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Review of Russian language studies on radionuclide behaviour in agricultural animals: transfer to animal tissues

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Abstract

Data on radionuclide transfer to animals from research performed in the former Soviet Union were reviewed to collate transfer coefficient values (F_f) to animal tissues such as liver, kidney and bone, but not muscle which has previously been reported. The derived values were compared with selected data published in the English language literature. The new data are mainly for ^{90}Sr and ^{137}Cs, although some data were also provided for ^{3}H, ^{54}Mn, ^{59}Fe, ^{60}Co, ^{22}Na ^{65}Zn, ^{131}I and U. The Russian language data may provide a basis for better informed evaluation of radiation dose from the consumption of such animal products, which can form important components of the diet in some countries.

1. Introduction

It is widely recognised that animal products are potentially important contributors to the exposure of the public for many contamination scenarios relevant for radiation protection. Therefore, a response to environmental contamination requires the capability for predicting radionuclide transfer to a wide range of animal products. Extensive studies were performed in many countries to fill these gaps during the last 70 years. The data obtained have been summarised by several authors (Ng 1982, van den Hoek, 1989; Richmond, 1989; Coughtrey and Thorne 1993, Green and Woodman 2003). The IAEA also published a compilation of animal transfer parameters initially in 1994 in TRS 364 which was then updated in TRS 472 in 2010 (IAEA, 1994; IAEA, 2010).

Although large programmes of experiments on transfer of radionuclides to a wide range of different agricultural animals were conducted in the former USSR, only a few of these results were known in the English language literature or taken into account in the publications listed above. To fill in this gap an extended review of the data published in different Russian language sources was undertaken which critically reviewed the available information. The outcome has been presented in a series of publications that described radionuclide gut absorption, transfer to milk, muscle of animals and poultry, and data on biological half-lives in different animal tissues Fesenko et al. (2007a, 2007b, 2009a, 2009b, 2015). These data were partially used for TRS 472 by the IAEA on radionuclide transfer in the terrestrial and freshwater environments published in 2010 (IAEA, 2010).

Nearly all available data on radionuclide transfer factors to animals were for radionuclide transfer to muscle, milk and eggs. There have been few available data on radionuclide transfer to animal tissues other than muscle which are commonly termed offal and can also form part of the human diet (liver, kidney, lung etc.). To address this deficiency the data from the research programmes performed in the FSU were collated and evaluated.

Most of the studies on radionuclide transfer to animal tissues involved the mobile fission products, ^{90}Sr and ^{137}Cs. However, some experiments were performed also with ^{3}H, ^{54}Mn, ^{60}Co, ^{65}Zn and U. The animals involved in those experiments were mainly ruminants (cattle, sheep and goats), but also included monogastrics species (pigs and rabbits) and poultry (largely hens).

This paper represents the final paper in a series of related to the Russian language studies. The previous papers considered gut absorption, transfer to milk and to animal tissues as well as to poultry and biological half-lives (Fesenko et al., 2007a, 2007b, 2009a, 2009b, 2015). The main objective of the paper was to compile and critically review relevant research published in the Russian language literature on radionuclide transfer to animal and poultry tissues (other than muscle) and to make these data available for international reviews.

From the beginning of the 1960s, animal experiments in the USSR were conducted mainly in response to the Kyshtym accident and global contamination of the environment followed above-ground nuclear tests (Alexakhin et al., 2004, UNSCEAR, 2011). Special attention in these experiments was given to ^{90}Sr as a main dose forming radionuclide because of the need to remediate areas affected by the Kyshtym accident. Also, to a lesser extent, there was a focus on ^{137}Cs which was one of the main dose-forming radionuclide in most of the areas affected by global fallout (UNSCEAR, 2011). Furthermore, because of the wide deployment of nuclear techniques in the Soviet Union, some experiments were addressed to accumulation of ^{3}H, ^{54}Mn, ^{59}Fe, ^{60}Co, ^{22}Na ^{65}Zn, ^{131}I and U in a variety of animal products. Although, these experiments were largely focused on radionuclide accumulation in milk and muscle of domestic animals, the transfer of specific radionuclides to high-accumulating target organs such as thyroid and lung (^{131}I), bones (^{90}Sr, U) and liver (Pu) were also quantified.

Only a few texts published in the Russian language on this research topic were cited in English language reviews, notably Buldakov (1961) and Prister (1967). In compiling the original Russian information, preference was given to original publications. Alternative reference to reviews (Annenkov, 1967; Sirotkin, 1977; 1987; 1991) were only used when the original information was not available.

More than 50 research articles and book chapters were reviewed using a quality control procedure which considered the adequacy of experimental descriptions. It also ensured that duplications arising from data description in multiple publications was identified. Transfer coefficient values (F_f), defined as the radionuclide activity concentration in the tissue - Bq kg^{-1} fresh weight (fw) divided by the daily intake of the radionuclide (Bq d^{-1}), were checked or, where possible, derived. Only 30 of the sources were selected for further analysis that finally provided 533 F_f values used for the evaluation presented in this paper. The F_f values derived within the assessments were subdivided into animals of different ages enabling assessment of the age dependence of the parameters used to describe radionuclides transfer to animals and of the varying agricultural practices. The compiled F_f values from Russian literature have been compared with relevant data for the reported radionuclide/organs combinations in the English language literature. Major experimental details of the studies reviewed are given in Table 1.

2. Radionuclide transfer to cattle tissues

In all, 37 references were reviewed to derive *Ff* values for cattle. Only 6 of them were identified as publications providing original data without duplications and with a clear description of the experiment design. One hundred and twenty six *Ff* values were derived from the publications reviewed. Most of the information (70 records) was for ^{90}Sr, followed by ^{137}Cs (26 records) and ^{60}Co (25 records). A few *Ff* values were derived for ^{106}Ru (skeleton) and ^{125}Sb (liver). Following the approach used by Fesenko et al. (2009a) three categories of cattle were considered, namely cows and bulls above 1 year old (adult cattle), young bulls aged 12-18 months and calves aged 3-4 months. The data on radionuclide transfer to animals were assessed separately for these categories because of differences in *Ff* for radionuclide accumulation by, and excretion from, animals of different ages (related to liveweight).

2.1 Adult cattle

Data for two radionuclides ^{60}Co and ^{90}Sr were reported in Sirotkin (1977, 1987) and Sirotkin et al. (1987) ((Table 2). Long-term experiments with ^{60}Co were part of a radiobiological research programme and only the data for animals where there were no biological effects were selected for evaluation. Two publications (Sirotkin, 1977; Sirotkin et al., 1987) provided data for several long-term experiments with adult animals. Data for ^{60}Co were given for animals exposed to ^{60}Co from birth to the age of 32 months (Sirotkin et al., 1987).

Although the purpose of experiments was evaluation of biological effects, the accumulation of ^{60}Cs in most of the animals were also measured to assess doses to individual organs. The highest *Ff* values of 3.9×10^{-2} - 1.2×10^{-2} d kg^{-1} were for the liver and kidney and the lowest of 2.0×10^{-4}- 7.0×10^{-4} d kg^{-1} were for blood and skeleton. The *Ff* of ^{60}Co to other tissues varied from 3-5 d kg^{-1}. In a shorter-term experiment of 140 d with one lactating cow, Voigt et al. (1987) reported *Ff (*d kg^{-1}) values for liver of 7.1x 10^{-3}, lung of 7.2 x 10^{-4} and kidney of 2.4 x 10^{-3} d kg^{-1}. The values are lower than those of the Russian data, but the same two organs have higher transfer of ^{60}Co. The transfer of ^{60}Co to skeleton in Sirotkin et al. (1987) was c. 8 x10^{-4} d kg^{-1} which was similar to that in Voigt of 2.7 x 10^{-4} and 9.0 x 10^{-5} d kg^{-1}. The paper also provided information on ^{60}Co accumulation in some stomach compartments; an *Ff* of 1.9×10^{-2}, 3.4×10^{-2} and 4.8×10^{-2} d kg^{-1} was reported respectively for the rumen, reticulum and omasum (Sirotkin et al., 1987).

The highest *Ff* values for Sr to cattle tissues $(2.3\pm1.6) \times 10^{-1}$ d kg^{-1} were measured for skeleton, which is a key storage organ for both calcium and its analogue, strontium, in the body of mammals. Transfer coefficient values for other tissues were around two orders of magnitude lower, at $(1.4\pm1.2)\times10^{-3}$, $(1.4\pm0.5)\times10^{-3}$ and $(1.2\pm0.6)\times10^{-3}$ d kg^{-1}, for liver, kidney and lung, respectively. The lowest *Ff* values of $(4.7\pm2.9)\times10^{-3}$ were for the heart. Overall, the studies demonstrated that there was a similar accumulation of ^{90}Sr in different types of soft tissues in adult cattle. Although there are large amount of data for ^{90}Sr for cattle, there are fewer studies in English language literature on ^{90}Sr and no reported *Ff* values for organs were identified.

2.2 Young bulls

The data were derived from Sirotkin et al. (1970, 1972 and 1977). The *Ff* values for young bulls were mainly reported for ^{90}Sr and ^{137}Cs; limited data were also available for ^{106}Ru transfer to liver and skeleton and ^{125}Sb transfer to liver (Table 3).

For ^{90}Sr the *Ff* values for different bull tissues had similar patterns to that for adult animals, although they were 2-4 times higher than those for the adults. The highest *Ff* values of $(7.0\pm0.4)\times10^{-1}$ d kg^{-1} were for skeleton and the mean *Ff* values for soft tissues varied from $(1.93\pm 0.12)\times10^{-3}$ d kg^{-1} (for heart) to $(5.5\pm2.1)\times10^{-3}$ d kg^{-1} for kidney.

Data for ^{137}Cs were only available for young bulls (Sirotkin et al. 1970, 1972). No statistically significant differences were identified for ^{137}Cs *Ff* values to various soft tissues. Overall, the *Ff* values measured for heart, kidney, liver, lung and spleen were in good agreement with that for ^{137}Cs to offal of $(5.8 \pm1.7)\times10^{-2}$ d kg^{-1} measured in the same study (Table 3). For skeleton low *Ff* values for ^{137}Cs ranged from 0.8-0.9 × 10^{-2} d kg^{-1}. There are a few data for radiocaesium transfer to offal in English language literature, largely reported in studies after the Chernobyl accident for adult cattle and experiment and lasting for less than half that of the 300 d duration in Russia. Transfer coefficient values reported for lung, liver, kidney, spleen, heart and brain in two associated experiments. In Greece, lactating cows were fed ionic ^{134}Cs and in Pripyat lactating and non-lactating cows were fed $^{134/137}$Cs in hay for 95 d (Assimakopoulos et al., 1995). All *Ff* values for the soft tissues were within an order of magnitude and a range of 1.3 x 10^{-2} - 7.8 × 10^{-2} d kg^{-1}. Other reported *Ff* values for organs from Sumerling (1984) and Voigt et al. (1987) for liver, lung and kidney were lower at (4.3-9.0) × 10^{-3}, 2.5 × 10^{-3} and 5.3 x 10^{-3} respectively. Transfer of ^{137}Cs to bone reported by Voigt et al. (1987) was lower at (0.35-2.6) × 10^{-3}. Although no relevant data were found for the transfer of ^{137}Cs to tissues of cattle of a similar age to that from Russian language studies, these data are generally consistent with those for young bulls (See Table 3).

The mean *Ff* value for ^{106}Ru for transfer to liver was $(2.6\pm0.8)\times10^{-3}$ d kg^{-1}, whilst that for ^{125}Sb to liver of $(1.1 \pm 0.3)\times10^{-2}$ d kg^{-1} was substantially higher than the *Ff* for ^{90}Sr.

2.3 Calves

For calves aged 2-5 months, data were available for ^{60}Co, ^{90}Sr and ^{137}Cs based on Annenkov (1967), Sirotkin (1977, 1987) and Sirotkin et al. (1980).

The data for ^{60}Co were derived for cattle exposed from birth to an age of 32 months (Sirotkin et al., 1987). For the purpose of our assessments, the *Ff* values were evaluated based on the data for calves exposed for 90 days. The general patterns of ^{60}Co distribution in the tissues were similar to those identified for adults, i.e. highest *Ff* values $(7.4\pm1.2)\times10^{-2}$ and $(1.0\pm0.2)\times10^{-1}$ were for ^{60}Co to the kidney and liver. The lowest ^{60}Co *Ff* values $(1.8\pm0.3)\times10^{-2}$ d kg^{-1} were for the skeleton. The ^{60}Co *Ff* values to other tissues were at the similar level and ranged (2-6) × 10^{-2} d kg^{-1}. Overall, the *Ff* values for young animals (2-5 m age) were higher than those reported for adult animals. The ratios of the *Ff* values derived for calves to those for adults ranged from 2.5 (liver) to 25 skeleton reflecting differences in accumulation of ^{60}Co in different tissues. The study also provided information on ^{60}Co accumulation in some stomach compartments which are not given in

Table 4. The *Ff* values of 1.9×10^{-2}, 3.4×10^{-2}, 4.8×10^{-2} d kg^{-1} were for rumen, reticulum, omasum and abomasum (Sirotkin et al., 1987).

For ^{90}Sr, the highest mean *Ff* value was to skeleton $(3.6\pm1.0)\times10^{0}$ d kg^{-1}. Th the Ff values for the combined offal (i.e. the internal organs and edible entrails of animals) ranged from $(3.8\pm3.4)\times10^{-3}$ d kg^{-1} - $(8.8\pm 0.3)\times10^{-3}$ (liver). The *Ff* value for combined offal (i.e. the internal organs and edible entrails of animals) of $(5.1\pm0.9)\times10^{-3}$ d kg^{-1} was in agreement with the above values.

A general point related to all these data is the effect of liveweight on transfer coefficients to various animal tissues. The mean *Ff* values for skeleton and heart were 15-20 fold higher than those for adult animals; for the other tissues these values were lower and ranged from 3.7 (lung) to 6.7 (kidney). The reduction of the *Ff* values for calves depending on age / liveweight also contributed to the higher uncertainty (compared to the older animals) associated with the mean values calculated for different tissues.

3. Radionuclide transfer to sheep tissues

The number of the studies and, hence, available *Ff* values to sheep tissues are higher compared with those measured for cattle. This allows better statistical evaluation of the data and comparison between data provided by different literature sources. Sixty eight records were derived for ^{90}Sr transfer to different tissues of adult sheep (41 records) and kids (27 records) from long-term experiments by Burov et al. (1969) supplemented with *Ff* from Buldakov (1961) on ^{90}Sr transfer to liver and skeleton (Table 5). Thus, most of the *Ff* values from Table 5 were for ^{90}Sr transfer to liver and skeleton. Three publications by Buldakov (1961, 1964 and 1967) provided most of the data on ^{137}Cs and ^{144}Ce transfer to sheep tissues (Table 6). Some additional information was available in Korneyev et al. (1977) and Annenkov et al. (1991).

