STUDIES OF THE ANATOMICAL, PHYSIOLOGICAL AND METABOLIC CHARACTERISTICS OF THE INDIAN POPULATION FOR SETTING UP A REFERENCE MAN

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Abstract

This paper presents Indian data on various human characteristics such as physical, anatomical, physiological and metabolic parameters. The knowledge of these parameters is required for dosimetric purposes and for developing secondary radiation standards for occupational workers and the general public. The data reported are for the adult population, as well as for the younger population at the ages newborn, and 1, 5, 10 and 15 years. On the basis of the collection, collation and generation of the above data, the characteristics of the Reference Indian Man are proposed. The comparison of Indian data with that for ICRP Reference Man (representing the Caucasian population) shows that most of the physical, physiological and anatomical characteristics of the Indian population are smaller. The weights of a few smaller organs such as thyroid, testes, etc. are comparable and the daily intake of drinking water, the sweat rate and urine excretion rate etc. are higher than those for ICRP Reference man.

INTRODUCTION

The description of human data on physical, physiological, anatomical and metabolic parameters is required for radiation control and assessment (internal and external dosimetry): 1) through the development of appropriate phantom for calibration purposes, 2) by recommending realistic secondary radiation standards such as ALI (annual limit on intake), DAC (derived air concentrations) for various radionuclides, and 3) by obtaining the reliable metabolic factors (retention half-lives, distribution factors-F2) for different radionuclides.

Until recently, the radiation protection practices in different countries made use of the reference data compiled by the International Commission on Radiological Protection (ICRP) [1]. These data however are representative of the caucasian population (European and North American in origin). A few of the studies carried out in India [2-5] and in Japan [6], have demonstrated beyond doubt that Asians are much different from Caucasians in physique, as well as in customs and habits. This realization underlines the need to develop the human models representative of Indian and Asian population in order to strengthen the radiation protection in this region.

After the Chernobyl Nuclear Accident in Russia (1986) it became clear that it is not only the radiation worker (adult population group), but also the members of the public in other age groups (including younger age groups) who are also exposed to the risk of radiation. It, therefore, became necessary to obtain additional data on the relevant parameters for newborn, and 1, 5, 10, and 15 year age groups.

In Bhabha Atomic Research Centre, a programme was undertaken to collect, collate and generate relevant reference data for radiation protection purposes. This report deals with the data for Indian population on different parameters: 1) physical and anthropometric, 2) anatomical, 3) physiological, and 4) metabolic parameters. Wherever possible, data on the younger age groups are also reported.

PHYSICAL AND ANTHROPOMETRIC DATA

Body Weight and Height

The weight and height on the Indian population in different age groups are shown in Table 1. The main source of these data are three extensive reports [7-9] for surveys carried out for rural and urban populations, by the National Nutrition Monitoring Board (NNMB) in India. The data on weight of newborns were collected by Dang et al [10]. The data on newborns is also supported by the body weight data reported by many other workers [11-16]. The extensive studies carried out by NNMB [7-9] assume greater importance in view of the fact that weight and height parameters, even for the same age groups, have been shown to vary with different factors such as, the origin of the population group (rural or urban), socio-economic status, religion, etc. [17].

The data reported in Table 1 are the weighted means of the different socio-economic groups in the urban and rural areas. Additional weight was given to the distribution of population in the urban (27%) and rural population (73%) to arrive at the final data. The repeat survey (NNMB Report 1988-90) [9] of the rural population group, after 10-12y period, showed an increase of about 1 Kg body weight in male adults. A marginal increase was also observed in the height. For the female population however, this effect was less pronounced.

TABLE I. WEIGHT AND HEIGHT OF INDIAN POPULATION (MALE AND FEMALE) IN DIFFERENT AGE GROUPS

Age group (year)	Weight (Kg)		Height (cm)	
	Male Mean±SD	Female Mean±SD	Male Mean±SD	Female Mean±SD
Newborn*	2.9±0.3 (250)	2.8±0.3 (250)	49.0±2.0 (250)	48.0±2.0 (250)
0.25	6.2±1.6 (2,284)	5.9±1.0 (2,088)	63.6±6.0 (2,284)	62.7±7.0 (2,088)
1	8.5±1.5 (1,643)	8.1±1.5 (1,357)	74.4±5.0 (1,643)	72.4±5.5 (1,357)
5	14.6±2.0 (1,477)	14.2±2.0 (1,360)	102.7±6.0 (1,477)	100.8±9.0 (1,360)
10	22.9±3.5 (1,454)	22.9±3.4 (1,302)	128.1±7.0 (1,454)	128.5±7.0 (1,302)
15	38.3±6.5 (954)	38.7±6.0 (764)	154.2±8.5 (954)	148.8±6.0 (764)
20	48.6±6.1 (2,461)	43.3±5.5 (3,800)	163.3±7.0 (2,461)	151.0±6.0 (3,800)
20-50	51.5±8.5 (12,189)	44.2±8.0 (14,101)	163.4±7.5 (12,189)	151.0±6.5 (14,101)

* Newborn includes ages up to one week

The number of subjects covered in each population group are shown in parenthesis.

TABLE II. SITTING HEIGHT AND CHEST CIRCUMFERENCE OF THE INDIAN POPULATION (MALE AND FEMALE) IN DIFFERENT AGE GROUPS

Age group (year)	Sitting height (cm)		Chest circumference (cm)	
	Male Mean±SD	Female Mean±SD	Male Mean±SD	Female Mean±SD
Newborn*	33.0±3.5 (240)	32.5±2.8 (260)	35.0±2.5 (240)	34.1±3.8 (250)
1	45.4±2.9 (2,906)	44.2±2.9 (2,906)	43.3±4.7 (2,874)	42.3±4.0 (2,654)
5	57.0±3.3 (3,484)	56.0±3.4 (3,484)	50.8±5.4 (2,358)	50.1±3.8 (2,175)
10	67.5±3.6 (4,065)	67.1±4.0 (4,065)	59.1±4.8 (2,809)	58.4±4.7 (2,523)
15	79.8±5.2 (3,609)	77.9±3.7 (3,609)	70.9±7.6 (2,122)	71.5±6.5 (1,394)
20	85.0±3.6 (1,757)	79.2±3.5 (1,757)	77.3±8.6 (1,140)	74.6±6.3 (552)
20-50	85.8±4.7 (270)	80.0±4.1 (250)	80.8±8.7 (270)	78.0±6.0 (260)

* Newborn includes ages up to one week

The number of subjects covered in each population group are shown in parenthesis.

