ESTIMATION OF ANNUAL GENETICALLY SIGNIFICANT DOSE FROM DIAGNOSTIC RADIOGRAPHY IN KADUNA STATE.

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DECLARATION.

It is hereby declared that

1. The report presented in this thesis is the result of research carried out by the author.

2. This thesis has not been submitted in whatever form to any other institution, organization or body for the award of any degree and

3. All inclusions from the work of others have been duly acknowledged.

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CERTIFICATION.

This project report entitled Estimation of Annual Genetically Significant Dose from Diagnostic Radiography in Kaduna State by CHUKWUKA EMMANUEL MOKOBIA meets the regulations governing the award of the degree of Master of Science of Ahmadu Bello University, and is approved for its contribution to knowledge and literary presentation

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Chairman, Supervisory Committee

_____ Date: _____
Member, Supervisory Committee

_____ Date: _____
Head of Department.

_____ Date: _____
Dean, Postgraduate School.

DEDICATION.

This dissertation is dedicated
to my Lord and Saviour Jesus Christ
who alone knows it all and gives
to whoever He chooses what He
chooses.

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ABSTRACT

The genertically significant dose from X-ray diagnostic procedures has been determined in many countries. For the estimation of the annual genetically significant dose from X-ray radiography in Kaduna state the age and sex distributions of patients who under-went five diagnostic examinations were obtained from, X-ray depart rents of four sample hospitals. Entrance exposures to the skin were measured using free- in air method. Organ doses were then estimated using Rosentein's "Handbook of selected Organ Doses for projections Common in Diagiostic Radiology."

Child expectancies for various age-sex groups in Kaduna state were calculated by combining the number of members of a cohort surviving to reach successive age bands of Specified duration with the age specific maternity/ paternity rates. The maximum child expectancies for the sexes were found to be 2.97 and 1.98 for males and females respectively.

The annual GSD from diagnostic radiography for five examinations was then estimated by combining the age-sex distributions with child expectancies and gonadal doses per person per examination. The annual GSD for Kaduna state was estimated to be 37.4.± 3.9 μGy.

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ABBREVIATIONS. DEFINITIONS. GLOSSARIES AND SYMBOLS

AF : Added filtration

ASMFR: Age-specific marital fertility rate.

D_{ij} : Average gonadal dose received by the patients in the ith age group as a result of undergoing the jth type of examination

Fig. : Figure

FDA : Food and Drug Administration.

FS : Field size

GSD : Genetically Significant Dose.

HVL : Half value layer - The thickness of a specified absorber required to reduce the intensity of a given beam of radiation to one half of its original value.

$Hv\ell = \frac{0.693}{\mu}$. where μ is linear attenuation coefficient.

ICR : International Congress of Radiology.

ICRP: International Congress on Radiological Protection established in 1928 by the Second International Congress of Radiology.

IF : Inherent filtration.

KeV : The energy of any individual electron in the beam Thus 80 KeV = 80.000 electron volts.

KV_p : The maximum Voltage across the X-ray tube. This Causes acceleration of the electrons. Thus 80 KV_p means that the maximum voltage across the tube is

80.000 volts.

mA : Tube Current in millampere.

mrad : Millirad. Unit of absorbed dose (energy absorbed per unit mass). 1 rad = 10^{-2} Gy.

mR : MilliRoentgen. Unit of exposure. (Induced charge per unit mass of air).

Micron (μ): Unit of length equal to 10^{-6} metres.

N_i : Total number of persons in the ith age group.

N_{ij} : Number of persons in the ith age group undergoing the jth type of examination per year.

NPB : National Population Bureau.

NRPB : National Radiological Protection Board.

O : Ovaries.

OPCS : Office of Population Censuses and Surveys.

P : Detector (Probe of the Victoreen 660)

P_i^M : Average child expectancy for the males in the ith age group.

P_i^F : Average child expectancy for the females in the ith age group.

S : X-ray source.

S^2 : Variance.

SS : Assumed skin surface.

T : Testes.

UNSCEAR: United Nations Scientific Committee on the Effects of Atomic Radiation.

Z : Atomic number.

≥ : Greater than or equal to.

≤ : Less than or equal to.

Σ : Sum.

Definition

Absorbed Dose: The energy imparted to matter by ionizing radiation per unit mass of irradiated material at the place of interest.

Cataract: A cluding of the crystalline lens of the eye which obstructs the passage of light.

Coherent Scattering: Scattering of photons or particles in which there are definite phase relationships between the incoming and the scattered waves.

Compton Scattering: The scattering of a photon by an electron. Part of the energy and momentum of the incident photon is transfered to the electron and the remaining part is carried away by the scattered photon.

Filter: A sheet of material, usually metal, placed in a beam of radiation to absorb preferentially the less penetrating components.

Heredity: Transmission of characters and traits from parent to offspring.

Latent Period: The period or state of seeming inactivity between the time of exposure of tissue to an

injurious agent and response.

Monte Carlo Method: A method permitting the solution by means of a computer of problems of physics, such as those of neutron transport, by determining the history of a large number of elementary events, by the application of the mathematical theory of random variables.

Mutation: Alteration of the usual hereditary pattern, usually sudden.

Organ: Group of tissues which together perform one or more definite functions in a living body.

Pair production: An absorption process for X and γ radiation in which the incident photon is annihilated in the vicinity of the nucleus of the absorbing atom, with subsequent production of an electron and positron pair. This reaction only occurs for incident photon energies exceeding 1.02 MeV.

Phantom: A volume of material approximating as closely as possible the density and effective atomic number of tissue. Ideally a phantom should behave in respect to absorption of radiation in the same manner as tissue.

Photoelectric Effect: Process by which a photon ejects an electron from an atom. All the energy of the photon is absorbed in ejecting the electron and in impating kinetic energy to it.

Photon: A quantity of electromagnetic energy (E) whose value in joules is the product of its frequency (ν) in hertz and Planck's constant (h), $E = h\nu$.

Radiation: The emission and propagation of energy through space or through a material medium in the form of waves.

Radiography: The making of shadows/images on photographic emulsion by the action of ionizing radiation. The image is the result of the differential attenuation of the radiation in its passage through the object being radiographed.

Scattering: Change of direction of subatomic particles or photon as a result of a collision or interaction.

Shield: A body of material used to prevent or reduce the passage of particles or radiation.

Syndrome: The complex of symptoms associated with any disease.

X-Rays : Penetrating electromagnetic radiations whose wavelengths are shorter than those of visible light. They are usually produced by bombarding a metallic target with fast electrons in a high vacuum.

1. Contemporary medical practices in Nigeria have witnessed a pronounced increase in the use of X-rays with X-ray facilities being available in most hospitals in the country and Kaduna state in particular.

Apart from X-rays, man is exposed to radiation from other medical uses, occupational exposures, fallout, natural background radiation and so on. Appendix I, Table 1a presents a list of natural and man made sources in USA as given by (Hall, 1978). It has been established that exposure from the medical applications of radiation is the largest man-made contribution to the population dose. A fact which is clearly shown in Table 1a Appendix I. Darby at al (1981) had submitted that besides being the largest man made contributor to the population dose, medical applications of radiation results in the highest doses to individuals and to individual organs and consequently has become of particular interest.

Hall (1978) summarises the effects of radiation on living things particularly humans as

(i) somatic mutation

(ii) genetic mutation

(iii) effects on the embryo and fetus and

(iv) immediate radiation death.

The somatic effect according to (Wall and Kendall,1980) can be usually justified by the patients' overiding personal gain, however the patients' descendants receive no such direct benefit. The risk to them therefore demands careful monitoring. In recognition of this, a number of investigations have been made in several countries aimed at estimating the genetic detriment. A list of countries where the GSD has been estimated is given in Table 1b/Appendix II . This list of countries was compiled by (Sope at al 1974).

This project presents the estimated annual genetically significant dose from diagnostic radiology for Kaduna state as well as the contributions of the sample hospitals to the overall Annual GSD of Kadun state. It is hoped that this estimate will inspire further works in other states of the Federation. The estimate was made using information from the radiological records of selected hospitals, the gonadal doses per person per examination associated with selected radiological examinations, the population distribution of Kaduna state and the child expectancy factors estimated by us.

2. LITERATURE REVIEW

2.1 Definition of GSD

The genetically significant Dose (GSD) which is an index of the presumed genetic impact of radiation exposure on the whole population has been defined by United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) as : "the dose which, if, received by every member of the population, would be expected to produce the same total genetic injury to the population as do the actual doses received by the various individuals".

Several investigators had derived various mathematical expressions for GSD with all the derivations solidly based on the UNSCEAR definition. Darby et al (19 ?) assumed that the genetic injury resulting from the irradiation of an individual is proportional to the gonadal dose received and to the number of future childre to the individual after exposure. They then stated that

$$\text{genetic injury} = \sum \alpha P_\ell D_\ell = \alpha \sum P_\ell D_\ell \qquad (1)$$

where P_ℓ is the child expectancy of the ℓth individual

D_ℓ is the gonadal dose to the ℓth individual

α is a constant of proportionality and

$\sum$ is summation over every individual in the population.

They argued that if all individuals in the population were to receive exactly the GSD, the total genetic injury would be the same as that resulting from the actual doses received hence :

$$\alpha \sum P_\ell \, GSD = \alpha \sum P_\ell \, D_\ell \qquad (2)$$

$$\therefore \quad GSD = \frac{\sum P_\ell \, D_\ell}{\sum P_\ell} \qquad (3)$$

According to them, it is convenient to group the population by age and sex when considering the annual GSD from diagnostic radiology and then to consider the number of persons who underwent each of the various examination types within each age-sex group. The annual GSD they concluded can be written in form

$$GSD = \frac{\sum_{k\ell} \varepsilon_{k\ell} \, \bar{D}_{k\ell}}{\sum_{k} \varepsilon_{k}} \qquad (4)$$

where $\varepsilon_{k\ell}$ is the total number of future children expected by those in age sex group k undergoing examinations of type ℓ in a year ;

$D_{k\ell}$ is the mean gonadal dose received by an individual in age-sex group k who underwent an examination of type ℓ; and

ε_k is the total number of future children expected by those in age-sex group k

Equation (4) above tallies with the expression for GSD given by (Fry et al, 1970) thus

$$GSD = \frac{\sum D_i N_i P_i}{\sum \hat{N}_i P_i} \qquad (5)$$

where D_i is the average gonad dose for a specified type of exposure for a person in age-sex class (i);

N_i is the number of persons in age-sex class (i) who had the specified type of exposure during a year;

P_i is the expected number of future children to an individual in age-sex class (i); and

$\hat{N}_i$ is the number of persons in age-sex class (i) in the total population.

Rosenstein (1976) also using the basic UNSCEAR definition of GSD derived another mathematical expression thus :

$$GSD = \sum_j \sum_k P_k^F R_{jk}^F (\bar{d}_e)_{jk}^F + \sum_j \sum_k P_k^M R_{jk}^M (\bar{d}_e)_{jk}^M + \sum_j P^f R_j^f (\bar{d}_e)_j^f \qquad (6)$$

where F, M and f denote female, male and fetus respectively

j indexes the type of examination

k indexes the age interval

P_k^F, P_k^M are the ratios of the number of expected future children for individuals in age interval k to the total number of persons in age interval K within the entire population.

$(\bar{d}_e)^F_{jk}$, $(\bar{d}_e)^M_{jk}$ are the mean gonad dose for an examination of type j received by persons in age interval k

p^f is the fraction of future children for fetuses

R^f_j is the ratio of the number of examinations of type j for pregnant females to the number of fetuses (live births) for the year and

$(\bar{d}_e)^f$ is the average ovarian dose received by female; of ages 15 to 44 from examinations of type j.

Still using the basic UNSCEAR definition, (Supe et al, 1974) in their work on Genetically significant Dose to the Population in India used the expression

$$GSD = \frac{\sum_i \sum_j \left[P_{ij} N_{ij} D^M_{ij} + P_{ij} N_{ij} D^F_{ij} \right]}{\sum_i \left[N_i P^M_i + N_i P^F_i \right]} \qquad (7)$$

where $P_{ij} = P_i$ is the average child expectancy factor for persons in the ith age group

N_{ij} is the number of persons in the ith age group undergoing the jth type of examination per year.

