STUDY OF THE FACTORS AFFECTING THE ISODOSE CURVES OF GAMMA RADIATION

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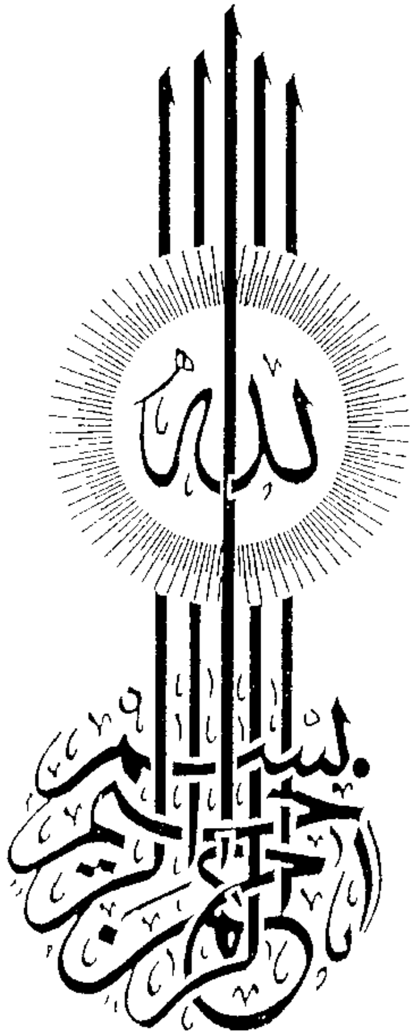
بسم الله الرحمن الرحيم

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II. CHAPTER 1

INTRODUCTION AND LITERATURE SURVEY

1.1. General Introduction and Aim of Work :

The use of physical phantoms of homogeneous composition was the mild stone in the development of physical and clinical dosimetry. However, with the development of dose measurement apparatus it was found that descriptancies between physical measurements in homogeneous phantoms and in the body of the patient exist. It was realised later that such differences are related to the anatomical and heterogeneous composition of the various sections of the body, for example the chest is composed of bones, air and soft tissues.

Various attempts at constructing phantoms of almost similar composition as that of the human body were attempted. Various correction factors for inhomogeneity has been calculated and measured by different authors in the last three decades [[illegible] Graeme et al., ([illegible]), [illegible] et al., ([illegible]), Massey ([illegible]), Stewart ([illegible]), Jones ([illegible]), and [illegible] (1957)].

The aim of the work is to study and compare results of the Central Axis Depth Dose in homogeneous and heterogeneous phantoms using two different qualities of monochromatic beams, namely cobalt-60 and caesium-137 sources. Furthermore, studying the effects of various volumes of human tissues, bone and air incorporated in the homogeneous phantom on the values of Central Axis Depth Dose (CADD).

1.2. Literature Survey, Dosimetry :

The first attempt of measuring ionizing radiations was made by Dorn in 1897, using a thermocouple for direct energy determination. The Gradines (1900) carried out numerous measurements on "The absorbability of Roentgen rays" using a modified version of the penetrameter described by Roentgen himself in 1897.

Holzknech (1902) described his chromoradiometer based on the photo-chemical effect of Roentgen rays on a mixture of potassium chloride and sodium carbonate. Lord Blyths Wood and Ascoble (19[illegible], 1[illegible]) made what appeared to be the earliest detailed study of the intensity of X-rays. Von Laue in 1912 discovered the X-ray diffraction which at last permitted measurement of the wavelengths of the radiation.

Many different physical effects of ionizing radiations were used in X-ray measurements. These are calorimetric; chemical; photographic, solid state coloration and fluorescence effects. In the early times of radiotherapy, the biological effect of ionizing radiations was used to measure radiations using the erythma skin dose (Selizui; 1916). This method was considered to be an emperical method as it depends on many biological variables in the skin as well as on personal factors. However, it was a very useful method in clinical practice.

The interaction of ionizing radiations with matter produces many chemical effects. Furthermore, a number of these effects have been, and are being, used in dosimetry.

