PARAMETERS AFFECTING DETECTION EFFICIENCY AND RESPONSE FOR γ-EMITTERS IN WHOLE BODY COUNTERS

Thesis Submitted

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ABSTRACT

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Due to the wide use of radioisotopes in industry, medicine , agriculture and other various fields of science and technology, it is probable to result in internal contamination of users involved. Thus, it is required to perform periodic checks for radioisotope workers to have an early indication of any contamination, in order to take relevant protective measurs. The whole Body Counter (WBC) is considered to be essential in estimating internal contamination of γ-emitters.

The main objective of this thesis is to investigate certain physical parameters which affect performance of WBC, namely; efficiency and geometrical response, with the eventual purpose of establishing a design for WBC of high efficiency and uniform response.

To accomplish this objective, all parameters affecting detection efficiency and relative response* are investigated in case of one detector with respect to a point source moving in air and in a standard lung phantom. The lung is chosen for this study since it represents a large organ where nonuniformities in detection efficiency could appear clearly.

Detection efficiency and relative response are calculated as a function of :

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* Detection efficiency for the moving source normalized to that with the source in the middle of the lung phantom.

1- Height of a point source from crystal surface :

It is found that detection efficiency decreases as height increases and relative response improves when increasing that distance.

2- Dimension of the crystal :

a- with the crystal thickness fixed
Results indicate that both detection efficiency and relative response improve, gradually with increasing crystal radius.

b- with the crystal radius fixed
Results indicate that both detection efficiency and relative response improve by increasing the crystal thickness.

3- Medium around the source (air or phantom) :

The results show reduction in both detection efficiency and uniformity of relative response as attenuation coefficient of surrounding medium is increased.

4- Number of detectors :

It is found that increasing number of detectors results in marked increase in detection efficiency and slight improvement in relative response. Detection efficiency as well as relative response are computed for several detectors reaching up to eight distributed in different geometries arround the standard lung phantom.

Results show that efficiency increases by increasing number of detectors and the nonuniformity in reasponse could reach up to 300% for a one detector system. The largest variation in relative response is for the point source positioned in the preferal parts of the phantom.

To acheive a uniform relative response a suitable collimator could be attached to each detector to attenuate photons comming from source when positianed in preferal parts of phantom. Investigations are carried out for a system of four NaI crystal each of 20 ∅ and 10 cm thickness surrounded by lead collimator of the same diameter and having 4 cm thickness.

In another arrangement the collimator used is rectangular and it is found that rectangular collimator has a prevelage in making the response uniform for all positions of point source inside standard lung phantom.

Practicaly estimation of lung contamination is performed with detectors fixed with respect to lung, meanwhile, detection of whole body internal contamination is carried out using whole system in the scan technique.

The computed results indicate that increasing the scan distance reduces detection efficiency but gives more uniformity of relative response. However an optimum scanning distance is found to be 200 cm where relative error arising from length of human body is smaller than that arising from body thickness. An overall error from that optimum scanning distance is found to be about 25% and mainly due to human body thickness.

The investigation led to the design of a WBC composed of four 20 Ø x 10 cm detectors attached to four lead collimators which has a good efficiency and uniform response. This system can be used in a fixed position for the measurement of organ contamination, and in scan geometry, for measurement of whole body contamination.

CHAPTER ONE

CHAPTER 1

INTRODUCTION

1.1 General :

The development of nuclear physics has taken its starting point from the discovery of natural radioactivity.

In 1895 ROENTGEN has discovered the new type of radiation namely, the x-ray. One year later, 1896 in Paris, it was by that BECQUEREL was led to detect the atomic radiation. His aim at first was to study phosphorescence of uranium salts after that he discovered the potential hazards of ionizing radiation few years after its discovery.

Atoms when they emit radiation by themselves are called natural radioactive, while those which do not emit any are called stable atoms. One can excite the atomic nucleus by an outer projectile directed to it and the nucleus thus sends out a certain type of radiation. The hazards of this radiation were, first recognized in 1920 and consequently the necessary protective measures for controlling these ionizing radiation were considered.

Various means and methods have been employed to control personal external and internal exposure to ionizing radiation. Control of internal contamination of man can be performed indirectly througth the measurement of radioactivity of excreta[1] or by direct assessment when the isotope involved emits gamma rays. Internal contamination by beta emitters in sufficient quantities can also be measured directly through the produced bremsstrablung radiation[2,3].

Internal contamination can be due to the entry of radioactive material through ingestion, inhalation or wounds. It can also be due to activation of human body itself by its exposure to an external flux of particles which have enough energy to initiate nuclear reactions in the body materials. For example fast neutrons thermalized in the human body can produce this type of activation to the sodium 23 atoms present in the blood producing mainly ^{24}Na ($^{23}Na(n,\gamma)^{24}Na$)reaction [4,5].

Different instruments have been developed for the direct assessment of gamma emitters present in man these are known by whole body monitors. Types of human body monitors vary according to the purpose of their use. The detection system of whole-body monitor should be able to measure amounts far below the maximum permissible limit and to differentiate between these different materials.

Modern whole body counters are capable to measure and assess the concentration of naturally existing radionuclides[6,7] present in man such as ^{40}K.

1.1-2 Historical review of whole body counters :-

Schlundt (1929) made the first measurment by using two litre ionization chamber 30 cm a part from the subject which was lying in supine position. He was able to measure a quantity of radioactivity in amounts ranging from 5 to 100 mg radium equivalent[8].

He took into consideration the geometry of the human body and its self-absorption by inserting sealed radon ampoules in a phantom representing the real distribution pattern of radium in human body.

Evans (1937) used a single Giger Muller Counting tube at one meter from the subject present in the arc geometery. The minimum detectable activity was 0.1 mg radium equivalent Rajewsky (1940) developed an ionization chamber of 10 litre capacity which was able to detect radium deposits of 0.1 m Ci , the apparatus could be moved along three coordinates at right angles to each ather[9], do its was possible to detect the localized radium deposit in the patient's body .

Rajewsky and Dreblow (1941) used the so called gamma -ray measurment[10] which was able to detect the position of radium deposit in the body. The sensitivity of this device was sufficient to detect amounts of radium as low as 0.1 Ci from 20 centimeters distance and for 20 minutes measuring time.