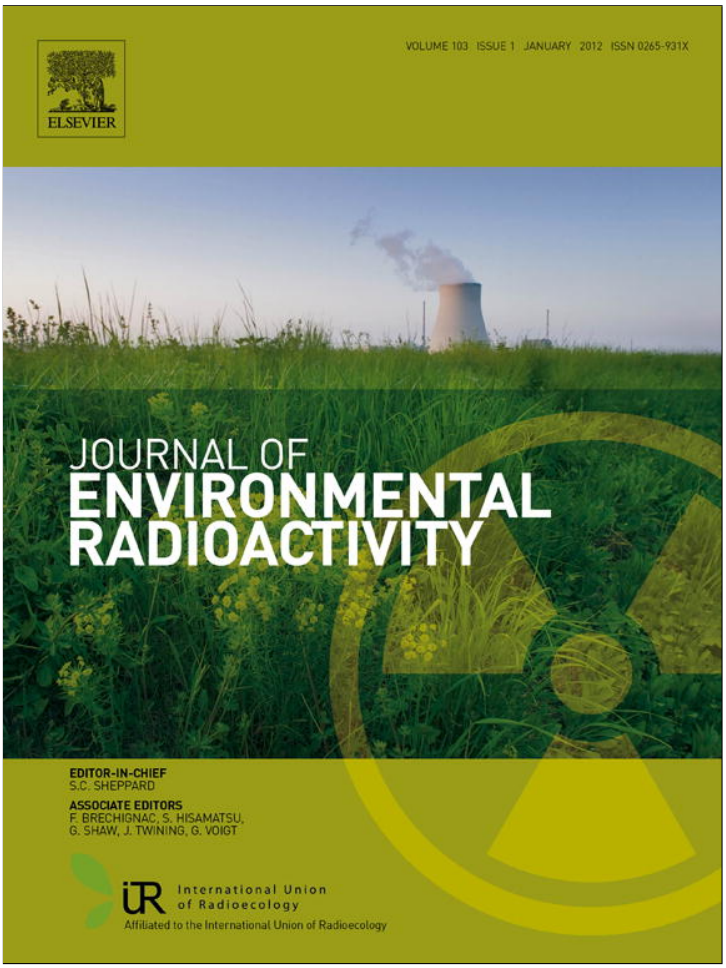

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Strontium biokinetic model for mouse-like rodent

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ABSTRACT

Model describing the biokinetics of strontium for murine rodent is suggested. The model represents modification of the ICRP model for reference human with reduced number of compartments: Blood, Gastrointestinal tract, Soft tissues, Skeleton, Urinary bladder. To estimate transfer rates of the model the published experimental data on strontium retention in body of laboratory and wild mice were analyzed. A set of eleven transfer rates suggested for the strontium biokinetic model for murine rodent satisfactorily describes both the laboratory experiments (relative standard error of 9.5%) and data on radiostrontium content available for wild animals. Application of the model allows estimation of strontium distribution by organs and tissues both in the cases of acute and chronic exposure with assessment of strontium activity in organs with time since beginning of exposure. The developed strontium biokinetic model will be used for internal dose assessment for murine rodents inhabiting East-Ural Radioactive Trace, where ^{90}Sr intake is a significant source of contemporary internal exposure.

1. Introduction

Until recently, the protection of the environment in situations of radiation exposure was considered in terms of approach stating that compliance with the radiation dose limits established for the human is sufficient to guarantee the protection of non-human species (biota). However, at the end of 1990-s a number of leading specialists expressed an opinion that in general the environment is wider than "mankind's environment", so the important limitations and restrictions are attributable to radiation protection based on this approach (Alexakhin and Fesenko, 2004; Bréchignac, 2003; Pentreath, 2002, 1999; Strand et al., 2000). Agreeing with the arguments of opponents of the anthropocentric approach ICRP in its new recommendations expands the system of radiological protection and includes in its objectives the protection of the environment (ICRP, 2007, 2008). Given that the most radiosensitive component of the environment is biota (Bréchignac, 2003), it was suggested to establish a set of Reference Animals and Plants (Pentreath, 2009, 1999) that are hypothetical entities with the assumed basic biological, anatomical, physiological and life-history characteristics of a particular type of animal or plant, as described to the generality of the taxonomic level of family (ICRP, 2007).

