GENETICALLY SIGNIFICANT DOSE ASSESSMENTS OF OCCUPATIONALLY EXPOSED INDIVIDUALS INVOLVED IN INDUSTRIAL AND MEDICAL RADIOGRAPHIC PROCEDURES IN CERTAIN ESTABLISHMENTS IN NIGERIA

by

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The main source of radiation doses received by humans from man-made sources of ionizing radiation in medicine and industry comes from X-rays. The genetic risks of ionizing radiation effects on an individual who is occupationally exposed largely depend on the magnitude of the radiation dose received, period of practice, workload and radiological procedures involved. In this work, using the linear non-threshold model, we have attempted to assess the level of genetic risk of occupationally exposed individuals in two medical and industrial establishments in Nigeria by estimating their genetically significant dose values. The estimation was based on continuous personnel radiation dose monitoring data for the individuals in each of the establishments over a three year period (1998-2001). The estimated genetically significant dose values in the years considered were 12 mSv for the medical, and 29 mSv for the industrial personnel. Appropriate radiation protection precautions should be taken by the personnel to adhere to standard operational practices in order to minimize the genetically significant dose resulting from radiological practices.

Key words: radiation risk, genetic dose, radiography, occupational dose, Nigeria

INTRODUCTION

When ionizing radiation passes through matter, both excitation and ionization take place, thereby altering the structure of the molecules it interacts with. When the molecule affected belongs to a living cell, the cell may be damaged directly by the radiation or indirectly by the free radicals produced in adjacent molecules. Many forms of damage can be incurred from radiation, but the most important one is that done to the deoxyribonucleic acid (DNA). A damage to DNA results in gene mutation, chromosomal aberration, and breakages or cell death. More frequently, repair mechanism can take place. If the repair is not perfect, it may result in a viable but modified cell. The occurrence and proliferation of a modified cell can be influenced by other changes in the cell caused either before or after the exposure to radiation. If the cells in an organ or tissue are destroyed or prevented from reproducing and functioning normally, there will be loss of organ function. A modified germ cell, for instance in the gonads of an exposed individual, may transmit incorrect hereditary information which may cause severe hereditary effects. These types of effects are referred to as genetic effects. For somatic cells, the harmful effect is limited to the exposed individual and such an effect is known as a somatic effect. The amount of energy deposited or transferred to the absorber per unit track length is called linear energy transfer (LET) and radiations are known as high-LET and low-LET radiation, depending on the length and density of the ionization track they leave behind. Although low-LET radiation can cause double stranded DNA breaks (DSBs), they tend to interact with the DNA indirectly, through the dissociation of water and by inflicting oxidative damage to DNA bases [1]. Increases in biological effec-

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tiveness with decreasing energy photons γ (LET) have long been observed in radiobiological studies, especially studies of dicentric chromosome aberrations in human lymphocytes [2]. On a quantitative basis, the genetic effects of radiation are estimated by the doubling-dose method (equilibrium value after many generations of exposure) or the direct method (values for the first generation after exposure) [3]. Because of the cumulative nature of the doses imparted to genetic materials and its relative sensitivity, it has been considered worthwhile to estimate the net average dose to the genetic pool of occupationally exposed individuals arising from medical and industrial X-ray exposures in Nigeria, with the sole aim of assessing the effects of the doses received to their unborn.

Methods of estimating radiation risks from exposure to low-LET radiation (photons and electrons) require assumptions on the dose and dose-rate effectiveness factor (DDREF) which take into account that risks at low doses and low dose rates of these radiations may be lower than the estimates based on the linear extrapolations of observed risks at higher acute doses [4]. When radiation protection and estimating radiation effects or risks to exposed individuals are concerned, DDREF for low-LET radiations is generally assumed to be independent of energy. A linear dose response relationship in which the probability of a stochastic effect is proportional to the absorbed dose is assumed in this work. It implies that any radiation exposure, no matter how small, involves some degree of risk. If each member of a population consisting of individuals of the same age and sex is exposed to a given dose of ionizing radiation, the number of them getting radiation-induced effects will depend on the duration of exposure to that radiation. The longer the dose is spread out, the lower the incidence of cancer. This is due to the latent period for the development of the disease and the reduced number of person-years experienced as the population ages [5]. Essentially, this does not depend on the assumption of dose-rate dependent molecular repair mechanisms [6, 7].

MATERIALS AND METHODS

Dosimetric data

The personnel-monitoring dosimetric data used in this work was obtained from the Federal Radiation Protection Service (FRPS), Department of Physics of the University of Ibadan, Nigeria. Typical of the difficulties the FRPS has to deal with is the fact that it operated without a law regulating issues of radiation protection in the country. However, in 1995, a nuclear safety and radiation protection law has been proclaimed by Act 19 of the Federal Republic of Nigeria [8]. The enactment of this law brought about the establishment of a nuclear regulatory authority known as the Nigerian Nuclear Regulatory Authority (NNRA). As a component of its operation, the Act also recognized the establishment of a radiation research institute. As such, the FRPS has now been upgraded to the status of our institute, known as The National Institute of Radiation Protection and Research (NIRPR).