D_{ij} is the average gonad dose received by the patients in the ith age group as a result of undergoing the jth type of examination and

N_i is the total number of persons in the ith age group in the population.

M and F denote male and female respectively.

In this paper, we have used (7) above since it was found more applicable. A slight modification was however made because of our limitations. Gonadal doses per person per examination were used as against mean gonadal doses since we were unable to calculate the mean gonadal doses owing to the non-availability of records on retakes or re-examinations.

2.2 Nature and Production of X-rays

X-rays are a member of a group of radiations called electromagnetic radiations. Electromagnetic radiation is the transport of energy through space as a combination of rapidly fluctuating electric and magnetic fields. Other members of the electromagnetic radiation include :

i. Ultra-violet radiation
ii. Visible light
iii. Infra-red radiation and
iv. Radio waves

X-rays have a dualistic nature and thus can be considered as waves or as photons sharing a number properties thus

i. They all travel with same velocity,
ii. All transfer energy from place to place, in quanta given by $\varepsilon = h\nu$ where h, is Planck's constant and ν is the frequency.
iii. All suffers attenuation when passing through matter as a result of absorption and scattering and
iv. All obey the inverse square law, $I \alpha \frac{1}{d^2}$ where I is the radiation intensity at any place and d is the distance of the source to the place.

X-rays are produced by energy conversion when a fast-moving stream of electrons is suddenly stopped by

high atomic number target, (anode) of an X-ray tube. Usually, this is accompanied by the production of large quantity of heat. Christensen et al (1978) said that this heat can however be minimised by using the line focus principle and a rotating anode. Two processes are responsible for the generation of X-rays

when the accelerated electrons strike the target. One process involves reaction of the incident electrons with the nuclei of the atoms of the target. This produces bremsstrahlung. The spectrum is continuous in nature. The other process involves collision between the high-speed electrons and the electrons in the shell of the target atoms. This is called characteristic radiation.

2.3 Basic Interactions Between X-Rays and Matter.

According to (Christensen et al, 1978), there are five basic ways in which X-ray photons interact with matter thus

(i) Coherent scattering - Thomson scattering , or Ray leigh scattering.

(ii) photoelectric effect

(iii) Compton scattering

(iv) Pair production and

(v) photo disintegration.

In diagnostic radiology, only two of these five interactions are important - the photo electric effect and Compton scattering. Coherent scattering is numerically unimportant. Pair production occurs at energies $\geq$ 1.02 MeV while photo disintegration occurs at energies $\geq$ 7.0 MeV. Due to these energy considerations, pair production and photodisintegration are considered unimportant in diagnostic radiology where energies above 150 KeV are rarely used (Christen et al, 1978).

Photo electric effect is predominant with low-energy photons and high atomic number absorbers. It does not produce scattered radiation but it enhances natural tissue contrast. The later property stems from the fact that the number of photoelectric reactions is proportional to z^3 where z is the atomic number of the absorber. Thus the phtoelectric effect magnifies the difference in tissues composed of different photoelectric elements e.g. bone and soft tissue. Since the photoelectric effect enhances natural tissue contrast and does not produce scatter radiation, it is capable of producing radiographic images of excellent quality. However all the energy of the incident photon is absorbed by the patient through this process consequently patients receive more radiation dose from this process than from

any other type of interaction. From the standpoint of patient exposure then, the photoelectric proce-s is undesirable since it negates the goal of keeping the doses to the patients at the barest minimum. In practice however, the effect of photoelectric reaction is minimised by using high energy (KV_p) techniques. This technique relies on the fact that photoelectric cross section is proportional to $\frac{1}{(\text{Energy})^3}$.

On the other hand, Compton scattering is prevalent at higher diagnostic energies. This interaction accounts for almost all of the scatter radiation that are encountered in diagnostic radiology. This scatter radiation from Compton reaction posses a major safety hazard since the scattered photons still retain most of their original energies as illustrated in Table 2. Appendix III. From this Table, it is obvious that a scattered photon still retains most of its original energy and consequently posses a major safety hazard. The probability of a Compton reaction depends upon the total number of electrons in an absorber and hence upon its density and the number of electrons perogram. Since all elements contain approximately the same number of electrons per gram, irrespective of their atomic numbers, then, the number of Compton reaction is

independent of the atomic number of the absorber. Compton reactions occur with free electrons that is electrons whose binding energies are much less than the energies of the incident photons. Photon energies used in diagnostic radiology range from 10 to 150 KeV. At this energy range, only outer shell electrons are free in high atomic number elements consequently the number of Compton reactions are few. On the otherhand, all the electrons in low atomic number elements e.g. those found in soft tissues, can be considered free because even those on the K-shell have binding energies less than 1 KeV. Hence the number of Compton interactions increased since there are more free electrons for the incident photons to interact with. Generally radiographic image contrast is less with Compton reactions than with the photo electric

2.4 Biological Effects of X-Rays

The effects of radiation on the human body were classified into two main groups by (Martin and Harbison, 1979) thus

(i) somatic and

(ii) genetic.

According to them, somatic effects arise from damage to the ordinary cells of the body and affect only the

irradiated person. On the otherhand, hereditary/ genetic effects are due to damage to the cells in the reproductive organs - the gonads. This damage may be passed on to the person's children and subsequently to later generations.

For (Hall, 1978) the effects of radiation on living things particularly humans are

(i) somatic mutation

(ii) genetic mutation

(iii) Effects on the embryo and fetus and

(iv) immediate radiation death.

The first two-somatic and genetic mutations according to him, are of most concern when large numbers of people are exposed to small doses of radiation either for medical purposes or as a result of nuclear power stations. He identified four types of radiation death which according to him are determined by the magnitude of the dose thus

(i) Prodromal syndrome

(ii) Central Nervous system (CNS)

(iii) Gastrointestinal and

(iv) Hematopoietic syndrome.

Early radiation effects are those which occur in the period from a few hours up to a few weeks after an acute exposure. Their effects are due to major depletion of cell populations in a number of body organs due to cell-killing and the prevention or delay of cell division.

On the otherhand, late somatic effects of radiation are characterised by long and variable latent period. The main late effect of somatic mutation is the induction of cancer. Other possible late effects in the views of (Martin and Harbison, 1979) are the formation of cataract in the eye lens and slight reduction of life expectation of individuals. The later according to them, is backed up by some experiments performed on animals. However observations of human populations exposed at relatively high levels indicate that, if life-shortening occurs at all, it is very slight (Hall. 1978)

Genetic effects of radiation result from damage to the reproductive cells. This damage takes the form of alterations known as genetic mutations in the hereditary material or the cell. X-rays can induce gene mutations and these mutations
/caused by X-rays are indistinguishable from naturally occuring mutations. Since X-rays can cause an increase in in mutation rate, it can increase the production of recessive genes. Recessive genes by nature are associated with a considerable number of diseases hence X-rays can increase the number of genetically- abnormal people present in future generations. Consequently, excessive genetic damage would be very serious and strict control must be exercised over the exposure of a given population.

Hall (1978) on the Effects of Radiation On the Embryo and Fetus, noted that it is a special case for which every effort should be geared towards avoiding. He remarked that while it is true that radiation can cause problems at any time during the development of the embryo or fetus, it is the period when the organs are developing that is most vulnerable that is from the 9th day to the 6th week after conception. Though this fact was found out from experiments conducted with mice irradiated with small doses under carefully controlled conditions, he asserted that while caution must always be exercised in extrapolating from mouse to man, this is the best that can be done presently because of the impossibility of studying the effects of small doses on human embryos and fetuses. The present practice is to adopt the '10-DAY Rule' or 'Elective Booking system'. This rule means that X-ray procedures on fertile females can only be carried out during the first 10 days after the start of a menstrual period when it is quite certain that they are not pregnant.

(I C R P, 1977) introduced another term to distinguish between effects for which the probability of occurrence depends on the dose received and those for which the severity not the probability of occurrence varies with the dose. The former are stochastic effects

while the latter non-stochastic. The most important somatic stochastic effect is the induction of cancers. The risk of cancer induction increases with increasing dose without threshold. Genetic effects are also regarded as stochastic at the dose levels involved in radiation protection. Examples of non-stochastic injuries are cataract of the lens, damage to the blood vessels and impairment of fertility. The severity of any of these effects varies with the radiation dose received but they are not detectable unless a quite high threshold dose is exceeded.

3. RESEARCH PROCEDURES

3.1 Sample Centres.

Four hospitals in the state were selected as data collection centres. The hospitals are located in Zonkwa, Kaduna, Zaria and Malumfashi (Fig. 3.1). The sample hospitals in Kaduna, Zaria and Malunfashi are all Ahmadu Bello University Teaching Hospitals while the one in Zonkwa is a mission hospital under the Roman Catholic mission. The hospitals are :

(i) St. Louis Hospital Zonkwa.

(ii) Ahmadu Bello University Teaching Hospital Kaduna.

(iii) Ahmadu Bello University Teaching Hospital Zaria and

(iv) Ahmadu Bello University Teaching Hospital Malunfashi.

It was also originally intended to gather data from the Kaduna state hospital in Katsina. All efforts failed as the hospital authorities refused to cooperate. Consequently the idea of using Katsina was dropped. However from Fig. 3.1, it is obvious that the sample towns are fairly well spread out. Besides, the sample hospitals in Malumfashi, Zaria and Kaduna are teaching hospitals and are consequently supposed to attract many patients

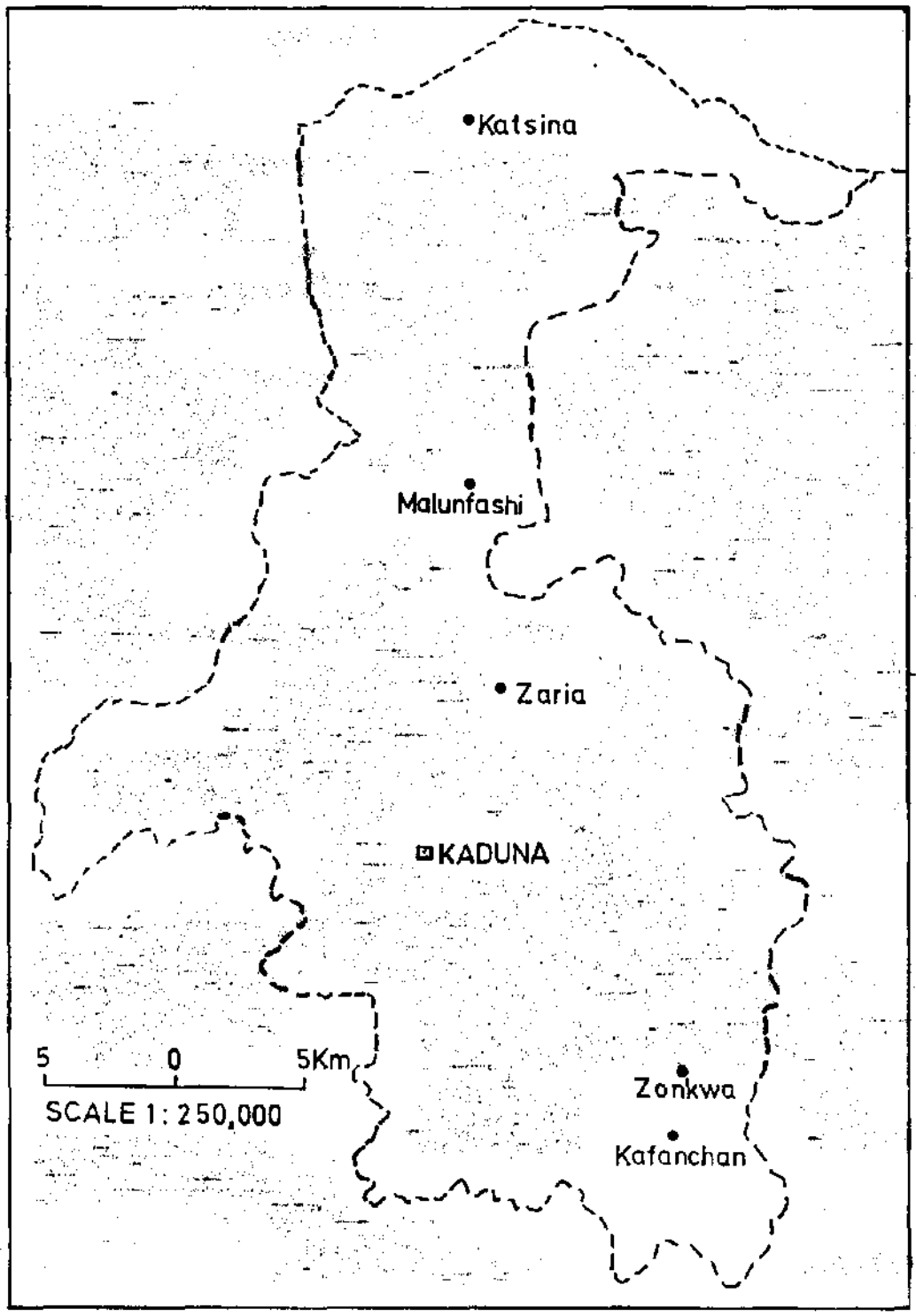


FIG. 3.1: LOCATION OF THE SAMPLE HOSPITALS

from their respective environments. St. Louis hospital in Zonkwa is reportedly the oldest in the area and has a long standing reputation hence it also attracts many patients from neighbouring towns and villages. For these reasons, it is justifiable to use these four hospitals as samples. This kind of procedure is not unusual since earlier investigators had had cause to tce this line (Darby et al, 1981 and Supe et al, 1974).