Sitting Height, Chest Circumference, Head Circumference and Head Diameter

The source of data for these two parameters for population in the 1, 5, 10, 15 and 20 year age groups is the national level survey conducted (1956-65) by the Indian Council of Medical Research (ICMR) [17]. The data in the newborn and 20-50y age groups were collected by the authors. The figures given in parenthesis denote the number of subjects included for the study of each parameter. It should be noted that in the extensive study by ICMR, due consideration was given to different variables by carefully choosing the subjects included in the study.

The data collected by the authors is for a smaller number of subjects, but is equally important, because the subjects studied by the authors were from the target population (low to lower middle income group with body weight and height dimensions within one to two standard deviations of the mean for these age groups).

Proposed Physical Data for Reference Indian Man

The measured data on adult population along with the proposed reference values are shown in Table 4. The dimensions of some of the physical parameters such as, body height, weight, body surface area and sitting height have been rounded to the nearest integer. This

TABLE III. HEAD CIRCUMFERENCE AND DIAMETER FOR INDIAN POPULATION (MALE AND FEMALE) IN DIFFERENT AGE GROUPS

Age group (year)	Head circumference (cm)		Head diameter (cm)	
	Male Mean±SD	Female Mean±SD	Male Mean±SD	Female Mean±SD
Newborn*	38.0±3.9 (250)	37.0±3.4 (240)	9.1±0.3 (18)	9.0±0.2 (10)
0.25	41.6±2.9 (424)	40.6±3.6 (293)	---	---
1	44.4±3.6 (2,903)	43.6±1.8 (2,643)	---	---
5	48.5±2.7 (2,241)	47.8±1.7 (2,159)	13.0±1.1 (240)	13.2±1.6 (210)
10	50.4±1.7 (2,647)	50.1±1.6 (2,784)	13.4±1.2 (230)	13.6±1.4 (215)
15	52.6±1.8 (2,337)	52.2±1.8 (1,627)	14.8±1.0 (200)	14.2±1.5 (190)
20	53.6±1.7 (939)	52.6±1.7 (421)	15.0±1.3 (180)	14.3±1.3 (160)
20-50	54.0±2.0 (210)	52.9±2.1 (250)	15.1±1.3 (290)	14.3±1.2 (220)

* Newborn includes ages up to one week

The number of subjects covered in each population group are shown in parenthesis.

was done on the basis of the observed increase in the physical dimensions of adult population in the revised survey conducted by NNMB [9] after a gap of about 10y. The reference data being obtained now, is likely to be used in years to come. So the rounding off of the dimensions to the higher side (by about 2-3%) for the proposed Reference Indian Man would be appropriate. The body surface area was based on the reported values (Vyas, et al, 1965; Banerjee and Sen, 1958; Kamat, et al, 1977) as well as by applying the Du Bois (1916) [20] formula to the weight and height data obtained for the adult population.

ANATOMICAL

Anatomical data such as the weights and sizes of the body organs along with other physical features are required for the development of a realistic phantom as well as for internal dosimetry. Until now, the dimensions and weights of body organs for caucasian population (MIRD phantom) [49] were being used for dose calculations.

The radiation dose is generally assessed in terms of the energy deposited per unit mass of the organ. Venkatraman, et al (1963) [22] reported lower organ weights for the adult Indian population and suggested that for the Indian adult, the radiation dose per unit intake of

TABLE IV. MEASURED AND PROPOSED PHYSICAL DATA ON ADULT INDIAN (MALE AND FEMALE) POPULATION

Parameter	Male		Female	
	Measured	Proposed	Measured	Proposed
Body Wt. (kg)	51.5±8.5	52.5	44.2±8.0	45.
Standing Ht. (cm)	163.4±7.5	164	151.0±6.5	151.
Sitting Ht. (cm)	85.8±4.7	86	80.0±4.1	80.
Body surface area (M^2)	1.61±0.16	1.62	1.40±0.06	1.40
Chest width (cm)	38.0±3.1	38.	37.0±4.0	37.
Chest Circum. (cm)	80.8±8.7	81.	78.0±6.0	78.
Chest depth (cm)	19.0±2.0	19.	18.0±2.0	18.
Head Circum. (cm)	54.0±2.0	54.	53.0±2.0	53.
Head Dia. (cm)	15.0±1.0	15.	14.0±1.0	14.
Head depth (cm)	19.0±2.0	19.	18.0±2.0	18.
Head Ht. (cm)	23.0±2.0	23.	21.0±2.0	21.
Neck Circum. (cm)	35.0±5.0	35.	31.0±4.0	31.

radioactivity would be larger in comparison to that for the caucasian population. On the basis of this observation they had suggested to lower the maximum permissible body burden (MPBB) levels for a large number of radionuclides.

The studies of Venkatraman, et al [22] provided information on the weighted mean organ weights on the combined male and female population which was reported as Indian Standard Man data at that time. A more detailed study was therefore needed to obtain data on individual male and female populations in adult and also on the younger age groups.

The data collected earlier was critically evaluated and additional data were collected to obtain the organ weights for the adult and younger population. These data were obtained from 24 medical institutions located in 18 cities of India covering almost the entire region of the country (Fig. 1). In all, about 14,500 post mortem cases (about 10,000 male and 4,500 female) of accidental deaths were studied. These subjects were healthy at the time of the accident.

In the case of the population in younger age groups, because of the practical difficulties and other considerations, only a smaller number of subjects (10-50 in each age group) could be studied to obtain the organ weight data.

Organ Weights for Different Age Groups

The mean organ weights along with the associated standard deviations (SD) for brain, heart, kidneys (2), liver, lungs (2), spleen, pancreas, testes (2) and thyroid, for 0, 1, 5, 10, 15y, and adult age groups are shown in Tables 5 and 6. The figures given in parenthesis are for the number of subjects studied for each organ and in each age group. In the case of lungs, kidneys, testes, the weight of both right and left organs were added to obtain the final weight.

