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TRANSLATIONS FROM GIGIYENA I SANITARIYA
(Hygiene and Sanitation)
Vol 28, No 1, 1963
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TRANSLATIONS FROM GIGIYENA I SANITARIYA

(Hygiene and Sanitation)

Following is a translation of five articles from the above-mentioned Russian-language medical journal, Vol 28, No 1, 1963.

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Problem of Individual Dosimetric Control Methods

pages 53-55

Candidate of medical sciences
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Ministry of Health RSFSR

The "Sanitary rules of work with radioactive substances and sources of ionizing radiations" No 333-60 of 25 June 1960 state that in the case of individuals directly engaged in work with sources of ionizing radiations the determination of individual irradiation doses (beta, gamma, and neutrons) should be carried out for each weekly period. The sanitary rules also specified that the rate of conducting dosimetric determinations is established by the administration of the enterprise or establishment in accordance with the local organs of sanitary control. As shown by the results of numerous checkings of the state of individual dosimetry on the examined objects, daily dosimetric tests are carried out in the overwhelming majority of cases.

At present the most widespread devices used in the determination of the individual total irradiation dose in individuals working with sources of ionizing radiation in industrial X-ray-defectoscopy and gammadefectoscopy, in X-ray therapeutic and X-ray-diagnostic offices, and in servicing gamma-apparatus of various designation, are devices of the KID type. Much less frequently devices of the DK-0.2, IFK, or ILK type are employed. The sensitivity of individual dosimeters of the KID type permits the recording of irradiation doses within the range of 0.02 to 2 r. Recording of irradiation doses lesser than 0.02 r is possible, but the obtained data are not reliable.

It is a known fact that in the majority of enterprises

and establishments the work connected with irradiation of the personnel is carried out periodically during the week, with the unequal distribution of the dose at various days of the week. Thus, for instance, at some days of the week the magnitude of irradiation dose can be below the maximally permissible level (MPL), i.e., the passable sensitivity threshold of the KID ionization chambers, and in other instances -- above MPL. For example, an individual working with a source of ionizing radiation is subjected for five days of the week to the effect of a radiation dose below the sensitivity of the KID device, although each of the magnitudes below 0.02 r may denote any figure within a 0 to 0.02 r range and comprise, respectively, one half, one quarter, or one eighth part of the daily MPL irradiation, and one day he will receive an irradiation dose of 0.07 r; then, upon daily recording of individual doses, the KID indexes in the journal will appear as follows:

| Monday | Tuesday | Wednesday | Thursday | Friday | Saturday | Total per week |
|---------|---------|-----------|----------|---------|----------|----------------------|
| >0.02 r | >0.02 r | >0.02 r | 0.07 r | >0.02 r | >0.02 r | ? |

At the same time the actual total irradiation dose might be above the weekly MPL of irradiation (i.e., 0.1 r).

Considering the above stated, it is natural to suggest a change in the system of individual dosimetry by conducting control determinations not daily, but weekly. Hence, the dosimeters will be issued for one week (on Monday) and their readings will be recorded only once a week (on Saturday).

In view of the existing opinion that many individual dosimeters do not meet the technical requirements and produce during the weekly period a considerable self-discharge, even without the action of ionizing radiation (which may complicate the evaluation of the measurement data), we carried out a special check-up on the correspondence to technical requirements of 10 KID sets (200 individual dosimeters). Of the 10 sets, seven were employed, and three were left idle. First, the efficiency of all 200 dosimeters was checked according to the following method: individual dosimeters were charged, follow-

ing which the dose was measured at once. It was found that all 200 dosimeters recorded a 0 dose, i.e., they were in good working order. Following the check-up, the dosimeters were recharged and left on the premises where no radiation sources were present for one week. The results of subsequent measurements showed that the self-discharge of the chambers for each weekly period varied: two to four dosimeters of each set showed a half self-discharge or more, whereas the rest of the chambers from each set showed fairly stable readings during each of the four weeks of the check-up; the self-discharge of the chambers comprised no more than 10 to 15 percent.

The causes of defects of ionization chambers may vary, but one of them proved to be quite typical. Insofar as it is connected with the manufacturing plant, its detailed discussion is important. We took several X-ray pictures of a few dosimeters, in order to ascertain the position of the central electrode. The X-ray picture of several dosimeters showed that in five which produced the most unstable readings the central electrodes proved to be markedly displaced to the walls.

Obviously, incorrectly set central electrodes changed the capacitance of the ionization chamber as compared with the standard. Analogous data were reported by the associate of Rostov X-ray Station, N.K. Meserev. Thus, it can be assumed that also in the other set of individual dosimeters there is a definite number of inadequate chambers where the evaluation of measurement recordings introduces an error into the practice of individual dosimetry. The use of such dosimeters, naturally, led to errors even when daily individual dosimetry was conducted, thus causing doubt in the correctness of the individual control as a whole.

A situation of this kind leads to the desorientation of individuals subjected to the effect of ionizing radiations, as well as the workers who are in charge of ensuring radiation safety; it weakens their attention to the problem of personal safety and prevents them from the timely carrying out of corresponding sanitary-hygienic and therapeutic-prophylactic measures.

In order to eliminate errors in recording the magnitudes of weekly irradiation doses, connected with self-discharge of the chambers, it is necessary to conduct a thorough preliminary check-up of all dosimeters on self-discharge as follows. The charged chambers are left for one week in a room

where the possibility of the effect of ionizing radiation is definitely excluded. After a week, readings are recorded of the degree of self-discharge in each dosimeter; the readings are entered in a special journal. Individual dosimeters in which the chamber discharge shows more than 0.05 r per week should be considered unusable; the discharge recordings of other dosimeters which usually comprise 0.01 to 0.03 r per week should be subtracted from the operating indexes of weekly dosimetry.

Once every three months a control check-up should be made of the chambers for the weekly self-discharge. The magnitude of irradiation dose for each three months should be entered in the ambulatory record together with the data of periodical medical examinations. When an employee is referred for consultation to the hospital or to the chief occupational pathologist it is necessary to mark down the dynamics of occupational irradiation of the employee, according to a three month's period.

Received 11 April 1962

The Problem of Determining the Maximum Permissible
Levels of Strontium-90 Content in Food Products

pages 83-89

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Long-life radioactive isotopes (strontium-90, cesium-137, cerium-144, and others), falling out from the stratosphere and upper layers of the troposphere on the earth surface together with radioactive precipitates, are included in the general cycle of substances in nature and may, jointly with the stable isotopes, enter the human organism along various biological chains, depending on their physical and chemical properties, physico-chemical form, and other conditions.

In Table 1 are cited the data relating to the most important radioactive isotopes from the point of view of radiation hygiene.

Of all radioactive isotopes responsible for the artificial radioactivity of the biosphere strontium-90 is most important to man. It is chemically analogous to calcium, and together with the latter it participates in the structure of the growing bone tissue. It is considered at present that 99 percent of strontium deposited in the entire organism is firmly fixed in the bone tissue (International Commission on Radiological Protection, 1959), by creating in it a certain depot from which the radiation effect takes place.