3.2 Data Collection.

3.2.1 Gonadal Doses.

The doses to the gonads (testes and ovaries) were estimated for five radiological examinations thus

(i) chest
(ii) pelvis
(iii) Fermur
(iv) Abdomen and
(v) Lumbar spine

These five examinations were chosen because earlier investigations reveal that, they contribute significantly to the gonadal doses when compared with other X-ray examinations (Rosenstein, 1976 and Darby et al, 1981). The contribution of chest examination to the gonadal doses follows from its frequency while the contributions of pelvis, fermur, abdomen and lumbar

spine are attributed to their nearness to the gonads.

Using the set up Fig. 3.2.1a , developed by (Fletcher and Cember, 1980), free- in air exposures were measured using a Victoreen 660. These free-in air exposures were used to estimate the organ doses. For this purpose, Rosenstein's "Handbook of selected organ doses for projections common in diagnostic radiology" was used. The organ dose estimates were based on a combination of the handbook data with measured operating parameters of the -ray machines. Estimated gonadal doses per person per examination for the five radiological examinations in each of the sample hospitals are given in Table 3.2.1. The set up Fig. 3.2.1a was used because it was not practicable to use phantoms or real patients. The use of Rosenstein's "Handbook of selected organ doses for projections common in diagnostic radiology" is deemed appropriate since Rosenstein compiled this using the Monte Carlo method and a standard radiological person phantom. In effect, the effects of scatter are adequately taken into account. In Figs. 3.2.1b-d, the histograms of gonadal doses for pelvis, femur and lumbar spine for the sample towns are illustrated. From all the four s, it is evident that gonadal doses per person per examination for each of

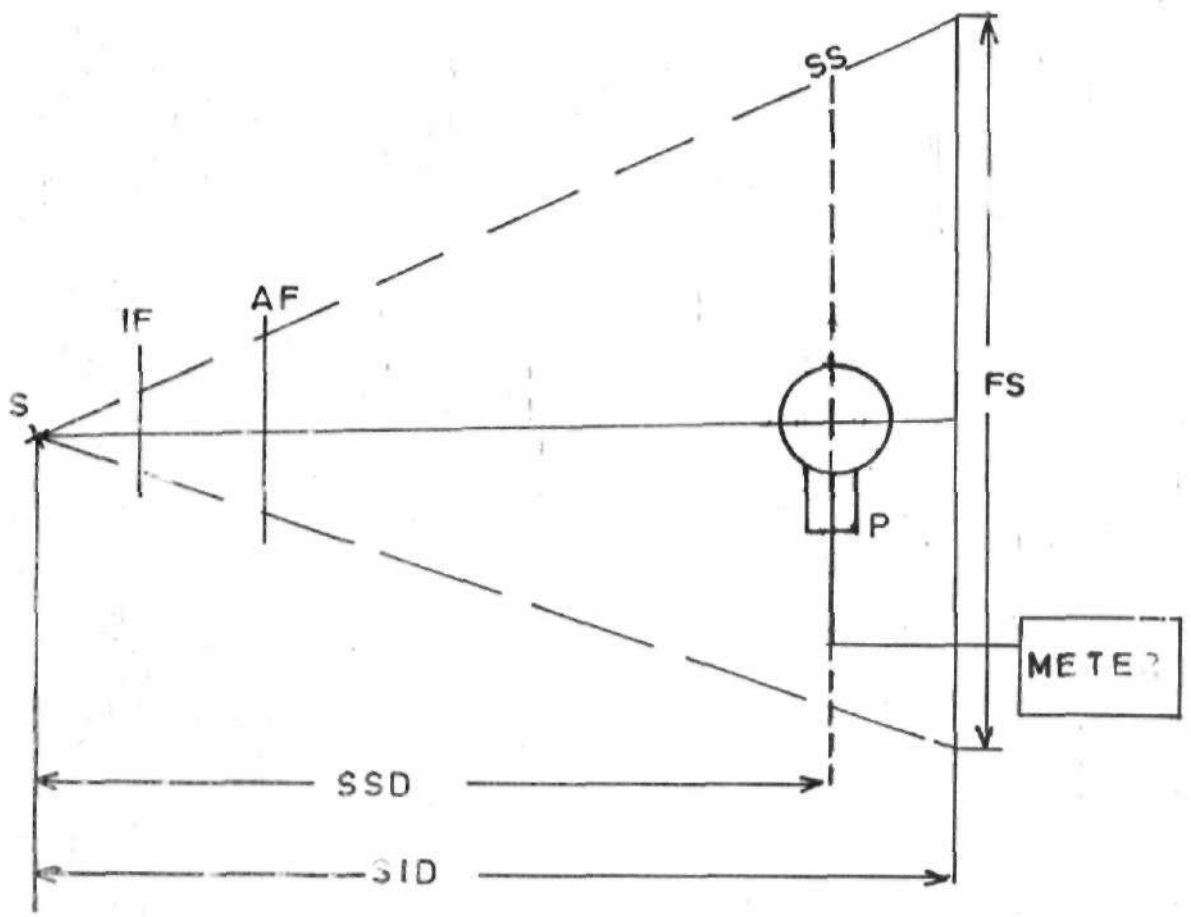


Fig.3.2.1a: Set-up for measuring free-in air exposures

S ——— Source

IF, AF —— Inherent filter, Added filter

SS ——— Assumed skin surface

FS ——— Field size at image plane

P ——— Probe of the victoreen 660

SSD —— Source to skin distance

SID —— Source to image distance

Table 3.2.1 Estimated Gonadal Doses per person per Examination in mrads

HOSPITAL	ABUTH, ZARIA		ABUTH, KADUNA		ABUTH, MALUNFASHI		ST.LOUIS, ZONKWA	
EXAMINATION	T	O	T	O	T	O	T	O
CHEST (AP)	-	0.06	-	0.07	-	0.06	-	0.08
PELVIS (AP)	113.37	23.00	142.69	28.95	165.33	32.16	663.07	139.35
FEMUR (AP)	36.41	0.48	62.80	0.82	52.86	0.69	175.71	2.29
LUMBAR SPINE (AP)	0.26	14.59	1.00	50.55	0.30	16.66	1.63	82.19
ABDOMEN (AP)	3.26	41.18	7.42	93.63	4.80	60.45	14.48	182.80

T → Testes, O → Ovaries

All examinations are for plain radiography.