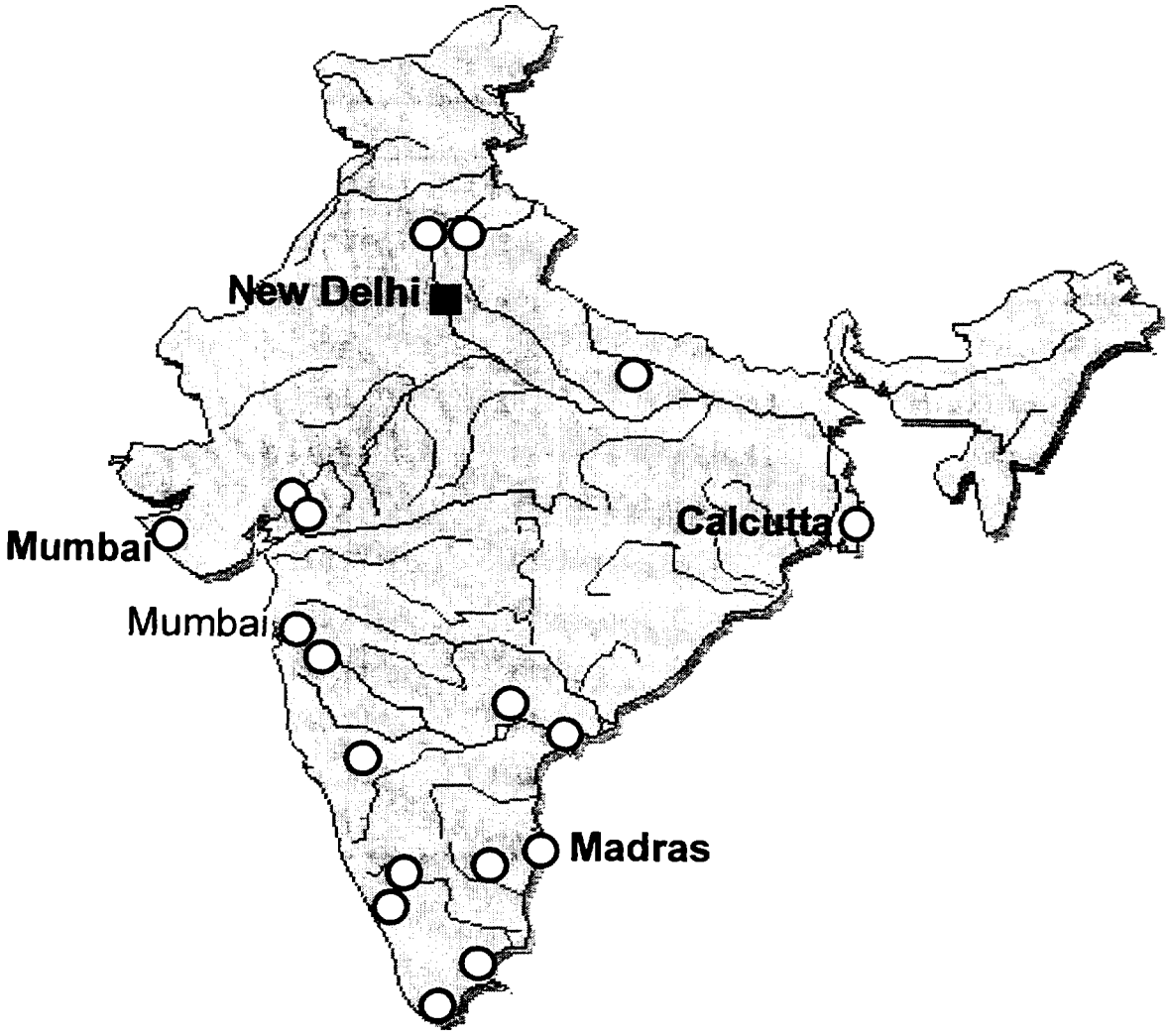

FIG. 1. Indian sampling locations for anatomical studies.

The organ weight data for the newborns of both male and female sex were combined to obtain the final data because: 1) the number of subjects belonging to either sex were rather small, and 2) the differences between the individual organ weights at the newborn stage were not statistically significant.

The average weights of only those organs are reported in Tables 5 and 6, for which the data could be obtained from at least four different locations in the country. The limited data on the organ weights of the younger age group also covers one location each from north, west, south and east India.

Proposed Organ Weights for Reference Indian Man

The data obtained on the organ weights of the adult Indian population are extensive and large enough to use as the basis to propose anatomical parameters for RIM. Table 7 gives the values of the proposed organ weights for the adult population along with the measured data. The proposed weights are marginally higher for the major organs, because it was observed that the weights of the larger organs are in proportion to the body weight and the body weight of the Indian adult has shown increase at the rate of 1 kg in every ten years (NNMB Report 1988-90) [9]. Therefore the weights have been rounded off on the higher side by increasing their values by about 2-3% of the observed values.

TABLE V. MEAN (± sd) ORGAN WEIGHTS OF INDIAN POPULATION IN DIFFERENT AGE GROUPS - (g)

Organ	Age - years				
	Newborn	1		5	
	Combined	M	F	M	F
Brain	295±138 (15)	785±133 (10)	670±215 (12)	986±230 (14)	1010±230 (10)
Heart	17±7 (14)	39±12 (13)	35±12 (10)	73±50 (23)	74±28 (14)
Kidney (2)	20±7 (14)	56±16 (13)	51±18 (10)	98±39 (26)	95±39 (11)
Liver	99±32 (14)	250±103 (12)	222±81 (10)	478±172 (25)	448±150 (16)
Lungs (2)	63±21 (11)	123±36 (12)	98±30 (12)	252±137 (25)	208±55 (18)
Spleen	7±4 (14)	23±13 (12)	21±8 (10)	58±31 (24)	58±23 (14)
Pancreas	3±1 (10)	14±6 (16)	11±6(10)	25±12 (16)	31±13 (12)
Testes (2)	2±1 (11)	3±1 (10)	--	6±3 (11)	--
Thyroid	1.5±0.4 (18)	3±1 (10)	--	4±2 (13)	--

The number of subjects covered in each population group are shown in parenthesis.

PHYSIOLOGICAL PARAMETERS

The data on the physiological parameters such as pulmonary function, water balance and body composition for adult Indian population only are reported. It was not possible to obtain the physiological data for the younger age groups.

Pulmonary Function

The knowledge of the pulmonary standards is important in radiation protection. Some of these parameters have been reported to determine the retention pattern of the inhaled airborne aerosols in the pulmonary region of the human body (Subaramu, 1974; Bell and Gilland, 1964; Bouhuys, 1970) [23-25]. The pulmonary standards included in the present study are: vital capacity, maximum breathing capacity, minute volume, respiratory rate and tidal volume.

