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Determination of Dose Rates from Natural Radionuclides in Porcelain Dental Materials

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Abstract. There are three main aims that make this study particularly important and interesting to radiometric studies. Firstly, it will provides information on the concentration composition of natural and the associated man-made radioactivity of imported dental porcelain materials to be used by most dental laboratories in Great Jamahiriya. Since these materials do not pass radiation inspection tests before their entry or use and there is a large variety of supply source of these dental materials to be used for all dental works on Libyan patients, anomalies can be identified easily. Secondly, the analysis of selective elemental abundance (*U*, *Th*, and *K*) and dose rate calculations may be used to calculate effective dose rates to dental laboratory technicians and also to the patient who will be using these specific materials. This research project will provide the first results of such measurements and the corresponding average annual effective dose rates equivalent to the patients using these materials and also to the dental technician and doctors work in the various dental laboratories that make use of these materials in their daily work. A total number of 30 dental powder samples were collected from a number of dental laboratories around Tripoli area will be analyzed. In this research project, the results from this preliminary survey regarding Th, U and K elemental concentrations in a wide variety of dental materials by means of high-resolution X-ray spectrometry will be presented. Further results from these investigations concerning activity concentrations and the associated dose rates, effective dose and the committed dose due to the use of these materials are going to be calculated and compared with other published data elsewhere and recommendation of their use will be derived accordingly.

Key Word: Dental; Porcelain; Gamma-spectrometry ; Uranium; Dose Rate; Effective dose

Introduction

Gamma radiation emitted from naturally occurring radioisotopes, such as ^{40}K and the radionuclides from the ^{232}Th and ^{238}U series and their decay products (also called terrestrial background radiation), which exist at trace levels in most porcelain powder formations, represents the main external source of irradiation to the human body. More specifically, natural environmental radioactivity and the associated external exposure due to gamma radiation depend primarily on the source mixture and the manufacturer content of the powder materials, and it appears to be present in minute amounts and varies from one sample to the other[1].

The specific levels of natural and man-made radiation are related to the geological composition from the raw materials made off these dental porcelain powder , and to the content in thorium (Th), uranium (U) and potassium (K) of the rock from which the porcelain originate for a specific manufacturers.. In terms of natural radioactivity, it is well known, for instance, that igneous rocks of granitic composition are strongly enriched in Th and U (on an average 15 $\mu g\, g^{-1}$ of Th and 5 $\mu g\, g^{-1}$ of U), compared

to rocks of basaltic or ultramafic composition (< 1 $\mu g\ g^{-1}$ of U) [2,3]. For that reason, higher radiation levels are associated with igneous rocks and lower levels with sedimentary rocks. There are exceptions, however, as some shales and phosphate rocks have relatively high content of those radionuclides[1].
Since no systematic data on the porcelain powder materials that are imported to Libya were available, this research project was carried out as a pilot project with the objective to systematically measure the gamma radiation in the products, and determine its contribution to the annual effective dose equivalent to the patient and to the dental laboratories handling these materials.

Research Problem.

- There is no local standard (permissible level) for the porcelain imported into Libya which used for dental purposes.
- Unawareness of importers, lack of specialty among the importers
- Different importing channels to the Libyan market
- Using HPGe-detector to measure samples of porcelain powder materials

Aim of Research.

Three main aims that make this study particularly important and interesting to radiometric studies. Firstly, it will provides information on the concentration composition of natural and the associated man-made radioactivity of imported dental porcelain materials to be used by most dental laboratories in Great Jamahiriya. Since these materials do not pass radiation inspection before their use and there is large variety of supply source of these dental materials to be used for all dental works on Libyan patients, anomalies can be identified easily. Secondly, the analysis of selective elemental abundance. There are (Th/U, K/U, and K/Th ratios) and dose rate calculations may be used to calculate effective dose rates to dental laboratory technicians and also to the patient who will be using these specific materials.
This research project will provide the first results of such measurements and the corresponding average annual effective dose rates equivalent to the patients using these materials and also to the dental technician and doctors work in the various dental laboratories that make use of these materials in their daily work. Using 30 dental samples collected from a number of dental laboratories around Tripoli area were collected and measured. In this research project the results from this preliminary survey regarding Th, U and K^{40} elemental concentrations in a wide variety of dental materials by means of high-resolution γ–ray spectrometry are presented. Further results from these investigations concerning activity concentrations and the associated dose rates, effective dose and the committed dose due to the use of these materials was calculated and compared with other published data elsewhere and recommendation of their use will be derived accordingly.

