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Irradiation Effect of Pollution: Potassium-40 Element in Ceramco Dental Material

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Abstract: Different types of materials were used for dental prosthetics restoration, including feldspathic ceramics, glass ceramics, zirconia-based ceramics, alumina-based ceramics, resin-based materials, and Ceramco. The possibility pollution of this material with radioactive elements were investigated by Veronese et al. (2006). In this study, dose rate of ^{40}K in Ceramco dental materials composition was determined by Fluka code. The dose levels for the 1 Bq activity of ^{40}K naturally present in it was calculated as 0.032 nGy/Bq. The annual dose in teeth and head are 1.01 and 3.07 mGy/annual respectively resulted from ^{40}K in Ceramco per one teeth filling. Although most of the measured values are below the recommended limits, results indicate the patients who show high ^{40}K values may be due to pollution. Potassium in Ceramco may be received higher dose levels than annual dose limit. Therefore the pollution of Ceramco to ^{40}K is important for mouth health.

Key words: Pollution, Potassium-40, Ceramco, dental, gamma, dose, mouth health.

Introduction

Nowadays, various materials are used to fill teeth. Despite the fact that during the last few years, with the development and modification of materials, the use of dental material such as composite, Gold Inomer, Ceramco etc. is very common. There is the potential for these substances to be polluted with radioactive materials (Veronese et al., 2006). Uranium is one of the radioactive elements observed in Ceramco and dental materials that have been analyzed by the HPGe detector (Akkurt et al., 2015). The radioactive elements in the tooth filling materials are toxic metals that cause the contamination of these materials (Asaduzzamzn et al., 2017). Potassium is one of the most important elements in human water and food (Datta et al., 2010). In addition to food, it may also exist in non-edible substances such as dental materials. Potassium in the dental materials may be naturally or artificially contaminated with potassium-40. Since 0.012 of natural potassium contains potassium-40, there exists the possibility of potassium-40 contamination in Ceramco as one of the most widely used dental materials (Gill et al., 2018).

Potassium-40 is a gamma and beta emitting element. The effect of radiation on the mouth, the salivary and mucous glands depends on the amount of doses and causes Atrophy of the salivary glands and causes a change in the secretion of the glands and creation of drying mouth. The drying mouth caused by the Ceramco and dental material nuclear pollution, can cause worm

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formation and teeth decay (Mansourbahmani et al., 2018). This paper tries to investigate the annual dose rate of Ceramco contamination with ^{40}K using Fluka simulation. So far, many codes such as Fluka, MCNPx etc. have been used to dose calculation (Battistoni et al., 2007). The Fluka code is a multi-purpose nuclear code that has the ability to transport particles in all energy ranges (Ruhm et al., 2014). In addition, it is similar to other codes such as Geant4, MCNP, Mars and Phits (Oh et al., 2011; Rühm et al., 2014). By Fluka code, the 60 atomic and nuclear particles-antiparticles can be detected and analyzed (Battistoni et al., 2011).

Materials and Methods

The simulated geometry includes: a cylindrical phantom with 10 cm diameter and height, which consists of soft tissue. Inside the phantom, the jaw bone and tooth was simulated. The examined material in this study was Ceramco. The shape intended for teeth is a cube with a dimension of 8 × 8 × 8 mm^3 and the Ceramco material is 8 × 8 × 3 mm^3 above it. Figure 1 shows the geometry of this problem.

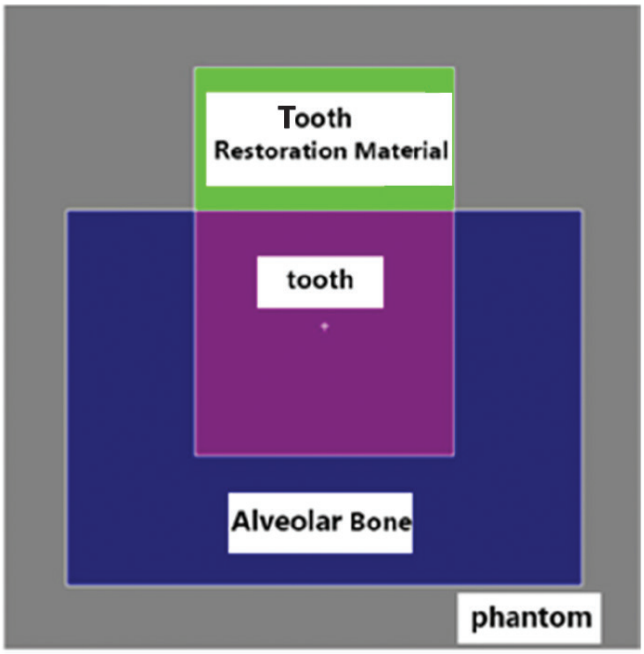

Figure 1: Defined geometry for the problem.

