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Calculation of Air Kerma of CT Contrast Agents and Painkiller

Saniye Tekerek*

Vocational School of Health Services, Kahramanmaraş Sutçu Imam University, Turkey

ABSTRACT

In this study have investigated the mass attenuation coefficient and air Kerma of some CT contrast agents and painkiller. The mass attenuation coefficient and air Kerma of Iotrolan, Iodixanol, Iohexol, Ioxilan, Ioversol, Iomeprol, Ketoprofen, Flurbiprofen, Etodolac, Ibuprofen, Meloxicam, Diflofenac and Aspirin have been calculated by using WinXCom in the energy range from 1 keV to 1000 keV. The current study would be useful to develop new shielding materials in radiation application fields.

INTRODUCTION

Investigation of radiation effects on biologically important molecules is very important research in medicine and radiation biophysics. The study of radiation interactions with sample and the data on the attenuation of X and gamma-rays in biologically shielding and dosimetric materials assumed great significance by virtue of their various applications [1].

The results show that MAC is a useful physical quantity to determine the Kerma for compounds. Values of MAC depend on the chemical content of the investigated compounds. The photon interaction parameters were investigated to verify the applicability of the mixture rule over different samples in various energy.

The kerma vary markedly from sample to sample, with the highest values usually being for the lower atom masses. Gamma and X-rays are extensively used for diagnostics in nuclear medicine, CT scanning, gamma knife surgery, mammography, radiotherapy, radiology. As a consequence, various human tissues and biological material are exposed to high radiation. It is very important to know that how these material can be affected when exposed radiation [2]. Kerma is the sum of the Initial kinetic energies of all charged particles liberated by indirectly Ionizing particles in a small volume element of a specified material divided by the mass of material in that volume element [3].

The Mass Attenuation Coefficient (MAC) is a fundamental photon interaction property for calculation of shielding properties in biological materials [4], human body organs [5] and tissue substitutes [6] were investigated by different researchers. Some researchers studied Kerma values of various fatty acids and some carbohydrates [7], some vitamins in the energy range of 356.61–661.66–1250 and 1408.01 keV [8] photon kerma parameters for human body organs [4].

Our present investigation of MAC and Kerma of some contrast agents, and painkiller compounds for total radiation interaction processes should be useful to scientists. It is needed to know about the mass attenuation coefficient in order to calculate air Kerma of the compounds.

*Corresponding author

Saniye Tekerek, Vocational School of Health Services, Kahramanmaraş Sutçu Imam University, Turkey

ORCID ID: orcid.org/0000-0003-3326-358X

E-mail: saniyetekerek@ksu.edu.tr

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In this study air Kerma values was calculated for some medically important compounds. The MAC and Kerma are informed us about the characteristic properties of some medical compounds. The aim of present investigation is to study the behavior of these compounds absorption parameters i.e. MAC (μ/ρ) and Kerma.

In medical imaging field, the knowledge about how the high energy beam interacts with CT agent compounds leads to progress the clinical diagnosis by the CT scan. The medical imaging field information about air Kerma the scattering radiation interacts in with medium can be guide progress the this field [5,9,10]. However, although the CT agents are part of imaging and dosimetre information such studies for Kerma values of this materials are less in literature. Consequently, investigation of the radiation interaction with these CT agents and painkiller have is to be reached. In the present work, the CT contrast agents and painkiller have been calculated for the first time in terms of the air Kerma.

MATERIALS AND METHODS

The computed tomography investigation, a photon is sorption as it passes through a human body organ by CT agents.

This study was undertaken to obtain information on MAC and Kerma for some medical compounds. Values of MAC depend on the chemical content of the investigated compounds. This present parameters were investigated to verify the practicable of the mixture rule over different medical compounds in constant energy. MAC and air Kerma at high photon energy were investigated since compounds have grand scale application in the technology of medical and nuclear field.

The mass attenuation coefficients for any chemical compound are estimated using the elemental values the Bragg's-rule formula [11].

Total MAC is calculated by equation [12].

$$\frac{\mu}{\rho} = \frac{1}{\rho} \ln \left(\frac{I_0}{I} \right)$$

where (I) attenuation, (I_0) unattenuation intensity, ρ (gr/cm³) is the density of the compounds.