Radioactive Compounds in Some Dental Restoration and Porcelain Materials.

It should be brought into the open the question; if the use and concentration of radioactive compounds in dental materials has accelerated during later years. No scientific articles have been found dealing with this subject. However, several patents reveal the use of radioactive compounds in dental restorations .One of the big changes that have taken place within dentistry in recent years is that of the introduction of dental restorations.
Cahn et.al has stressed the fact that ; X-ray opacity is readily achieved by non-radioactive substitutes: “Radiopacity of composites, which is essential for restorations in posterior teeth, is readily achieved by incorporation of Ba, Sr, or Zn in the glass

formulation." [4]. Also another study by Rheinberger .V et.al. reveals in their patent that thorium is used as one such filler [5]: A passage from the British patent GB695278:"A dental cement contains uranium compounds, e.g. uranyl compounds and red coloring materials, e.g. gold oxide, chrome-alumina colours, copper aluminate and manganic oxide, which give the cement an appearance similar to natural teeth both in natural and artificial light" [6] .

Uranium in Dental Porcelain Powders and Dose Induced in Oral Mucosa.

Dental porcelain powders used in Greece have been measured for their radioactivity. The methodology used was mainly based on gamma spectroscopy. In addition, neutron activation analysis and the delayed neutron technique were used in low level radioactivity measurements. The ^{238}U concentration varied from about 3.6 Bq.kg^{-1} up to 5.6 kBq.kg^{-1}. The dose equivalent induced at the surface of oral mucosa ranged from 2.3 mSv per year up to 3.6 Sv per year, respectively. The uranium concentration in the cases examined was lower than the maximum permissible concentration of this element in such materials; that of 6.17 kBq.kg^{-1} (500 ppm) corresponded to a surface dose equivalent of about 4 Sv per year.

Materials and Methods.

At the radiation measurement laboratory of the radiation protection department of the Tajura-Libya Nuclear Research Center, this research project was carried out, a total of 30 samples were measured and their spectra were collected. Using a known standard mixed sources of gamma-ray energies, an energy and efficiency calibration curves were plotted. The best fit line on the calibration curve proved that the Multi Channel Analyzer (MCA) channels all had the same width of energy. The best fit line matched the data with a least squares fit of $R^2 = 1$. Using the 30% efficiency HPGe- detector in which was connected with the MCA using Aptec software, all of the of 28 samples spectra were measured and collected. All of their features, including the main photo peaks of the natural radionuclides were identified and quantified a sample spectrum is shown in Fig 1. The naturally occurring radionuclides considered in the present analysis of the measured γ–ray spectra were: ^{212}Pb (with a main gamma energy at 239keV and a gamma yield of 43.1%), ^{214}Pb (352keV, 37.1%), ^{214}Bi (609keV, 46.1%), ^{228}Ac (911keV, 29%), and ^{40}K (1461keV, 10.7%).

