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THE IN VIVO MEASUREMENT OF LEFT KIDNEY CADMIUM CONTENT BY NEUTRON- CAPTURE PROMPT- GAMMA RAY ANALYSIS

H. SEVİMLİ

Ankara Nuclear Research and Training Center,
Beşevler - Ankara

ABSTRACT

5 Ci ^{238}Pu-Be isotopic neutron source was used for in-vivo measurement of cadmium concentration of left kidney. Cadmium is a highly toxic and non-essential heavy metal. The applied method involves the activation of left kidney cadmium with thermal neutrons and counting the characteristic 559 keV prompt-capture gamma rays from ^{113}Cd using a well shielded Ge(Li) dedector. Cadmium content of normal kidney tissue is 10-30 ppm (1,5-4,5 mg total) and in this work detection limit was found as 125 ppm (16,2 mg total).

ÖZET

5 Ci ^{238}Pu-Be izotopik nötron kaynağı kullanılarak sol böbrekte in-vivo kadmiyum ölçümü yapılmıştır. Termal nötron aktivasyonu esnasında oluşan 559 keV enerjili ani gamaların sayımı Ge(Li) dedektörü ile yapılmıştır. Kadmiyumun böbrekteki normal seviyesi 10-30 ppm (1,5-4,5 mg toplam), dedeksiyon limiti 125 ppm olarak bulunmuştur ki bu da endüstri işçilerinde rastlanan seviyedir.

INTRODUCTION

Cadmium is a by-product of zinc production and there are no areas being mined and processed exclusively for cadmium.

Cadmium is mainly used in electroplating industry and other important uses include alloys, pigments, batteries and plastic stabiliser, all of which account for approximately 90 % of cadmium produced. The minor applications include fungicides, rubber additives, phosphorus of T.V. tubes and nuclear reactor components.

Cadmium is not found in the tissues of infants but

accumulates gradually throughout the life. This accumulation may be the result of air contamination, of cadmium in the diet (principal food sources are liver and shellfish), and of smoking cigarette. Approximately half of the total cadmium absorbed is concentrated in the liver and kidneys where it is bound to a specific protein and excreted very slowly. Normal liver and kidney tissue contains 1-5 ppm and 10-30 ppm cadmium respectively /1/.

Since cadmium is released very slowly from the organs, measurements of blood and urine levels are poor indices of long term exposure and correlate poorly with clinical symptoms /2/. A measurement of storage organ concentrations could be expected to be a more realistic index of exposure and provide a better correlation with symptoms.

Mc Lellan, et al. suggested the possibility of utilization of an isotopic neutron source for the measurement of organ cadmium /3/. They designed a portable system in order to permit measurement of industrial workers at their place of employment. They described the performance of such a portable system utilizing a 10 Ci ^{238}Pu-Be neutron source. Some facilities were developed for measurement of kidney and liver cadmium with the use up to 85 Ci ^{238}Pu-Be neutron source /4,5/.

EXPERIMENTAL

The technique utilizes the measurement of 559 keV gamma rays, emitted promptly under slow neutron capture by ^{113}Cd (12,3 % isotopic abundance). The yield of this gamma ray is 80 per 100 neutron captures in natural cadmium /6/.

A neutron howitzer containing 5 Ci ^{238}Pu-Be (10^7 neutron/s) had already been constructed as multipurpose irradiation system (Fig. 1). The neutron source is located in water with an aluminum tube and it can be rotated in the howitzer. This portable system was used for the measurement of left kidney cadmium.

A 40 x 30 x 20 cm plexiglass trunk-like phantom was filled with water /7/; kidney like phantom was filled with 500 ppm cadmium solution $(CdNO_3)_2$ and positioned within the trunk-like phantom as left kidney. The phantom was placed for irradiation.

Thermal neutron flux on the body phantom was measured as 10^3 neutron/cm^2.s by using gold foil with a cadmium foil.