The use of a more convenient, thermoluminiscent dosimetry technique (TLD), was employed in monitoring efforts of the defunct FRPS. The FRPS is equipped with a Salaro (Vinteen) Dual Channel TLD reader (model 680). The reader has an in-built computer system unit to facilitate accurate dose assessment after appropriate calibration. It can also be programmed to automatically anneal TLD chips for fresh use and maintenance of data files for each of the radiation workers. As said, the detailed calibration procedure and occupational radiation protection dosimetry adopted in Nigeria has been well documented elsewhere [9]. In this work, the occupational effective radiation dose data for personnel in two tertiary teaching hospitals and industrial establishments over a three year period (1998-2001) were studied. The quantity effective dose defined by the International Commission on Radiological Protection (ICRP) exclusively for low doses and radiation workers, is a measure of the estimate of radiation risk to the exposed individual and the consequent genetic risk to the progeny for the next two generations [10]. Continuous radiation dose monitoring data pertaining to this period exist, enabling a correct estimation of said genetic effects. No attempt in this regard has been carried out in our country.

A genetically significant dose

A genetically significant dose (GSD) for a population is defined as the average of all individual equivalent doses to gonads (gonadal dose), each weighted by their expected future number of children conceived after exposure. Equivalently, the product of the GSD and the number of persons in the population is expected to estimate the same injury to the genetic pool of the population as will be produced by the actual doses received by various individuals. Mathematically, the GSD is expressed by the equation [3]

$$\mathrm{GSD} = \frac{\sum_i \sum_j \sum_k N_{ijk} D_{ijk} P_{ij}}{\sum_i \sum_j N_{ij} P_{ij}} \qquad (1)$$

where N_{ijk} is the number of individuals of sex type i, age group j, and exposure type k; N_{ij} is the number of individuals of sex type i, age group j; D_{ijk} is the average gonadal dose to an individual of sex type i, age group j, and exposure type k, and P_{ij} is the expected average number of children conceived after exposure by an individual of sex type i, age group j in the first generation. The sex indices (i = 1 or 2) denote males and females, respectively, while the exposure indices (k = 1, 2, …) refer to specific exposure types. Since one exposure type for only one organ was considered k =1, eq. (1) can be summarized as

$$\mathrm{GSD} = \frac{\sum_{i}\sum_{j}(N_{ij}D_{ij}P_{i}^{(M)} + N_{ij}D_{ij}P_{i}^{(F)})}{\sum_{i}\sum_{j}(N_{i}P_{j}^{(M)} + N_{i}P_{j}^{(F)})} \quad (2)$$

where (M) and (F) denote male and female, respectively.

Both the male and female gonad doses were taken to be the effective dose values on the gonadal level (trunk) or chest organs of the workers. In the case of occupationally exposed persons focused in this study, as it is usually practiced, TLD badges were either placed on the gonadal level (trunk) or on the chest. Under protective devices such as a lead apron they were, equally, placed under the lead apron. The effective dose calculated from TLD records is assumed to represent the gonadal dose. This assumption, however, is considered to be the maximum possible dose scenario.

RESULTS AND DISCUSSION

The distinction between the personnel according to sex in the two teaching hospitals and industrial establishments considered in this study is presented in tabs. 1-4. In the case of the medical establishments (tabs. 1 and 2), it pertains to personnel involved in three general procedures that constitute sources of exposure: radiography, fluoroscopy, and special examinations. In the sense it has been given here, radiology refers to general purpose radiography and interventional procedures. The category of occupationally exposed persons in the industry (tabs. 2 and 4) includes those involved in non-destructive testing, well logging, luminizing, thickness, moisture, density and level gauging, tracer techniques, fluoroscopic, and crystallographic analyses of materials.

The said personnel in each of the establishments were further re-grouped according to their age groups.

Table 1. Sex, age, and dose distribution of personnel for the Jos teaching hospital

Age group	No. of personnel per sex		Average dose *D* [mSv]		Average no. of expected children	
	Male	Female	Male	Female	Male	Female
26-30	2	1	0.3	0.4	3	2
31-35	4	2	0.5	0.6	5	4
36-40	7	1	0.7	0.7	4	3
41-45	5	1	1.0	1.9	3	3
46-50	5	1	1.3	1.7	2	0
51-55	0	2	0	2.3	0	0

Table 2. Sex, age, and dose distribution of personnel for the University teaching hospital, Ibadan

Age group	No. of personnel per sex		Average dose *D* [mSv]		Average no. of expected children	
	Male	Female	Male	Female	Male	Female
26-30	3	6	0.3	0.5	3	2
31-35	11	9	1.8	0.8	4	3
36-40	9	12	1.0	0.9	4	3
41-45	10	4	1.8	1.2	4	2
46-50	5	2	1.4	1.4	3	1
51-55	4	1	1.9	1.6	2	0

