HEALTH PHYSICS ASPECTS OF THE IN-VIVO ANALYSIS OF HUMAN DENTAL ENAMEL BY PROTON ACTIVATION.

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INTRODUCTION.

The technique of fluorine analysis by low energy nuclear reaction has often been described (1, 2) and the application to fluorine concentration determination is now routinely used in various laboratories. Usually the sample is placed in a chamber and maintained under vacuum. This technique was adapted to non-vacuum analysis (3) allowing the handling of the samples at atmospheric pressure, and thus permitting in-vivo analysis of human teeth.

As described in a previous paper (4), the protons, having an initial energy of 3 MeV, emerge in air through a tantalum window in which they lose part of their energy; the distance in air between the foil and the impact point on the surface of the tooth being 0.8 cm. The residual energy of the proton beam is 2.725 MeV at the surface of the enamel and the beam diameter is 2 mm.

When the beam crosses the tantalum foil, X-rays and γ-rays from Ta(p,p'γ) reaction are produced. Other nuclear reactions take place when the protons interact with fluorine, phosphorous, sodium etc... contained in the tooth enamel. A typical spectrum is shown in Fig.1.

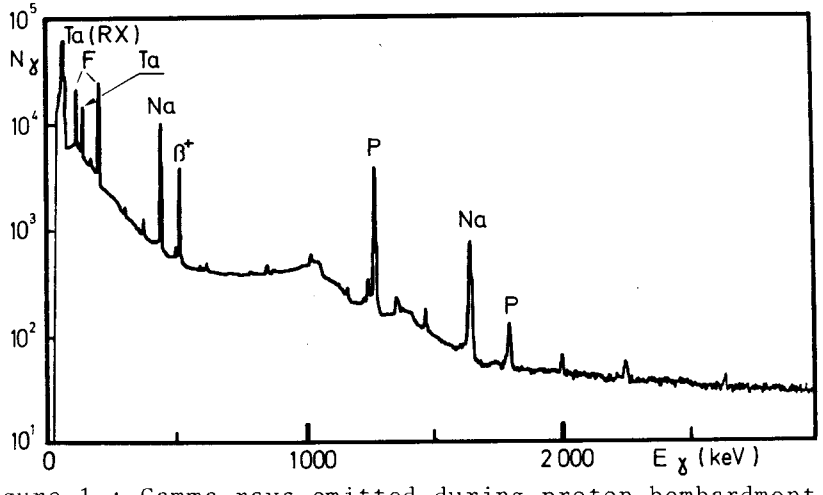

Figure 1 : Gamma-rays emitted during proton bombardment of human teeth and recorded with a Ge(Li) detector.

These γ-rays are used for the determination of the absolute concentrations of these elements in the surface of the tooth. Each measurement takes 1 min, with a beam intensity of 20 nA, which corresponds to a power dissipation of 0.055 W. No heat can be felt by the patient during the bombardment.

The technique of fluorine measurement by prompt activation allows repeated determinations on the same area of tooth enamel both before and after topical application of fluoridated compounds.

EXPERIMENTAL PROCEDURE.

In tooth enamel, ionization, produced by charged particles losing their energy, is very intense over a short range, 30-40 μm. This process can produce local destruction of the enamel and emission of soft X-rays that are completely screened by the tooth and the surrounding frame; hence they are not observable. Neutrons are not observed because the proton energy is below the neutron threshold for the majority of nuclei present in the teeth. Any dose rate is thus due mainly to hard X-rays and γ-rays induced in atomic and nuclear reactions. Due to the short irradiation time, as mentioned above, the dose delivered to the patient is very small : a few μrad. Preliminary measurements have been taken during a 60 min.run made on an extracted tooth to obtain the order of magnitude of the dose around the irradiated tooth. Neutron dose rates were measured with a neutron REM counter (Nuclear Enterprise type NM1), and the dose rate was less than the minimum observable, i.e. 0.1 mrem/hr. To estimate the absorbed dose of gamma-rays, LiF chips were placed around the mouthpiece surrounding the tooth, and an ionization chamber of 500 cm^3 with a tissue equivalent wall of 300 $mg.cm^{-3}$ (Babyline type Nardeux) was used 5 cm behind the beam spot. The dose rate observed with the ionization chamber was less than 1 mrad/hr, but too small to be measured with the LiF chips, indicating that the neutron and γ-ray dose delivered in the mouth area is very small.

To estimate more exactly this very small radiation rate we decided to use $CaSO_4$:Dy chips in longer irradiations on an extracted tooth and to determine the doses to the skin and inside the head, a phantom skull was obtained. This phantom contains a human skull embedded in a tissue-equivalent medium contoured to human features.
This phantom is cut into 2.5 cm slices (Fig.3), and each slice contains drilled holes, arranged in a matrix, which are capable of holding the TLD dosimeters.

