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MEDICAL AND BIOLOGICAL EFFECTS OF RADIOCESIUM INCORPORATED INTO THE HUMAN ORGANISM
The Institute of Radiation Safety "BELRAD"

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The publication deals with the effects of the biospheric radioactive cesium upon a man's health as well as with anti-radiation safety measures. In this book the author presents the results of his own numerous research, in particular, medical examination of large population groups from the territories contaminated by radioisotopes as a result of the Chernobyl disaster and laboratory tests on animals. Detailed analysis of pathological modifications is given, these modifications occurring in different organs and systems while radioactive cesium incorporation with account of its concentration. Special attention is paid to toxic effects of this radioisotope, the syndrom of incorporated long-living radioisotopes being emphasized. Data on personal safety measures to prevent radioactive cesium penetration into the human organism as well as the ways of its elimination are presented. The publication is intended for a wide range of people, practitioners and researchers, investigating the problems of incorporated radioactive elements upon the human organism.
INTRODUCTION

The problem of small dozes of incorporated radioisotopes.

Current situation in the Republic of Belarus forces everyone to think seriously about a man's health. From the demographical figures, there exists an evident threat to the nation's survival in the XXIst century. Analysis of causes and effects shows the leading role of radioactive elements in originating the most frequent pathological processes and illnesses, in particular, tumors, cardiac and vascular disorders. To our mind, it is connected with both the Chernobyl disaster of 1986 and numerous nuclear explosions in different point of the Planet which have happened long before. Huge amount of radioisotopes having been released into the environment, the lives of thousands and millions of people in the present and in the future will be subjected to constant danger.

The Chernobyl disaster (the greatest catastrophe of the 20th century) has still aggravated the problem of radiation effect upon the human organism. It has also allowed a number of latent negative issues to be brought to light. Here, loosely or unintentionally, the role of a scientist becomes more evident in estimating the negative effects of radiation.

The term "weak dozes of radioactive emission" has been continuously introduced into the society since the Chernobyl disaster. The essence, kept in mind, have not had any clear scientific definition. Radiobiological effects of the external radiation, in particular, one's understanding of acute and chronical radiation sickness, have formed the most likely basis to define this term. Their estimation started from some indefinite level or threshold, thus, acquiring the term "non-stochastic". For example, radiation doze of 1 Gray and above was thought to cause acute radiation sickness, it being lower, there existed no threat of the illness. Hence, lower level of radiation was accepted to be totally harmless for the human organism. This concept has been concerned with the external irradiation only. The situation with radioisotopes incorporation is quite the opposite. Its effect is considerably higher, it being connected both with radiation from the decaying elements and with their influence upon the metabolic processes in tissue and vital cell structures.
Here, it would be appropriate to consider the effects of different amounts of radioisotopes upon separate organs and systems as well as upon the organism on the whole. With account of scientific data available, there is no reason to speak of harmless radiation dozes, particularly those connected with radioisotopes incorporation.

Radioactive emission of any type (external or that connected with incorporated radioactive elements) may have unfavorable effect. Genetic consequences and carcinogenic effects of "weak" radiation dozes upon humans have been already described in detail, corresponding risk levels being revealed [27]. However, the effects of incorporated radioisotopes of different concentration upon the entire organism and separate systems have been completely ignored, this issue being of special significance while designing medical programs and carrying out the corresponding curative and preventive measures for every individual case.

For this reason, numerous scientific research of many thousands of children and adults' health, results evaluation of clinical and laboratory investigations and experiments on animals, structural investigations of vital organs of Gomel region residents after the Chernobyl disaster have been carried out at the Gomel Medical Institute in the period from 1990 to 1999.

The following methodological approaches form the basis for the investigation accomplished:

1) Assessment of the medical and biological effects with account of the dose of radioisotopes incorporated by the organism.
2) Investigation of pathological processes clinically and by experimental simulation among laboratory animals (the clinical and experimental approach).
3) Investigation of structural, functional and metabolic modifications evolving in the organism, its individual organs and systems.
4) Assessment of the severity of pathological conditions, such as disorders of the integrating processes in the organism. This approach allows pathological modifications in separate organs to be brought together.
Chapter 1

RADIOACTIVE CESIUM INCORPORATION INTO THE HUMAN OR ANIMAL ORGANISM, REASONS AND GOVERNING FACTORS.

As a result of the Chernobyl disaster in 1986, over 180 million Curies of radioactive substances have been released into the environment [16]. Among all the radioisotopes, radioactive Cesium takes the first place. About 3.1 thousand km$^2$ of the territory of Belarus, Russia and the Ukraine have been contaminated by this radioisotope, the contamination density there being over 1480 kBq/m$^2$, about 7.1 thousand km$^2$ with contamination density of 555-1480 kBq/m$^2$, about 17.9 thousand km$^2$ with that of 185-555 kBq/m$^2$, about 76.1 thousand km$^2$ with that of 37-185 kBq/m$^2$. Over 3.8 million people have inhabited this area by the moment of the disaster. There exist 23 known radioactive Cesium isotopes, 137 Cs and 134Cs being the most wide-spread ones. They have half-lives, respectively, 30 years and 2.06 years.

Cesium being easily dissolved in water and spreading rapidly in the environment, it could be detected at considerable distance from the disaster only several years after.

It should be emphasized, this radioisotope has been detected at the territory of the former USSR (in particular, Russia, Belarus and the Ukraine) already in the 60-ies, long before the Chernobyl disaster [15]. Its concentration in the atmosphere has been found considerable.

Having penetrated into the soil, Cesium is actively absorbed by plants and incorporates in the human and animal organisms with food. Agricultural plants (grain crops, vegetables, fruit), meat, milk, berries and mushrooms appear the main sources of this radioisotope in the human organism. The most usual way of cesium incorporation into the human organism is with milk, mushrooms, berries, wild animals meat. Its concentration may reach significant quantities. In particular, radiocesium concentration in the blueberries sam pie fram Stolinsky district, Brest region in 1996 was 7613 Bq/kg, that in mushrooms 24435 Bq/kg [17].

However, the existing radiation safety norms allow far more considerable radiocesium concentration in the human organism. In
1996 allowed for the Republic concentration of Cesium in beef and mutton reached as far as 600 Bq/kg, that in milk being up to 111 Bq/kg, in wild berries up to 185 Bq/kg, in dried mushrooms up to 2300 Bq/kg, in vegetables up to 100 Bq/kg, in potato up to 180 Bq/kg, in bread up to 74 Bq/kg.

Pronounced products consumption led to the considerable $^{137}$Cs accumulation in the organisms of millions of people both in the contaminated area and far around.

What concerns the residents of areas with high contamination level (Vetkovski district) radiocesium concentration increases as a function of age (Fig. 1). In particular, children born in 1978-1981 had the $^{137}$Cs concentration about 120 Bq/kg, meanwhile those born in 1989-1996 had it equal to 60 Bq/kg.

![Fig. 1. Comparative analysis of $^{137}$Cs accumulation among residents of Vetka as a function of age.](http://enfants-tchernobyl-belarus.org)

We see the reason for this process in more continuous period of $^{137}$Cs half-excretion for older children. Moreover, small kids in these regions are provided with food from the government sources with existing radiation products control.

Thus, the increase in radiocesium accumulation in the children's organisms from heavily contaminated areas should be emphasized (Fig. 2). Two brothers (born in 1982 and 1981) from the village of Svetilovichi, Vetkovski district, Gomel region may serve an example. The $^{137}$Cs concentration in their organisms has been respectively 1525 and 1882 Bq/kg, with average $^{137}$Cesium
concentration for local children being 128,38±13,83 Bq/kg (data of 1996).

Measurements of 1997 have revealed children with $^{137}$Cs concentration up to 2296 Bq/kg and 1257 Bq/kg, the fact that implies serious radiation load upon the human organism, 10,38 and 5,68 msV/per year respectively [17]. In 1993 three-to-seven year olds from Gomel have got the radiocesium concentration about 30,32±0,66 Bq/kg, while students aged 18 to 20 about 20-30 Bq/kg.

Radiocesium accumulation has been also registered among the kids of 3 to 7 years old from Grodno - about 29,74±0,67 Bq/kg (data of 1993) and also among 64% of junior pupils of Minsk, the average incorporation level being 14,0±1,46 Bq/kg (data of the year 2000).

Feeding laboratory animals with oats, containing about 400 Bq/kg of $^{137}$Cs, has manifested its significant accumulation in the organisms after several weeks (60-150 Bq/kg).

After perorai incorporation and absorption by blood, significant quantities of Cesium are secreted into the intestinal lumen.
and reabsorbed by the colon. Mainly kidneys are responsible for the excretion of $^{137}$Cs from the organism with urine and, occasionally, faeces.