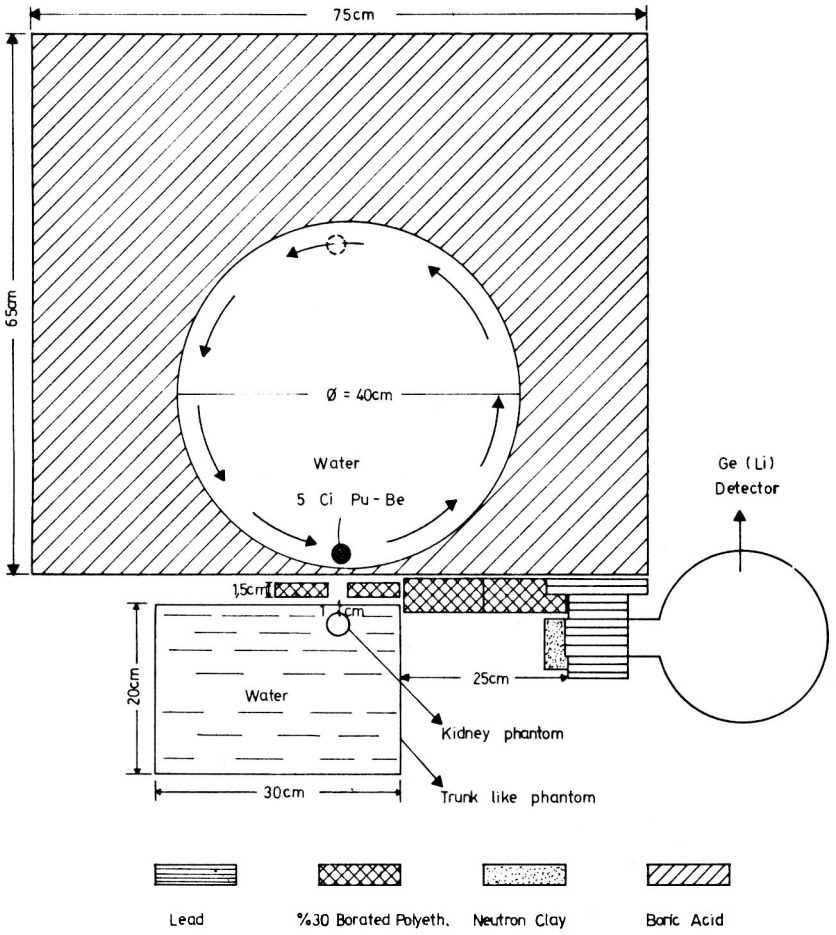

Fig. 1. Irradiation and detection facility.

The gamma ray detection system consists of a horizontal Ge(Li) detector (efficiency 10 %, 51 cm^3) coupled to multichannel analyzer.

After obtaining the best shielding position of the detector, the concentration of cadmium was decreased step by step (Fig. 2). Duration of measurement was 2000 s. A typical spectrum containing 250 ppm cadmium is shown in Fig. 3. The observed 569 keV peak from ^{207m}Pb did not show any serious effect on the spectrum.

RESULTS AND CONCLUSION

Fig. 2 shows the relationship between the number of counts and Cd concentration in left kidney. The reproducibility of the measurement was 5 %.