The density and composition of the materials are listed in Table 1.

Based on Table 1, the Ceramco is one of the materials which has potassium. The potassium-40 isotope is a radioactive substance with 1.28 × 10^9 years half-life. It decays to calcium-40 by emitting a beta particle (89% of the time) and to the Argon-40 by electron capture (11% of the time). Therefore, the radiation hazards caused by this radiation can be verified.

Table 1: Compounds (mass percent) of materials used in this study

Soft tissue		*Dentine*		*Ceramco*		*Aveoar bone*	
Density (g/cm^3)	*2.97*	*2.18*		*2.6*		*1.8*	
Ca	36.4	Ca	30.5	Na	8.32	Ca	14.7
O	41.92	O	36.4	K	7.07	O	41.0
C	1.47	C	11.3	Al	14.65	C	27.8
P	17.5	P	15.0	Si	15.24	P	7.0
H	0.98	H	3.08	O	38.97	H	6.4
N	0.13	N	2.5	Sn	15.76	N	2.7
Mg	0.4	Mg	1.1				
Na	0.6	Na	0.2				
F	0.01	F	0.02				
Zn	0.016	Zn	0.018				
Cl	0.25	Cl	0.03				
K	0.3	K	0.07				
Fe	0.003						
Cu	0.01						
Si	0.003						

Results

For this Fluka simulation, the type of the precision problem (high accuracy) and the cut-off energy for electrons was 10 KeV and for the photons was 20 KeV. The definition for this problem is as shown in Figure 1. The number of simulation particles is 5×10^5 in this simulation; potassium-40 is used as a source of radiation. To variance reduction, the percentage of potassium-40 is considered equal to 0.012 in the natural potassium. Table 2 shows potassium-40 nuclear information.

In this research, the USRBIN detectors have been used to measure energy, and the flux of electron and photonic in different parts of geometry (Song et al., 2015).

Figure 2 displays the energy remain in the system from different views.

Figures 3 and 4 show the electrons and photons flux in the tooth and around respectively.

Figures 5 and 6 show the distribution of electrons and photons in the tooth and around respectively.

Figure 7 shows the distribution energy remain in the head phantom.

Table 2: Potassium-40 Nucleus Information (*phi.nmsu.edu/~pvs/teaching/phys593*)

Isotope	*Half-life (y)*	*Natural abundance (%)*	*Specific activity (Ci/g)*	*Decay mode*	*Radiation energy (MeV)*		
					Alpha	*Beta*	*Gamma*
^{40}K	1.3 billion	0.012	7.1E-6	Beta, EC	-	0.52	0.16

EC = electron capture, Ci = curie. ^{40}K decays by both emitting: a beta particle (89%) and EC (11%).

