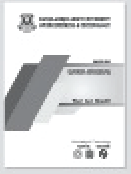

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Calculation of Internal Radiation Dose due to Acute Ingestion of ^{90}Sr for Bangladeshi People by Adopting HATM Model

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Abstract: Activity of radionuclide, absorbed dose, committed equivalent dose, committed effective dose due to acute intake of 1 Bq of ^{90}Sr through ingestion have been calculated by using locally developed software that has been prepared basing on the human alimentary tract model. Due to ingestion maximum radiation dose is deposited in the alimentary tract, which consists of seven tissue compartments, e.g., OC, OP, ST, SI, LC, RC and RSC. Tissue masses of alimentary tract for Bangladeshi people have been considered to calculate the above mentioned quantities for different age groups such as new born, 1 yr, 5 yrs, 10 yrs, 15 yrs (male and female) and adult (male and female). Regarding age the variation of absorbed dose, committed equivalent dose and committed effective dose follows the sequence: new born >1 yr> 5 yr> 10yrs > 15 yrs> adult female > adult male. The absorbed dose, committed equivalent dose and committed effective doses are found maximum for new born age group; then it decreases as the age increases. Regarding compartment the trends of variation of maximum absorbed dose are: ST > LC > OP > RSC > RC >SI for ^{90}S r. The variation pattern of committed equivalent dose is RSC > LC > RC > ST > SI > OP. The highest committed effective dose per Bq intake for each radionuclide is found in the alimentary tract of a new born baby. This value in stomach is, 2.16×10^{-6} mSv/Bq. For other age groups these values are slightly smaller than those for a new born baby.

Keywords: *Absorbed dose; Committed equivalent dose; Committed effective dose; Human alimentary tract model (HATM)*

Introduction: Radionuclides once entered into the body through different routes of entry [1] can notbe eliminated completely. It gives out energy continuously as long as it remains inside the body. So it is important to assess internal radiation dose to measure risk of human health. Occupational workers, and public can be internally exposed by radiation due to ingestion of contaminated food following nuclear reactor accident, accidental intake during use of unsealed radioisotope in the field of nuclear medicine, radioisotope production laboratory and research facility or during routine work at the workplaces with unsealed radioisotope. That's why the authorities such as UNSCER [2], IAEA [3] and ICRP [4] develop the radiation safety standards. Internal radiation dose cannot be measured directly; of course some models are there which are being used for assessment of internal radiation dose, based on the radioactivity by bioassay measurement and whole body counting. The present study describes a generic methodology for the calculation of internal radiation doses due to acute intake of beta emitting radionuclides through ingestion. Software has been developed in Visual Basic language. The software is user friendly and is found to work well as desired. This can comfortably be used for the purposes of calculation of internal radiation doses due to intake of radioisotopes through ingestion by radiation workers and public at large. Activity of radionuclide, absorbed dose, committed equivalent dose, committed effective dose due to acute intake of 1 Bq of ^{90}Sr through ingestion have been calculated by using the software that has been

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prepared basing on the human alimentary tract model. Due to ingestion maximum radiation dose is deposited in the alimentary tract, which consists of seven tissue compartments, e.g., Oral Cavity (OC), Esophagus (OP), Stomach (ST), Small Intestine (SI), Left Colon (LC), Right Colon (RC) and Rectosigmoid Colon (RSC). Tissue masses of alimentary tract for Bangladeshi people have been considered to calculate the above mentioned quantities for different age groups such as new born, 1 yr, 5 yrs, 10 yrs, 15 yrs (male and female) and adult (male and female).

The HATM: There are various ICRP and MIRD models are similar in terms of their assumption and defining equation. Contemporary internal dosimetry models began with the single compartment models of ICRP 2 [5] and 10 [6]. The MIRD methodology [7-9] and ICRP 26 [10] and 30 [11] developed the concept of source and target organs. ICRP 60 [12] and ICRP 66 [13] continue to refine to internal dosimetry model. The new human alimentary tract model (HATM) [14] considers the movement of radionuclides throughout the alimentary tract from ingestion to elimination.

The model (HATM) includes compartments representing the oral cavity (OC) and esophagus (OP) to account for doses received from transit or retention of activity in the upper regions of the tract. The model partitions the large intestine into three regions frequently addressed in colonic transit studies. It also includes compartments to account for nuclear transformations due to retention of a radionuclide in tissues of the alimentary tract in those cases where tissue retention is indicated by available information. The model includes pathways to account for absorption from the oral mucosa, stomach, or segments of the colon if specific information is available. HATM provides age- and gender-specific transit times for all segments of the tract depicted in the model and, for the upper segments (oral cavity, esophagus, and stomach), also provides material-specific transit times.

The 1990 recommendations of ICRP introduced specific risk estimates and tissue weighting factors, wT, for radiation-induced cancer of the esophagus, stomach and colon, requiring dose estimates for each of these regions. HATM takes account of sites of radionuclide absorption and retention in the alimentary tract and routes of excretion of absorbed radionuclides into the alimentary tract. Doses are calculated for sensitive cells in each region: mouth, oesophagus, stomach, small intestine and colon.

Methodology: The proposed work is calculation based. Mathematical expression for activity, number of disintegration, absorbed dose, committed equivalent dose and committed effective dose for different tissue compartments of HAT due to intake of some beta emitting radionuclides through ingestion has been derived in the work. The viewpoints of HATM [14] have been adopted to formulate mathematical equations for retention and number of radioactive disintegrations that take place in different compartments of the digestive tract at a given time after intake of radionuclides. Subsequently the equivalent dose, committed equivalent dose and committed effective dose in each tissue or organ of interest have been formulated. A database library has been generated in Microsoft Access to store relevant data for assessment of retention and cumulated activity and equivalent doses in each of the compartments for different age groups of Bangladeshi population and ICRP reference subjects. A software has been developed to calculate the above mentioned quantities rapidly.

Mathematical Formalism: The general equation of activity can be written from the equation in the form of H. Bateman's equation [15] as

$$A_i = N_o \sum_{i=1}^{n} C_i e^{-\lambda_i t}$$
$$= N_O\left(C_1 e^{-\lambda_1 t} + C_2 e^{-\lambda_2 t} + \ldots\ldots\ldots\ldots + C_n e^{-\lambda_n t}\right)$$ Eq.1

Here A_i is the activity in organ i (i=1,2,3…………………7)

λ_i is the transfer rate of the radionuclide from the organ i

$$C_m = \frac{\prod_{i=1}^{n} \lambda_i}{\prod_{i=1}^{n} (\lambda_i - \lambda_m)}$$
$$= \frac{\lambda_1\lambda_2\lambda_3 \ldots\ldots\ldots\ldots \lambda_n}{(\lambda_1-\lambda_m)(\lambda_2-\lambda_m)(\lambda_3-\lambda_m)\ldots\ldots\ldots\ldots(\lambda_n-\lambda_m)}$$ Eq. 2

