Determination of Uranium Concentration In Female And Male Children's Teeth Samples Using Fission Tracks In CR-39 From Different Countries.
Sallama .S.Hummadi
Al–Mustansiriyah University College of Science

Abstract

The aim of this work is to measure the uranium concentration in male and female children's teeth samples collected from different countries. The uranium concentration in teeth samples were measured by using CR-39 track detector. The nuclear reaction is used as a source of nuclear fission fragments is (n ,f) obtained by the bombardment of $^{235}$U with thermal neutrons with flux $(5000 \text{ n cm}^{-2} \text{s}^{-1})$ from (Am-Be) neutron source. The concentration values were calculated by a comparison with standard samples was which prepared. The obtained results show that the concentration is ranging from $(0.3204 \pm 0.06 \text{ ppm})$ in Oman for female to $(0.1965 \pm 0.04 \text{ ppm})$ in UAE for male, the uranium concentration was the highest in Oman for female.

الخلاصة

الهدف من البحث هو قياس تركيز اليورانيوم في نماذج أسنان الأطفال من الذكور والإناث جمعت من دول مختلفة ثم قياس تركيز اليورانيوم في نماذج الأسنان باستخدام تقنية عدثات الإشعاع في كشف الأثر النووي CR-39 الناتجة عن قصف نوى اليورانيوم 235 بالنيترانونوات الحرارية من المصدر بفัญي نيترون (Am-Be) )5000 n cm$^{-2}$s$^{-1}$ وتم تحديد التراكيز بالحسابات المعتمدة على المقارنة مع النماذج القياسية والتي تم تحضيرها في المختبر. النتائج المستحصلة تتبين أن تراكيز اليورانيوم تتراوح ما بين $(0.3204 \pm 0.06 \text{ ppm})$ في دولة عمان وكمان $(0.1965 \pm 0.04 \text{ ppm})$ في الإمارات العربية المتحدة.
Introduction

Radiation is a general term used to describe the emission or transfer of energy, as waves or particles, through the air or other substances. Milliard kinds of radiation are the sun’s rays, microwaves used for cooking in microwave ovens, radar used to track or guide planes, and radiowaves for mobile phones. Ionizing radiation from radioactivity is caused by the disintegration of an extremely small piece of matter known as a nucleus. The nucleus is itself a constituent part of another minute particle known as an atom. All matter is made up of atoms. There are various forms of ionizing radiation depending on the nucleus and form of decay involved:

- alpha particles
- beta particles

There are a number of sources of ionizing radiation and all can interact with the human body to cause damage. Possible damage to the human body by ionizing radiation depends on a number of factors:

- The amount of radiation involved.
- The kind of ionizing radiation which the body is exposed to (alpha, beta, gamma, x-rays).
- Whether the radiation source is inside or outside the body assuming the radiation source is inside the body, in what part of the body the source is located, how long it stays there and the type of organ which absorbs the radiation.

Alpha radiation has very little penetrating power. Materials that emit alpha are already stopped by the skin. But when these materials enter the body through inhalation or swallowing, they may be harmful.

Beta radiation is able to penetrate further through up to 1 or 2cm of tissue. Outside the body materials that emit beta radiation may be harmful to the surface tissue of the body; when such materials enter the body, they may harm the organs in which they are present. Gamma radiation penetrates even further and is able to go straight through the
body. This may harm the organs in the body. X-rays are the same nature as gamma rays and can also affect the organs in the body[1].

**Sources of radiation**

**Natural sources**

Natural sources of radiation are cosmic radiation and terrestrial radiation arising from the decay of naturally occurring radioactive substances.

**Uranium Radiation Exposure**

Human tissue exposed to radiation may develop cancer. The radiation from each of the nuclides present in the uranium decay series affects the human health in a different way, depending on:

- The type of radiation (alpha, beta, gamma) and its decay energies.
- The exposure situation (external, ingestion, or inhalation).
- The behavior of the nuclide inside the human body (depending on its chemistry), in case of ingestion or inhalation.
- The specific radiation sensitivity of the type of tissue exposed.