In contemporary dosimetric concept absorbed dose is the main characteristic of ionizing radiation impact and it is defined as the energy deposited per unit mass of organ or tissue. Responses of living organisms to irradiation can be considered as a function of absorbed dose, and therefore the assessment of this quantity is an important issue (Alexakhin and Fesenko, 2004). The approach developed by ICRP for the tasks of human dose assessments in situations of internal exposure is based on biokinetic models of radioactive elements and dosimetric models of organs and systems (gastrointestinal tract, skeletal system etc.) of the human being. Assessment of plants and animals internal doses also requires studying of radionuclides metabolism, developing of relevant biokinetic and dosimetric models (Pentreath, 1999; Strand et al., 2000).

One of the most significant radiation accidents in the human history was that appeared at Mayak nuclear plant in 1957, which resulted in radioactive contamination of large territory (East-Ural Radioactive Trace, EURT) (Jones, 2008; Kryshev et al., 1998; Nikipelov et al., 1989). Area of EURT was contaminated by a range of short and long-lived radioactive isotopes. Currently, after a considerable period of time after the accident, the main dose contributing radionuclide in EURT is ^{90}Sr, which is a bone-seeking element with slow elimination from the bone tissue. Non-human EURT biota has been studied for a long time and considerable amount of radiobiological data was accumulated (Prister, 2008) as well as data on radiation exposure effects in mouse-like rodents population were collected (Gileva et al., 2000, 1996; Grigorkina, 2004; Grigorkina and Olenev, 2009; Grigorkina and Pashnina, 2007; Starichenko, 2011, 2004; Vasil'ev et al., 2010, 1996, 2003). At the same time

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dosimetry of wild animals, particularly small mammals, was not paid enough attention.

For assessment of contemporary radiation exposure of EURT non-human biota it is suggested to choose murine rodents as a group of representative species considering that mouse-like animals are ubiquitous and more comprehensively studied comparing with other animals. Murine rodents do not directly correspond to Reference Rat suggested by ICRP that is represented by an ellipsoid with dimensions of 20 × 6 × 5 cm and mass of 0.314 kg. For this simple geometric form the cases of internal and external exposure were considered by Taranenko et al. (2004) and dose conversion coefficients are presented in ICRP Publication (2008). However, when calculating doses due to incorporated radionuclides the mammal was modeled using a homogeneous distribution of the radionuclides within the ellipsoid. Such approach is hardly suitable for the case of intake of radionuclides specifically accumulating in certain organs and tissues, e.g. strontium, which is bone-seeking element. EURT murine rodents have less body weight and dimensions, besides the analysis of published data presented below shows that mice demonstrate specific values of strontium retention in the body.

Design of internal dose assessment approach for biota that takes into account non-uniform distribution of radionuclide in animal organs and tissues can be based on modification of appropriate models developed for humans. In this paper the analysis of dynamics of ^{90}Sr content in organs and tissues of laboratory and wild animals was carried out applying published data. Performed analysis allowed designing and verification of strontium biokinetic model for murine rodent.

2. Review and analysis of published data

Developing of biokinetic model was based on published experimental data on strontium retention in skeleton of laboratory mice after acute injection. The researches on strontium retention in wild animals in the case of prolonged intake were considered for verification of the model, however the number of such data was lower. Searching of published data was carried out through specialized abstract databases and indexing resources such as PubMed, Scopus, Web of Sciences, eLIBRARY.RU. Also the data presented in the monographs on the subject were considered.

Results of experiments with laboratory mice and rats were analyzed, while data on other small mammals (rabbits and dogs) were not considered. When analyzing the published data particular attention was paid to dependence of strontium retention both in skeleton and whole body on time since beginning of exposure. Both acute injection and prolonged intake were investigated. Totally the list of publications used for combined analysis included more than twenty items.

In the studies with acute injection of radiostrontium the results as follow were obtained.