There are three principal ways of entry of strontium-90 into a human organism: with the inhaled air, drinking water, and food products. Each of these ways does not completely exclude the other two means of entry of strontium-90 into a human organism; hence, the accumulation of this radioisotope in the bone tissue takes place at the expense of a simultaneous entry of strontium-90 with the inhaled air, drinking water, and food products. However, in studying each of these ways of entry of strontium-90, it is easy to ascertain that the amount of isotope entering the organism by various ways is not uniform.

The inhalation way is of the least importance, because the strontium-90 content in the surrounding air is at present negligible, and is many times lower than the maximum permissible levels (MPL). The role of drinking water is also insign-

nificant, since via water, according to the available data, no more than 10 percent of the total strontium-90 entering the organism can be accounted for (Bryant, et al.). Most important, hygienically, is the entry of strontium-90 into the organism by means of food products. This type of entry includes the greatest number of biological chains, the most important of which are: soil -- plant -- man; soil -- plant -- animal -- animal husbandry products -- man; water -- animal -- animal husbandry products -- man, etc.

As per data of English scientists (Hauthorn, Bryant, Chamberlain, et al.), the mean strontium-90 concentration in milk on the farms of Great Britain comprised in 1959 on the average 9.6 micromicrones per gram of calcium (10 micromicrones per liter of milk). The greatest concentration was noted in Central Wales where it reached 32 micromicrones per gram of calcium.

It has been established by the investigations of Japanese scientists Nezu and Asano in the city of Mito that, during the first six months of 1960, the strontium-90 content in vegetables and greens varied from 12.4 to 21.2 mmc per kg of raw weight. According to the data of American scientists Michelson and Erving, who had determined the levels of the content of radioactive substances in the samples of milk and other food products, obtained from various cities of the United States in 1960, the daily entry of strontium-90 with milk comprised on the average 10.9 mmc per gram of calcium, and with the rest of the food -- approximately 19.5 mmc per gram of calcium.

A correct hygienic evaluation of the results of radiochemical and radiometric determinations of strontium-90 in food products can be based only on their comparison with the MPL magnitudes. One must also never forget that the extent of their accumulation in the human organism and, hence, the degree of their radiation effect depend on the fact as to how correctly one had determined the MPLs of the content of various radioisotopes in the air, water, and food products.

The data in the literature on the magnitudes of MPL content of strontium-90 in the food products are contradictory. Thus, for example, prior to the beginning of 1960 in the United States the Maximum Permissible Concentration (MPC) of strontium-90, according to the recommendations of the National Committee on Radiological Protection of the United States, comprised 08 mmc per kg of the product or liter of milk, Ac-

According to the other data, the figure of 100 mmc per gm of calcium in the product was taken as maximally permissible. The Committee of the National Academy of Sciences of the United States in its report recommended as a maximally permissible concentration (MPC) 100 mmc per gm of calcium, but in the same report a magnitude of 50 mmc per gm of calcium is mentioned. The Ministry of Health of the State of California suggested in April 1958, as a MPC, $2 \cdot 10^{-10}$ c of strontium-90 per kg of the food product (milk, vegetables, etc.). In February 1959, the 2nd Subcommittee of the National Committee of Radiological Protection of the United States in its unofficial suggestions recommended to reduce the levels of permissible strontium-90 content in food products. Thus, for example, the MPC of strontium-90 in milk was planned to be reduced from 80 to 60 mmc and even to 16 mmc per liter.

In March 1960 a report appeared in the American press that the MPC of strontium-90 in milk and other food products, as well as in water and air, has been reduced from 80 to 33 mmc per kg or liter. Following an accident which had taken place in one of the reactors of the Windscale Atomic Center (Great Britain), the Council of Medical Research of Great Britain, jointly with its subcommittees on external and internal irradiation, decreed that for prolonged periods of time and independently of the age of individuals residing on a territory contaminated with radioactive fallout the dose of daily entry of strontium-90 into food products should not be permitted to exceed $2 \cdot 10^{-9}$ c. It was pointed out that, at this concentration of strontium-90 and the daily entry into the organism of one gram of calcium, the concentration of this isotope in the growing bones will not exceed one quarter of its concentration in the diet, i.e., 0.5 mmc per gm of calcium (500 SU) (1). The dose in the inorganic part of the bone will not under these circumstances exceed 1.5 rad annually, and the irradiation dose of the bone marrow will be considerably less.

In the Soviet Union the MPC of radioactive substances in food products of vegetable and animal origin is usually calculated on the basis that the total amount of activity entering with the daily ration, including water, should not exceed 2.2 MPC curies daily, where 2.2 liters per day is the accepted MPC 24-hour consumption of water, and MPC -- the maxi-

(1) One strontium unit (SU) represents concentration of strontium-90 in human bones, soil, food products, and other objects of investigation expressed in mmc per one gram of calcium.

maximum permissible concentrations of radioactive substances in water (sanitary regulations No 333-60).

According to the recommendations of the International Committee of Radiological Protection (ICRP) (Munich, 1959), the MPC of strontium-90 in drinking water, used by the population residing near the so-called controlled zone, has been determined as equalling $1 \cdot 10^{-10}$ curies per liter, and for the rest of the population -- $3 \cdot 10^{-11}$ curies per liter. It follows from the above data that the maximally permissible entry of strontium-90 with food products and water into the gastrointestinal tract for the population residing near the controlled zone must not exceed $2.2 \cdot 10^{-10}$ per 24 hours, and for the rest of the population this figure is reduced 3-fold and comprises $6.6 \cdot 10^{-11}$ curies per 24 hours.

In sanitary regulations No 333-60, approved on 25 June 1960 by the chief state sanitary inspector of the USSR and chairman of the State Committee of the Council of Ministers USSR on the Use of Atomic Energy, the MPC of strontium-90 in water has been established as equal to $3 \cdot 10^{-11}$ c per liter. On this basis, the magnitude of maximum permissible 24-hour entry of strontium-90 was established as equal to $2.2 \cdot 3 \cdot 10^{-11} = 6.6 \cdot 10^{-11}$ c. In Table 2 are cited the data on maximally permissible entry doses of strontium-90 into the human organism, accepted by various international organizations, national committees, and State Sanitary Inspection of the USSR.

Unfortunately, in the sanitary regulations No 333-60 no concrete calculation method is cited of the MPC of radioactive isotopes in the food products. The regulations only mention that the MPC of various isotopes in the food products of vegetable and animal origin is established according to local conditions, taking into account that the total amount of activity entering with the 24-hour ration should not exceed 2.2 MPC curies per 24 hours. It is stipulated simultaneously that this recommendation is based on a very rough estimate and that in each concrete case a special scrutiny is needed based on more precise calculations.

It can thus be stated that in the approach to the substantiation of MPCs of radiostrontium in food products there is no unanimous opinion as to the method of their calculation.