The Burov study included data for ^{90}Sr administration from birth to 1095 days and animals were sampled from 15 days after the start of administration. In Table 5, only data for animals slaughtered on 240, 365, 547 and 1095 days after administration commenced were selected and there was no statistically significant differences identified for these four sets of data. The *Ff* values for ^{90}Sr to heart were based on Burov (1969) data ranged from $(2.2\text{-}3.5)\times10^{-3}$ d kg^{-1} The *Ff* values for lung and kidney were around 2.5 times higher than that for the heart at $(6.5\pm1.9)\times10^{-3}$ d kg^{-1} and $(7.3\pm2.9)\times10^{-3}$ d kg^{-1}, respectively whilst the mean values for spleen and liver were similar to those for the heart at $(3.2\pm0.6)\times10^{-3}$ d kg^{-1} and $(2.9\pm0.6)\times10^{-3}$ d kg^{-1}, respectively.

For Buldakov experiments, two groups of sheep with an age at the time of administration of 365 d and 1095 d were used. The duration of administration varied between 18 and 300 days. Initial statistical analysis showed that there was no statistical difference between the individual datasets so the data considered was those for samples taken for animals aged 365 and 1095 days at the start of the administration. The *Ff* values for these groups of animals was $(2.0\pm0.9)\times10^{-3}$ and $(1.9\pm0.9)\times10^{-3}$ d kg^{-1}, respectively, whilst for the whole data set the liver mean *Ff* value was $(2.0\pm0.8)\times10^{-3}$ d kg^{-1}. These data not differ substantially from the Burov data for liver of $(2.9\pm0.6)\times10^{-3}$ d kg^{-1} so a combined *Ff* value (based on the all available data) for ^{90}Sr transfer to liver has been derived of $(2.9\pm0.6)\times10^{-3}$ d kg^{-1}.

Similar calculations were made for skeleton. As for adult sheep, the *Ff* values for younger animals, i.e. for lamb aged below 6 months, were based on Burov (1969) supplemented with *Ff* values for ^{90}Sr to skeleton from Buldakov and Moscalev (1968) (Table 5). As shown for adults, there are large differences between ^{90}Sr transfer to the skeleton of young animals of (2.9±1.3) $\times 10^{1}$ d kg^{-1} and that to other tissues. The ratios of the *Ff* values for the skeleton to that of other tissues was (1.6-3.6)$\times 10^{3}$ d kg^{-1}. The mean *Ff* values to other tissues ranged from (8.0±1.0)$\times 10^{-3}$ d kg^{-1} for the heart and (1.9±0.7)$\times 10^{-2}$ d kg^{-1} for spleen.

For ^{137}Cs the highest *Ff* to adult sheep were for kidney (1.8±0.1)$\times 10^{-1}$ d kg^{-1} and liver (1.5±0.8)$\times 10^{-1}$ d kg^{-1}. The *Ff* values to heart of (8.5±3.3) × 10^{-2} d kg^{-1}, lung of (8.5±0.9)$\times 10^{-2}$ d kg^{-1} and spleen of (7.0±3.2)$\times 10^{-2}$ d kg^{-1} were similar and the lowest *Ff* values of (2.2±0.4)$\times 10^{-2}$ d kg^{-1} were for skeleton. Andersson & Hansson (1989), who fed lambs hay containing ^{137}Cs for a period of 42d and slaughtered at 8 months of age, reported *Ff* values for heart – 1.4 x 10^{-1} d kg^{-1}; liver – 1.2 x 10^{-1} d kg^{-1} and kidney – 2.6 x 10^{-1} d kg^{-1}. Combining relevant *Ff* (d kg^{-1}) values reported in English language literature, the mean values for the different tissues for adults were, in descending order, were: kidney – 3.0 x 10^{-1}; spleen – 2.9 x 10^{-1}; heart – 2.3 x 10^{-1}; lung – 1.9 x 10^{-1}; liver – 1.7 x 10^{-1} and bone – 2.3 x 10^{-2} (Beresford et al. 1989; Assimakopoulos et al. 1995; Howard & Lindley 1985; Howard et al. 1987; Howard et al. 1989). Overall, there is little difference in the reported *Ff* values for soft tissues; bone is consistently low. There is no apparent difference is soft tissues *Ff* values for lambs and adult sheep.

The *Ff* values for ^{144}Ce were typically lower than those for ^{137}Cs and similar to those derived for ^{90}Sr for some tissues. The ratios for ^{90}Sr *Ff* values to that of the same tissues for ^{144}Ce vary from 0.2 (bone) -3.5 (liver). The mean *Ff* value of ^{144}Ce for bone of 1.4x10^{-2} is almost an order of magnitude higher than that reported by Beresford et al. (1998) for lamb of 3.1x10^{-3}; the mean *Ff* value of ^{144}Ce was similar for liver (8x10^{-3} vs 7.3x10^{-3}) and kidney (3x10^{-3} vs 1.7x10^{-3}) . The difference can be explained by the much longer duration of the experiment in Russia than that of Beresford et al. (1998) which used a single pulse administration to enable the development of a dynamic model.

4. Radionuclide transfer to goat tissues

Studies on radionuclide transfer to goat tissues were mainly performed for ^{90}Sr (Burov et al., 1969). Goat which were 1.5 year old were slaughtered at various times after beginning chronic administration of the radionuclides. Based on the biological half-life data for different animal tissues in Fesenko et al. (2015) only the data for exposure times longer than 30 days were used to derive Ff values (Table 7).

As for cattle, among the soft tissues, the highest *Ff* of ^{90}Sr was for kidney at (3.0±2.1)$\times 10^{-2}$ d kg^{-1}, and *Ff* was 3-5 times fold lower for lung (7±0.2) $\times 10^{-3}$, spleen (5.0±1.0)$\times 10^{-3}$, liver (4.0±1.0) $\times 10^{-3}$ and heart (4.0±1.0)$\times 10^{-3}$ d kg^{-1}. The *Ff* to skeleton was around three orders of magnitude higher at 1.1±0.4)$\times 10^{1}$ d kg^{-1}. For young animals (aged 1-6 months) the mean *Ff* values were about two fold higher compared with adult animals at (2.0±0.2)$\times 10^{-2}$, (1.0±0.8)$\times 10^{-2}$, (0.8±0.2)$\times 10^{-2}$, (0.7±0.2)$\times 10^{-2}$ and (0.7±0.1)$\times 10^{-2}$ d kg^{-1} for kidney, lung, liver, heart and spleen, respectively.

Data on ^{137}Cs transfer to goat offal was found in the Russian literature. However, there are a few data for radiocaesium transfer to goat offal in English language literature, largely reported in studies after the Chernobyl accident for adult goats. Transfer coefficient values were reported for muscle, lung, liver, kidney, spleen, heart and brain in two associated experiments. In Greece, lactating goats were fed ionic ^{134}Cs and in Pripyat lactating and non-lactating goats were fed $^{134/137}$Cs in hay for 95 d (Assimakopoulos et al., 1995). All F_f values for the soft tissues were within a range of $1.9 \times 10^{-1} - 1.1 \times 10^{0}$. The highest value was for kidney; all the F_f values were within an order of magnitude.

The distribution of radiocaesium accumulated in tissues of goats were reported following peroral administration of ^{137}Cs after 7d and 14d normalised to a constant body weight and reported as % dose per gram tissue rather than F_f. (Ekman, 1961). The highest accumulation was in the kidney after 7d, the Cs accumulation was halved after 14d. The levels of ^{137}Cs in bone was significantly lower than that of other soft tissues.

5. Radionuclide transfer to pig tissues

Data from 37 studies on radionuclide transfer to pig tissues, carried out between 1960 and 1996, were analysed to identify F_f values for ^{32}P, ^{90}Sr, ^{106}Ru, ^{137}Cs, ^{238}U and ^{239}Pu. In all, 190 records were derived. Most of the F_f values available for pigs were for ^{137}Cs (101 records) followed by ^{90}Sr (41 records), reflecting the importance of these exposure pathway for accidental situations after the Chernobyl and Kyshtym accidents (Tables 8-10).

5.1 ^{90}Sr transfer to pig tissues

The data for ^{90}Sr were mainly taken from Annenkov et al. (1964) and Burov et al. (1971) (Table 8). The reported F_f values were rather homogeneous; the mean F_f for soft tissues ranged from $(3\text{-}5)\times10^{-3}$ d kg^{-1}. For skeleton the F_f value of 1.7 ± 0.7 d kg^{-1} was much higher than for other soft tissues which is consistent with other reported data. For example, similar observations were reported by Werner (1971) for sows given ^{90}Sr in a capsule for 105 d although F_f was not derived. Deposition in bone was about 100 fold higher than that in soft tissues. Of the soft tissues, the lowest ^{90}Sr activity concentrations were in lung.

For piglets aged 1-6 months, the inhomogeneity between F_f for tissues was greater, with higher F_f (d kg^{-1}) values for liver $(1.2\pm0.6)\times10^{-3}$ and kidney $(1.4\pm0.3)\times10^{-2}$ and lower values for heart $(7.0\pm0.1)\times10^{-3}$. The F_f value for skeleton of (2.2 ± 0.1) d kg^{-1} was similar to that for adult pigs. In Werner (1971), the ^{90}Sr activity concentrations were 5 or 6 times higher in younger sows than older. The difference was expected since both had the same daily dose of ^{90}Sr, but the younger weighed half as much as the older.

5.2 ^{137}Cs transfer to pig tissues

The F_f values for ^{137}Cs transfer to pig tissues are given in Table 10. The data for ^{137}Cs were taken from a variety of sources, including Annenkov et al. (1990), Annenkov et al. (1991), Chmyrev (1996), Ilyin and Moscalev (1961), Nikitina et al. (1972), Shilov (1980) and Sirotkin (1977) (Table 9).

The highest mean F_f values were to kidney (0.29 ± 0.16 d kg^{-1}), followed by heart (0.23 ± 0.14 d kg^{-1}), liver (0.15 ± 0.07 d kg^{-1}), spleen (0.15 ± 0.1 d kg^{-1}) and lung (0.095 ± 0.06 d kg^{-1}). The lowest F_f was observed for fat (0.006 ± 0.0004)d kg^{-1}), which is a popular by-product from pig consumed in many Eastern European countries. The F_f values for ^{137}Cs transfer to piglets aged 1-5 months followed the patterns described for adult pigs although the *Ff* value were around 3 times higher than those for adult pigs (Shilov, 1980). The *Ff* value of 0.091 for fat was the lowest value estimated among all tissues measured.

The *Ff* value for ^{137}Cs transfer to liver of adult pigs assess in Table 9 was (1.5±0.7)×10^{-1} d kg^{-1}. Other similar data of a mean *Ff* of 1.4×10^{-1} d kg^{-1} with a standard deviation 6.0×10^{-2} d kg^{-1}.for pigs was reported by Green et al. (1961). The *Ff* values for ^{137}Cs transfer to liver in pigs reported by Green and Woodman (2003) ranged from (0.8-2.2)×10^{-1} d kg^{-1} with an overall mean of 1.4×10^{-1} d kg^{-1} and standard deviation of 6.0×10^{-2} d kg^{-1} based on six reported values.

5.3 Other radionuclides

Data for transfer of other radionuclides to pig tissues are given in Table 11. The *Ff* values for eight experiments with ^{32}P, ^{106}Ru, ^{238}U and ^{239}Pu, were reported by Burov and Sarapultsev (1974) Ilyin and Moscalev (1961), Prister (1967) and Sirotkin (1991.

The *Ff* values for ^{32}P for both adult pigs aged 185 d and piglets aged 128 and 152 days at the time of slaughtering were reported by Iliyn and Moscalev (1961). The *Ff* values for adult pigs were (7.6±5.4)×10^{-2}, (4.0±2.8)×10^{-2}, and (3.4±2.4)×10^{-2} d kg^{-1}, for liver, heart, and kidney, respectively. Data for piglets were around two fold higher than those for adult pigs.

Uranium *Ff* values were published by Prister (1967). The *Ff* value declined in the order: heart - (2.1±0.93)×10^{-1} d kg^{-1} kidney - (1.5±0.7)×10^{-1} d kg^{-1} lung - (4.2±1.9)×10^{-2} d kg^{-1} and liver - (3.1±1.4)×10^{-2} d kg^{-1}. Data on accumulation of uranium from other sources do not give *Ff* values for organs. The importance of bone, and to a lesser extent muscle, as accumulators of ^{238}U body burden was also reported by Linsalata et al. (1994) for cattle, but no *Ff* values were given for offal. Skwarzec et al. (2010) reported similar accumulation of ^{234}U, ^{238}U in kidney and liver of roe deer.

Sirotkin (1991) reported an *Ff* value in adult pig offal of 2.0×10^{-4} d kg^{-1} for ^{239}Pu when the duration of the study was 960d. For adult sheep, Howard & Lindley (1985) reported concentration ratios (CR) rather than *Ff* values for ^{238}Pu and $^{239/240}$Pu which were higher for liver (5.9x10^{-2}) than for (in declining order) kidney, muscle, liver and bone. Stanley et al. (1976) reported accumulation in dairy cattle organs after continuous oral administration of PuO_2 for 19d and sacrifice after 42d, accumulation decreased in the order: bone and small intestine>liver > lung > kidney. During the same experiment with cattle sacrificed after 73d there was no difference in accumulation in bone, liver or kidney. Skwarzec et al. (2010) reported accumulation in roe deer of ^{239}Pu in kidney and liver in which ^{239}Pu accumulation was lower than for the U isotopes and highest in kidney.

Quantification and comparison or *Ff* or CR for these transuranic with long biological half-lives are difficult as the radionuclides would be expected to continue to accumulate at different rates for different tissues over the normal lifetime of agricultural animals.

Table 11 provides some additional limited information for ^{106}Ru *Ff* to liver of 2.0±0.7 ×10^{-2} d kg^{-1} and kidney of suckling piglets aged 1-2 months of 0.11±0.09 d kg^{-1}. The study also reported a considerable decline in the reported *Ff* with time for Ru in piglets aged 21 days who were slaughtered after 15 d, 30 d and 60 d (Burov and Sarapultsev, 1974).

Model derived equilibrium *Ff* values for ^{106}Ru in sheep tissues based on experimental data for a single administration over 1 y of 2.8 x 10^{-2} d kg^{-1}, 1.7 x 10^{-2} d kg^{-1} and 6.0 x 10^{-3} d kg^{-1} were derived for bone, kidney and liver respectively. Biological half-life values ranged from 3.9 d in kidney to 54 d in liver (Beresford et al. (1998) and would have impacted differently on the F_f tissues values considerably.