For materials deposited into first, second, 3rd, 4th, 5th, 6th and 7th compartment can be obtained by putting i=2, 3, 4, 5, 6 and 7 respectively into Eqn. (2)

$$A_1 = N_o e^{-\lambda_1 t}$$ eq. 3

$$A_2 = N_O \lambda_1 \lambda_2 \left(\frac{e^{-\lambda_1} t}{(\lambda_2 - \lambda_1)} + \frac{e^{-\lambda_2} t}{(\lambda_1 - \lambda_2)} \right)$$ eq. 4

$$A_3 = N_0 \lambda_1 \lambda_2 \lambda_3 \left(\frac{e^{-\lambda_1 t}}{(\lambda_2-\lambda_1)(\lambda_3-\lambda_1)} + \frac{e^{-\lambda_2 t}}{(\lambda_1-\lambda_2)(\lambda_3-\lambda_2)} + \frac{e^{-\lambda_3 t}}{(\lambda_1-\lambda_3)(\lambda_2-\lambda_3)} \right)$$ Eq. 5

$$A_4 = N_0 \lambda_1 \lambda_2 \lambda_3 \lambda_4 \left(\begin{array}{c} \frac{e^{-\lambda_1 t}}{(\lambda_2-\lambda_1)(\lambda_3-\lambda_1)(\lambda_4-\lambda_1)} + \\ \frac{e^{-\lambda_2 t}}{(\lambda_1-\lambda_2)(\lambda_3-\lambda_2)(\lambda_4-\lambda_2)} + \\ \frac{e^{-\lambda_3 t}}{(\lambda_1-\lambda_3)(\lambda_2-\lambda_3)(\lambda_4-\lambda_3)} + \\ \frac{e^{-\lambda_4 t}}{(\lambda_1-\lambda_4)(\lambda_2-\lambda_4)(\lambda_3-\lambda_4)} \end{array} \right)$$ eq. 6

$$A_5 = N_0 \lambda_1 \lambda_2 \lambda_3 \lambda_4 \lambda_5 \left(\begin{array}{c} \frac{e^{-\lambda_1 t}}{(\lambda_2 - \lambda_1)(\lambda_3 - \lambda_1)(\lambda_4 - \lambda_1)(\lambda_5 - \lambda_1)} + \\ \frac{e^{-\lambda_2 t}}{(\lambda_1 - \lambda_2)(\lambda_3 - \lambda_2)(\lambda_4 - \lambda_2)(\lambda_5 - \lambda_2)} + \\ \frac{e^{-\lambda_3 t}}{(\lambda_1 - \lambda_3)(\lambda_2 - \lambda_3)(\lambda_4 - \lambda_3)(\lambda_5 - \lambda_3)} + \\ \frac{e^{-\lambda_4 t}}{(\lambda_1 - \lambda_4)(\lambda_2 - \lambda_4)(\lambda_3 - \lambda_4)(\lambda_5 - \lambda_4)} + \\ \frac{e^{-\lambda_5 t}}{(\lambda_1 - \lambda_5)(\lambda_2 - \lambda_5)(\lambda_3 - \lambda_5)(\lambda_4 - \lambda_5)} \end{array} \right) \quad \text{Eq. 7}$$

$$A_6 = N_0 \lambda_1 \lambda_2 \lambda_3 \lambda_4 \lambda_5 \lambda_6 \left(\begin{array}{c} \frac{e^{-\lambda_1 t}}{(\lambda_2 - \lambda_1)(\lambda_3 - \lambda_1)(\lambda_4 - \lambda_1)(\lambda_5 - \lambda_1)(\lambda_6 - \lambda_1)} + \\ \frac{e^{-\lambda_2 t}}{(\lambda_1 - \lambda_2)(\lambda_3 - \lambda_2)(\lambda_4 - \lambda_2)(\lambda_5 - \lambda_2)(\lambda_6 - \lambda_2)} + \\ \frac{e^{-\lambda_3 t}}{(\lambda_1 - \lambda_3)(\lambda_2 - \lambda_3)(\lambda_4 - \lambda_3)(\lambda_5 - \lambda_3)(\lambda_6 - \lambda_3)} + \\ \frac{e^{-\lambda_4 t}}{(\lambda_1 - \lambda_4)(\lambda_2 - \lambda_4)(\lambda_3 - \lambda_4)(\lambda_5 - \lambda_4)(\lambda_6 - \lambda_4)} + \\ \frac{e^{-\lambda_5 t}}{(\lambda_1 - \lambda_5)(\lambda_2 - \lambda_5)(\lambda_3 - \lambda_5)(\lambda_4 - \lambda_5)(\lambda_6 - \lambda_5)} + \\ \frac{e^{-\lambda_6 t}}{(\lambda_1 - \lambda_6)(\lambda_2 - \lambda_6)(\lambda_3 - \lambda_6)(\lambda_4 - \lambda_6)(\lambda_5 - \lambda_6)} \end{array} \right) \quad \text{Eq. 8}$$

$$A_7 = N_0 \lambda_1 \lambda_2 \lambda_3 \lambda_4 \lambda_5 \lambda_6 \lambda_7 \left(\begin{array}{c} \frac{e^{-\lambda_1 t}}{(\lambda_2 - \lambda_1)(\lambda_3 - \lambda_1)(\lambda_4 - \lambda_1)(\lambda_5 - \lambda_1)(\lambda_6 - \lambda_1)(\lambda_7 - \lambda_1)} + \\ \frac{e^{-\lambda_2 t}}{(\lambda_1 - \lambda_2)(\lambda_3 - \lambda_2)(\lambda_4 - \lambda_2)(\lambda_5 - \lambda_2)(\lambda_6 - \lambda_2)(\lambda_7 - \lambda_2)} + \\ \frac{e^{-\lambda_3 t}}{(\lambda_1 - \lambda_3)(\lambda_2 - \lambda_3)(\lambda_4 - \lambda_3)(\lambda_5 - \lambda_3)(\lambda_6 - \lambda_3)(\lambda_7 - \lambda_3)} + \\ \frac{e^{-\lambda_4 t}}{(\lambda_1 - \lambda_4)(\lambda_2 - \lambda_4)(\lambda_3 - \lambda_4)(\lambda_5 - \lambda_4)(\lambda_6 - \lambda_4)(\lambda_7 - \lambda_4)} + \\ \frac{e^{-\lambda_5 t}}{(\lambda_1 - \lambda_5)(\lambda_2 - \lambda_5)(\lambda_3 - \lambda_5)(\lambda_4 - \lambda_5)(\lambda_6 - \lambda_5)(\lambda_7 - \lambda_5)} + \\ \frac{e^{-\lambda_6 t}}{(\lambda_1 - \lambda_6)(\lambda_2 - \lambda_6)(\lambda_3 - \lambda_6)(\lambda_4 - \lambda_6)(\lambda_5 - \lambda_6)(\lambda_7 - \lambda_6)} + \\ \frac{e^{-\lambda_7 t}}{(\lambda_1 - \lambda_7)(\lambda_2 - \lambda_7)(\lambda_3 - \lambda_7)(\lambda_4 - \lambda_7)(\lambda_5 - \lambda_7)(\lambda_6 - \lambda_7)} \end{array} \right) \quad \text{Eq. 9}$$

Where

λ_R = The radioactive decay constant for the radioactive nuclide

λ_{OC}, λ_{EP}, λ_{ST}, λ_{SI}, λ_{LC}, λ_{RC}, λ_{RSC} are constants for the loss of the material from oral cavity, esophagus, stomach, small intestine, left colon, right colon and rectosigmoid colon respectively. Values of these quantities are given in Table 1. A_{OC}, A_{EP}, A_{ST}, A_{SI}, A_{lc}, A_{RC}, A_{RSC} are the activity of radionuclide in OC, EP, ST, SI, LC, RC, RSC respectively.

Absorbed Dose: The absorbed dose in a particular organ after a certain time (t) of intake is given by

$$D(t) = 1.6\times10^{-19}\times10^{6}\times10^{3}\sum[A(t)\sum SEE(t\leftarrow S)_i]_j \text{ mSv} \qquad \text{Eq. 10}$$

Where,

A(t) is the activity at any organs after a time t from ingestion.

$$SEE(T\leftarrow S)_i = \frac{Y_i E_i AF(T\leftarrow S)_i w_R}{M_T} \text{ Mev} \quad Kg^{-1} \text{ per transformation}$$

Where

Yi is the yield of radiations of type i per transformation

Ei is the average, or unique energy of radiation i in MeV

AF(T <← S) is the absorbed fraction that is the average fraction of energy absorbed in T from radiation arising in S;

wR the radiation weighting factor and MT is the mass of the target organ in kg.

