# "REGULARITIES IN METABOLISM OF RADIOACTIVE ISOTOPES UPON INCIDENCE ON THE SKIN"

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## Abstract

This report based on the experimental data and calculated-dosimetric estimates for the first time presents a discussion on the metabolic regularities of radionuclides of the elements of various groups of the Mendeleev periodic system when their solutions are applied to the skin. Common features in the distribution of these agents in the skin irrespective of their chemical origin have been established. Essential differences in the accumulation levels of radioactive substances in the skin and in the level of percutaneous resorbtion have been found. It is shown that transfollicular route is the main way of radionuclide penetration into the body through the skin.

In order to develop the problem of setting standards for skin contamination with radioactive substances and to find effective decontamination means, one must have proper data on the regularities in metabolism of radioactive substances when they come in touch with the skin integument.

Three consecutive stages in the metabolism of radioactive substances are conventianally assumed as follows:

on the surface of the skin, within the skin and within the body.

1. The analysis of the kynetics of radioactive contamination of the skin and of the dynamics of its decontamination may allow us to assume that radionuclides on the surface of the skin are distributed superficially at least as three layers /1,2 /. The upper friable and easily removed layer is formed as a result of mechanical deposition of radionuclides (carriers). The second layer is formed due to physico-chemical processes that determine the interaction of a radioactive

substance with active groups (radicals) of the skin superficial structures. Formation of the third layer /2/ is stipulated by ionic exchange between the macrocomponent (the surface of the skin) and the microcomponent (the radioactive ion).

Results of hystoautoradiographic studies allow us to come to the conclusion that the main route for the penetration of the majority of radioactive substances into the skin is the transfollicular route and to a lesser extent it is the transepidermal route /3/.

2. Metabolism of radioactive substances within the skin layer after their solutions are deposited on the surface of the skin has been studied mainly by Soviet scientists /3-5/ as well as by Japanese specialists /6-9/. Methods of solving this complex task have been found and use the technique of radiometry of consecutive horizontal skin sections 20-40 μm thick /3/. This allowed us to have data on the levels of accumulation, the mode of the intercutaneous distribution and elimination from the skin of pigs of uranium fission fragments ($Cs^{137}$, $Sr^{89}$, $Ba^{140}$, $Y^{91}$, $Ce^{141,144}$, $Nd^{147}$, $Pr^{143}$, $Te^{132}$, $Mo^{99}$, $I^{131}$) /3/ as well as of $Po^{210}$ /5/ and transuranium elements ($Pu^{239}$, $Am^{241}$) /4/.

Analysis of the experimental data has established that the character of the distribution within the skin of uranium fission products is the same despite their chemical origin. The characteristic feature is a sharp reduction in the concentration of radionuclides within the skin according to the depth of the layers down to 200 μm, a more moderate reduction in the layer from 200 to 600 μm and almost a uniform distribution in still deeper layers.

Analogous regularities have been also noted in principle for $Po^{210}$, $Pu^{239}$ and $Am^{241}$ /4,5/.

The curve showing the distribution within the skin of fragmentary radionuclides down to the depth of 600 μm is well described by the following exponential equation:

$$C_x = C_o(a_1 e^{-K_1 x} + a_2 e^{-K_2 x} + a_3 e^{-K_3 x}), \text{ where}$$

$C_x$ is the concentration of a radionuclide at the depth of x, μCi/(cm$^2$·μm), $C_o$ is the concentration extrapolated to the depth x=o, x is the depth in μm; $a_1$, $a_2$, $a_3$ are the contribution of each exponent to the general function of distribution; $K_1$, $K_2$, $K_3$ are the constants characterizing the gradient of decreased concentration for the corresponding exponents, μm (see Table 1).

Experimental data and calculated absorbed doses within the skin for β-sources of various energies prove the adequacy of the surface distribution model for estimating absorbed doses of β-radiation in the skin, beginning with the energy of 0.2 MeV. In the case of more soft β-radiation sources, account should be made of the contribution to the dose due to the effect of radioactive substances that have penetrated into the skin /3/.

Osanov and his colleagues /4/ have estimated experimentally the dose distribution function for a thin plane α-source.

While the general character of the intercutaneous distribution of radioactive substances within the skin is quite of one and the same type and does not depend considerably on the time of the radionuclide exposition on the surface of that organ, the levels of their accumulation within the skin differ considerably. According to this index, all the radionuclides that have been studied may be arranged in the following order: $I^{131}$, $Po^{210} > Ce^{144}$, $Pr^{143}$, $Nd^{147} > Mo^{99}$, $Te^{132} > Sr^{89}$, $Ba^{140} > Cs^{137} > Pu^{239}$, $Am^{241}$.

According to the data obtained by us, the maximum accumulation of the radionuclides within the skin is achieved in a relatively short interval after the radioactive solution is applied onto the skin (within 15 minutes to one hour). The amount of radioactive substances in the skin (the surface layer 30/Mm deep being excluded) is within the range from 4–5 per cent ($I^{131}$, $Po^{210}$) to 0.1 per cent ($Pu^{239}$) of the amount of the radionuclide applied to the surface of the skin.

In order to study the intimate exchange mechanisms of radioactive substances in the skin it is very important to have data available pertaining to the peculiarity of their interaction with various biochemical components of that organ.