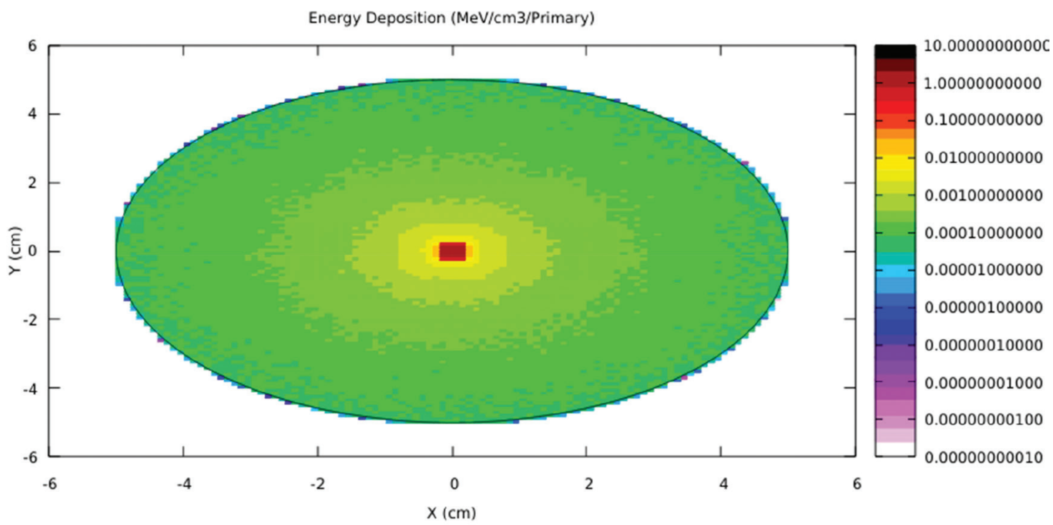

Figure 2: Distribution of energy remain in the tooth and around.

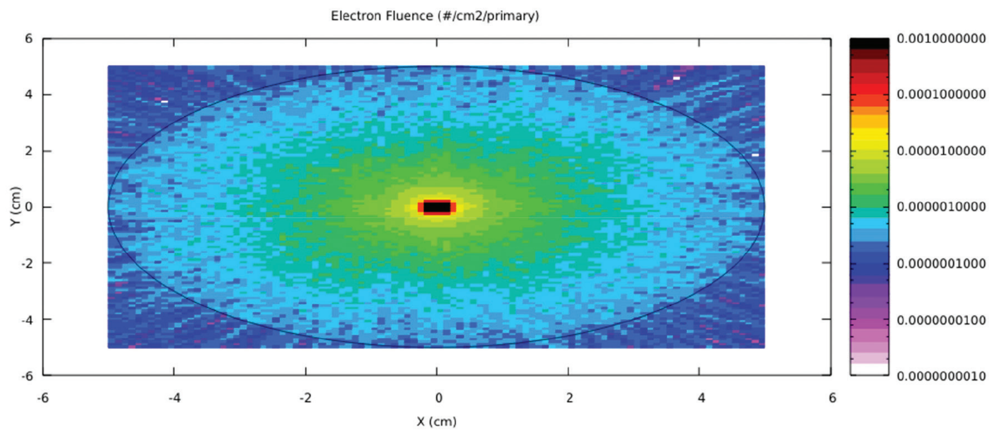

Figure 3: The electron flux created in the tooth and around.

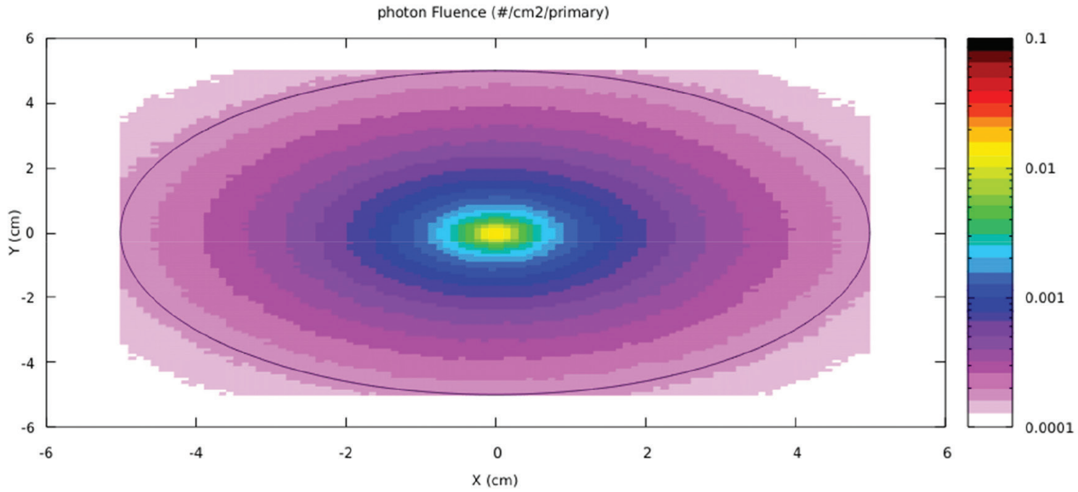

Figure 4: The photon flux generated in the tooth and around.