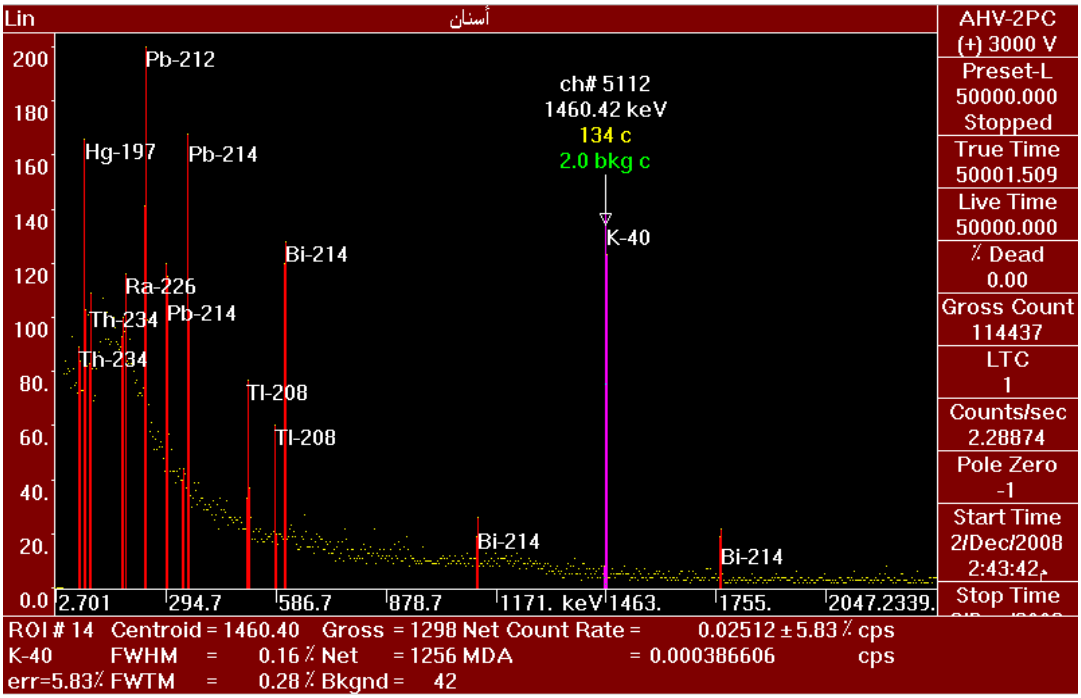

Fig 4.2 Shows the main detected Spectrum and the main peaks from false teeth sample.

Under the assumption that secular equilibrium was reached between ^{232}Th and ^{238}U and their decay products, the concentration of ^{232}Th was determined from the average concentrations of ^{212}Pb and ^{228}Ac in the samples and that of ^{238}U was determined from the average concentrations of the ^{214}Pb and ^{214}Bi decay products (Hamby and Tynybekov, 2000; Tzortzis et al., 2003a). Thus, an estimation of radionuclide concentration of ^{232}Th and ^{238}U was obtained, whereas a direct measurement of ^{40}K concentration was achieved. The environmental gamma-ray background at the laboratory site was determined using an empty similar glass container under identical measurement conditions. From measurements prior, during and after the various samples counting. It was found that the background levels in the laboratory were maintained constant during the whole period of the samples measurements.

Minimum Detectable Activity Calculations..

Depending on the background of the measured spectra, the Minimum Detectable Activity (MDA) was calculated to be 1.0 x10^{-2} *Bq* kg^{-1} for both ^{232}Th and ^{238}U, and 4.0x10^{-2} *Bq* kg^{-1} for ^{40}K, for the counting time of 14 *hours.* From these values, detection limits of 2.5x10^{-3} μ*g* g^{-1}, 8.1x10^{-4}μ*g* g^{-1}, and 1.3μ*g*g^{-1} were derived, for thorium, uranium and potassium elemental concentrations, respectively.

Results and discussion

Considering all samples studied, elemental concentrations of thorium ranged from

2.5x10^{-3} μ*g* g^{-1} to 9.8 μ*g* g^{-1}, from 8.1x10^{-4} μ*g* g^{-1} to 3.2 μ*g* g^{-1} for uranium, and from 1.3x10^{-4} % to 1.9 % for potassium. The arithmetic mean values of the measured elemental concentrations over all samples are: (1.2 ± 1.7) μ*g* g^{-1}, (0.6 ± 0.7)

$\mu g\ g^{-1}$ and (0.4 ± 0.3) %, for thorium, uranium and potassium, respectively, while median values obtained worldwide are 7.4 $\mu g\ g^{-1}$, 2.8$\mu g\ g^{-1}$, and 1.3 %, respectively. The latter mean values are derived by transforming the corresponding worldwide average activity concentrations of 30, 35, and 400 $Bq\ kg^{-1}$ (UNSCEAR 2000 Report) for ^{232}Th, ^{238}U and ^{40}K radionuclides, into Th, U, and K elemental concentrations, respectively.

Conclusions

High-resolution γ–ray spectrometry was used to determine elemental concentrations of the radioactive elements of thorium, uranium, and potassium in a number of 28 dental material samples collected from a number of dental laboratories around Tripoli area. The number of the samples collected can be considered as representative of the imported dental materials to Libya and these sample originated from the various countries and appear to be generally having lower naturally occurring radionuclide concentration. The measured sample were imported from a number of various European countries which has showed varied concentration levels. Further research on more dental material samples is highly recommended in order to direct the importing channels to the countries of the lowest natural radioactivity levels to lower the patient effective doses in the future.

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