Such natural incorporation of the radiocesium with food leads to its different accumulation in the organism with account of sex, age, physiological state, and in individual organs also with account of the pathological process character.

Pronounced differences in Cesium accumulation by males and females should be emphasized. Radiocesium being incorporated enterally, male organisms accumulate it more intensively than female. It is confirmed by the results of numerous experimental investigations (Fig.3) of laboratory animals and by radiometric measurements among the residents of the Gomel region.

![Graph showing $^{137}$Cs accumulation among experimental males and females.](http://enfants-tchernobyl-belarus.org)

Radiocesium concentration has been observed to rise considerably in the mother's organism during pregnancy. However, placental barrier presents a physiological protection for a foetus from radiocesium penetration. An offspring being born, it has minimum radioisotopes concentration. Later, radiocesium accumulates intensively in the organism with maternal milk (Fig.4).

In general, milk appears the most popular product among pre-school children and is mainly responsible for high radioisotopes
concentration. Here, the average $^{137}\text{Cs}$ concentration among the children of this very age from the relatively clean regions (Gomel) in 1993 has been the highest (30.0 Bq/kg) as compared to those of other ages, mainly due to high milk products consumption rate.

![Graph showing dynamics of $^{137}\text{Cs}$ accumulation among females and offsprings during lactation.]

It is very noticeable, people with rhesus-positive blood accumulate higher amount of radiocesium than those with rhesus-negative one. It has been confirmed by the results of pregnant women studies. Radioisotopes concentration in placenta among Rh-negative women has been authentically lower than among Rh-positive ones, respectively; 88.76 Bq/kg and 137.53 Bq/kg. Average $^{137}\text{Cs}$ concentration among Rh-negative students of the Gomel Medical Institute amounted to 18.09 ± 3.88 Bq/kg, while among those Rh-positive — to 23.81 ± 8.22 Bq/kg. Hence, clear interrelation between radioisotopes accumulation and protein antigenetic determinants on the red corpuscle surface which form the rhesus factor is observed.

With total $^{137}\text{Cesium}$ concentration among rats being 100-150 Bq/kg, heart manifested the highest rate of $^{137}\text{Cs}$ concentration.
The least concentration is found in the bone and muscular tissues (Fig. 5). However, they accumulate the main part of it, their mass taken into account. The $^{137}$Cs concentration in kidneys and spleen turns out considerable.

Skeleton muscles also turn to accumulate $^{137}$Cs, with a lot more Cesium being incorporated into the human organism (Fig. 6).

Study of the internal organs of adults and children who have died of different illnesses in Gomel again manifests the inhomogeneity in $^{137}$Cs accumulation (Fig. 7).

Radiometrical studies of the autopsied material have revealed clear dependence of $^{137}$Cs incorporation into the internal organs on the pathological process character.

In particular, heart muscle of those died of heart and vascular diseases contains authentically more $^{137}$Cs than of those died of the illnesses of alimentary canal. Infectious illnesses result in far larger amount of 137 Cs a$^{137}$ulated in liver, stomach, small intestine and pancreas, as compared to illnesses of heart, vascular and alimentary canal (mainly stomach and duodenum ulcer).
Children with infectious pathologies accumulate more $^{137}$Cs in skeletal muscles than those with congenital defects.

Hence, $^{137}$Cs incorporation in different organs and systems is observed among the residents of $^{137}$Cs contaminated regions, its degree depending on a series of factors, mainly on the $^{137}$Cs amount, penetrating into the human organism (primarily with food products), sex, age, physiological condition, their structural and functional parameters, the character and the degree of a pathological process.

Primarily kidneys excrete radiocesium from the organism. Up to 80% of $^{137}$Cs introduced within a single time is excreted within a month.

It should be noted, the period of $^{137}$Cs half-excretion from the human organism is 70 days, from mice 3 days, from rats 18 days [7].

There exists a number of agents, influencing the process of radioactive cesium incorporation by human and animal organisms, enterosorbents, in the first place, which combine radioactive elements, microelements, bacterial preparations, chemical
compounds in the lumen of the gastrointestinal tract which excrete them.

A variety of different groups of such compounds have been proposed. Yet, not all of them satisfy the requirements: 1) to restore the processes of metabolism, 2) not to distort the structure of the gastrointestinal tract and other organs.

A number of enterosorbents have been tested at the Gomel Medical Institute in 1992-1999 in experiments with laboratory animals to assess their effectiveness in respect to $^{137}$Cs.

The sorbents containing modified clay and dextrin has been rated as the most promising enterosorbents which never aggravate the effect of radioisotopes upon the liver and kidney tissues, unlike those containing organic silica or charcoal.
Pectopal belongs to this group of effective compounds. Being introduced into the gastrointestinal tract of the laboratory animals (albino rats), it provides comprehensive protection of the organism from $^{137}\text{Cs}$, constantly incorporated into the organism (Fig. 8).

**Fig. 8.** Dynamics of radioisotopes concentration in the control and experimental rat groups.
Chapter 2

BASIC PATHOLOGICAL PROCESSES RESULTING FROM RADIOACTIVE CESIUM INCORPORATION, THEIR FORMATION MECHANISMS.

Radioactive Cesium incorporation in the human organs and tissues results in definite structural and metabolic modifications with further disorders of separate organs and the entire organism. Threat to the organism becomes inevitable already with small amount of incorporated Cesium, as it penetrates the cells of vital organs and systems.

Here, traces of disorder manifest themselves primarily in most differentiated cells. To comprehend the fact, experimental simulation of the process of radioactive Cesium incorporation into the laboratory animais organisms must have been developed and extrapolated on the human organism. Studies of structural, functional and metabolic modifications while radiocesium accumulation to its corresponding accumulation in the human organism have been performed.

Clinical and experimental studies with account of radiocesium incorporated in the organism have allowed typical pathological modifications in some organs and systems to be revealed.

2.1 Cardiovascular system.

The problem of the radiation effects upon the cardiovascular system has been reflected in local and foreign publications. In the majority of cases the cardiac functions and its metabolic activity have been rated with consideration of external irradiation of the whole body or in the region of the heart primarily in experimental conditions, structural modifications of the myocardium being not determined. The investigations performed dealt with $^{137}$Cs, incorporated into the organism and its effects.

In particular, electrocardiographic examination of children of different age groups (from 14 days to 14 years old) living in the contaminated regions (Gomel region — 1-5 Ci/km$^2$) has manifested high frequency of cardiac activity disorders within the range 55,9%-98,1% primarily due to the disorders of conduction of the cardiac
impulse in the form of incomplete blockades of the His right stem bundle, upset redox processes of the myocardium and automatism violation of the sinus bundle.

The average accumulated dose has amounted to 30,32±0,66 Bq/kg, the Gomel children aged 3-7 have manifested direct proportionality between the accumulated dose and ECG modifications (Fig.9).

![Bar chart](image)

**Fig. 9.** Frequency of ECG modifications among the children aged 3 to 7 in Gomel as the function of incorporated dose.

The dependence in question has been basically due to the disorders of intraventricular conduction in the form of incomplete blockades of the His right stem bundle (Fig. 10) and upset myocardium metabolism.

Examinations of the students (18-20 years old) of the Gomel Medical Institute show the pronounced ECG modifications in 48,7 % of cases, average $^{137}$Cs concentration being 26,00±2,00 Bq/kg. Similar to ECG features examination, the children with different doses incorporated $^{137}$Cs were found dose-dependent while analyzing arterial pressure. The dose of incorporated $^{137}$Cs increasing, the number of children with elevated arterial pressure becomes higher. Totally, about 41,6 % of children from the regions with the contamination rate above 15 Ci/km$^2$ have been observed to acquire the symptoms of the arterial hypertension [11]
Thus, a series of modifications in electrocardiographic activity has been revealed in time of investigations of the electrophysiological processes in the cardiac muscle of those living in highly contaminated regions with the frequency being a function of the internally accumulated dose.

Assessment of the section materials of the residents of the Gomel region after the Chernobyl disaster has manifested myocardium disorder in 99% of sudden death cases. Diffusious disorders of muscle cells in the form of dystrophical processes and necrosis attract special attention, giving evidence to toxic effects being present. This pathological process has been accompanied by the pronounced $^{137}\text{Cs}$ incorporation into the cardiac muscle (about 26 Bq/kg). If we consider durable cardiovascular illnesses, $^{137}\text{Cs}$ concentration in the region of the heart appeared several times higher — 136,8±33,1 Bq/kg (data presented after the analysis of the results of pathomorphological and radiometric studies of 123 death cases in the medical institutions of Gomel and of 285 sudden death cases). These data give evidence to $^{137}\text{Cs}$ participation of the disorder of the myocardium structure.

To prove the effects of endogenously incorporated radioisotopes upon the myocardium experimental studies of
laboratory animals (albino rats) have been carried out. Radiocesium has been incorporated in the enteral way with food (oats grains) or with its water solution introduced inside the stomach. The processes have been simulated with different $^{137}$Cs concentration.