Table 2 presents the data of the distribution of the radionuclides of molybdenum, tellurium, strontium, barium, yttrium, cerium, praseodymium and neodymium between various skin fractions (soluble in lipids, soluble in water and residual).

These studies carried out in cooperation with Shvydko, N.S., /3/ have also considered the distribution of radionuclides in the above mentioned fractions after their isolation from epidermis, derma and subcutaneous connective tissue. All the experiments yielded identical results that testified to the fact that despite their chemical origin, all the radionuclides present in the skin were mainly linked with insoluble proteins and hardly solving inorganic compounds (phosphates, sulphates, etc).

A relatively small amount of radionuclides interact with lipids and proteins soluble in water. All this allows us to suppose one type of mechanism that determines parameters of time for exchange and elimination of radionuclides from the skin.

This hypothesis is to some extent corroborated by the results of preliminary studies /5,10/ aimed at estimating effective half-lives ($T_{eff}$) of a number of radioactive substances in the skin (see Table 3).

As one can see from Table 3, despite the origin of a radionuclide in this or that group of elements of the Mendeleev periodic system, they have a common feature which is a rapidly exchangeable fraction (with $T_{eff}$ equal to several hours) that accounts for 65–95 per cent of the amount of radionuclides deposited in the skin. The contribution of the relatively slowly exchangeable fraction (with $T_{eff}$ equal to several days) is of the order of 5–35 per cent.

3. The levels of percutaneous resorbtion of radioactive substances into the body depend on the type of the chemical compound and the aggregate state of a radionuclide. As can be seen from systematized data obtained during our studies and from the published data, the range of values of this index lies within several hundredth fractions of a per cent up to several per

cent of the amount of the radionuclide applied to the surface of the skin. This allows us to classify radioactive substances according to their low, medium and high level of percutaneous resorbtion. With due consideration to some exceptions depending on the type of the chemical compound we classify the following elements: uranium, thorium, transuranium and transplutonium elements, radionuclides of the sulphur subgroup (tellurium, polonium) as radionuclides with the low level of percutaneous resorbtion (to the tenths fractions of a per cent); radionuclides of the elements of the II$^{nd}$ group, uranium fission products as radionuclides with the medium level of percutaneous resorbtion (from several fractions of a per cent to one per cent) and radionuclides of the alkaline elements, the chrome subgroup, the VII$^{th}$ and VIII$^{th}$ groups of the periodic system as those with high level of percutaneous resorbtion (more than one per cent). At the same time the analysis of all the available data on the exchange of radioactive substances being applied onto the surface of the skin did not reveal any correlation between the levels of their accumulation in the skin and within the body.

4. Comparison of the peculiarities in the distribution within various organs and tissues of radionuclides of the elements of various groups of the Mendeleev periodic system depending on the route of their entering the body, allows one to conclude that the character of their distribution when they are applied on the skin is the same as in the case when they enter the gastro-intestinal tract.

Under the conditions of additional total body X-irradiation, the exchange of radioactive substances applied onto the skin varies insignificantly. Therefore, this factor should not be listed among those that may aggravate radiation effects on the living organism.

Table 1

The values of the parameters of the function characterizing the change in the concentration of $\beta$-radionuclides in the skin according to various depths

| Parameter | $a_1$ | $a_2$ | $a_3$ | $K_1$ | $K_2$ | $K_3$ |
|---|---|---|---|---|---|---|
| Value | 0.83 | 0.15 | 0.02 | $6.93 \times 10^{-2}$ | $1.73 \times 10^{-2}$ | $2.56 \times 10^{-3}$ |

Table 2

The distribution of radionuclides in various skin fractions, %

| Radionuclide | Fraction | | |
|---|---|---|---|
| | soluble in lipids | soluble in water | residual |
| $Mo^{99}$ | 14.5±2.5 | 29.6±6.4 | 55.9±8.0 |
| $Tl^{132}$ | 11.8±2.6 | 6.5±1.6 | 81.7±11.4 |
| $Sr^{89}$ | 10.3±2.7 | 14.4±4.3 | 75.3±17.2 |
| $Ba^{140}$ | 11.1±2.9 | 7.7±2.4 | 81.2±11.3 |
| $Y^{91}$ | 11.4±2.2 | 4.4±1.2 | 84.2±1.3 |
| $C^{141,144}$ | 12.5±0.5 | 3.8±0.2 | 83.7±0.2 |
| $Pr^{143}+Nd^{147}$ | 5.8±0.7 | 1.9±0.1 | 92.3±0.7 |

Table 3

The kynetics of elimination from the skin of some radioactive substances

| Radio-nuclide | compound | $T_{eff_1}$, hours | per cent | $T_{eff_2}$, days | per cent | Biblio-graphy |
|---|---|---|---|---|---|---|
| $H^3$ | $H_3O$ | 1 | 95 | 12 | 5 | (10) |
| $Cs^{137}$ | CsCl | 8 | 65 | 2 | 35 | (10) |
| $Pu^{239}$ | $Pu(NO_3)_4$ | 13 | 80 | 5 | 20 | (10) |
| $Po^{210}$ | $Po(NO_3)_4$ | 8 | 70 | 15 | 30 | (5) |

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