In a number of experiments strontium retention in rats during the first hours and days after injection was investigated. In Ray et al. (1956) male rats were given a single intraperitoneal injection of ^{90}Sr (1.5–30 μCi/g). On the first and fifth day after acute injection the ^{90}Sr content in femur was 4.0 ± 0.1 and 4.3 ± 0.2% (with a standard deviation) of injected strontium respectively. It was assumed that ^{90}Sr content in whole skeleton is twenty times greater than in femur, i.e. on first day the skeleton accumulated 79% of injected strontium. According to the study 6 h after intraperitoneal injection ^{90}Sr content in skeleton of rats (age thirty-one to forty-four days), was 52.5%, on the second day – about 82% (Ray et al., 1956). Similar high level of strontium in bones of rats was also shown in study of effect of hormones on the mobilization of strontium from bone (Barmada et al., 1971). In control group the cumulative excretion during the first day was 11.4% of injected strontium and 15.3% during the 4-day period. In the study of sulphates impact on the ^{85}Sr retention in the organism of male rats the whole body strontium content after administration by means of a stomach tube in control animals was lower (20–30% on the second day) (Volf and Roth, 1966).

The data on the retention of strontium in mice for the initial period after the administration are presented by Cohn et al. (1957) and Buldakov and Moskalev (1968). On the first day after administration of ^{85}Sr in the form of $SrCl_2$ solution by means of gavage the strontium content in laboratory mice was 7.8% in skeleton and 1% in gastrointestinal tract of amount ingested (Cohn et al., 1957). Strontium content in soft tissues several hours after administration was about 10% and rapidly dropped to negligible value. Buldakov and Moskalev in their review (1968) gave higher estimates of strontium retention. In the skeleton of mice the ^{90}Sr content was 37.8% of injected strontium in 4–6 h after intraperitoneal injection. Strontium retention in mice skeleton for terms longer than few days after injection was 42.6% and 17.8% on fourth and sixteenth day respectively (Buldakov and Moskalev, 1968).

It should be noted that numerous studies have shown that soon after the acute administration the activity of strontium in the soft tissues becomes negligible and activity in the skeleton is approximately 100 times higher than in the soft tissues in ten days. Therefore, for the term above ten days the data on strontium retention in the whole body can be entirely attributed to the skeleton. In Nelson et al. (1963) the effect of a number of agents on the elimination of radiostrontium was examined in the case of intraperitoneal injection to CBA mice, males all aged 75–80 days. After correction for decay whole body ^{85}Sr content of control animals was 54.0, 41.1 and 35.1% of injected value on the third, fourteenth and ninetieth day, respectively. Similar results were obtained in Nilsson and Rönnbäck (1988) where influence of low temperature on the excretion of ^{85}Sr from the organism of adult CBA mice was investigated. In control group that was kept in normal room temperature, +24 °C, ^{85}Sr retention was 47.2 ± 1.5, 36.7 ± 0.8 and 30.3 ± 0.8% on the third, fourteenth and thirtieth day after intraperitoneal injection respectively. For the animals that were taken into a low temperature area at +4 °C strontium retention was lower and amounted to 35.5 ± 1.9, 27.4 ± 1.3 and 20.4 ± 1.0 at the same times after injection. The strontium retention decrease caused by low-temperature treatment was also shown in experiments with rats of Cohn et al. (1969).

Lower retention levels were reported in Starichenko and Zhukovskii (2012) where ^{90}Sr was intraperitonealy injected to CBA mice in the form of $SrCl_2$. After acute administration of 7500 Bq the strontium content in femur was 61 and 39 Bq and in skeleton 2411 and 1576 Bq on the fifth and fourteenth day respectively. Such values of ^{90}Sr activity in skeleton correspond to 32 and 21% of injected dose.

In Takahashi et al. (1989) after intravenous injection of 0.74 kBq/g to female C3H/H mice approximately 45% of the injected ^{89}Sr was excreted during the first week and the total amount of ^{89}Sr excreted between the second and the eighth week after injection was about 20%. In the case of injection of 74.0 kBq/g excretion during the first week remained at the same level and elimination between the second and the eighth week decreased to 16%. In Rönnbäck and Nilsson (1975) the influence of oestrogen on the excretion of strontium in CBA mice aged 65–70 days after intraperitoneal injection of 0.8 μCi of ^{90}Sr and ^{85}Sr in the form of $Sr(NO_3)_2$ was investigated. On 20th and 60th day whole body strontium content reduced to approximately 20% and 15% respectively.

Data on strontium retention in male mice in dependence on age are presented in Nilsson et al. (1980). On the 20th and 60th day the whole body strontium content for animals of older group

(administration on the 168th day of life) was about 22% and 15% of the injected radionuclide respectively. For younger animals (administration on the 30th day of life) the strontium retention was higher and reached 45 and 35% respectively.