It is perfectly obvious that it would be incorrect to accept the same MPC value for all types of food products irrespective of their nutritive value and their content of mineral substances. The basic difficulty of ascertaining the MPC

Table 1. Radioactive isotopes which are of interest from the point of view of radiation hygiene

| Радиоактивный элемент (1) | Время при жизни Уран-235 (в %) | Нагрузка (3) | Эффективный период полувыделения из организма человека (в днях) (4) | Критический орган (5) | Доля энергии, выделяемая из организма человека в критическом органе (в %) | Предельно допустимое содержание изотопа в критическом органе (в %) | Предельно допустимая концентрация изотопа в воздухе рабочей зоны (в см ³) (8) |
|---------------------------|--------------------------------|--------------|---|------------------------|---|--|---|
| Углерод-14 (9) | - | β | 12 | Жировая ткань (21) | 0,5 | 300 | $2 \cdot 10^{-7}$ |
| Стронций-89 (10) | 4,6 | β | 50,4 | Кости (22) | 0,21 | 4 | $3 \cdot 10^{-9}$ |
| Стронций-90 (11) | 5,0 | β | 6400 | " | 0,09 | 2 | $3 \cdot 10^{-11}$ |
| Иттрий-91 (12) | 5,0 | β | 58 | " | $7,5 \cdot 10^{-5}$ | 5 | $8 \cdot 10^{-9}$ |
| Цезий-95 (13) | 6,4 | β, γ | 55,5 | Все тело (23) | 10^{-1} | 20 | $2 \cdot 10^{-6}$ |
| Иттрий-95 (14) | 6,4 | β, γ | 33,5 | " | 10^{-1} | 40 | $3 \cdot 10^{-8}$ |
| Род-131 (15) | 2,8 | β, γ | 7,6 | Щитовидная железа (24) | 0,3 | 0,7 | $6 \cdot 10^{-10}$ |
| Цезий-137 (16) | 6,2 | β, γ | 40 | Все тело (23) | 1,0 | 30 | $1 \cdot 10^{-9}$ |
| Барий-140 (17) | 6,0 | β, γ | 10,7 | Кости (22) | 0,035 | 4 | $7 \cdot 10^{-9}$ |
| Кезий-144 (18) | 5,3 | β, γ | 243 | " | $3 \cdot 10^{-4}$ | 5 | $3 \cdot 10^{-9}$ |
| Прометий-147 (19) | 2,6 | β | 570 | " | $2,5 \cdot 10^{-5}$ | 60 | $6 \cdot 10^{-9}$ |
| Плутоний-239 (20) | - | - | 172000 | " | $2,4 \cdot 10^{-5}$ | 0,04 | $5 \cdot 10^{-11}$ |

- 1 Radioactive isotope
- 2 Yield upon fission of uranium-235 (in percentages)
- 3 Radiation
- 4 Effective period of half elimination from the human organism (in days)
- 5 Critical organ
- 6 Isotope fraction entering the critical organ from the human gastrointestinal tract
- 7 Maximally permissible content of the isotope in the critical organ (μс)

- 8 MPC in the water of open reservoirs (in curies per liter)
- 9 Carbon-14
- 10 Strontium-89
- 11 Strontium-90
- 12 Yttrium-91
- 13 Zirconium-95
- 14 Niobium-95
- 15 Iodine-131
- 16 Cesium-137
- 17 Barium-140
- 18 Cerium-144
- 19 Promethium-147
- 20 Plutonium -239
- 21 Fatty tissue
- 22 Bones
- 23 Entire body
- 24 Thyroid gland

Remarks: The data on the yield of various isotopes upon fission of uranium-235 and in the form of radiation are cited according to Landham and Anderson; regarding the effective period of half-elimination, the critical organs, the isotope fraction entering from the gastrointestinal canal into the critical organ, and the MFLs of the content of the content of radioactive isotopes in the critical organ -- according to the recommendations of ICRP (1959); the MPCs in the water of open reservoirs -- according to the sanitary regulations No. 333-60.

of strontium-90 in food products consists of the heterogeneity of the chemical composition of various products, including their content of trace elements.

Table 2. Maximally permissible doses of strontium-90 content in a 24-hour ration of the population, accepted by various organizations

| Источники информации ① | Предельно допустимое поступление стронция-90 в 24-часовой рацион ② | |
|---|--|-------------------|
| | в к. э. в сутки ③ | в с. э. в сутки ④ |
| Рекомендации Совета медицинских исследований Великобритании для загрязненного радиоактивными осадками района ⑤ | $2 \cdot 10^{-9}$ | 2000 |
| Рекомендации МКРЗ-1959 для населения контролируемой зоны ⑥ | $2,2 \cdot 10^{-10}$ | 220 |
| Рекомендации МКРЗ, 1959 г., МКРЗ 1960 г. и санитарные правила № 333-60, утвержденные Государственной санитарной инспекцией СССР для всего населения ⑦ | $6,6 \cdot 10^{-11}$ | 66 |

- 1 Source of information
- 2 Maximally permissible strontium-90 entry with 24-hour ration
- 3 in curies per 24 hours
- 4 in strontium units (SU) per 24 hours
- 5 Recommendations of the Council of Medical Research of Great Britain for a region contaminated with radioactive fallout
- 6 Recommendations of ICRP-1959 for the population residing near the controlled zone
- 7 Recommendations of ICRP, 1959, ICRP, 1960, and sanitary regulations No 333-60, approved by the State Sanitary Inspection of the USSR for the entire population

Remarks: Estimate of 24-hour entry into the organism of strontium-90 in strontium units has been made on the premise that the average entry of calcium with the daily diet is within the range of one gram.

Strontium represents an element of the alkali earth group; in its chemical characteristics it is similar to calcium, barium, and radium. Strontium-90 is precipitated together with calcium in the form of phosphates or carbonates and, upon entering the human organism, it is deposited together with these elements mainly in the bone tissue. It

accompanies calcium in its move along the biological nutrition chains from the biosphere into the human organism. The quantitative content of calcium in the ration exerts a considerable effect on the strontium-90 metabolism. On the basis of above-indicated data, we consider it more correct to evaluate the MPC of strontium-90 in various food products in connection with their calcium content.

The 24-hour entry of calcium into the human organism fluctuates for various terrestrial regions between 0.24 to 1.87 grams per 24 hours. A child, despite its smaller weight than that of an adult, needs no less than a gram of calcium in its daily food ration (B.I. Zbarskiy, G. Sherman).

Calcium belongs to the elements is assimilated with difficulty. Its assimilability depends to a great extent on the content of other elements in the food and, in the first place, phosphorus and magnesium, as well as proteins and fats. In this connection, the 24-hour calcium norm is determined not so much by its absolute food content, as by the ratio between it and other food ingredients (phosphorus, etc.). At its optimal ratio to the above components, the 24-hour assimilation of calcium should range within 0.8 grams (B.I. Zbarskiy). The majority of regions of the RSFSR, the Ukraine, and Belorussia are characterized by a sufficiently high calcium content of the diet. In the regions where calcium content in the local products is low its lack is compensated by the supply of calcium-enriched products from other regions of the country, as well as through a special calcination of a number of products which comprise the 24-hour ratio (for instance, calcination of bread by means of thorough baking).