Committed Equivalent Dose: The committed equivalent dose for each type of radiation is given by

$$H(T\leftarrow S)_i = U_s\times1.6\times10^{-13}\times SEE(T\leftarrow S)_i \text{ sv} \qquad \text{eq. 11}$$

Where U_s is the number of transformation of j in S over the lifetime following intake of the radio nuclide. The expression for the number of transformations in the various organs in the alimentary tract following ingestion of 1 Bq of activity.

Oral cavity: $$U_{OC} = \frac{1}{\lambda_{OC}+\lambda_R}$$

Esophagus: $$U_{EP} = \frac{1}{(\lambda_{OC}+\lambda_R)(\lambda_{EP}+\lambda_R)}$$

Stomach: $$U_{ST} = \frac{1}{(\lambda_{OC}+\lambda_R)(\lambda_{EP}+\lambda_R)(\lambda_{ST}+\lambda_R)}$$

Small intestine: $$U_{ST} = \frac{1}{(\lambda_{OC}+\lambda_R)(\lambda_{EP}+\lambda_R)(\lambda_{ST}+\lambda_R)(\lambda_{SI}+\lambda_R+\lambda_B)}$$

Left colon: $$U_{LC} = \frac{1}{(\lambda_{OC}+\lambda_R)(\lambda_{EP}+\lambda_R)(\lambda_{ST}+\lambda_R)(\lambda_{SI}+\lambda_R+\lambda_B)(\lambda_{LC}+\lambda_R)}$$

Right colon: $U_{RC} = \frac{1}{(\lambda_{OC}+\lambda_R)(\lambda_{EP}+\lambda_R)(\lambda_{ST}+\lambda_R)(\lambda_{SI}+\lambda_R+\lambda_B)(\lambda_{LC}+\lambda_R)(\lambda_{RC}+\lambda_R)}$

Rectosigmoid colon: $U_{RSC} = \frac{1}{(\lambda_{OC}+\lambda_R)(\lambda_{EP}+\lambda_R)(\lambda_{ST}+\lambda_R)(\lambda_{SI}+\lambda_R+\lambda_B)(\lambda_{LC}+\lambda_R)(\lambda_{RC}+\lambda_R)(\lambda_{RSC}+\lambda_R)}$

Committed Effective Dose: Committed effective dose for any organ of alimentary tract is the product of committed equivalent dose and tissue weighting factor

$$E(\tau) = \sum H_i \times W_i \text{ mSv} \qquad \text{Eq. 12}$$

Where Wi is the tissue weighting factor.

Results and Discussion:

Aactivity, absorbed dose, committed equivalent dose and committed effective doses due to acute ingestion of 1 Bq of ^{90}Sr.Tissue masses of alimentary tract for Bangladeshi people have been considered to calculate the above mentioned quantities for different age groups such as new born, 1 yr, 5 yrs, 10 yrs, 15 yrs (male and female) and adult (male and female).

Activity: Activity has been calculated at different compartments of HAT of the subjects of age groups: new born, 1 yr, 5 yrs, 10 yrs, 15 yrs (male), 15 yrs (female) and adult (both male and female) and time elapsed as considered in the work is mostly 0.5 hr, 1 hr, 2 hrs, 4 hrs, 8 hrs, 12 hrs, 24 hrs and 48 hrs after the ingestion of the radionuclide. Variation of activity vs. time has been shown in Figs. 1-7 for the above mentioned 7 compartments. Activity vs. time graph plotted for OC (Fig. 1) shows that for the organ a peak is obtained within a short period after ingestion. The peak represents maximum amount of intake. This is a very short time and is characteristic of the associated organ. The activity decreases following approximate exponential pattern after reaching the maximum value and the time taken to fall down to 1.11×10^{-2} Bq of activity is around 0.15 hr.

The excreted radionuclide will then appear in the next tissue, e.g. OP. Hence after the lapse of the time of stay in the organ described before, OP should show a growth. As found in the work this is there for which a peak corresponds to the organ, OP at around 0.02 hr after ingestion. The activity in the esophagus is the maximum at this time. The rising rate is 9.6 Bq/hr. After 0.2 hrs the activity reduces to 1.23×10^{-3}Bq. This time is small, again possibly due to the low transit time of the organ.The excreted radionuclide is then deposited in the later tissue, e.g. ST. Fig. 3 shows that for ST the activity level reaches to the maximum (0.89 Bq) at a time 0.15hr after ingestion. Then the dose decreases exponentially (approximately). Finally it reduces to a value of 1.97×10^{-4} Bq, 10 hrs after ingestion.

The excreted radionuclide from ST is then deposited in the later tissue, e.g. SI, the pattern of accumulation can be observed through Fig. 4. In case of SI, the maximum value of activity, being 0.179Bq, appears at about 0.6 hr after the ingestion. The rising rate is 0.3Bq/hr. It takes a time of 15hrs to reach to the value of approximately 1.18×10^{-6} Bq. The radionuclide then goes to the later tissue, LC; the pattern of growth of radioactivity is shown in Fig. 5.In the case of LC the peak appears at 4hrs after the ingestion, the rising rate towards attaining the maximum value is 0.2Bq/hr. However after 120hrs the activity level falls down to approximately 5.28×10^{-5}Bq.

One may observe from Fig. 6 that in the case of RC, the activity rises up to attain the maximum value in 12 hrs of duration, the maximum activity being 0.36Bq. The rising rate is 0.03Bq/hr. The activity value then continuously decreases and after an elapse of 160 hrs it retains approximately 2.47×10^{-5}Bq in total. The falling rate is guided by an exponential function approximately. In case of RSC the maximum value of activity (0.269) is obtained at 27hrsafter ingestion, the average rising rate of activity is 9.96×10^{-3} Bq/hr during this time. After around 180 hrs the activity becomes approximately 4.01×10^{-5} Bq.

Absorbed Dose: Figs. 8-13 show the variation of absorbed dose in the compartments OP, ST, SI, LC, RC and RSC for a new-born baby who is assumed to have ingested 1 Bq of the radionuclide ^{90}Sr. Calculations have been done for time elapsed 0 to 180 hrs since then. The absorbed dose in OP decreases very rapidly, its value becoming practically insignificant after a period of around 0.15 hrs. The absorbed dose values in ST, SI, LC, RC and RSC increases exponentially and then decreases. This pattern of variation is as expected, mainly because of biological excretion phenomenon. The effect of radioactive half-life is also active in these cases. The maximum absorbed dose per Bq intake of ^{90}Sr are found to be 3.01×10^{-9}, 3.98×10^{-9}, 1.87×10^{-10}, 3.43×10^{-9},1.61×10^{-9} and 2.81×10^{-9} mSv for OP, ST, SI, LC, RC and RSC respectively. Similar results are found for the age groups: 1 yr, 5 yrs, 10 yrs, 15 yrs (male), 15 yrs (female) and adult (male) also. The absorbed dose values in different parts of human alimentary tract for adult (male) are found to have the lowest value because of the relatively larger tissue mass. The absorbed doses for female are equal to that for male. The values increase with the decrease of ages.