The vital capacity obtained for 2,620 male subjects (age range 17-54y) by 18 different workers from different regions of India [5, 23, 28-41] were in the range 2.8-4.0 L with a mean value of 3.3 ± 0.4 L. The highest value of vital capacity was for the north Indian population

which is also reported [17] to have larger physical parameters in comparison to those for the average Indian. For female subjects, there are only two studies. The systematic study carried out by Kamat, et al [5] for about 500 female subjects in the age range 18-47y, gave the mean vital capacity figure of 2.2 ± 0.2 L. The average vital capacity reported for females by the other worker is also similar to that reported by Kamat, et al. The results are shown in Table 8. In comparison to the ICRP data [1], Indian values are 30% lower. One or two of the isolated studies on the population groups whose body weight and height were not representative of the average Indian have not been included [55].

Maximum breathing capacity data are reported for 940 male subjects (age range 17-62y) by 8 workers [8, 34-40] and data for female subjects is reported for 572 subjects [5,37]. On the basis of the results, mean maximum breathing capacity values of 123 ± 15 L and 78 L were obtained for male and female subjects respectively (Table 8). There are no equivalent data available for ICRP Reference Man to compare with.

TABLE VI. MEAN (± sd) ORGAN WEIGHTS OF INDIAN POPULATION IN DIFFERENT AGE GROUPS - (g)

Organ	Age - years					
	10		15		Adult (>18 Years)	
	M	F	M	F	M	F
Brain	1142±182(15)	1084±182 (14)	1208±172 (23)	1150±100 (18)	1236±127 (9,599)	1140±120 (3,070)
Heart	140±58 (30)	134±78 (21)	208±95 (35)	220±105 (29)	243±52 (9,599)	211±47 (3,194)
Kidney (2)	141±37 (27)	143±32 (20)	198±51 (38)	217±54 (31)	224±48 (9,599)	207±47 (3,194)
Liver	785±203 (30)	617±208 (21)	888±245 (36)	954±244 (31)	1135±251 (9,501)	1051±226 (3,190)
Lungs (2)	462±220 (29)	413±198 (20)	645±242 (41)	598±226 (29)	841±154 (6,887)	670±140 (2,307)
Spleen	102±55 (25)	89±62 19)	118±49 (35)	132±44 (28)	137±67 (9,626)	119±59 (3,194)
Pancreas	55±15 (17)	47±15 (11)	80±28 (20)	73±25 (14)	96±34 (714)	82±32 (298)
Stomach	--	--	--	--	135±25 (2,680)	140±34 (796)
Testes (2)	7±2 (11)	--	22±15 (10)	--	35±5 (350)	--
Thyroid	8±3 (10)	--	12±5 (11)	--	19±7 (500)	18±7 (120)

The number of subjects covered in each population group are shown in parenthesis.

TABLE VII. THE MEASURED AND PROPOSED ORGAN WEIGHTS FOR REFERENCE INDIAN MAN (RIM) - (g)

Organ	Weight (g)			
	Male		Female	
	Measured	Proposed	Measured	Proposed
Brain	1236	1250	1140	1150
Heart	243	250	211	220
Kidney (2)	224	230	207	210
Liver	1135	1175	1050	1075
Lungs (2)	841	870	670	690
Spleen	137	140	119	120
Pancreas	96	100	82	85
Stomach	135	135	125	125
Prostate	21	20	--	--
Testes (2)	35	35	--	--
Adrenals	13	13	12	12
Thyroid	19	19	18	18

Tidal volume is the amount of air or gas breathed in and out in one cycle. Four studies for the male subjects [5,23,38,41] and two for the female subjects [6,36] are reported in the literature. The tidal volume for Indian subjects was in the range 0.51 - 0.61 L and 0.35 - 0.42 L respectively.

Respiratory rate is the number of cycles in one minute that the air is breathed in and out by an individual. The three studies reported in the literature [5,23,41] for both male and female subjects give mean values of 19.7 and 20 for male and female population respectively. The authors however in the present study obtained a lower value of 15 cycles each for both male and female populations. About 80 cases each were studied for the two population groups. The respiratory rate reported by ICRP Reference Man [1] is also 15 for both male and female population groups.

Minute volume is the volume of air breathed in and out in one minute, and is obtained by multiplying tidal volume and the respiratory rate. If the RR values reported by other workers [5,23,41] is used to obtain the minute volume for the Indian population, then higher minute volume is obtained in comparison to the ICRP value [1] (Tables 8 and 9). However when the RR value of 15 obtained by the authors is employed, then the value thus obtained for the Indian population is comparable with ICRP data. The authors propose to use the later value.

There is only one study that presents data on total lung capacity [5]. Data were obtained for 55 male and 27 female subjects from South India in the age range 20-50y. The mean total lung capacity reported is 4.9 ± 0.2 L and 3.7 ± 0.2 L respectively for the male and female group. The total lung capacity reported for ICRP Male is 4.4 L.

TABLE VIII. PULMONARY STANDARDS FOR ADULT INDIAN POPULATION

Parameter	No. of Studies	Age group (years)	No. of subjects	Measured range	Values (L) Mean ± SD
Vital Capacity (VC)					
Male	18	17 - 54	2,620	2.80 - 3.98	3.3 ± 0.4
Female	1	18 - 47	504	--	2.2 ± 0.2
Maximum Breathing Capacity (MBC)					
Male	8	17 - 62	940	110 - 153.6	125.3 ± 18
Female	2	17 - 47	572	--	78.0
Tidal Volume (TV)					
Male	4	adult	--	0.51 - 0.65	0.54 ± 0.08
Female	3	adult	--	0.35 - 0.42	0.38 ± 0.03
Respiratory Rate (RR)					
Male	3	adult	--	19 - 21	19.7 ± 1.0
Female	3	adult	--	19.4 - 21	20.0 ± 1.0
Minute Volume (MV)					
Male		TV x RR = 19.7 x 0.54 (15x0.54)			10.6 (8.1)
Female		TV x RR = 20 x 0.38 (15x0.38)			7.6 (5.7)

TABLE IX. PULMONARY STANDARDS FOR INDIAN ADULT POPULATION AND ICRP REFERENCE MAN

Parameter	Values in liters			
	Indian		ICRP	
	Male	Female	Male	Female
Vital capacity (VC)	3.3	2.2	4.3	3.3
Maximum breathing capacity (MBC)	125.3	78	--	--
Tidal volume (TV)	0.54	0.38	0.5	0.4
Respiratory rate (RR)	15.0	15.0	15	15
Minute volume (MV)	8.1	5.7	7.5	6.0

