Yu. I. Bandazhevsky

PATHOLOGY OF INCORPORATED RADIOACTIVE EMISSION

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The publication deals with the effect of incorporated radioisotopes upon the condition of vital systems of the organism. The author has employed the clinical and experimental approach to analyze the relationship between the origination of a variety of pathological conditions and the quantity of radioisotopes incoroporated by the organism, primarily ^{137}Cs, considering its extensive prsence in the environment after the disaster at the Chernobyl nuclear power plant.

The publication is intended for various practitioners, researchers investigating the problems of radiation effect upon the human organism. It can also serve as a manual for students of medicine and biology.

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FOREWORD

The Chernobyl disaster has brought about a lot of grief and suffering to the people of Belarus, Ukraine, Russia. Partially it has been due to the lack of awareness about valid information how the factors of radioactive fall-out affect the human organism.

Release of a huge quantity of radioisotopes into the environment has placed the lives of many thousands and millions of people of the living and future generations under constant threat.

In order to reduce the negative effect of radiation agents upon the human organism to the minimum, profound medical research is required using the results of fundamental studies. The present publication evaluates the results achieved by the author and researchers of the Gomel Medical Institute in numerous research projects aimed at assessing the effect upon the human organism of the Chernobyl radioisotopes which contaminated the environment . The accomplished research has been based on the following methodological approaches:

1. Assessment of the medical and biological effects with the consideration 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 (the morphofunctional approach).

4. Assessment of the severity of pathological conditions, such as disorders of the integrating processes in the organism in order to combine together the pathological modifications evolving in different organs.

The author hopes that the treated problems will attract the medical and scientific community and will welcome with appreciation all comments and suggestions.

CHAPTER 1

1. FEATURES OF INCORPORATION OF RADIOISOTOPES BY HUMAN AND ANIMAL ORGANISMS AND GOVERNING FACTORS

The disaster at the Chernobyl Nuclear Power Plant in 1986 led to a release of at least 180 million Curies of radioactive substances (letting alone the radioactive fallout of several tons of nuclear fuel around the station (V.B. Nesterenko, 1992). Among all the radioisotopes released into the atmosphere the major contributors into the dose rate are Iodine-131, Cesium 137 and 134, Strontium-90.

Iodine-131 has the half-life 8.05 days, Cesium-134 — 2.06 years, Cesium-137 — 30 years, Strontium-90 — 29.12 years, meanwhile Plutonium-239 — 24,390 years (V.B. Nesterenko, 1992).

While the short-living isotopes (iodine-131, strontium-90), inert gases (krypton, xenon, etc.) were the main contributors into the dose rate, Cesium 137 and 134 became the governing contributors in the second period. Also the effect of strontium-90 and transuranium radioisotopes (Plutonium) included into the composition of "hot" particles should be taken into consideration. These radioactive elements are incorporated by the organism with food, water and air, in addition to creating the external gamma-background.

Iodine-131 has the half-life 8.05 days and the main paths of its incorporation are gastric, inhalation (absorption through outer skin makes up 1-2%) (V.A. Bazhenov et al., 1990).

Significant sources of penetration of radioactive iodine into the human organism are foodstuffs of plant and animal origin, specifically milk, fresh milk products, leaf vegetables. Iodine-131 concentration in the organisms of goats and sheep exceeds that in cows several times. Meat basically does not contain this radioisotope, yet its significant quantities are contained in bird eggs.

Iodine-131 is rapidly absorbed by blood and lymph. The quantity and rate of absorption, accumulation of this radioisotope in organs and tissues, the rate of its excretion from the organism depend upon age, sex, concentration of stable iodine in food (V.B. Bazhenov et al., 1990). The thyroid gland manifests its maximum concentration. Already two hours after introduction of the isotope its concentration in the thyroid amounts to 5-10%, and after 24 hours 25-30% of the total amount (V.A. Bazhenov et al.).

Other organs (kidneys, liver, muscle and bone tissues) accumulate this radioactive isotope in much smaller quantities.

It has been revealed that iodine-131 crosses the placental barrier and penetrates from the mother's organism into the fetus predominantly accumulating in the thyroid (V.A. Bazhenov et al, 1990).

Primarily kidneys excrete the radioactive iodine from the organism. Iodine-131 effects upon the human organism during the first days after the disaster are injuries of the thyroid. The dose burden upon this organ due to the incorporation of radioactive iodine by humans is produced within a relatively short period of time 2.5-3 months after the disaster because of the short half-life of this element.

It has been revealed that the thyroids of children (aged 0-17 years) living in the Khojniki district received the highest doses of radiation (242-527 cGr). The thyroid doses in Gomel amount to 15-60 cGr, in Minsk - from 2.4 to 9.2 cGr.

Cesium has 23 known radioactive isotopes, yet at present the current situation is primarily determined by 137 and 137 isotopes.

The half-life of Cesium-134 is 2.06 years, that of Cesium-137 is 30 years.

After peroral incorporation and absorption by blood significant quantities of Cesium-137 are secreted into the intestinal lumen and reabsorbed by the colon. Such natural incorporation of the radioisotope together with food (grain crops grown in the areas contaminated with radioisotopes) leads to its different accumulation in tissues and organs.

Feeding female and male common breed albino rats and Vistar line rats with oats containing about 400 Bq/kg of ^{137}Cs would result in its significant accumulation in the organism after several weeks.

The maximum ^{137}Cs concentration has been registered in the tissue of the myocardium (Fig. 1), while its concentration in bone and muscle tissues is much less (Yu.I. Bandazhevsky, G.S. Bandazhevskaya, 1995). Radiometric measurements of the autopsied material have revealed the maximum quantities of this radioisotope in the thyroid gland per unit of the organ weight, somewhat less in the heart, liver, skeleton muscle (Yu.I. Bandazhevsky, A.M. Perepletchikov, 1996). These results are confirmed by the studies of E.F. Lushnikov et al. (1996) who have demonstrated that the maximum quantities of ^{137}Cs are registered in the internal organs among the residents of the Bryansk and Kaluga Region.

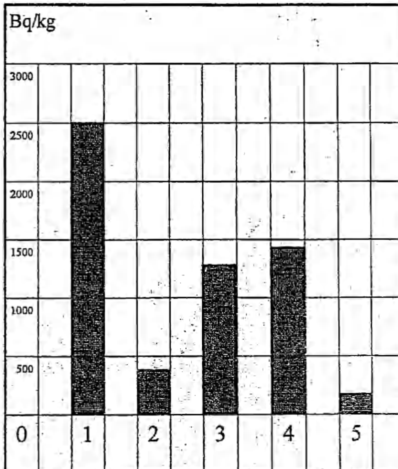

Fig. 1.Accumulation of ^{137}Cs by organs and bodies of experimentazl animals: *1* — heart; *2* — liver — *3* - spleen; *4* - kidneys; *5* - body

Pronounced differences in the accumulation of ^{137}Cs by males and females should be emphasized. When the radioisotope is incorporated enterally male organisms accumulate it more intensively than females. It is confirmed by the results of numerous experimental studies of laboratory animals (Yu.I. Bandazhevsky, N. E. Fomchenko et al., 1995) and by radiometric measurements among the residents of the Gomel Region (Yu.I. Bandazhevsky et al., 1996).

A comparative analysis of accumulation of ^{137}Cs by children has manifested that its concentration increases as a function of age (Fig. 2). In particular, children born in 1978-1981 had the ^{137}Cs concentration about 120 Bq/kg, meanwhile the children born in 1989-1996 had it equal to 60 Bq/kg.

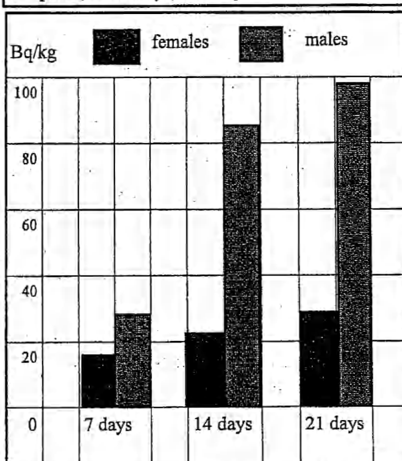

Fig. 2. Accumulation of ^{137}Cs in organisms of experimental males and females

Laboratory newly-born animals manifest the least ^{137}Cs concentration in experiments (Fig. 3) (Yu.I. Bandazhevsky, T.S. Ugolnik, 1995). It is confirmed by the results of radiometric studies of the autopsied material of the children of the first year of life (Yu.I. Bandazhevsky, A.M. Perepletchikov, 1996; E.F. Lushnikov et al, 1996).
Meanwhile, the concentration of gamma-sources (^{137}Cs and ^{134}Cs) increases strongly in the mother's organism during pregnancy (Yu.I. Bandazhevsky, T.S. Ugolnik, 1995) exceeding the accumulation by non-pregnants (Fig. 3).

Analysis of accumulation of radioisotopes in the organisms of the offspring manifests its rise in the areas with heavier ^{137}Cs contamination (Yu.I. Bandazhevsky et al., 1996).

In particular, the average ^{137}Cs concentration in the organisms of Gomel children per unit of body weight amounts to 30.0 Bq/kg (at a contamination level with this element 1-5 Ci/km^2), meanwhile its accumulation is much larger in the areas with a much higher contamination level (Fig. 4).

