EGSnrc, using either the Storm & Israel (EGSnrc(S&I)) or XCOM (EGSnrc(XCOM)) photoelectric cross-sections, to the coefficients directly taken from NIST tables. Consistently, Figure 2 shows that EGSnrc(XCOM) can calculate mass energy-absorption coefficients that are accurate within ±1% of the accepted NIST data in the region where EGSnrc(S&I) is off by up to 4%. The agreement between EGSnrc(XCOM) and NIST data is inside 0.5% when performed in air (results not shown).

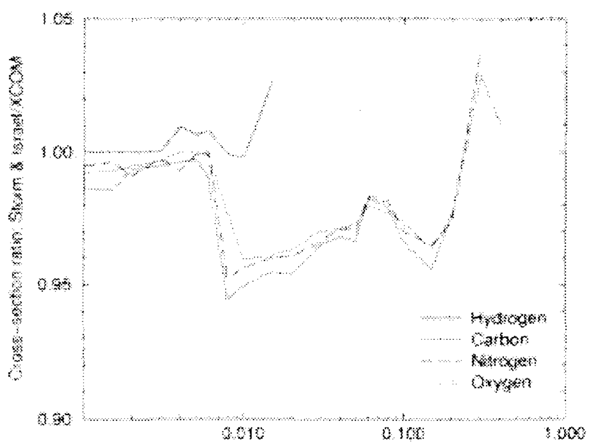

Fig. 1. Ratio of Storm & Israel over XCOM photoelectric cross-sections for low-Z dosimetrically important elements.

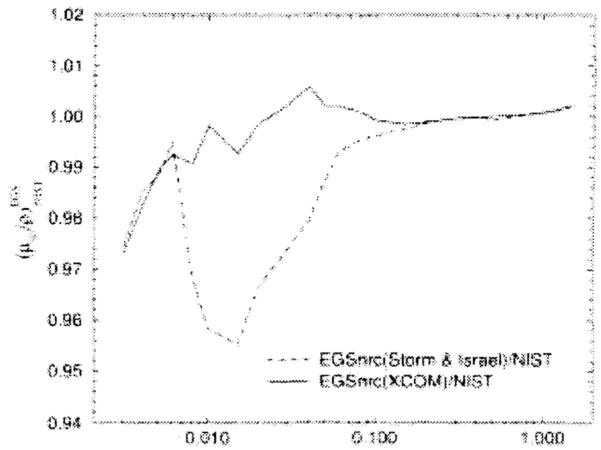

Fig. 2. Ratios (EGSnrc/NIST) of mass energy-absorption coefficients of water as calculated using EGSnrc(S&I) and EGSnrc(XCOM).

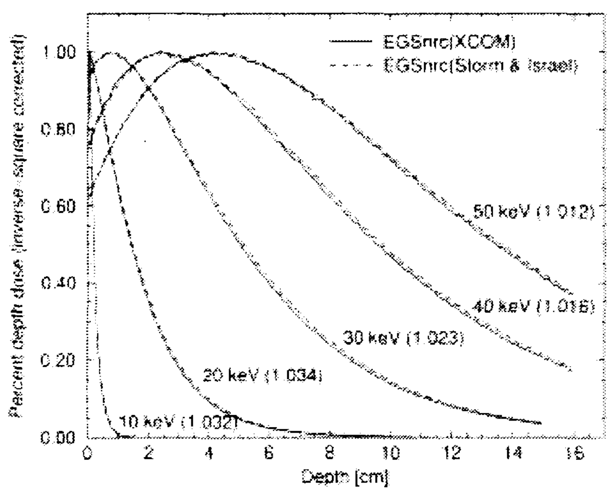

Fig. 3. Comparison of calculated, inverse-square corrected, depth-dose curves for monoenergetic point sources in water using EGSnrc(S&I) and EGSnrc(XCOM).
In brackets: ratio (XCOM/S&I) of dose at d_{max}.

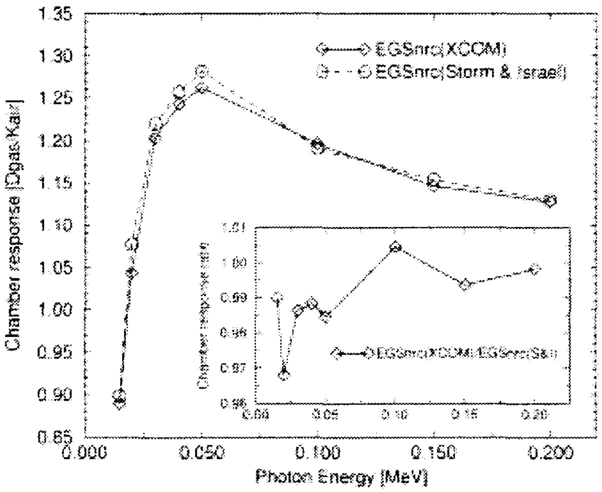

Fig. 4. Ion chamber response of an Exradin A11 ion chamber for different monoenergetic photon beams calculated using EGSnrc(S&I) and EGSnrc(XCOM). Insert: ratio (XCOM/S&I) of chamber response.

We evaluated the consequences of updating the photoelectric cross-sections in EGSnrc by comparing inverse-square corrected depth-dose distributions for monoenergetic point sources in water. Figure 3 demonstrates that EGSnrc(XCOM)-generated relative depth dose curves are not as penetrating as those generated using the Storm & Israel photoelectric cross-sections. The absolute dose ratios (XCOM/S&I) at depth of d_{max}, indicated in brackets in Figure 3, show that absolute differences are of the order of 3% to 1% from 10 keV to 50 keV, respectively. The surface dose calculated using EGSnrc(XCOM) is also 3% to 1.5% higher than for EGSnrc(S&I) for 10 keV to 50 keV, respectively. Figure 4 shows that for applications involving the calculation of ion chamber response, systematic differences between the two datasets can be found of the order of 3% to 1.5% for energies between 20 keV and 50 keV.

XCOM-based photoelectric cross-sections differ from Storm & Israel data tables by up to 5% over an energy range of 8 keV to 200 keV. This leads to differences in mass energy-absorption coefficients (hence collision kerma) of similar magnitude when photoelectric absorption is the predominant photon interaction process. Absorbed doses calculated using EGSnrc for applications in brachytherapy and kilovoltage x-rays systematically change by up to 3% at depth of maximum dose. EGSnrc calculated ion chamber response in this energy region is affected by up to 3% at 20 keV.

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