Journal of Applied Sciences

ISSN 1812-5654

science alert

ANSInet
an open access publisher
http://ansinet.com

Journal of Applied Sciences 7 (9): 1343-1346, 2007
ISSN 1812-5654

Occupancy Factor Model for Exposure to Atmospheric Radiation by Urban and Rural Dwellers in Nigeria

A.M. Arogunjo and A.S. Adekola
Department of Physics, Federal University of Technology, P.M.B, 704, Akure, Nigeria

Abstract: A mathematical representation is described, which has been developed to calculate the average time spent for indoor and outdoor activities by urban and rural dwellers. Questionnaire has been developed and administered to people residing at Lagos State and Benin City representing urban dwellers and some villages in Edo State representing rural dwellers. The independent variables of the mathematical representation were extracted from the information gathered through the questionnaire. The result shows that average city dwellers spent 20.33% of the total time per day exposed to atmospheric radiation while an average rural dweller spent 26.88% of the time per day exposed to atmospheric radiation. Also, the time spent by average city dweller for outdoor activities is between 2.391 and 7.369 h, while the time spent by an average rural dweller for outdoor activities is between 3.99 and 8.91 h. This implies that rural dwellers are more exposed to atmospheric radiation than city dwellers.

Key words: Model, exposure, time, outdoor, indoor, urban, rural

INTRODUCTION

The amount of radiation absorbed by an individual in a given geographical area like Nigeria over the years, have not been fully predicted or estimated. This is because, of the limitation posed by the inability to properly evaluate the average time spent indoor or outdoor per day by people living either in urban or rural areas. Researches show that people engaging in outdoors activities have a higher percentage of radiation absorption, but the estimated radiations absorbed from the atmosphere per day have not been fully achieved (Glowaik and Pacyna, 1980).

In this study, attempt is made to estimate the average time spent outdoor/indoor, in other to properly estimate the amount of outdoor radiation (solar, ionizing and non-ionizing) absorbed per day; which will in turn help to determine the amount of dose absorbed at any given time. The need to determine the average time spent for radiation absorption and subsequently the amount of absorbed dose is pertinent because of its many effects, which include somatic and genetic effects.

Somatic effects are those effects, which do manifest instantly in individual that encountered the exposure. It can further be classified either as short-term recoverable effects or long-term irrecoverable effects. The former involves effects such as skin infection (deformation) which can be cured or recovered from within given period of time, while the latter involves infection such as cataract, anemia, tumor etc., which can not be cured or recovered from, rather it is terminal (Lagarde, 2003; Motersill *et al*., 2002; Prokic *et al*., 2002; Gransty and LaMarre, 2004).

Genetic effects on the other hand are these effects that do not manifest instantly but in a later generation such as abnormal nails and toes, mutation of the chromosomes, which results in changes in physical features of offspring (UNSCEAR, 1988).

Development of the model: Average Time Spent Indoor or outdoor by urban and rural dwellers per day is expressed in terms of the exposure rate. The rate at which an individual is exposed to radiation (exposure rate) can be expressed as:

$$E(t) = \frac{N}{t} \quad (1)$$

where t is the exposure time, N is the absorbed radiation.

This means that the total amount of radiation (solar, ionizing and non-ionizing) absorbed by any individual is directly proportional to the time of exposure. The steps employed in estimating the time spent outdoor in order to predict the exposure rate is hereby presented. The following assumptions are considered appropriate as to properly account for all the activities considered to be outdoor.

Corresponding Author: A.M. Arogunjo C/O Dr. Uwe Oeh, Institut für Strahlenschutz Ingolsträdter Landstraße 1 D-85764 Neuherberg, Germany

- The activities can either be classified as indoor or outdoor.
- The activities are considered as variables (independent).
- The percentage of the time slots for indoor or outdoor activities is considered as parameters.
- Each activity has a component or percentage of indoor and outdoor.
- Everyone living in the urban or rural area, has something doing at any particular time, in other words, no one is idle.
- The activities are hereby classified as follows: Academics/Occupation, Sleep/Rest, Leisure and other activities. Other activities include the ones outside academics/occupation, leisure and sleep/rest, i.e., miscellaneous activities
- It is also assumed that sleeping time is an indoor activity and it takes an average of 8 h out of the 24 h a day (Brown, 1983).
- Absorbed radiation increases with time spent outdoors.