6. Radionuclides transfer to poultry and rabbit tissues

Altogether, data from 27 experiments described in six publications were reviewed and 93 relevant records were identified. However, after taking into account the experimental designs only 56 F_f values could be used (Table 13). Of these 56 records 75% were for radionuclide transfer to chicken tissues, 3 records were for duck and 10 records were for rabbits. Most of the data (28 records) were for ^{137}Cs, followed by ^{65}Zn (19 records) and ^{90}Sr (6 records). Limited information was also available for ^{22}Na, ^{54}Mn and ^{60}Co.

6.1 Hens, Goose and ducks

Shilov and Koldayeva (1978) reported time dependent F_f values for ^{137}Cs transfer to different chicken tissues. The hens aged 70 days were administered ^{137}Cs for 30, 65, 150 and 360 days. Additional F_f values were reported from an experiment by Sirotkin (1977) with 80 days administration of ^{137}Cs to hens aged 410 days at the start of the experiment.

Overall, the mean F_f values for ^{137}Cs transfer to different chicken tissues were similar for soft tissues. They were (1.5 ± 0.2) d kg^{-1}, (0.80 ± 0.08) d kg^{-1}, (1.1 ± 0.3) d kg^{-1}, (1.3 ± 0.2) d kg^{-1}, (1.5 ± 0.2) d kg^{-1}, for heart, lung, liver, kidney and spleen, respectively. Chicken stomach muscle had a slightly higher F_f value of 2.2 ± 0.2 d kg^{-1}) compared with other tissues.

As for ^{90}Sr, Koldayeva et al. (1969) and Sirotkin (1977, 1978) reported the F_f values for liver $(6.0\pm 3.0)\times10^{-2}$ d kg^{-1}, and lung $(5.0\pm 2.0)\times10^{-2}$ d kg^{-1}, for hens aged 270 days which were administered ^{90}Sr for 30 days. The study by Koldayeva et al. (1969) also provided extended data for ^{90}Sr transfer coefficients to skeleton for hens aged 30, 60, 90, 147, 270, 270 and 254 days, which were administered ^{90}Sr from 50 to 254 days. The resulting F_f values varied widely with a mean of 1.6×10^{-1} d kg^{-1} and standard deviation of 1.9×10^{-1} d kg^{-1} Additionally, Sirotkin (1987) reported some data for ^{65}Zn and ^{54}Mn to offal, which had higher F_f values for ^{65}Zn 3.0±1.1 d kg^{-1} compared with that for ^{54}Mn 1.0 $\times10^{-4}$ d kg^{-1}.

The distribution of Cs accumulation in tissues of hens was studied following peroral administration of ^{134}Cs and sacrifice after 4d, 7d, 14, 28d, 28d and 42d (Ekman, 1961). The highest accumulation (reported as % dose per gram tissue) was in the kidney after 4d and ^{134}Cs accumulation was significantly lower after 42d. The tissues liver, heart and spleen also followed the trend. The F_f value declined in the order: kidney - 2.5 $x10^0$ d kg^{-1} , heart - 2.0 $x10^0$ d kg^{-1}, liver - 1.2×10^0 d kg^{-1} and lung - 0.9×10^0 d kg^{-1} for 3 hens dosed with ^{134}CsCl for 25d (Ekman, 1961).

Some limited data are available for radionuclide transfer to duck and goose. Burov (1984) reported F_f values for ^{22}Na, ^{60}Co and ^{90}Sr transfer to ducks aged 188 days, whilst Astasheva et al. (1991) provides data of 75 days experiment on ^{137}Cs transfer to blood, heart, kidney, liver and lung of geese aged 1170 days.

Caesium-137 concentration ratios of 0.23 (meat/feed) were measured in control livers of broiler chickens after a fattening period of 42d (Voigt et al., 1993).

6.2 Rabbits

Data for rabbits were derived from the radiobiological experiment with assessment of the long-term effects of internal irradiation of rabbits administered ^{65}Zn (Avrunina, 1965). Over 90d of ^{65}Zn administration the highest transfer was to liver (6.0-6.7 d kg^{-1}) and kidney (2.7-5.6 d kg^{-1}) whilst transfer to spleen, lung and heart was 2-3 fold lower. When ^{65}Zn was administered for longer (180 days), the accumulation in liver and kidney was higher (Table 11).

Semioshkina et al. (2007) reported rabbit ^{137}Cs and ^{90}Sr *Ff* values for muscle slaughtered 42d after isotope administration commenced. Using the reported activity concentrations for organs supplied *Ff* values can be derived heart, lung, liver, kidney and bones. For ^{137}Cs, heart (3.9±0.08) ×10^{-1} d kg^{-1} has the highest *Ff, the* lung, liver and kidney had similar *Ff* values whilst the lowest value was for rabbit bones (1.0±0.2) ×10^{-1} d kg^{-1}. For ^{90}Sr the highest *Ff* value was for bone (6.1±0.03) ×10^{-1} d kg^{-1}, whilst the lowest value was for lung (6.8±0.8) ×10^{-2} d kg$^{-1.}$

7. Radionuclide distribution among different tissues

Strontium is a strong analogue of calcium and, therefore, ^{90}Sr accumulation in bone occurred in all animals, with statistically significant differences for ^{90}Sr Ff to skeleton compared with that for the other tissues reported. Similar observations were published in the English language literature (eg, Paakkola & Miettinen 1963), The Ff values for ^{90}Sr to kidney were higher than that for other soft tissues.

Phosphorus is a bone-seeking radionuclide. However, the only data available from the reviewed Russian language literature gave a higher accumulation of ^{32}P in pig liver than bone.

A statistically significant higher Ff value for liver was also found for ^{65}Zn *Ff* to rabbit liver. The accumulation of ^{65}Zn in liver is consistent with the higher concentration of stable zinc reported in liver compared with other organs of rabbits (McIntosh & Lutwak-Mann 1972).

Caesium is an analogue of potassium, which is a major metabolic element, and behaves in a similar manner in animal tissues. The distribution of radiocaesium between different tissues presented in the tables is consistent with that English language publications for both ruminants and monogastric animals. The ^{137}Cs Ff values for soft tissues tended to be higher for kidney whilst the lowest Ff value was for fat and accumulation in bone was also consistently low. These comparisons are confirmed by data presented by several English language publications including McClellan et al. 1962 (cattle); Paakkola & Miettinen 1963 and Skuterud et al. 2005 ((reindeer), Green et al. 1961 and Voigt et al. 1988 (pig), and Howard et al. 1989 (sheep).

Furthermore, recent studies in Japan on cows from highly contaminated areas near the Fukushima Daiichi NPP showed that kidney consistently had the highest concentration of radiocesium among internal organs, whereas the liver was lowest (Sato et al. 1986, 1987). Characteristics of the stable cesium distribution were similar to those of radiocaesium.

Semioshkina et al. (2006) reported ^{137}Cs and ^{90}Sr *Ff* values for heart, lung, liver, kidney, spleen and bones from a horse slaughtered 90d after the start of the study. For ^{137}Cs, spleen (7.3×10^{-2} d kg^{-1}) has the highest *Ff*, whilst lowest value was for bones

(1.3×10^{-2} d kg^{-1}). For ^{90}Sr the highest F_f value was for bone (2.7×10^{-1} d kg^{-1}), whilst the lowest value was for heart (7×10^{-2} d kg^{-1}).

The data for ^{60}Co showed a higher F_f to liver which is consistent with the known behaviour of stable cobalt which is mainly located in the liver in mammals, as it is used in activating hydrolytic enzymes which increasing the synthesis of nucleic acids and muscle proteins. The F_f values for ^{60}Co to other tissues were similar with the exception of bone where F_f values were lower for both adult cattle and calves. English language studies on pigs (monogastrics rather than ruminants) gave different data with the highest F_f values for kidney which were 1.4-3.3 fold higher than that for liver (Voigt et al. 1988); F_f for other offal was lower.

The skeleton and liver were the main storage organs for ^{144}Ce. The Russian language data are consistent with data from sampling of sheep tissues for a period of up to a year after a single administration of ^{144}Ce in which the activity concentrations were initially highest in liver, but which declined rapidly whereas those in bone gradually increased to a plateau (Beresford et al. 1998).

The highest uranium Ff values to pigs were found to be in bone, kidney and heart and the lowest were observed in liver and lung. For cattle, Linsalata et al. (1989) also reported highest transfer of 238U to bone which contained by far the highest proportion of the total body burden (>85%). In soft tissues the ^{238}U activity concentration was highest in the kidney and lowest in liver and lungs.

The paucity of data for ^{106}Ru did not allow a detailed evaluation of its distribution among animal tissues. However, there was a more than 5 fold higher F_f value to kidney compared with that for liver for ^{106}Ru in pigs (Burov & Sarapultsev (1974). In the single administration experiment to sheep by Beresford et al. (1998) the kidney had the highest activity concentrations of ruthenium whereas the muscle had the lowest of the soft tissues analysed. The associated model predicted that bone would be the major storage organ although measurable data were lacking.

8. Age effect

There are many data in the Russian language literature documenting changes in radionuclide transfer to the animals or poultry tissues with age. For instance, three fold higher Ff values for young bulls were reported compared to the Ff for adult animals. In general, the decrease of F_f with age could be explained the lower permeability of the membranes of the gut wall of mature animals compared with young animals, which have a greater need to absorb a wide range of nutrients and essential elements (Sirotkin, 1987). Another explanation is the losses of some nutrients, such as potassium, from the tissues when their active growth is terminated and growth of the radionuclide intake with the liveweight.

Good evidence for the decline in F_f values with age for cattle has been reported for ^{90}Sr by Sirotkin (1977). One hundred animals were exposed to ^{90}Sr from birth for four years. Animals were slaughtered at 30, 90, 135, 180, 365, 570 690, 780 and 1230 d of radionuclide administration. Although, ^{90}Sr transfer to muscle, heart, lung, liver, kidney, bone and spleen were measured, only data for kidney, liver and skeleton are presented as an example here (Fig. 1).

The general patterns of change in F_f values to different cattle tissues are quite similar, displaying sharp increase which followed by sharp decrease at the very early age and plateau at the age of around two years. As Figure 1 clearly demonstrates, there are considerable reductions with age in F_f for all tissues, which is likely to be the result of high calcium requirements for skeletal development as well as the decreasing efficiency of calcium absorption with increasing age (NRC, 2001). The statistical processing of the data suggested best fit of the F_f values available of:

$$F_f = F_f^0 \times \exp(-a \times t) + b \qquad (1)$$

with R^2 ranged for kidney, liver and skeleton 0.7-0.8.

A general point is that "*a*" values of the equation (1) of around 0.007 were nearly the same for all tissues studied and were a twofold lower to the similar value (0.014) derived for ^{90}Sr from statistical analysis of the absorption coefficient values presented in our recent publication (Fesenko et al., 2007a, 2007b).

Another obvious point is that F^0_f (0.01-0.02 d kg^{-1}) and "*b*" values of the equation ((4-8)×10^{-4} d kg^{-1}) were similar for soft tissues (offal) and were quite different from the values for bones (12 and 0.25 d kg^{-1}).

Long-term experiments measuring variation in ^{137}Cs F_f values with age were reported for pigs by Shilov (1980). Twenty four 5-day pigs were exposed to ^{137}Cs for 5, 15, 20, 30, 90, 790 and 1300 days. Three animals for each date were sampled and ^{137}Cs was measured in muscle (see Fesenko et al., 2009), heart, lung, liver, kidney, spleen, blood, fat and the skeleton (Fig. 2).

Although the F^0_f values for soft pig tissues were quite similar, namely, in a range of 1.5-3, these were around two orders of magnitude higher than those for cattle.

The age-dependence of F_f values differ from those measured for the rest tissues and was best described by a two component exponential model displaying long-term reduction of ^{137}Cs in fat. Similar phenomenon was also observed for potassium where the fraction of potassium in the muscles increases and decreases in the bones with age and increase in the weight of pigs. The concentration of potassium in whole carcasses also decreases with an increase in the mass of animals, which is probably due to increased fat deposition.

As for neutron activation radionuclides, Sirotkin (1987) reported F_f values for transfer to offal of hens exposed to ^{65}Zn from birth to 270 days. The time scale of the research was more detailed compared to cattle and pigs. This provides evidence for two competing processes, namely an increase of accumulation of radionuclides because of the constant intake of ^{65}Zn and reductions in permeability of the membranes of the gut resulted in the peak in F_f values (Fig. 3).

Data on age dependence of F_f values for ^{144}Ce transfers to sheep tissues illustrate effect of administration duration on dynamics of radionuclide transfer to sheep tissues, based on Buldakov (1961). Twelve sheep aged 540 d exposed to ^{144}Ce were sampled after 18, 105, 300 and 1140 d of radionuclide administration (Fig. 4). The F_f values presented in Figure 4 demonstrate two folds increase corresponding growth of the exposure duration from 18 to 105 days. Thus, data of Fig. 4 indicate that administration of ^{144}Ce for 300 days is required for proper assessment of the F_f values to sheep tissues.

Overall, the data on age dependence presented in this section allow the conclusion that assessment of the radionuclide accumulation in young animals is accompanied with high uncertainty and supplementary information on age of slaughtered animals should be used to increase accuracy in assessment of the animal products contamination.

9. Radionuclide and species differences

The *Ff* values for various animal tissues vary with radionuclide for each of the species studied. Nevertheless, consistently the highest *Ff* for soft tissues (offal) were reported for ^{137}Cs, the lowest were for ^{90}Sr and ^{144}Ce. For bone the *Ff* of ^{90}Sr and ^{106}Ru were higher than that of other tissues (Fig. 5). The *Ff* values for ^{137}Cs to cattle and other agricultural ruminants are lower than that to offal of birds (hens) and monogastric animals (pigs) (fig. 6).

Conclusion

The data derived from the Russian sources were compiled, reviewed and compared with that from the English language literature, where *Ff* values for similar tissues and radionuclides were available. Many of the *Ff* values derived from the Russian and Western studies were similar, although some of the Russian *Ff* values tended to be a somewhat higher than those reported in the English language literature. The observed differences could be explained by different age of sampled animals and differences in farming practices in Russia and Western countries. The *Ff* values to different tissues were radionuclide dependent, reflecting specific features of the element metabolism in the body of the animals. Clear age dependence of the *Ff* values was observed for all animals studied. As anticipated, the highest *Ff* values were observed for poultry, followed by pigs, sheep and finally cattle. These patterns of the animal contamination, should be taken into account in assessment of farming practices in the contaminated areas.

The information presented here substantially increases the amount of available data on radionuclide transfer to animals and poultry, and can be used for updating the related international documents, such as IAEA (2001, 2010).