Radiocesium concentration in the animals' organisms of $63.35 \pm 3.58$ Bq/kg (in control $5.43 \pm 0.87$ Bq/kg) has led to essential metabolic shifts in the myocardium tissues, namely, to the suppression of activity of the most vital enzymes, such as alkaline phosphatase and creatin phosphokinase (Fig. 11).

Creatin phosphokinase being a key enzyme of the energy metabolism in the cardiac muscle and governing reactions between macroergic phosphate and creatin, its suppressed activity causes substantial disorder of the energy processes, leading to the modifications in the contractile apparatus, namely myofibrils in the form of contractions or their declustering and lysis of different degrees.

Modification of the polarization behavior of cardiomyocytes in the form of expanding A-dises presents a morphological criterion of
this pathology (Fig. 12). Damage of the myocardium, structure is accompanied by the intensified activity of AST and increasing in creatinin in the blood serum (Fig. 13).

![Graph showing height of anisotropic discs in myocardium of experimental animals.](http://enfants-tchernobyl-belarus.org)

**Fig. 12.** Height of anisotropic discs in myocardium of experimental animals:
1 – experiment; 2 - control (p<0.05).

![Graph showing modifications in basic metabolic indices in the blood serum of experimental animals.](http://enfants-tchernobyl-belarus.org)

**Fig. 13.** Modifications in the basic metabolic indices in the blood serum of the experimental:
1 - creatinine contents; 2 – asparate aminotransferase (p<0.05).

Average 40-60 Bq/kg of incorporated Cs have led to clearly defined ultrastructural damage of the ventricle cardiomyocytes. From
10 to 40% of all the cells have acquired decompensated modifications not allowing regular contracting. Destruction of the contractile apparatus has been observed, primarily of the contraction type with no lysis revealed. Canaliculi of the sarcoplasmatic net have been widened, mitochondria swelling and focal sarcoplasma edema have been registered, giving evidence to the disorder in membranes penetrability and serious shifts in ion metabolism.

Presence of the myelin-like structures evidences to the enhancement of peroxide membranes oxydation. Mitochondria destruction manifested itself in their hyperplasia and hypertrophy, increasing in number of intermitochondrion contacts. Durable functional tension as well as growing oxygen starvation, evidenced by increasing endothelium penetrability may appear the reasons for the structural modifications mentioned above.

Other cells have demonstrated compensatory adaptation processes of different degrees [3].

Radiocesium accumulation in the animais organisms up to 100-150 Bq/kg has caused still more serious myocardium modifications. Diffusious cardiomyocited destruction, focal infiltrates of lymphoid cells and macrophages and vascular plethora have been registered. The increase in creatinine up to 41,20±1,60 Nmol/l (33,11 ±2,45 Nmol/l, p<0,001 in control) has been indicated in the blood serum. Radiocesium accumulation up to 900-1000 Bq/kg has caused death for over 40% of animais, interfiber and intra-cell edema with most cells being destructed.

In separate cases inflammatory infiltrates in the region of epicardium and pericardium have been observed.

Thus, the experimental studies with laboratory animais have manifested the fact that radiocesium incorporation in the organism and cardiac muscle results in their cell structure damage.

The degree of pathological process is the function of the amount of incorporated radioisotopes.

The results of experimental studies supplement the data on electrophysiological and clinical investigations of children, living at the radiocesium contaminated territories, giving vivid picture of radiocesium contribution to the highly specialized myocardium cells. However, radiocesium being incorporated in the cells of many organs and systems, its impact on the cardiovascular system should
be applied to the organism on the whole with consideration of other vital organs being damaged.

2.2. Kidneys

Kidneys are actively involved in the process of radiocesium excretion from the organism, its concentration reaching considerable doses in this organ (while studying death cases among the residents of Gomel region the average $^{137}$Cs concentration among adults has amounted to 192.8±25.2 Bq/kg, children 645.3±134.9 Bq/kg).

While microscope examination of kidneys tissue, pathological modifications have been brought to light in all structural component of the organ, maximum being observed in nephrons.

Degenerative atrophycal modifications in the form of necrosis of capillary loops have been revealed in the majority of cases, these modifications being of different degree. Glomerula with little space between their capsule and capillary loops filled with edema liquid have been registered. Here, capillary lumen has reduced considerably, their wall became thinner. Mesanginal matrix has also reduced to a great extend. Finally, glomerulus has been left optically "empty", mesanginal cells and capillaries of the glomerulus have been lysised without any sign of inflammation, forming a cavity. Morphological modifications of the glomerulum filter in the form of developing destruction of the glomerulus structures to their total elimination have been defined by us as the phenomenon of the "melting ice-floe".

Capillary loops of some glomerula have been found enlarged and plethoral, with separate walls getting thicker and manifesting double contour (while silver impregnation). Their basal membrane has been thickened due to polysugar substances accumulation. Erythrocytes and protein enriched liquid have been present in the glomerula lumens, which squeezed capillary loops.

Mesanginal matrix contributed by the effect of its moderate metachromasia has been marked, resulting in the capillary lumen stenosis.

Periglomerula fibrosis has been formed in some glomerula, consisting of concentric collagen layers placed extramembraneous outside the glomerulum capsule. Symptoms of the glomerulum sclerosis and hyalinosis have been also present.
Damage of canalicula cells has been accompanied by the severe protein and fatty dystrophy. Epitheliocytes necrosis together with the basal membrane destruction and the symptoms of walls rejection have been registered.

Here, nephrotelium has been shedding inside the canaliculus lumen. Separate canalicula have been subjected to the atrophy with simultaneous epithelium flattening.

Morphological interstition modifications have manifested themselves in the edema of friable connecting tissue.

Cell infiltration of the stroma has been observed accidentally and manifested itself in the focal clump of lymphocytes, acidophilic leukocytes, plasmatic cells and mononuclea, basically located in the perivascular places. Leukocyte infiltration has been only rarely observed in the places of canaliculus structures destruction.

The symptoms of regeneration of the epithelium lining of the canalicula and kidney stroma have become evident in separate cases. Kidneys have been found to have the similar histological structure in case of sudden death with the average radiocesium concentration 36,5 Bq/kg.

To tie together the pathological modifications mentioned above and radiocesium incorporation, laboratory examination of this organ has carried out with animals (albino rats), having different degree of $^{137}\text{Cs}$ concentration.

$^{137}\text{Cs}$ incorporation of $63,35\pm3,58$ Bq/kg has been accompanied by the infiltration of the glomerula loops by the lymphoid histiocytosis cells, mesanginal cells proliferation, occasionally with glomerulus fragmentation or destruction.

The infiltration of the glomerula loops by the lymphoid histiocytosis cells has been even more vivid with $^{137}\text{Cs}$ concentration 100-150 Bq/kg, together with frequent mesanginal cells proliferation, and glomerulus fragmentation or destruction. Granular and hyaline drop epithelium dystrophy of straight and tortuos canalicula has been determined.

Simultaneously, urea concentration has been registered higher in the blood serum (Fig.14) as compared to the control group (as in case with the Gomel children).

$^{137}\text{Cs}$ being amounted to 900-1000 Bq/kg, the pronounced disorder of the structural elements and glomerula due to hemorrhage to the kidney tissue has been registered in the form of
epithelium and vascular net necrosis with their total destruction and cavity appearance. Canalicula have shown vacuole and granular dystrophy as well as epithelium cells necrosis.

Hence, radiocesium introduced into the animal organism leads to damage in actively functioning kidney structures — primarily in the vascular net of the glomerula apparatus with their complete destruction with the incorporation degree getting higher.

The alternative processes, observed in the animal kidney glomerula and canalicula containing radiocesium, correspond to pathological modifications registered from those died in the Gomel region. This clearly proves the fact that kidneys, being the main organ of the radiocesium excretion, are the first to face the problem of destruction, playing the leading part in the development of total toxical pathological process.

2.3. Liver

The liver is one of the key organs governing the level of metabolic modifications in the organism.

Similar to myocardium and kidneys, clinical and experimental assessment has been involved to estimate the state of this organs.
Radiometric studies of those died in Gomel hospitals have revealed the average $^{137}$Cs concentration in the liver 162.6±15.7 Bq/kg for adults and 246.8±0.9 Bq/kg for children.

Considerable structural liver changes, common for all death cases have manifested themselves in degenerative processes combined with the disorder of blood circulation. Pronounced cellular and nuclear polymorphism of the parenchyma liver elements, cells of different sizes, mainly double- and multinuclear, nuclei of different shape, size and color intensity is of special attention. Numerous proliferating and hypertrophied Kupffer's cells are found among structurally modified hepatocytes. Fatty dystrophy of the liver cells is regularly observed, varying in its degree.