A relationship between the time-spent indoor or outdoor, which is the dependent variable and the various factors/activities, which forms the independent variables, is to be developed. Table 1 presents the parameters that have been used in the development. It is obvious that each factor (variable) has components of indoor and outdoor, which could be calculated in percentage. The total time spent indoors and outdoors per day is 24 h.

Let the time spent for indoors be X, the time spent outdoors be Y and the total time spent indoor and outdoor be Z. Hence

$$Z = X + Y \tag{2}$$

Since X and Y are considered in this work to depend on four variables as presented in Table 1, X and Y are therefore function of L, A, M and R i.e., X = f (L, A, M, R) and Y = f (L, A, M, R).

It is also assumed that X and Y are linearly related to L, A, M, R, since each independent variable operates separately and tend to follow a regular sequence (Lagarde, 2003; Motersill *et al*., 2002; Cross and Moscardini, 1985; Edwards and Horton, 1989; Hocking, 1984). However, each independent variable or activity depends on a parameter, which is a fraction or percentage of the time slot for each activity. Hence

$$X = \alpha_1 L + \alpha_2 A + \alpha_3 M + \alpha_4 R + \tag{3}$$

$$Y = \beta_1 L + \beta_2 A + \beta_3 M + \beta_4 R + \tag{4}$$

Table 1: Parameters adopted in developing the model

Factor/activities	Time	Indoor	Outdoor
Leisure	L	α_1	β_1
Academics/occupation	A	α_2	β_2
Miscellaneous activities	M	α_3	β_3
Rest	R	α_4	β_4

Equation 3 and 4 are continuous and they depend on the number of variables to be considered. In this study, four variables were considered. Equation 3 and 4 therefore become

$$X = \alpha_1 L + \alpha_2 A + \alpha_3 M + \alpha_4 R \tag{5}$$

$$Y = \beta_1 L + \beta_2 A + \beta_3 M + \beta_4 R \tag{6}$$

Making Y the subject in Eq. 2, we obtain

$$Y = 24\text{-}X \text{ (since } Z = 24) \tag{7}$$

Substituting X of Eq. 3 into Eq. 7, we obtain

$$Y = 24\text{-}\alpha_1 L\text{-}\alpha_2 A\text{-}\alpha_3 M\text{-}\alpha_4 R \tag{8}$$

Adding 6 and 8, we obtain

$$2Y = 24\text{-}(\alpha_1\text{-}\beta_1)L\text{-}(\alpha_2\text{-}\beta_2)\,A\text{-}(\alpha_3\text{-}\beta_3)\,M\text{-}(\alpha_4\text{-}\beta_4)\,R \tag{9}$$

$$\begin{aligned} Y = 12 &- \left(\frac{\alpha_1 - \beta_1}{2}\right)L - \left(\frac{\alpha_2 - \beta_2}{2}\right) \\ &A - \left(\frac{\alpha_3 - \beta_3}{2}\right)M - \left(\frac{\alpha_4 - \beta_4}{2}\right)R \end{aligned} \tag{10}$$

Similarly

$$\begin{aligned} X = 12 &+ \left(\frac{\alpha_1 - \beta_1}{2}\right)L + \left(\frac{\alpha_2 - \beta_2}{2}\right) \\ &A + \left(\frac{\alpha_3 - \beta_3}{2}\right)M + \left(\frac{\alpha_4 - \beta_4}{2}\right)R \end{aligned} \tag{11}$$

Declaring a new function, let

$$\begin{aligned} T_1 &= \left(\frac{\alpha_1 - \beta_1}{2}\right)T_2 + \left(\frac{\alpha_2 - \beta_2}{2}\right) \\ T_3 &= \left(\frac{\alpha_3 - \beta_3}{2}\right) \text{and } T_4\left(\frac{\alpha_4 - \beta_4}{2}\right) \end{aligned} \tag{12}$$