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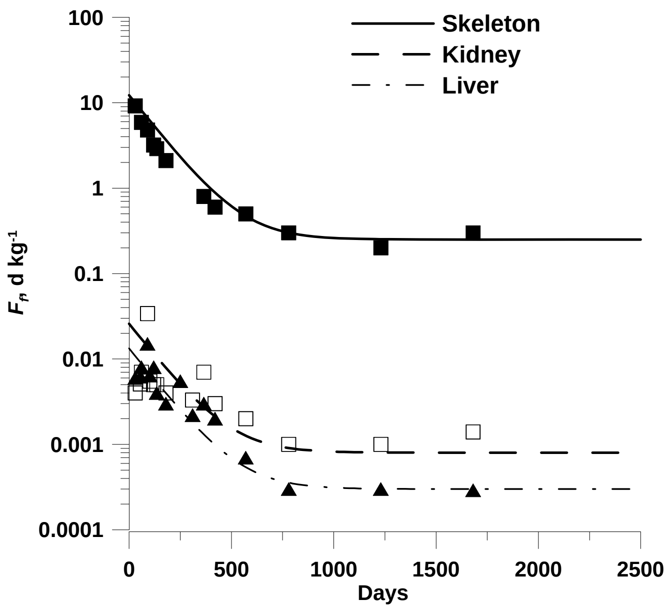


Figure 1. Change with age in the F_f values for ^{90}Sr transfer to some cattle tissues. The lines are fits to the data of $F_f = F_f^0 \times \exp(-a \times t) + b$

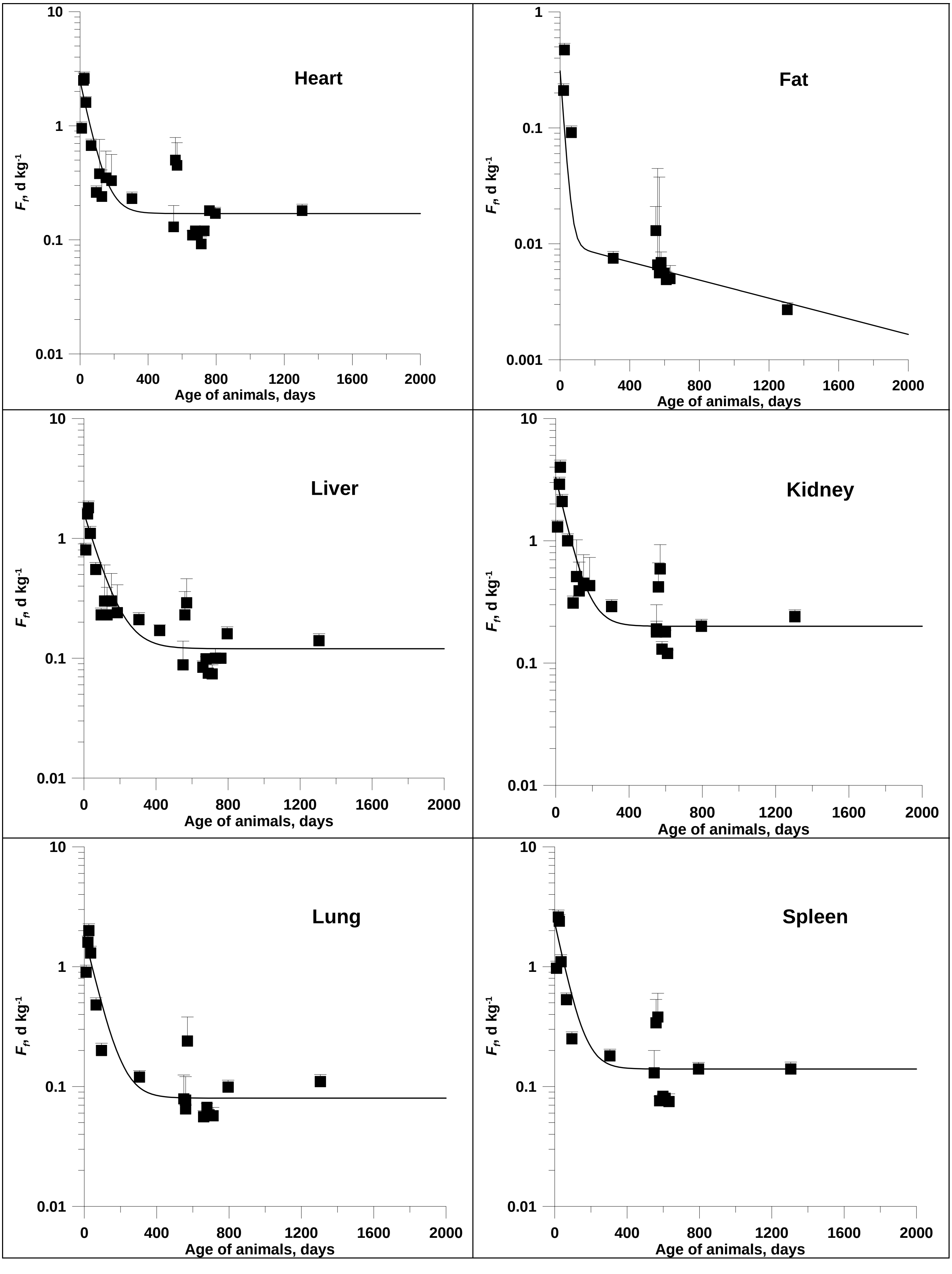


Figure 2. Variation with age in the F_f values for ^{137}Cs transfers to some pig tissues

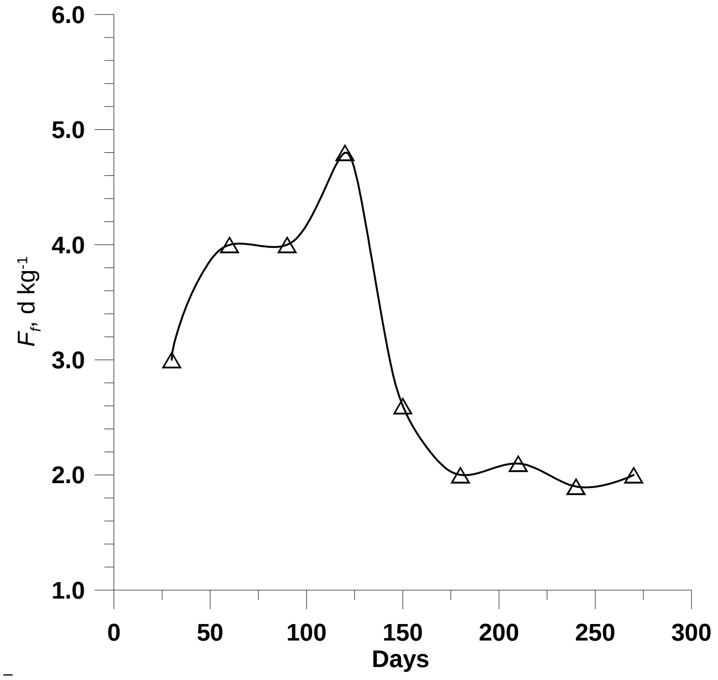


Figure 3. Change with age in the F_f values for ^{65}Zn transfer to hen’ offal

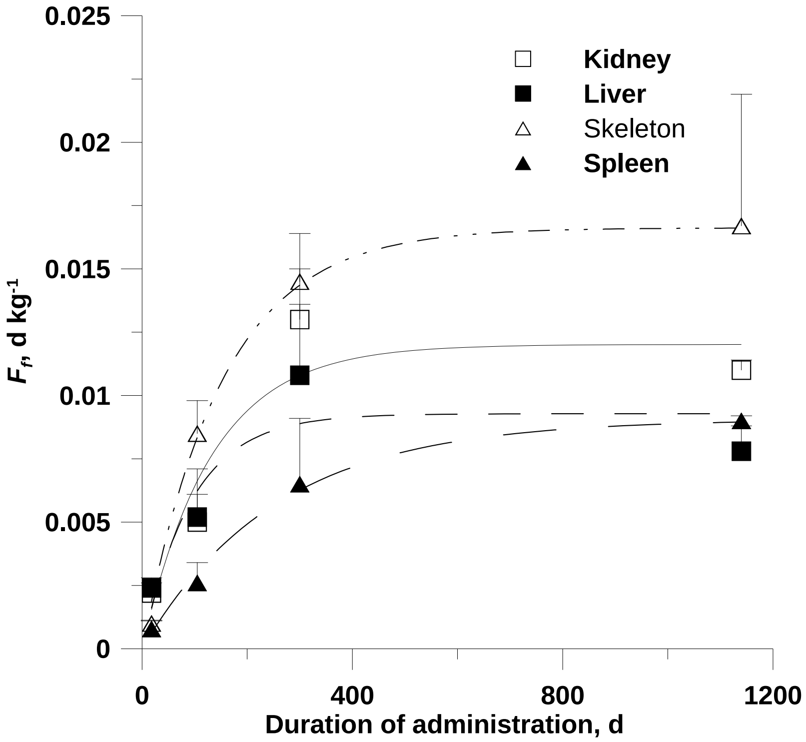


Figure 4. Dependence of F_f values for ^{144}Ce to sheep tissues on duration of radionuclide administration.

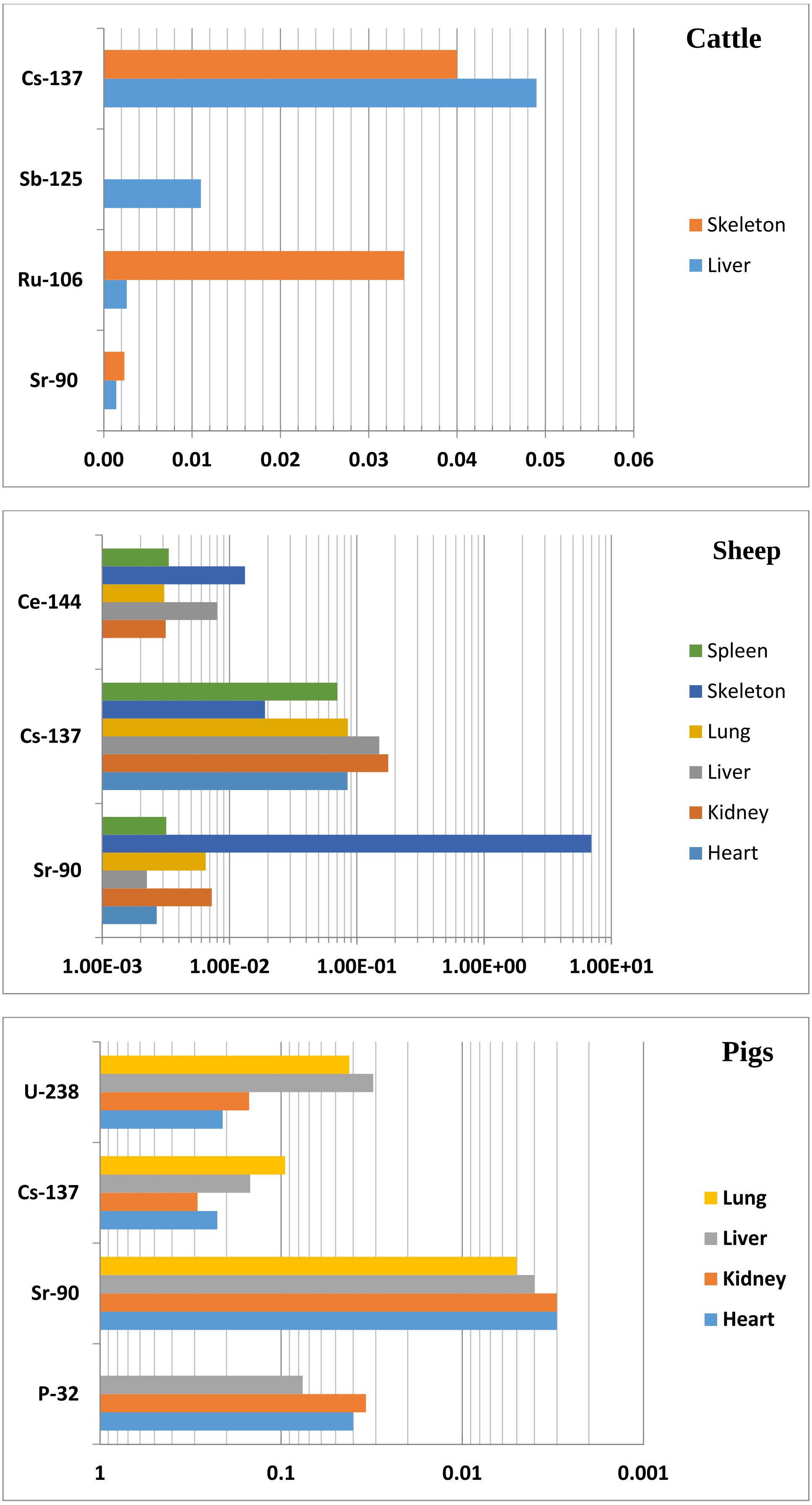
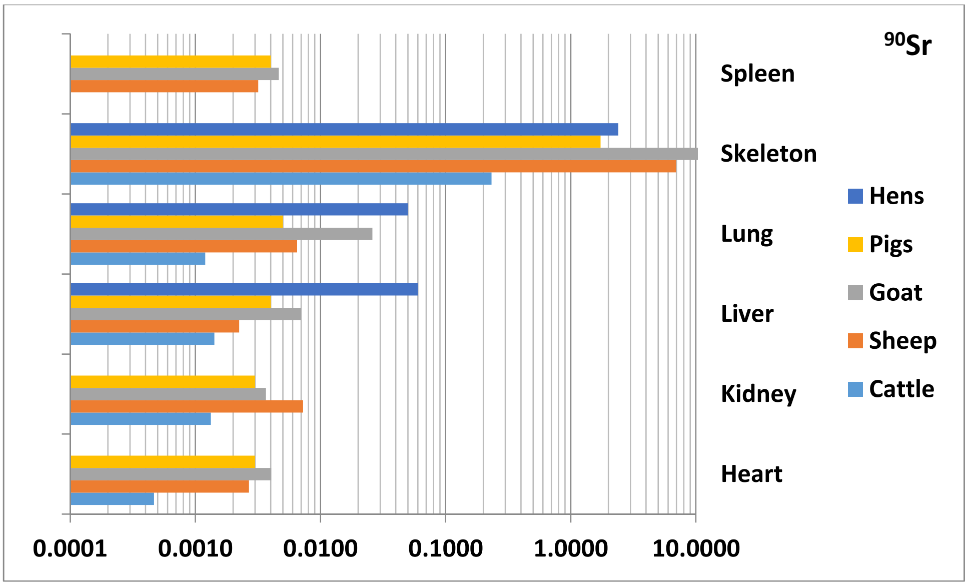


Figure 5. Comparison of F_f values for different radionuclides to the tissues of adult cattle and pigs.