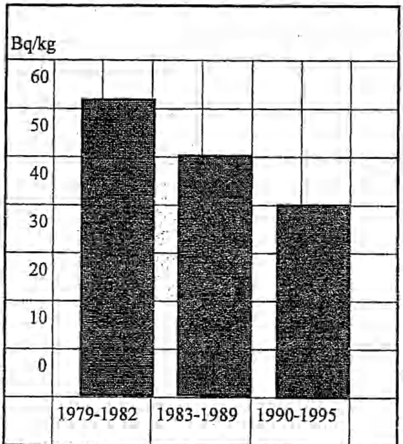

Fig. 3. Comparative analysis of ^{137}Cs accumulation among residents of Vetka as function of age

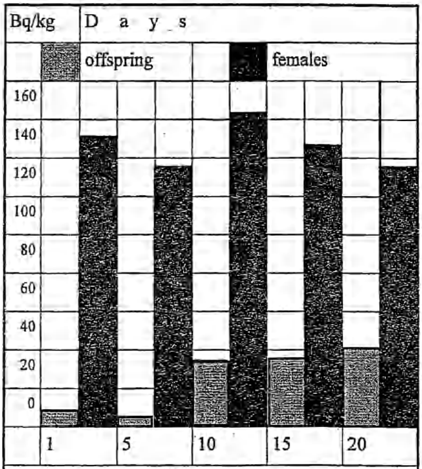

Fig. 4. Dynamics of ^{137}Cs accumulation among females and offspring during lactation

In particular, the average ^{137}Cs concentration per body weight in the organism of Gomel children in 1994 amounted to 30.0 Bq/kg (with the soil contamination 1-5 Ci/km^2), meanwhile in the areas with a higher level of contamination, its accumulation is significantly higher (Fig. 5).

A high probability of incorporation of radioisotopes with mushrooms and berries in the radiation contaminated areas should be taken into consideration.

Mainly kidneys are responsible for the excretion of ^{137}Cs from the organism when up to 80% of ^{137}Cs introduced within a single time is excreted within a month. The period of half-excretion of ^{137}Cs from human organism is 70 days, from mice 3 days, from rats 18 days, from guinea pigs 19-25 days, from rabbits 19 days (N.V. Zhuravlev, 1990).

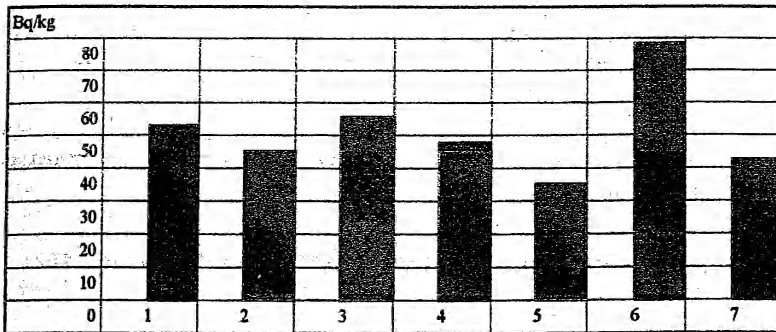

Fig. 5. Accumualtion of ^{137}Cs among children in different communites of Vetka distrtict: *1* — B. Nemki (5-15 Ci/km^2);*2* — M. Nemki (5-15 Ci/km^2); *3* — Perelevka (5-15 Ci/km^2); *4* — Stolbun (5-15 Ci/km^2); *5* — Khalch (5-15 Ci/km^2); *6* — Svetilovichi (15-40 Ci/km^2); *7* — Vetka (15-40 Ci/km^2)

There is a number of reagents influencing the process of incorporation of radioactive cesium by human and animals 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 reduce the accumulation of radioisotopes in the organism; and (2) to restore the processes of metabolism.

A number of enterosorbents have been tested at the Gomel Medical Institute in experiments with laboratory animals to assess their effectiveness in respect to ^{137}Cs. The sorbent containing 60% of modified clay and 40% dextrin has been rated as the most promising enterosorbent which never aggravates the effect of radioisotopes upon the liver and kidney tissues, unlike other sorbents, such as organic silica or charcoal (N.E. Fomchenko, 1997).

Experiments with sorbents containing pectins, have manifested their high effectiveness in excreting radioisotopes from the organism. Pectopal belongs to this group of effective compounds (Yu.I. Bandazhevsky, I.K. Lyakhova, 1997).

Strontium (^{90}Sr) is a radiation source having half-life 28.5 years (V.F. Zhuravlev, 1982). Strontium is a stable microelement actively involved in the metabolism of plants, it is constantly present in the tissues and organs of man and animals. Being analogous to calcium, upon incorporation it gets involved in the mineral metabolism.

It penetrates into the organism through the intestinal gastric tract, lungs and skin (V.S. Kalistratova, 1990). The greatest risk is produced when irradiation is due to the penetration of ^{90}Sr through the nutrition tract (V.I. Ternov, 1988) when the levels of absorption of strontium vary from 5 to 100% (V.S. Kalistratova, 1990).

This process is influenced by a number of physiological factors (age, pregnancy, lactation, condition of vital systems of the organism). Irrespective of the way and rate of incorporation, soluble ^{90}Sr compounds are accumulated by the bone tissue.

Concentration of this isotope in the bones of rat is 40-60 times higher already after 24 hours than in kidneys, spleen and muscles (V.S. Kalistratova, 1990) with skeletons of male rats accumulating more than the skeleton of female rats. Introduction of ^{90}Sr into the organism of pregnant animals leads to its accumulation in the bone tissue of the offspring (V.S. Kalistratova, 1990).

The rate of strontium metabolism in the bone tissue of man is directly proportional to age: it is 100% among infants (up to one year of age), 40% among children and adolescents, 20% among adults (V.I. Ternov, 1988).

Thus, continuous incorporation of ^{90}Sr leads to its maximum accumulation in childhood. Paroxysmal incorporation of this radioisotope leads to its greater concentrations among senior age adults.

CHAPTER 2.
BIOCHEMICAL AND BIOPHYSICAL EFFECTS OF INCORPORATED RADIOISOTOPES

Considering that the main spectrum of the radioactive elements in the Chernobyl atmospheric fallout are the isotopes with gamma- and partially beta-emission, their effect upon the biophysical processes in the cell and its ultrastructures will be considered in the first place.

Nuclear emission breaks off electrons from atoms in the cells producing ions and excited atoms and causing the appearance of radicals which induce various reactions in the organism (V.F. Zhuravlev, 1990).

One of the primary reactions induced by the ionizing radiation is the evolution of free radical processes of peroxide oxidation of lipids yielding toxic substances as final products. They affect the components of the cellular membrane, numerous enzymes and the genetic apparatus causing evolution of radiation injury (I.N. Verkhoglyad et al., 1991).

The organism possesses a chemophysical system of controlling the cellular metabolism with membranes. The main components of the system are the generation of peroxide radicals of lipids, antioxidants, composition of lipids, fluidity of the lipid component of membranes, membrane-bound proteins-receptors, enzymes, passage forming proteins. In the normal condition all these parameters are interrelated structurally and functionally, in case one is modified the remaining are modified also. Even many years after exposure to ionizing radiation of any rate individuals retain modifications in the system controlling peroxide oxidation of lipids (E.V. Berulakova et al, 1996).

Thus, nucleoproteids and biolipids are the main substrates of the primary oxidation reactions.

The nuclear DNA in eukaryotic cells is the main target damaged by radioactive emission (G.M. Oburatov, 1996). Various primary damages of DNA result from intranuclear ionization. Only double-thread ruptures of DNA can cause genetic and lethal effects.

The method based on the analysis of the frequency of chromosomal aberrations or the number of dicentric and circular chromosomes is the most perfected and objective method of evaluating the effect of radioactive emission upon the cell's genetic apparatus (N.P. Bochkov, 1993). This method has allowed to detect chromosomal damage of human lymphocytes induced by small radiation doses (Lloyd, Edwards, 1993), specifically by radioisotopes in Gomel, the Gomel region, in a number of areas of the Ukraine (M.A. Pilinskaya et al., 1992), (M.A. Pilinskaya, S.S. Dybskiy, 1992), (E.V. Domracheva et al, 1992), (V.G. Zajnullin et al., 1992).

The data about the doses of irradiation of residents of two districts of the Gomel Region and the city of Gomel indicate that over 15% of the population have received over 20 cGr, about 3% over 60 cGr (E.V. Domracheva et al., 1991).

Thus, the cytogenetic method can be useful for reconstructing radiation doses received by population (A.V. Sevankaev et al, 1992; N.P. Bohckov, 1993a).

The genom instability after chronic irradiation of cells *in vitro* and *in vivo* is manifested by a higher incidence of lymphocytes with micronuclei which result from terminal divisions or the appearance of dicentrics and rings (I.I. Pelevina et al., 1996).

Experiments with laboratory mice using the food produced in the areas contaminated with radiation have manifested that significant accumulation of 137Cs and concurrent external irradiation of the animals' organisms cause various types of cytogenetic injuries: structural (primarily reciprocatory translocations) and genom (tetra-, hexo-, octo- and higher level ploids). While the frequency of chromosomal aberrations in somatic cells increases together with the dose burden, this relationship is absent in sexual cells. Males have manifested the most pronounced cytogenetic effects (R.I. Goncharova, N.I. Ryabokon, 1995). It is believed that the difference in the pattern of dose-effect curves based on the frequency of chromosomal aberrations in somatic and immature sexual cells can be explained by a number of causes, including dose differences in the induction of reparative systems of sexual and somatic cells.