By induction therefore, it would be convenient to represent the four parameters of Eq. 12 with a generalized equation given as (4)

$$T_i = \left(\frac{\alpha_i - \beta_i}{2}\right) \text{where } i = 1,2,3,4,5,.....n \quad (13)$$

Thus Eq. 10 and 11 can be represented by

$$X = 12 + T_1L + T_2A + T_3M + T_4R \quad (14)$$

$$Y = 12 - T_1L - T_2A - T_3M - T_4R \quad (15)$$

Equation 14 and 15 are the mathematical representation that was employed to determine the time spent indoor and outdoor by any person living either in an urban or rural environment. In a more concise manner, they can be written as

$$X = 12 + \sum_{i=0}^{n} T_iL_i \quad (16)$$

$$Y = 12 - \sum_{i=0}^{n} T_iL_i \quad (17)$$

where L_i represent the variables and T represents the parameters. The values of these parameters T_i can be calculated from the relative percentage spent indoor and outdoor of the timeslot for each activity.

Using the model and data acquisition: In obtaining the appropriate values of the variables and their corresponding model parameters, questionnaire was administered to people residing at Lagos State and Benin City representing urban dwellers and some villages in Edo State representing rural dwellers. In order to consider a larger proportion of the populace, people were grouped based on the closeness and similarities of their activities. It was assumed that the sampled population is engaged in one activity or the other, either schooling (student) or working (workers). For convenience, we have not considered the non-working class, though the models described by Eq. 16 and 17 can be used to accommodate the non-working class (including Pensioners, Job seekers and full house wife). The timeslot for occupation of the aforementioned group of people would be taken as zero. The time spent for other activities and the percentage indoor and outdoor for each of the activities will vary from person to person. The summary of the average time slot for urban dwellers for each of the activity is presented in Table 2 while Table 3 presents the values of T_i estimated from α_i and β_i for each of the activities. Similar presentations have been made for rural dwellers in Table 4 and 5.

Equation 16 and 17 have been solved by developing FORTRAN subroutine to evaluate numerically the time spent for indoor and outdoor activities using their dependable variables.

Table 2: The summary of the average time slot for urban dwellers for each of the activity for the eight groups of people considered in this study

Activity	Student	Banking	Brewery/ construction/ insurance	Health care/ hospitals/ clinics	Civil service	Force/ para-military/ military	Crafts/ business/ petty trading	Agro-allied/ miscellaneous industries
Leisure	3	2	3	1	4	4	3	3
Academics/occupation	10	11	9	12	8	10	9	9
Miscellaneous activities	3	3	4	3	4	2	4	4
Rest	8	8	8	8	8	8	8	8

Table 3: Values of T_i estimated from α_i and β_i for each of the activity as applicable to urban dwellers

Activity	Student	Banking	Brewery/ construction/ insurance	Health care/ hospitals/ clinics	Civil service	Force/ para-military/ military	Crafts/ business/ petty trading	Agro-allied/ miscellaneous industries
Leisure	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Academics/occupation	0.3	0.3	0.3	0.3	0.3	0.1	-0.1	0.3
Miscellaneous activities	-0.1	0.2	-0.1	0.2	-0.1	0.2	0.2	0.2
Rest	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5

Table 4: The summary of the average time slot for rural dwellers for each of the activity for the four groups of people considered in this study

Activity	Farming	Petty trading	Health care	Extension services
Occupation	10	9	12	8
Miscellaneous activities	6	7	4	8
Rest	8	8	8	8

Table 5: Values of T_i estimated from α_i and β_i for each of the activity as applicable to rural dwellers

Activity	Farming	Petty trading	Health care	Extension services
Occupation	-0.2	-0.1	0.2	-0.1
Miscellaneous activities	0.3	0.3	0.3	0.3
Rest	0.5	0.5	0.5	0.5

Table 6: The results of the computation of time spent outdoor for urban and rural dwellers