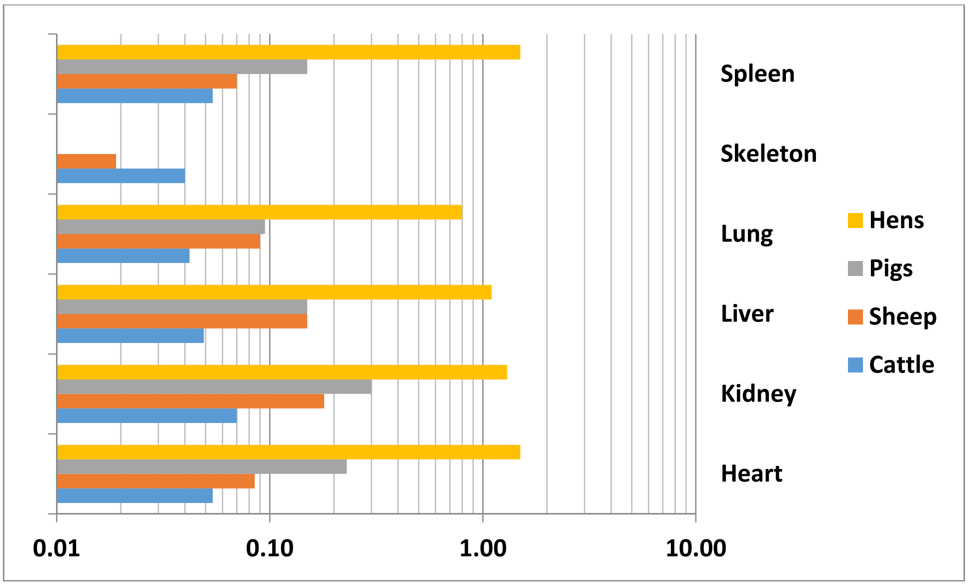


Figure 6. Comparison of F_f values for ^{90}Sr and ^{137}Cs for animals and poultry.

Table 1. Details of references for radionuclide transfer studies in animals giving data for various tissues* conducted in the USSR and fSU

Reference	*Radionuclides*	*Experimental details and data analysis*
		Cattle
Annenkov (1967)	^{90}Sr	Review of research on ^{90}Sr transfer to farm animals carried out from 1957-1967. Results are also given for ^{90}Sr transfer to calves, aged 60 and 120 d administered with ^{90}Sr for 30 d. F_f values given for kidney, liver, lung and skeleton.
Sirotkin et al. (1970)	^{90}Sr, ^{106}Ru, ^{125}Sb, ^{137}Cs	F_f values estimated based on data from an experiment with 3 young bulls aged 6 months which had received radionuclides throughout their life-time.
Sirotkin et al. (1972)	^{137}Cs	Chronic administration experiments with 27 calves (initial liveweight 36±5 kg) for 300 d.
Sirotkin (1977)	^{90}Sr, ^{137}Cs	Experiments and field studies on radionuclide transfer to feeds and animals (refers to some experiments in other references). 100 cattle received ^{90}Sr from birth for four years. Animals were slaughtered at 30, 90, 135, 180, 365, 570 690, 780 and 1230 d of radionuclide administration. Both ^{90}SrCl$_2$ and plant-incorporated ^{90}Sr were used for the experiments. Measured ^{90}Sr transfer to muscle, heart, lung, liver, kidney, bone and spleen. Data for ^{137}Cs were provided for calves and young bulls exposed to ^{137}Cs from birth for 60, 150 and 300 days.
Sirotkin et al. (1980)	^{60}Co	Experiment with three cows aged 980 days, and for four calves aged 90 d administered ^{60}CoCl$_2$ from birth. F_f values given for 26 tissues including muscle, blood, heart, spleen, kidney, lung and bone.
Sirotkin (1987)	^{60}Co, ^{90}Sr	Major review of experiments with oral administration to farm animals and poultry carried out in the 1960s-1980s in the South Ural accidental zone and in Obninsk, Russia. Details of individual experiments are not given. Experiments carried out by the author which had not previously been published.
Sirotkin et al. (1987)	^{60}Co	Experiment with fifteen animals exposed to ^{60}CoCl$_2$ from birth to 32 months. Target tissues: blood, brain, heart, liver, lung, kidney, skeleton, spleen.
		Sheep and goats
Buldakov (1964)	^{137}Cs	Measured transfer of ^{137}Cs to muscle, bone, liver, lung, spleen and skin of 22 adult sheep administered ^{137}Cs for 30 and 105 d.
Buldakov and Burov (1967)	^{144}Ce	Samples of kidney, liver, spleen and skeleton were taken 1140 d after administration of ^{144}Ce to sheep aged 1.5 y commenced.
Buldakov and Moscalev (1968)	^{90}Sr, ^{137}Cs, ^{106}Ru	Five animals aged 540 d were chronically administered ^{90}Sr for 120 d. Five lambs were administered ^{90}Sr from birth for 15 d. 15 sheep aged 365, 1095 and 1825 d were administered ^{90}Sr for 300 d. 28 sheep aged 3 y were administered ^{137}Cs for 75 d. Data for kidney, liver, lung, bone and spleen are presented.

Burov et al. (1978)	^{137}Cs	13 sheep aged 2-2.5 y were administered ^{137}Cs and the transfer measured 16, 32, 128, 256 and 486 d after chronic ^{137}Cs administration commenced. Another experiment measured ^{137}Cs transfer to 21 sheep and goats 8, 16, 32, 128, 256 and 486 d of chronic ^{137}Cs administration. Tissues sampled were muscle, liver, skin and bone.
Burov et al. (1969)	^{90}Sr	27 sheep and 22 goats administered ^{90}Sr from birth. Sheep were slaughtered 15, 30, 60, 120, 240, 540 and 1080 d after ^{90}Sr administration commenced and goats at 15, 30, 60, 120, 240, 360 and 730 d after ^{90}Sr administration commenced. ^{90}Sr transfer was measured to muscle, heart, lung, liver, kidney, bone and spleen.
Panchenko and Burov (1970)	^{90}Sr	Paper gives additional information on experimental conditions and outcomes of research originally described by Burov et al. (1969). Detailed information on liveweight of animals and their organs was given for each date of sampling. Measured ^{90}Sr transfer to muscle, heart, lung, liver, kidney, bone and spleen.
	Pigs	
Annenkov et al. (1964)	^{90}Sr	34 piglets aged 75-90 days with 90-95 kg liveweight were orally administered ^{90}Sr for 30, 60, 90, 164 and 254 days into the dosing period and then 30 and 60 d after cessation of radionuclide chronic administration. Tissues of interest were muscles, liver, lung and skeleton.
Annenkov et al. (1990)	^{137}Cs	Post Chernobyl experiment measured ^{137}Cs transfer from contaminated feeds to muscle, liver, heart lung and kidney of 24 sows (20 months old; liveweight 156.4±6.3 kg).
Annenkov et al. (1991)	^{137}Cs	Effects of pregnancy on plant incorporated ^{137}Cs transfer to 24 “Large White” sows were studied. Animals were 20 months old with an initial liveweight of 165.4±6.3 kg. Variation in F_f values with stage of pregnancy with sample times of 0, 60, 78, 90 and 100 d. Cs-137 transfer wa measured to muscle, heart, lung, liver, kidney, bone and spleen
Burov et al (1971)	^{90}Sr	36 piglets were administered ^{90}Sr from birth to 20, 50, 90, 180, 730 and 1440 days. Transfers were measured to muscles, liver, heart, lung, kidney, spleen and skeleton.
Burov, Sarapultsev (1974)	^{106}Ru	24 pigs aged 3 weeks were administered ^{106}Ru for 62 d. Animals were slaughtered 1, 5, 8, 15, 30 and 60 d after administration started. Tissues sampled were bone, muscle, liver, kidney and skin.
Chmyrev (1996)	^{137}Cs	Measured ^{137}Cs transfer to various tissues derived from an experiment with 24 sows, liveweight 156±6.3 kg when experiment commenced. Transfers were also measured to liver, heart, lung, kidney, spleen and fat from first day to 120th day of the pigs pregnancy.
Iliyn and Moscalev (1961)	^{32}P, ^{90}Sr, ^{137}Cs	14 runner pigs aged 3.5 m (liveweight of 95-108 kg) were orally administered ^{32}P, ^{90}Sr, ^{137}Cs for 85 d. Samples of muscle, heart, liver and kidney were taken at 15, 29, 53 and 86 d into the dosing period.

Nikitina et al. (1972)	^{137}Cs	24 newborn piglets (liveweight 1.55±0.17 kg) and 24 Large White weaner pigs (liveweight 18.4±0.34 kg) aged 60 d were administered ^{137}Cs from birth up to age of 60 days (piglets) and from age of 60 d for 360 d. In both cases animals were slaughtered 5, 10, 20, 30, 60, 120, 260 and 360 d after administration started. Tissues of interest were muscles and liver.
Prister (1967)	^{238}U	Five piglets were administered U as $UO_2(NO_3)_2 \cdot 6H_2O$ for 270 days. Liveweight at slaughter was 100-120 kg. Transfer of U measured to bones, heart, kidney, blood, muscle, lung and liver.
Shilov (1980)	^{137}Cs	27 piglets aged five days were administered ^{137}CsCl for 5, 15, 20, 30, 60, 90, 300, 790 and 1300 days and then tissues sampled. The F_f values were measured in muscle, heart, lung, liver, kidney, spleen, skin, blood, fat and bones. K in feed and tissues was also measured.
Sirotkin (1977)	^{137}Cs	Comprehensive review of experiments on radionuclide transfer to animals (refers to some experiments in above references). Values for ^{137}Cs were used from research not referred to in the previously reviewed papers. Tissues of interest were muscles, heart and liver.
Sirotkin (1991)	^{239}Pu	Comprehensive review of experiments on radionuclide transfer to animals (refers to some experiments in above references). Values for ^{239}Pu to offal for 3 pigs exposed for 960 d were taken from the research not referred to in the previously reviewed papers.
		Poultry and rabbits
Astasheva et al, (1992)	^{137}Cs	45 geese aged 3 y with a liveweight of 3.7 kg were administered ^{137}Cs for 75 d. Samples of heart, blood, muscle, liver, kidney and lung were taken after 1, 8, 12, 20, 30, 40, 60 and 75 d after the experiment commenced.
Avrunina (1965)	^{65}Zn	5 rabbits with a liveweight of 3.7 kg were administrated ^{65}Zn for 540 days. Data were reported for heart, muscle, liver, kidney, lung and spleen.
Shilov and Koldayeva (1978)	^{137}Cs	Thirty cocks aged 70 d were orally administered ^{137}CsCl daily. Then slaughtered after 6, 9, 31, 66, 151 and 360 d. F_f values were measured after 6, 9, 31, 66, 151 and 360 d of exposure. Tissues of interest were muscle, heart, lung, liver, kidney, bone and spleen
Sirotkin (1977)	^{137}Cs	Comprehensive review of experiments on radionuclide transfer to animals (refers to some experiments in above references). Values for ^{137}Cs were taken from the research not referred to in the previously reviewed papers. Tissues of interest were muscles, heart and liver.
Sirotkin (1987)	^{54}Mn, ^{65}Zn	Summary of large set of experiments with administration of ^{65}Zn to chickens of different ages, reporting transfer to combined offal for 30, 60, 90, 120, 150, 180, 210, 240, 270. Chickens aged 730 d were orally administered ^{54}Mn and slaughtered at 5, 15, 60 and 70 d after radionuclide administration. commenced

*Focusing on tissues other than muscle

Table 2. F_f values for radionuclide transfer to the tissues of adult cattle, d kg^{-1}

Nuclide	*Tissue*	*Mean ±SD*	*Age, d*	*Duration, d*	*References*
^{60}Co	Blood	$(2.0\pm0.3)\times10^{-4}$	1	960	Sirotkin et al. (1987)
	Brain	$(3.6\pm0.54)\times10^{-3}$	1	960	Sirotkin et al. (1987)
	Heart	$(4.3\pm0.65)\times10^{-3}$	1	960	Sirotkin et al. (1987)
	Liver	$(3.9\pm0.59)\times10^{-2}$	1	960	Sirotkin et al. (1987)
	Lung	$(2.7\pm0.41)\times10^{-3}$	1	960	Sirotkin et al. (1987)
	Kidney	$(1.3\pm1.9)\times10^{-2}$	1	960	Sirotkin et al. (1987)
	Skeleton	$(7.0\pm1.1)\times10^{-4}$	1	960	Sirotkin et al. (1987)
	Skeleton	8.0×10^{-4}	1	1080	Sirotkin (1987)
	Skeleton	8.0×10^{-4}	1	1260	Sirotkin (1987)
	Spleen	$(3.3\pm0.5)\times10^{-3}$	1	960	Sirotkin et al. (1987)
^{90}Sr	Heart	0.8×10^{-3}	1	570	Sirotkin (1977)
	Heart	0.3×10^{-3}	1	780	Sirotkin (1977)
	Heart	0.3×10^{-3}	1	1230	Sirotkin (1977)
	Kidney	1.4×10^{-3}	1681	144	Sirotkin (1977)
	Kidney	0.2×10^{-2}	1	570	Sirotkin (1977)
	Kidney	0.1×10^{-2}	1	780	Sirotkin (1977)
	Kidney	0.1×10^{-2}	1	1230	Sirotkin (1977)
	Liver	2.9×10^{-3}	1681	144	Sirotkin (1977)
	Liver	0.7×10^{-3}	1	570	Sirotkin (1977)
	Liver	0.3×10^{-3}	1	780	Sirotkin (1977)
	Liver	0.3×10^{-3}	1	1230	Sirotkin (1977)
	Lung	2.9×10^{-3}	1681	144	Sirotkin (1977)
	Lung	2.9×10^{-3}	1537	144	Sirotkin (1977)
	Lung	2.0×10^{-3}	1	570	Sirotkin (1977)
	Lung	1.0×10^{-3}	1	780	Sirotkin (1977)
	Lung	6.0×10^{-4}	1	1230	Sirotkin (1977)
	Skeleton	0.3×10^{-0}	1681	144	Sirotkin (1977)
	Skeleton	0.5×10^{-0}	1	570	Sirotkin (1977)
	Skeleton	0.3×10^{-0}	1	690	Sirotkin (1977)
	Skeleton	0.1×10^{-0}	1	1230	Sirotkin (1977)