In Van Putten (1962) effect of various treatments aimed at increasing the elimination of ^{85}Sr after a single injection to 10-week-old female hybrid mice were investigated. It was obtained that for control animals receiving basal diet the whole body strontium content on 24th day was 38.1 ± 4.9% (with a standard deviation). Reduction of phosphorus in the diet resulted in a significant decrease in retention of ^{85}Sr. In Starichenko et al. (1993) ^{90}Sr content in the skeleton of mice of several strains was 20–23% on 25th day after intraperitoneal injection. In Varga et al. (1994) the approaches to enhance the elimination of ^{85}Sr from the body of Swiss mice (22–25 g) of both sexes were studied. Strontium retention for control animals on 28th day was 47.2 ± 5.8% of the administered ^{85}Sr.

Results of experiments with the acute administration considered above are summarized on Fig. 1, where the points represent the data on strontium retention in organism of small mammals with time after injection. Presented experimental data demonstrate significant variability of parameters characterizing the strontium retention, which also was noted in some early reviews of experimental data (Buldakov and Moskalev, 1968; Gaschak et al., 2011; Shvedov and Akleyev, 2001). In spite of high variability the dependence of strontium retention (R, %) on time (t, day) can be described and well fitted by two-exponential function (Cohn et al., 1957; Lyubashevskii, 1980):

$$R(t) = K_1 \exp(-\alpha_1 t) + K_2 \exp(-\alpha_2 t), \quad (1)$$

where $K_1 = 67.8\%$; $K_2 = 32.2\%$; $\alpha_1 = 0.44$ day^{-1}, $\alpha_2 = 0.003$ day^{-1}. Values of standard error for α_1 and α_2 coefficients are 0.13 and 0.002 respectively.

In a number of researches the ^{90}Sr retention under prolonged intake was studied. In the case of strontium intake with drinking water (Synhaeve et al., 2011) radionuclide activity concentration in the male mouse carcass reached the plateau in the 12th week after beginning of contamination at the level of 2–2.5 Bq/g that is about 80% of daily intake. In contrast no plateau was reached for females. In Shvedov and Akleyev (2001) it was obtained that strontium activity concentration in skeleton doesn't reach a plateau even 12 months after the beginning of treatment. In Buldakov and Moskalev (1968) the rate of ^{90}Sr accumulation in the skeleton of mice receiving the radionuclide in the food in dependence on age at the beginning of contamination was investigated. By 100th day for the mice exposed to strontium since the age of 14, 30, 70 and 150 days the accumulation were 1400, 1000, 570 and 490% of daily intake respectively.

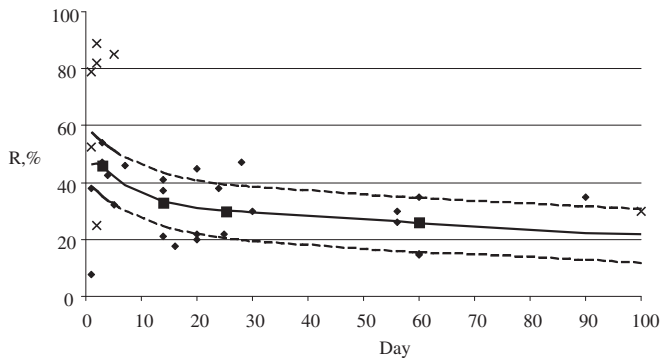

Fig. 1. Retention of strontium in skeleton of mice and rats with time since acute injection (% of intake). Diamonds – mice experimental data; crosses – rats experimental data; squares – referent values used for model validation; solid line – retention according to developed model with standard error (dash line).