Time spent for outdoor activities (h)	Y_1	Y_2	Y_3	Y_4	Y_5	Y_6	Y_7	Y_8
Urban dwellers	4.4	3.5	4.8	3.5	3.6	7.2	4.8	7.4
Rural dwellers	8.2	6.8	4.4	6.4	-	-	-	-

RESULTS AND DISCUSSION

The results of the computation are presented in Table 6 for urban and rural dwellers. The average time spent for outdoor activity by an average city dweller has been calculated to be 4.88 h. This is the mean average time of the data presented in Table 6. Similarly, the average time spent for outdoor activity by an average rural dweller has been calculated to be 6.45 h. This implies that average city dwellers spent 20.33% of the total time per day exposed to atmospheric radiation while an average rural dweller spent 26.88% of the time per day exposed to atmospheric radiation. This time of exposure is enough to cause a large accumulation of both radioactive and solar radiation and dose in the body, which could result to several side effects. These effects can results to sickness or infections, which could be terminal in nature.

The sample variance for the data presented in Table 6 for urban and rural dwellers are 2.489 and 2.46, respectively. This enables us to estimate the extent of deviation from the mean value in order to predict the confidential interval. It follows therefore that the time spent by average city dweller for outdoor activities is between 2.391 and 7.369 h, while the time spent by an average rural dweller for outdoor activities is between 3.99 and 8.91 h. Rural dwellers are more exposed to atmospheric radiation than city dwellers. This follows therefore that rural dwellers absorb more radiation than urban dwellers. This is likely responsible for the high rate of skin infections (deformation) such as tumor, cataracts, abnormal nail and short life span among rural dwellers.

CONCLUSIONS

We have attempted, in this study, to develop a mathematical representation of the time spent for outdoor and indoor activities by urban and rural dwellers. The mathematical model representation has been used to calculate the occupancy factor for outdoor activities by urban and rural dwellers. The occupancy factor for city dweller is between 2.391 and 7.369 h with a mean of 4.88 h, while that rural dweller is between 3.99 and 8.91 h with a mean of 6.45 h. This corresponds to the time for radiation exposure and absorption during the day time. This in turn would predict the total amount of radiation absorbed, given the exposure rate for the urban and rural populace. This is of a particular interest in the determination of dose from nuclear radiations released into the environment from nuclear accident, nuclear weapon test and UV radiation.

The model presented in this research for the city and rural dwellers can also be used as an economic index to determine the level of productivity in a given population.

REFERENCES

Brown, L., 1983. National radiation survey in the UK. Indoor occupancy factors. Radiat. Prot. Dosim., 5: 203-208.

Cross, M. and A.O. Moscardini, 1985. Learning the Art of Mathematical Modeling. Ellis Harwood Limited, pp: 15-24, 55, 67-72.

Edwards, D. and M. Horton, 1989. Guide to Mathematical Modeling. The Macmillan Press Ltd., pp: 1-46.

Glowaik, B.J. and J.M. Pacyna, 1980. Radiation dose due to atmospheric release from coal fired power plants. Health Phys., 16: 23-28.

Gransty, L.R. and J.R. LaMarre, 2004. The annual effective dose from natural sources of ionizing radiation in Canada. Prot. Dosimetry, 108: 215-226.

Hocking, R.R., 1984. The Analysis of Linear Models. Brooks /Cole Publishing Company, pp: 3, 52.

Lagarde, F., 2003. Methodology issues in epidemiological assessment of health effects of low-dose ionizing radiation. Radiat. Prot. Dosimetry, 104: 297-313.

Motersill, C., K. O'Malley and C.B. Segmour, 2002. Characterization of a Bystander effect induced in human tissue explant culture by low LET radiation. Prot. Dosimetry, 99: 163-167.

Prokic, V., P. Jacob and W. Heidenreich, 2002. Possible implication of non-linear radiobiological effects for the estimation of radiation risk at low doses. Prot. Dosimetry, 99: 279-281.

United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR), 1988. Ionizing Radiation: Sources and Biological Effects. Report on the General Assembly (New York: UN).