The activity and composition of the nuclides present may even change with time, due to transportation or migration processes, as well as from decay or ingrowth of nuclides. This is of particular concern, since each of the uranium decay series contains a gaseous member a nuclide of radon. Fifty tons of uranium seep into the rivers and spruits of the west rand every year and simply disappear. Long-term exposure to uranium, just one of a host of heavy metals found in the river systems of the Wonderfontein Spruit, can lead to kidney failure and even cancer but for a long time no one has known what the effects of uranium have had on the people living in the area.[2]

Radioactive elements defined by the number of protons in their nuclei are differentiated from their isotopes. An isotope is formed by the penetration of sub-atomic particles such as neutrons into the nucleus, resulting in a new usually unstable nucleus. These natural radionuclides
are background loads, distributed over great areas. They enter the human body through foodstuffs, drinking water and air. This background level in Germany varies as much as 20%, depending on the geological nature of soils and the altitude of residency (Fig. 1). [2]

Fig (1) represents some naturally occurring radioactive isotopes. [2]

![Diagram of radiation sources]

**Man-made sources**

Man-made sources of radiation contribute a small portion of the average annual dose for a person living in earth. It is mainly found in medicine, which is of beneficial use. In total it contributes 14% of the average annual dose compared with 86% from naturally occurring radioactivity. A number of man's activities involve the use of radioactive materials. The most important of these is the use of radioactive materials for medical applications such as the diagnosis and treatment of cancer patients. Some manufactured goods also contain small radioactive sources, e.g. smoke detectors, energy generation for example nuclear energy production, extraction of oil and natural gas, and burning coal -
also involves the release of small amounts of radioactivity to the environment. There is also a low level of residual radioactivity in the environment from the nuclear bomb tests of the 1950s and 1960s. A severe nuclear accident, like Chernobyl, can add to this man-made radioactivity in the environment. [3]

Medical

There are three ways in which radiation is used in medicine: x-rays, nuclear medicine, radiotherapy. X-rays are used to assess injury by taking pictures of the inside of a person's body. Nuclear medicine introduces radioactive material into the body to diagnose and treat disease. In the treatment of cancer radiotherapy uses radiation to treat the illness. Ionizing radiation is essential in modern medicine; the average annual dose is 0.30 mSv. In order to regulate the amount of radiation used, all medicinal exposures must be justified and can only be carried out if sanctioned by a doctor. In some cases people get exposed to more radiation than others, depending on the disease that is being treated. The doses involved in a chest x-ray can be as low as 0.02 mSv, posing less risk to health than smoking one cigarette. [3]

Solid State Nuclear Track Detector

A solid state nuclear track detector or SSNTD (also known as an etched track detector or a dielectric track detector, DTD) is a sample of a solid material (photographic emulsion, crystal, glass or plastic) exposed to nuclear radiation (neutrons or charged particles, occasionally also gamma rays), etched, and examined microscopically. The tracks of nuclear particles are etched faster than the bulk material, and the size and shape of these tracks yield information about the mass, charge, energy and direction of motion of the particles. The main advantages over other radiation detectors are the detailed information available on individual particles, the persistence of the tracks allowing measurements to be made over long periods of time, and the simple, cheap and robust construction of the detector. [4]

The Basis of Solid State Nuclear Track Detector
Detection is that charged particles damage the detector within nanometers along the track in such a way that the track can be etched many times faster than the undamaged material. Etching, typically for several hours, enlarges the damage to conical pits of micrometer dimensions that can be observed with a microscope. For a given type of particle, the length of the track gives the energy of the particle. The charge can be determined from the etch rate of the track compared to that of the bulk. If the particles enter the surface at normal incidence, the pits are circular, otherwise the ellipticity and orientation of the elliptical pit mouth indicate the direction of incidence. SSNTDs are commonly used to study cosmic rays, long-lived radioactive elements, radon concentration in houses, and the age of geological samples. A material commonly used in SSNTDS is polyallyl diglycol carbonate (PADC), also known as tastrak, CR-39. It is a clear, colorless, rigid plastic with the chemical formula $C_{12}H_{18}O_7$. Etching is usually performed in solutions of caustic alkalis such as sodium hydroxide, often at elevated temperatures for several hours. [5]

**Experimental part:**
The teeth samples were dried then crushed and sieved (2mm diameter). (0.5g) weight of the powdered teeth samples and the standard which prepared of different uranium concentration were pressed into a pellet of (1cm) diameter and (1.5mm) thickness. CR-39 nuclear track detector thickness (1000 μm) and area approximate to ($1 \times 1 \text{ cm}^2$) were used.