Table 3. F_f values for radionuclide transfer to young bull tissues, d kg^{-1}

Nuclide	*Tissue*	*Mean ± SD*	*Age, d*	*Duration, d*	*References*
^{90}Sr	Heart	1.8×10^{-3}	1	250	Sirotkin (1977)
	Heart	0.2×10^{-2}	1	180	Sirotkin (1977)
	Heart	0.2×10^{-2}	365	365	Sirotkin (1977)
	Kidney	0.4×10^{-2}	180	180	Sirotkin (1977)
	Kidney	0.7×10^{-2}	365	365	Sirotkin (1977)
	Liver	$(1.6\pm0.2)\times10^{-3}$	1	180	Sirotkin et al. (1970)
	Liver	2.2×10^{-3}	200	110	Sirotkin (1977)
	Liver	0.4×10^{-2}	1	135	Sirotkin (1977)
	Liver	5.5×10^{-3}	1	250	Sirotkin (1977)
	Liver	0.3×10^{-2}	1	180	Sirotkin (1977)
	Liver	0.3×10^{-2}	1	365	Sirotkin (1977)
	Lung	0.6×10^{-2}	1	180	Sirotkin (1977)
	Lung	0.5×10^{-2}	1	365	Sirotkin (1977)
	Lung	3.3×10^{-3}	200	110	Sirotkin (1977)
	Lung	1.6×10^{-3}	1	250	Sirotkin (1977)
	Offal	1.9×10^{-3}	1	300	Sirotkin (1987)
	Skeleton	2.1×10^{0}	1	180	Sirotkin (1977)
	Skeleton	0.8×10^{0}	1	365	Sirotkin (1977)
	Skeleton	0.2×10^{0}	200	110	Sirotkin (1977)
^{106}Ru	Liver	$(2.6\pm0.8)\times10^{-3}$	360	180	Sirotkin et al. (1970)
	Skeleton	3.4×10^{-2}	360	180	Sirotkin et al. (1970)
^{125}Sb	Liver	$(1.1\pm0.3)\times10^{-2}$	180	180	Sirotkin et al. (1970)
^{137}Cs	Blood	$(0.9\pm0.1)\times10^{-2}$	1	300	Sirotkin et al (1972)
	Heart	5.4×10^{-2}	1	300	Sirotkin (1977)
	Kidney	7.0×10^{-2}	1	300	Sirotkin (1977)
	Liver	4.9×10^{-2}	1	300	Sirotkin (1977)
	Lung	4.2×10^{-2}	1	300	Sirotkin (1977)
	Offal	$(5.8\pm1.7)\times10^{-2}$	1	300	Sirotkin et al (1972)
	Skeleton	$(0.8\pm0.1)\times10^{-2}$	1	300	Sirotkin et al (1972)
	Skeleton	0.9×10^{-2}	1	300	Sirotkin (1976)
	Spleen	5.4×10^{-2}	1	300	Sirotkin (1977)

Table 4. F_f values for radionuclide transfer to calves (2-5 m) tissues, d kg^{-1}

	Tissue	*Mean ± SD*	*Age, d*	*Duration, d*	*References*
^{60}Co	Heart	$(6.8\pm1.1)\times10^{-2}$	1	90	Sirotkin et al. (1980)
	Liver	$(1.0\pm0.2)\times10^{-1}$	1	90	Sirotkin et al. (1980)
	Lung	$(1.9\pm0.3)\times10^{-2}$	1	90	Sirotkin et al. (1980)
	Kidney	$(7.4\pm1.2)\times10^{-2}$	1	90	Sirotkin et al. (1980)
	Offal	$(3.6\pm0.9)\times10^{-2}$	1	90	Sirotkin et al. (1980)
	Skeleton	$(1.8\pm0.3)\times10^{-2}$	1	90	Sirotkin et al. (1980)
	Spleen	$(2.3\pm0.4)\times10^{-2}$	1	90	Sirotkin et al. (1980)
^{90}Sr	Heart	6.1×10^{-3}	1	55	Sirotkin (1977)
	Heart	0.6×10^{-2}	1	90	Sirotkin (1977)
	Heart	13.9×10^{-3}	1	101	Sirotkin (1977)
	Heart	0.9×10^{-2}	1	135	Sirotkin (1977)
	Liver	0.8×10^{-2}	90	30	Annenkov (1967)
	Liver	0.2×10^{-2}	30	30	Annenkov (1967)
	Liver	2.2×10^{-3}	1	55	Sirotkin (1977)
	Liver	6.4×10^{-3}	1	101	Sirotkin (1977)
	Liver	1.2×10^{-3}	1	125	Sirotkin (1977)
	Liver	1.5×10^{-2}	1	90	Sirotkin (1977)
	Lung	0.5×10^{-3}	60	30	Annenkov (1967)
	Lung	1.1×10^{-3}	60	30	Annenkov (1967)
	Lung	0.3×10^{-2}	135	135	Sirotkin (1977)
	Lung	7.8×10^{-3}	1	55	Sirotkin (1977)
	Lung	5.0×10^{-3}	1	101	Sirotkin (1977)
	Lung	0.9×10^{-2}	90	90	Sirotkin (1977)
	Kidney	0.5×10^{-3}	30	30	Annenkov (1967)
	Kidney	5.1×10^{-3}	1	55	Sirotkin (1977)
	Kidney	5.5×10^{-3}	1	101	Sirotkin (1977)
	Kidney	3.2×10^{-3}	1	125	Sirotkin (1977)
	Kidney	3.4×10^{-2}	1	90	Sirotkin (1977)
	Kidney	0.5×10^{-2}	1	135	Sirotkin (1977)
	Offal	4.4×10^{-3}	1	60	Sirotkin (1987)
	Offal	5.7×10^{-3}	1	150	Sirotkin (1987)
	Skeleton	3.2×10^{0}	60	30	Annenkov (1967)
	Skeleton	2.9×10^{0}	1	135	Sirotkin (1977)
	Skeleton	4.8×10^{0}	1	90	Sirotkin (1977)
	Spleen	7.6×10^{-3}	1	55	Sirotkin (1977)
	Spleen	2.4×10^{-3}	1	101	Sirotkin (1977)
	Spleen	1.3×10^{-3}	1	125	Sirotkin (1977)
^{137}Cs	Heart	40.3×10^{-2}	1	60	Sirotkin (1977)
	Heart	37.9×10^{-2}	1	150	Sirotkin (1977)
	Lung	27.7×10^{-2}	1	60	Sirotkin (1977)
	Lung	26.4×10^{-2}	1	150	Sirotkin (1977)
	Liver	20.3×10^{-2}	1	60	Sirotkin (1977)
	Liver	33.8×10^{-2}	1	150	Sirotkin (1977)
	Kidney	59.1×10^{-2}	1	60	Sirotkin (1977)
	Kidney	42.8×10^{-2}	1	150	Sirotkin (1977)
	Skeleton	1.1×10^{-1}	1	60	Sirotkin (1977)
	Skeleton	5.6×10^{-2}	1	150	Sirotkin (1977)
	Spleen	34.5×10^{-2}	1	60	Sirotkin (1977)
	Spleen	41.2×10^{-2}	1	150	Sirotkin (1977)

Table 5. F_f values for ^{90}Sr transfer to sheep tissues, d kg^{-1}

Tissue	*Mean ± SD*	*Age, d*	*Duration, d*	*References*
Adults (>6 m)				
Heart	(2.5±0.6)×10^{-3}	1	240	Burov et al. (1969)
Heart	(3.5±0.2)×10^{-3}	1	365	Burov et al. (1969)
Heart	(2.2±0.3)×10^{-3}	1	547	Burov et al. (1969)
Heart	(2.5±0.3)×10^{-3}	1	1095	Burov et al. (1969)
Lung	(9.3±3.4)×10^{-3}	1	240	Burov et al. (1969)
Lung	(5.5±1.1)×10^{-3}	1	365	Burov et al. (1969)
Lung	(5.0±0.2)×10^{-3}	1	547	Burov et al. (1969)
Lung	(6.2±0.2)×10^{-3}	1	1095	Burov et al. (1969)
Liver	(3.1±1.1)×10^{-3}	1	240	Burov et al. (1969)
Liver	(2.1±0.7)×10^{-3}	1	365	Burov et al. (1969)
Liver	(3.4±0.8)×10^{-3}	1	547	Burov et al. (1969)
Liver	(3.1±0.4)×10^{-3}	1	1095	Burov et al. (1969)
Liver	(0.9±0.1)×10^{-3}	365	18	Buldakov and Moskalev (1968)
Liver	(3.3±2.0)×10^{-3}	365	28	Buldakov and Moskalev (1968)
Liver	(1.0±0.1)×10^{-3}	365	90	Buldakov and Moskalev (1968)
Liver	(1.5±0.6)×10^{-3}	365	165	Buldakov and Moskalev (1968)
Liver	(2.2±0.3)×10^{-3}	365	300	Buldakov and Moskalev (1968)
Liver	(1.6±0.1)×10^{-3}	1095	18	Buldakov and Moskalev (1968)
Liver	(2.1±0.1)×10^{-3}	1095	28	Buldakov and Moskalev (1968)
Liver	(1.6±0.3)×10^{-3}	1095	165	Buldakov and Moskalev (1968)
Liver	(2.0±0.4)×10^{-3}	1095	300	Buldakov and Moskalev (1968)
Liver	(3.5±0.2)×10^{-3}	1825	28	Buldakov and Moskalev (1968)
Liver	(0.8±0.1)×10^{-3}	1825	90	Buldakov and Moskalev (1968)
Kidney	(8.1±0.7)×10^{-3}	1	240	Burov et al. (1969)
Kidney	(1.1±0.2)×10^{-2}	1	365	Burov et al. (1969)
Kidney	(4.8±1.0)×10^{-3}	1	547	Burov et al. (1969)
Kidney	(5.1±1.0)×10^{-3}	1	1095	Burov et al. (1969)
Spleen	(4.1±0.4)×10^{-3}	1	365	Burov et al. (1969)
Spleen	(2.9±0.8)×10^{-3}	1	547	Burov et al. (1969)
Spleen	(2.7±0.5)×10^{-3}	1	1095	Burov et al. (1969)
Spleen	(3.0±1.0)×10^{-3}	1	1080	Burov et al. (1969)
Skeleton	1.5±1.1	365	165	Buldakov and Moskalev (1968)
Skeleton	1.7±1.2	365	300	Buldakov and Moskalev (1968)
Skeleton	(7.4±5.2)×10^{-1}	1095	165	Buldakov and Moskalev (1968)
Skeleton	(9.1±6.4)×10^{-1}	1095	300	Buldakov and Moskalev (1968)
Lamb<6 m				
Heart	(0.9±0.2)×10^{-2}	1	15	Burov et al. (1969)
Heart	(0.8±0.05)×10^{-2}	1	30	Burov et al. (1969)
Heart	(1.1±0.08)×10^{-2}	1	60	Burov et al. (1969)
Heart	(0.6±0.05)×10^{-2}	1	120	Burov et al. (1969)
Lung	(1.5±0.3)×10^{-2}	1	15	Burov et al. (1969)
Lung	(1.5±0.1)×10^{-2}	1	30	Burov et al. (1969)
Lung	(2.9±0.4)×10^{-2}	1	60	Burov et al. (1969)
Lung	(1.8±0.3)×10^{-2}	1	120	Burov et al. (1969)
Liver	(1.0±0.08)×10^{-2}	1	15	Burov et al. (1969)
Liver	(0.92±0.14)×10^{-2}	1	30	Burov et al. (1969)
Liver	(1.4±0.02)×10^{-2}	1	60	Burov et al. (1969)
Liver	(1.0±0.3)×10^{-2}	1	120	Burov et al. (1969)
Kidney	(1.6±0.06)×10^{-2}	1	15	Burov et al. (1969)
Kidney	(1.4±0.04)×10^{-2}	1	30	Burov et al. (1969)

Kidney	$(1.9\pm0.3)\times10^{-2}$	1	60	Burov et al. (1969)
Kidney	$(1.2\pm0.3)\times10^{-2}$	1	120	Burov et al. (1969)
Spleen	$(0.73\pm0.1)\times10^{-2}$	1	15	Burov et al. (1969)
Spleen	$(0.93\pm0.2)\times10^{-2}$	1	30	Burov et al. (1969)
Spleen	$(0.85\pm0.2)\times10^{-2}$	1	60	Burov et al. (1969)
Spleen	$(0.88\pm0.2)\times10^{-2}$	1	120	Burov et al. (1969)
Skeleton	40.2	1	18	Buldakov and Moskalev (1968)
Skeleton	53.4	1	28	Buldakov and Moskalev (1968)
Skeleton	18.1	1	165	Buldakov and Moskalev (1968)
Skeleton	19.9	1	15	Burov et al. (1969)
Skeleton	21.0	1	30	Burov et al. (1969)
Skeleton	21.9	1	60	Burov et al. (1969)
Skeleton	28.1	1	120	Burov et al. (1969)

Table 6. F_f values for ^{137}Cs and ^{144}Ce transfer to sheep tissues, d kg^{-1}