For the purpose of evaluating the magnitude of calcium intake with a 24-hour ration we accepted it as one gram, which is within range of the true average calcium content in the diet of the majority of population of the Soviet Union. On the basis of the data in Table 2 and of the content of calcium in various nutrition products (I.S. Popov, M.F. Tomme, et al.), an estimate was made of the MPC of strontium-90 for various food products. The obtained data are summarized in Table 3.

Such an approach in the determination of strontium-90 MPC in various food products is, in our opinion, better substantiated because it offers a more correct idea as to the role of various products as "suppliers" of strontium-90 to the organism, as well as their specific importance in the overall activity of the 24-hour ration in regard to strontium-90;

it also makes possible the regulation of the quantity of the entry of strontium-90 into the human organism with the food.

Table 3. MPCs of strontium-90 in food products (in curies per kg or liter)

| Породный продукт ① | Содержание кальция (в г на 1 кг продукта) ② | Предельно допустимая концентрация стронция-90 (в 1 кг или 1 л) в различных пищевых продуктах, рассчитанная на основании рекомендаций ③ | | |
|--------------------|---|--|--|---|
| | | Совета медицинских исследований Великобритании для ограниченного радиоактивного загрязнения района ④ | МКРЗ, 1959 г. для населения, проживающего вблизи контролируемой зоны ⑤ | МКРЗ, 1959 г. и МКРЗ, 1960 г. в санитарных правилах № 333-60, утвержденных Главной Государственной инспекцией для всего населения ⑥ |
| Молоко ⑦ | 1,30 | $2,4 \cdot 10^{-9}$ | $2,7 \cdot 10^{-10}$ | $7,9 \cdot 10^{-11}$ |
| Творог ⑧ | 3,00 | $6,0 \cdot 10^{-9}$ | $6,6 \cdot 10^{-10}$ | $2,1 \cdot 10^{-10}$ |
| Сыр ⑨ | 9,30 | $1,9 \cdot 10^{-8}$ | $2,1 \cdot 10^{-9}$ | $6,6 \cdot 10^{-10}$ |
| Картофель ⑩ | 0,14 | $2,8 \cdot 10^{-1}$ | $3,1 \cdot 10^{-1}$ | $1,0 \cdot 10^{-11}$ |
| Зерно ⑪ | 0,60 | $1,2 \cdot 10^{-6}$ | $1,3 \cdot 10^{-10}$ | $4,2 \cdot 10^{-11}$ |
| Капуста ⑫ | 0,48 | $9,0 \cdot 10^{-10}$ | $1,0 \cdot 10^{-10}$ | $3,2 \cdot 10^{-11}$ |
| Свекла ⑬ | 0,40 | $8,0 \cdot 10^{-10}$ | $0,9 \cdot 10^{-10}$ | $2,8 \cdot 10^{-11}$ |
| Морковь ⑭ | 0,60 | $1,2 \cdot 10^{-9}$ | $1,3 \cdot 10^{-10}$ | $4,2 \cdot 10^{-11}$ |
| Яблоки ⑮ | 0,07 | $1,4 \cdot 10^{-10}$ | $1,5 \cdot 10^{-11}$ | $5,0 \cdot 10^{-12}$ |
| Говядина ⑯ | 0,12 | $2,4 \cdot 10^{-10}$ | $2,7 \cdot 10^{-11}$ | $7,9 \cdot 10^{-12}$ |
| Свинина ⑰ | 0,06 | $1,2 \cdot 10^{-10}$ | $1,3 \cdot 10^{-11}$ | $4,2 \cdot 10^{-12}$ |
| Любой продукт ⑱ | K | $2 \cdot 10^{-9}$ K | $2,2 \cdot 10^{-10}$ K | $6,6 \cdot 10^{-11}$ K |

- 1 Food product
- 2 Calcium content (in grams per one kg of product)
- 3 MPC of strontium-90 (in curies per kg or liter) in various food products, calculated on the recommended basis
- 4 Of the Council of Medical Research of Great Britain for a region contaminated with radioactive fallout
- 5 Of the International Committee of Radiation Protection, 1959, for the population residing near the controlled zone
- 6 Of the ICRP, 1959, NCRP, 1960, and sanitary regulations No 333-60, approved by the Main State Inspection for the entire population
- 7 Milk
- 8 Cottage cheese
- 9 Cheese

- 10 Potatoes
- 11 Grain
- 12 Cabbage
- 13 Beets
- 14 Carrots
- 15 Apples
- 16 Beef
- 17 Pork
- 18 Any product

The correctness of the suggested method of estimating the MPC of radiostrontium in food products is strengthened by the estimation of its possible accumulation in the human organism. The strontium-90 concentration in human bones (upon establishing a balance) can be estimated according to the following formula

$$Q \text{ of bone} = \alpha \cdot Q \text{ of food}$$

where Q of bone -- strontium-90 concentration in the newly formed bone tissue (in SU); α -- discrimination coefficient of "food -- bone" Q of food -- mean level of the strontium-90 content in a 24-hour portion (in SU).

According to numerous investigations, the discrimination coefficient of "food -- bone" (α), under conditions of human diet consisting of regular mixed food, comprises 0.25 (report of the Scientific Council of the USSR).

Based on this formula, it is easily possible to prove that, upon prolonged use of food products where the human gastrointestinal tract receives a total of no more than $0.66 \cdot 10^{-10}$ c (66 SU -- maximally permissible magnitude for the entire population) and $2.2 \cdot 10^{-10}$ curies per 24 hours (220 SU -- maximally permissible magnitude for the population residing near the controlled zone), an average of not more than 16.5 and 55 SU can become accumulated in the organism of these individuals, when a balanced concentration has taken place.

At the same time, according to the ICRP recommendations (1959), the MPC of strontium-90 in the organism of large population groups ("load" on the organism) comprises 67 SU, and in the organism of individuals residing near the controlled zone -- 200 SU.

In the sanitary regulations No 333-60 no concrete figures were given of the permissible content of various radionuclides, including strontium-90, in the organism or in the critical human organ. Nevertheless, by employing Table 1 regarding maximally permissible doses of external and internal irradiation for various population groups, cited in the appendix No 2 to these regulations, it is possible to show that, in the case of individuals residing within the range of the sanitary-protective zone (B category) and of the entire population (C category), the content ("load") of this isotope in human bones is also permitted, respectively, as 200 SU and 67 SU. Indeed, according to these regulations, internal irradiation is permitted of the critical organs of the 3rd group, to which also the bones belong, with a dose of three ber/year (biological equivalent roentgen) for the B category and one ber/year for the C category. At present it is customary to accept that one SU, taking into account the non-uniform distribution of strontium-90 in the bones, creates a dose of 0.015 ber/year (N.G. Gusev, Irgan). The ratio of magnitudes of the permissible annual dose of internal irradiation to the dose, induced by strontium-90 with specific concentration of one SU present in the bone, enables one to obtain the sought magnitudes of the permissible "load" on the organism as 200 SU for the B category and 67 SU for the C category.