TABLE X. BODY COMPOSITION FOR ADULT INDIAN POPULATION GROUPS

	Parameter	Measured value (l)	Average body wt. of population (kg)	ml per kg body wt. (ml/kg)	Ref.
A)	Blood Volume (l)				
	1	4.00	52.5 (M&F)	76.2	[19]
	2 A	3.61	50.0 (M)	72.2	[18]
	2 B	4.60	62.5 (M)	73.6	"
	2 C	3.20	43.5 (F)	73.5	"
	Average			73.9	
B)	Total body water (l)			Percentage of body weight	
	1	31.7±0.8	52.5 (M&F)	62.1	[19]
	2	34.5±5.2	59.0 (M)	58.6	[42]
	Average			60.3	
C)	Extra cellular fluid	11.6±0.3			
	Intra cellular fluid	20.1±0.5			
D)	Lean Body Mass			Percentage of body weight	
	Lean body mass (LMB)	44.8	52.5 (M&F)	87.7	[19]
	(Kg)		59 (M)	79.8	[42]
	Lean body mass	47.1			
E)	Total body fat (kg)	6.8±1.1	52.5 (M&F)	13.0	[19]
F)	Skeleton weight (kg)	6.5	50 (M)		[43]
G)	Mineral (kg)	3.1±0.1	52.5 (M&F)	6.1	[19]

Body Composition

The data reported here are only for the adult population. The main source of information is the work by Banerjee and Sen [18], who have studied the above parameters in a group of male and female subjects with mean body weight of 52.5 Kg. In addition to the data by these workers, another group of workers (Vyas et al) [19] have measured the blood volume for two sets of populations belonging to higher and lower socio-economic groups with distinctly different body weights. Avadhani and Shetty [42] have reported values of lean body mass, they have also determined the total body water in the adult population using the ethanol dilution method. These data are presented in Table 10 along with the data on skeleton weight, total body fat and mean weight of minerals for the adult population group.

TABLE XI. PROPOSED BODY COMPOSITION OF REFERENCE INDIAN MAN

Parameter	Male	Female
1. Lean Body Mass (kg)	45 (58.0)	38 (43.0)
2. Body Fat (kg)	6.8 (13.5)	5.5 (16.0)
3. Blood Volume (l)	3.9 (5.2)	3.3 (3.9)
4. Total Body Water (l)	31.5 (42)	27 (29)
5. Minerals (kg)	3.1 (4.1)	2.8 (-)
6. Skeleton Weight (kg)	7.0 (10)	6.0 (6.8)

1. This data has been arrived at using the body weight fractions for some of these body components.

2. The values given in parenthesis are for ICRP Reference Man

3. The values for Indian adult are proposed for 52.5 and 45 Kg male & female

Most of these parameters bore fixed ratio to the weight of the subjects. The body weight ratio of some of these parameters were employed to arrive at the proposed body composition of Reference Indian Man (Table 11), with 52.5 Kg and 45 Kg body weights for male and female subjects. The ICRP data are also included in Table 11 for comparison purposes and are shown in parenthesis. Although most of the body composition parameters are lower than those for the ICRP data [1] for the caucasian population, in the ratio of the body weight, yet for the average Indian, the fat content is lower than the caucasian population by a factor of 2. Much lower body fat content can be explained in terms of much lower dietary intake of fat (25% of that for the caucasians).

Water Balance

The information on the daily intake of water is important 1) for calculating the permissible radioactivity in water, and 2) in the study of the half-life of the important radionuclide ^{3}H as shown in the work of Dang et al [43]. The total excretion of water is through faeces, urine, sweat and insensible water loss (through moisture in breath and skin pores). The total intake and excretion of water determines the water balance in the human body.

The intake of water by Indian population (adult age group) has been studied by Raghunath and Soman [4] and also by ICMR [44]. The daily water excretion study was carried out by ICMR [44] and also by Dang et al [45]. The two studies on daily water consumption show that average adult in India consumes 4.5 L of water through different sources (Table 12). This consumption value is 1.5 times higher than that reported for ICRP Reference Man.

TABLE XII. WATER BALANCE STUDIES ON ADULT INDIAN POPULATION

Population group	No. of subjects	Water Intake (l)				Total
		Drinking water	Fluids Tea/coffee	Meal Preparation	Water of oxidation	
BARC middle income (Bombay)						
Male	81	1.68±0.49	0.95±0.23	1.6	0.3	4.5
Female	20	1.16±0.27	0.95±0.2	1.2	0.3	3.6
Low income group (Calcutta)		Drinking water + fluids		Meal preparation		
Spring (M)	4	1.45		2.19		3.64
Summer (M)	7	3.57		1.89		5.46
Winter (M)	6	2.05		1.46		3.51
Total Mean (M)	17	2.36		1.85		4.2

Water Excretion Data

Population group	Excretion routes			Insensible water loss
	Feces	Urine	Sweat	---
BARC middle income	---	2.0	---	
Low income group from Calcutta	0.2	2.16	---	

TABLE XIII. PROPOSED WATER BALANCE FOR REFERENCE INDIAN MAN (ADULT GROUP)

Daily Intake (l)		Daily Excretion (l)	
Sources	Volume	Routes	Volume
Drinking water	1.8	Urine	2.0
Milk	0.1	Feces	0.2
Hot beverages Tea/coffee	0.7	Sweat	1.1
Daily meal preparation	1.6	Insensible loss (Moisture in breath, etc.)	1.1
Water of oxidation	0.3		

TABLE XIV. DAILY AVERAGE INTAKE OF PRINCIPAL NUTRIENTS (g/cu/d)

Nutrient	Intake by population (adult)		
	Rural	Urban	National
Protein (g)	62	59	61.2
Fat (g)	24	45	29
Energy (kCal)	2283	2240	2272
Calcium (g)	0.556	0.632	0.575

Data reported here is on the basis of intake per consumption unit per day

TABLE XV. AVERAGE INTAKE OF FOODSTUFF (g/cu/d)

Food component	Intake in area		
	Rural (1988-90)	Urban (1975-79)	National average
Total cereals & millets	490	405	469
Pulses	32	42	35
Total Vegetables	60	78	65
Roots & tubers	40	70	48
Nuts & oilseeds	8	14	10
Condiments & spices	13	14	14
Fruits	13	44	20
Flesh foods	12	21	14
Milk	96	133	100
Fats & oils	13	24	15
Sugar & jaggery	29	28	29

The fluid intake was found to vary with the season, being highest in summer and lowest in winter, as shown in Table 12. For Indians, the major source of water intake is the drinking water itself, followed by water required for the preparation of the daily meals. The daily intake of fluids by female population was obtained to be 0.75 times the intake by male adult.

The excretion of water is mainly through urine, which is about 2.2 L (range: 0.6 - 3.1 L) followed by loss through sweat and insensible water loss through the moisture in breath and invisible water loss through the skin pores. The urinary excretion and the sweat rate are known to vary with the atmospheric temperature and with the season. In winter, the urine excretion was found to be 2.2 L and in summer it was obtained to 1.3 L for an urban population group (Dang et al) [45].