Strontium metabolism in wild animals was investigated on the territories contaminated after accidents at "Mayak" nuclear plant and Chernobyl nuclear power plant. In the review (Gaschak et al., 2011) it was shown that for murine rodents from Chernobyl exclusion zone the ^{90}Sr excretion from their bodies occurred with half-lives of about 10–50 days, and 90% of dynamic equilibrium with chronic intake was reached on 33–166 day. According to Baryakhtar et al. (2003) the half-lives of strontium elimination was 12 days for bank voles captured from the central sites of Chernobyl zone and given 'clean' food, and 50 days for laboratory mice. As it was shown in the analysis of numerous results of Chernobyl zone murine rodents investigations the average skeleton strontium content is 93% of that in the whole body, with strontium content in soft tissues at a level of 0.6% of that in skeleton. Changing in the radionuclide intake with the diet affects the total radionuclide content more rapidly and significantly than factors such as age, gender and species-specific differences, neutralizing the effect of those factors. The authors of the review (Gaschak et al., 2011) pointed out that in Chernobyl zone the contribution of incorporated ^{90}Sr to small mammals exposure significantly increased with time after the accident. The content of ^{90}Sr in the body of small mammals in the early years after the accident is a largely dependent on bioavailability of radiostrontium. The review presents the ^{90}Sr transfer coefficients in the soil-to-animal chain for small rodents. For the trapped wild animals, these coefficients vary in a very wide range: from tenths to tens (Bq/kg)/(kBq/m^2).

Skeleton strontium content for murine rodents from EURT was lower in comparison with the animals from Chernobyl Zone and amounted 83–87% of the accumulated in the body (Starichenko and Zhukovskii, 2012). For animals trapped in the EURT in 2009 transfer coefficient from ^{90}Sr surface contamination to the skeleton activity lies in the range 20–700 (Bq/kg)/(kBq/m^2), that correspond to coefficient of transfer from surface contamination to whole body in the range from several to tens (Bq/kg)/(kBq/m^2).

Collected and analyzed data on the acute intake and retention of strontium in body of mice allow estimation of the coefficients included to strontium biokinetic model for murine rodent. The coefficients were found by requiring agreement of model retention with some target reference values $R(T_j)$. The reference values of retention were estimated for four times T_j after injection using least square method. Experimental data on retention r_i in mice were considered with weights $W_{ij} = 1/(T_j - t_{ij})^2$ and $W_{ij}(t_{ij} = T_j) = 2$. By that way the reference values of strontium retention in skeleton as follow were chosen: 46% by the end of third day, 33% on 14th day, 30% on 25th day and 26% on 60th day (Fig. 1).

3. Model development and coefficients assessment

For development of strontium biokinetic model for murine rodent the analogous ICRP model for human was used with some adjustment and simplification. In particular the model was reduced by abandoning the division of gastrointestinal system into compartments and combining other soft tissues into single model organ since no differentiated data are available for mice. The skeleton is modeled by two compartments with slow and fast exchange rates that follows from two-exponential dependence of retention on time since acute injection.

Suggested model presented on Fig. 2 includes five compartments – Blood, Gastrointestinal tract (GIT), Soft tissues, Skeleton, Urinary bladder, and eleven transfer rates (λ_1–λ_{11}):

– to Blood from Gastrointestinal tract (λ_1), Soft tissues (λ_{10}), Skeleton (λ_4 – fast and λ_6 – slow components);

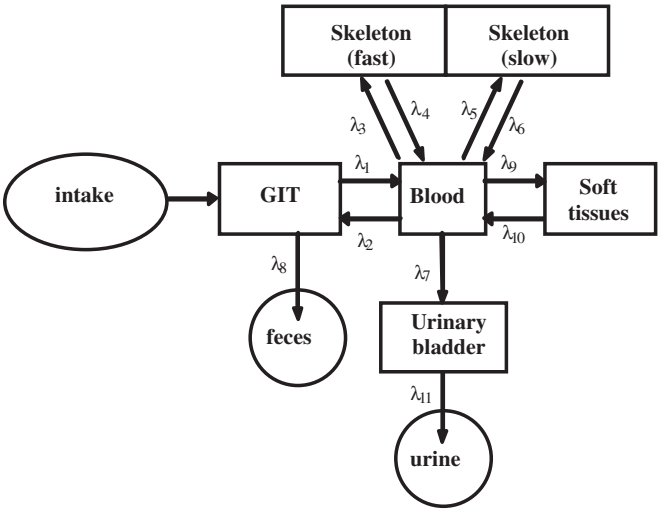

Fig. 2. Schematic illustration of the biokinetic model.

- from Blood to Soft tissues (λ_9), Skeleton (λ_3 – fast and λ_5 – slow components), Gastrointestinal tract (λ_2) and Urinary bladder (λ_7);
- excretion from Gastrointestinal tract to feces (λ_8);
- excretion from Urinary bladder to urine (λ_{11}).