The effect of small doses of ionizing radiation upon the organism is explained by a number of researchers (A.H. Ejdus, 1996) from the point of view of the theory of non-specific responses of cells to the damaging effect. The theory is based on the principles of non-specific regulation of the activity of enzymes by low-molecular substances and compartmentalization of low-molecular substances in the cells. The result is that each portion of the cells maintains a low enough concentration of those substances which would strongly inhibit the evolving reactions of fermentation, while elevated concentrations in other compartments are adapted to the enzymes localized in them due to the differences in the concentration of effective control of various enzyme-ligand couples within the above range of non-specific regulation. According to this mechanism, it is enough to reduce the concentration of low-molecular components by reducing a portion of them using an external agent to destroy the integrity or permeability of the plasmatic membrane in order to stimulate the activity of some enzymes.

Small doses of radiation (1 cGr) increase the adaptation response of the organism and only significantly higher doses intensify the inhibiting effect of reverse compartmentalization of cellular substrates due to the damage of the function of intracellular membranes.

V.A. Vetukh and V.N. Malakhovsky (1991) assume that dose dependencies in the appearance of a number of genetic disorders admit a linear threshold-free dependence.
The effect of ionizing radiation upon the phospholipid layers of the membranes of erythrocytes lead to structural and conformation modifications of the latter due to intensified mobility and reduced degree of ordering (V.I. Dreval, 1993).

The surface charge of membranes changes, the viscosity of lipids reduces without any substantial modification of the structure of membrane proteins (V.I. Dreval, 1993).
Variations of the concentration of phospholipids in the membranes of mitochondrias of the fetus' and mother's liver have been registered after a single-time exposure to one and two Gy doses of ionizing radiation (I.A. Shirinova et al., 1992).

The above modifications of lipid-protein interactions persists until the 50th-100th day after exposure (G.G. Egutkin et al, 1993), meanwhile pronounced modifications of membrane lipids are observed during the initial 50 days after exposure, the level of cholesterol increases, the relative concentrations of linoleic, arachidonic and other non-saturated fatty acids, the concentration of phospholipids reduce (G.G. Egutkin et al, 1993).

The damage of membranes, specifically inhibition of membrane enzymes Na+-, K-ATP-ase, Mg ATP-ase may be induced by irradiated solutions of sugars (I.P. Edimecheva et al., 1992).

Damage of the brain tissues is attributed to the toxic effect of a highly reactive nitrogen oxide (NO) appearing already during the first minutes after irradiation (V.L. Sharygin et al., 1994).

CHAPTER 3

CONDITION OF METALOBISM AND FUNCTIONAL MODIFICATIONS OF ORGANS AND SYSTEMS UNDER THE EFFECT OF INCORPORATED RADIOISOTOPES

3.1. CARDIOVASCULAR SYSTEM

The problem of the effect of radiation upon the cardiac functions of man and animals has been reflected in local and foreign publications. In the majority of cases the cardiac functions have been rated with the consideration of external irradiation of the whole body or in the region of the heart primarily in experimental conditions. In particular, single time exposure of experimental animals (dogs, rabbits, rats) to a dose of 15 Gy and more produces degenerative and necrotic modifications of the myocardium (A.P. Amvrosjev et al., 1989) accompanied by the evolution of exhudative pericarditis (Schultz-Hector, 1992) leading to hemodynamic disorders in the form of minute and impact volume reduction, expansion of the diastolic volume of the left ventricle (Schultz-Hector et al., 1992). It has been observed that the functioning of the cardiovascular system is upset by general irradiation with ^{60}Co gamma quanta of rats due to the exhaustion of the activating effect of the median brain blue spot (V. A. Fedorovich, 1991) and suppression of the modulating effect of the rear nuclei of the brain seam (V.A. Sjusjukin, A.I. Ledeneva, 1991)].

The detected restructuring of the neurohormonal control governs the suppression of adaptation capabilities of the blood circulation system and may stimulate the evolution of prepathological conditions (L.M. Lobanok, 1991).

External exposure of the organism, including the heart, causes suppression of the contractile activity of myofibrils, reduction of the volume rate of coronary circulation (M.A. Tatarinchik, A.E. Kirienkov, 1991).

Functional modifications of the cardiovascular system can possibly be attributed to the damage of blood vessels, specifically arterioles (A.G. Zakharov et al., 1992), or capillaries (Darcourt et al., 1992), variation of the volume of catecholamines and electrolytes in vessel walls (S.A. Litvinov, 1992).

Using isolated rat heart preparations it has been demonstrated that external gamma irradiation with a dose 6 Gy suppresses the contractility of the myocardium and alters the chronotropic relations: the relationship between the frequency-force and the potentiating effect in the atria at the interval of rest increases, while the potentiating effect in the ventricles reduces. Modification of the chronotropic relationships may be due to the alteration of the calcium transport in the heart cells (V.V. Shilov, L.M. Lobanok, 1991).

After a single exposure to X-ray and neutron irradiation in doses 0.4 and 1.0 Gy the rabbits would not manifest any significant disorder of the functional condition of the cardiovascular system, yet pronounced responses to pharmacological preparations have been registered (G.P. Katsnelson, 1991). It is possibly due to the modification of the structural and functional density, the affinity to the "beta" agonist and sensitivity to the sulfohydril reagent (N.V. Gerasimovich, 1991).

The results of the experimental research accomplished by E.F. Konoplya et al. (1996) allow to conclude that acute gamma-irradiation with doses 0.25; 0.5 and 1.0 Gy upsets the calcium transport system of the sarcoplasmatic reticulum of the muscular tissue. The activity of Ca2+ATP at doses 0.25 and 0.5 Gy increases, while it is strongly suppressed at a dose 1.0 Gy.

It is assumed that the appearance of peroxide groupings in fatty acidic chains of phospholipids under the effect of ionizing radiation alters the structure of the membranes of the sarcoplasmatic reticulum, their penetrability by various substances and the activity of membrane-bound enzymes, specifically Ca2+ATP.

These results are corroborated by the data obtained while screening the population affected by the Chernobyl radiation. In particular, 95.5% of the children and adolescents have manifested disorders of the functional condition of blood circulation in the form of upset rhythm of the cardiac activity, conduction, metabolic and restorative processes in the myocardium, suppressed tolerance of physical exercise, elevated arterial pressure.

These disorders of the functional condition of the cardiovascular system are most pronounced among the children aged between 6 and 10 years assumed healthy before (V.N. Novikova, 1991).

I.S. Tsybulskaya et al. [143] indicate also that 74.4% of the children during their first year of life in the areas where the soil is contaminated with radiation within 5-20 Ci/km^2 manifest pronounced electrocardiographic modifications: intricate rhythm disorders, alteration of the teeth of the ventricular repolarization.

Domination of the syndrome of premature repolarization of ventricles and elevated arterial pressure are typical for these groups of children (A.N. Arinchik, G.L. Nalivajko, 1991).

Vagotonia with asympathycotonic reactivity has been revealed among 36 out of 102 examined children aged 11-15 years living in the area with the ^{134}Cs, ^{137}Cs soil contamination 0.4-10 Ci/km^2. The children in this group have manifested disorders of the lipid metabolism in the form of hypocholesterinemia, hypolipidemia, hypophosphatemia (L.V. Kvashnina et al., 1992). V.V. Nedvestkaya and S.A. Ljalikov (1994) also indicate modifications of the vegetative regulation evolving among the children aged 6-17 years in the contaminated areas of Belarus which are more pronounced among girls than among boys. These modifications are characterized by the suppression of the tone of the sympathetic compartment of the nervous system, a tendency towards hyporeactivity and stress of the compensatory mechanisms of the parasympathetic compartment. Correlation analysis has revealed a close relationship between vegetovascular dystonia appearing among the children evacuated from the heavily contaminated areas, and thyroid hyperplasia, psychic disorders, disorders of digestive organs (A.U. Lagutin, V.M. Sidelnikov, 1992).

Children from the affected areas manifest modifications of the responses of the cardiovascular system to catecholamines (L.S. Valeva et al., 1993).

Arterial hypotonia detected among 34.3% of boys and 30.2% of girls in the Gomel and Moguilev regions reflects disorders of the vegetative regulation of cardiac functions (A.V. Sikorenskii, G.E. Vagel, 1992). Modifications of cardiac functions are registered among adults exposed to external irradiation, in addition to children.

It has been demonstrated that men aged 20-40 years who were involved in the cleaning-up operations in 1986-1988 after the disaster manifest disorders of neurohumoral regulation of the cardiac tone and myocardium contractility (S.S. Korytko, 1991). The incidence of cardiac ischemias and arterial hypertensions among liquidators of the Chernobyl aftermath is validly higher than among individuals in the control group in Moscow (V.M. Shamarin, et al., 1996). Disabled individuals with cardiac ischemias living in the contaminated areas have more frequent and stable cardiac rhythm disorders than individuals with similar pathologies living in "clean" areas (N.T. Arinchina, V.K. Milkamanovich, 1992).

Dysfunction of the vegetative nervous system in the form of secondary domination of the stray nerve tone as bradicardias and ectopic precardiac rhythm has been observed among male liquidators and evacuated individuals (G.P. Karaseva, 1991).