Sometimes, hepatocytes with fine-drop fat inclusions have been observed in the peripheral portions of the lobules, in the region of portal tracts. The fatty dystrophy has been primarily of the subtotal and total character, defining morphological state of the fatty hepatosis - the liver appeared in the form of optically empty "net" withthin layers of the stroma. Different portions of the liver lobules have contained fine focus of the parenchyma necrosis. Portal tracts have been widened with the symptoms of the edema and faint cell infiltration, presented primarily by macrophages and lymphohistiocytasis elements. Focal or diffuse sclerosis of the peri-portal stroma has been determined. Some focal intra-lobule infiltrates have been registered which contain macrophages and lymphocytes along the sinusoid. The Disse spaces have been dilated. Modifications in the system of the liver microcirculatory blood circulation have manifested the sudden plethora of the central lobule veins. Here, sinusoid capillaries have been dilated, their wall entity being partially violated. Capillary endotelium is observed with the marks of edema. Pronounced hemorrhage has been observed primarily in the central portions of the liver lobules.

Hence, dystrophy and necrobiotic modifications in the liver of those living for a long time in the Gomel region should be emphasized due to considerable radiocesium incorporation. Average $^{137}$Cs concentration in the liver observed in sudden cases has amounted to 28.0 Bq/kg. About 42.8% of the cases have been accompanied by the symptoms of fatty hepatosis or cirrhosis.

$^{137}$Cs incorporation up to $63.35\pm3.58$ Bq/kg has caused protein dystrophy of the hepatocites and disorder on blood
circulation in the organisms of the laboratory animals, that of 100-150 Bq/kg resulting in more profound dystrophic modifications and circulation disorder.

$^{137}$Cs incorporation of 900-1000 Bq/kg has led to the pronounced congestion in the central portions of the liver lobules, protein and fat dystrophy of the hepatocytes. Focus of the hepatocytes necrosis has been also registered. From this, $^{137}$Cs penetration into the organism has caused structural liver modifications. Metabolic shifts are certain to accompany this process. This is proved by the laboratory studies of the children aged 3 to 7, living permanently in Gomel (control group of children of the same age is from Grodno).

$^{137}$Cs concentration in the organisms of the Gomel children exceeding 30 Bq/kg has resulted in less protein, albumin, creatinin, cholesterin contained in blood (Fig. 15-18), the fact that gives evidence to the disorder in the synthetic liver functioning.
At the same time, calcium concentration has appeared higher as compared to the control group (Fig. 19). It is likely to be explained by the sensitivity changes in the protein kinase to the ions of Ca$^{2+}$ due to irradiation.

Reduced glucose contents has been registered in the blood serum with radiocesium concentration above 37 Bq/kg (Fig. 20), which evidences about modifications in not only liver, but also in the pancreas functioning.
Depression of the lactate dehydrogenase activity (Fig. 21) and increase in the ALT activity (Fig. 22) has been registered, confirming the seriousness of the liver cells disorder. Children with $^{137}\text{Cs}$ concentration above 200 Bq/kg have experienced rapidly increasing AST activity, reflecting promotion of the catabolic processes.

Radiocesium incorporation in the organisms of laboratory animals (60-100 Bq/kg) has resulted in the depression of creatin phosphokinase and alkaline phosphatase activity and rising lactate dehydrogenase activity in the liver tissues, in the blood serum with the same process going in alkaline phosphatase [12].

Hence, radiocesium incorporation into the man and animals organism causes serious structural metabolic modifications in the liver tissues, special emphasis being given to the degree of $^{137}\text{Cs}$ incorporation and the effect durability. It should be noted, in everyday life the liver is subjected to the effects of the incorporated radiocesium as well as other chemical and biological toxicants, alcohol taking the first place among them. Two-facet impact of the radiocesium and alcohol leads to several times more serious liver destruction with further fat hepatosis and cirrhosis. The liver being affected by the hepatitis virus, it still aggravates the situation. This happens also due to the modifications in the immunity system functioning.
2.4. The immunity system.

There exist numerous publications dealing with the questions of the immunity system state of people of various age groups affected by radiation. However, no clear notion of the modifications, resulting from radiocesium incorporation into the human organism has been given.

To assess the immunity system state, its basic function in the organism has been accepted as that of protection and integration.

Protecting function being considered, the investigations have been carried out to assess phagocyte cells function as the primary link of the immunity system and the level of the serum immunoglobulins, with the consideration of the previous publications [2]. The children aged 3 to 6 from Gomel ($^{137}$Cs concentration 1-5-Ci/km$^2$) have been registered to have the phagocytosis activity of the neutrophile lymphocyte and Jg A concentration in the blood serum considerably lower, than those from clear zones (Grodno), the Jg M level being higher. Jg G contents in the both groups has been defined to be the same (Table 1).

Radiocesium being progressively incorporated with food or water solution, experiments with laboratory animals (albino rats and rabbits) have manifested reduction in total protein contents in the blood due to $\alpha_1$ and $\alpha_2$ globulin fractions (Table 2).

The modifications revealed give evidence to the distortions in functioning of a number of the systems links under internal and external radiation effects. It should be noted, children, evacuated from the clean regions have got the level of the phagocytosis lymphocyte activity corresponding and even exceeding the control figures, with the exception of Jg A contents. (Table 1).

The indicated modifications in the immunity system appear the reason for a number of infectious illnesses, namely tuberculosis (a tremendous number of cases have been registered in the Republic recently, especially in the affected regions), viral hepatitis, acute respiratory illnesses.

The integrative link of the immunity system has been estimated from its correlation connections, both inside the humoral link and from its connection to the other systems. Immunological indices and those of metabolism in the blood serum have been
studied among the children from the territories with the contamination rate 1-5 Ci/km$^2$ and 15-40 Ci/km$^2$ and radiocesium concentration, respectively, 33,60±0,12 and 128,38±13,38 Bq/kg, and 29,60±0,72 Bq/kg in the control group (radiocesium contamination level less than 1 Ci/km$^2$).

Table 1.
Immunologie indices of children aged 3-6 from the territories in question

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<th>Main group (Gomel)</th>
<th>Control group (Grodno)</th>
<th>Children settled out from the firm control territories</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phagocyte activity of the neutrophilic leukocytes</td>
<td>$36,69±0,88^{++}$</td>
<td>$47,83±1,37$</td>
<td>$51,74±2,01$</td>
</tr>
<tr>
<td>Jg A ($'$/n)</td>
<td>$1,04±0,05^{+}$</td>
<td>$1,38±0,08$</td>
<td>$0,94±0,09^{++}$</td>
</tr>
<tr>
<td>Jg M ($'$/n)</td>
<td>$1,28±0,06^{+}$</td>
<td>$1,01±0,06$</td>
<td>$1,23±0,13$</td>
</tr>
<tr>
<td>Jg G ($'$/n)</td>
<td>$11,60±0,28$</td>
<td>$12,32±0,49$</td>
<td>$10,53±0,86$</td>
</tr>
</tbody>
</table>

+ - p<0,05 as compared to the control group;
++ - p<0,01 as compared to the control group.

The children in the control group (with minimum radiocesium concentration in soil) have been registered to have positive correlation of the immunoglobulines of different classes and the negative ones between the Jg G contents and triiodine thyronin.

The children from the territories with radiocesium concentration 1-5 Ci/km$^2$ lose correlation between the JgA and Jg M concentration and acquire positive correlation between Jg G, Jg A level and hormones of the thyroid gland, the fact that proves the sufficient contribution of the immunoglobulines to the pathogenesis of the thyroid glands illnesses. Also, the number of correlations of Jg Gand Jg M with metabolism indices (urea, bilirubin, creatinin, uric
acid, glucose, calcium, amylo peptidase, aspartase amino peptidase, alanin amino peptidase, albumins, GGTP, phosphates, triglycerides) among these children has reduced sharply as compared to the control group (Fig. 23). The character of the connections revealed is modified as well: negative in the control group and positive in the test group. This fact is believed to indicate the weakening impact of humoral factors of the immunity system on the metabolism processes.

Table 2.

<table>
<thead>
<tr>
<th>The indices</th>
<th>Radiocesium concentration, Bq/kg</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Group N1</td>
</tr>
<tr>
<td></td>
<td>40.91±10.62</td>
</tr>
<tr>
<td>Total protein g/l</td>
<td>65.56±3.74</td>
</tr>
<tr>
<td>Albumines (%)</td>
<td>36.32±1.70</td>
</tr>
<tr>
<td>α₁-globulines (%)</td>
<td>13.84±1.01</td>
</tr>
<tr>
<td>α₂-globulines (%)</td>
<td>15.63±0.91</td>
</tr>
<tr>
<td>β-globulines (%)</td>
<td>14.52±0.88</td>
</tr>
<tr>
<td>γ-globulines (%)</td>
<td>19.69±1.41</td>
</tr>
<tr>
<td>Albumine to globulin ratio (A/g)</td>
<td>0.58±0.04</td>
</tr>
</tbody>
</table>

+ - p<0.05 as compared to Group 1

Children from the territories with ¹³⁷Cs contamination rate 15 Ci/km² and its concentration in the organism above 200 Bq/kg are observed to lose correlations between immonoglobulins, hormones and metabolism indices and acquire new connections of the cortisol,
thus proving the effect of radiation upon the character of immunometabolic interrelations (Fig. 24).