Table 3. Sex, age, and dose distribution of personnel for the OZMA company, Warri

Age group	No. of personnel per sex		Average dose *D* [mSv]		Average no. of expected children	
	Male	Female	Male	Female	Male	Female
26-30	4	0	0.8	0	3	0
31-35	8	0	1.6	0	5	0
36-40	11	0	3.3	0	3	0
41-45	6	0	5.0	0	3	0
46-50	3	0	7.1	0	2	0
51-55	1	1	13.8	9.9	1	0

Table 4. Sex, age, and dose distribution of personnel for the BATEK company, Warri

Age group	No. of personnel per sex		Average dose *D* [mSv]		Average no. of expected children	
	Male	Female	Male	Female	Male	Female
26-30	2	0	1.9	0	2	0
31-35	3	0	2.9	0	4	0
36-40	5	0	3.7	0	3	0
41-45	7	0	2.4	0	3	0
46-50	1	0	2.3	0	2	0
51-55	3	0	2.3	0	2	0

The number of personnel in each age group range per sex type and total doses received during the periods under consideration are also presented in tab. 1-4, for all of the establishments. As could be observed, total doses for the medical personnel, both male and female (tabs. 1 and 2), were low in comparison with those pertaining to the industrial employees (tabs. 3 and 4). Individual radiation doses were all greater than 1 mSv per year. It has also been observed that the total doses for both female and male relating to the medical personnel did not appear to significantly differ in values from one group range to another and that they were all less than 3 mSv per year.

The age group of 51-55 years recorded highest radiation doses in comparison with the lower age range groups. This may be due to the fact that those individuals, being experienced, could have demanded and achieved involvement in more demanding and challenging radiological procedures, even though they constituted a smaller percentage of the population in each of the studied establishments. The homogeneity in radiation dose value for each age range group pertaining to the medical personnel may also be an indication of similar work environment characteristics.

Also presented in tabs. 1-4, is the childbirth rate expectancy for the personnel (male and female) in each of the establishments. The male fertility rate for a given age group was assumed to be the same as the female fertility rate in other establishments. Using eq. (2) and data presented in tabs. 1-4, the GSD for each establishment were estimated and the results presented in tab. 5. As for the medical establishments, the Jos teaching hospital has a GSD of 11 mSv, while the University teaching hospital in Ibadan was found to have a value of 13 mSv. In the case of the industrial personnel, 42 mSv was obtained for OZMA, while 16 mSv was the result obtained for BATEK. These estimates are seen as representing maximum values and are not expected to have any genetic impacts on the health of the unborn children.

Although the GSD estimate does not represent a significant value when compared to the extreme terrestrial background radiation dose value (~100 mSv per year), in some countries in which no serious health effects have been reported [11-13], strong legislative mandates and other appropriate action should be taken in order to ensure the adherence to standard operational practices, if GSD resulting from radiological practices is to be reduced.

Table 5. Genetically significant doses (GSD) for each of the establishments

Establishment	GSD [mSv]	Contribution [%]	
		Male	Female
Jos teaching hospital	11	74	26
University teaching hospital, Ibadan	13	55	45
OZMA company, Warri	42	97	3
BATEC company, Warri	16	100	0

CONCLUSION

In this paper, a genetically significant dose of occupationally exposed personnel in diagnostic radiology and industrial radiography has been estimated. Age, sex, and radiation dose distributions were based on dosimetric data of the occupationally exposed persons in two tertiary and industrial establishments in the country, for the period of 1998 to 2001. The estimated GSD values during the years considered, in average, amount to 12 mSv for the medical and up to 29 mSv for the industrial personnel.

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ПРОЦЕНА ГЕНЕТСКИ СИГНИФИКАНТНИХ ДОЗА ТОКОМ РАДИОГРАФИЈЕ ЗА ПРОФЕСИОНАЛНО ИЗЛОЖЕНА ЛИЦА У НЕКОЛИКО ИНДУСТРИЈСКИХ ПОСТРОЈЕЊА И МЕДИЦИНСКИХ УСТАНОВА У НИГЕРИЈИ

Најзначајнији допринос излагању појединца од вештачких извора зрачења потиче од примене рендгенског зрачења у медицини и индустрији. Генетски ефекти излагања професионално изложених лица зависе од примљене дозе, времена излагања, радног оптерећења и карактеристика радиолошке процедуре. Користећи модел о линеарној, без прага, зависности дозе и ефекта, процењен је ниво генетског ризика за професионално изложена лица у две медицинске установе и два индустријска постројења у Нигерији. На основу резултата индивидуалног мониторинга у периоду 1998-2001 процењена је генетски сигнификантна доза. Процењена вредност била је 12 mSv у медицинским установама и 29 mSv у индустријским постројењима. Правилна примена мера заштите од зрачења представља неопходан предуслов за очување добре радиолошке праксе и минимизацију генетски сигнификантне дозе.

Кључне речи: радијациони ризик, генетска доза, радиографија, професионално излагање, Нигерија