The values of some transfer rates can be assessed using the experimental data on strontium retention in body of laboratory mice presented above. At the same time complete set of model coefficients couldn't be gained from the experimental data. In this case we set a requirement consisting in general agreement with human model (ICRP, 1993) taking to account reduced number of compartments. The following considerations and arguments were applied to choose the values of model coefficients as well.

Data on experiments with animals don't allow to estimate accurately transfer rate linking Gastrointestinal tract and Blood. However the value of this parameter should be large enough to provide elimination of strontium to Blood during first day. In the human model this value is 2.57 day^{-1}. Given the fact that retention in the skeleton is about 50% in period of the first few days, the ratio and values of transfer rates correspond to radionuclide elimination from the Blood should provide accumulation of about half of the initial activity of strontium in the Skeleton in the early days. Therefore the initial rate of transfer from Blood to Skeleton should be approximately equal to the sum of the rates of transfers from Blood to other compartments. In order to achieve the rapid remove of strontium from Blood to Skeleton the rate of this process should be sufficiently high. In human model the sum of similar coefficients is 3.75 day^{-1}.

Retention of strontium in the Skeleton should be well described by a two-exponential function (Cohn et al., 1957; Lyubashevskii, 1980). In the developed biokinetic model this dependence is taken into account by applying the two parts of the Skeleton with fast and slow excretion. Fast and slow transfer rates for Skeleton should be close to the calculated parameters of the curve presented by Equation (1) and shown on Fig. 1.

The transfer from Urinary bladder to urine together with transfer from GIT to feces provides removal of strontium from the body. The rates of transfer from GIT and Urinary bladder are associated with frequency of emptying of these organs that can be accepted as about few times per day.

Transfer from Blood to Urinary bladder provides gradual removal of strontium from Skeleton and Soft tissues. The value of transfer rate λ_7 is close by the order of magnitude to sum of λ_4, λ_6 and λ_{10}. In the human model the parameter similar to λ_7 is equal to 1.73 day^{-1}.

The ratio of transfer rates between the Blood and Soft tissues should provide a minor retention in Soft tissues. In the human model the sum of parameters similar to λ_9 and λ_{10} are quite large and amount to 9.00 day^{-1} and 2.62 day^{-1} respectively.

Suggested biokinetic model is described by a system of eleven differential equations. To solve the system the computer code Winact (Leggett et al., 1993) developed for human biokinetic modeling was applied where input parameters are transfer rates and radionuclides' intake while output parameters are activity of the radionuclide in the ascertained compartments with time. The acute and chronic intake cases are provided for estimation with Winact.

The second column of Table 1 contains the ranges of transfer rates that correspond to less than one percentage point deviation of retention from the target values. The ranges were obtained using sensitivity and robustness analysis. Accepted transfer rates values are presented in the third column of Table 1. The parameters values are presented with minimal accuracy – one significant figure, considering large variability of experimental data.

The model with parameters presented in Table 1 describes the data on strontium retention in skeleton of murine rodents presented on Fig. 1 with standard error of 9.5% (Fig. 1). The values of strontium retention in whole body, Soft tissues and Blood as well as total excretion with urine and feces for the case of acute intake of ^{90}Sr activity 1 Bq obtained with developed model are shown on the Fig. 3.

Prolonged strontium intake was simulated under an assumption of equality of transfer rates in the case of prolonged intake to those in the case of acute injection. This approach does not take into account the time variation of transfer rates e.g. with age of animal. Skeleton activity in the case of chronic exposure to 1 Bq per day is presented on Fig. 4a. The dependence of strontium accumulation in the Skeleton on time for 12 months after beginning of intake is in satisfactory agreement with the data given in Shvedov and Akleyev (2001). As can be seen on Fig. 4a the Skeleton activity raises approximately linearly during the first 100 days and accumulation reaches the factor of 14 and this value is in agreement with experimental data as well. Whole body activity rise in 3.4 times for period from third to 16th week of chronic intake that is close to values obtained for case of contaminated water intake (4.7 and 5.8 for males and females respectively, Synhaeve et al., 2011). Plateau of dependence of strontium retention in Skeleton on time since beginning of exposure appears in 1000 days. It is essential that this value corresponds to and even exceeds the life duration of murine rodents. As can be seen on Fig. 4b the daily excretion of strontium growths rapidly during first two weeks and then approaches

Table 1
Transfer rates of developed Strontium biokinetic model for mouse-like rodent.