**Fig. 23.** Non-parametric correlation of immunoglobuline, hormones and metabolism indices among children from the territories with different radioisotopes contamination level.

**Fig. 24.** Non-parametric correlation among teenagers with different radioisotopes concentration levels.
The correlated modifications mentioned above test if y to the processes of children adaptation to the constant radiocesium impact, with stable pathological processes occurring where the immunity system is involved.

It is proved by the results of allergological examination of the children from the contaminated regions. Positive and sharply positive allergie reaction to the protein of cow milk has been registered among the schoolchildren of the village Svetilovichi, Vetkovski district, Gomel region in 50% of cases, average radiocesium concentration in the organism being $128,38 \pm 13,38$ Bq/kg.

2.5. Haemopoetic system.

The assessment of numerous data on the laboratory hematological examination of children and teenagers from the contaminated regions has allowed a series of modifications to be brought to light, namely, reduction of erythrocytes, accidentally accompanied by the macrocytosis, leuko- and lymphopenia and also quantitative and qualitative modifications in the neutrophile and eosinophile leukocytes.[5,25]

In our studies, we have defined hematological indices of the children from the territories with different $^{137}$Cs contamination rate and varied $^{137}$Cs concentration in the organism. In particular, the following groups were formed:

1) Gomel, $^{137}$Cs concentration in the soil being 1-5- Ci/m$^2$, average $^{137}$Cs concentration in the children organism amounting to 30, $32 \pm 0,66$ Bq/kg
2) The village of Vetka, $^{137}$Cs concentration in the soil being 15-40- Ci/m$^2$, average $^{137}$Cs concentration in the children organism amounting to $70,53 \pm 8,86$ Bq/kg
3) The village of Stolbun, $^{137}$Cs concentration in the soil being 5-15 Ci/m$^2$, average $^{137}$Cs concentration in the children organism amounting to $80,07 \pm 6,82$ Bq/kg
4) The village of Svetilovichi, $^{137}$Cs concentration in the soil being 15-40 Ci/m$^2$, average $^{137}$Cs concentration in the children organism amounting to $106,54 \pm 31,29$ Bq/kg
5) Grodno (the control group), $^{137}$Cs concentration in the soil being $<1$ Ci/m$^2$, average $^{137}$Cs concentration in the children organism amounting to $29.74\pm 0.67$ Bq/kg.

The investigations performed have manifested that with $^{137}$Cs concentration rising in the children organism, the quantity of erythrocytes decreases, the concentration of hemoglobin being above the control value (Fig. 25,26). Thus, those subjected to the external and internal radiation have been marked with the reduction in proliferation activity of the hemopoietic sprout. However, this doesn't affect the process of Fe saturation.

Children from Vetka and Svetilovichi (groups 2 and 4) have been marked with reduced number of leukocytes, primarily due to bacillus nuclear neutrophiles and monocytes. At the same time the number of lymphocytes has increased. •

Defining the quantity of thrombocyte appears essential for diagnosis. The lability of thrombocyte growth (both thrombocytes products increasing and decreasing) evidences to the
disadvantageous state of the children's haemopoetic system. The number of thrombocytes has been increased by the children aged 3 to 6 as compared to the control group. However, the modifications mentioned exist within the physiological parameters.

Investigations with the laboratory animais (Vistar line rats) with $^{137}\text{Cs}$ incorporation amounting to 62.76±3.84 Bq/kg (9.76±1.77 in the control group) have confirmed the results of the laboratory hematological children examination and revealed the decrease in the absolute erythrocytes number and relative number of the bacillus nuclear neutrophile leukocytes.

Restoration of the physiological state of the myelocytious sprout among the children evacuated from the territories with $^{137}\text{Cs}$ concentration above 40 Ci/km$^2$ is worth special attention.

Thus, clinical and laboratory investigations of the hematological statues of a child's organism (3-8 years old) have revealed a series of modifications, being a function of the degree of internal and external radiation effect upon the organism.

The modifications mentioned have consisted in the doze-dependent decrease in number of the bacillus nuclear neutrophile erythrocytes and leukocytes, increase in the relative lymphocytes number and decrease in the absolute thrombocyte number. Being the haemopoetic sprout indices, they emphasize the unfavorable
processes in the children's organism, which may result in the pathological process, penetrating many organs and systems.

2.6. Female reproductive system.

The female reproductive system is extremely sensitive to ionizing radiation. Hormonal changes in the hypophysis-ovary-uterus system with further disorder in the ovulatory and menstrual functions are characteristic of this sensitivity, especially in its initial stage. 

$^{137}$Cs incorporation by the female organisms of fertile age in the areas affected by the Chernobyl disaster leads to the inversion of the hormonal background, resulting in the upset menstrual cycle.

$^{137}$Cs accumulation exceeding 40 Bq/kg, a valid reduction of progesterone and rise of estradiol concentration occur in the second phase of the cycle and vice versa during the first phase. (Fig. 27-30). These pathological modifications have negative effect upon the female health. The following illnesses tend to increase in number due to increase in $^{137}$Cs concentration in the organism: inflammation of appendage, upset menstrual cycle, uterine mioma, infertility. Increase in testosterone production governs the appearance of masculine attributes. Clinical observations are proved by the laboratory tests with animals. $^{137}$Cs incorporation up to $54,30 \pm 6,28$ Bq/kg ($14,05\pm3,31$ Bq/kg, $p<0,001$ in the control) by the female rats results in the reduction of progesterone in the estrus stage up to $23,96\pm6,94$ Nmol/l ($61,01\pm15,66$ Nmol/l, $p<0,05$ in control) and reduction of the uterus thickness.
Thus, $^{137}$Cs incorporation leads to pronounced functional changes in the hypophysis-ovary-uterus system, revealed in the upset sexual function. Modifications occurring in other endocrine organs, in particular, epinephros and thyroid gland should be taken into account as well.

2.7. Evolution of pregnancy and fetus development.

Pregnancy is accompanied by a pronounced accumulation of $^{137}$Cs in the mother's organism. Feeding laboratory animais with oats containing this radioisotope in the amount 445 Bq/kg has manifested that its concentration by the end of pregnancy (the 21st day) exceeds 120 Bq/kg. Similar results have been attained with animais fed by beef with $^{137}$Cs concentration 5587 Bq/kg. It has given rise to preimplantation fetus death - 2,27±0,52 (0,80±0,31, p<0,05 in control), upset bone system formation, revealed through the development delay and osteogenesis of the tubular bones. $^{137}$Cs is accumulated primarily in placenta, amounting to 200 Bq/kg with the females from the contaminated areas. Meanwhile, $^{137}$Cs does not penetrate basically into the fetus organism. The function of the placenta belonging to the most essential among the provisory organs, accumulation of radioisotopes definitely affects the function of the fetoplacentary complex. Primarily it relates to the hormonal correlation in the mother-fetus system. In particular, the
concentration of cortisol in the mother's blood increases with $^{137}$Cs accumulation in the placenta, while in the fetus blood it has the opposite tendency (Fig. 31).

Rise on the progesterone concentration in the mother and fetus' blood with increase of $^{137}$Cs concentration should be emphasized. By the end of pregnancy, progesterone concentration in the mother's blood exceeds significantly the estradiol concentration, which causes complications while childbirth, $^{137}$Cs concentration being above 100 Bq/kg.

Increase in testosterone concentration with simultaneous estradiol reduction, especially true for the fetus blood, is noteworthy. It is likely to result in the placenta testosterone transformation into the estradiol. Rising testosterone concentration may stimulate hypothalamo-hypophysaric mother's system with further increase in tropin. The mother's cortisol products being stimulated, it depresses this hormone synthesis in the fetus epinephros.

Apart from this, special attention should be paid to the rise in concentration of T3 and T4. Complex metabolic modifications in the mother and fetus organisms are accompanied by structural changes
of the placental villus apparatus, when the number of intermediate villi increases and terminal villi reduces with significant number of trophoblastic cells being present.

Rise in number of the scincytial buds, angiomatosis of terminal villi, cytotrophoblast evolution prove that the compensatory processes and the hormone producing function of the placenta are activated.