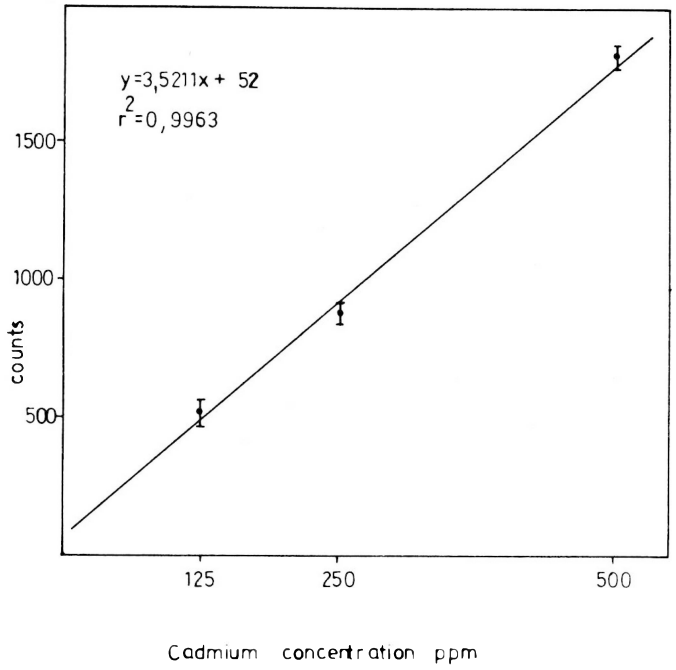

Fig. 2. Number of 559 keV Cd promt gamma rays against Cd concentration in the left kidney.

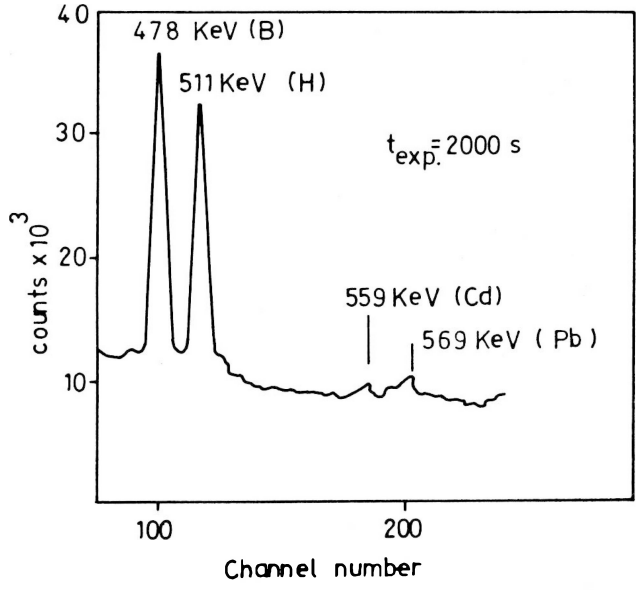

Fig. 3. Prompt gamma ray spectrum of kidney phantom containing 250 ppm Cd.

The detection limit found as 125 ppm was comparable with the highest value of 300 ppm which is quoted in the literature for the workers exposed to cadmium /8/. The level of cadmium detectable with our apparatus is so far from normal range if compared with other studies (Table-1). This is due to our source intensity and using one detector.

TABLE-1. Comparison of the detection limits.

Reference	Source	Detection limit (mg)	Dose Rate
/4/	85 Ci ^{238}Pu-Be	2,5	1,2 rem/h
/5/	200 µg ^{252}Cf	5	0,07 rad
This work	5 Ci ^{238}Pu-Be	16,2	-

Due to the lack of tissue-equivalent liquid (Table-2) dosimetry measurement was not performed in this work. Though, considering the results of previous studies (Table-1), it can be concluded that dose rate could be expected under the reported value.

TABLE-2. The composition of the tissue-equivalent liquid.

Composition	% (by weight)
NaCl	0,4
$K_2S_2O_8$	0,8
$CaHPO_4$	1
Urea	7,8
Glycerol	22
H_2O	68

The interferences of right kidney and liver are not observed in the measurement of left kidney and the Cd measurement is independent of concentration distribution within the kidney /4/.

The limit of detection is imposed by count rate, background and dose. The cyclotron base measurements have the advantages that the neutron source can be pulsed to reduce background counts arising from neutron

related events, that the source to subject distance is relatively long (3 m) which allows space for good collimation and shielding system and dose rate is high enough to permit doses of about 0,5 rem (5 mSv) to be delivered in reasonable measurement times /9/.

The measurement of cadmium in liver has also been tried by the use of a liver phantom (20 x 10 x 10 cm) containing 4,7 g phosphorus. But due to the interference of 558 keV prompt gamma rays of phosphorus (3.77 prompt gamma rays per 100 neutron captured) Cd could not be observed.

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