The proposed water balance data for Reference Indian Man (RIM) including both the intake and excretion values, is shown in Table 13.

TABLE XVI. PER CAPITA INTAKE OF PROTEIN (g) AND CALORIE (kcal) IN DIFFERENT AGE GROUP OF RURAL POPULATION

Age group (years)	Protein Intake (g)	Calories (kCal)
1	12.6	504
2	22.1	756
5	28.8	1080
12	40.0	1407
13-16 (M)	45.1	1600
(F)	41.0	1540
16-18 (M)	54.6	1920
(F)	44.5	1694
Adult Male	54.5	2042
Adult Female	45.9	1725

TABLE XVII. AVERAGE DAILY CONSUMPTION OF FOOD COMPONENTS BY YOUNGER INDIAN POPULATION - (g)

Age (Years)	Food components						
	Cereals	Pulses	Vegetables	Fruits	Flesh & eggs	Milk (ml)	Fat & Oil
2	176	14	31	18	6	68	5
5	263	21	51	23	7	62	7
12	400	35	62	-	-	110	18
15 (M)	440	30	70	-	-	90	18
15 (F)	-	-	-	-	-	90	-

METABOLIC PARAMETERS

The daily intake of principal nutrients for rural and urban groups, along with the weighted mean values of national average for adult population are shown in Table 14. The data on the national average is obtained by giving appropriate weight for the population distribution in the rural and urban areas of the country. The intake data are reported in terms of consumption units (CU).

The consumption unit (CU) is the coefficient for computing calorie requirement for different groups of Indian population. The CU values for adult sedentary worker is taken as 1.0 and for moderate and heavy worker the CU values are taken as 1.2 and 1.6 respectively. Similarly, the CU values for female workers in different groups are 0.8, 0.9 and 1.2 respectively.

TABLE XVIII. PERCENTAGE OF TOTAL CALORIES DERIVED FROM VARIOUS FOOD INGREDIENTS FOR INDIAN POPULATION IN DIFFERENT AGE GROUPS

Food Ingredient	Percentage calories contributed in each age group (y)						
	1-3	3-5	5-7	7-9	9-12	12-18	Adult
Cereals	66	76	77	80	80	84	81
Pulses	6	5	5	5	5	4	5
Milk & milk products	13	8	7	5	5	4	5
Sub Total	85	89	89	90	90	92	91
Sugar & jaggery	7	5	7	6	6	4	5
Fats & Oils	5	3	2	2	2	1	1
Veg. & fruits	3	3	3	3	3	3	3

Major percentage of calories 85-92% are supplied by cereals, pulses and milk products.

TABLE XIX. AVERAGE DAILY INTAKE OF A FEW SELECTED ELEMENTS BY INDIAN POPULATION IN DIFFERENT AGE GROUPS

Element	Daily intake at different ages (y)				
	2	5	12	15	Adult
Ca(g)	0.24	0.29	0.31	0.36	0.40
Na(g)		Main contribution from salt			5.9
K(g)	0.8	0.95	1.2	1.6	1.8
Mg(g)	0.25	0.3	0.4	0.5	0.5
S(g)	0.32	0.45	0.55	0.62	0.6
P(g)	0.6	0.9	1.1	1.3	1.3
Cu(mg)	0.6	0.9	1.6	1.8	2.2
Zn(mg)	4.6	5.0	7.2	8.5	10.3
Mn(mg)	1.8	2.8	4.0	4.5	5.1
Fe(mg)	8.9	11.8	15.0	20.0	19.0
Co(μg)	6.0	9.0	13.2	16.0	16.0
Cr(μg)	45.	70.	95.	120.	130.
Se(μg)	48.	67.	97.	110.	110.
Cs(μg)	3.5	5.1	7.0	8.5	9.0

The intake was obtained by the analysis of individual food components.

TABLE XX. THE COMPARISON OF DAILY DIETARY ELEMENTAL INTAKE BY ADULT INDIAN, JAPANESE & ICRP

Element	India	Japan	ICRP
Ca(g)	0.4	0.55	1.1
Na(g)	5.9	5.2	4.4
K(g)	1.8	2.0	3.3
Mg(g)	0.5	0.21	0.34
S(g)	0.6	-	0.85
P(g)	1.3	1.0	1.4
Cu(mg)	2.2	1.3	3.5
Zn(mg)	10.3	7.6	13.0
Mn(mg)	5.1	4.5	3.7
Fe(mg)	19.0	11.0	16.0
Co(μg)	16.0	-	300.
Cr(μg)	130.	180.	300.
*Mo(μg)	105.	-	200.
Se(μg)	110.	-	150.
I(μg)	250.	-	200.
Cs(μg)	9.0	-	10.
*Th(μg)	2.2	0.4	3.0
*U(μg)	0.8	0.7	1.9

(* Data for urban population)

TABLE XXI. INTAKE OF PRINCIPAL NUTRIENTS BY INDIAN INFANTS

Age (months)	Intake of Nutrients			
	Protein (g)	Fat (g)	Calories (kCal)	Calcium (g)
1 - 2	6.5	20.0	384	0.16
4 - 6	7.6	23.5	450	0.19

The data on the daily intake of various food components such as cereals, pulses, total vegetables, fruits, flesh foods, milk, fat and oils etc., are shown in Table 15. These data are also shown for rural, urban and national average values and are in consumption units. The urban data was arrived at by giving due weight to the population distribution in different socio-economic groups in urban areas along with the consumption pattern in those different groups. National average is finally computed by using intake pattern by rural and urban population along with the population distribution in the two areas.

These data on the intake of principal nutrients and food components were obtained essentially from the extensive surveys at the national levels, two of them for the rural population (NNMB Reports, 1980 and 1988-90) [8-9] and one for the urban (NNMB Report, 1984) [7].

When the intake of principal nutrients by adult population (Indian) is compared with the intake data for ICRP [1] and Japanese [Tanaka, 1988; Kawamura and Tanaka, 1992) [46-47] Reference Man, it was observed that the Indian adult consumes less protein and calories. The intake of fat is also much lower for an average Indian. These factors could explain the lower average body weight for height in the case of the Indian population in different age groups.