Kerma is the ratio of air mass attenuation coefficient and compound mass attenuation coefficient to each other. The Kerma value of a compound relative to air was calculated using Formula 6:

$$\text{Kerma} = \frac{\left(\frac{\mu}{\rho} \right)_{\text{compounds}}}{\left(\frac{\mu}{\rho} \right)_{\text{air}}}$$

where; $\left(\frac{\mu}{\rho} \right)_{\text{compounds}}$ is compound mass attenuation coefficient and $\left(\frac{\mu}{\rho} \right)_{\text{air}}$ is air mass attenuation coefficient.

The MAC is the amount of initial beam energy transferred to kinetic energy charged particules by radiation interaction. Energy mass attenuation coefficient related to air mass attenuation coefficient through the following relation Formula;

$$\frac{\mu_{\text{en}}}{\rho} = \frac{\mu_{\text{tr}}}{\rho} (1 - \bar{g})$$

where $\left(\frac{\mu_{\text{tr}}}{\rho} \right)$ is mass attenuation energy transferent coefficient

$\left(\frac{\mu_{\text{en}}}{\rho} \right)$ is mass attenuation energy absorption coefficient (cm²/g)

$\bar{g}$: bremsstrahlung fraction

For low atomic number samples and beam energies below 1 MeV, the bremsstrahlung fraction $g \approx 0$; $(\mu_{\text{en}}/\rho) \approx (\mu_{\text{tr}}/\rho)$ [13].

RESULTS AND DISCUSSION

In this study, mass attenuation coefficients and air Kerma of CT agents and painkiller compounds have been investigated in the energy range between 1 keV and 1000 keV. The values of the MAC have been calculated by the WinXCom data programme. The values of air Kerma were calculated by using mass attenuation coefficient for each CT contrast agent and painkiller.

The mass attenuation coefficient was increased with the increasing iodine ratio in the CT contrast agents compounds as shown in table 1, this increment attributes to the high molecular weight of iodine compounds. Results shows that the fractional weight increases linearly with increasing I content.

Kerma values relative to air for the total beam interaction of the CT agents and painkillers have major values at lower energies and minor values at higher radiations in figures 1-3.

The considered of chemical bind of target CT agent and painkiller compounds with was decreased the energy transfer by elastic scattering by nuclei of molecules, but simultaneously the incoherent scattering tends to increase with energy in figures 4-7.

The increased values of Kerma in case of CT contrast agents compounds may be attributed to the higher absorption due to presence of iodine in compounds. In

Table 1: MAC of CT contrast agents compounds.

Energy keV	Mass attenuation coefficient (cm ² /gr)					
	Iotrolan	Iodixanol	Iohexol	Ioxilan	Ioversol	Iomeprol
1	5847	5958	5806	5455	5874	5972
1.5	2357	2413	2339	5208	2369	2418
2	1165	1196	1156	2386	1172	1198
3	418.1	430.5	414.7	1181	420.5	430.9
4	198.9	205.2	197.3	424.6	200.1	205.4
5	410.1	428.4	406.2	446.0	413.0	427.6
6	298.0	311.6	295.1	438.4	300.1	311.0
8	140.5	146.9	139.1	305.6	141.5	146.7
10	78.04	81.65	77.30	144.1	78.60	81.48
15	26.43	27.650	26.170	80.070	26.620	27.59
20	12.23	12.790	12.110	27.120	12.310	12.76
30	4.172	4.360	4.134	12.540	4.201	4.350
40	10.47	10.970	10.370	17.380	10.550	10.95
50	5.879	6.157	5.824	10.760	5.921	6.142
60	3.648	3.818	3.615	6.037	3.674	3.809
80	1.735	1.811	1.720	3.745	1.747	1.807
100	0.995	1.036	0.987	1.779	1.001	1.034
150	0.403	0.415	0.400	1.018	0.405	0.415
200	0.241	0.246	0.240	0.410	0.242	0.246
300	0.143	0.144	0.143	0.244	0.143	0.144
400	0.111	0.111	0.111	0.144	0.111	0.111
500	0.094	0.094	0.094	0.111	0.094	0.094
600	0.084	0.084	0.084	0.095	0.084	0.084
800	0.071	0.071	0.071	0.084	0.071	0.071
1000	0.063	0.063	0.063	0.071	0.063	0.063

Name and chemical formula of compounds for the selected CT contrast agents and painkiller.