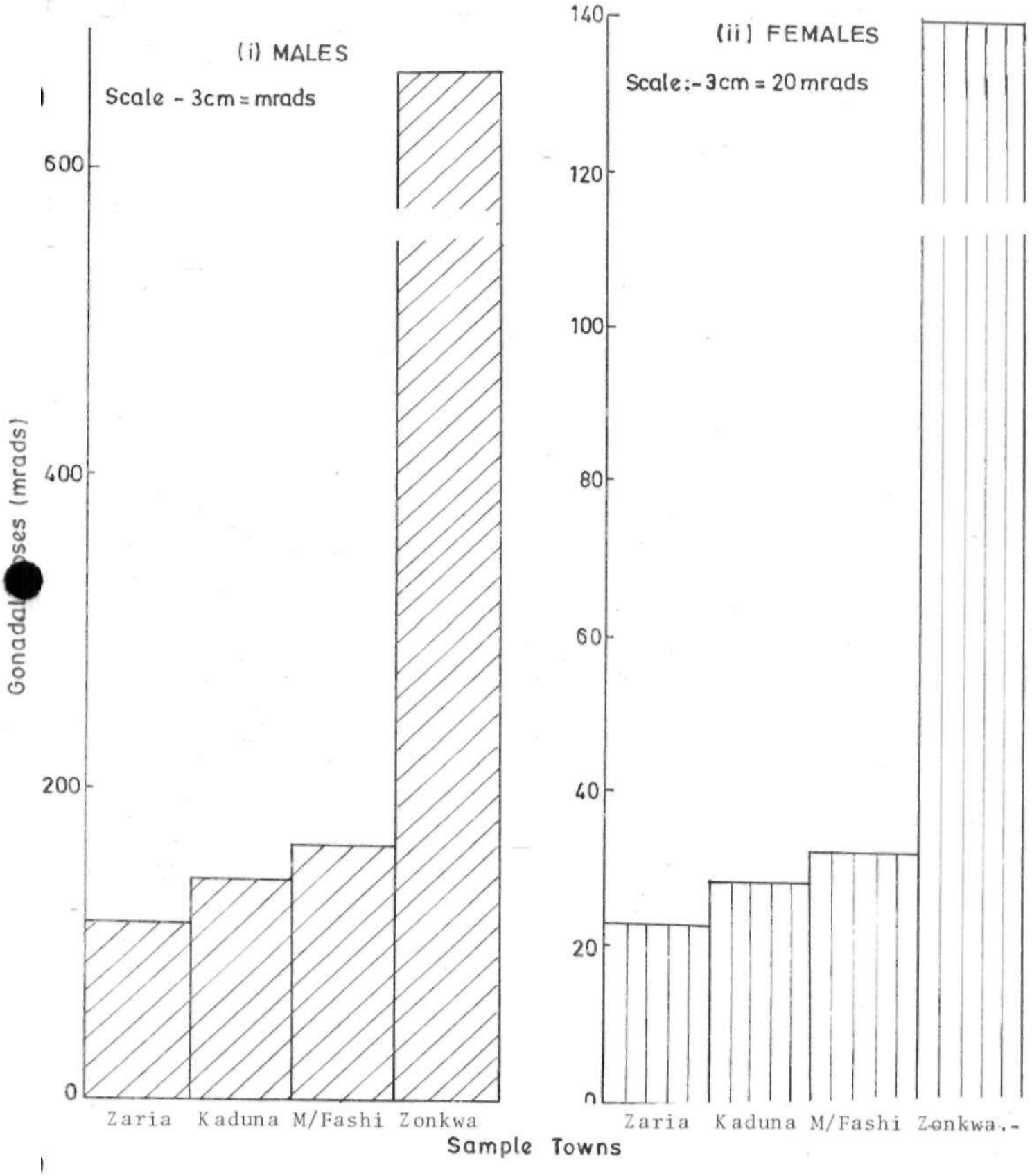


Fig. 3.21b : Histogram of gonadal doses from pelvis examination

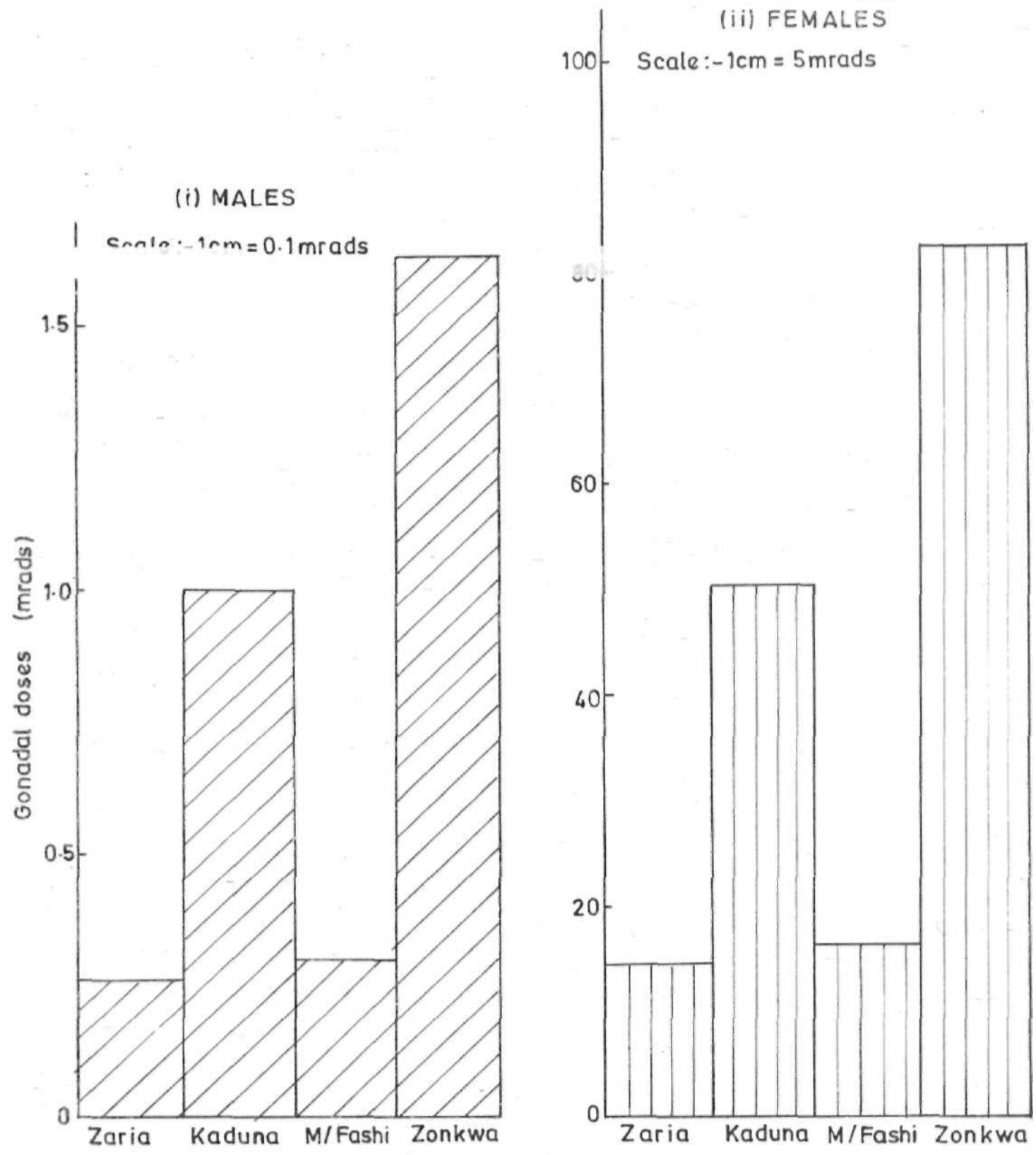


Fig. 3·2·1d : Histogram of gonadal doses from lumbar spine examination

these examinations are greater in Zonkwa than in any of the other hospitals. This is true for both males and and females. This is serious particularly as the teaching hospitals ought to be used as standards.

As an illustration of the estimation of the gonadal doses, suppose the entrance exposure for an AP projection of lumbar spine on a 35 cm x 42.5 cm field size is 224 mR when the machine parameters are 85 KV_p, SID = 100 cm and HVL = 2.3 mm AL, then, the dose to the ovaries can be estimated thus:

From the Handbook, the dose to the ovaries from a normalised skin exposure of 1000 MR under the given machine parameters is 168 mrads

$$\therefore \quad 224 \text{ mR at the same machine parameters} = \frac{168 \times 224}{1000}$$

$$= \underline{38 \text{ mrads}}$$

For cases, where the field sizes and SID values were different from those in the handbook, the organ doses were estimated using the relationship developed by (Fletcher and Cember, 1980) thus

$$ED = \frac{E_x}{1000} \times D_H \times \frac{SID_H}{SID_M} \times \frac{A_M}{A_H} \qquad (8)$$

where ED is the estimated organ dose

E_x is the measured entrance exposure

D_H is the normalised handbook value of organ dose

SID_H is the SID value in the handbook

SID_m is the measured SID value

A_M is the measured field size and

A_H is the handbook field size

Gonadal doses per person per examination were estimated. Because of non-availability of records on retakes and re-examinations (though we tried to get such data) it was impossible to estimate the mean gonadal dose per person per year.

3.2.2 Patient Distribution.

The distribution of patients examined for the five selected radiological examinations, viz, chest, pelvis, fermur, abdomen and lumbar spine for three years 1984 to 1986 in each of the sample hospitals were obtained from the radiological records of the hospitals and are given in Tables 3.2.2(a-d). The radiological records were specific on the sex of infants. However a bulk of the records have many patients registered as adults. For this work, i was assumed that any person from 20 years upwards can be regarded as an adult. Consequently the number of patients registered as adults for each of the radiological examinations in each hospital were equally shared out to age groups 20-24 years and

upwards. In compiling these radiological records the monthly statistics of the X-ray departments of the sample hospitals were combined with the records from the actual daily registers, where available.

From Tables 3.2.2 (a-d), the number of patients who underwent chest radiological examination clearly tops the list in all the sample hospitals. The chest X-ray distributions of Ahmadu Bello University Teaching hospitals in Zaria and Kaduna are represented in fig. 3.2.2a. Zaria recorded a higher X-ray chest examination when compared with Kaduna. A similar distribution is represented in fig. 3.2.2b for Ahmadu Bello University Teaching hospital, Malunfashi and St. Louis hospital Zonkwa. Malunfashi has a higher record of chest X-ray examination than Zonkwa. However the shapes of the curves in both figures are identical and they both are identical to a similar curve drawn by (Supe et al, 1974) and given in Appendix IV, fig. 3.2.2c. The indentical nature of the chest X-ray distributions of both the Indian case and those of the present investigation clearly shows that chest radiological examination is the most frequent in almost every part of the world.

TABLES 3.2.2a Distribution of Patients Examined for the Selected five Radiological Examinations

EXAMINATION	CHEST		PELVIS		FERMUR		ABDOMEN		LUMAR SPINE	
AGE (YEARS)	MALE	FEMALE	MALE	FEMALE	MALE	FEMALE	MALE	FEMALE	MALE	FEMALE
0 - 1	145	115	2	3	5	5	16	8	2	1
2y - 4	290	230	5	6	11	11	32	16	5	3
5 - 9	202	132	9	5	22	17	31	20	2	2
10 -14	147	108	9	8	13	9	18	13	5	4
15 - 19	119	115	15	21	20	6	13	33	7	4
20 - 24	334	197	14	29	32	8	25	74	20	8
25 - 29	319	201	22	19	46	3	32	91	21	13
30 - 39	366	299	24	15	61	9	42	109	39	23
40 - 49	306	200	22	9	35	6	34	31	39	19
50 - 59	250	166	20	9	18	4	18	23	26	19
60+	258	145	13	5	7	5	17	19	22	12

ABUTH ZARIA.

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TABLES 3.2.2b Distribution of Patients Examined for the Selected five Radiological Examinations.

EXAMINATION	CHEST		PELVIS		FERMUR		ABDOMEN		LUMBAR SPINE	
AGE (YEARS)	MALE	FEMALE	MALE	FEMALE	MALE	FEMALE	MALE	FEMALE	MALE	FEMALE
0 - 1	123	97	5	7	9	9	11	7	4	2
2 - 4	245	194	12	14	19	19	23	11	11	6
5 - 9	171	112	21	12	39	30	22	14	4	4
10 - 14	124	392	21	18	23	16	13	9	11	8
15 - 19	100	97	34	48	35	11	9	23	15	8
20 - 24	283	167	32	67	57	14	18	52	42	17
25 - 29	270	170	51	44	81	5	23	64	44	27
30 - 39	309	253	55	34	108	16	30	77	82	48
40 - 49	258	169	51	21	62	11	24	22	82	40
50 - 59	212	140	46	21	37	7	13	16	55	40
60^{+}	218	122	30	12	12	9	12	13	46	25

ABUTH, KADUNA

Table 3.2.2c Distribution of Patients Examined for the Selected five Radiological Examinations.

EXAMINATION	CHEST		PELVIS		FERMUR		ABDOMEN		LUMBAR SPINE	
AGE (YEARS)	MALE	Female	MALE	FEMALE	MALE	FEMALE	MALE	FEMALE	MALE	FEMALE
0 - 1	19	15	0	0	2	2	2	1	0	0
2 - 4	38	30	0	0	4	4	5	2	1	1
5 - 9	27	17	1	0	7	5	5	3	0	0
10 -14	19	14	1	1	4	3	3	2	1	1
15 - 19	16	15	1	1	6	2	2	5	1	1
20 - 24	44	26	1	2	10	3	4	11	4	2
25 -29	42	26	1	1	15	1	5	13	4	3
30 - 39	48	39	2	1	20	3	6	16	8	5
40 - 49	40	26	1	1	11	2	5	5	8	4
50 - 59	33	22	1	1	6	2	3	3	5	4
60^{+}	34	19	1	0	2	2	3	3	5	3

Table 3.2.2d Distribution of Patients Examined for the Selected five Radiological Examinations.

EXAMINATION	CHEST		PELVIS		FERMUR		ABDOMEN		LUMBAR SPINE	
AGE (YEARS)	MALE	FEMALE	MALE	FEMALE	MALE	FEMALE	MALE	FEMALE	MALE	FEMALE
0 - 1	8	6	0	0	0	0	1	0	0	0
2 - 4	15	12	0	0	0	0	2	1	0	0
5 - 9	11	10	1	0	1	1	2	1	0	0
10 - 14	8	6	1	0	0	0	1	1	0	0
15 - 19	6	6	1	1	1	0	1	2	0	0
20 - 24	18	10	1	2	1	0	1	3	1	0
25 - 29	17	11	1	1	1	0	2	4	1	1
30 - 39	19	11	1	1	2	0	2	5	2	1
40 - 49	16	11	1	1	1	0	2	2	2	1
50 - 59	13	9	1	1	1	0	1	1	1	1
60^{+}	14	8	1	0	0	0	1	1	1	1