Special significance is given to congenital evolution defect in case of $^{137}$Cs incorporation. From statistical data, the quantity of congenital evolution effects among the residents of $^{137}$Cs contaminated territories is increasing year after year. Here, multifactorial defects take the first place, which are the product of both genetic predisposition and extra environmental components. The factor of irradiation may be responsible for genetic defects of the previous generations, living in $^{137}$Cs contaminated Gomel and Mogilev regions and appear as an extra environmental factor, contributing to the genetic defects, if not a true teratogenic agent.

Radiation analysis of the fetus with the congenital defects of the nervous system (anancephalitis, ensencephalitis, cephalocele) has evidenced to the pronounced $^{137}$Cs concentration in their placentae as compared to other fetL Hence, direct or indirect effects of $^{137}$Cs upon the mother-fetus system affects the fetus development, its antenatal and postnatal death.

2.8. Nervous system.

The nervous system is one of the first to respond to radiation effect. $^{137}$Cs incorporation by the animal organism up to $63.35\pm3.58$ Bq/kg ($p<0.001$ at $5.43\pm0.87$ Bq/kg in the control) is responsible for the pronounced disbalance in the cerebral hemispheres of neuro active aminoacids and biogenic moniamines in different compartments of the central nervous system, specifically excitant transmitters (asparat and glutomat) and decelerating ones (GAMC and glycine). The degree of the process is determined by the duration of radioisotopes incorporation by the organism. Reduction in norepinephrine and serotonin concentration in the cerebral hemispheres is observed. Variations in the data bank of biogenic amines and neuro active aminoacids under the effect of incorporated radioisotopes are noteworthy, as compared to the external
irradiation. Still a number of reconstructed effects (inhibition of the serotonin system, early GAMC system activation) is comparable with the effect of moderate lethal and superlethal doses for experimental animals [12].

Durable $^{137}$Cs incorporation in the children's organism (19.70±0.90 Bq/kg) with chronic pathologies of the gastrointestinal track leads to tension in adaptive and compensative mechanisms of the vegetative regulation, appearing as prevailing hypersympaticotonie variant of the vegetative reactivity.

Degree and frequency of the disfunction of the vegetative nervous system is a function of $^{137}$Cs, incorporated in the organism. Increase in $^{137}$Cs concentration over 100 Bq/kg results in growing number of children with hypersympaticotonie [11].

In the post-disaster period, the increase of mental diseases of organic structure and depression disorders has been registered [4]. Nevertheless, unlike those advocating the theory of post-disaster radiophobia, we substantiate the fact with the continuous radiocesium effect upon the nervous system structures, especially upon the developing organism. Experimental irradiation of the uterus mucous among the pregnant female animals during the implantation period has resulted in the systematic disorders of the nervous reactivity [24].

Neurophysiological studies of the Ukrainian scientists [18] have stated the presence of disfunction of the limbicoreticulum structures, primarily in the left (governing) hemisphere. This disfunction manifests functional and structural cerebral disorders, stipulated for the prenatal and postnatal effects of the radiation.

2.9. The organ of vision.

The organ of vision is highly sensitive to radioactive emission, both external and internal, stipulated for the radiocesium incorporation in the organism. The examinations of the children from the affected regions in 1996 have manifested frequent pathological modifications of the organ of vision of those living in Vetka and Svetilovichi (with $^{137}$Cs concentration 15-40 Ci/km$^2$) respectively, in 93.4% and 94.6% of cases. The average $^{137}$Cs concentration in the
children's organisms from these territories amounted to 89.93±3.65 Bq/kg and 128.38±13.38 Bq/kg, respectively.

Cataract, destruction of the vitreous body, cycleasthenia and the refraction anomaly appear the most wide-spread pathological modifications of the organ of vision. A direct proportionality is clearly observed between the amount of incorporated $^{137}\text{Cs}$ and the incidence of cataract (Fig. 32).

Reduction in the quantity of radiocesium in the organism eliminates the above pathological conditions as it is evidenced by the results of children screening in the Vetka district. Experiments with laboratory animals (albino rats) have manifested that radiocesium causes disorders in the development of the cornea when it loses fibers and becomes vasculated.

The present state of the organ of vision among the children from the affected territories, with considerable $^{137}\text{Cs}$ concentration in their organisms forces urgent therapeutic and preventive measures. Here, unbiased assessment is required, unifying joint activities of various practitioners, primarily ophthalmologists, as well as the
specialists in the sphere of sorbtion, endecology; radiometry and radiobiology.

2.10. The syndrom of long-living incorporated radioisotopes.

Basing on the results of the investigations performed, we may conclude the following: durable incorporation of the long-living $^{137}\text{Cs}$ in the human and animals' organisms causes disorder of internal organs (heart, liver and kidneys) with distortion of the cellular trophy and energetic processes.

The degree of disorder is the function of the $^{137}\text{Cs}$ concentration in the organism and the organs mentioned above. The more intense is the process, the higher is the degree of disorder. As a rule, several organs are subjected to the radiotoxic effects simultaneously, provoking the effect of metabolic disfunction. It should be noted, the organs and tissues with the negligible or absent cells proliferation (myocardium) under physiological condition suffer to the greatest extent. Radiocesium accumulated in the organism intrudes the metabolic processes and affects membrane cell structures.

As a result, many vital systems, their structure and functions are violated, primarily, the cardiovascular system (Fig. 33).

Structural modifications in the myocardium under progressive radiocesium accumulation prove its toxic effects, with the energetic system and mitochondrion being violated. Deep and irreversible changes (due to the increase in $^{137}\text{Cs}$ concentration) lead to the necrobiotic processes in a cell!. Suppression of the creatin phosphokinase appears as a consequence to the energetic instability.

The incorporation effect being considered, the metabolic processes violation in the organism and its separate organs should be attributed primarily to the toxic effects of radiocesium and great concentration of other radioactive isotopes with long half-life time, as a result of the Chernobyl disaster.

Ionizing effects of $^{137}\text{Cs}$ and other radioisotopes manifest themselves during their intense incorporation.

The vascular system violation with $^{137}\text{Cs}$ manifests itself in the increasing number of people suffering from the severe
pathological disease - hypertension, arising already in the early childhood.

Apart from toxic effect of radiocesium, pathological modifications in the vascular system lead to the cell destruction in brain, heart, kidneys and other organs.

Kidneys are the key organ governing the process of radiocesium excretion from the organism. According to V. Zhuravlev [7], 6 to 9 times more $^{137}$Cs is excreted from the organism with urine than with feces.

It affects the vascular system of the canaliculi and glomeruli systems of the nephron structure. Destruction of the structural and functional kidney elements, first of all glomeruli, has manifested itself in the typical histological picture. Considerable $^{137}$Cs concentration has been registered in the organ tissue. The results of the experiments with $^{137}$Cs and CsCl solutions introduced into the
animals organs state that the modifications in question have been stipulated for the toxic effect of the radiocesium.

Kidneys destruction is one of the main reason of $^{137}$Cs and the products of metabolism accumulation in the organism and their toxic effect upon the myocardium and other organs and also of the arterial hypertension. If the cases of sudden death in Gomel are considered, 89% of the cases are accompanied by this organ destruction, this state being not registered during their life time.

Serious pathological modifications of the liver are also noteworthy. The progress in toxic dystrophy of the liver with prevailing destruction of the cellular protein and metabolism transformations, resulting in fet-like substances formation, contributes to such severe pathological processes like fatty hepatosis and cirrhosis.

Disorder in the synthetic function of the liver manifests itself in the changes in albumines, cholesterin and creatinin synthesis. Cellular structures violation results in the increasing activity of the ALT and AST in the blood serum. The state of the immunity system should be considered separately. The results of numerous experiments do not provide any clear picture of the modifications, caused by the radiocesium incorporation. With a single pathological process being developed, the immunity system pathology is clearly observed. This is especially true for the positive correlation between immunoglobulin and the thyroid gland hormones.

In this account, we consider the thyroid gland disorders after the Chernobyl disaster to be connected not only with radioactive iodine but also with the durable radiocesium incorporation in the organism and in this organ and with the various immunoglobulin classes capacity to bind the thyroid gland hormones.

The hormones mentioned being excluded from the metabolic chain, the pituitary gland-thyroid gland system functioning is violated. As a result, the considerable amount of thyroid-stimulating hormone is extracted, which stimulates the thyroid gland with further proliferation of the follicule epithelium, conditioning the neoplastic transformations.

Thus, the radiocesium effect upon the thyroid gland should be considered from the point of immune regulation violation in organs and tissues and with account of the disorder character.
Constant $^{137}\text{Cs}$ incorporation does not allow the full value reparation processes in the thyroid gland to be realized, destroys cellular differentiation, contributes to the conversion of the structural cellular elements into the antiagents for the immunity system.

With immunologic reaction arising, autoantibodies and immunocompetent cells damage the thyroid gland, accompanied with the autoimmune thyroiditis and the thyroid gland cancer.