Compound Name	Chemical Formula	Compound Name	Chemical Formula
Iotrolan	C ₃₇ H ₄₈ I ₆ N ₆ O ₁₈	Ketoprofen	C ₁₆ H ₁₄ O ₃
Iodixanol	C ₃₅ H ₄₄ I ₆ N ₆ O ₁₅	Flurbiprofen	C ₁₅ H ₁₃ FO ₂
Iohexol	C ₁₉ H ₂₆ I ₃ N ₃ O ₉	Etodolac	C ₁₇ H ₂₁ NO ₃
Ioxilan	C ₁₈ H ₂₄ I ₃ N ₃ O ₈	Ibuprofen	C ₁₃ H ₁₈ O ₂
Ioversol	C ₁₈ H ₂₄ I ₃ N ₃ O ₉	Meloxicam	C ₁₄ H ₁₃ N ₃ O ₄ S ₂
Iomeprol	C ₁₇ H ₂₂ I ₃ N ₃ O ₈	Diflofenac	C ₁₄ H ₁₁ Cl ₂ NO ₂
		Aspirin	C ₉ H ₈ O ₄

Figure 1 Plot for air Kerma of CT agent compounds in the energy range of 1-200 keV.

Figure 2 Plot for air Kerma of CT agent compounds in the energy range of 1-60 keV.

Figure 3 Plot for air Kerma of painkiller compounds in the energy range of 1-20 keV.

case of contrast agent compounds we observed just inverse behavior as compared to painkiller compounds mixture that the Kerma is continuously increased as the I concentration increased in contrast agents compounds. The calculated air Kerma for all compounds have been shown in tables 2-4.

CONCLUSION

This study was undertaken to obtain information on MAC and air Kerma for some medical compounds. These kinds of results can be a guide for researchers working in different branches. The μ/ρ values can be used to calculate the linear attenuation coefficient for the selected CT agents and painkiller compounds. MAC and air Kerma at high photon energy were investigated since present compounds

Figure 4 Coherent scattering of compounds in the energy range of 1-60 keV.

Figure 5 Incoherent scattering of compounds in the energy range of 1-100 keV.

Figure 6 Coherent scattering of compounds in the energy range of 1-60 keV.

Table 2: MAC of painkiller compounds.

Energy Kev	Mass attenuation coefficient (cm ² /gr)						
	Ibuprofen	Etodolac	Ketoprofen	Flurbiprofen	Aspirin	Meloxicam	Diclofenac
1	2386	2499	2537	2672	2957	2733	2586
1.5	770.6	809.3	821.8	873.5	970.5	899	850.3
2	336.9	354.4	359.9	384.6	428.5	398.7	377.7
3	102.1	107.6	109.3	117.5	131.3	216.8	140.4
4	43.09	45.44	46.16	49.86	55.78	555	489.7
5	21.94	23.15	23.51	25.46	28.51	344.5	434.3
6	12.62	13.32	13.52	14.67	16.42	158.1	202.9
8	5.302	5.592	5.675	6.165	6.895	85.28	110.9
10	2.754	2.898	2.938	3.189	3.556	51.08	67.16
15	0.929	0.9684	0.9776	1.05	1.153	22.5	29.97
20	0.5013	0.5159	0.5179	0.5473	0.5891	11.85	15.9
30	0.2839	0.2864	0.2847	0.2925	0.3039	3.711	5.001
40	0.2277	0.2273	0.2249	0.2276	0.2319	1.681	2.241
50	0.2042	0.2029	0.2003	0.2011	0.203	0.6269	0.795
60	0.191	0.1893	0.1866	0.1867	0.1875	0.3669	0.4369
80	0.1751	0.1732	0.1705	0.1701	0.1701	0.2713	0.3064
100	0.1645	0.1626	0.16	0.1594	0.1591	0.2265	0.2462
150	0.1464	0.1445	0.1422	0.1415	0.141	0.1859	0.1934
200	0.1336	0.1319	0.1297	0.1291	0.1286	0.1668	0.17
300	0.1159	0.1144	0.1125	0.1119	0.1114	0.1428	0.1429
400	0.1037	0.1024	0.1007	0.1002	0.09973	0.1289	0.1284
500	0.0947	0.0934	0.0919	0.0914	0.0910	0.1111	0.1103
600	0.0875	0.0864	0.0850	0.0845	0.0841	0.0992	0.0984
800	0.0769	0.0759	0.0746	0.0742	0.0739	0.0905	0.0897
1000	0.0691	0.0682	0.0671	0.0667	0.0664	0.0836	0.08294

Table 3: Calculation air Kerma of CT contrast agents compounds.