Comparison of the above magnitudes (200 SU and 67 SU) with the possible "loads on the organism," calculated on the basis of the data on the permissible (according to regulations No 333-60) strontium-90 content in the population's diet, shows that the sanitary regulations provide a four-fold reserve in regard to the MPC of strontium-90 in the ration.

In conclusion it should be pointed out that with all above stated data we do not wish to insist on the premise that the magnitude of permissible strontium-90 entry into the organism, or the MPLs of strontium-90 content in food products must be expressed in strontium units. We only wish to underline that the method of calculation of MPC of strontium-90 in food products, based on the evaluation of calcium present in the food products, is more correct.

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**Comments on Sanitary Rules of Work with Radioactive
Substances and Sources of Ionizing Radiation**

pages 95-96

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"Sanitary rules of work with radioactive substances and sources of ionizing radiations," published in 1960, despite their unquestionable advanced nature, are not free of certain faults. In a number of instances, in the supplements, there is no sufficient clarity in the statement of premises, accurate use of designations, terms and, even, measurements. These defects not only hamper the use of the regulations, but may even lead to various interpretations of the same clauses. The following additions, changes, and clarifications are suggested.

1. In supplement No 1, paragraphs 12-16, useful information is cited regarding alpha-, beta, and gamma-X-ray and neutron radiations, respectively, but there are no data on their characteristic -- the ionizing effect and penetrating property -- both representing an important prerequisite for creating an idea of the most important fact -- the radiation danger and relative biological effectiveness (RBE) of these radiations.

These paragraphs should be supplemented with information concerning the ionizing effect and penetrating property of the corresponding radiations.

2. On the basis of the same considerations, it is advisable to include in supplement No 1 additional paragraphs concerning the nature and properties of other radiations -- the flow of multicharged ions, recoil nuclei, and thermal and fast neutrons (and not simply neutrons as mentioned in paragraph 16).

3. Before paragraph 27 on the maximum permissible dose it is more expedient to include a special paragraph with a precise determination and indication of the size and strength of the dose. This paragraph can be formulated as follows: "A dose is the radiation measure which is gaged by means of roentgen in gamma- and X-ray radiations, and by the physical

equivalent of roentgen in other radiations. The strength of a dose related to the unit of time; it is gaged in $\frac{R}{hr}$, or by the ratio of roentgen unit derivatives to the given time segment (minute, hour, week, etc.)." The absence of such formulations and indications of measurements in the examined supplements resulted, to a certain extent, in a lesser precision of definitions, terms, and measurements.

Indeed, the doses are designated in Table 1 by the extent of the strength of the dose ($\frac{R}{hr}$) and ($\frac{R}{week}$), and in Table 2 it refers to the strength of the dose, wherein the dose is designated by the extent of the strength of the dose on page 50 (paragraph 5), 51 (paragraph 6 and 8), 53 (paragraph 4), 72 (paragraph 6, twice), 74, etc.

4. There is no justification for the lack of preciseness in the use of designations -- a fact which greatly hampers the use of the book. On page 69 the letter K designates a gamma-constant of an isotope, and on page 70 -- a complete gamma-constant of an isotope. In formula (3) representing the strength of r dose and D dose K-gamma is included. On page 69 the letter D is employed to designate the dose, whereas two pages previously the letters D-gamma, D₀, n, D₀, n and D₀ designate the strengths of gamma-rays, thermal neutrons, fast neutrons, and the maximally permissible dose. The designation of the dose with letter D and the dose strength with letter r should be strictly followed in all regulations and supplements.

5. It follows from formula 1 on page 69: $M = \frac{Q \cdot K}{0.4}$ and formula on page 70: $t = \frac{M \cdot mg\text{-equiv of Radium}}{Q \text{ curies}}$ shows the quantity of milligram-equivalents (mg-equiv) of radium which correspond to the activity of one microcurie. Therefore, it would be more correct to designate m as the gamma-activity of the isotope in mg-equiv of radium, and the product $t \cdot Q = M$ as the complete gamma-activity. In Table 2 of supplement 3 the letter M designates the activity of gamma-radiation sources in mg-equiv of radium, and on page 69 it designates the gram-equivalent. Letter t on page 70 designates a coefficient, and on page 92 (supplement 5) -- a gamma-equivalent.

The need of straightening out the terms, designations, and measurements is perfectly obvious, and this should have been done during the first reissue of the book.

6. Without entering into a discussion concerning the

substantiation of the real necessity of establishing three categories of irradiation, it can be pointed out that the Table 1 of supplement 2 is scarcely necessary. In the first place, for each category one maximally permissible dose (strength?) was shown, regardless of radiation properties whereas for category A in Table 2 various strengths of doses were envisaged, based on the table of radiation properties. Instead of citing a table, it would have sufficed to mention in the footnote: for category B -- 10-fold, category C -- 100-fold less, as compared with category A. Secondly, the internal irradiation is regulated by the maximum permissible concentration (MPC) established in Table 5 of supplement 2. If MPC ensures safety at the place of work, why introduce in addition some maximally permissible doses of internal irradiation of individual organs, and is the second half of Table 1 necessary? We must also take into account that the MPCs themselves must still be verified.

Thirdly, the dose strength $1 \frac{\text{mber}}{\text{week}}$, established for category C, can be variously interpreted on account of the lack of concrete specification as to time. Thus, for example, if this category will be irradiated for the period of the action time of the ionizing radiation device, then at a 36-hour week the excess of the dose strength of the natural background will $\frac{1 \text{ mber}}{\text{week}} = \frac{1}{36} \frac{\text{mber}}{\text{hour}} \approx 0.03 \frac{\text{mber}}{\text{hour}}$, i.e., almost three-fold greater than the excess envisaged in paragraph 22 of the regulations.

7. Also doubtful is the part of paragraph 5 of supplement 2 which states that 100 mber correspond to 100 mrad, since these units differ as to the amount of consumed energy (93 and 100 $\frac{\text{erg}}{\text{g}}$).

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**Changes in the Nasal Mucous Membrane Upon Adaptation
to Cold in the North**

pages 97-99

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As a result of observations conducted in the North, a high resistance to cold was found in individuals with a long work record under these conditions.

The increased resistance to cold, as shown by observations, not only produces a good work capacity of these individuals under conditions of low temperatures but also leads to a lesser incidence of respiratory diseases. An entirely different picture is observed in individuals who have worked in the North less than a year. They were compelled to discontinue their work in the cold on account of severe pains in the unprotected parts of the body. Simultaneously, an increased incidence in the number of cases of respiratory diseases was noted in these individuals.

This fact led to the investigation of the phenomena originating as the result of cooling off of the nasal mucosa and the upper respiratory tract.