Nuclide	*Tissue*	*Mean ± SD*	*Age, d*	*Duration, d*	*References*
^{137}Cs	Heart	$(1.2\pm0.09)\times10^{-1}$	1095	30	Buldakov (1964)
	Heart	$(5.4\pm0.42)\times10^{-2}$	1095	105	Buldakov (1964)
	Heart	1.2×10^{-1}	1095	30	Sirotkin (1977)
	Kidney	$(1.8\pm0.3)\times10^{-1}$	1095	30	Buldakov (1964)
	Kidney	$(1.7\pm0.2)\times10^{-1}$	1095	105	Buldakov (1964)
	Kidney	$(1.8\pm0.4)\times10^{-1}$	548	30	Buldakov and Moskalev (1968)
	Liver	$(1.9\pm0.9)\times10^{-1}$	1095	30	Buldakov (1964)
	Liver	$(2.0\pm0.4)\times10^{-1}$	1095	105	Buldakov (1964)
	Liver	$(1.5\pm0.1)\times10^{-1}$	548	30	Buldakov and Moskalev (1968)
	Liver	6.0×10^{-2}	1095		Sirotkin (1977)
	Lung	$(7.9\pm1.9)\times10^{-2}$	1095	30	Buldakov (1964)
	Lung	$(8.1\pm0.6)\times10^{-2}$	1095	105	Buldakov (1964)
	Lung	$(9.5\pm0.6)\times10^{-2}$	548	30	Buldakov and Moskalev (1968)
	Skeleton	$(1.9\pm1.2)\times10^{-2}$	548	30	Buldakov and Moskalev (1968)
	Skeleton	2.5×10^{-2}	1	30	Buldakov and Moskalev (1968)
	Spleen	$(7.9\pm0.61)\times10^{-2}$	1095	30	Buldakov (1964)
	Spleen	$(3.4\pm0.13)\times10^{-2}$	1095	105	Buldakov (1964)
	Spleen	$(1.4\pm0.9)\times10^{-2}$	548	18	Buldakov and Moskalev (1968)
	Spleen	$(9.8\pm6.9)\times10^{-2}$	548	30	Buldakov and Moskalev (1968)
^{144}Ce	Liver	$(0.52\pm0.09)\times10^{-2}$	548	105	Buldakov and Burov (1967)
	Liver	$(1.08\pm0.42)\times10^{-2}$	548	300	Buldakov and Burov (1967)
	Liver	$(0.78\pm0.10)\times10^{-2}$	548	1140	Buldakov and Burov (1967)
	Lung	$(0.37\pm0.10)\times10^{-2}$	548	105	Buldakov and Burov (1967)
	Lung	$(0.39\pm0.07)\times10^{-2}$	548	300	Buldakov and Burov (1967)
	Lung	$(0.16\pm0.03)\times10^{-2}$	548	1140	Buldakov and Burov (1967)
	Kidney	$(0.50\pm0.21)\times10^{-2}$	548	105	Buldakov and Burov (1967)
	Kidney	$(0.13\pm0.12)\times10^{-2}$	548	300	Buldakov and Burov (1967)
	Kidney	$(0.11\pm0.04)\times10^{-2}$	540	1140	Buldakov and Burov (1967)
	Offal	0.5×10^{-2}	1	960	Sirotkin (1991)
	Skeleton	$(0.85\pm0.13)\times10^{-2}$	548	105	Buldakov and Burov (1967)
	Skeleton	$(1.45\pm0.19)\times10^{-2}$	548	300	Buldakov and Burov (1967)
	Skeleton	$(1.67\pm0.52)\times10^{-2}$	540	1140	Buldakov and Burov (1967)
	Spleen	$(0.26\pm0.18)\times10^{-2}$	548	105	Buldakov and Burov (1967)
	Spleen	$(0.65\pm0.46)\times10^{-2}$	548	300	Buldakov and Burov (1967)
	Spleen	$(0.09\pm0.02)\times10^{-2}$	548	1140	Buldakov and Burov (1967)

Table 7. F_f values for ^{90}Sr transfer to goat tissues, d kg^{-1}

Tissue	*Mean ± SD*	*Age, d*	*Duration, d*	*References*
Adults (>6 m)				
Heart	$(6.4\pm1.6)\times10^{-3}$	1	365	Burov et al. (1969)
Heart	$(3.3\pm0.4)\times10^{-3}$	1	547	Burov et al. (1969)
Heart	$(2.4\pm0.6)\times10^{-3}$	1	730	Burov et al. (1969)
Kidney	$(1.1\pm0.1)\times10^{-2}$	1	365	Burov et al. (1969)
Kidney	$(9.5\pm0.2)\times10^{-3}$	1	547	Burov et al. (1969)
Kidney	$(5.8\pm1.3)\times10^{-2}$	1	730	Burov et al. (1969)
Liver	$(5.7\pm0.9)\times10^{-3}$	1	365	Burov et al. (1969)
Liver	$(3.0\ \pm0.8)\times10^{-3}$	1	547	Burov et al. (1969)
Liver	$(2.3\ \pm0.8)\times10^{-3}$	1	730	Burov et al. (1969)
Lung	$(9.5\pm0.6)\times10^{-3}$	1	365	Burov et al. (1969)
Lung	$(6.4\pm1.0)\times10^{-3}$	1	547	Burov et al. (1969)
Lung	$(5.1\pm0.3)\times10^{-3}$	1	730	Burov et al. (1969)
Skeleton	15.8	1	240	Panchenko and Burov
Skeleton	14.0	1	365	Panchenko and Burov
Skeleton	8.2	1	540	Panchenko and Burov
Skeleton	7.4	1	720	Panchenko and Burov)
Spleen	$(5.3\pm0.4)\times10^{-3}$	1	365	Burov et al. (1969)
Spleen	$(3.6\pm0.1)\times10^{-3}$	1	547	Burov et al. (1969)
Spleen	$(5.0\pm0.9)\times10^{-3}$	1	730	Burov et al. (1969)
Kids (< 6m)				
Heart	$(1.2\ \pm0.1)\times10^{-2}$	1	15	Burov et al. (1969)
Heart	$(1.8\pm0.2)\times10^{-2}$	1	30	Burov et al. (1969)
Heart	$(0.8\pm0.06)\times10^{-2}$	1	60	Burov et al. (1969)
Heart	$(5.4\pm0.03)\times10^{-3}$	1	120	Burov et al. (1969)
Heart	$(8.4\pm0.2)\times10^{-3}$	1	240	Burov et al. (1969)
Kidney	$(2.1\pm0.3)\times10^{-2}$	1	15	Burov et al. (1969)
Kidney	$(2.3\pm0.1)\times10^{-2}$	1	30	Burov et al. (1969)
Kidney	$(2.2\pm0.3)\times10^{-2}$	1	60	Burov et al. (1969)
Liver	$(1.3\ \pm0.2)\times10^{-2}$	1	15	Burov et al. (1969)
Liver	$(1.2\pm0.4)\times10^{-2}$	1	30	Burov et al. (1969)
Liver	$(9.0\pm2.0)\times10^{-3}$	1	60	Burov et al. (1969)
Liver	$(6.0\pm1.0)\ )\times10^{-3}$	1	120	Burov et al. (1969)
Liver	$(9.0\pm2.0)\times10^{-3}$	1	240	Burov et al. (1969)
Lung	$(1.7\pm0.2)\times10^{-3}$	1	15	Burov et al. (1969)
Lung	$(1.9\pm0.3)\times10^{-3}$	1	30	Burov et al. (1969)
Lung	$(1.9\pm0.4)\times10^{-3}$	1	60	Burov et al. (1969)
Lung	$(1.6\pm0.3)\times10^{-2}$	1	120	Burov et al. (1969)
Lung	$(1.5\pm0.2)\times10^{-2}$	1	240	Burov et al. (1969)
Skeleton	23.4	1	15	Panchenko and Burov
Skeleton	27.3	1	30	Panchenko and Burov
Skeleton	26.4	1	60	Panchenko and Burov)
Skeleton	21.7	1	120	Panchenko and Burov
Spleen	$(1.3\pm0.7)\times10^{-2}$	1	15	Burov et al. (1969)
Spleen	$(1.2\pm0.4)\times10^{-2}$	1	30	Burov et al. (1969)
Spleen	$(5.5\pm0.1)\times10^{-3}$	1	60	Burov et al. (1969)
Spleen	$(5.6\pm0.1.5)\times10^{-3}$	1	120	Burov et al. (1969)
Spleen	$(8.2\pm0.1)\times10^{-3}$	1	240	Burov et al. (1969)

Table 8 F_f values for ^{90}Sr transfer to pig tissues, d kg^{-1}

Tissue	*Mean ± SD*	*Age, d*	*Duration, d*	*References*
Adult pigs (>6 m)				
Heart	$(0.4\pm0.02)\times10^{-2}$	1	180	Burov et al (1971)
Heart	$(0.2\pm0.01)\times10^{-2}$	1	730	Burov et al (1971)
Heart	$(0.2\pm0.01)\times10^{-2}$	1	1460	Burov et al (1971)
Liver	$(0.4\pm0.05)\times10^{-2}$	80	90	Annenkov et al. (1964)
Liver	$(0.5\pm0.07)\times10^{-2}$	80	164	Annenkov et al. (1964)
Liver	$(0.3\pm0.03)\times10^{-2}$	80	254	Annenkov et al. (1964)
Liver	$(0.5\pm0.02)\times10^{-2}$	1	180	Burov et al (1971)
Liver	$(0.3\pm0.01)\times10^{-2}$	1	730	Burov et al (1971)
Liver	$(0.2\pm0.01)\times10^{-2}$	1	1460	Burov et al (1971)
Lung	$(0.4\pm0.05)\times10^{-2}$	80	90	Annenkov et al. (1964)
Lung	$(0.6\pm0.13)\times10^{-2}$	80	164	Annenkov et al. (1964)
Lung	$(0.6\pm0.18)\times10^{-2}$	80	254	Annenkov et al. (1964)
Lung	$(0.7\pm0.03)\times10^{-2}$	1	180	Burov et al (1971)
Lung	$(0.4\pm0.02)\times10^{-2}$	1	730	Burov et al (1971)
Lung	$(0.3\pm0.01)\times10^{-2}$	1	1460	Burov et al (1971)
Kidney	$(0.4\pm0.02)\times10^{-2}$	1	180	Burov et al (1971)
Kidney	$(0.3\pm0.01)\times10^{-2}$	1	730	Burov et al (1971)
Kidney	$(0.2\pm0.01)\times10^{-2}$	1	1460	Burov et al (1971)
Skeleton	2.4±1.4	80	90	Annenkov et al. (1964)
Skeleton	1.7±0.9	80	164	Annenkov et al. (1964)
Skeleton	1.1±0.5	80	254	Annenkov et al. (1964)
Spleen	$(0.6\pm0.02)\times10^{-2}$	1	180	Burov et al (1971)
Spleen	$(0.3\pm0.01)\times10^{-2}$	1	730	Burov et al (1971)
Spleen	$(0.2\pm0.01)\times10^{-2}$	1	1460	Burov et al (1971)
Piglets (<6 m)				
Heart	$(0.6\pm0.02)\times10^{-2}$	1	50	Burov et al (1971)
Heart	$(0.8\pm0.03)\times10^{-2}$	1	90	Burov et al (1971)
Liver	$(1.0\pm0.05)\times10^{-2}$	80	30	Annenkov et al. (1964)
Liver	$(0.4\pm0.05)\times10^{-2}$	80	60	Annenkov et al. (1964)
Liver	$(1.8\pm0.07)\times10^{-2}$	1	50	Burov et al (1971)
Liver	$(1.5\pm0.06)\times10^{-2}$	1	90	Burov et al (1971)
Lung	$(0.6\pm0.03)\times10^{-2}$	80	30	Annenkov et al. (1964)
Lung	$(0.4\pm0.2)\times10^{-2}$	80	60	Annenkov et al. (1964)
Lung	$(1.6\pm0.07)\times10^{-2}$	1	50	Burov et al (1971)
Lung	$(1.7\pm0.07)\times10^{-2}$	1	90	Burov et al (1971)
Kidney	$(1.6\pm0.07)\times10^{-2}$	1	50	Burov et al (1971)
Kidney	$(1.2\pm0.05)\times10^{-2}$	1	90	Burov et al (1971)
Skeleton	2.1±0.6	80	30	Annenkov et al. (1964)
Skeleton	2.3±1.3	80	60	Annenkov et al. (1964)
Spleen	$(1.1\pm0.4)\times10^{-2}$	1	50	Burov et al (1971)
Spleen	$(1.0\pm0.4)\times10^{-2}$	1	90	Burov et al (1971)
Spleen	$(0.6\pm0.02)\times10^{-2}$	1	180	Burov et al (1971)

Table 9. F_f values for ^{137}Cs transfer to pig tissues, d kg^{-1}

Tissue	*Mean ± SD*	*Age, d*	*Duration, d*	*References*
Adult pigs (>6 months)				
Fat	$(1.3\pm0.8)\times10^{-2}$	540	10	Annenkov et al. (1991)
Fat	$(6.6\pm3.8)\times10^{-2}$	540	20	Annenkov et al. (1991)
Fat	$(5.6\pm3.2)\times10^{-2}$	540	30	Annenkov et al. (1991)
Fat	$(0.69\pm0.2\times10^{-2}$	520	60	Chmyrev (1996)
Fat	$(0.6\pm0.1)\times10^{-2}$	520	78	Chmyrev (1996)
Fat	$(0.5\pm0.1)\times10^{-2}$	520	90	Chmyrev (1996)
Fat	$(0.5\pm0.2)\times10^{-2}$	520	112	Chmyrev (1996)
Fat	$(0.8\pm0.1)\times10^{-2}$	5	300	Shilov (1980)
Fat	$(0.3\pm0.04)\times10^{-2}$	5	1300	Shilov (1980)
Heart	$(3.3\pm2.3)\times10^{-1}$	100	85	Iliyn and Moscalev (1961)
Heart	$(2.3\pm0.3)\times10^{-1}$	5	300	Shilov (1980)
Heart	$(1.7\pm0.2)\times10^{-1}$	5	790	Shilov (1980)
Heart	$(1.8\pm0.3)\times10^{-1}$	5	1300	Shilov (1980)
Heart	$(1.2\pm0.1)\times10^{-1}$	720	10	Annenkov et al. (1990)
Heart	$(1.1\pm0.1)\times10^{-1}$	600	60	Annenkov et al. (1991)
Heart	$(1.2\pm0.07)\times10^{-1}$	600	78	Annenkov et al. (1991)
Heart	$(1.1\pm0.1)\times10^{-1}$	600	90	Annenkov et al. (1991)
Heart	$(9.2\pm1.4)\times10^{-2}$	600	112	Annenkov et al. (1991)
Heart	$(1.3\pm0.7)\times10^{-1}$	540	10	Annenkov et al. (1991)
Heart	$(5.0\pm2.9)\times10^{-1}$	540	20	Annenkov et al. (1991)
Heart	$(4.5\pm2.6)\times10^{-1}$	540	30	Annenkov et al. (1991)
Heart	1.8×10^{-1}	400	360	Sirotkin (1977)
Kidney	$(1.8\pm0.4)\times10^{-1}$	540	10	Annenkov et al. (1990)
Kidney	$(1.9\pm1.1)\times10^{-1}$	540	10	Annenkov et al. (1991)
Kidney	$(4.2\pm2.4)\times10^{-1}$	540	20	Annenkov et al. (1991)
Kidney	$(5.9\pm3.4)\times10^{-1}$	540	30	Annenkov et al. (1991)
Kidney	$(1.3\pm0.2)\times10^{-1}$	520	60	Chmyrev (1996)
Kidney	$(1.8\pm0.06)\times10^{-1}$	520	78	Chmyrev (1996)
Kidney	$(1.2\pm0.08)\times10^{-1}$	520	90	Chmyrev (1996)
Kidney	$(4.3\pm3.0)\times10^{-1}$	100	85	Iliyn and Moscalev (1961)
Kidney	$(2.9\pm0.4)\times10^{-1}$	5	300	Shilov (1980)
Kidney	$(2.0\pm0.3)\times10^{-1}$	5	790	Shilov (1980)
Kidney	$(2.4\pm0.3)\times10^{-1}$	5	1300	Shilov (1980)
Liver	$(1.0\pm0.2)\times10^{-1}$	720	10	Annenkov et al. (1990)
Liver	$(8.8\pm5.1)\times10^{-2}$	540	10	Annenkov et al. (1991)
Liver	$(2.3\pm1.3)\times10^{-1}$	540	20	Annenkov et al. (1991)
Liver	$(8.4\pm1.1)\times10^{-2}$	600	60	Annenkov et al. (1991)
Liver	$(9.9\pm0.4)\times10^{-2}$	600	78	Annenkov et al. (1991)
Liver	$(7.5\pm1.3)\times10^{-2}$	600	90	Annenkov et al. (1991)
Liver	$(7.4\pm1.4)\times10^{-2}$	600	112	Annenkov et al. (1991)
Liver	$(2.9\pm1.7)\times10^{-1}$	540	30	Annenkov et al. (1991)
Liver	$(2.4\pm1.7)\times10^{-1}$	100	85	Iliyn and Moscalev (1961)
Liver	$(1.7\pm0.2)\times10^{-1}$	60	360	Nikitina et al. (1972)
Liver	$(2.1\pm0.3)\times10^{-1}$	5	300	Shilov (1980)
Liver	$(1.6\pm0.2)\times10^{-1}$	5	790	Shilov (1980)
Liver	$(1.4\pm0.2)\times10^{-1}$	5	1300	Shilov (1980)
Liver	1.0×10^{-1}	400	360	Sirotkin (1977)
Lung	$(6.5\pm0.5)\times10^{-2}$	540	20	Annenkov et al. (1990)
Lung	$(7.9\pm4.6)\times10^{-2}$	540	10	Annenkov et al. (1991)
Lung	$(7.7\pm4.4)\times10^{-2}$	540	20	Annenkov et al. (1991)
Lung	$(2.4\pm1.4)\times10^{-1}$	540	30	Annenkov et al. (1991)
Lung	$(5.6\pm0.7)\times10^{-2}$	600	60	Annenkov et al. (1991)