Energy keV	Kerma					
	Iotrolan	Iodixanol	Iohexol	Ioxilan	Ioversol	Iomeprol
1	1.634	1.665	1.623	1.525	1.642	1.669
1.5	1.997	2.045	1.982	4.414	2.008	2.049
2	2.228	2.287	2.210	4.562	2.241	2.291
3	2.600	2.677	2.579	7.345	2.615	2.680
4	2.662	2.746	2.640	5.682	2.678	2.749
5	10.644	11.119	10.542	11.575	10.719	11.098
6	13.339	13.948	13.209	19.624	13.433	13.921
8	14.885	15.563	14.737	32.376	14.991	15.542
10	16.041	16.783	15.889	29.620	16.156	16.748
15	17.218	18.013	17.049	52.163	17.342	17.974
20	16.432	17.184	16.270	36.437	16.539	17.144
30	12.135	12.682	12.024	36.475	12.219	12.653

40	42.857	44.904	42.448	71.142	43.185	44.822
50	28.567	29.917	28.299	52.284	28.771	29.845
60	19.581	20.494	19.404	32.405	19.721	20.446
80	10.464	10.923	10.374	22.587	10.537	10.899
100	6.465	6.732	6.413	11.559	6.504	6.719
150	2.970	3.064	2.954	7.513	2.985	3.059
200	1.951	1.995	1.944	3.324	1.959	1.993
300	1.337	1.351	1.336	2.283	1.340	1.350
400	1.158	1.163	1.158	1.506	1.159	1.162
500	1.083	1.084	1.084	1.274	1.083	1.084
600	1.044	1.044	1.046	1.173	1.045	1.044
800	1.008	1.006	1.010	1.191	1.008	1.006
1000	0.992	0.989	0.994	1.122	0.992	0.989

Table 4: Calculation air Kerma of painkiller compounds.

Energy keV	Kerma						
	Ibuprofen	Etdolac	Ketoprofen	Flurbiprofen	Aspirin	Meloxicam	Diflofenac
1	0.667	0.698	0.709	0.747	0.826	0.764	0.723
1.5	0.653	0.686	0.696	0.740	0.822	0.762	0.721
2	0.644	0.678	0.688	0.735	0.819	0.762	0.722
3	0.635	0.669	0.680	0.731	0.817	1.348	0.873
4	0.577	0.608	0.618	0.667	0.746	7.427	6.553
5	0.569	0.601	0.610	0.661	0.740	8.941	11.272
6	0.565	0.596	0.605	0.657	0.735	7.077	9.082
8	0.562	0.592	0.601	0.653	0.730	9.035	11.749
10	0.566	0.596	0.604	0.655	0.731	10.499	13.805
15	0.605	0.631	0.637	0.684	0.751	14.658	19.524
20	0.674	0.693	0.696	0.735	0.791	15.921	21.362
30	0.826	0.833	0.828	0.851	0.884	10.794	14.546
40	0.932	0.930	0.921	0.932	0.949	6.881	9.173
50	0.992	0.986	0.973	0.977	0.986	3.046	3.863
60	1.025	1.016	1.002	1.002	1.006	1.969	2.345
80	1.056	1.045	1.028	1.026	1.026	1.636	1.848
100	1.069	1.057	1.040	1.036	1.034	1.472	1.600
150	1.080	1.066	1.049	1.044	1.041	1.372	1.427
200	1.084	1.070	1.052	1.047	1.043	1.353	1.379
300	1.085	1.071	1.053	1.048	1.043	1.337	1.338
400	1.086	1.072	1.054	1.049	1.044	1.350	1.344
500	1.087	1.073	1.055	1.049	1.045	1.275	1.266
600	1.087	1.073	1.055	1.049	1.045	1.231	1.222
800	1.087	1.073	1.055	1.049	1.045	1.279	1.268
1000	1.087	1.073	1.055	1.049	1.045	1.315	1.304

Figure 7 Incoherent scattering of compounds in the energy range of 1-150 keV.

have large-scale usage in the technology of medical, nuclear science, and geosciences.