ST. Louis, Zonkwa,

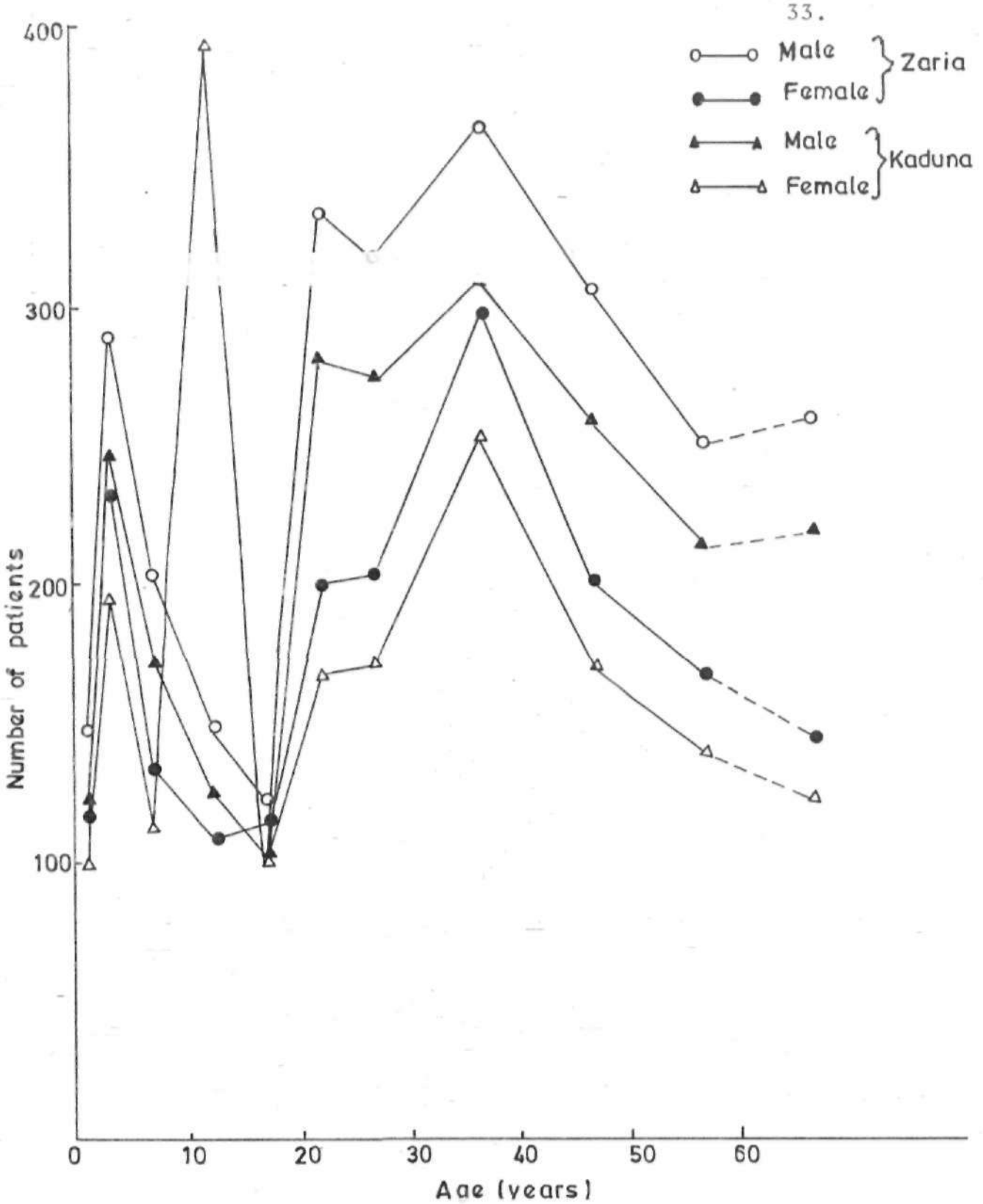


Fig. 3·2·2a : Chest x-ray distribution in ABUTH, Zaria and Kaduna

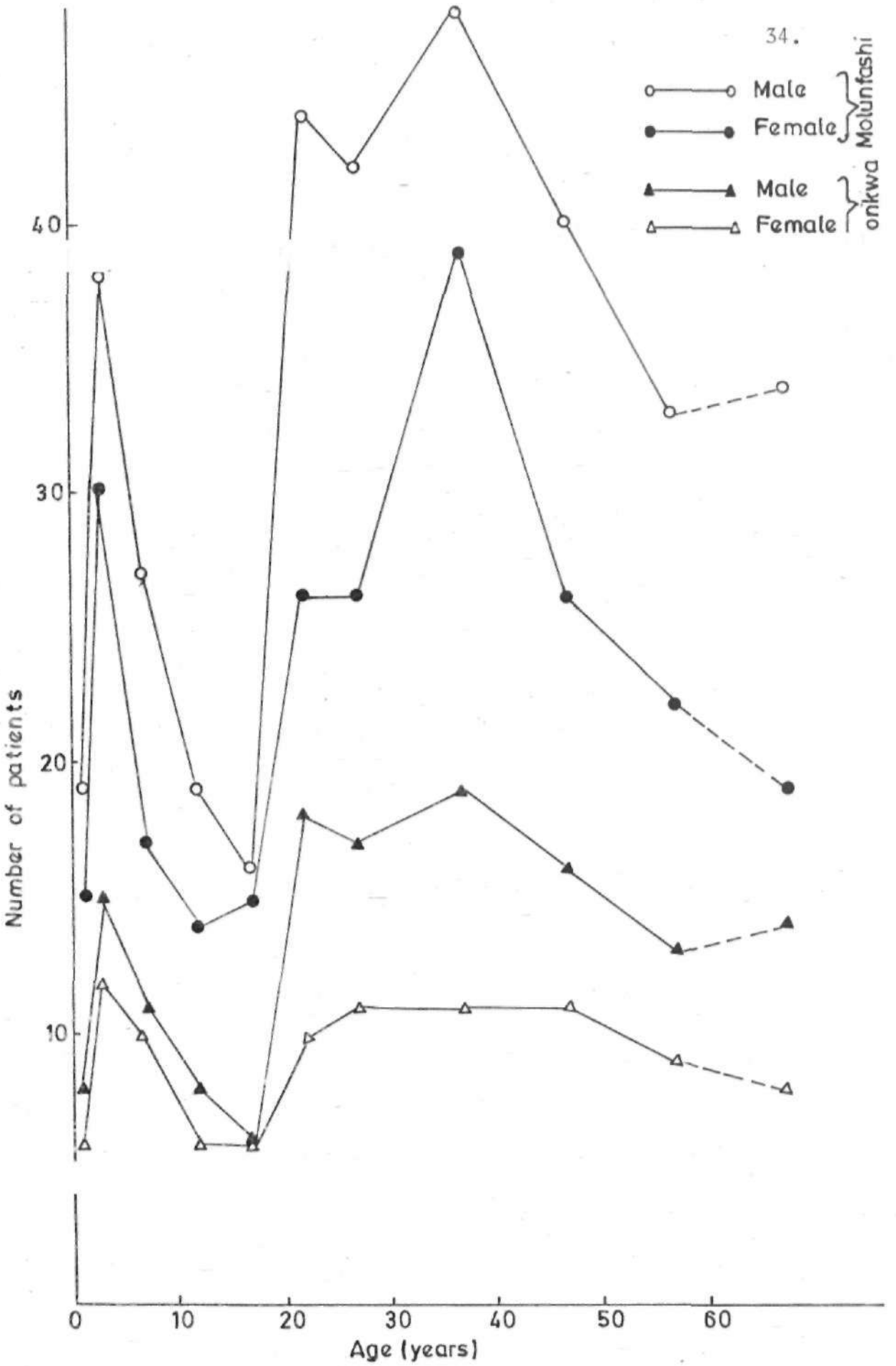


Fig.3·2·2b : Chest x-ray distribution in ABUTH Malunfashi and St. Louis Zonkwa

3.2.3 Population Distribution of Kaduna State

From Kaduna State Ministry of Finance and Economic planning, the following population information were obtained:

(i) Kaduna State Summary of population by age group and sex 1963 census and

(ii) Kaduna State 1963 census population and projectrons from 1978 - 1985 by districts and local government council areas.

Using these information, the population distributions of the four sample towns where the sample hospitals are located for 1986 were worked out considering a 2½% constant annual growth rate for urban and rural areas and a 7% constant annual growth rate for Kaduna capital city. Similarly, the projected population of Kaduna State for 1986 by age- sex groupings was determined. The projected age-sex distributions of the sample towns and of Kaduna State as a whole are given in Tables 3.2.3 (a) and (b) respectively. The projections were made using the relationship

$$P = P_o\left\{1 + \frac{R}{100}\right\}^n \qquad (9)$$

where P is the projected population for the year in question

P_o is the population as at the 1963 census

R is the annual constant growth rate and

n is the number of years e.g. 1963 to 1986.

Table 3.2.3a Projected Age-sex Distribution of Sample Towns

AGE GROUP	KADUNA		ZARIA		MALUNFASHI		ZONKWA	
	MALE	FEMALE	MALE	FEMALE	MALE	FEMALE	MALE	FEMALE
0 - 1	32,126	56,689	29,538	52,122	22,183	38,347	9,996	17,638
2 - 4	32,126	56,691	29,538	52,124	22,184	39,146	9,996	17,639
5 - 9	55,465	52,720	50,996	48,493	38,300	36,405	17,257	16,403
10 - 14	38,265	30,862	35,183	28,375	26,423	21,311	11,906	9,602
15 - 19	26,318	43,108	24,198	39,635	18,713	29,767	8,189	13,413
20 - 24	32,638	43,194	30,009	39,714	22,537	29,826	10,155	13,439
25 - 29	25,304	31,159	23,266	28,649	17,473	21,516	7,873	9,695
30 - 39	30,300	35,578	27,860	32,712	20,924	24,568	9,428	11,070
40 - 49	16,078	16,219	14,783	14,913	11,102	11,200	5,002	5,046
50 - 59	8,854	8,659	8,141	7,961	6,114	5,979	2,755	2,694
60^{+}	13,853	24,445	12,737	22,476	9,566	16,880	4,310	7,606

This projection was done based on data from Kaduna State Government 1963 census projections 1978 - 1985 [Tables 1, 9 and 19].

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Table 3.2.3b. Projected Age-sex Distribution of Kaduna State

AGE GROUP	1963 CENSUS		1986 PROJECTION	
	MALE	FEMALE	MALE	FEMALE
0 - 1	196,440	201,890	346,640	611,685
2 - 4	196,445	202,090	346,649	611,701
5 - 9	339,152	322,372	598,471	568,861
10 - 14	233,982	188,710	412,887	333,000
15 - 19	160,928	263,596	283,975	465,144
20 - 24	199,575	264,119	352,172	466,067
25 - 29	154,729	190,530	273,036	336,211
30 - 39	185,283	217,553	326,952	383,896
40 - 49	98,312	99,176	173,482	175,007
50 - 59	54,143	552,947	95,541	93,431
60^{+}	84,708	55,069	149,477	263,769

The 1963 census figures were obtained from Kaduna State Government 1963 census projections 1978-1985 (Table 19). However some slight modifications were made. The 1986 projection was done using the formula mentioned in 3.2.2 with the conditions i.e the annual growth rate taking into consideration.

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This relationship (9), was deduced after a careful study of the projected figures from 1978 to 1985. For these projections (1978 to 1985) it was clearly stated that R is 2½% for urban and rural areas and 7% for Kaduna capital city.

CHILD EXPECTANCY

4.1 Definition and Mathematical Expression.

According to (Taylor, 1980) the number of children expected by a group of persons of a given age is the sum of the products of the number of persons surviving to subsequent ages and the paternity/maternity rate for the persons at these ages. Thus if N in dividuals make up a cohort of a given sex in age band A, then the number of children expected to be produced by the cohort when it is in the later age band B is given by $C = M R Y$. (10)

where C is the number of children expected to be produced by the cohort when it is in the later age band.

M is number of members of the cohort surviving to reach age band B

of duration Y years.

From equation (10), Taylor defined the child expectancy of an average individual presently in age band A when he/she is in age band B as

$$P = \frac{M R Y}{N} \qquad (11)$$

where P is the child expectancy of an average individual presently in age band A.

M is the number of members of the cohort surviving to reach the age band B,

R is the annual age-specific paternity or maternity rate

Y is the duration of the later age band and

N is the number of persons in the cohort.

From expression (11) above, it is evident that child expectancy is determined by two main factors thus

(i) number of members of the cohort surviving to each successive age bands of specified duration in years.

(ii) age-specific maternity/paternity rate.

Consequently this factor is bound to differ for different countries. This fact is confirmed by the values of the child expectancies for India (Nothern Region) and U.K. given in Table 4.1 Appendix V. From Table 4.1 Appendix V. it is also true that child expectancies for both males and females generally increase with age up to a maximum and then decreases to zero. Thus for U.K., the maximum child expectancies occured at the age band 10- 14 years while for India they occured at ages 15 - 19 years for males and 10 - 14 for females. Interestingly, the calculated child expectancies for both sexes for Kaduna State in this investigation exhibit the same trend with a maximum child expectancy occuring at ages 15 - 29 years for both sexes (Table 4.4).