Organ donor → Organ receiver	Range, day^{-1}	Value, day^{-1}	Similar value in human model
GIT → Blood	(2.0–3.5)E+00	3.0E+00	2.57E+00
Blood → GIT	(1.5–2.5)E-01	2.0E-01	5.25E-01
Blood → Bone_1	(4.0–5.0)E+00	4.0E+00	3.75E+00[a]
Bone_1 → Blood	(5.0–6.0)E-01	5.0E-01	
Blood → Bone_2	(0.9–1.1)E+00	1.0E+00	
Bone_2 → Blood	(5.5–6.5)E-03	6.0E-03	5.75E-04[a]
Blood → UBCont	(1.9–2.1)E+00	2.0E+00	1.73E+00
GIT → Feces	(2.5–4.0)E+00	3.0E+00	
Blood → SoftT	(3.0–4.0)E+00	4.0E+00	9.00E+00[a]
SoftT → Blood	(0.9–1.2)E+00	1.0E+00	2.62E+00[a]
UBCont → Urine	(3.0–5.0)E+00	4.0E+00	

[a] The figure represents the sum of transfer rates.

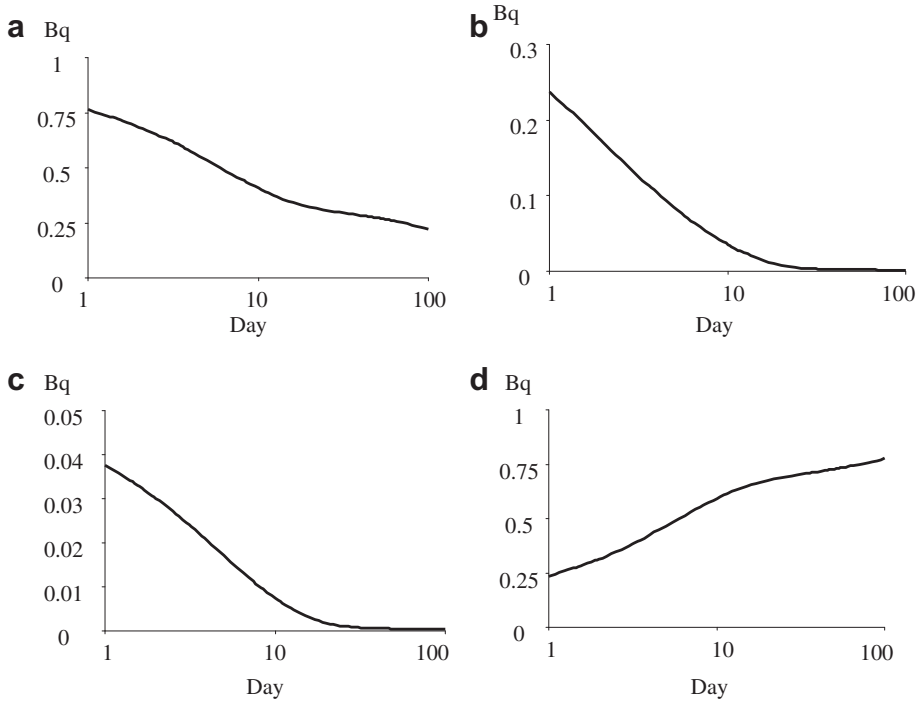

Fig. 3. Activity of ^{90}Sr after 1 Bq injection a) in whole body, b) in Soft tissues, c) in Blood; d) total excretion.

gradually to value of daily intake. The 90% dynamic equilibrium is reached on 100th day that is in agreement with (Gaschak et al., 2011).

The model dependence of Skeleton ^{90}Sr activity on time may be used for estimation of average daily intake that can be applied for further verification of the developed model. Necessary data on ^{90}Sr content are available for murine rodents trapped in 2009 at the EURT at sites with initial contamination in the range 0.74–18.5 MBq/m^2 (Malinovsky et al., 2012). By results of measurements of ^{90}Sr activity in 20 animals the average skeleton activity of ^{90}Sr was 93 Bq. Assuming that the intake was constant for at least 45 days before the trapping of animals, the estimated average daily intake was 9 Bq. With an average rodent weight of 18 g daily food consumption could be about 2.6 g (dry weight) (Bachmanov et al., 2002) which corresponds to the activity concentration of ^{90}Sr in food (vegetation) on the level of 3.5 kBq/kg air-dry weight. According to the study of radioactive contamination of vegetation on the sites of animals trapping the ^{90}Sr activity concentration of vegetation was 1.8–4 kBq/kg dry weight (Mikhaĭlovskaia et al., 2011).