A number of authors studied the reaction of nasal mucosa vessels to repeated cooling of various parts of the body, but they were conducted under experimental conditions only (V.F. Undrits and R.A. Zasosov, 1932; M.Ye. Marshak and N.K. Vereshchagin, 1935; N.F. Timofeyov and N.Ya. Sinitsina, 1940; B.B. Keyranskiy, 1948; F.F. Lebedev, 1934, et al.).

We conducted observations on 130 individuals of various length of service in the North. After a 50-minute adaptation to room temperature (18 to 20° at relative humidity of 50 percent), the lower extremities were cooled in water at 5° temperature for 30 minutes. The vascular reaction of nasal mucosa was judged according to the temperature of the latter, measured by means of copper-constantan thermocouples.

The obtained results are shown in Fig 1. In a consider-

able number of the investigated, with a short work period in the North (two to five months), upon cooling of the lower extremities, a marked vascular reaction was observed in the nasal mucosa which was manifested in a sharp reflex spasm of the vessels during the first minutes of cooling, and a gradual vascular dilatation toward the end of the cooling period (Fig 1,A).

In a lesser part of investigated with a short work period in the North, the cooling of lower extremities led, on the contrary, to a marked vascular dilatation with a considerable influx of blood to the nasal mucosa. This condition was observed during the entire period of cooling of the lower extremities (Fig. 1, B).

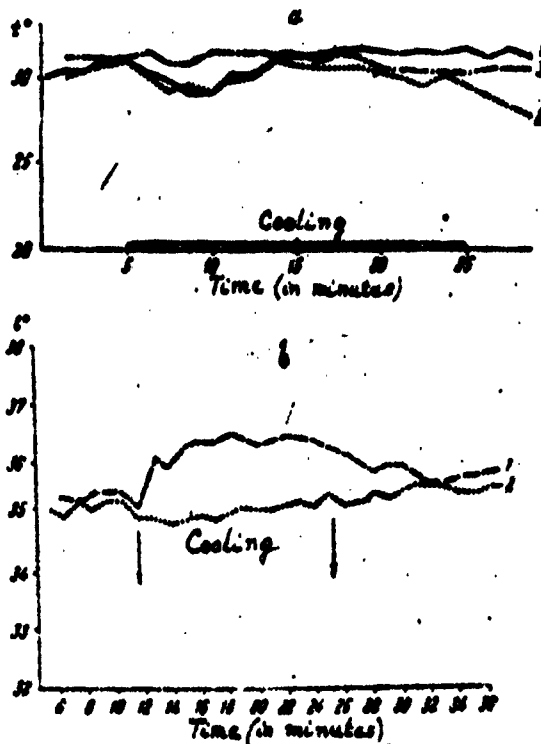
In investigated individuals with work period in the North over two years no such reactions were noted following cooling of the lower extremities.

The non-uniform trend of the reaction to cooling of lower extremities in individuals with a short period of service in the North, apparently, is the result of a different set-up of the physical thermoregulation. The important fact is, however, that the reaction itself in these individuals was fairly well expressed. With the lengthening of work service in the North, the reaction of the nasal vessels to cooling gradually decreases and, even, completely disappears. In individuals with work service of over two years we observed no reaction whatsoever.

In order to follow up the vascular reaction changes in the nasal mucosa during the process of constantly repeated cooling of various parts of the body, we conducted experiments on a group comprising six individuals of short service periods in the North. The experiments consisted of a 15-minute daily cooling of lower extremities in water at 5° for a period of two months.

During the initial stage of the procedures with cooling of lower extremities, the temperature of nasal mucosa in some of the investigated rose sharply during cooling -- by one degree on the average, as compared with the initial temperature. In other individuals, on the contrary, during the moment of immersion of the lower extremities in water, a reduction of the temperature of nasal mucosa by 0.8° was noted. Within 7-8 minutes from the start of the experiment, the temperature of the nasal mucosa was restored and subsequently, even, exceeded the initial level. However, as time went on, the cha-

reactor of temperature reaction underwent a gradual change. Whereas in the beginning a rise in temperature was noted upon cooling of the lower extremities, within two months of adaptation procedures the temperature of nasal mucosa was holding at the initial level almost during the entire time of the cooling period.



Temperature changes of the nasal mucosa following cooling of lower extremities in individuals with various length of service in the North.

- a. 1 -- length of service up to a year;
 2 -- one to one-and-a-half years;
 3 -- up to three years.
- b. 1 -- short period of service;
 2 -- service period of two years, or more.

In other investigated, at the start of cooling procedures a reduction of the temperature of nasal mucosa was observed, with a subsequent rise, however, as the procedures were repeated, a gradual leveling off of the reaction was observed. Thus, for instance, after two months, the

temperature of nasal mucosa held almost at the same level during the cooling of lower extremities.

A characteristic feature is the feeling and behavior of the tested individuals during the first and subsequent days of cooling. Following the first few immersions of the lower extremities in cold water, the investigated noted a sensation of sharp pain in the cooled areas. Within a few minutes this sensation gradually abated, but it reappeared on the 10th-15th minute of cooling. Sometimes the procedure had to be stopped on account of sharp pains.

Simultaneously, following immersion of the lower extremities in water, almost all tested individuals noted a sensation of "scratching" in the nose and a mucous discharge. Objectively, a picture of coryza developed which lasted during the entire testing period. The body temperature in some individuals rose to 37 degrees. The pulse accelerated by two to five beats per minute, and the individuals noted a certain worsening of their general feeling.

These symptoms disappeared after the 8th-12th seance. The sharp pain experienced during the immersion of lower extremities in water also decreased considerably, so that the cooling could be extended to 30 minutes.

Thus, as the cooling seances continued, the reflex vascular reaction of the nasal mucosa and other concomitant phenomena gradually decreased and disappeared completely toward the end of the 2nd month. Hence, the periodically continued effect of cold during work in open air under Arctic conditions leads to a gradual abatement of all phenomena in the nasal mucosa which had been observed in individuals who had been working for a short period of time under these conditions. According to the data of I.S. Kandror (1960), et al., during the first few months of work in the North, the respiratory diseases were observed much more frequently than under conditions of extended periods of work. The question arises, whether the changes in nasal mucosa reaction are connected with the onset of respiratory diseases. Z.G. Rabinovich (1937) and I.V. Filatov (1936) observed, under conditions of general and local cooling, profound morphological changes in the nasal mucosa which attested to the impairment of the function of the nasal mucosa of the vascular system and glands.

According to the data of investigators (Francis, et al.), the nasal mucosa possesses virustatic properties. F.F. Lebedev,

A.N. Freydovich, L.G. Perets, et al., (1934) succeeded in demonstrating that nasal mucosa possesses not only virustatic but also bactericidal properties.

This leads to the conclusion that the change in the function of nasal mucosa, possibly, induces the impairment of the wholeness of the barrier and reduction of its protective properties. Hence, vasomotor disturbances and some morphological and histological changes in the nasal mucosa, probably, not only of the nose but also other parts of the upper respiratory pathways which, as shown by our observations, originate most frequently upon cooling of the lower extremities in non-acclimatized individuals, create conditions for the development and, possibly, also of intensification of the activity of microflora which is always present in these areas (Puchkov, Yerastov, (1) L.G. Perets, et al., 1947).