4.2 Number of individuals surviving from a given cohort.

The number of registered deaths for two years according to age groups in Zaria were obtained from the medical records department of Ahmadu Bello University Teaching Hospital. The average deaths in a year by age-sex groups were then worked out and are presented in Tables 4.2a and 4.2b. In Table 4.2b, the values normalised to 10,000 individuals are presented since the size of a cohort is normally 10,000 as indicated by (Taylor, 1980). A typical example of the normalisation procedure is as follows :

From Table 3.2.3a, the male population in the age band 0 - 1 years for Zaria is 29,538.

Average number of deaths per year for the said age-sex group is 105

hence $29,538 \equiv 105$

$\therefore \quad 10,000 \equiv \frac{105 \times 10,000}{29,538} = 36$

$\therefore$ Average number of deaths per year per 10,000 individuals in the age band = 36

The normalised average deaths per year were then used to work out the number of individuals surviving from a given cohort of 10,000 from one age band to another. The results for both sexes are given in Table 4.2c and 4.2d.

Table 4.2a Average Deaths per year by age and sex; Zaria population

AGE GROUP	No. of Deaths per Zaria population	
	MALE	FEMALE
0 - 1	105	95
2 - 4	211	190
5 - 9	48	30
10 - 14	17	10
15 -19	14	20
20 - 24	14	20
25 - 29	33	28
30 - 39	60	42
40 - 49	50	20
50 - 49	35	25
60^{+}	34	30

The values were o'tained from medical records department of ABUTH, ZARIA. They represent average values, for 1985, and 1986.

Table 4.2b Average Deaths per year per 10,000 persons in Zaria by age and sex.

AGE GROUP	No. of Deaths Per 10,000 persons.	
	MALE	FEMALE
0 - 1	36	18
2 - 4	71	36
5 - 9	9	6
10 - 14	5	4
15 - 19	6	5
20 - 24	5	5
25 - 29	14	10
30 - 39	22	13
40 - 49	34	13
50 - 59	43	31
60^{+}	27	13

Table 4.2c Number of males surviving to the midpoint of an age band from cohorts of 10,000 males starting at the midpoint of a given age bands, Zaria.

	0 - 1	2-4	5-9	10-14	15-19	20-24	25-29	30-39	40-49	50-59	60+
0- 1	10,000	9964	9893	9884	9879	9873	9868	9854	9832	9798	9755
2-4		10,000	9929	9920	9915	9909	9904	9890	9868	9834	9791
5-9			10,000	9991	9986	9980	9975	9961	9939	9905	9862
10-14				10,000	9995	9989	9984	9970	9948	9914	9871
15-19					10,000	9994	9989	9975	9953	9919	9876
20-24						10,000	9995	9981	9959	9925	9882
25-29							10,000	9986	9964	9930	9887
30-39								10.000	9978	9944	9901
40-49									10,000	9956	9923
50-59											
60+										10,000	9957
											10,000

Table 4.2d. Number of females surviving to the midpoint of an age band from cohorts of 10,000 females starting at the midpoint of a given age band; Zaria.

	0-1	2-4	5-9	10-14	15-19	20-24	25-29	30-39	40-49	50-59	60+
0-1	10,000	9982	9946	9940	9936	9931	9926	9916	9903	9890	9859
2-4		10,00	9964	9958	9954	9949	9944	9934	9921	9908	9877
5-9			10,000	9994	9990	9985	9980	9970	9957	9944	9913
10-14				10,000	9996	9991	9986	9976	9963	9950	9919
15-19					10,000	9995	9990	9980	9967	9954	9923
20-24						10,000	9995	9985	9972	9959	9928
25-29							10,000	9990	9977	9964	9933
30-39								10,000	9987	9974	9943
40-49									10,000	9987	9956
50-59										10,000	9969
60+											10,000

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4.3 Age-specific fertility rates

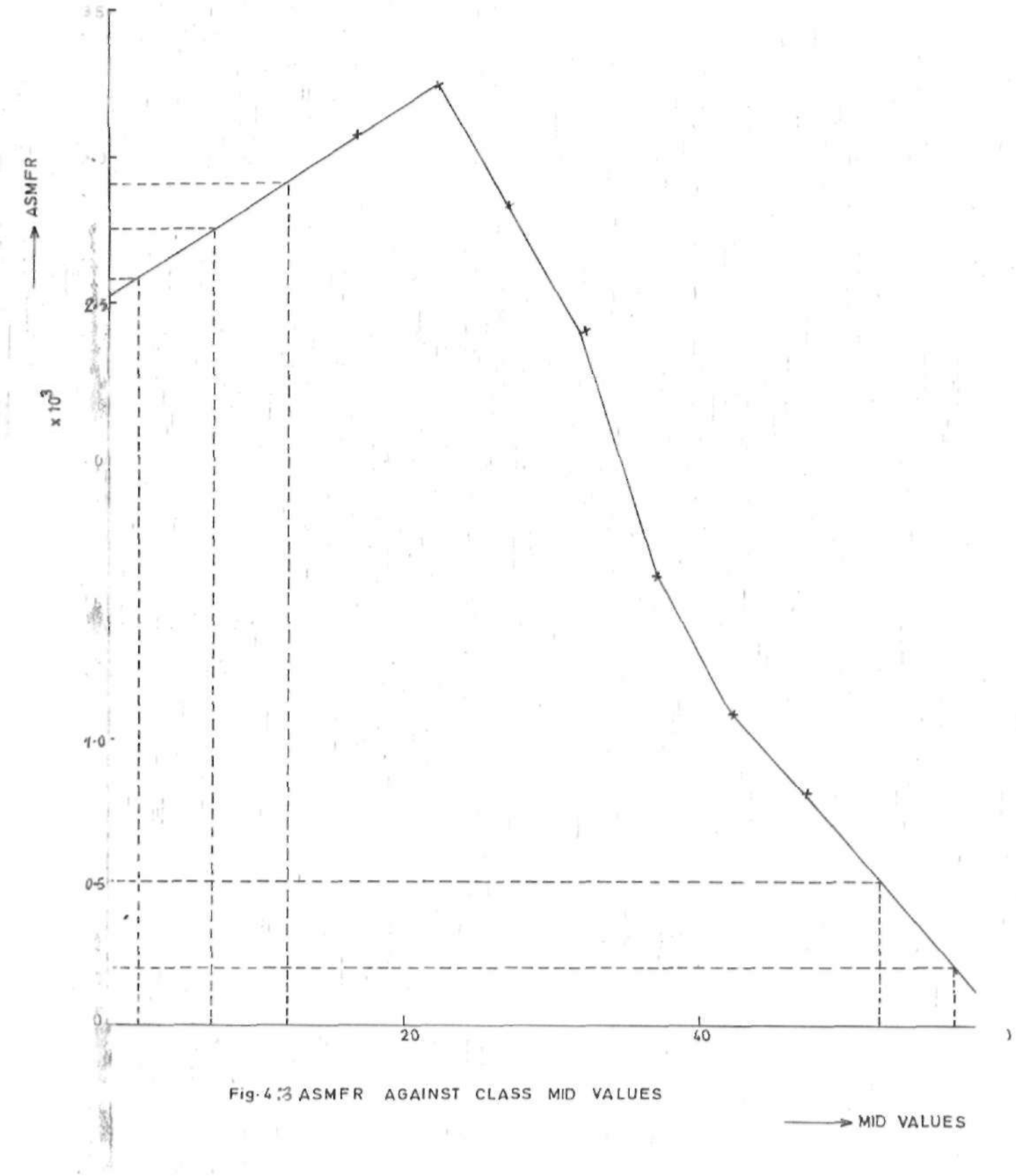
The age-specific maternity was obtained from the Nigeria Fertility Survey 1981/82 Principal Report, Volume 1, p. 76. This is a publication of the National Population Bureau, Lagos. The fertility rates as given in Table 5.3 of the said report do not contain information for ages below 15 years and above 49 years. A graph of age-specific marital fertility for ever-married women against the mid values of the age groups for females (Fig. 4.3) was drawn. From this grap (Fig. 4;3) the age-specific marital fertility for ever-married women below the age of 15 years and above the age of 49 years were extrapolated. The fertility rates from the original Table, Table 5.3 p. 76 of the fertility survey, as well as the extrapolated ones are given in Appendix VI, Table 4.3

In this work, it was assumed that

(i) the age-specific marital fertility as given in the Table from the fertility survey report have remained constant since 1981/82 till date.

(ii) all the women in the cohorts were at one time or the other married and

(iii) These age-specific marital fertility rates though for Nigeria, is also applicable to



Fig·4·3 ASMFR AGAINST CLASS MID VALUES

Kaduna state and consequently to the sample centres considered for this work.

The extrapolated age-specific maternity was considered adequate since the graph of age-specific marital fertility for ever-married women against the age groups (Fig.4.3) used for the extrapolations tallies with a similar graph (Fig. 5.1) on page 77 of the Nigeria Fertility Survey 1981/82. There were no records of the age-specific paternity rates. This issue is discussed later.

The first two assumptions were made because the 1981/82 Nigeria fertility survey is the latest available survey that is currently fairly acceptable for the country. Besides, the fertility survey gives fertility information for the average Nigeria woman of which a woman in Kaduna State is also represented. It was assumed that all the women in the cohort were at one time or the other married because the Nigeria Society generally frowns at child bearing outside marriage. It is worth mentioning that (Taylor, 1980) also assumed the constancy of the age-specific fertility rates while working on Estimation of child expectancy for the population of the United Kingdom in 1974.

4.4 Estimation of Child Expectancy.

Using equation (II) page 29 and the calculated values of M and R, the child expectancies for each female age group were calculated. The average child expectancy for each particular age group was found subsequently. The child expectancies for males could not be worked out directly using equation (II), since there were no records of age-specific fertility rates for males. The values for males were then worked out using direct proportion. However, since most of the male population of Kaduna state marry more than one wife due to the Islamic factor, the child expectancies obtained by direct proportion for the male population for each age group were multiplied by a factor of 1.50 which represents the mean of the average number of wives per husband for Niger Republic and Upper Volta which are predominantly moslem. These average values of number of wives per husband for Niger Republic and Upper Volta were obtained from Demographic Handbook for Africa 1978, a publication of the United Nations, P. 85. The child expectancies for various age-s groups for Kaduna State as estimated in this project are given in Table 4.4. These child expectancy values though calculated for Zaria were assumed to suffice for Kaduna State.

An illustration of the calculation of child expectancy is as follows:

From Table 4.2d number of persons in age ban' 15-19

Table 4.4 Child Expectancy by age and sex: Kaduna State, Nigeria.

Age band	Child Expectancy	
	Male	Female
0 - 1	2.93	1.96
2 - 4	2.94	1.97
5 - 9	2.96	1.97
10 - 14	2.96	1.97
15 - 19	2.97	1.98
20 - 24	2.97	1.98
25 - 29	2.97	1.98
30 - 39	0.96	0.64
40 - 49	0.53	0.35
50 - 59	0.0	0.0
60^{+}	0.0	0.0

years surviving to reach 20 - 24 years is 9995. From Appendix VI Table 4.3. the age-specific maternity rate of individuals in the age band 20 - 24 years is 3243. It then follows that child expectancy for this age is

$$\frac{9995 \times 3243 \times 5}{10{,}000 \times 10{,}000} = \frac{1.62}{}$$

This procedure is repeated for other age groups above 20 -24 years. The mean value of these child expectancies was calculated and taken to represent the average child expectancy for persons in age group 15 - 19 years. The whole process is repeated for other age groups. A close study of the calculated female child expectancies as represented in Table 4.4 reveals that like in the child expectancies of India and U.K., Appendix V. Table 4.1 there is a gradual increase up to a maximum then a decrease down to zero. In view of this the male child expecta ncy were worked out using proportions. However, these values were multiplied by 1.5 which represents the mean of the average number of wives per man in Niger Republic and Upper Volta as already mentioned in P. 49. For Kaduna State, the maximum child expectancies are 2.97 and 1.98 for males and females respectively and these occur between the ages (15 - 29) years.