Committed Equivalent Dose: Figs. 14-16 show the variation of committed equivalent dose in the organs OP, ST, SI, LC, RC and RSC for 8 different age groups of people due to the ingestion of the radionuclide ^{90}Sr. Committed equivalent dose value is the maximum in case of new-born age group subjects. Then it decreases as age increases, its value becoming almost same for 15 yrs (male), 15 yrs (female), adult (male) and adult (female) because of their having nearly equal body mass. The maximum committed equivalent dose per Bq intake of ^{90}Sr are found to be 6.20×10^{-7}, 1.8×10^{-5}, 1.33×10^{-6}, 1.7×10^{-5}, 1.71×10^{-5} and 4.0×10^{-5} mSv for OP, ST, SI, LC, RC and RSC respectively. Fig. 17shows the variation of committed equivalent dose by OP, ST, SI, LC, RC, RSC for the considered 8 different age groups of people. Committed equivalent dose has a minimum value in OP due to a very small number of transformations. In the next organ e.g., ST this value is rising due to its greater number of transformations. In SI this value is again decreasing due to its larger mass. In LC and RC this value is almost same because of their equal mass and transformation number. In RSC committed equivalent dose is maximum due its lowest mass.

Committed Effective Dose: Figs. 18-20 show the variation of committed equivalent dose by OP, ST, SI, LC, RC, and RSC for the 8 different age groups of people mentioned before due to the ingestion of the radionuclide ^{90}Sr. Amongst all the calculated effective dose values the maximum is observed in case of new-born age group. Then it decreases as age increases.The committed effective dose value becoming almost same for 15 yrs (male), 15 yrs (female), adult (male) and adult (female) because of their having nearly equal body mass. The maximum committed effective dose per Bq intake of 90Sr are found to be 2.5×10^{-8}, 2.2×10^{-6}, 1.6×10^{-7}, 2.0×10^{-6}, 2.06×10^{-6} and 4.8×10^{-6} mSv for OP, ST, SI, LC, RC and RSC respectively. Fig 21 shows the variation of committed effective dose in the compartments OP, ST, SI, LC, RC and RSC for the age groups: 1 yr, 5 yrs, 10 yrs, 15 yrs (male), and adult (female). Committed effective dose has a minimum value in OP due to a very small number of transformations. In the next organ e.g., ST this value is rising due to its greater number of transformations. In SI this value is again decreasing due to its larger mass. In LC and RC this value is almost same because of their equal mass and transformation number. In RSC committed equivalent dose is the maximum due its lowest mass. Similar results are found for the age groups: 1 yr, 5 yrs, 10 yrs, 15 yrs (male), 15 yrs (female) and adult (male) also.

Table 1. Mean residence time and the rate constants of different parts of HAT

Name of the organs	Mean residence time	Rate constant(/d)
Oral cavity	12 sec	720
Esophagus	40 sec	2160
Stomach	70 min	20.57
Small intestine	4 hour	6
Left colon	12hour	2
Right colon	12 hour	2
Rectosigmoid colon	12 hour	2

Comparison of the present results for committed equivalent dose in Sv has been made with the results quoted in Refs. [1,10].

Table 2. Comparison of the calculated results arising in stomach (ST) due to ^{90}Sr

AgeReferences	(Ref. 1)	Present Work	ICRP-56(Ref.10)
1 yr	$5.92x10^{-9}$	$4.71x10^{-10}$	$1.1x10^{-8}$
10 Yrs	$1.30x10^{-9}$	$1.08x10^{-10}$	$3.40x10^{-9}$
Adult	$7.93x10^{-10}$	$6.67x10^{-11}$	$1.80x10^{-9}$

Table 3. Comparison of the calculated results arising in small intestine (SI) due to ^{90}Sr

Age References	(Ref.1)	Present Work	ICRP-56(Ref.10)
1 yr	$5.92x10^{-9}$	$4.71x10^{-10}$	$1.1x10^{-8}$
10 Yrs	$1.30x10^{-9}$	$1.08x10^{-10}$	$3.40x10^{-9}$
Adult	$7.93x10^{-10}$	$6.67x10^{-11}$	$1.80x10^{-9}$

Above mentioned tables (2, 3) shows that the calculated equivalent dose values of the present work are less than the corresponding previously calculated results. This has been happened possibly because of the following reasons.

I) In the present sturdy only beta particle is considered, hence the energy yield factor is less. And as the dose depends on energy yield factor linearly, the dose values are law here.

II) In the present study the number of compartments is also more than that of the previous works. Thus the total dose is distributed throughout the whole tract and hence the dose per compartment becomes lower.