Lung	$(6.7\pm0.5)\times10^{-2}$	600	78	Annenkov et al. (1991)
Lung	$(5.8\pm0.4)\times10^{-2}$	600	90	Annenkov et al. (1991)
Lung	$(5.7\pm1.0)\times10^{-2}$	600	112	Annenkov et al. (1991)
Lung	$(1.2\pm0.2)\times10^{-1}$	5	300	Shilov (1980)
Lung	$(9.9\pm1.4)\times10^{-2}$	5	790	Shilov (1980)
Lung	$(1.1\pm0.16)\times10^{-1}$	5	1300	Shilov (1980)
Spleen	$(1.3\pm0.7)\times10^{-1}$	540	10	Annenkov et al. (1991)
Spleen	$(3.4\pm1.9)\times10^{-1}$	540	20	Annenkov et al. (1991)
Spleen	$(3.8\pm2.2)\times10^{-1}$	540	30	Annenkov et al. (1991)
Spleen	$(7.6\pm0.7)\times10^{-2}$	520	60	Chmyrev (1996)
Spleen	$(8.3\pm0.3)\times10^{-2}$	520	78	Chmyrev (1996)
Spleen	$(8.0\pm0.5)\times10^{-2}$	520	90	Chmyrev (1996)
Spleen	$(7.5\pm1.2)\times10^{-2}$	520	112	Chmyrev (1996)
Spleen	$(1.8\pm0.3)\times10^{-1}$	5	300	Shilov (1980)
Spleen	$(1.4\pm0.2)\times10^{-1}$	5	790	Shilov (1980)
Spleen	$(1.4\pm0.2)\times10^{-1}$	5	1300	Shilov (1980)
Piglets (>6 m)				
Fat	$(2.1\pm0.3)\times10^{-1}$	5	15	Shilov (1980)
Fat	$(4.7\pm0.7)\times10^{-1}$	5	20	Shilov (1980)
Fat	$(9.1\pm1.3)\times10^{-2}$	5	60	Shilov (1980)
Heart	$(3.8\pm3.8)\times10^{-1}$	100	14	Iliyn and Moscalev (1961)
Heart	$(2.4\pm1.7)\times10^{-1}$	100	28	Iliyn and Moscalev (1961)
Heart	$(3.5\pm2.5)\times10^{-1}$	100	52	Iliyn and Moscalev (1961)
Heart	2.5±0.4	5	15	Shilov (1980)
Heart	2.6±0.4	5	20	Shilov (1980)
Heart	1.6±0. 2	5	30	Shilov (1980)
Heart	$(6.7\pm0.9)\times10^{-1}$	5	60	Shilov (1980)
Heart	$(2.6\pm0.4)\times10^{-1}$	5	90	Shilov (1980)
Kidney	$(5.1\pm5.1)\times10^{-1}$	100	14	Iliyn and Moscalev (1961)
Kidney	$(3.9\pm2.\ 8)\times10^{-1}$	100	28	Iliyn and Moscalev (1961)
Kidney	$(4.5\pm3.2)\times10^{-1}$	100	52	Iliyn and Moscalev (1961)
Kidney	2.9±0.4	5	15	Shilov (1980)
Kidney	4.0±0.6	5	20	Shilov (1980)
Kidney	2.1±0.3	5	30	Shilov (1980)
Kidney	1.0±0.14	5	60	Shilov (1980)
Kidney	$(3.1\pm0.4)\times10^{-1}$	5	90	Shilov (1980)
Liver	$(3.0\pm3.0)\times10^{-1}$	100	14	Iliyn and Moscalev (1961)
Liver	$(2.3\pm1.6)\times10^{-1}$	100	28	Iliyn and Moscalev (1961)
Liver	$(3.0\pm2.1)\times10^{-1}$	100	52	Iliyn and Moscalev (1961)
Liver	1.6±0.2	5	15	Shilov (1980)
Liver	1.8±0.3	5	20	Shilov (1980)
Liver	1.1±0.2	5	30	Shilov (1980)
Liver	$(5.5\pm0.8)\times10^{-1}$	5	60	Shilov (1980)
Liver	$(2.3\pm0.3)\times10^{-1}$	5	90	Shilov (1980)
Lung	1.6±0.2	5	15	Shilov (1980)
Lung	2.0±0.3	5	20	Shilov (1980)
Lung	1.3±0.2	5	30	Shilov (1980)
Lung	$(4.8\pm0.7)\times10^{-1}$	5	60	Shilov (1980)
Lung	$(2.0\pm0.3)\times10^{-1}$	5	90	Shilov (1980)
Spleen	2.6±0.4	5	15	Shilov (1980)
Spleen	2.4±0.3	5	20	Shilov (1980)
Spleen	1.1±0.2	5	30	Shilov (1980)
Spleen	$(5.3\pm0.7)\times10^{-1}$	5	60	Shilov (1980)
Spleen	$(2.5\pm0.4)\times10^{-1}$	5	90	Shilov (1980)

Table 10. F_f values for radionuclide transfer to pig tissues, d kg^{-1}

Nuclide	*Tissue*	*Mean ± SD*	*Age, d*	*Duration, d*	*References*
Adult pigs (>6 m)					
^{32}P	Heart	$(4.0\pm2.8)\times10^{-2}$	100	85	Iliyn and Moscalev (1961)
	Liver	$(7.6\pm5.4)\times10^{-2}$	100	85	Iliyn and Moscalev (1961)
	Kidney	$(3.4\pm2.4)\times10^{-2}$	100	85	Iliyn and Moscalev (1961)
^{238}U	Heart	$(2.1\pm0.9)\times10^{-1}$	1	270-300	Prister (1967)
	Kidney	$(1.5\pm0.7)\times10^{-1}$	1	270-300	Prister (1967)
	Lung	$(4.2\pm1.9)\times10^{-2}$	1	270-300	Prister (1967)
	Liver	$(3.1\pm1.4)\times10^{-2}$	1	270-300	Prister (1967)
^{239}Pu	Offal	2.0×10^{-4}	1	960	Sirotkin (1991)
Piglets (< 6 m)					
^{32}P	Heart	$(4.8\pm3.4)\times10^{-2}$	100	28	Iliyn and Moscalev (1961)
	Heart	$(6.2\pm4.4)\times10^{-2}$	100	52	Iliyn and Moscalev (1961)
	Liver	$(2.1\pm2.1)\times10^{-1}$	100	14	Iliyn and Moscalev (1961)
	Liver	$(1.5\pm1.0)\times10^{-1}$	100	28	Iliyn and Moscalev (1961)
	Liver	$(1.3\pm0.9)\times10^{-1}$	100	52	Iliyn and Moscalev (1961)
	Kidney	$(1.5\pm1.5)\times10^{-1}$	100	14	Iliyn and Moscalev (1961)
	Kidney	$(9.0\pm6.4)\times10^{-2}$	100	28	Iliyn and Moscalev (1961)
	Kidney	$(8.7\pm6.2)\times10^{-2}$	100	52	Iliyn and Moscalev (1961)
^{106}Ru	Liver	$(3.0\pm2.2)\times10^{-2}$	21	15	Burov and Sarapultsev (1974)
	Liver	$(2.1\pm1.5)\times10^{-2}$	21	30	Burov, and Sarapultsev (1974)
	Liver	$(1.8\pm1.3)\times10^{-2}$	21	60	Burov, and Sarapultsev (1974)
	Kidney	$(2.4\pm1.7)\times10^{-1}$	21	15	Burov, and Sarapultsev (1974)
	Kidney	$(1.7\pm1.2)\times10^{-1}$	21	30	Burov, and Sarapultsev (1974)
	Kidney	$(4.8\pm3.4)\times10^{-2}$	21	60	Burov, and Sarapultsev (1974)

Table 11. F_f values for radionuclides transfer to poultry and rabbit tissues, d kg^{-1}

Nuclide	*Tissue*	*Mean ± SD*	*Age, d*	*Duration, d*	*References*
Chicken					
^{54}Mn	Offal	1.0×10^{-4}	730	60	Sirotkin (1987)
	Offal	1.0×10^{-4}	730	70	Sirotkin (1987)
^{65}Zn	Offal	3.0	1	30	Sirotkin (1987)
	Offal	4.0	1	60	Sirotkin (1987)
	Offal	4.0	1	90	Sirotkin (1987)
	Offal	4.8	1	120	Sirotkin (1987)
	Offal	2.6	1	150	Sirotkin (1987)
	Offal	2.0	1	180	Sirotkin (1987)
	Offal	2.1	1	210	Sirotkin (1987)
	Offal	1.9	1	240	Sirotkin (1987)
	Offal	2.3	1	270	Sirotkin (1987)
^{137}Cs	Heart	1.6±0.2	70	30	Shilov and Koldayeva (1978)
	Heart	1.5±0.3	70	65	Shilov and Koldayeva (1978)
	Heart	1.50±0.6	70	150	Shilov and Koldayeva (1978)
	Heart	1.2±0.1	70	360	Shilov and Koldayeva (1978)
	Heart	1.8	410	80	Sirotkin (1977)
	Liver	0.96±0.2	70	30	Shilov and Koldayeva (1978)
	Liver	0.94 ±0. 2	70	65	Shilov and Koldayeva (1978)
	Liver	1.1±0.03	70	150	Shilov and Koldayeva (1978)
	Liver	0.8 ±0.1	70	360	Shilov and Koldayeva (1978)
	Liver	1.5	410	80	Sirotkin (1977)
	Lung	0.7±0.1	70	30	Shilov and Koldayeva (1978)
	Lung	0.8±0.1	70	65	Shilov and Koldayeva (1978)
	Lung	0.9±0.2	70	150	Shilov and Koldayeva (1978)
	Lung	0.8 ±0.0 8	70	360	Shilov and Koldayeva (1978)
	Kidney	1.3±0.1	70	30	Shilov and Koldayeva (1978)
	Kidney	1.2±0.3	70	65	Shilov and Koldayeva (1978)
	Kidney	1.5±0.3	70	150	Shilov and Koldayeva (1978)
	Kidney	1.1±0.1	70	360	Shilov and Koldayeva (1978)
	Spleen	1.5 ±0.1	70	30	Shilov and Koldayeva (1978)
	Spleen	1.7±0.2	70	65	Shilov and Koldayeva (1978)
	Spleen	1.3±0.2	70	150	Shilov and Koldayeva (1978)
	Spleen	1.3±0.1	70	360	Shilov and Koldayeva (1978)
	Stomach[1]	2.3±0.3	70	65	Shilov and Koldayeva (1978)
	Stomach[1]	2.1±0.5	70	150	Shilov and Koldayeva (1978)
	Stomach[1]	2.3±0.1	70	360	Shilov and Koldayeva (1978)
^{90}Sr	Liver	$(2.8\pm0.9)\times10^{-2}$	270	30	Koldayeva et al. (1969)
	Liver	$(8.7\pm0.9)\times10^{-2}$	250	30	Sirotkin (1977)
	Lung	$(2.7\pm0.9)\times10^{-2}$	270	30	Koldayeva et al. (1969)
	Lung	9×10^{-2}	270	30	Sirotkin (1977)
	Lung	2.9×10^{-2}	270	30	Sirotkin (1987)
	Skeleton	2.4	150	30	Koldayeva et al. (1975)
	Skeleton	1.1	365	30	Koldayeva et al. (1975)
Duck					
^{22}Na	Lung	17.5±2.5	188	120	Burov (1984)
^{60}Co	Liver	0.3	188	120	Burov (1984)
^{90}Sr	Liver	0.04	180	120	Burov (1984)

Goose					
^{137}Cs	Blood	0.2±0.06	1170	75	Astasheva et al (1991)
	Heart	0.7±0.2	1170	75	Astasheva et al (1991)
	Kidney	0.9±0.3	1170	75	Astasheva et al (1991)
	Liver	0.4±0.1	1170	75	Astasheva et al (1991)
	Lung	0.4±0.2	1170	75	Astasheva et al (1991)
Rabbits					
^{65}Zn	Heart	1.8 ± 0.6	90	90	Avrunina (1965)
^{65}Zn	Heart	2.2 ± 0.9	90	90	Avrunina (1965)
^{65}Zn	Liver	6.0 ± 2.5	90	90	Avrunina (1965)
^{65}Zn	Liver	6.7 ± 5.5	180	90	Avrunina (1965)
^{65}Zn	Lung	1.4 ± 0.5	90	90	Avrunina (1965)
^{65}Zn	Lung	2.2 ± 1.2	90	90	Avrunina (1965)
^{65}Zn	Kidney	5.6 ± 1.7	90	90	Avrunina (1965)
^{65}Zn	Kidney	2.7 ± 1.4	180	90	Avrunina (1965)
^{65}Zn	Spleen	1.6 ± 0.6	90	90	Avrunina (1965)
^{65}Zn	Spleen	3.8 ± 2.2	90	90	Avrunina (1965)

[1] muscles