Evolution of arterial hypertension is one of the manifestations of the above condition (N.S. Zanozdra, E.G. Kuchinskaja, 1991). In particular, borderline hypertension has been detected among individuals in the contaminated areas 1.5 times more frequently than in the "clean" areas (I.I. Goncharik, 1992).

Thus, stable neurovegetative disorders in the form of the neurocirculatory dystonic syndrome among the individuals affected by radioisotopes indicate the involvement of hormonal and humoral mechanisms in the induction of functional pathology, including that of the cardiovascular system (A.M. Kovalenko, 1991).

Yet, for evaluating the consequences of the Chernobyl disaster it is more essential to determine the effect of internal irradiation from incorporated radioisotopes upon the condition of vital systems, including the cardiovascular system.

In particular, when incorporated ^{131}I creates absorbed doses in the thyroid after 1-12 months at a level 94.6-94.7 Gy, the responses of the myocardium to the stimulation of alpha-adrenergic receptors is attenuated, while the responses of the coronary passage to such stimulation are intensified (A.E. Kirienko et al., 1992).

Incorporation of ^{131}I and ^{137}Cs by rats induces modifications of the heart pace-maker activity, the functional condition of the coronary vascular passage, electric and contractile activity of cardiomyocytes and flat muscle vascular cells (A.E. Kirienko et al., 1990).

Examinations of the children living in the contaminated areas (Gomel — 1-5 Ci/km^2) have revealed high frequency of disorders of cardiac activity - 72.3%, 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 and vegetovascular dystonias, together with a close relation between the doses of endogenously incorporated radioisotopes and electrocardiographic disorders. Though the average accumulated dose in the organisms of children in these two groups did not have any valid difference and amounted to 30.32 ± 0.66 Bq/kg in the test and 29.74 ± 0.67 in the control ($p > 0.1$), the Gomel children have manifested a more pronounced and statistically valid direct proportionality between the accumulated dose and ECG modifications, valid differences between the subgroups of 11-25.9 Bq/kg and 37.0-74.0 Bq/kg (Fig. 6).

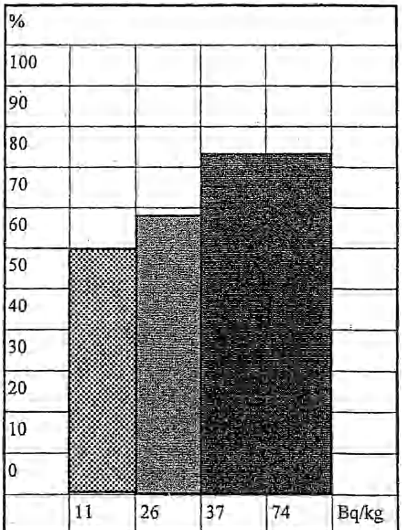

Fig. 6. Frequency of ECG modifications among children in Gomel as function of incorporated dose

The children with the above accumulated doses but living in Grodno did not manifest any valid differences in the frequency of registered ECG modifications.

This fact in the main group is basically due to the disorders of intraventricular conduction in the form of incomplete blockades of the His right stem bundle (Fig. 7).

When children accumulate significantly higher doses of radioisotopes 89.93 ± 3.65 Bq/kg on the average (Vetka) the ECG-registerable effects have been detected among 86.8% with the disorders of the intracardiac conduction amounting to 53.95% (G.S. Bandazhevskaya, 1996).

Examinations of the students of the Gomel Medical Institute have yielded similar results (Yu.I. Bandazhevsky, et al., 1996).

Thus, investigation of the electrophysiological processes in the cardiac muscle among children in the areas with higher levels of radioactive contamination has revealed a number of modifications of electrocardiographic activity with the frequency being a function of the internally accumulated dose.

Damage of the myocardium structure is accompanied by the intensified activity of AST **in the blood serum (Fig. 8).**

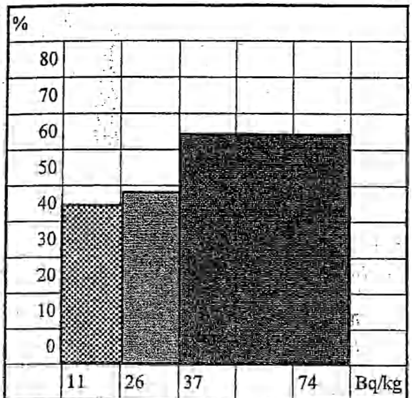

Fig. 7. Frequency of distribution of cardiac conduction disorders among children in Gomel as function of incoroporated dose of radioisotopes

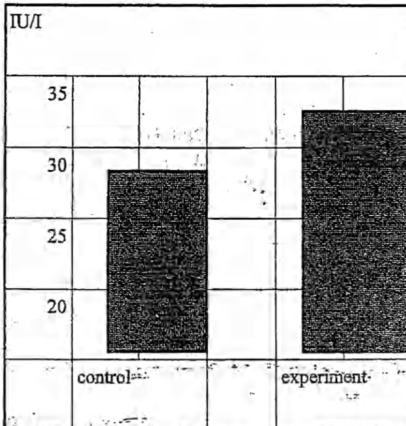

Fig. 8. Comparative values of AST activity in blood serum among children of experimental and control groups ($p < 0.001$)

Experimental studies of laboratory animals (the Vistar line rats) evidence the effect of endogenously incorporated radioisotopes upon the myocardium.

The experimental animals were kept during ten days on a diet of oats containing radioactive elements in the concentration exceeding the control level 10 times (^{137}Cs concentration was 445.7 Bq/kg, ^{90}Sr - 15.5 Bq/kg). This diet would bring the ^{137}Cs concentration in the organisms of the animals in the test group to 63.35 +\- 3.58 Bq/kg versus 5.43 +\- 0.87 Bq/kg in the control group ($p < 0.001$).

In this way the animals would accumulate radioisotopes within a relatively short period of time, ^{137}Cs in particular. A direct proportionality between the accumulated ^{137}Cs dose and the concentration of this element in the grain.

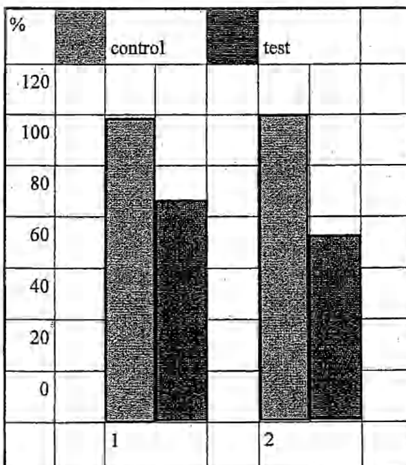

Fig. 9. Variations of activities of enzymes in myocardium tissue among experimental animals (% versus control): *1* — alkaline phosphatase; *2* — creatinphosphokinase ($p < 0.05$)

Analysis of the results has indicated that the myocardium tissue acquires the maximum concentration of this radioactive element.

Significant concentrations of ^{137}Cs have been registered among the residents of Gomel and the Gomel Region (Yu.I. Bandazhevsky, A.M. Perepletchikov, 1996). It is manifested by the suppressed activity of the most essential enzymes, such as alkaline phosphatase and creatin phosphokinase (Fig. 9). Considering that creatinin phosphokinase is a key enzyme of the energy metabolism in the cardiac muscle governing reactions between macroergic phosphate and creatinin, its suppressed activity leads to substantial disorders of the functions of cardiomyocytes.

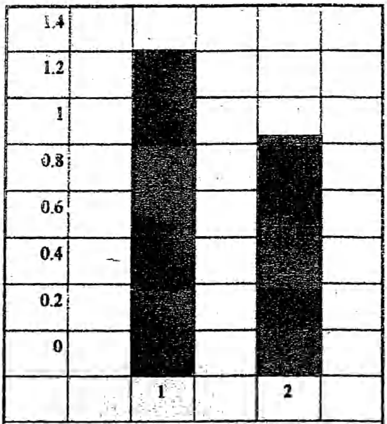

Fig. 10. Height of anisotropic discs in myocardium of experimental animals: *1* — experiment; *2* — control ($p < 0.05$)

Disorders of energy processes in the heart modify its contractile apparatus, vis. myofibrils in the form of contractions or their declustering and lysis in various degrees of expression (L.M. Nepomnjashchikh, 1966).

Modification of the polarization behavior of cardiomyocytes in the form of expanding A-discs is a morphological criterion of this pathology (Fig. 9-10). The obtained data explain origination of disorders of cardiac conduction, including the cardiac rhythm, induced by incorporated radioisotopes.

Examinations of the biopsied material have manifested that contracted cardiomyocytes with ultrastructural modifications and disorders of the structures of insert discs and atrophic cardiomyocytes and cells with signs of apoptopic degeneration typical for this condition prevail in the arhythmogenic portions of the heart, unlike the non-arhythmogenic zones (Bakerija, et al., 1995).

Thus, it has been experimentally demonstrated that incorporation of radioisotopes by laboratory animals with food (primarily ^{137}Cs) damages the myocardium cells producing relevant structural and functional modifications. Clinical and experimental studies have revealed a significant sensitivity of the myocardium cells of a growing organism to incorporated radioisotopes. A whole combination of modifications evolves evidencing a direct injury of the cardiac muscle, organs and systems controlling its functions. The role of pathological processes evolving in the cardiac nervous apparatus should be taken into consideration by all means.

Hence, the problem of reducing doses of internal accumulation of radioisotopes comes into foreground, including application of sorption preparations (Yu.I. Bandazhevsky et al., 1994), requiring to project treatment actions for improving metabolic processes in the myocardium.