Figure 2 shows the energy dependance of the $CaSO_4$:Dy teflon disks (0.4 mm thick), including a correction to take into account the energy spread of the gamma-ray spectrum.

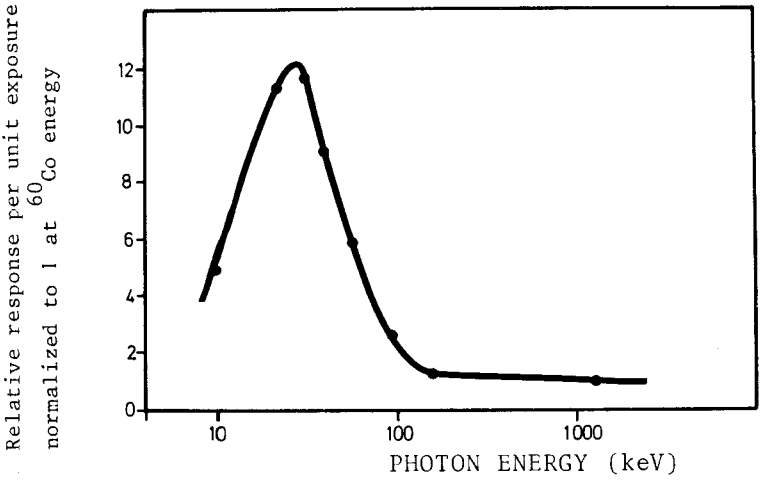

Figure 2 : Energy dependance of the $CaSO_4$:Dy teflon disks

Table 1 summarizes the percentage of the total photon yield for various energy intervals.

TABLE 1 : Percentage of photons emitted during the fluorine determination versus energy.

Energy (keV)	Mains origins of the photons	Percentage normalized to 100 for the entire spectrum.
10-100	Ta X-rays and Compton γ-rays	97.2 %
100-200	γ-rays from Na and F	1.6 %
200-1000	γ-rays from Na and β^+ annihilation	0.5 %
1000-2000	γ-rays from Na and P	0.4 %
2000-8000	high energy γ-rays from F	0.3 %

The calibrated TLD dosimeters were placed in the matrix at appropriate levels of the head which was then placed in the same position as the patient for an 8 hr irradiation under identical experimental conditions.
For each slice, a map of the exposure data was obtained. This data is presented in Figure 3, where the doses (in µrad) correspond to those which would be received after a 1 min. irradiation time.

SUMMARY.

The health physics aspects of the in-vivo analysis of human dental enamel by fast proton activation have been studied. Doses to the head including surface skin and in-

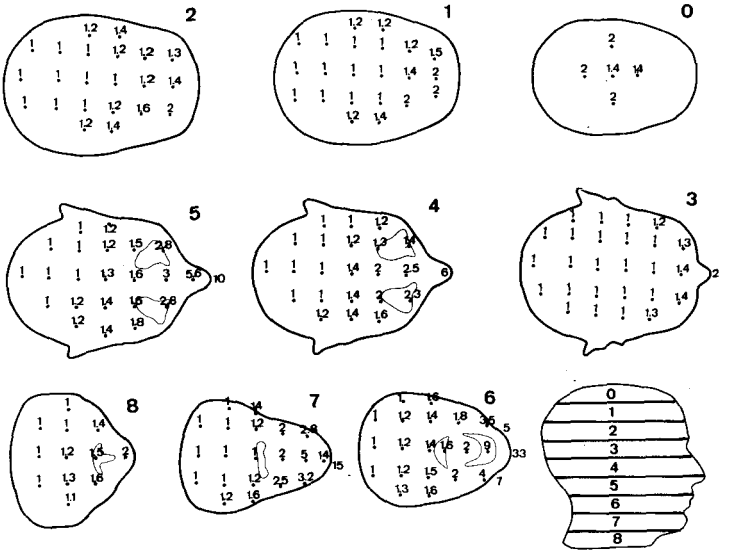

Figure 3 : Doses, in micro-rad, received by the patient during the in-vivo analysis (corresponding to 1 min. irradiation time).

terior regions of the brain and mouth were determined using TLD materials in a phantom head. The maximum dose to the head occurs on the right part of the lips and is of the order of 30µrad. In the mouth, behind the tooth analysed, the average dose is 10µrad, and the average over the whole head is of the order of 1µrad; this is twice the dose received by personnel who spend the same period of time in the counting room a considerable distance from the beam line.

As shown in a previous paper (4) no residual destruction has been found in the first 30µm of the enamel, which is the total range of the 2.7 MeV protons penetrating hydroxyapatite. Indeed, even more than 2 years after in-vivo analysis, there is no apparent destruction of tooth enamel.

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