Thus comparisons of modeling and studies of ^{90}Sr retention in the case of chronic intake support reliability of the model.

4. Discussion and conclusion

Developed strontium biokinetic model for murine rodent represents modification of ICRP model for reference human with reduced number of compartments. Application of the model allows estimation of strontium distribution by organs and tissues both in the cases of acute and chronic exposure with dependence of strontium activity in organs on time.

The model is based on published experimental data on strontium retention in body of laboratory mice. The reliability of the model is supported by the data on experiments and observations of

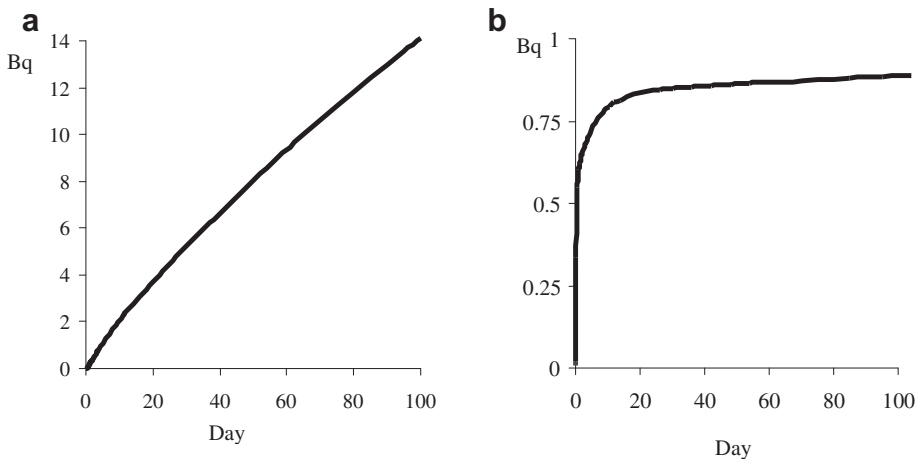

Fig. 4. Activity of ^{90}Sr in a) Skeleton and b) daily excretion in the case of chronic strontium intake (1 Bq per day).

^{90}Sr retention in laboratory mice as well as murine rodents inhabiting contaminated territories.

Important feature of used experimental data on acute injection consists in studying of strontium retention for the period of time that is compatible with life duration of the animals, i.e. the parameters of metabolism are changing during the experiment. Mainly, strontium was injected to animals about ten weeks old while the retention is measured in elder ones. Consequently the developed model is considered to be appropriate for case of age at beginning of exposure of murine rodent from few to ten weeks old. It is necessary to note that age-determined retention of radiostrontium had been evidenced for ages 14–168 days (see e.g. Nilsson et al., 1980; Buldakov and Moskalev, 1968).

To analyze the influence of age at beginning of exposure on the developed model we simulated dependence of fast transfer rate from blood to skeleton λ_3 on the variation of target values of retention. The simulation was undertaken under assumption of constant relation between λ_3 and λ_4, λ_5 and λ_6 and constant values of other parameters. Age-dependent target values of retention for 20th and 60th days after intake were taken from Nilsson et al. (1980). It was obtained that λ_3 considerably changes from nine to two with age at beginning of exposure from 30 to 180 respectively.

Data on the strontium retention in body of newborn mice in case of chronic intake can be found elsewhere (Synhaeve et al., 2011). At the same time the experimental data on acute strontium intake for immature rodents that are necessary for analysis of the strontium biokinetics were unavailable.

From radioecological point of view it is rather the ^{90}Sr activity concentration in organs and tissues than whole body activity that is directly associated with absorbed dose. In order to estimate the concentration it is necessary to know whole body weight as well as organs' weights in dependence on age of the model animal. Considering constant chronic intake and weight increasing with age the activity concentration is not a linear function of strontium activity.

Developed strontium biokinetic model will be used for internal dose assessment for murine rodents inhabiting EURT territories. Comparison of dose estimations with studied effect of radiation exposure constitutes radiobiological basis for radiation protection of EURT biota.

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