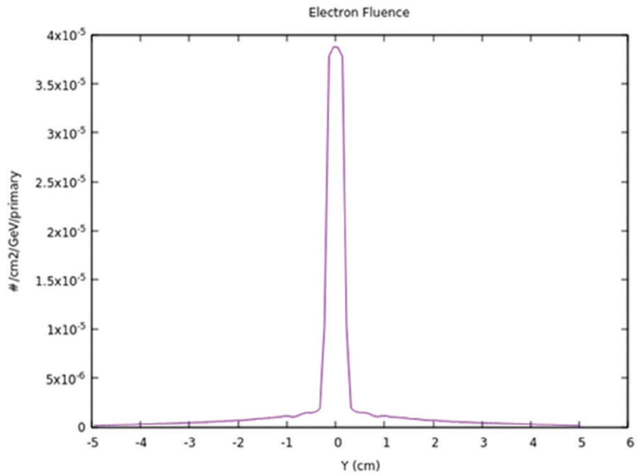

Figure 5: The distribution of electrons in tooth and around.

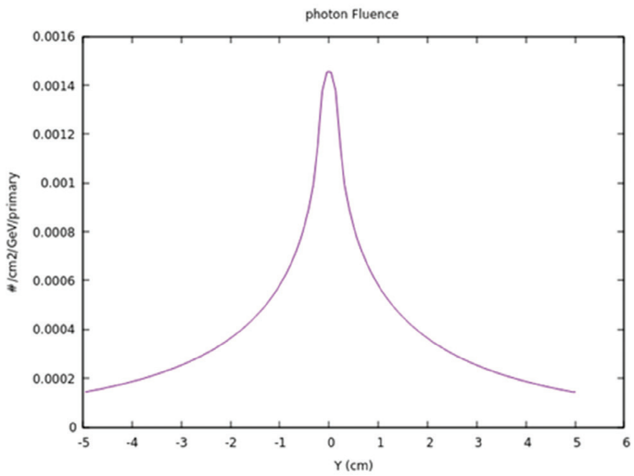

Figure 6: The distribution of photons in tooth and around.

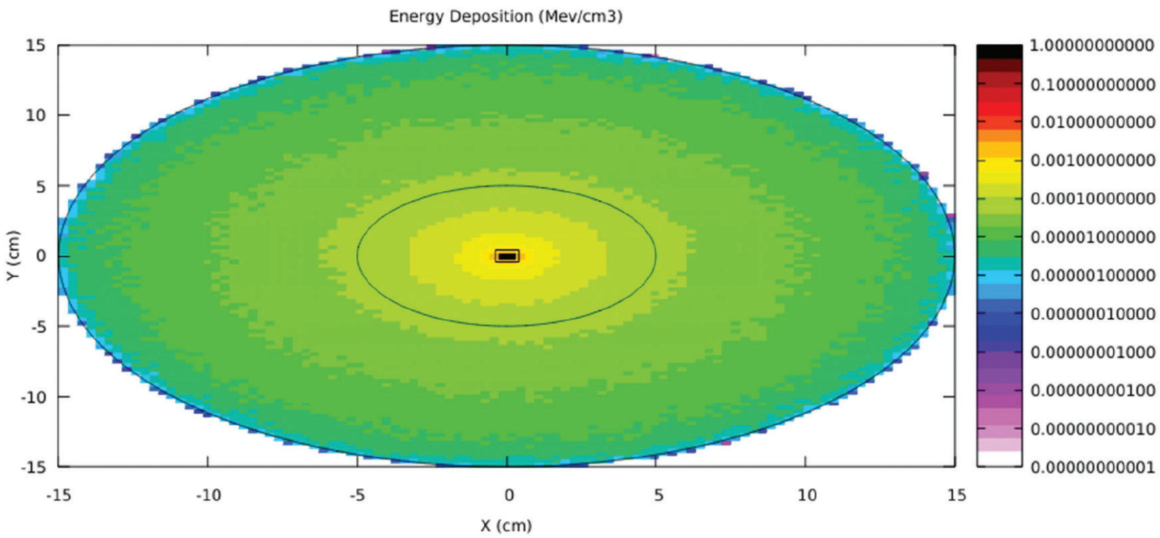

Figure 7: Distribution of energy remain in the head phantom.