Analysis of the arterial pressure among children with different incorporated doses has revealed a dose-dependent effect. As the dose increases the number children with hypertension goes up. Totally 41.6% of the children in the areas contaminated with ^{137}Cs in excess of 15 Ci/km^2 manifested arterial hypertension (A.I. Kienja, N.M. Ermolitskii, 1997).

3.2. NERVOUS SYSTEM

The nervous system is one of the first to respond to radiation effects, both local and general, affecting the entire organism (U.I. Moskalev, 1991).

Penetration of long-living radioactive elements (^{137}Cs, ^{90}Sr) into the organism causes a pronounced loss of equilibrium of neuroactive amino acids and biogenic monoamines in various compartments of the central nervous system, specifically the exciting transmitter, such as aspartate and glutamate, and decelerating agents, such as gamma amino oleic acid (GAOA), glycin. The degree of expression of the process is determined by the duration of incorporation of radioisotopes by the organism.

A more intricate pattern of variations of the bank of biogenic amines and neuroactive amino acids under the effect of incorporated radioisotopes is noteworthy, compared with external irradiation, still a number of reconstructed effects (inhibition of the serotonin system, early activation of the GAOA-system) is comparable with the effect of moderate lethal and superlethal doses for experimental animals (V.V. Lelevich, E.M. Doroshenko, 1995).

Injury of the brain tissues can be due to the toxic effect of the highly reactive nitrogen oxide they contain (V.L. Sharygin, et al., 1994).

Incorporation of ^{137}Cs causes dysfunction of the vegetative nervous system, with the incidence of the elevated tone of the sympathetic nervous system being directly proportional to the quantities of the incorporated radioisotope.

3.3. THYROID GLAND

The thyroid gland is the most vulnerable organ in respect to radiation and has suffered most from the Chernobyl disaster. The gland has manifested pathological effects specifically clearly after a significant period. In particular, the diseases of the thyroid gland in 1990 in the Gomel region amounted to 126.1 cases per 100,000 with the rise in 1995 to 1,154.5 cases, meanwhile among children these cases numbered 3106.1 per 100,000. These figures are still higher in the areas proportionally denser radioactive levels amounting to 4,056.9 generally in the Braguin district and to 1,9072.6 among the children. The leading factor of internal irradiation has been ^{131}I with the collective dose for the thyroid gland amounting to 22,000 (R.I. Halitov, et al., 1993). Exactly this radioisotope has led to substantial disorders in the areas adjacent to Chernobyl. In particular, examinations of the individuals after their involvement in the cleaning-up operations have demonstrated the compensated condition of the thyroid system just among 35.6%, hyperthyreosis among 39.7%, hypothyreosis among 24.7% (V.N. Petrov, N.M. Petrov, 1991). Dr. O.V. Kopylova and her co-researchers have obtained similar results showing the condition of hyperthyrexinemia among 40.0% of the children in the areas of radiation risk, other medical researchers (N.B. Pashinskaja et al., 1991) also report a suppressed function of the thyroid gland among 37.9% of the children.

G.S. Bandazhevskaya (1966) registered a higher concentration of thyroxin in the blood among children aged 3-7 years old in 1995 in Gomel (1-5 Ci per km^2 of ^{137}Cs) compared with the control having a directly proportional relation with the concentration of incorporated radioisotopes (Fig. 11, 12). Meanwhile the concentration of triiodine thyronin is much below the control level (Fig. 13). E.L. Strukov et al. (1994) believe that this condition accompanies a complicated evolution of diseases of the cardiovascular and digestive systems.

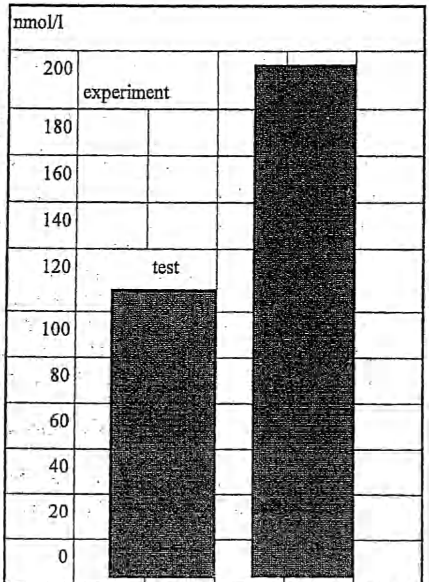

Fig. 11. Comparative values of thyroxin (T_4) in blood serum of children in experimental and control groups ($p < 0.001$)

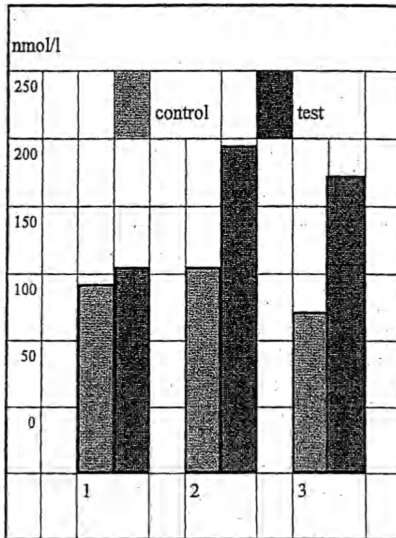

Fig. 12. Thyroxin (T_4) concentrations in blood serum among children of test & control groups as function of incorporated dose of radioisotopes: *1* — 11-25.9 Bq/kg; *2* — 26-36.9 Bq/kg; *3* — 37-74 Bq/kg ($p < 0.001$)

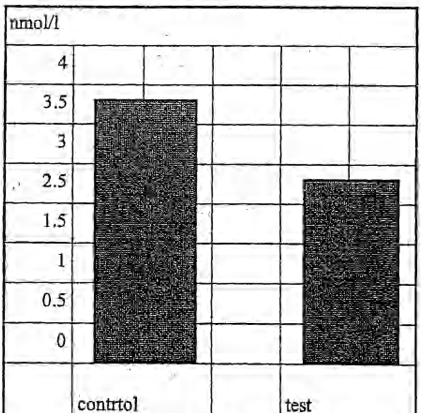

Fig. 13. Comparative concentrations of triiodine thyronin (T_3) in blood serum of children of test and control groups ($p < 0.001$)

It should be remarked that the above hyperthyrexinemia commonly evolves without any pronounced clinical manifestations (E.V. Epshtein et al., 1993). A somewhat higher level of triiodine thyronin in the blood with a simultaneous reduction of the secretion of thyreotropin was observed among the children and adolescents during the first three years after Chernobyl indicating a functional activation of the thyroid system (A.F. Tsyb et al., 1991). The intricate metabolism of thyroid hormones should be taken into consideration. The basic hormone of the thyroid gland of a normal man is T_4. Less than 20% of the total zero of T_3 is produced monodeiodinizing of T_4 in peripheral tissues. The liver and kidneys are the main transformers of T_4 into T_3 (I.I. Dedov et al., 1992). The basic effects of the thyroid hormones are determined by T_3. Small doses of radiation lead to suppressed secretion of the thyroxin binding globulin, a higher total concentration of thyroxin in the blood would occur versus the reduced concentration of progesterone and prolactin among pregnant women (weeks 12-32 of pregnancy) (N.S. Akulich et al., 1990). Individuals with a dose burden 400 Gy upon the thyroid gland become predisposed to hypothyreosis (L.N.. Astakhova et al., 1993).

In addition to the altered hormonal secretion by the thyroid gland, structural modifications have been detected proving the evolution of the gland's pronounced pathology. The ultrasound screening of girls aged 6-18 years who stayed within the 30 km zone during the explosion revealed changes in their thyroid glands typical for hypoplasia and moderate thyreofibrosis (I.V. Vovk et al., 1992).

Pathoanatomical investigations of the thyroid glands of fetuses and children in the Gomel region who died of various diseases, have revealed morphological manifestations of a stronger functional activity of the gland, such as noticeable stimulation of the processes of desquamation of thyrocytes, reduction of the relative volume of the thyroid epithelium in the gland due to cytolysis, valid reduction of the sizes of follicles followed by their collapse and substitution with the connective tissue stroma (E.D. Cherstvoj et al., 1993).

Experimental studies corroborate the results of clinical observations. In particular, intra-abdominal administration of 500 kBq of ^{131}I would alter the calcium-phosphorus metabolism and its hormonal regulation among rats and cause a shift in the production of thyroid hormones (I.M. Bagel et al., 1990). In addition to ^{131}I, significant changes in the thyroid gland can be induced by repeated external gamma irradiation (1 Gy) leading to stable structural and functional disorders among laboratory animals. In the long term these disorders result in the appearance of hypothyreosis demonstrated by the reduced concentration of thyroxin in the blood, stimulation of the thyreotropic function of the hypophysis, inhibited activity of -glycerophosphate dehydrogenase as a thyroxin dependent enzyme in the liver (J.H. Turakulov et al., 1992).

The incidence of the thyroid nodular pathology among the children in the Gomel Region exceeds 15%, including 2.54% thyroid cancers ((L.N.. Astakhova et al., 1993).
The Kaluga Region manifests similar results where nodular goiters have been increasing since 1994, together with thyroid cancers (follicular and papillary forms). The dose of radioactive iodine absorbed by the thyroid gland varied from 25.6 to 169 cGy (E.G. Matvienko et al., 1996).

