# THE BACKGROUND OF IN-VIVO MEASUREMENT AND THE SELF-COMPENSATION METHOD

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## INTRODUCTION

The objective of this study is to solve the background problem in whole body counting(WBC), especially for these nuclides emitting low energy gamma rays. We have examined that where does various background in in-vivo measurement come from and how to eliminate them. The history of reduction and subtract methods for WBC background is developing gradually. At first screening the subject and the detector in a lead chamber, and subtracting the background of equipment, then subtracting the background of phanton, recently using control person and appropriate detector. Even if one carefully choose control person whose height, weight and potassium-40 content are similar to a subject, the results of subtraction is rarely satisfactory. The radiation irradiated from the naturally occurring radionuclides or contaminated source in the subject or control person is scattered by his own body and degraded its energy, but only a part of scattered radiation with same energy as the radiation being detected is taken as background. The reason is that human body is very complicat, same source strength does not mean it would have same amount of low energy scattering radiation, and any detector can not distinguish the rays with same energy but different sources. We have developed a new subtraction method taking a part of the in-vivo spectuum as a compensation term.

## ANALYSIS

Suppose a subject with internal contamination of $A_S$ Bq. radionuclide S emitting gamma ray with energy $E_S$. In a given WBC equipment the measured energy spectrum can represent as

$$A_S\cdot\eta\cdot F(E_s,E_x,B_i$$

where $\eta$ is a transfer factor, the counts per minute due to 1 Bq. of radionuclide S, with similar distribution in body, at ideal condition, i.e. there is no any scattering by body tissue or orgin. F is characteristic function of energy spectrum, it is dependent on ray's initial energy $E_s$, emitting energy $E_x$ and human body factors $B_i$, such as height, weight, muscle thickness, fat proportion, relative position of different tissues density and the distrabution of nuclide S in the body. The function always express as follows:

$$F(E_S,E_x,B_i)=\begin{cases}0 & \text{when } E_x>E_s\\ 1-\Delta & \quad\;\; E_x=E_s\\ \Delta_x(E_x) & \quad\;\; E_x<E_s\end{cases}\qquad(1)$$

where $\Delta$ is the decrease fraction of the primary ray, while it emit out the body. $\Delta_x$ is the low energy gamma ray fraction, which is a succesive scattering spectrum and as a function of $E_x$.

If D is the measured nuclide, its gamma ray energy $E_d$, activity $A_d$, and S is a nature radionuclide, $E_s>E_d$. The energy $E_d$ is detected in energy range $E_1$ to $E_2$. Then the counting rate M in this range is

$$M=\int_{E_1}^{E_2}(A_s\eta F_s+A_d\eta F_d)\,dE_x=\int_{E_1}^{E_2}A_s\eta\Delta_x dE_x+\int_{E_1}^{E_2}A_d\eta(1-\Delta_d)\,dE_x\qquad(2)$$

The first term in Eq.(2) is the background due to S, only the second term is just the demanded quantity.

The criterion for choosing control person is that whose S content approximates to the subject. That means the both terms:

$$\int_{E_s-\delta}^{E_s+\delta}A_s\eta F_s dE_x=\int_{E_s-\delta}^{E_s+\delta}A_s\eta(1-\Delta)\,dE_x\qquad(3)$$

are equal. Even if $\Delta$ greatly vary, the variation of $(1-\Delta)$ may be notobviously, while $\Delta$ is small, it is in general much less than 1. The variation of $\Delta_x$ is greater than that of $\Delta$ , and $\Delta_x$ is a factor in background term of Eq.(2). This is the reason why same $A_s$ can not obtain similar background in the $E_1$ to $E_2$ range.

## SELF-COMPENSATION METHOD

Beside the characteristic energy range $E_1$ to $E_2$ of nuclide D, we take another energy range $E_3$ to $E_4$, $E_3$ is larger than $E_2$ but much less than $E_s$. The counts in $E_3$ to $E_4$ range is:

$$\int_{E_3}^{E_4}(A_s\eta F_s+A_d\eta F_d)dE_x=\int_{E_3}^{E_4}A_s\eta\Delta_x dE_x \tag{4}$$

This is quite like the background term of Eq.(2). If $E_3,E_4$ is very near $E_1,E_2$, the difference between $\Delta_x$ in these two range might be very small. It is reasonable to use Eq.(4) to compensate Eq.(2), then we have

$$M_c=\int_{E_1}^{E_2}A_s\eta\Delta_x dE_x+\int_{E_1}^{E_2}A_d\eta(1-\Delta_d)dEx-K\int_{E_3}^{E_4}A_s\eta\Delta_x dE_x \tag{5}$$

where K is the compensation constant, which can be determined in following method.

For non-contaminated person $A_d=0$, then Eq.(5) becomes

$$M_c^0=\int_{E_1}^{E_2}A_s\eta\Delta_x dE_x-K\int_{E_3}^{E_4}A_s\eta\Delta_x dE_x\equiv 0 \tag{6}$$

These two integrals are measurable, so that the K is solved. In practice, K is statistically determined by a lot of ordinary persons.

## APPLICATION

We have measured lead-210 in skull for five tin miners and nine ordinary non-contaminated men. The spectrum data are treated by four methods for comparison.

(1) Counts in the range of $E_1$ to $E_2$ of miner is subtract by counts in same range of control person.

(2) Same as (1) but only take the counts in the peak area.

(3) Constant slope method: the slope is determined by $N(E_3)$ and $N(E_4)$ in the spectrum, then only the upside counts in range of $E_1$ to $E_2$ are taken into account.

(4) The self-compensation method as mentioned above.

The results of ordinary men are given in Table 1. The perceptibility is more or less like the concept of minimum detectable activity but with a definite coefficient. The miners' data are given in Table 2, the values in Table 2 are in unit of perceptibility. The data in these two tables show that the proposed method gets best effect.

Table 1 Ordinary men's data (in counts per 30 minutes)

| | | Method (1) | (2) | (3) | (4) |
|---|---|---|---|---|---|
| **Mean value** | $\bar{N}$ | 217 | -3.9 | -920.6 | 0 |
| Standard deviation | s | 20.25 | 18.99 | 661.5 | 18.74 |
| Perceptibility | Definition | $2\sqrt{2}\,\sigma$ | $2\sqrt{2}\,\sigma$ | $2\sigma$ | $2\sigma$ |
| | Value | 57.3 | 53.7 | 1223. | 37.5 |
| | Equivalent value* (Bq) | 6.1 | 5.7 | 129.6 | 4.0 |

*This value is equivalent to that obtained at following condition, two detectors, measuring time of 120 minutes with a calibration factor 9 Bq./cpm.

Table 2 Miners' data (in perceptibility)

| Number | Total measuring time (min.) | Analysis method (1) | (2) | (3) | (4) |
|---|---|---|---|---|---|
| $M_1$ | 60 | 1.5 | 1.3 | -1.3 | 2.8 |
| | 345 | 2.9 | 3.6 | -2.1 | 6.5 |
| $M_2$ | 155 | 0.3 | -0.4 | -1.5 | 0.1 |
| $M_3$ | 60 | -0.3 | 0.2 | -0.3 | -0.2 |
| | 150 | 0.9 | 0.7 | -0.7 | 0.4 |
| $M_4$ | 150 | -0.5 | 0.8 | -1.9 | 0.4 |
| $M_5$ | 60 | 0.1 | 0.7 | -0.7 | 1.1 |
| | 150 | 1.2 | 0.9 | -1.4 | 1.9 |