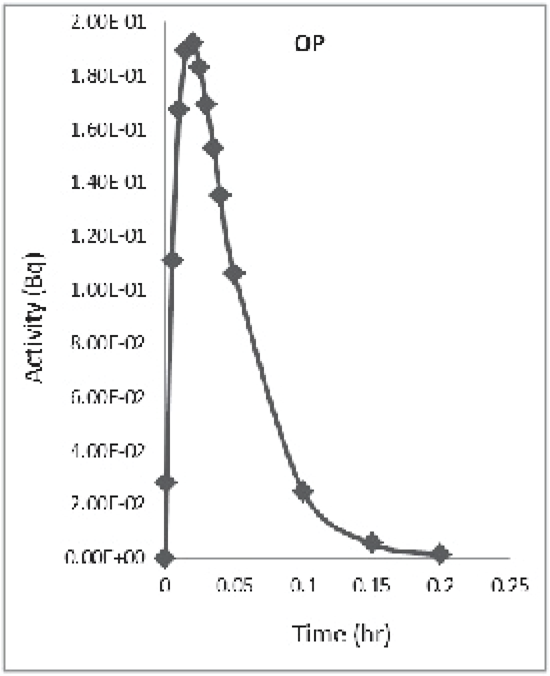

Fig. 1: Time variation of activity in OC

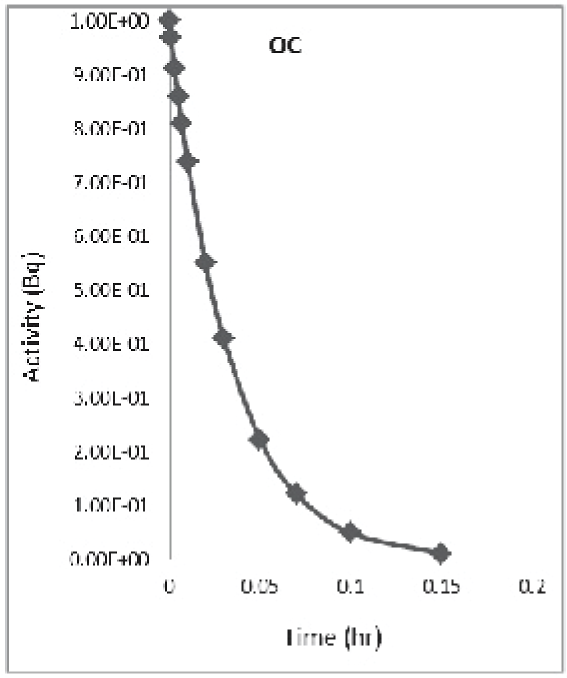

Fig. 2: Time variation of activity in OP

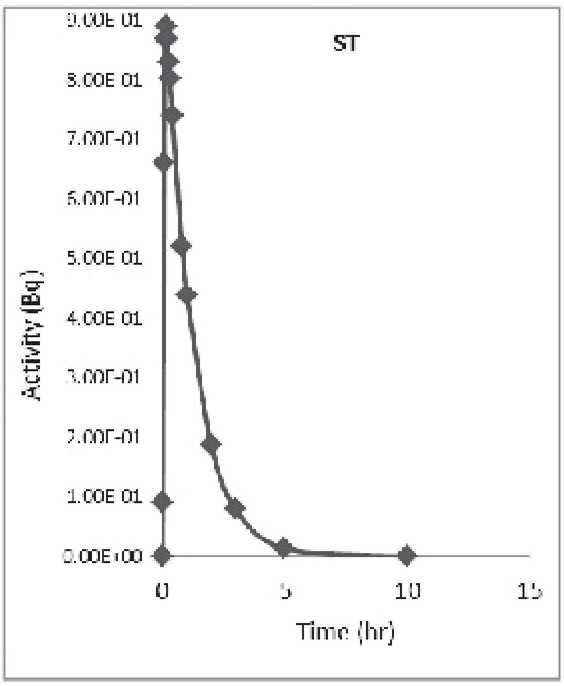

Fig. 3: Time variation of activity in ST

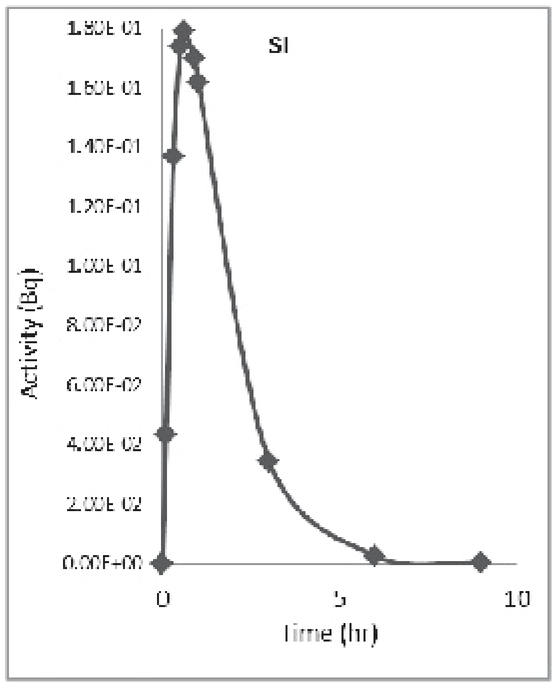

Fig. 4: Time variation of activity in SI

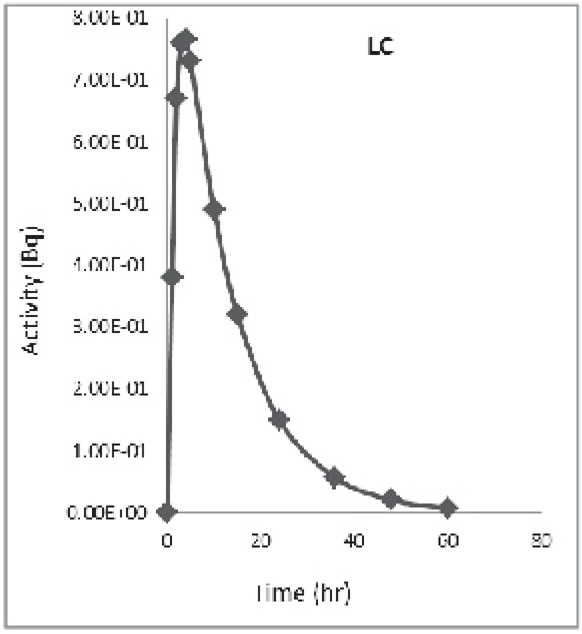

Fig. 5: Time variation of activity In LC

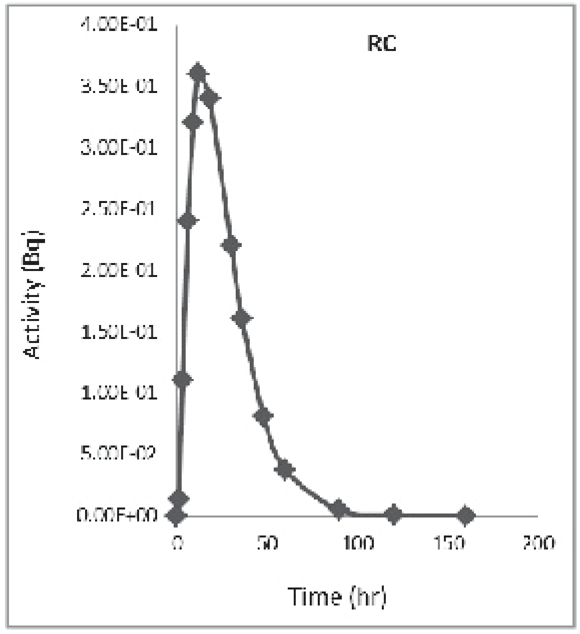

Fig. 6: Time variation of activity in RC

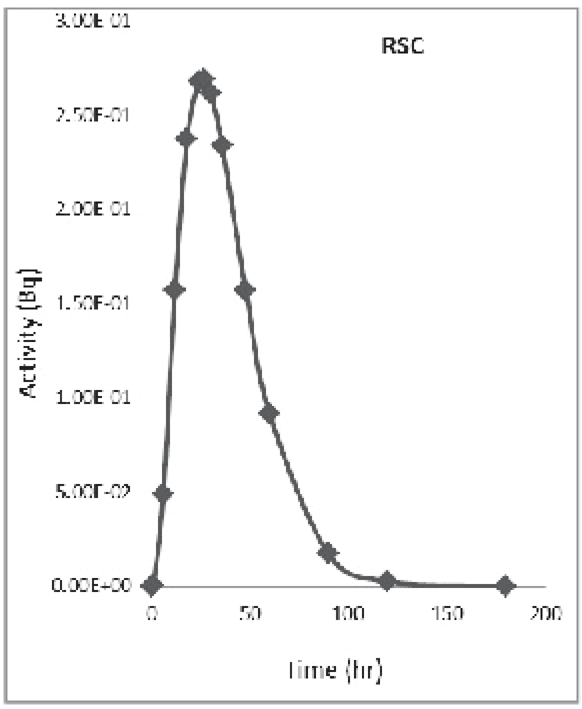

Fig. 7: Time variation of activity in RSC

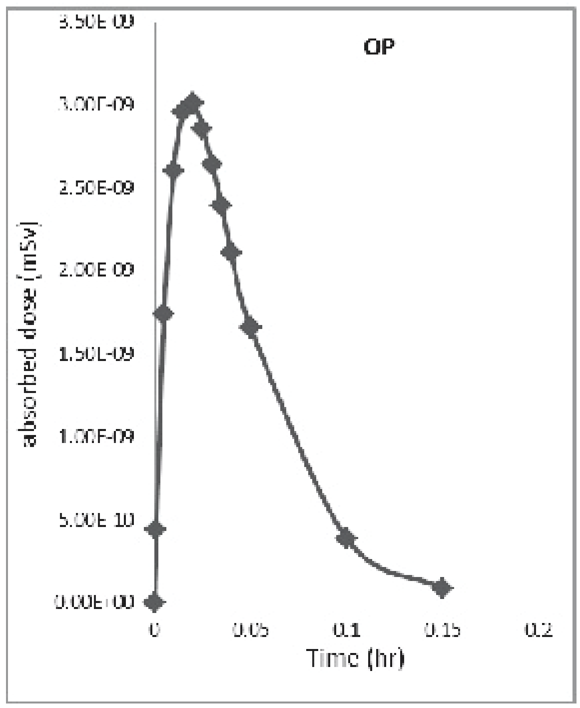

Fig. 8: Time variation of absorbed dose in OP

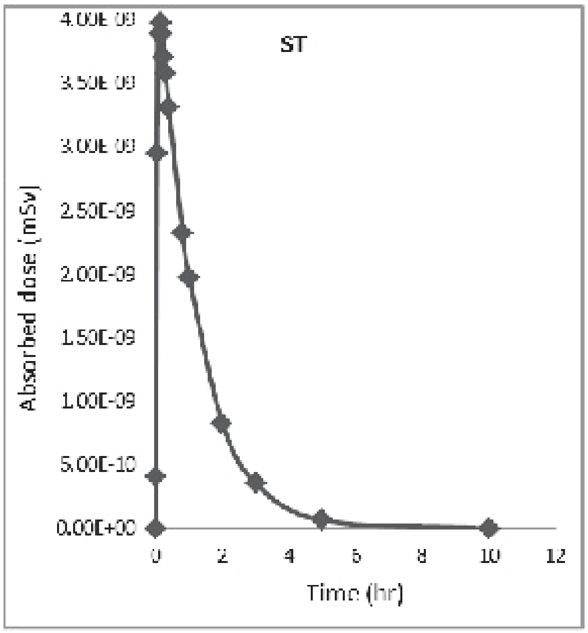

Fig. 9: Time variation of absorbed dose in ST

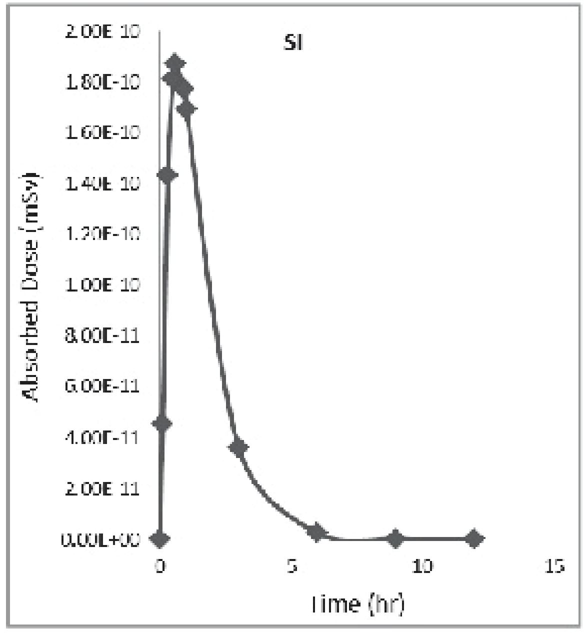

Fig. 10: Time variation of absorbed dose in

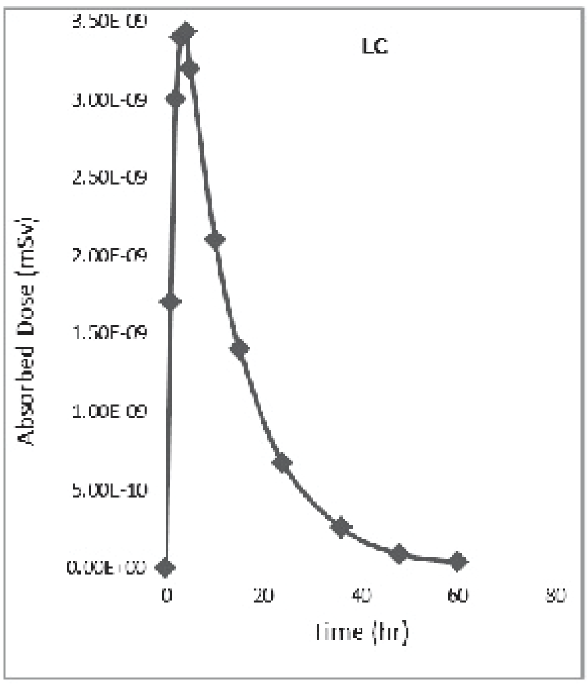

Fig. 11: Time variation of absorbed dose in LC

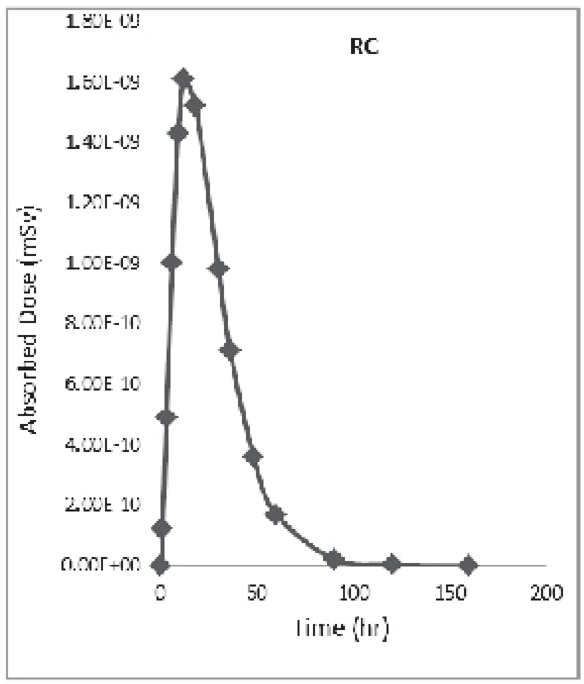

Fig. 12: Time variation of absorbed dose in RC