Nevertheless, the children in the Khojniki district (aged 0-17 years) show the highest doses of irradiation of the thyroid gland (242-527 cGy) versus 15 to 60 cGy in Gomel, 2.4 to 9.2 cGy in Minsk. The children which were aged under five years at the moment of the disaster received the maximum doses (I.I. Dedov et al., 1992).

This effect of radioactive iodine resulted in more frequent thyroid disorders, specifically thyroid cancers, nodular goiters, autoimmune thyreoditis. A sharp rise in the number of thyroid cancers occurred in the Republic of Belarus on the fifth year after Chernobyl. During the last decade 422 cases have been registered among children and 3,492 among adults and adolescents (I.M. Drobyshevskaja et al., 1996). Thyroid cancers are most frequent among adolescents in the Khojniki district.

The clinical and morphological analysis of thyroid cancers among the children in Belarus has revealed several features of the diseases:

1. A relatively short latent period between the probable cause factor and the clinical manifestation of tumors.
2. Domination of capillary carcinomas with manifestations of reduced histological differentiation having a pronounced localization and a high frequency of metastasizing (A.V. Furmanchuk et al., 1992; L.S. Baleva, E.E. Karneeva, 1996).

The pathogenesis of the above pathological conditions is primarily due to the initial effect of ^{131}I. It has been noted that the disaster led to the release of 20 to 30% into the atmosphere from 60-70 million Curies of ^{131}I contained in the reactor (G.A. Gerasimov, 1991). The "iodine impact" severely injured the structural components of the thyroid tissue. Taking into consideration the short life of ^{131}I a period of repair - restoration followed, when the immunity system would play a paramount role of controlling the processes of proliferation and differentiation of the follicular epithelium and the neighboring cells.

Apart from ^{131}I, the radioactive releases created conditions when other long living radioisotopes would affect continuously the human organism, specifically ^{137}Cs and ^{90}Sr. They would modify the functions of many vital systems and tissues of the organism, including the immunity system and the thyroid cells which would accumulate them intensively (Yu.I. Bandazhevsky, A.M. Perepletchikov, 1996). It would lead to the damage of the most essential ultrastructures of the cells, modification of the antigen determinants on the surfaces of the cytoplasm membrane.

The result is that the structural components of thyroid cells become antigens for the immunity system. An immunological response appears when the cellular structures of the thyroid gland are damaged by the autoantibodies and immunocompetent cells, finally leading to the appearance of autoimmune thyreoditis and, after that, in a number of cases, to thyroid cancers. A relationship has been established between the radiation burden upon the thyroid gland, the populations of antigens and the microsomal fractions of the thyroid gland (A.M. Poverennyi et al., 1996).

The reactions between immunoglobulins and thyroid hormones, such as thyroxin, should be taken into consideration in the pathogenesis of thyroid diseases. It has been established that immunoglobulins of different classes (J, A, M) are capable to bind thyroxin, triiodine thyronin (O.V. Sviridov et al., 1992). The children in Gomel have manifested correlation between the concentration of Ig and the level of T4, while the children in the control areas have manifested none.

When the hormones are bound by immunoglobulins, they are eliminated from the metabolic chain and naturally the functions of the hypophysis - thyroid system become upset.

The processes lead to the liberation of significant quantities of thyreotropic hormone enhancing the pressure upon the thyroid gland and boosting proliferation of the follicular epithelium creating conditions for neoplastic transformations.

3.4. IMMUNITY SYSTEM

Radioactive elements produce a pronounced effect upon the immunity system. Similarly like it is done for other vital systems, pathological effects should be discriminated based on the external irradiation and internal irradiation of the organism from incorporated radioisotopes.

In the first case adults manifest an acute radiation disease with a strong drop of the total quantity of leukocytes and lymphocytes with variations of the concentration of immunoglobulins and C-reactive protein in the peripheral blood as a function of the stage of the disease (A.A. Ivanov et al., 1991).

The thymus-dependent CD^{4+} and the lymphocytes belong to the group of T-helpers in the peripheral blood and make up the most vulnerable lymphocyte population (A.A. Chumak

Variations in the system of proteins of the acute phase, vis. a reduction of the concentration of complements and a rise of the C-reactive protein concentration are typical for the primary response during the initial period. The peak period of the radiation disease is characterized by pronounced modifications of the cellular and humoral immunity and the factors of non-specific protection, vis. a reduction of the lymphocyte count and concentration of properdin, lysosim, immunoglobulins in the blood and a rise of the concentration of the C-reactive protein and the complement. Hyperleucocytosis with the leftward shift of the blood formula towards myelocytes and singular myeloblasts are registered among the majority of the children with radiation injuries during the first days (V.N. Bebeshko et al., 1991).

Both a temporary rise and decline of the leukocyte count together with the disorders of concentrations of T- and B-lymphocytes and a distorted ratio between helpers and suppressors can occur in the remote period of the disease (A.A. Ivanov et al., 1991; A.A. Ivanov et al., 1993).

Fitters, erectors and designers after involvement in the elimination of the Chernobyl aftermath demonstrated four years later lack of equilibrium and a dysfunction of the immunity homeostasis, irrespective of the dose of ionizing irradiation (N.P. Savina, et al., 1995).

Loss of equilibrium of the subpopulation composition of T-lymphocytes, periodical reduction of the concentration of B-lymphocytes, major classes of immunoglobulins in the blood serum, reduction of the parameters of the index of immunoregulation have been registered among individuals after involvement in the cleaning-up operations (T.V. Vorontsova et al., 1990, R.J. Bruveret, 1991; V.G. Komissarenko et al., 1991; T.V. Kozyreva et al., 1991; I.V. Radovskaja, 1992), as well as among children from the Chernobyl orphanage which manifested reduction of the concentration of immunoglobulins M, G and A, suppressed phagocytary activity of neutrophil granulocytes at normal hematological parameters (Z.G. Isaeva et al., 1991).

Liquidators basically healthy at the moment of examination manifested reduction of the subpopulation of T-active lymphocytes and concentration of rosette-forming neutrophils alongside with the rise of the number of autorosettes (N.M. Galitskaja et al., 1991).

Microcytosis of lymphocytes is 6-7 times more frequent among the children in the contaminated areas compared with the control is a typical feature of the cells of the lymphoid series (I.P. Danilov, L.Ja. Krylova, 1991).

A large dense nucleus and a meager cytoplasm are typical for the lymphocytes of the peripheral blood (Ju.K. Novoderchinina et al., 1995).

The population of natural killers, their cytotoxic activity, the concentration of immunoregulatory cells and B-lymphocytes most frequently deviate from the norm among the individuals living in the area with ^{137}Cs contamination 15-47 Ci/km^2 (E.G. Kuzmina et al., 1993; N.I. Lisjanyi et al., 1991).

A similar situation is observed among the liquidators involved during 1986-1987 in the Chernobyl area 5-6 years after the disaster (T.V. Mikheenko et al., 1996).

The immunity status of the examined persons typically manifests lymphopenia, reduction of the percentage of general rosette-forming lymphocytes and the population of NK-cells, T-suppressors-killers, deficiency of B-cells, inhibited activity of neutrophils (I.V. Oradovskaja, 1993) and monocytes (I.V. Volchek et al., 1991).

Disorders of the composition of subpopulations of lymphocytes feature reduction of the concentration of CD^{+3}, HLA-DR- cells (A.A. Chumak et al., 1992).

So, the examined individuals have shown modifications primarily of the TT-cellular immunity with a significant rise of Ig, A and M (T.V. Kozyrev et al., 1991; V.I. Telkov et al., 1993). Still, reduction of the concentration of all immunoglobulins (V.G. Komissarchenko et al., 1991) rise of Ig,M A.A. Ivanov, 1991; A.A. Akleev et al., 1991) and Ig G, and drop of the concentration of Ig A (V.G. Koledenko et al., 1991; N.N. Salitskaya et al., 1990), have been registered.Reduction of the secretory Ig A in the saliva (O.F. Melnikov et al., 1991) were observed during two post-disaster years.

The detected modifications reflect the condition of B-lymphocytes under the effect of radioisotopes (T.V. Miheenko et al., 1991).

Like the adults, the children in the contaminated areas have manifested a valid reduction of the concentrations of T- and B-lymphocytes, major classes of immunoglobulins (G.I. Vinogradov, V.K. Vinarskaja, 1991; N.N. Galitskaja, A.V. Elinov, 1992), suppressed proliferative activity of T-cells during stimulation of PGA (O.E. Vatin et al., 1991).

The children in the areas contaminated with ^{137}Cs to the tune of 1-5 Ci/km^2 have manifested inhibition of the phagocytary activity of neutrophil leukocytes against the rise of the concentration of IgM and drop of the concentration of IgA in the blood compared with the control (Ju.I. Bandazhevsky et al., 1995). Meanwhile a possibility to stimulate effectively the cytotoxic activity of natural killers with immunomodulators having different mechanisms of actions allows to assume that the suppression of the activity is of functional nature and is reversible (O.F. Melnikov et al., 1991). Domination of the helper population of T-lymphocytes is a typical feature (G.I. Kovalev et al, 1990; A.K. Cheban et al., 1991).

Exclusively high radiosensitivity of the population of T-suppressors and their precursors is noteworthy among all the cells of the lymphoid series (V.T. Komissarenko et al., 1993). Predominant inhibition of the suppressor link of the immunity system among the children in the areas affected by radioisotopes (O.S. Dehtjareva et al., 1991) is accompanied by the rising concentration of IgM, G and circulating immunity complexes in the blood (S.K. Evtushenko et al., 1992).