In the light of above stated it becomes clear why cooling of the extremities in individuals with a short work period in the North, or non-acclimatized ones, represents one of the important factors in the etiology of respiratory diseases. Apparently, upon cooling of lower extremities, not only certain protective reactions are absent in these individuals (very slow contraction of the blood vessels in the cooled area of the body, absence of an increased metabolism), but also an extensive generalized reaction sets in which causes in the nasal mucosa and other parts of the upper respiratory tract a number of changes which disorganize the normal activity of the mucosa. Therefore, prevention of the origin of conditions which contribute to the increased activity of microflora in the nasal mucosa and other parts of the upper respiratory tract is the paramount task.

Hence, an active adjustment to cold under Arctic conditions represents a factor which ensures a normal activity of the mucosa of the upper respiratory tract and considerably reduces the possibility of onset of certain respiratory diseases in these individuals.

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**Passage of Strontium-90 From Milk to Various
Dairy Products During Various Technological
Production Processes**

pages 105-108

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In the present work an attempt has been made to elucidate the problems of passage of strontium-90 into dairy products. No sufficient data have been published to judge the extent of the transfer of radioactive strontium from milk to dairy products which are widely used in human nutrition.

In the study of the passage of strontium-90 into dairy products a special experiment was conducted; it consisted of two parts: a) determination of the relative passage of calcium, stable strontium, and strontium-90 from milk during the standard technological process into cream, skimmed milk, casein, butter, and buttermilk; b) determination of the relative passage of calcium and strontium-90 to cottage cheese, cheese, and casein during the three different processes of their preparation.

The milk for experimentation was obtained from the same cow which had been previously contaminated with strontium-90. The milk products were obtained under laboratory conditions according to the technical process described in the book of M.S. Kovalenko (1960). All obtained products were calcined at 400 to 500°, in the obtained ashes the content of potassium, calcium, stable strontium and strontium-90 was determined. Calcium concentration was established by the standard oxalate-permanganate method. The determination error in regard to calcium was ± 5 percent.

The spectrographic method was employed in the determination of the content of potassium and stable strontium. The determination error was not higher than + 10 percent. Strontium-90 was isolated by means of fuming nitric acid, with subsequent separation of mixtures of rare earths on ferric hydroxide. The activity of samples was measured on a low background device (three imp/min) according to the yttrium-90 radiation on STS-5 counters. Determination error from + 8 to ± 30 percent.

The yield of ready products in the first part of the work is shown in the scheme. The content of strontium-90, stable strontium, calcium, and potassium-40 is cited in Table 1.

As seen in Table 1, the absolute content of strontium-90 is not uniform in various dairy products: high in casein and low in cream. The relative content of radioactive strontium per gram of calcium and milligram of stable strontium is virtually almost uniform in all dairy products. It means that radioactive strontium enters dairy products together with calcium, and that the processes of milk treatments affecting calcium concentration at the same time also change the concentration of strontium (the stable, as well as the radioactive one).

In Table 2 the data are cited regarding the passage of radioactive strontium from milk to various dairy products following processing. Knowing the yield of the product, the amount of potassium, calcium, and strontium which has passed from milk to each dairy product could be calculated (in percentages to their initial content in the milk).

It is seen from the data in Table 2 that from four to five percent of potassium, calcium, stable or radioactive strontium pass into cream. The passage of these elements from cream into butter could not be determined on account of a number of technical difficulties. However, since the entire mass of potassium, calcium, and strontium, contained in cream, has been detected in the final product after processing of butter to buttermilk, it could be assumed that even if strontium-90 passes into butter, its quantity is very small and is measured in fractions of one percent.

During the obtaining of casein and whey from skimmed milk, calcium, stable, and radioactive strontium were distributed proportionally: 20-25 percent of elements passed into casein, 60 to 70 percent -- into whey.

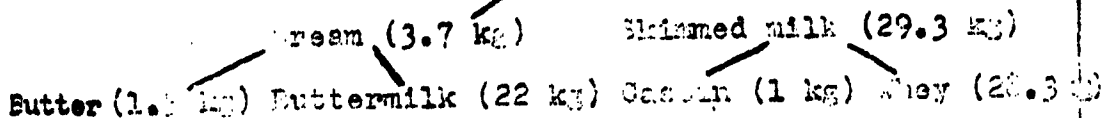
In the second part of the work, by means of three methods -- acid, acid rennet fermentation, and calcium chloride precipitation -- cottage cheese, cheese, and casein were obtained. The percentage yield of raw cheese was close to the state norms of expenditure of raw material for the obtaining of one kg of the product. The yield of cheese was approximately one-and-a-half times above norm, because in this experiment the cheese had not been subjected to the necessary ripening. Casein was analyzed in its raw form, without drying.

Table 1. Certain physicochemical indexes of the composition of milk and dairy products

| Product ① | Fat ② | ③ Components | | | | ④ Strontium | |
|----------------|-------|----------------|-----------|--------------------|--|------------------------|---------------------------------|
| | | potassium-40 ④ | calcium ⑤ | stable strontium ⑥ | strontium-90 ⑦ (in 10 ⁻¹⁰ c/kg) | strontium-90/calcium ⑧ | strontium-90/stable strontium ⑨ |
| Milk ⑩ | 4.0 | 1.08 | 1.00 | 0.49 | 5.28 ± 0.88 | 828 ± 79 | 1070 ± 210 |
| Cream ⑪ | 41.0 | 0.86 | 0.51 | 0.20 | 1.57 ± 0.21 | 278 ± 79 | 728 ± 220 |
| Skimmed milk ⑫ | 0.07 | 1.18 | 1.30 | 0.80 | 6.80 ± 1.40 | 888 ± 130 | 1260 ± 410 |
| Casein ⑬ | — | 0.88 | 8.12 | 3.80 | 28.0 ± 3.0 | 420 ± 88 | 925 ± 180 |
| Whey ⑭ | — | 1.23 | 0.69 | 0.38 | 2.80 ± 1.0 | 508 ± 178 | 828 ± 220 |
| Buttermilk ⑮ | — | 1.0 | 0.68 | 0.44 | — | — | — |

- 1 Product
- 2 Fat (in percentages)
- 3 Content
- 4 potassium-40 (in 10⁻⁹ in c/kg)
- 5 calcium (in gm/kg)
- 6 stable strontium (in mg/kg)
- 7 strontium-90 (in 10⁻¹⁰ in c/kg)
- 8 strontium-90/calcium
- 9 strontium-90/stable strontium
- 10 Milk
- 11 Cream
- 12 Skimmed milk
- 13 Casein
- 14 Whey
- 15 Buttermilk
- 16 Ratio

Yield of various dairy products
Milk (33kg)