The epinephros also appear affected by the incorporated radiocesium, the level of cortisol being a function of the radiocesium concentration in the organism.

The modifications in the cortisol production are especially noticeable for the neonates, their mothers having accumulated the considerable $^{137}\text{Cs}$ concentration in the organisms (mainly in placenta). Hence, these children are famous with their ill-adaptation to the intrauterine existence.

Pathology of the female reproductive system is a product of endocrine functions violation. Radiocesium is responsible for the disbalance in the correlation progesterone-estrogen with the women of the fertile age in different phases of the estral cycle, being a key factor for the infertility. The radiocesium incorporation in placenta and other endocrine organs during pregnancy gives rise to hormone disorders both in the mother organism and fetus. In particular, the $^{137}\text{Cs}$ concentration rising, the testosterone contents increases as well as the thyroid gland hormones and cortisol in blood.

Distortion of the hormone statues in the mother-fetus system due to radiocesium leads to the extended pregnancy time, childbirth and postnatal child evolution complications.

In case of natural feeding radiocesium penetrates the child's organism. Thus, the mother's organism purifies itself, while that of a child's becomes $^{137}\text{Cs}$-contaminated. Many systems being formed in this period, radiocesium has an extremely negative effect upon the child's organism.

Haemopoetic system marks the radiation effect upon the human organism. In the post-disaster period the authentic erythrocytes decreasing with regular hemoglobin contents has been registered among the children from the territory of firm control (15-40 Bq/kg) with considerable $^{137}\text{Cs}$ concentration (over 500 Bq/kg). The residents of other areas have been registered to have no essential modifications of the blood forming sprout. However, there still
exists a chance of disorder in the haemopoetic system, which is confirmed by the statistical data.

The nervous system is the first to respond to the radioisotopes incorporation. Radiocesium incorporation within 40-60 Bq/kg, which is due to the 28-days animal's feeding with oats, causes distinct disbalance of the biogeneous monoamines and neuroactive amoniacids in different compartments of the brain, in particular, in the cerebral hemispheres. This is reflected in time of various vegetation disorders.

The organ of vision is extremely sensitive to the effects of the incorporated radioisotopes. The children with high level of radiocesium incorporation (15-40 Ci/km, Vetkovski district) have been registered to get high frequency of pathologies of the organ of vision, mainly, the eye lens modifications with the symptoms of cataract. Year after year the process is still aggravated.

Thus, penetrating the organism, a long-living radioisotope of $^{137}$Cs affects a number of the vital organs and systems. As a result, highly differentiated cells are violated, the process being dependent on the radiocesium concentration. The destruction of the energetic mechanism lies in the basis of the process, leading to the protein destruction. In this connection, characteristic feature of the $^{137}$Cs effect upon the human organism appears the depressed metabolic processes in the cells of vital organs and systems, due to the direct influence and the effects of the toxic tissues (nitrogen compounds), violation of the tissue trophy due to the vascular system disorder.

The pathological modifications in the human and animal organisms caused by $^{137}$Cs may be joined together into the syndrome of the long-living incorporated radioisotopes. (SUR)

The syndrome appears in the cases of radiocesium incorporation in the organism (its degree being the function of the incorporation quantity and time) and is characterized by the metabolism pathology, stipulated for the structural and functional modifications in the cardiovascular, nervous, endocrine, immune, reproductivce, digestive, urinary excretion and hepatobiliar systems.

The quantity of the radiocesium, SUR inducing, may vary, depending on age, sex and the functional organism condition.

Children have been registered to have considerable pathological modifications in the organs and systems with the incorporation level over 50 Bq/kg. At the same time, metabolic
discomfort in the individual systems, primarily in the myocardium, has been registered with $^{137}\text{Cs}$ concentration amounted to 20 Bq/kg.

The definition of the pathological modifications, appearing due to the natural radiocesium incorporation in the human and animais' organisms, which is true for the residents of both contaminated and "clean" territories, somehow differs from the viewpoint of some scientists [20]. They single out separate syndromes in the vulnerable systems, giving no attention to the integral pathological process with the radioisotope incorporation effects being present.

The data presented give evidence to the unfavorable effects of even tiny radiocesium incorporation, both on the contaminated and clean territories. The process is accompanied with its toxic effects upon the vital organs, primarily heart, liver and kidneys.

Ignorance of their state and lack of the corresponding therapeutic and preventive measures may result in the inevitable organism destruction. The situation is still aggravated with the accompanying unfavorable factors: nicotine, alcohol, hypodynamia, infectious agents.
Chapter 3

CONSEQUENCES OF DURABLE RADIOACTIVE CESIUM INCORPORATION INTO THE HUMAN ORGANISM.

In reality, it appears extremely difficult to single out the radiocesium-borne pathological effects in the human organism, as there exist various other radiation and non-radiation factors affecting the human organism.

However, from the data on the clinical and laboratory investigations among children and laboratory experiments with animals, with account of $^{137}$Cs concentration, a number of pathological conditions and illnesses governed by the radiocesium may be stated.

First of all, this is true for the cardiovascular diseases. We define the myocardium pathology as cardiomiopatia, associated with radiocesium effect, which corresponds exactly to the definition of the expert committee. They consider cardiomiopatia as the myocardium disorder of different type of genesis, being not inflammatory in the morphology or coronary in origin [10, 14].

Diffuse damage of the muscle cells in the heart without any pronounced respond from the organism presents the best illustration. Radiocesium damaging microcirculatory bed, this does not result in any local asphyxia of the considerable myocardium sites with further infarct (necroses with violated blood circulation).

It is hard to predict the frequency of these processes, the reason being poor examination of the myocardium in lethal cases. Thorough examination of the histological specimens in sudden death cases in Gomel region has revealed diffuse character of the myocardium damage. No doubt, there existed other factors contributed to the cardiac activity depression. However, radiocesium plays it own part in this process. It is also true for the classical infarcted myocardium cases, $^{137}$Cs reducing anti-thrombus activity of the vascular wall, facilitating thrombocyte, coagulative and fibrinolytic sections of the hemostasis system and thus manifesting the process of the blood coagulation in vessels [23].

Kidneys damage contributes to the radiocesium being detained in the organism. Thus, in spite of numerous reasons
presented by famous cardiologists [22], we consider radiocesium responsible for the cardiovascular system violation.

Several practically substantiated facts should be compared. Radiocesium incorporation in food products and human organisms at the territory of the former USSR, in 8elarus as well, has been registered since the 60-ies [15].

The 60-ies are also marked by the steady increase of cardiovascular diseases and death rate [8].

At the same time, the Scandinavian countries (Sweden) have introduced firm control of the radiocesium concentration in food products since the 60-ies, which allowed the number of cardiovascular diseases to be sharply reduced (4 times less). What concerns radiocesium and other radioisotopes, preventive measures in the countries of Europe reduced the number of death cases from the cardiovascular disease, while the former USSR experiences their further growth (Fig. 34).

<table>
<thead>
<tr>
<th>Country</th>
<th>Rate</th>
</tr>
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<tbody>
<tr>
<td>Sweden</td>
<td>34,13</td>
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<tr>
<td>Germany</td>
<td>35,69</td>
</tr>
<tr>
<td>Great Britain</td>
<td>55,74</td>
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<td>Poland</td>
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<td>Ukraine</td>
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<td>Estonia</td>
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<td>Russia</td>
<td>135,92</td>
</tr>
<tr>
<td>Belarus</td>
<td>143,12</td>
</tr>
</tbody>
</table>

*Fig. 34. Ischemic heart disease rate in Europa (for 100 thousand inhabitants).*
Similar situation is observed with oncologic diseases. As compared to the 1976, the sickness rate of the malignant kidney neoplasms in the Republic of Belarus in 1995 has increased 4 times more (among males) and 2.8 times more (among females), that of the malignant bladder neoplasms - 2 times more (males) and 1.9 times more (females), that of the malignant rectum neoplasms - 2.1 times more (males) and 1.4 times more (females), in lungs - 2 times more (for males), in the thyroid glands - 3.4 times more (males) and 5.6 times more (females), in colon - 2.1 times more for both males and females.

In Gomel region the number of kidney cancer cases has increased five times as much (among males) and 3.76 times as much (among females), those of rectum cancer - 2.1 times as much among males and 1.4 times as much among females, those of thyroid gland - 5 times as much among males and 10 times as much among females [19].

From 1987 to 1997 the number of kidney cancer cases in the Republic has increased 2.4 times as much, those of thyroid gland - 3.5 times as much, those of rectum - 1.4 times as much, those of colon - 1.6 times as much, with the number of stomach cancer remaining practically the same.

During the same period the kidney cases in Gomel region have increased 4 times as much among the rural population and 2.2 times as much among the urban citizens, lung cancer cases respectively, 1.6 times as much and 1.5 times as much [9].