Perhaps the best known chemical effect of radiation is the blackening of a photographic film-indicator using a certain type of glass which fluorescens when exposed to ionizing radiations. Certain materials have been developed which show changes in their electrical resistances when exposed to ionizing radiations, and this change in resistance may be used to measure radiations.

The chemical action of ionizing radiations may produce and yield certain chemicals by means of which radiation doses can be measured. The chemical dosimeter used in the early days of radiotherapy was the Pastille Saboroud dosimeter which was made of barium platinum cyanide. The colour of this compound changes from pale green to brown as the dose absorbed by it is increased.

In an attempt to establish a unit of ionizing radiation dose, Son (1925) suggested in the first International Congress of Radiology (I.C.R.U.) a unit of radiation dose measured by the free air-chamber. This unit, called the Roentgen, is defined as follows :- "The quantity of X-radiation which when the secondary electrons are fully utilized and the wall effect of the chamber avoided; produces, in one cm^3 of atmospheric air at 0°C and 76 cm Hg pressure, one e.s.u. of charge of either sign.

The late twenties and thirties of this century were the golden years of radiological physics. In a single decade, radiation dosimetry was transformed from a patchwork of facts and fancies into a coherent measured data and technological development.

Dosimetry was placed on a sound technical basis by the construction of the standard free-air chambers. Since the theory as well as the practice of air wall cavity ionization chambers were developed; reliable measurements of dose distribution in X-ray beams were made. (Cohen, 1972).

The quantity of radiation exposure dose in which the Roentgen was used, has been re-defined in 1938 as follows :

"The quantity of X- and gamma radiations such that the associated corpuscular emission per 0.001293 gm of air; produces ions carrying 1 e.s.u. of quantity of electricity of either sign". The definition of the Roentgen makes it impossible to measure radiation if the beam has an energy of more than 3 MeV., furthermore it lends itself only to the measurement of electromagnetic radiations neglecting its use for dose measurement of particles such as electrons; protons and neutrons. As a result of such limitations, a new unit of dose radiation was established in 1956.

The Roentgen was considered as the unit of exposure dose and a new radiation dose, the unit of radiation absorbed dose or the RAD was established.

Undoubtedly the fifties was the decade of rapid progress in radiological physics. The dominating factor was the availability of radioactive ^{60}Co for teletherapy and ^{131}I and many other radionuclides for clinical use.

During the sixties, high energy particle accelerators and digital computers were used and the decade was repeated for the development of non-ionizing radiation dosimetry.

Alternative means of dosimetry ranging from calorimeters for the absolute deterlination of absorbed dose; to thermoluminescent rods and discs for clinical measurements were developed.

Virtually every aspect of the solid state as well as the chemical changes in the liquid state were explored for dosimetric purposes. The beginning of this decade earmarked the application of many of these methods which were hailed as major "breakthroughs" but by the end of the same decade, they had mostly become of limited value; and the ionization chamber remained the supreme method of clinical dosimetry.

1.3. <u>Physical Dosimetry</u> :

Once the physical unit of radiation quantity, the Roentgen; had been formally defined and adopted in 1928, physicists set to work to realize the new unit. This entailed the design and construction of "free-air ionization chamber"; such that a direct relationship could be established between the primary volume of air irradiated and the electric charge collected. These chambers were developed in central laboratories.

Late in 192[illegible] Kaye and Binks developed parallel plate free air chambers. Their first chamber had a plate separation of 4 cm and was suitable for radiation up to 100 KV. Later, the same workers adopted the chamber to measure up to 230 KV by adjustable electrodes with a separation in the range of 4-12 cm.

Mayneord (1929) constructed a free air chamber according to the design of Friedrish and used it to determine the magnitude of the "Pastille dose" which at that time was widely used in radiotherapy. Mayneord demonstrated that the Pastille dose was not constant but depended on the quality of the radiation employed. Kemp and Hall (1945) were able to demonstrate defficiencies which existed in the geometries of both the NPL and the NBS standard chambers which had led to errors of 2-3 percent in the realization of the roentgen at deep therapy range (about 200 KV).