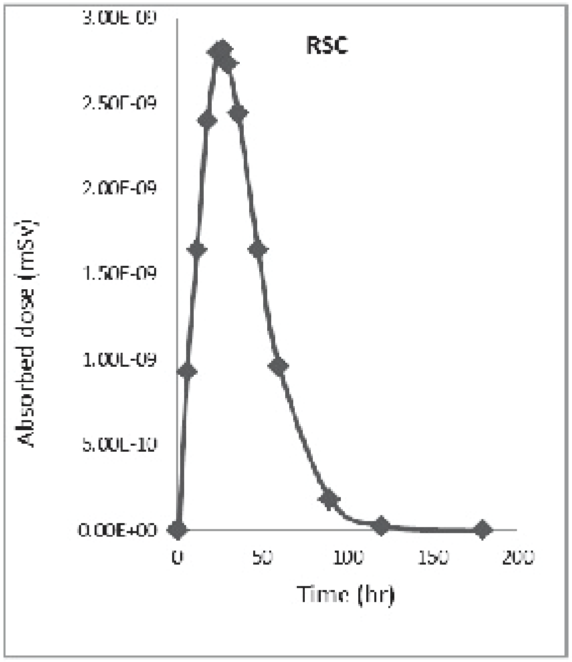

Fig. 13: Time variation of absorbed dose in RSC

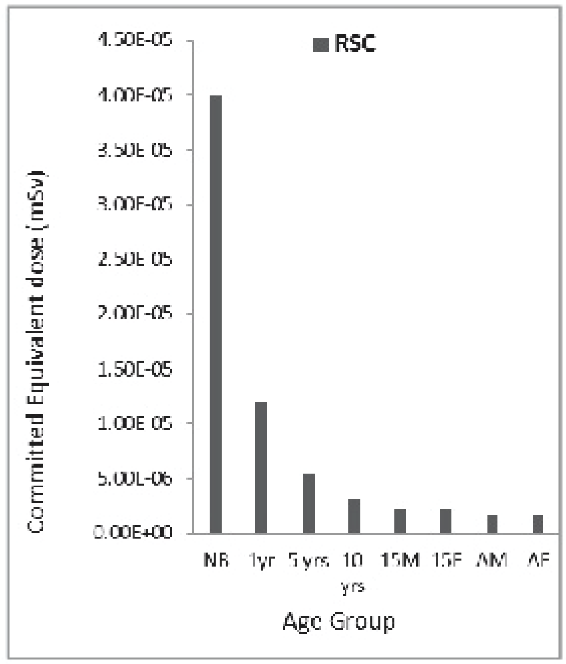

Fig. 14: Age variation of committed equivalent Dose in RSC

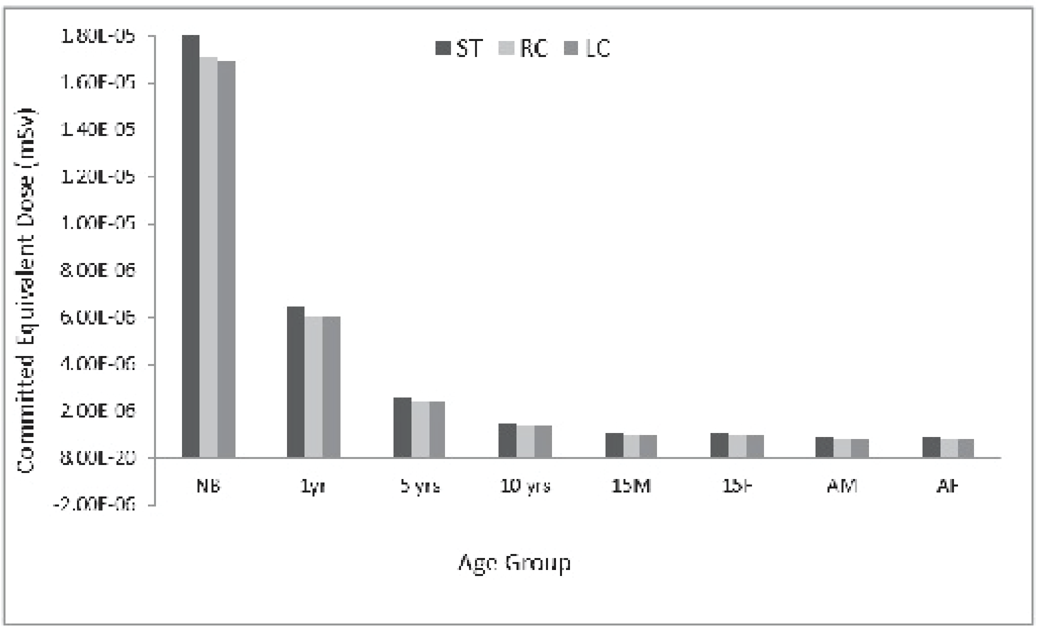

Fig. 15: Age variation of committed equivalent dose in ST, RC and LC

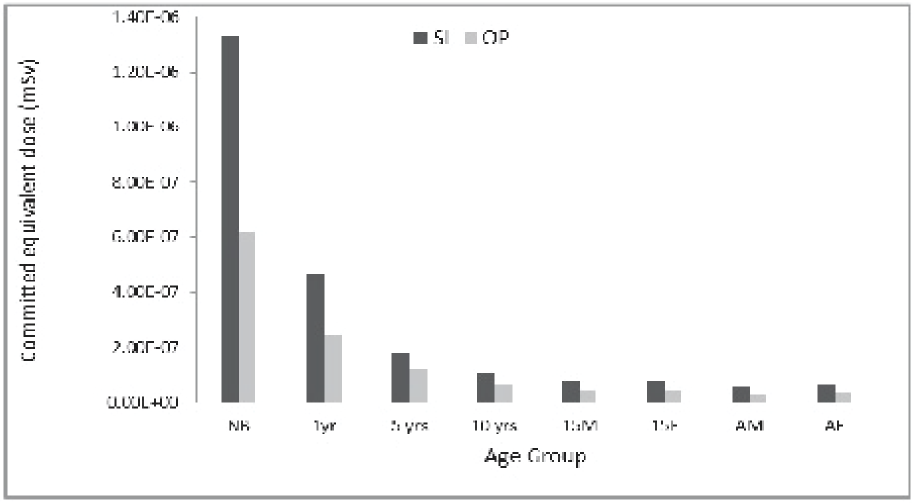

Fig. 16: Age variation of committed equivalent dose in SI and OP

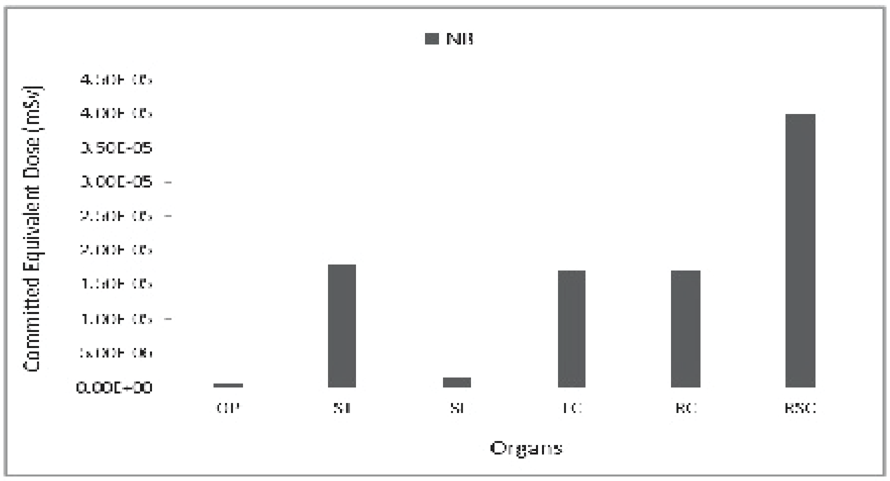

Fig. 17: Organ variation of committed equivalent dose of NB

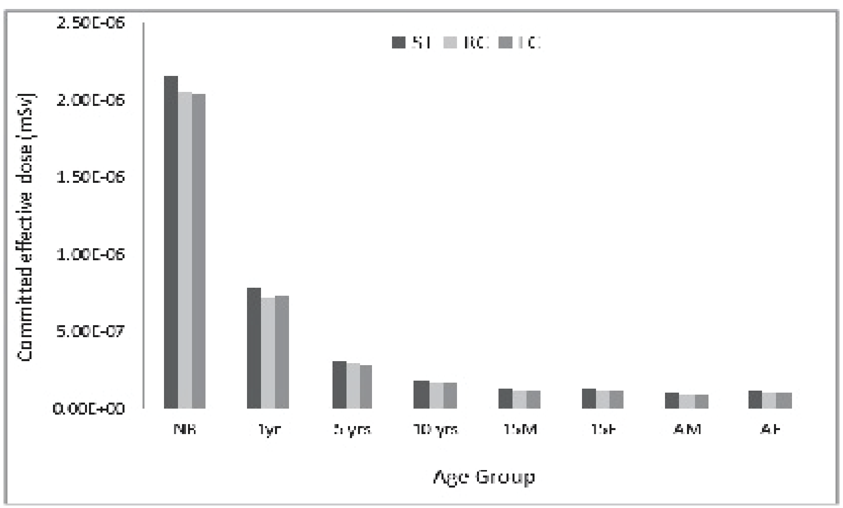

Fig. 18: Age variation of committed effective dose in ST, RC and LC

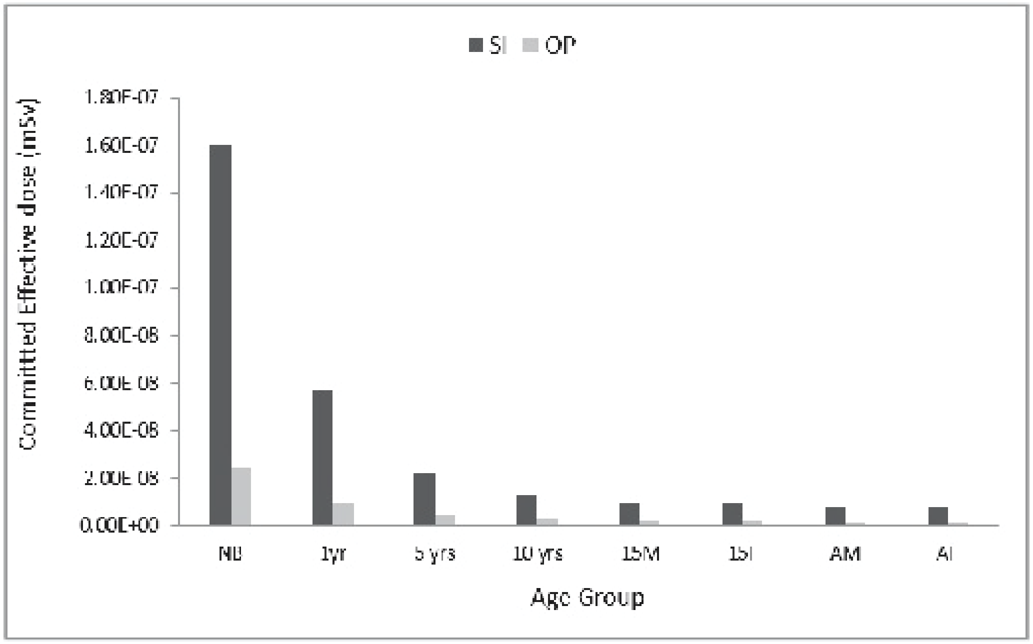

Fig. 19: Age variation of committed effective dose in SI and OP

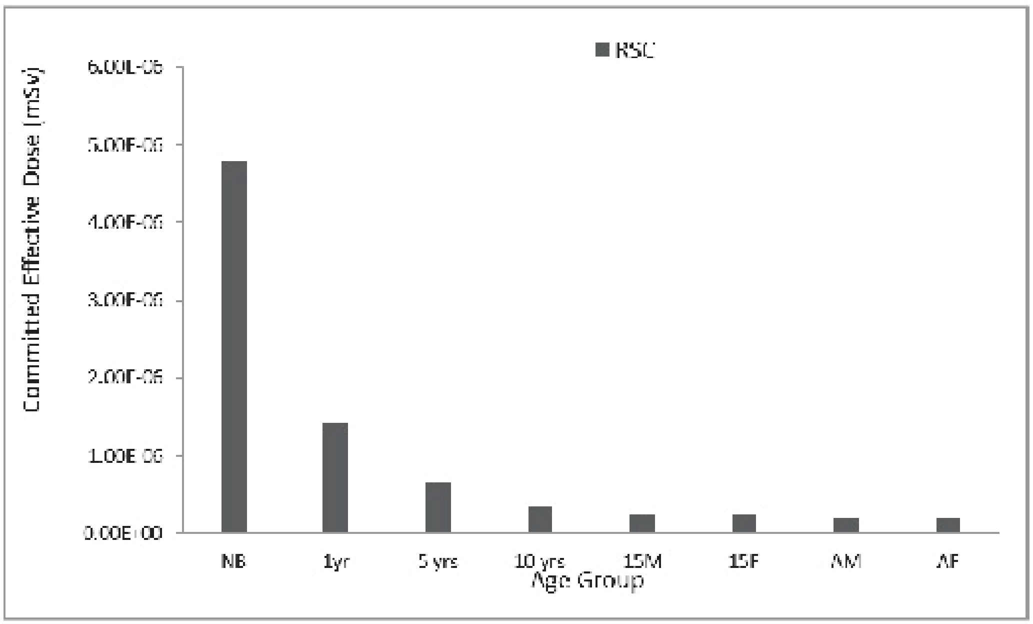

Fig. 20: Age variation of committed effective dose in RSC

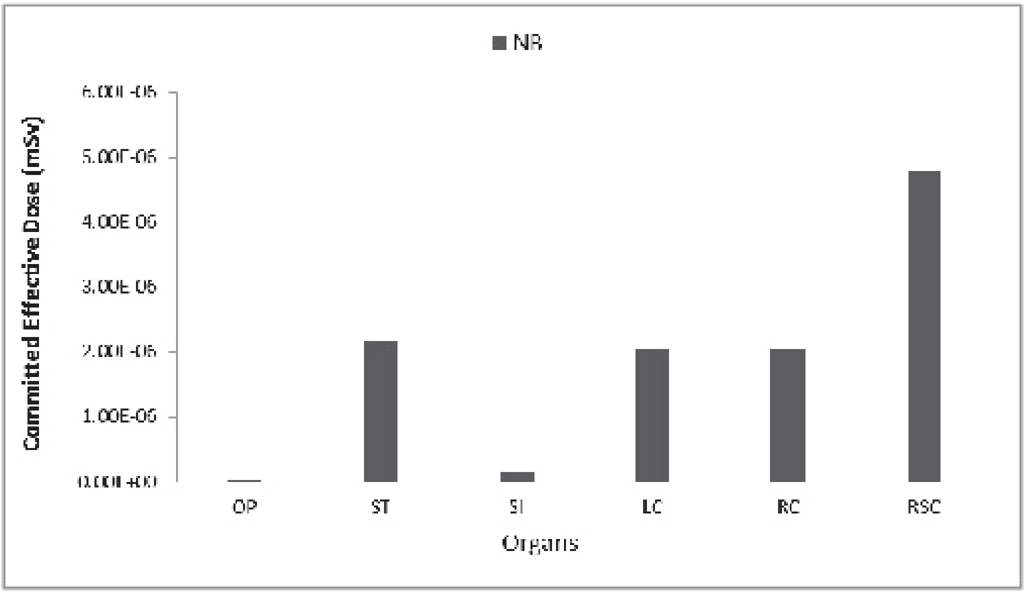

Fig. 21: Organ variation of committed effective dose