However, the humidity of the same product obtained by various means was identical; therefore, the examination results of the mineral composition of the finished product were comparable.⁽¹⁾

Table 2. Passage of potassium, calcium, stable and radioactive strontium from milk to dairy products (in percentages)

| Продукт ① | Калий ② | Кальций ③ | Средний стронций ④ | Радиоактивный стронций ⑤ |
|-------------|------------|------------|--------------------|--------------------------|
| Сметана ⑥ | 3.7±0.7 | 8.7±0.6 | 4.4±0.9 | 3.3±1.0 |
| Опыт ⑦ | 100.0±20.0 | 100.0±10.0 | 88.0±18.0 | 101.0±20.0 |
| Сыворотка ⑧ | 100.0±20.0 | 89.0±8.0 | 68.0±14.0 | 87.0±28.0 |
| Казеин ⑨ | 8.0±0.6 | 28.0±3.0 | 23.0±4.0 | 20.0±4.0 |
| Творог ⑩ | 8.1±1.8 | 8.8±0.8 | 6.0±1.8 | |

- 1 Product
- 2 Potassium
- 3 Calcium
- 4 Stable strontium
- 5 Radioactive strontium
- 6 Cream
- 7 Skimmed milk
- 8 Whey
- 9 Casein
- 10 Buttermilk

In comparing the content of calcium in cottage cheese, cheese, and casein, as cited in Table 3, with the corresponding concentration cited in Sudagyan's table, it can be seen that in our experiments the calcium content was lower. In order to check on the obtained results, we determined the calcium content in wheys which were left, following the obtaining of curds. The amount of calcium contained in cottage cheese, cheese, and casein equalled the difference between its content in the original milk and whey.

(1) The humidity was determined on the apparatus of Chizkova according to the method developed by the All-Union Scientific Research Institute of the Dairy Industry and employed at all dairy farms.

The content of calcium and strontium-90 is given in Table 3

Table 3. Calcium and strontium-90 content in dairy products

| Продукт ① | Содержание кальция (г/кг) ② | Содержание стронция-90 (в 10^{-10} г/кг) ③ |
|--------------------------------|-----------------------------|--|
| Кислотный способ ④ | | |
| Творог ⑤ | $0,83 \pm 0,04$ | $2,0 \pm 0,2$ |
| Сыр ⑥ | $0,55 \pm 0,03$ | $1,3 \pm 0,1$ |
| Казеин ⑦ | $0,83 \pm 0,04$ | $2,8 \pm 0,3$ |
| Кислотно-сычужный способ ⑧ | | |
| Творог ⑤ | $0,91 \pm 0,5$ | $6,1 \pm 0,6$ |
| Сыр ⑥ | $0,92 \pm 0,05$ | $3,8 \pm 0,4$ |
| Казеин ⑦ | $1,06 \pm 0,05$ | $5,6 \pm 1,2$ |
| Осаждение хлористым кальцием ⑨ | | |
| Казеин ⑦ | $4,1 \pm 0,2$ | $11,8 \pm 1,2$ |

- 1 Product
- 2 Calcium content (in gm/kg)
- 3 Strontium-90 content (in 10^{-10} g/kg)
- 4 Acid method
- 5 Cottage cheese
- 6 Cheese
- 7 Casein
- 8 Acid-rennet fermentation method
- 9 Precipitation with calcium chloride

The data cited in Table 3 show that with the acid method the specific activity of the products was at the lowest level and comprised only half of the activity of milk. With the acid-rennet fermentation method the activity of products was somewhat higher. Maximal activity was observed upon precipitation of the curd with calcium chloride. The difference in the activity of the products obtained by various methods was analogous to the difference in calcium content.

It should be pointed out that, since cheese and casein were not of a standard consistency at the moment of analysis, it can be assumed that subsequently (after ripening) the specific activity of the products will in-

crease even more, and that the difference of the activity between these products and milk will be even greater.

Table 4. Passage of calcium and strontium-90 into cottage cheese, cheese, and casein during various technological processes of their preparation (in percentages)

| Продукт ① | Путь ② | | Средний процент кальция и стронция-90 в продукте ⑤ |
|-------------------------------------|-----------|---------------|--|
| | кальций ③ | стронций-90 ④ | |
| Кислотный способ ⑥ | | | |
| Творог ⑦ | 11,4±1,1 | 7,5±1,4 | 9,4 |
| Сыр ⑧ | 7,2±0,7 | 4,4±0,8 | 5,8 |
| Казеин ⑨ | 8,8±0,8 | 4,9±1,0 | 6,5 |
| Кислотно-сычужный способ ⑩ | | | |
| Творог ⑦ | 13,0±1,8 | 22,0±4,4 | 17,5 |
| Сыр ⑧ | 9,8±0,9 | 15,7±2,9 | 10,2 |
| Казеин ⑨ | 7,3±0,7 | 9,8±2,0 | 8,6 |
| Осаждение хлоридом кальция ⑪ | | | |
| Казеин ⑨ | 48,0±4,9 | 26,8±7,4 | 42,5 |

- 1 Product
- 2 Passage
- 3 of calcium
- 4 of strontium-90
- 5 Average percentage of calcium and strontium-90 passage into the product
- 6 Acid method
- 7 Cottage cheese
- 8 Cheese
- 9 Casein
- 10 Acid-rennet fermentation method
- 11 Precipitation with calcium chloride

The percentage of strontium-90 and calcium passage to various dairy products during various methods of their processing is shown in Table 4.

The above data show that the passage of calcium and strontium-90 to cottage cheese comprises 10-12 percent, to cheese 6-11 percent, to casein 6-9 percent. It should

be noted that the passage of these elements into various dairy products obtained by diverse technological processes is also not uniform: the smallest percentage of passage of strontium-90 and calcium from milk into dairy products was observed during the acid process of their preparation, and the highest -- upon precipitation with calcium chloride.

The result of the present work showed that technological processes which affect the calcium content in the finished product also affect the strontium content. It can be assumed that strontium in milk is bound with casein-phosphatecalcium complex in analogy with calcium.

Cream and butter can be prepared from milk contaminated with strontium-90 above the maximally permissible level, without resorting to special purification of the milk, because the percentage of strontium-90 passage to these products, especially to butter, is minimal.

Conclusions

1. The specific activity of various dairy products is not uniform. The activity of one kilogram of cream is three-fold lower, while that of cottage cheese, cheese, and casein is higher than the activity of milk.

2. Passage of strontium-90 from milk to cream comprises 4-5 percent, to butter -- less than one percent.

3. The specific activity of various dairy products depends on the method of their processing: with the acid method the activity of cottage cheese, cheese, and casein comprises only half of the activity of milk; with the acid-rennet fermentation method it is two-three-fold higher, and upon precipitation with calcium chloride it is five-fold higher than the activity of milk.

4. Milk contaminated with strontium-90 can be processed into cream and butter. When cottage cheese is obtained from contaminated milk, the acid method of processing is recommended, and in the case of cheese processing -- sour-milk cheeses are to be produced.

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