A higher concentration of interferon among the children in the heavily contaminated areas can be assumed as the organism's response to radiation (I.V. Korobko, L.P. Titov, 1991).

Some of the examined liquidators manifest a higher concentration of circulating interferon in the blood and all the examined individuals manifest inhibition of the synthesis of gamma-interferon evidenced by the suppressed functions of the interferon system (I.V. Korobko et al., 1996). This protein has an exceptional significance for the immunity system.

Basically healthy young individuals in Kiev have manifested five years after the disaster a reduced humoral and T-cell immunity and a noticeable inversion of the theophylin effect evidencing functional modifications of the T-cell immunity system (V.G. Komissarenko et al., 1993).

The results of the immunological screening of the population affected by radioisotopes are corroborated by the experimental studies of laboratory animals. During 1989-1990 the laboratory animals (rats, mice) kept in Chernobyl manifested strong modifications of the immunity system evidenced by the reduction of the absolute concentration of immunocompetent cells, specifically T-lymphocytes, stable and prolonged suppression of the activity of natural cytotoxic cells and antibody-dependent killer-cells (O.F. Melnikov et al., 1991). Meanwhile the population of B-lymphocytes in the experimental animals remains basically unchanged (Z.D. Savtsova et al., 1991).

The sheep in the Belorussian Lowlands with the density of radioactive contamination 40-100 Ci/km^2 manifest suppressed activity of neutrophils, reduced concentrations of T and B-lymphocytes (V.A. Budarkov et al., 1991).

The animals of the first and second generations have manifested the strongest immunity deficit modifications (O.F. Melnikov et al., 1991). Gamma-irradiation of the Vistar line rats has reduced the population of lymphocytes in the thymus, spleen and bone marrow and caused structural and functional damage of these cells (L.G. Bortkevich et al., 1989).

A significant suppression of the spontaneous cytotoxic behavior of NK-lymphocytes has been observed among the rats kept on a diet to achieve a dose of ^{89}Sr equal to 200 Bq/animal and ^{137}Cs equal to 250 Bq/animal after 30 days (N.N. Volkova, V.N. Korzun, 1991).

Disorders of the immunity response to the thymus-dependent antigen (ram's erythrocytes) persisted among the mice of the "clean" lines after injections of ^{125}I and ^{131}I (U.N. Anohin, N.V. Belorukova, 1992).

The above modifications of the immunity status of the individuals in the areas contaminated with radiation are due to a high radiosensitivity of immunocompetent cells. Different doses of radiation damage different cell populations. The doses 1.2-1.8 Gy produce pathologic effects in B-lymphocytes, the doses 2.0-2.5 Gy and up produce such effects in T-cells (A.A. Jarilin, 1988), among them T-suppressors are most vulnerable (I. Wasserman et al., 1979). It should be noted that thymocytes at the final stages of differentiation are more than twice sensitive to radiation than the thymocytes at the initial stage (V.M. Graevskaja, N.N. Zolotareva, 1991). Modifications of the functional activity of macrophages in the organism after exposure to radiation are due to a stronger permeability of cellular membranes (M.A. Tumanjan et al., 1992).

It is noteworthy that the intrauterine irradiation causes more pronounced modifications of immunity than irradiation during the first years of life (A.V. Akleev, M.M. Kosenko, 1991).

Dysfunctions of the macrophage system are due to the suppression of the antioxidant system (E.A. Lunina, et al., 1995).

Thus, radioisotopes produce strong modifications in the immunity system of man evidenced by a higher incidence of lymphadenopathies and secondary immunity deficits, basically due to the suppression of the T-system of lymphocytes (general and T-cell deficiency, deficit of T-helpers). The degree of clinical manifestations of immunity deficit stays below critical which is typical for primary immunological deficiency (L.S. Baleva, E.E. Korneeva, 1996).

Therefore, the immunity system should be considered as a critical organ affected by all types of radiation.

Damage of the immunity system links causes evolution of the immunological processes, specifically such as allergies and autoimmune conditions. Among the latter the most noticeable is autoimmune thyreoditis or Hashimoto goiter. Its spread among children has been registered in the areas with ^{137}Cs contamination above 1 Ci/km^2 five and six years after the disaster.

Rising numbers of autoimmune processes when antibodies to the antigens of the thyroid tissue appear positively correlates with the doses incorporated by the thyroid (I.M. Hmara, L.N. Astahova, 1996).

Allergies become more frequent among the children in the contaminated areas in response to quite common antigens, such as cow milk protein. The children in the areas with higher ^{89}Sr concentrations the tendency to allergies has been registered using the reaction of degranulation of obese cells in 36.8% of cases (versus 15% in the control). Cortisone concentration in the blood of the children is validly lower in a number of cases (Yu.I. Bandazhevsky et al., 1995).

Positive and strongly positive allergic reactions to the cow milk protein, allergens in oranges have been manifested in 1997 by 50% of the students of the Gomel Medical Institute and schoolchildren in the community of Svetilovichi (Yu.I. Bandazhevsky, I.A. Verner, 1997).

3.5. HAEMOPOIETIC SYSTEM

Radioactive emission is capable to produce corresponding modifications in the haemopoietic systems of man and animals as a function of radiation intensity and duration.

When man is exposed to a dose from 1 to 10 Gy an acute radiation disease appears. The hematological syndrome emerges on the 3rd or 4th week in the form of granulocytopenia, thrombocytopenia and anemia and plays an important role in the pathogenesis of the diseases (A.E. Ivanov, 1991).

Stable modifications of quantitative and qualitative parameters of the peripheral blood and bone marrow, strong modifications of the system of metal proteids of the blood plasma, reduced concentrations of Fe-transferin and Cu2+-ceruloplasmin occur during reconvalescence after acute radiation disease and among patients with the initial stages of depression of haemopoiesis after doses 0.3-1.0 Gy.

Scrutiny of cultures shows that the haemopoietic function at the level of closest offsprings of stem cells is retained by the majority of these individuals (V.G. Bebeshko et al., 1996).

During the initial fortnight in the Chernobyl zone the liquidators had transient leucocytosis, reticulosis, eosinophilia (U.N. Shishmarev et al., 1992), a greater number of stem nuclear neutrophil leucocytes (L.N. Ljubchenko et al., 1991; N.M. Oganesjan et al., 1991) and basophils L.N. Ljubchenko et al., 1991). The nuclei of mononuclears would increase in dimensions and become less optically dense.

Zverkova et al. (1991) indicate that after involvement in the elimination of the Chernobyl consequences a number of individuals would manifest neutrophilopenia, a leftward shift of the leucocytary formula, a greater concentration of monocytes.

During the next 30-50 days in the Chernobyl zone the count of thrombocytes, erythrocytes and reticulocytes would reduce (U.N. Shishmarev et al., 1992).

Four or five years later these individuals would manifest absolute lymphocytosis and monocytosis, reduced index of segmentation of cell nuclei, reduced concentration of myeloperoxidase in leucocytes (I.E.. Danilov et al., 1992).

Five or six years later quantitative and qualitative modifications of the leucocytary link are observed in the form of moderate relative and absolute lymphocytosis, eosinophilia and neutropenia. Larger radiation doses would produce lymphocytes and neutrophil leucocytes with a jagged nuclear shape, would cause appearance of additional nuclei. The number of chromatin outgrowth in neutrophils would increase (K.P. Zak et al., 1995).

Moreover, the liquidators showed four years later manifestations of the functional loss of organization in the hemostasis system: activation of hemocoagulation and aggregation of thrombocytes against the suppressed activity of fibrolysis and antithrombogenic features of vascular walls (S.I. Chekalina et al., 1995).

Like among adults, the children in the radiation-affected area manifest modifications of the haemopoietic system. The children in the areas with heavy contamination have the average concentrations of erythrocytes, hemoglobin validly less compared with the norm (T. I. Kozorezova et al., 1993). Basically healthy children evacuated from the city of Pripyat 36-40 hours after the disaster have manifested a moderate leucocytosis and a higher relative and absolute concentration of the cells of the granulocytary series (the stem nuclear and segment nuclear neutrophils, eosinophils).

The leucograms of these children typically show granular lymphocytes (V.G. Bebeshko, 1991) and enlarged neutrophil leucocytes with a toxigen and immature granularity (U.V. Stepanov et al., 1992). Hexagrams of these children did not manifest any significant modifications 1-4 years after the disaster. Also, the children after exposure to small doses of radiation manifest modifications of the morphological composition of the peripheral blood which have no pathological nature, such as leucopenia, lymphocytopenia (D. A. Torubarova, G.I. Kovalev, 1991). Suppressed activity of alkaline phosphatase in neutrophil granulocytes has been revealed among a number of children, together with a significant rise of the concentration of eosinophil granulocytes (K.P. Zak et al., 1991).

Analysis of an extensive bank of data of laboratory hematological examinations of children and adolescents living in the contaminated areas has revealed disorders in hexagrams, such as reduction of the number of erythrocytes accompanied by macrocytosis, leuco- and lymphopenias in a number of cases (A.F. Tsyb et al., 1996).

Thus, the peripheral blood of the children, after protracted exposure to small doses of radiation, manifests both qualitative and quantitative modifications in the erythroid series, neutrophil leucocytes, eosinophils, B-lymphocytes, the pattern and the tendencies of these modifications being dependent upon the age of the children and the level of general radiation (L.V. Evets et al., 1992).