These measurements had been made possible by Kemp's earlier developments (1945 b; 1946 a) of a simple circuit comprising essentially two capacitors and three switches - which enabled the ratio of two ionization currents to be measured directly and with high precission. The results of Kemp and Hall 1954 were confirmed by Wyckoff et al., (1954) and a new chamber as constructed at both standardizing laboratories. Greening (1965) developed a free-air chamber to be used in the range of 10-60 KV. The free-air ionization chamber is the laboratory instrument for practical uses in radiotherapy departments. It was necessary to develop "air wall" thimble chambers. Mayneord (1929) used a cylindrical chamber (length 2.0 cm, diameter 1.7 cm) of cardboard graphited internally for relative measurements in the water phantom. Later Mayneord and Roberts (1[illegible]) constructed a thimble chamber with graphite walls 4 mm thick which they calibrated against a free-air chamber. The thimble chamber was used for determining the dose rate from a 1 mg point source of radium filtered by 0.5 mm platinum. The result was [illegible].3 r/hour at 1 cm, which is exactly the same as the value found by Mayneord and Robert's 1937 in a very careful investigation using chambers of carbon, magnesium, lead and paraffin wax. An independent measurement by Gray (1937) gave the value [illegible] r/hour.

The design of practical dosimeters of the "Secondary Standard" type; i.e. instruments of stability and energy dependence such that they are suitable to form a link between the primary standard in the national laboratory and the field instrument used routinely in the hospital. Pride of place here must go to the Farmer Secondary Standard

Dosimeter (Farmer, 1955) which in its commerical form has been used throughout the world for 20 years.

Clinical dosimetry is the term given to radiation dosimetry applied specifically to the treatment of patients. Such dosimetry involves the synthesis of data relating to radiation beams and to the anatomy of the patient.

Historically, the patient was assumed to be similar to a cubic tank of water that is to say a homogeneous medium but during recent years heterogeneous media were deviced to solve the problem. Measurements in patient were used as well as the construction of heterogeneous media similar to the atomic number Z of human tissue.

Roentgen ray quality may be defined as the distribution of energy over all the wave lengths in the useful Roentgen ray beam applied to the patient. The Roentgen ray spectrum emitted from the target is composed of a continuous background upon which may be superimposed more or less intense bands of homogeneous radiation characteristic of the material of the target. In passing through various filters, these wavelengths are absorbed unequally according to the known laws of absorption so that the resulting spectral energy distribution curve may be very different in general appearance from the initial beam.

1.4. Spectral Distribution :

For each voltage applied across a given Roentgen ray tube is a discrete spectral distribution characteristic of that voltage. The spectral distribution due to the voltage change results in a composite spectrum made up of all the component spectra corresponding to all the possible values of the voltage applied. When a constant voltage is applied to a tube, the spectral distribution remains the same and characterises that particular voltage. The methods most commonly used in expressing Roentgen ray quality depend on the absorption of the radiation in a known thickness of a metal filter such as copper or aluminium.

1.5. Half Value Thickness (H.V.T.) :

The most suitable method for expressing radiation quality should have a sound theoretical, non-arbitrary relationship to the composite spectral distribution, provided that a reasonable and simple correlation between qualities of radiation produced by different voltage wave forms and permits a reasonable correlation with most quality measurements made by whatever method in the past. As against these qualification, the method must not be too complicated for general use.

However, the methods of determining the quality of Roentgen rays may be grouped as follows :

1) Determination of the full absorption curve.
2) Measurements of the half value layer and thickness.
3) Determination of the effective wavelength and average wavelength.

The half value layer method is considered the simplest of all methods as it requires no auxiliary calculations. Given radiation quality, the H.V.T. is defined as the thickness of copper or aluminium necessary to reduce the intensity to one-half its initial value. The result is expressed in mm of copper (or aluminium).

1.6. X-ray film Dosimetry :

The principle components of an X-ray film are the film base and the emulsion. The film base for the emulsion is made by dissolving wood or cotton in acetic anhydride in the presence of sulphuric acid. The cellulose combines with the acetic anhydride to form a thick solution and by washing and drying the cellulose acetate separates and is shreded into small particles which are dissolved in a special solvent containing a blue dye. The solvent evaporates from the cellulose acetate which solidifies to a transparent sheet