**Irradiation Source**

(Am-Be) neutron source with thermal neutrons flux (5x10$^3$ n/ cm$^2$.s) at a distance (5 cm) in paraffin wax was used. It emits fast neutrons from the $(α, n)$ reaction such as:

$$^{9}_{5}\text{Be} + ^4_2\text{He} \rightarrow ^{12}_6\text{C} + ^1_0\text{n} + 5.76 \text{ MeV} \ldots \ldots \ldots (1)$$

This source consists of a rod of (Am-Be) surrounded by a paraffin wax. The paraffin wax is usually used for moderating the fast neutrons to thermal neutrons. The neutron source with flux (5x10$^3$ n/ cm$^2$.s) was used to irradiated the teeth samples. Fig (1)

Fig (1): The irradiation of the detectors and samples to the neutron source [9].
Etchant Solution

After radiation time, detectors were etched by sodium hydroxide solution with (6.25 N) normality which prepared as:

\[ W = W_{eq} \times N \times V \quad \ldots \ldots \quad (2) \]

- \( W \) = the weight of NaOH needed to prepare the given normality.
- \( W_{eq} \) = equivalent weight of NaOH = addition of the atomic weight of Na, O and H = 40.
- \( N \) = normality = 6.25.
- \( V \) = volume of distilled water = 250 ml.

The enchant compartment has a volume of about 250 ml contains the NaOH solution with 6.25 N. This apparatus is closed assembly, except for small vent at the top of the condenser tube, which prevents any change of etchant normality (concentration) during the experiment due to evaporation. The etching was performed at 60°C while the etching time was 6.5 hr. After etching time, the track density or the number of tracks recorded by using an optical microscopes.[6]

**Result and discussion**

325
Track density ($\rho$) were calculated by

$$\text{Track density (\rho) = average of total pits / area of field view}$$

Uranium Concentration in teeth samples ($C_x$) were calculated by

$$C_x = \frac{\rho_x}{\rho_s} = \frac{\rho_s}{\text{Slope}}$$

Where $\frac{\rho_s}{c_s}$ is the slope of the relation between tracks density and uranium concentration (ppm) for standard teeth samples as shown in fig(2).

The present study results were obtained from nine female and male children tooth samples from different countries as shown in Table (1). The results includes the measurements of the uranium concentration for these samples were obtained using solid state nuclear track detector CR-39.

Uranium concentration in male and female children tooth samples from different countries shown in Table (2). The uranium concentration in samples was found to be at the maximum (0.3204 ppm) in Oman female of age 14 years, in contrast, the minimum uranium concentration was (0.1965 ppm) in a UAE male of age 10 years shown in Fig (3).

The world in which we live is a naturally radioactive environment; all matter is made up of 92 elements, some of which are naturally radioactive. This natural radioactivity may be found in rocks, soil, in materials used for building, in foods and liquids that we eat and drink, and in the human body itself. Cosmic radiation, arising from the sun or other galactic bodies, also contributes to natural radiation exposure.

Natural Uranium consists of $^{238}\text{U}$ (99.275%), $^{235}\text{U}$ (0.720%) and $^{234}\text{U}$ (0.005%) with half life ($4.49 \times 10^9$ year) [8]. It is found in nature in different forms, and the human body contains (90 µg) as average result from food chain. About 66% are found in bones and teeth, 16% in the liver, 8% in the kidneys and 10% in other tissues. The average annual intakes of Uranium by adults is estimated to be (460 µg) from ingestion and (0.59 µg) from inhalation [7].

The chief radiological hazard from $^{238}\text{U}$ Natural Uranium consists of $^{238}\text{U}$ (99.275%), $^{235}\text{U}$ (0.720%) and $^{234}\text{U}$ (0.005%) with half life ($4.49 \times 10^9$ year).
It is alpha radiation when inhaled or ingested. Alpha radiation is the most damaging form of ionizing radiation. Whoever, as $^{238}\text{U}$ decays into its daughter products Thorium and Protactinium, both beta and gamma radiations are released, further increasing the radiation burden.[8]

We all have trace amounts of uranium in our bodies and most of this is stored in our bones and teeth. Consequently, the "baby teeth" which children normally loose between age 5 and 12 are very useful specimens for analyzing stored uranium; these teeth can be obtained without any invasive procedure and they are readily stored and transported.