5 CALCULATIONS

5.1 Estimation of GSD

The contributions of the five radiological examinations chest, pelvis, fermur, abdomen and lumbar spine to the annual genetically significant dose from each of the sample hospitals were estimated. These contributions were sumed up to obtain the GSD estimate from each sample hospital. The annual genetically significant dose from X-ray diagnostic radiography in Kaduna State was then estimated by summing up the individual contributions of the sample hospitals.

In Table 5.1a, the estimated GSD for the sample towns as well as for Kaduna State are presented. From this Table, it is obvious that Ahmadu Bello University Teaching Hospital, Kaduna with an estimate of 20.52 μGy is the greatest contributor. Its contribution represents 4.3% of the estimated GSD for the state. On the other hand a sister teaching hospital at Malunfashi with an estimate of 2.68 μGy representing 7.4% toed the bottom line in the list of the four contributing hospitals. The percentage contributions of ABUTH Zaria and St. Louis hospital Zonkwa are 22.3 and 16.0 respectively.

Table 5.1a Estimated Annual GSD Contributions of the Five selected Radiological Examinations.

Examination	GSD (μGy)				
	Zaria	Kaduna	Malunfashi	Zonkwa	Kaduna State
Chest	0.0134	0.0146	0.0026	0.0027	0.0333
Pelvis	3.5621	9.5267	0.4806	3.3635	16.9329
Fermur	1.9864	6.0031	1.4103	0.7990	10.1988
Abdomen	2.4767	3.6583	0.71.67	1.6195	8.4712
Lumbar spine	0.1960	1.3090	0.0653	0.1442	1.7145
Total	8.2346	20.5117	2.6755	5.9289	37.3507

The estimated Annual Genetically Significant Dose from X-Ray Diagnostic Radiography for Kaduna State is 37.35 μ Gv . The GSD from Diagnostic Radiology in different countries is given in fig.5.1 Appendix VII. It must be enphasized that this work was restricted to radiography. In Appendix VIII Tables 5.1/(b-c) the computer print outs for the calculation involved in this estimation are presented.

5.2 Estimation of Standard Error.

There are a number of factors that may have contributed certain amount of errors in the esti tion of the Annual GSD for Kaduna State thus

(i) the inaccuracy of the population figure in Nigeria.

(ii) Not very accurate keeping of the radiological records in the sample hospitals.

(iii) the inaccuracy to some extent of the records of death in Zaria as recorded by the medical records department and

(iv) the personal errors introduced when extracting the statistical records etc.

In view of these, it was thought worthwhile to estimate the standard error associated with the estimated

value of GSD. The procedure for determining the standard error is given in Appendix IX Table 5.2. The estimated value of the standard error is 3.90 µGy

6. DISCUSSIONS, CONCLUSIONS AND ECCOMMENDATIONS.

6.1 Discussions.

From the estimated gonadal doses per person per examination (Table 3.2.1) and figures 3.2.1 (b-d), it is apparent that the highest gonadal doses per examination per person were recorded in Zonkwa. Lower gonadal doses were recorded in Zaria, Kaduna and Malunfashi; probably, because they are teaching hospitals and are supposed to be staffed by highly qualified radiological personnels, and they are supposed to enforce high radiological standards.

The gonadal doses per examination per person obtained from the sample hospitals in this investigation are presented in Table 6.1a along with gonadal doses obtained in two other separate investigations- USA and England. From this Table, it is obvious that the gonadal doses obtained for chest X-rays in the separate investigations tally. This is an indication of the fact that the contribution of chest X-rays to the gonadal doses- testes and ovaries, generally shows the same trend. Infact per person, the contribution of chest X-ray to the gonadal dose is insignificant. However the reverse is the case when considering a given population because of the large number of

Table 6.1a Gonadal doses (mrads) **for the selected five examinations from** different sources.

EXAMINATION	USA [18, 24]		ENGLAND [24]		ZARIA		KADUNA		MALUNFASHI		ZONKWA	
	T	O	T	O	T	O	T	O	T	O	T	O
CHEST	<0.01	0.06	< 1	< 1	-	0,06	-	0.07	-	0.06	-	0.08
PELVIS	57.00	148.00	121.00	456.00	113.37	23.00	142.69	28.95	165.33	32.16	663.07	139.33
FERMUR	*	*	*	*	36.41	0.48	62.80	0.82	52.86	0.69	175.71	2.29
(LUMBAR SPINE)	7.00	405.00	217.00	40.00	0.26	14.59	1.00	50.55	0.30	16.66	1.63	82.19
ABDOMEN	*	*	433.00	6.00	3.26	41.18	7.42	93.63	4.80	60.45	14.48	182.80

* → not available

T → Testes

O → Ovaries

The values for Zaria, Kaduna etc. are gonadal doses per person **per examination** while the values for U.S.A. and England are mean gonadal doses.

people who take the examination.

A closer study of the gonadal doses per examination per person as estimated in this investigation from the sample hospitals, reveals that the ovaries absorb a fairly sizeable amount of dose particularly during pelvis, lumbar spine and abdomen X-rays. This can be explained by the proximity of these organs to the ovary. By a similar argument, the significant absorbed dose to the testes during fermur and pelvis X-rays can be explained. In practice, gonad shields are used during these examinations to minimise the dose absorbed by the gonads.

Tables 3.2.2 (a-e) reveal that the selected types of examination show quite different age distributions. They also show that chest examinations are very common having the highest number of patients while lumbar spine examinations are rare recording the least number of patients in all the sample hospitals. These two revelations are in agreement with an earlier finding made by (Kendall et al, 1980). However unlike in the case reported by Kendall et al (1980), that examinations of the chest are comparatively rare in children, but very common amongst old people, parti-

cularly men, the data in Tables 3.2.2 (a-e) do not particularly show any such trend.

In Nigeria, like most third world countries, reliable demographic data are almost completely lacking (National Population Bureau Lagos, 1981/82). Since 1866, numerous attempts had been made, geared towards obtaining accurate population figures. These were abortive. The earliest attempts prior to 1952 were often not nationwide in character and were executed by administrators who lacked the necessary technical expertise and facilities. The 1952/53 and the 1962 censuses were modern in outlook but had their problems. In fact due to the political heat generated, the 1962 census had to be repeated the following year- 1963 amidst inflations and inconsistencies. Consequently there was a repeat census in 1973 which turned out worse than the one conducted in 1963. It is clear then that to date data from the 1963 census remain the most current census data for Nigeria and despite its questionable accuracy, all official population projections are based on it. It is only proper then that the population projections made in this investigation were based on the 1963 census.

The child expectancies calculated for Kaduna state for both sexes increased gradually to a maximum

between the ages of 15- 29 years and then decreased to zero. This trend of a gradual increase to a maximum followed by a fall to zero is also evident in the child expectancies calculated for other nations by other investigators (Supe et al, 1974 and Taylor, 1980). For example, in Appendix V, Table 4.1, the child expectancy for India increased to 5.417 between the ages of 15- 19 years for males and 10 - 14 years for females while the child expectancy for U.K. increase to 1.87 and 1.90 for males and females respectively between the ages of 10 - 14 years. Thus the child expectancies estimated for Kaduna state in this investigation are with the limitations mentioned acceptable.

For the estimation of GSD in Kaduna state, gonadal doses per person per examination were used because of the non-availability of records on retakes and re-examinations which made it impossible for us to estimate the mean gonadal doses per person in a given age group. Thus the GSD estimated is infact the Annual Genetically Significant Dose per person for five radiological examinations. This estimate for Kaduna state is less than the estimates for the state of Tamil Nadu and Nothern Region both in India with values 78.90 μGy and 215.00 μGy respectively (Supe et al, 1974). However it is important for clarity to differentiate

between Annual Genegitically Significant Dose from Total Annual Genetically Significant Dose. This distinction is illustrated by (Supe et al, 1974) as follows:

$$\text{Total Annual GSD} = \left\{\begin{array}{l}\text{Annual No. of}\\ \text{Examinations}\\ \text{per person of}\\ \text{the population}\end{array}\right\} \times \left\{\begin{array}{l}\text{Annual GSD}\\ \text{per person}\\ \text{per}\\ \text{examination}\end{array}\right\}$$

Darby and Wall (1981) writing 'on the genetically significant dose from diagnostic radiology in Great Britain' remarked that the conformity of an estimated GSD for any particular country with other estimates from countries with similar features is only an indication that the gonadal doses delivered in the particular country during X-ray examinations conform with those delivered in those countries with similar features and hence indicates the likelihood that the radiological practices are good. Thus GSD per se is not a direct indicator of good or bad radiological practices. However, it would appear that in as much as the estimated GSD for Kaduna State is less than the estimates for the developed countries (Fig. 5.1a, Appendix VII) and fairly compares with the estimates for Tamil Nadu State and Nothern Region both in India with estimates 78.90 μGy

and 215.00 μGy respectively that the radiological practices in vogue in the state as a whole are good. A comparison of the gonadal doses obtained from the sample hospitals with, the values from U.S.A. and England as presented in Table 6.1a also gives the same presupposition. The percentage contributions of the sample hospitals to the GSD of the state are as follows:

(i)	ABUTH	Malunfashi	7.4%	
(ii)	ST. Louis	Zonkwa	16.0%	
(iii)	ABUTH	Zaria	22.3%	and
(iv)	ABUTH	Kaduna	54.3%	

However, the percentages of persons examined radiologically per population of the sample towns are as follows :

(i) Malunfashi 0.2% out of a projected population of 49046 persons.

(ii) Zonkwa 0.2% out of a projected population of 22112 persons.

(iii) Zaria 0.9% out of a projected population of 653803 persons and

(iv) Kaduna 0.9% out of a projected population of 710651 persons.

The gonadal doses from all the sample hospitals during chest examination are about the same. For the rest of the examinations however- Pelvis, Fermur, Lumbar spine and Abdomen, St. Louis hospital Zonkwa recorded the highest gonadal doses while the smallest values were

recorded in ABUTH, Zaria. This case of lowest gonadal doses being recorded for this particular hospital might be due to the fact it has at least four qualified radiographers and well supervised technicians being a University teaching hospital/ (Table 6.1b). The teaching hospital in Kaduna is also priveledged to have well qualified radiological staff but at the time of this investigation, she had the problem of old and faulty X-ray machines. We had no choice but to use them since there were no alternatives. It is important to remark that the gonadal doses obtained from each of the sample hospitals/ to a certain extent compare favourably with the available values from USA and England (Table 6.1a).

The projected population of Kaduna state for 1986 is 7,666054 persons and from available records in the X-ray departments of the sample hospitals, only 2.2% of the 2,076030 persons in the sample towns were examined for any of the five radiological examinations for one year. From this evidence, it can be adduced that only a small fraction of the population of the state are exposed to X-ray facilities.

This issue of a few out of a large population of a location being exposed to X-ray facilities is not limited to Kaduna state alone. India is also another glaring example. Thus in fig. 5.1a, Appendix VII, the total annual /GSD estimate for India as against those for the developed

Table 6.1b Radiological staff distribution in the sample hospitals

Sample hospital	No. of Radiologists	No. of Radiographers	No. of Technicians
ABUTH. KADUNA	1	4	2
ABUTH ZARIA	1	4	4
ABUTH. MALUNFASHI	*	*	1
ST. LOUS. ZONKWA	-	-	1

*The radiologist and radiographers in ABUTH, ZARIA are responsible for Malunfashi.

nations is very low. Undoubtedly, the radiological practices in India are likely to be good but not better than in the developed nations. One likely reason for her low estimated GSD is that only a few out of her large population are exposed to X-ray examinations.