Conclusions

According to the results of this study, patients whose teeth are decayed and inevitably filled with Ceramco-type synthetic materials are exposed to radiation hazard. The amount of this radiation hazard is 0.0322 nGy/Bq for one decay of potassium-40 .The annual dose in teeth and head are 1.01 and 3.07 mGy/annual respectively resulted from ^{40}K in Ceramco per one teeth filling. Regarding the direct relationship between the presence of ^{40}K in Ceramco higher than normal level, the annual dose of radiation will be greater than the above limit. On the other hand, due to the very long half-life of potassium-40, if the patient's tooth which was filled with the Ceramco material, it is necessary to take appropriate methods to elimination of this pollution. Therefore, it is suggested to use Ceramco and other dental material with non-radioactive elements for filling the human teeth.

References

Akkurt, İ., Ermiş, R.B., Baş, P. and K. Günoğlu (2015). Radioactivity measurement on dental resin composites. *ActaPhysicaPolonica A*, **128(2B):** 34-36.

Asaduzzaman, K., Khandaker, M.U., Baharudin, N.A.B., Amin, Y.B.M., Farook, M.S., Bradley, D.A. and O. Mahmoud (2017). Heavy metals in human teeth dentine: A bio-indicator of metals exposure and environmental pollution. *Chemosphere*, **176:** 221-230.

Battistoni, G., Boehlen, T., Cerutti, F., Chin, P.W., Esposito, L.S., Fassò, A., Ferrari, A., Lechner, A., Empl, A., Mairani, A. and A. Mereghetti (2015). Overview of the FLUKA code. *Annals of Nuclear Energy*, **82:** 10-18.

Battistoni, G., Cerutti, F., Fasso, A., Ferrari, A., Muraro, S., Ranft, J., Roesler, S. and P.R. Sala (2007). The FLUKA code: Description and benchmarking. *AIP Conference Proceedings*, **896(1):** 31-49.

Datta, J.K., Layek, S., Banerjee, A., Mondal, N.K. and S. Gupta (2010). Physico-chemical characterization of water quality of eutrophied surface water body and ground water around the field crop research station, Burdwan, West Bengal. *Asian Journal of Water, Environment and Pollution*, **7(3):** 69-75.

Gill, D.S., Nirola, D.A., Maini, D.A. and D.R. Sidhu (2016). Radiation Induced Salivary Gland Damage. *Review on Pathogenesis and Management*, **4(2):** 75-82.

Mansourbahmani, H.R., Negarestani, A. and M.R. Rezaie (2018). IXRF Optimization for Harmful Element Detection in Iranian Dust. *Asian Journal of Water, Environment and Pollution*, **15(2):** 29-35.

Oh, J., Lee, H.S., Park, S., Kim, M., Hong, S., Ko, S. and W.K. Cho (2011). Comparison of the FLUKA, MCNPX, and PHITS codes in yield calculation of secondary particles produced by intermediate energy proton beam. *Nuclear Science and Technology*, **1:** 85-88.

Rühm, W., Mares, V., Pioch, C., Agosteo, S., Endo, A., Ferrarini, M., Rakhno, I., Rollet, S., Satoh, D. and H. Vincke (2014). Comparison of Bonner sphere responses calculated by different Monte Carlo codes at energies between 1 MeV and 1 GeV: Potential impact on neutron dosimetry at energies higher than 20 MeV. *Radiation Measurements*, **67:** 24-34.

Song, Y., Shin, J., Cho, S., Yoo, S., Cho, I., Kim, E., Jung, W., Choi, S. and K. Oh (2015). A comparison study of the ridge filter parameter by using FLUKA and GEANT4 simulation codes. *Journal of the Korean Physical Society*, **67(1):** 96-102.

Veronese, I., Guzzi, G., Giussani, A., Cantone, M.C. and D. Ripamonti (2006). Determination of dose rates from natural radionuclides in dental materials. *Journal of Environmental Radioactivity*, **91(1-2):** 15-26.