The per capita intake of protein and calories for different age groups of rural Indian populations are shown in Table 16. The intakes for 1, 2, 5, 12y age groups are given for mixed population, whereas for the age groups 13-16y, and 16-18y, and adult population the data are reported for male and female populations separately. It is clear from the data that the intake of both these nutrients increase with age, but the intakes of both protein and calories in the 16-18y and adult are comparable. The intakes reported here are on a per capita basis and not in consumption units. Although the per capita intakes of protein and calories reported in this table are for rural populations, the intake values for the urban population are not likely to be much different, as indicated from the calorie intake data per CU for the two population groups.

The major amount of energy (calories) for the Indian population in different age groups is derived from cereals, followed by pulses and then milk. Table 18 shows the percentage of total calories derived from various food components, for the population groups in the age range 1-3, 3-5, 5-7, 7-9, 12-18 and adult. As is clear from the Table, more than 85% of the total calories consumed are derived from cereals, milk and pulses and only a smaller percentage of calories are supplied by other food components.

Trace Element Intake

The intake of various trace elements by the Indian population groups in 2, 5, 12, 15y and adult were obtained by the trace element analysis of the individual food items, using the two analytical techniques of neutron activation analysis (NAA) and atomic absorption spectrophotometry (AAS), and from the amounts of individual food components consumed by different population groups. The reliability of the two analytical techniques for the trace analysis was tested by the analysis of Reference Materials with known concentrations of trace elements in them.

The intake of fourteen trace elements, Na, K, Ca, Mg, Cu, Zn, Fe, Se, Co, Cr, Cs, S and P by the Indian population in different age groups are given in Table 19. The analysis of the elements Ca, Mg, Na, K, Cu, Zn, Fe and Mn were carried out using AAS technique and for Fe, Co, Se, Cs, Cu and Zn, NAA technique was employed. The concentrations of S and P in different food components were obtained from the report on nutritive values of Indian foods [48].

The intake for a few more important elements such as Th, U, I were also obtained but only for the adult population group. Table 20 shows the comparison of the daily intake of

TABLE XXII. DAILY INTAKE OF A FEW SELECTED TRACE ELEMENTS BY BREAST FED INDIAN INFANTS

Age of Infant	Daily Intake								
	Cu (mg)	Zn (mg)	Fe (mg)	Mn (μg)	Co (μg)	Mo (μg)	Se (μg)	As (μg)	Hg (μg)
0 - 1 week	0.27	2.07	0.34	4.95	0.36	7.29	14.8	0.27	0.14
1 - 2 month	0.20	1.27	0.38	4.75	0.35	5.32	14.8	0.40	0.17
2.5 - 3.5 month	0.16	0.98	0.45	4.62	0.41	5.51	15.7	0.40	0.16

(1) Dang et al. (1983)
(2) Dang (1984)
(3) Dang et. al. (1984)

TABLE XXIII. ELEMENTAL COMPOSITION OF COMMERCIAL MILK POWDERS (RANGE OF VALUES)

Element	Unit	Concentration in powder	Concentration in reconstituted milk
Ca	μg/g	8200 - 33700	1170 - 4814
Na	"	4500 - 5400	643 - 771
Mg	"	680 - 850	97 - 121
Zn	"	23.5 - 39.1	3.4 - 5.6
Fe	"	8.3 - 75.0	1.2 - 11.0
Cu	"	0.9 - 9.4	0.1 - 1.3
Se	ng/g	354.6 - 818	52 - 117
Mn	"	258 - 465	37 - 66
Mo	"	66 - 114	9 - 16
Co	"	3.8 - 15.3	0.5 - 2.0
As	"	8.0 - 15.4	1 - 2
Hg	"	2.8 - 4.4	0.4 - 0.6

The reconstituted milk is prepared by mixing 30 g of powder in 200 ml of water.

trace elements by Reference adult population of India, Japan [47] and ICRP Reference Man [1] representing the caucasian population. The intake of elements Ca, K, Cu, Zn, Co, Cr, Mo, Th and U are lower for the Indian population when compared with the corresponding figures of ICRP Reference Man, whereas intakes of Na, Mg, Mn, Fe were found to be higher for Indians. The higher intake of Na and Mg could be due to increased requirements as the sweat rate is higher. Mn and Fe intake could be higher due to larger cereals component in diet which are rich in these two elements. The Co intake reported by ICRP is much higher and needs to be revised. The analysis of some of the standard US and European diets gave an estimated daily intake of about 20-30 microgram by European and US population groups. The elemental intake by the Indian population is generally comparable to that for the Japanese population.

Daily Intake of Nutrients by Infants in Early Stages of Life

The only source of nutrition for Indian infants through the first 4-6 months of life is the mothers milk. The intakes of nutrients such as protein, fat and calories in early stages of life could be easily estimated once the intake of milk is known. The values of nutrients in mothers milk are provided in NIN report on nutritive values of Indian foods [48]. Similarly, the intake of micronutrients such as trace elements in mothers milk along with the average intake of milk is known. Dang (1984) [49] has studied the daily intake of milk by Indian infants in the age groups 1-2 months and 4-6 months by test weighing method. The daily intake of milk for the two age groups was 0.59 ± 0.06 and 0.69 ± 0.09 L respectively. The results on daily milk intake obtained by Dang et al., were supported by similar studies [50-51].

Using the data on protein, fat, calorie and calcium for the 1-2 m and 4-6 m, the daily intake of these nutrients for two age groups is shown in Table 21.

The daily intake of trace elements during the first week and also in two other age groups - 1-2 m and 2.5 - 4.5 m were obtained. The intake reported in this table is for the elements Cu, Zn, Fe, Mn, Co, Mo, Se, As and Hg. These data were obtained by using the trace element concentrations determined by Dang et al [52-54], using neutron activation analysis for the breast milk obtained at different stages post partum. The results are reported in Table 22.

It was observed that generally the first milk (colostrum) had a few times higher concentration of most of the elements. Therefore the intake of elements such as Cu, Zn, Mn, Mo, is higher in the first week of life, although the volume of milk consumed is lower.

Although human milk is the ideal food for infants, many infants are fed on commercial milk, because either the mother is not able to lactate or she has to go to work. In that case the trace element supply to the infants depends upon the trace element concentrations in the commercial milk formulae. The range of concentrations of a number of elements, Na, K, Ca, Mg, Cu, Zn, Mn, Fe, Se, Co, Mo, As and Hg in a few popular brands of milk formulae available in the market are reported in Table 23. The milk powders are generally diluted 7 times with boiled water to reconstitute fluid milk. The expected range of elemental concentrations in reconstituted milk are also reported in Table 23. It was observed in the work of Dang (1984) that, with the exception of Cu, Mo, As and Hg, most of the elements are higher in commercial milk formulae. The concentrations of Cu and Mo are lower in commercial formulae and those of As and Hg are comparable with those in breast milk.