This led to the pronounced growth of the death rate from cancer, unlike the Scandinavian countries with steady reduction of the cases (Fig. 35).

The problem of the cardiovascular diseases and oncology being solved in the European countries, the life time of people is constantly increasing, unlike the former USSR.

In the Republic of Belarus and on the contaminated territories the problem of the life time is of special concern.

In 1998 the death rate in Gomel region reached 14%, while the birth rate 9%. It should be also stated, part of the neonates suffer from hypotrophy and congenital evolution defects. All attempts of the medical genetic institutions to prevent childbirth with serious defects in the vital organs and systems do not bring any positive results [13]. One shouldn't forget considerable death rate of feti at
the early pregnancy stage, which does not find clear clinical manifestation and is not registered. However, it appears one of the main reasons of the birth rate reduction. Many new families do not have children.

The demographic features mentioned manifest serious threat to the residents of the affected regions. Radiocesium spreading at a long distance with food, pathological modifications may appear among people, having no direct relation to radiation. The children of Minsk are registered to have $^{137}$Cs concentration over 20Bq/kg. Here, 85% of them have pathological modifications registered on the
ECG. In seldom cases of radiocesium being not contained in the organism, 25% of cases register ECG modifications.

Thus, relatively small radiocesium concentration is enough to cause serious metabolic modifications, primarily in the myocardium. To be fair, our compatriot S. Botkin already in 1888 showed the toxic effect of cesium salts upon the myocardium.

Kidneys appear intensely affected by the radiocesium as well. However, due to the angio architectoniks, radiation induced pathology of this organ has its own specific features. The diseases are seldom accompanied with nephrotic syndroms, are more severe and quicker in character, as compared to the ordinary chronic glomerulonephritis. The latter is characterized by frequent and early development of the malignant arterial hypertension.

Already in 2-3 years kidneys damage leads to the development of chronic renal failure, cerebral and cardio complications and hypernitrogenmia [26].

The $^{137}$Cs effect upon the liver tissues leads to the most severe process of fatty hepatosis, accompanied by the metabolism violation not only in this organ, but in the organism on the whole. The immunity system does not respond, which lead to frequent cirrhosis processes development.

We consider it essential to take into account the $^{137}$Cs effects upon the liver cells as well as the immunity system.

The latter being damaged, it contributes to some types of the viral hepatitis being spread on the affected territories. The proportion of the chronic hepatitis [6] increases, it forming the basis for the hepatic failure, and liver tumor diseases. The cellular immunity failure reflects itself in the increasing rate of tuberculosis [1]. There is much talking about the compulsory fluorography examinations of population. However, the route of the problem lies in the affection of the immunity system by the radiocesium incorporation, which is evidenced by the reduction of phagocytosis capabilities of the neutrophile leukocytes.

The unfavorable effect of the radiocesium upon the human organism is proved by the reduced life time rate of males as compared to females. It is primarily connected with the more frequent oncological and cardiovascular disorders among males (Fig. 36). It should be also noted, males are characterized by more intense radiocesium incorporation.
Thus, radiocesium penetrating into the human organism, it results in the disorder of many vital systems due to the decreased synthetic and metabolic processes in the cell structures.

With account of the results of scientific investigations, durable incorporation of even insignificant radiocesium doses (20-30 Bq/kg) may appear the reason for severe pathological and compensatory and adaptive changes in the organism.

Here, I touched upon only those pathological conditions which have been investigated with my participation, but not those described in the publications of the famous authors [21, 26].
Chapter 4

THE WAYS TO PROTECT THE HUMAN ORGANISM FROM RADIOISOTOPES EFFECTS

The radiocesium playing the essential part in the development of many diseases, prevention of its effects acquires special importance. The governmental and individual safety measures should be noted.

We would like the governmental safety measures from longliving radioisotopes ($^{137}$Cs in particular) to include firm state control over their concentration in food products. The existing republican norms (RDU-99) do not allow the organism to be fully protected from radiocesium, though their execution considerably reduces its penetration. Thus, radiometric examination of food products appears the necessity on the territories affected by radiocesium.

Any quantity of radiocesium may cause the pathological processes development. That is why, the existing norms should be more tough and the permissible levels of radiocesium concentration in food products should be reduced on the governmental level.

To our mind, the first thing to be taken into account is the toxic effects of $^{137}$Cs upon the vital organs and not the harmful effect produced by the long-living elements decomposition.

$^{137}$Cs penetrates the organism mainly with milk products and bread. Meat may also appear the source of $^{137}$Cs accumulation, especially beef. Special attention, therefore, should be paid to their processing to obtain less contaminated products.

$^{137}$Cs concentration is reduced in meat, if cattle are fed with clean products with daily addition of table salt for 4-6 weeks.

The milch herb should be split according to the radiocesium concentration in milk. Clean milk may be utilized for drinking while contaminated should be sent to milk plants to produce butter and cottage cheese with far less $^{137}$Cs concentration.

These approaches are applicable for household keeping on the contaminated territories. Sour cream, cottage cheese and butter should enjoy preference.

From the numerous experiments, if meat is previously soaked in fresh water, later kept in 25% brine for 3 months, and then...
boiled, it loses 90% of the accumulated radiocesium. The amount of brine should be equal to the amount of products being salted.

Meat and fish being boiled with some amount of chlorine Na, up to 70% of radiocesium remain in the brock. The same is true while the potato is boiled, 45% of radiocesium remaining in broth.

The great amount of radiocesium is contained in wild berries and mushrooms. That is why their utilization should be strictly forbidden or restricted in the affected areas.

In this connection, artificially cultivated mushrooms should be developed.

Regular radiometric studies are necessary to control radiocesium concentration in the organisms of those living in the contaminated areas.

Radiocesium accumulated should be excreted from the organism. Agents-sorbents with different composition are applicable for this purpose.

Enterai way appears the most popular one to introduce sorbents into the human organism. Specimens, called enterosorbents may be applied to excrete radiocesium from the organism only if they are able to bind it in the lumens of gastrointestinal tract and do not violate metabolism and vital internal organs. Pectin derivatives accompanied with the calyey additions, pectopal, in particular, belong to the most perspective preparations.

It should be kept in mind, it is much easier to prevent the radiocesium penetration in the human organism than to excrete it and to correct the violated metabolism.

Metabolism may be regulated by ail existing methods and medicines, vitamins and immunostimulators taking the first place.

It should be underlined, the situation is still aggravated by the accompanying unfavorable factors, such as nicotine, alcohol, hypodynamia, infectious agents, requiring regular adverlising of the healthy way of live.

From the data presented, a complex program of vital activity under the effect of long-living radioisotopes should be introduced and immediately implemented.
CONCLUSION

The Chernobyl disaster had a serious effect upon the organism of the majority of the world's inhabitants. The consequences of this effect are far from being defined, due to the diversity of the pathological effects, appearing as a result of the radioactive agents influence, their manifestation in the life of one or several generations.

$^{137}$Cs being one of the most wide-spread radioisotopes in the environment, the investigations have revealed the diversity of the interrelated modifications in different organs. If penetrated into the human organism and its organs, little radiocesium concentration appears extremely dangerous and leads to destruction or complications to the already existing diseases.

Organotropy to this radioisotope should also be taken into account, which is reflected in little doses. $^{137}$Cs is primarily incorporated by the myocardium, leading to serious structural metabolic modifications.

The official medicine completely ignores these facts, that is why the measures undertaken do not produce the desirable effect. Lethal cases of young people are presented by figures only in statistical reports.

It must be acknowledged, the second half of the 20$^{th}$ century has given rise to the radiation induced pathologies, manifested in a wide variety of the pathological processes and diseases.

The pathological processes, resulting from the radiocesium and other radioisotopes incorporation, should be considered in the whole organism. Thus, it will allow the most vulnerable organs and systems to be revealed and the right diagnostic, therapeutic and preventive measures to be taken.

The health condition of the affected population is a disaster, but, being a physician myself, I can not accept it to be hopeless. With all my faith in God and life, I appeal to anyone who can influence it: do your best to improve the situation.

There's nothing more precious on this Planet than life. And we should do everything possible to protect it.
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LIST OF ABBREVIATIONS

Rh - Rhesus factor
AST - asparate aminotransferase Al T - alanin aminotransferase
J - immunoglobulin
HPOS - phosphates TRIG - triglycerides
GGT - gamma-glutamat transpeptidase IDG - lactat dehydrogenase
GIU- glucose
CHOI - cholesterin
CA - calcium
UR - urine acid
BUN - urea
TP - total protein AlB - albumines CR - creatinine
T3 - triiodine thyronin T 4 - thyroxin
AMYP - amilo pectidase Kort - cortisol
CK - creatin phosphokinase TBII - total bilirubin
GAMC - gamma-amino oleic acid
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