Conclusion: Due to ingestion maximum radiation dose is deposited in the alimentary tract, which consists of seven tissue compartments, e.g., OC, OP, ST, SI, LC, RC and RSC. The transfer of radionuclides from oral cavity to esophagus has been considered an instantaneous process which gives less retention but activity in the entry route.

The following important observations could be made from the study:

a. Time required to get an insignificant value of activity depends more on decay constant of radionuclides than the rate constant of the considered organ. In this work it is observed that activity values became insignificant approximately after 0.3 hrs in OC, 0.4 hrs in OP, 12 hrs in ST, 15 hrs in SI, 100 hrs in LC, 150 hrs in RC and 200 hrs in RSC .

b. The absorbed dose for a new born baby has been observed to be higher than that of others having higher body mass. This is justified, since absorbed dose is inversely proportional to the mass of the tissue compartment of alimentary tract. It thus becomes high for a new born baby as the tissue mass is less than those of other age groups. Regarding age the variation of absorbed dose, committed equivalent dose and committed effective dose follows the sequence:

   new born >1 yr> 5 yr> 10yrs > 15 yrs> adult female > adult male.

c. Absorbed dose for an alpha emitting radionuclide is higher than a beta emitting radionuclides due to higher radiation weighting factor (wR).

d. The absorbed dose, committed equivalent dose and committed effective dose show a common tendency that these values are maximum for a subject of new born age group; then it decreases as the age increases for all the radionuclides of interest.

e. Regarding compartment the trends of variation of maximum absorbed dose are:

   ST > LC>OP>RSC > RC >SI

f. Regarding tissue compartments the variation pattern of committed equivalent dose is:

   RSC > LC > RC > ST>SI > OP

g. The highest committed effective dose per Bq intake for each radionuclide is found in the alimentary tract of a new born baby. These values for stomach are 3.72×10^{-6}mSv/Bq, 2.16×10^{-6}mSv/Bq, 8.64×10^{-7}mSv/Bq, 1.80×10^{-7}mSv/Bq, and 1.11×10^{-8}mSv/Bq.

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