Elemental Content of Body Organs

The elemental organ burdens for the adult population were obtained by carrying out the trace element analysis of a number of organ tissues obtained at autopsy performed on the healthy subjects who died from accidental deaths. The average concentrations of fifteen elements obtained on the basis of trace element analysis of organ tissues from 15-20 subjects

TABLE XXIV. COMPARISON OF THE ORGAN BURDENS FOR DIFFERENT ELEMENTS INDIAN AND ICRP REFERENCE MAN - (g)

Organ	Element							
	Na		K		Ca		Mg	
	1	2	1	2	1	2	1	2
Heart	0.30	0.40	0.54	0.72	0.009	0.012	0.033	0.054
Kidney	0.60	0.62	0.44	0.59	0.025	0.029	0.023	0.040
Liver	1.8	1.8	2.7	4.5	0.68	0.67	0.13	0.31
Lungs	1.8	1.8	1.3	1.9	0.10	0.09	0.067	0.071
Muscle	12.	21.	33.0	84.0	1.0	0.9	2.3	5.3
Brain	2.0	2.5	3.4	4.2	0.12	0.12	0.27	0.27
Skeleton	15.6	32.	9.5	15.0	680.	630.	3.4	11.0

1. Data for Indian Reference Man
2. Data for ICRP Reference Man.

TABLE XXV. COMPARISON OF THE ORGAN BURDENS FOR DIFFERENT ELEMENTS INDIAN AND ICRP REFERENCE MAN (g)

Organ	Element							
	P		Zn		Fe		Cu	
	1	2	1	2	1	2	1	2
Heart	0.38	0.48	0.0046	0.0084	0.012	0.015	0.0005	0.0011
Kidney	0.36	0.50	0.007	0.015	0.011	0.023	0.00044	0.00094
Liver	2.5	4.7	0.047	0.085	0.10	0.32	0.006	0.012
Lungs	0.80	0.78	0.009	0.011	0.18	0.36	0.0009	0.0012
Muscle	--	--	0.72	1.5	0.7	1.1	0.018	0.025
Brain	2.3	4.8	0.019	0.017	0.056	0.074	0.006	0.0081
Skeleton	310.	700.	0.16	0.48	0.23	0.8	0.0075	0.0072

1. Indian Reference Man Data
2. ICRP Reference Man Data

TABLE XXVI. COMPARISON OF THE ORGAN BURDENS FOR DIFFERENT ELEMENTS INDIAN AND ICRP REFERENCE MAN - (g)

Organ	Element							
	Mn		Co		Se		Hg	
	1	2	1	2	1	2	1	2
Heart	6.9 · E-5	6.6 · E-5	7.6 · E-6	10.0 · E-6	2. · E-5	8. · E-5	1.2 · E-6	4.5 · E-5
Kidney	1.7 · E-4	2.8 · E-4	3.0 · E-6	4.0 · E-6	--	--	--	8.7 · E-5
Liver	1.6 · E-3	2.5 · E-3	1.1 · E-4	1.1 · E-4	4.6 · E-4	1.2 · E-3	1.2 · E-5	5.5 · E-4
Lungs	3.0 · E-4	1.2 · E-4	3. · E-5	2. · E-5	1.7 · E-4	1.8 · E-4	1.2 · E-6	5.8 · E-4
Muscle	4.0 · E-3	1.5 · E-3	1.3 · E-4	2. · E-4	4.2 · E-3	5.0 · E-3	4.0 · E-5	4.2 · E-3
Brain	1.1 · E-4	3.9 · E-4	--	--	--	--	--	--
Skeleton	3.0 · E-3	5.2 · E-3	2.4 · E-4	3. · E-4	2.8 · E-3	--	5.2 · E-5	--

1. Indian Reference Man Data
2. ICRP Reference Man Data

TABLE XXVII. COMPARISON OF THE ORGAN BURDENS FOR DIFFERENT ELEMENTS INDIAN AND ICRP REFERENCE MAN

Organ	Element					
	Cs		La		Sb	
	1	2	1	2	1	2
Heart	1.4 · E-6	2.8 · E-6	2. · E-5	--	0.28 · E-6	2.2 · E-6
Kidney	1.9 · E-6	2.3 · E-6	1.6 · E-4	--	0.013 · E-5	9.3 · E-5
Liver	1.0 · E-5	2.0 · E-5	1.4 · E-4	--	0.03 · E-4	3.6 · E-4
Lungs	1.0 · E-5	6.0 · E-6	3.9 · E-3	--	4.3 · E-5	6.0 · E-5
Muscle	3.2 · E-4	5.7 · E-4	--	--	4.4 · E-5	--
Skeleton	4.0 · E-5	1.6 · E-4	--	--	0.012 · E-3	2.0 · E-3

1. Indian Reference Man Data
2. ICRP Reference Man Data

were employed along with the organ weight for proposed Reference Indian Man, to arrive at the elemental organ burdens. For the elemental analysis, the two techniques of neutron activation analysis (NAA) and atomic absorption spectrophotometry (AAS) were employed. The results of organ burdens for different elements are given in Tables 24-27, along with the corresponding burdens reported by ICRP [1] for the caucasian population. The data reported in these tables are only for adult males.

The elemental organ burden for the Indian population are expected to be lower that those for ICRP Reference Man, because of the small organ weights and have been found to

be so. However, in a few exceptional cases, they were comparable or marginally higher, for example, Mn, Cs, etc., which may be due to more dust in the tropical environment. Again, the organ burdens of Hg for Indian population were much lower than those for the ICRP Reference Man. The mercury burdens for ICRP Man appear to be quite high and need to be reconfirmed by generating more data for caucasian populations.

CONCLUSIONS

Collection, collation and generation of anatomical, physical, physiological and metabolic data were carried out with a view to developing Reference Indian Man (RIM), a human model for application in strengthening radiation protection in India and also in other Asian countries.

The Indian population is distributed in different socio-economic groups, religions, ethnic groups, areas etc. The human parameters such as physical features, dietary intake, physiological standards were found to be different for different groups. Every effort was made in the course of this study to give due weight to the population distribution in different groups, while arriving at the representative Reference Indian Man data.

The physical parameters such as body weight, height, the metabolic parameters like intake of principal nutrients and also most of the physiological parameters for an average Indian were smaller than those of the ICRP Reference Man. A few parameters such as the daily intake of drinking water and fluids which depend upon the climatic conditions were larger for an average Indian.

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