The uranium level in bones was found to change for the age groups tested, an indication of age-specific deposition. The age profile for uranium was comparable to the calcium turn-over rate. Thus, indicating that uranium deposition is probably- in part- dictated by this metabolic process. Showing the role of present uptake of uranium concentration in bones for populations exposed to significant uranium intake [9].

Uranium accumulates in bone, affects bone metabolism in laboratory animals, and when ingested in drinking water increases urinary excretion of calcium and phosphate, important components in the bone structure. Little is known about bone effects of ingested natural uranium in humans.

From the results, it is found that the children more sensitive to radiation than adults, because children are growing more rapidly, there are more cells dividing and a greater opportunity for radiation to disrupt the process. Take into account the differences in the sensitivity due to age and gender. Fetuses are also highly sensitive to radiation. The resulting effects depend on which systems are developing at the time of exposure [10].

Children's milk teeth accumulate heavy metal and radiation in their teeth because of the body's drive to acquire calcium for bone growth. Concentration of uranium in teeth is the only element which varies appreciably with the ages of the samples.

The age dependence of the natural concentration of uranium in the teeth, Uranium concentrations increase at first, then decrease with
increasing age, and therefore cannot be used by themselves to obtain absolute or even relative ages of the samples. The concentration of uranium in teeth with age, but not with sex.[11]

Fig(2): The relation between tracks density and uranium concentration (ppm) for standard teeth samples.

\[ y = 849.2x + 307.5 \]

Table (1): The countries which teeth samples were collected from as shown in table(1).
Fig(3) shows the Uranium concentration in male and female children’s teeth samples.

<table>
<thead>
<tr>
<th>No.</th>
<th>Age year</th>
<th>Gender</th>
<th>Nationality</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>8</td>
<td>Female</td>
<td>UAE</td>
</tr>
<tr>
<td>2</td>
<td>9</td>
<td>Female</td>
<td>Iraq</td>
</tr>
<tr>
<td>3</td>
<td>12</td>
<td>Female</td>
<td>Jordan</td>
</tr>
<tr>
<td>4</td>
<td>12</td>
<td>Female</td>
<td>India</td>
</tr>
<tr>
<td>5</td>
<td>14</td>
<td>Female</td>
<td>Oman</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Model</th>
<th>Age year</th>
<th>$p_x$(tracks/mm²) ± $b$</th>
<th>Uranium concentration ppm</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>8</td>
<td>2196.9 ± 323.8</td>
<td>0.2587 ± 0.03</td>
</tr>
<tr>
<td>2</td>
<td>9</td>
<td>2454.8 ± 400.6</td>
<td>0.2890 ± 0.04</td>
</tr>
<tr>
<td>3</td>
<td>12</td>
<td>2470.7 ± 283.8</td>
<td>0.2909 ± 0.03</td>
</tr>
<tr>
<td>4</td>
<td>12</td>
<td>2637.7 ± 383.9</td>
<td>0.3106 ± 0.04</td>
</tr>
<tr>
<td>5</td>
<td>14</td>
<td>2721.2 ± 550.9</td>
<td>0.3204 ± 0.06</td>
</tr>
<tr>
<td>6</td>
<td>9</td>
<td>2470.7 ± 283.8</td>
<td>0.2909 ± 0.03</td>
</tr>
<tr>
<td>7</td>
<td>10</td>
<td>1719.5 ± 317.1</td>
<td>0.2024 ± 0.03</td>
</tr>
<tr>
<td>8</td>
<td>11</td>
<td>1689.1 ± 267.1</td>
<td>0.1989 ± 0.03</td>
</tr>
<tr>
<td>9</td>
<td>10</td>
<td>1669.4 ± 383.9</td>
<td>0.1965 ± 0.04</td>
</tr>
<tr>
<td>10</td>
<td>10</td>
<td>Male</td>
<td>UAE</td>
</tr>
<tr>
<td>11</td>
<td>11</td>
<td>Male</td>
<td>UAE</td>
</tr>
<tr>
<td>12</td>
<td>10</td>
<td>Male</td>
<td>UAE</td>
</tr>
</tbody>
</table>

Table (2): Uranium concentration in children tooth samples from different countries.
References