For calculating kerma factors are thought to be necessary high photon energies but at low energies influence kerma factors, especially for compounds.

Kerma has been plotted with respect to the energy the CT agents and painkiller at different photon energies as shown in figures 1-3. It can be considered that there is an increase in MAC values since the concentration of high Z (iodine). This is because of the weight fraction of the high Z iodine increased at the compare of the other low Z elements. Moreover, it is clearly that the MAC decrease as the beam raises and this is due to the radiation can diffuse deeply in the absorber medical compounds without making any interaction. As a result the maximum values of MAC (17.38 cm²/gr) and air Kerma (71.142) occurs at 40 keV in Ioxilon. This behaviour of the Kerma can be explained due to the linear relation between MAC and Kerma.

References

1. Kaewkhao J, Laopaiboon J, Chewpraditkul W. Determination of effective atomic numbers and effective electron densities for Cu/Zn alloy. *Journal of Quantitative Spectroscopy and Radiative Transfer*. 2008;109:1260-1265. <https://bit.ly/3eKXmfC>
2. Robert CH. Kerma-Factor Determination By Charged-Particle Spectroscopy. 4th International Conference on Applications of nuclear techniques neutrons and their applications. <https://bit.ly/3lmv8ZY>
3. Roesch WC, Attix FH. Basic Concepts 1n Radiation Dosimetry. *Radiation Dosimetry*. Academic Press. New York. 1968;1:1-92.
4. Singh VP, Badiger NM, Vega-Carrillo RH. Studies on neutron and photon kerma parameters for human body organs. *Nuclear Technology and Radiation Protection*. 2016;31(2):128-134. <https://bit.ly/3cyQjUo>
5. Singh VP, Badiger NM. Study of effective atomic numbers and electron densities, kerma of alcohols, phantom and human organs, and tissues substitutes. *Nucl Technol Radiat Prot*. 2013;28:137-145. <https://bit.ly/38PmrlN>
6. Singh VP, Badiger NM, Kucuk N. Assessment of methods for estimation of effective atomic numbers of common human organ and tissue substitutes: Waxes, plastics and polymers. *Radioprotection*. 2014;49(2):115-121. <https://bit.ly/3vAySLR>
7. Manohara SR, Hanagodimath SM, Gerward L. Energy dependence of effective atomic numbers for photon energy absorption and photon interaction: studies of some biological molecules in the energy range 1 keV-20 MeV. *Med Phys*. 2008 Jan;35(1):388-402. doi: 10.1118/1.2815936. PMID: 18293593.
8. Demir D, Turşucu A. Studies on mass attenuation coefficient, mass energy absorption coefficient and kerma of some vitamins. *Annals of Nuclear Energy*. 2012;48:17-20. <https://bit.ly/3qSIPsx>
9. Kurudirek M. Effective atomic numbers and electron densities of some human tissues and dosimetric materials for mean energies of various radiation sources relevant to radiotherapy and medical applications. *Radiat Phys Chem*. 2014b;102:139-146. <https://bit.ly/3cDXsTH>
10. Kurudirek M. Effective atomic numbers, water and tissue equivalence properties of human tissues, tissue equivalents and dosimetric materials for total electron interaction in the energy region 10 keV-1 GeV. *Appl Radiat Isot*. 2014a Dec;94:1-7. doi: 10.1016/j.apradiso.2014.07.002. Epub 2014 Jul 15. PMID: 25061891.
11. Jackson FD, Hawkes DJ. X-Ray Attenuation Coefficients of Elements and Mixtures. *Physics Reports*. 1981;70:169-233. <https://bit.ly/3rYjJlr>
12. Hubbell JH. Review of photon interaction cross section data in the medical and biological context. *Phys Med Biol*. 1999 Jan;44(1):R1-22. doi: 10.1088/0031-9155/44/1/001. PMID: 10071870.
13. Podgorsak, Ervin B. Review of Radiation Oncology Physics. A Handbook for Teachers and Students Department of Medical Physics McGill University Health Centre Montréal, Québec, Canada. International Atomic Energy Agency Vienna, Austria. 2003. <https://bit.ly/3qWuzqG>

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