The beauty of the scientific process culminates in its humility and honesty to admit limitations. In the Estimation of the Annual Genetically Significant Dose from X-Ray Radiography in Kaduna state, such limitations as

(i) inaccuracy of population figures

(ii) inaccuracy of the records kept either in the medical records departments or the X-ray departments of the sample hospitals etc.

were not brushed aside. The estimated standard error is 3.90 μGy

6.2 Conclusions and Recommendations.

The estimated Annual Genetically significant Dose per examination per person for five radiological examinations- chest, pelvis, fermur, lumbar spine and abdomen in Kaduna state is 37.4 ± 3.9 μGy. This is broken down thus :

(i)	Malunfashi	2.67 μGy.
(ii)	Zonkwa	5.93 μGy

(iii) Zaria 8.24 µGy and

(iv) Kaduna 20.51 µGy

Generally, this estimated value indicates that the radilogical practices in Kaduna state are likely to be good. However the high gonadal doses estimated in St. Louis hospital Zonkwa suggests the need for a quality control programme. It is in this hospital that the highest gonadal doses were recorded for all the five examinations (Table 6.1a). Though these values as obtained from the hospital to a certain extent compare favourably with the values obtained in USA and England, they in some cases are pretty higher than values obtained from the teaching hospitals thus, Zaria, Kaduna and Malunfashi. For example, for pelvis examination, the gonadal doses recorded in Zonkwa were 663.00 mrads, 139.35 mrads as against 165.33 mrads, 32.16 mrads for Malunfash. or 142.69 mrads, 28.85 mrads for Kaduna or 113.37 mrads, 23.00 mrads for Zaria.

We wish to recommend the following :

(i) Since the term GSD is not a direct indicator of the goodness or otherwise of the radiological practices prevalent in a place, a standard value of GSD should be recommended for a given size of a population for indentical nations. Estimates from such nations can be compared with such a standard so that more positive

statements can be made about the radiological practices in the nations concerned.

(ii) Alternatively, a 'Genetic Effect' per person per examination should be worked out and could be designated GEPP. It could be defined as "the dose which if received by the gonads of an individual during a radiological examination would result in a genetic injury to the individual." Individual investigators could then cross check their values of GEPP with the standard. A conformity would be interpreated as good practice and vice versa. This can however be used to supplement the suggested standard GSD.

(iii) For the state, the electrive booking system or the 10 Day Rule should be adhered to very strictly in view of the fact that in some of the examinations considered, significant amount of doses were delivered to the ovaries. Also quality control should be instituted in the hospitals in the state.

(iv) Since population figures affect the calculation of GSD and is infact an important parameter, efforts should be made by the Federal Military Government to conduct a National census. This exercise is overdue.

(v) The radiological records in the X-ray departments should be improved upon to include information on

retakes and repeats. There should also be proper documentation of the sexes and ages of the patients

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Appendix I.

Table 1.2 Doses of Ionizing Radiation Received by the Human population from Natural and Man-Made sources in U.S.A [Hall, 1978]

Source	Average annual genetically significant dose (mrem)
Natural background	90
Medical uses	
Diagnostic radiology	16 (1964 estimate) 20 (1970 estimate)
Radiotherapy	3
Nuclear medicine	0.2
Occupational exposure (medical, industrial, and atomic energy workers)	0.8
Fallout from 1954-1962 period of nuclear weapons testing	1.5
Miscellaneous, including TV sets, luminous watches, cosmic rays to commercial jetliners, etc.	2
Nuclear power 1970)	0.003
Nuclear power estimate for 2000	< 1

Appendix II.

Table 1b. Annual Genetically Significant Dose from Diagnostic Radiology in various countries [Supe et al, 1974]

Country	Year	Total annual genetically significant dose (mrem)
Argentina	1950 - 1959	37.0
Denmark	1956 - 1958	27.5
Egypt		
Alexandria	1956 - 1960	7.0
Cairo	1955 - 1961	7.5
Fed. Republic of Germany	1957 - 1958	17.7
France	1957 - 1958	58.2
Italy	1957	43.4
Japan	1958 - 1960	39.0
Netherlands	1959 - 1960, 1967	20.0
New Zealand	1969	13.7
Norway	1958	10.0
Sweden	1955 - 1957	37.8
Thailand	1970	5.2- 1.3
U. K.	1964	14.1
U.S.A. (National)	1964	55.0
USSR	1964	27.0
Yugoslavia	1960 -1963	9.1
India	1967 - 1972	5.6

Appendix III

Table 2 Energy of Compton-scattered photons for various angles of deflection. [Christensen et al 1978]

Energy of incident phton (kev)	Energy of scattered photons (KeV)			
	Photon dellection angle (o)			
	30	60	90	180
25	24.9	24.4	24	23
50	49.6	47.8	46	42
75	74.3	70	66	58
100	98.5	91	84	72
150	146	131	116	95

Appendix IV

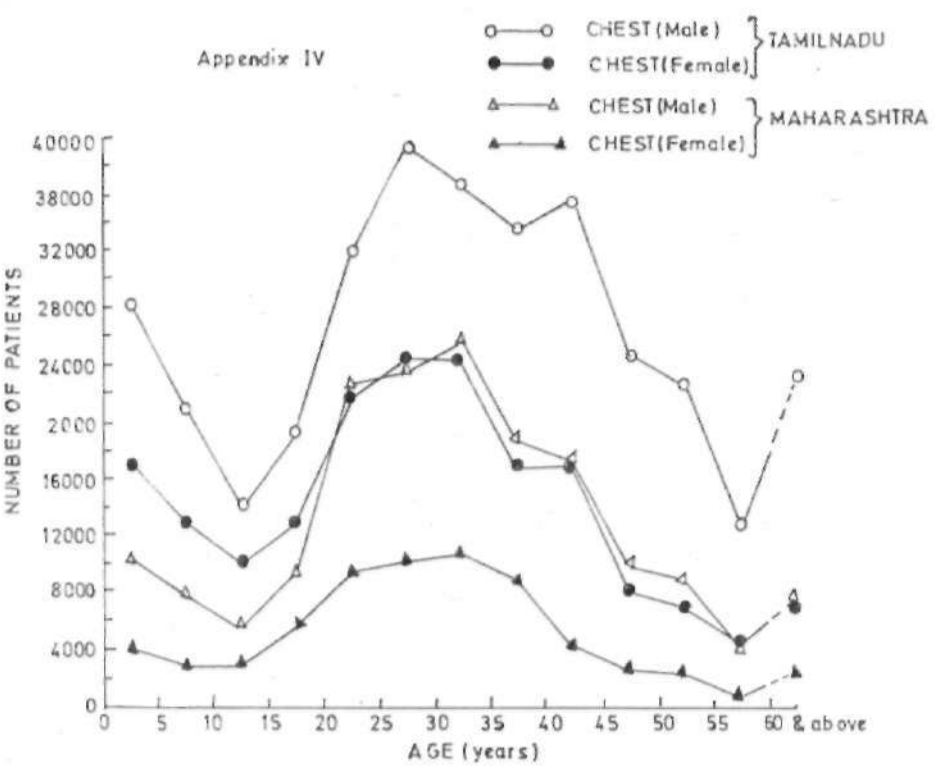


Fig.3-2-2c : Distribution by age of patients undergoing chest X-ray examination in Maharashtra and Tamil Nadu
(Supe etal, 1974)

Appendix V.

Table 4.1 Child Expectancies India Vs U.K. [Supe et al, 1974, Taylor F.E. 1980]

Age group (years)	India [Nothern Region]		U.K.	
	Male	Female	Male	Female
0 - 4	4.960	4.825	1.86	1.89
5 - 9	5.316	5.362	1.86	1.89
10 - 14	5.376	5.417	1.97	1.90
15 - 19	5.417	5.390	1.84	1.80
20 - 24	5.384	4.795	1.62	1.39
25 - 29	4.777	3.50	1.10	0.76
30 - 34	3.482	2.134	0.55	0.29
35 - 39	2.116	1.056	0.23	0.08
40 - 44	1.048	0.368	0.08	0.02
45 - 49	0.365	0.062	0.03	0.0
50 - 54	0.062	0.0	0.01	0.0
55 - 59	0.0	0.0	0.0	0.0
60^{+}	0.0	0.0	-	-

Appendix VI.

Table 4.3. Age-specific marital fertility rates for ever-married women

[National population Bureau, 1984]

Current Age	Age-specific marital fertility rates ASMFR, (ever married women).
*{ 00 - 1	1294
*{ 2 - 4	1294
*{ 5 - 9	2763
*{ 10 - 14	2913
15 - 19	3090
20 - 24	3243
25 - 29	2831
30 - 39	1979
40 - 49	916
*{ 50 - 59	350
*{ 60^{+}	0.0

* → The values of ASMFR for these age groups were extrapolated from a graph of ASMFR against the mid values of the various groups and so were not included in the original Table.

Appendix VII

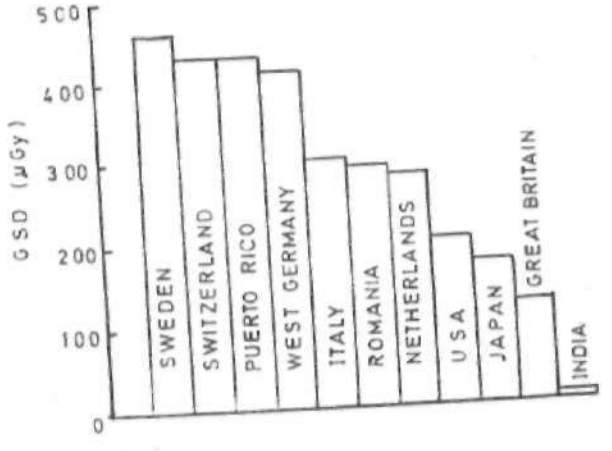


FIG. 5.1 : GSD from diagnostic radiology in different countries (Darby and Wall 1981)

Table 5.1a Computer Print out: GSD Calculation.

G.S.D. FOR: ABUTH ZARIA

ABDOMEN	G S D =	.24766872E+00
FEMUR	G S D =	.19864494E+00
LUMBAR SPINE	G S D =	.19598459E-01
CHEST	G S D =	.13429075E-02
PELVIS	G S D =	.35620583E+00

TOTAL G.S.D. = .82346085

G.S.D. FOR: ABUTH KADUNA

ABDOMEN	G S D =	.36582635E+00
FERMUR	G S D =	.60030917E+00
LUMBAR SPINE	G S D =	.13090181E+00
CHEST	G S D =	.14563664E-02
PELVIS	G S D =	.95267144E+00

TOTAL G.S.D. = 2.05116513

G.S.D. FOR: MAIUMFASHI

ABDOMEN	G S D =	.71669191E-01
FERMUR	G S D =	.14102885E+00
LUMBAR SPINE	G S D =	.65251063E-02
CHEST	G S D =	.26451683E-03
PELVIS	G S D =	.48063319E-01

TOTAL G.S.D. = .26755098

G.S.D. FOR: ZANKWA HOSPITAL

Appendix X.

Table. 5-2 Estimation of Standard Error.

GSD contribution from sample hospitals X [μGy]	X^2 $[\mu Gy]^2$
8.2346	67.8086
20.5117	420.7298
2.6755	7.1583
5.9289	35.1519
37.3507	530.8486

Variou Variance = $S^2 = \dfrac{\sum X^2 - \frac{(\sum X)^2}{n}}{n-1}$

$= \dfrac{530.8486 - (37.3507)^2/4}{3} = 60.6933$

Standard error, $S.E = \dfrac{S}{\sqrt{n}} = \pm\sqrt{\dfrac{60.6933}{4}} = \pm 3.90\ \mu Gy$

Appendix XI: Table 3. Gonad doses (mrad) for 1000 mR entrance skin free-in-air exposure [Rosenstein, 1976].

Beam quality Hvl (mm Al) →	1.5	2.0	2.5	3.0	3.5	4.0	Projection
Testes (AP)	41	60	78	94	109	123	Pelvis SID = 102 cm FS = 43.2 cm x 35.6 cm
Overies (AP)	98	151	206	262	318	374	
Testes (AP)	6.5	11	16	22	28	34	Abdomen SID = 102 cm FS = 35.6 cm x 43.2 cm
Ovaries (AP)	97	149	203	258	313	367	
Testes (AP)	1.1	2.2	3.7	5.6	7.8	10	Lumbar spine SID = 102 cm FS = 35.6 cm x 43.2 cm
Ovaries (AP)	91	139	188	238	288	336	

These values were obtained from Tables 6. 7 and 9 of Rosenstein's "Handbook of Selected Organ Doses for Projections Common in Diagnostic Radiology".