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SEMI-EMPIRICAL MODEL TO DETERMINE PURE β^--EMITTERS IN CLOSED WASTE PACKAGES USING BREMSSTRAHLUNG RADIATION

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Medical establishments and research laboratories use many different type of radionuclides for diagnostic, therapeutic and research purposes. As a final by product large amount of medical waste are produced. This waste represents both biological and radiation hazards, therefore it requires special treatments in both point of view. Biomedical waste is usually best managed on site by decay storage, with minimal transport risk and ALARA (as low as reasonably achieved) exposure levels.

The nuclear medical waste has characteristics fundamentally different from the nuclear fuel cycle waste. In medical practice radioactive material is used both in sealed and unsealed form, but major part of the medical waste is produced by using unsealed isotopes of relatively short half-life in most cases less than 100 days and of low specific activity. There are gamma-emitter, positron-emitter and pure beta-emitter among these isotopes. The positron-emitter isotopes have usually less than 2 hours half-life; therefore they do not contribute too much to the volume of the radioactive waste since they decay rapidly. Among the γ- and pure β^--emitters there are isotopes with half-life from seconds to several hundred days. Waste containing isotopes with longer half-life contributes mainly to that large volume of waste produced regularly at biomedical sites.

On site decay storage requires accurate determination of activity levels. Since quantitative estimation of isotope activity can be difficult where waste packages contain a mixed combination of β^--γ-emitters, segregation at the time of waste production is essential.
Accurate identification and quantitative measurement of γ-emitter isotopes is possible with a large volume, reverse electrode, high purity germanium detector even those cases when the isotope emits only low energy gamma photons. However, there is problem with the pure β^- emitting isotopes to measure. In biological healthcare and pharmaceutical research a range of unsealed pure β^--emitting isotopes are applied. The ^{3}H, ^{35}S, ^{32}P and ^{33}P are widely used for DNA sequencing studies. Also large amount of ^{3}H and ^{14}C are used in organic compound synthesis resulting in long-lived low-level radioactive waste. The β^--particles can be detected by beta counter but it is not applicable in the case of closed waste packages, since the β^--particles loss their energy quickly and they are not capable to escape from the sealed waste package. The emitted β^--particles have continuous energy spectrum and no direct gamma radiation follow the decay. The only means of detection of these β^--particles is through the bremsstrahlung radiation produced while the particle slows down. The cross section of the bremsstrahlung generation process depends on the initial energy of the slowing down β^--particles and is proportional to the atomic density n and the average Z^2 of the waste matrix.

$$\sigma \approx nZ^2 E(\beta)$$

The probability of this process is much lower than that of the ionisation process for beta particles but it is still high enough to produce measurable amounts of photons.

We studied the ^{35}S and ^{32}P pure β^--emitter sources in sealed waste packages. The continuous nature of the bremsstrahlung radiation prevents us using the "full-energy photo peak area" method. Instead a Region of Interest (ROI) was defined. Unlike for the full-energy photo peak method where the detector efficiency is calculated in the function of energy, for pure β^--emitters an optimised ROI was defined in the spectrum and a special efficiency, *eps*beta(E)* was determined.

$$eps*beta(E) = \varepsilon(E)_{abs}\, \varepsilon(E)_{geom}\, \varepsilon(E)_{att}\, \varepsilon(E)_{scat}\, \beta(E)_{bs}$$

The used geometry and the nature of the waste matrix requires time consuming efficiency calibrations of the detector system to be able to establish an efficiency - (matrix density, geometry, matrix composition, activity distribution) function. We studied experimentally the possible deviations of the *eps*beta(E)* function in case of non uniform activity distribution in order to be able to model the associated error in the measured activity for a certain isotope. On the basis of experiences we gathered a semi-empirical model was set up to establish the *eps*beta(E)* detector efficiency function to measure pure beta activity in sealed waste packages through bremsstrahlung radiation.

The model is based on the following criteria :
- Only one type of β^--emitter isotope is allowed in one waste package.
- Uniform activity distribution is supposed inside the waste drum.
- Constant waste matrix composition is assumed for each waste drum.
- Each component of the matrix material is supposed to be evenly distributed over the whole volume of the waste drum.

Some partial results are shown in figure 1, which compares the experimental results measured for ^{32}P isotope with the calculated ones using a reverse electrode Ge detector system.

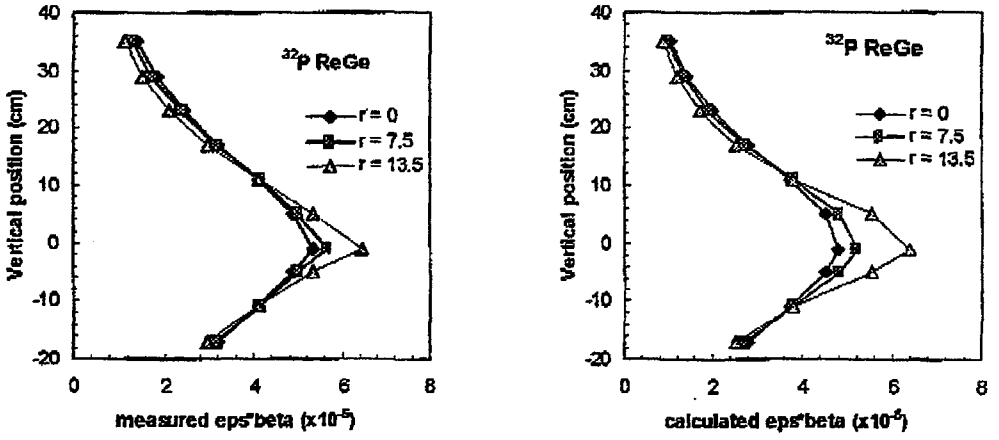

FIG. 1. Measured and calculated efficiency for high purity Ge detector and ^{32}P isotope in the function of geometry relative to the detector plane and rotating radius of the waste drum.