No pronounced rise of the incidence of leukemias or any other diseases of the myelocytary function has been registered in the affected areas during the period since the Chernobyl disaster (I.V. Osechinskii et al., 1994).

Yet, a statistically valid rise of the frequency of chronic lympholeucosis, paraproteinic hemoblastosis, non-Hodgkin's lymphomas is noteworthy. Moreover, since 1988 a statistically valid rise of acute non-lymphoblastose leukemias, chronic myeloleucoses has been registered (I.V. Osechinskii et al., 1991).

The hemoblastosis incidence is somewhat higher in the areas with mild radioactive contamination basically due to the number of acute lymphoblastose leukemias, chronic lympholeucoses and lymphogranulomatoses (I.V. Osechinskii et al., 1996).

Hence, the population affected by the Chernobyl disaster has been manifesting substantial modifications of the haemopoietic system for a number of years. They are typically related to the quantities of radioisotopes incorporated by the organism. It is evidenced by the results of evaluation of hematological examinations of children from the communities with different levels of soil contamination and different levels of radiation accumulation in the organism.

A reverse proportionality exists between the concentration of erythrocytes in the blood and the quantities of incorporated radioisotopes (Fig. 14)).

The children from the community of Svetilovichi (15-40 Ci/km^2 of ^{137}Cs) manifest the most pronounced reduction of the erythrocyte count. Yet, the concentration of hemoglobin among these children is much higher than the control level (Fig. 15). Other groups demonstrate a similar dependence. The results of clinical examinations and laboratory tests are corroborated by experimental studies of laboratory animals.

Rats born during the first months after the disaster would manifest throughout their life significant modifications of the peripheral blood and the bone marrow haemopoietic system, such as eosinophilia, lymphopenia, hypersegmentosis and fragmentation of the nuclei of neutrophils, their giant dimensions, double and more nuclear lymphocytes, inclusions of the nuclear matter in the cytoplasm of lymphocytes and erythrocytes, giant shapes of thrombocytes, porosity of the cytoplasm of eosinophils V.G. Pinchuk et al., 1991).

Ultrasound investigation of the bone marrow cells among male rats kept within the 30-km zone around Chernobyl has revealed significant submicroscopic modifications of the cells at various stages of maturity, including non-differentiated regions and mature forms of the cells of the neutrophil, eosinophil, monocytary and erythrocytary series of haemopoiesis and similar modifications in the stroma elements of the microenvironment, megakariots and endothelium (V.V. Afanasjeva et al., 1991).

Feeding Vistar line rats with oats containing ^{137}Cs in a concentration 445.7 Bq/kg during 20 days would reduce the concentration of erythrocytes in the blood compared with the control group fed with the grain containing ^{137}Cs in a concentration 44.2 Bq/kg (I.V. Vuevskaja, 1997). The concentration of ^{137}Cs in the organisms of the rats in the experimental group amounted to 62.76±3.84 Bq/kg compared with 9.76±1.77 Bq/kg in the control group.

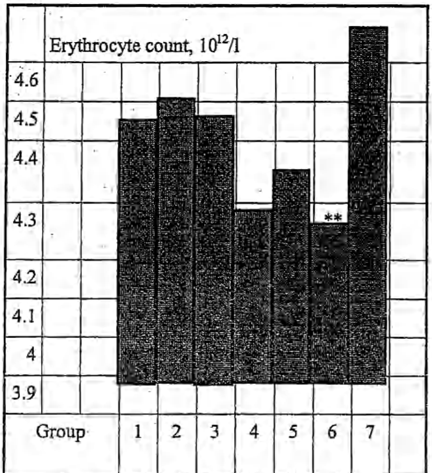

Fig. 14. Number of erythrocytes among children aged 6-8 years ($* p < 0.05$; $** p < 0.001$)

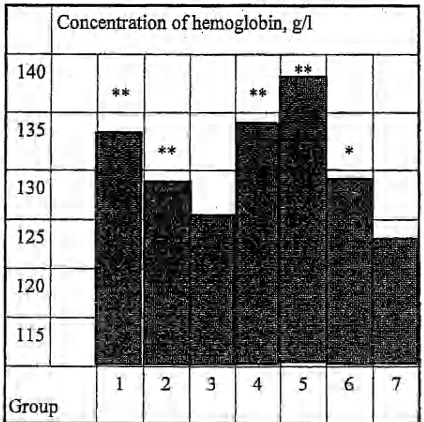

Fig. 15. Concentration of hemoglobin among children aged 6-8 years ($* p < 0.05$; $** p < 0.001$) in communities with different levels of soil contamination with ^{137}Cs : *1* — Gomel - 1-5 Ci/km^2; *2* — Svetlogorsk - < 1 Ci/km^2; *3* — Zhlobin - < 1 Ci/km^2; *4* — Vetka — 15-40 Ci/km^2; *5* — Stolbun - 5-15 Ci/km^2; *5* — Svetilovichi - 15-40 Ci/km^2; *6* — Grodno - < 1 Ci/km^2

So, individuals after exposure to elevated doses of external and internal radiation manifest suppressed proliferative activity of the haemopoietic function.

Meanwhile the process of saturation of the organism with iron suffers no changes. Yet, there is a number of reports of iron-deficit anemias in several regions which have gone up several times recently (V.I. Ponomarenko et al., 1993).

In a number of cases evolution of anemias among the children in the areas contaminated with radiation can be attributed to the disorders of lysis of transferin as one of the major glycoproteids of the blood plasma. Disorders of this process have been registered among experimental animals long time after exposure which unfavorably affects the iron

Liver damage induced by the incorporated ^{137}Cs is one of the causes of this pathological process (Ju.I. Bandazhevsky, N.E. Fomchenko, 1996),

3.6. RESPIRATORY ORGANS

Inhalation of radioisotopes with the air causes injuries of the respiratory organs. It has been vividly manifested among those who were involved in the cleaning-up operations at the Chernobyl Nuclear Power Plant. They were exposed to heavy dust with strong concentration of radioactive particles. They have manifested rise of bronchial and pulmonary diseases, extensive mortality due to malignant neoplasms in the respiratory organs (V.L. Sharygin et. al, 1996).

More frequent inflammatory diseases of the respiratory organs among the individuals living in the areas contaminated with radioisotopes relates directly to the conditions of the immunity system, specifically to the reduced levels of the serum and humoral IgA and inhibition of the fagocytary activity of neutrophil leukocytes (Yu.I. Bandazhevsky, et. al., 1995).

A vivid example is the incidence of tuberculosis which has shown a pronounced leap among the residents of the areas contaminated with radioisotopes.

3.7. LIVER AND METABOLISM CONDITION

Radioactive elements induce a combination of integrated structural and metabolic changes in internal organs and tissues under different conditions of their effect upon the organism.

The liver is one of the key organs governing the level of metabolic and exchange processes in the organism. Studies of the condition of the liver among wild rodents in the areas affected by radioactive elements and among albino rats, kept for long periods in the real Chernobyl conditions, have revealed a multiplicity of the types of liver damage, among them the most frequent are fat and vacuole dystrophies, coagulating necrosis of hepatocytes (V.G. Pinchuk et al., 1991; L.N. Shishkina et al., 1992).

Microscopic studies of liver tissues of experimental male and female animals after 45 days of dieting on oats containing radioisotopes (^{137}Cs in a concentration 373 Bq/kg) have shown granular and vacuole dystrophies of hepatocytes, expansion of the Disset space. Moderately pronounced disorders of blood circulation in the form of abundant blood in the intralobular veins are observed.

Intensified processes of peroxidation of lipids, alteration of the phospholipid composition of cytoplasmic membranes are typical features of the radiation effect upon the human organism. They may occur in any tissue, including the intestinal mucosa (J.V. Stepanov et al., 1992), in thymocytes (V.I. Dreval, 1993; Ahlers et al., 1992), fat tissue (G.G. Egutkin et al., 1993), lung tissues (E.A. Galitskii et al, 1992), muscular tissue (E.A. Galitskii, M.I. Selevich, 1992).

A single gamma irradiation of pregnant rats *in vivo* in doses 1 and 2 Grays would cause accumulation of the products of peroxidation of lipids and suppression of the activity of cytochrome-c-oxidase, NADN cytochrome-c-reductase, ATP-ase and PNA-ase in the nuclei of liver cells of these animals and their embryos (A.K. Mirahmedov et al., 1992).

Lipid peroxidation is assumed to be the main cause of damage and structural modification of cytoplasmic and mitochondrial membranes (A.A. Miljutin et al., 1993; Xiong Ve, Chen Zongrong, 1993).

Thus, alterations in the functional condition of the lipid peroxidation system have been established in the organisms of humans and animals in the areas contaminated with radiation (G.R. Gatsko et al., 1992), its inhibition (V.K. Kuhta et al., 1993). Still, it should be remarked that a new dynamic equilibrium between the lipid peroxidation system and the antioxidant protection is rapidly restored making it a mechanism of fast adaptation (A.V. Paranich et al., 1992).

Deficit of carotenes and vitamins acting as antioxidants is one of the factors impairing the antioxidant protection (T.S. Morozkina et al., 1993).

The organism's integral response to irradiation is reflected in the dynamics of reactions in the processes of transformation of hydrocarbons. The first phase (first hours after irradiation) is characterized by accelerated production of glycogens and delayed glycogenolysis; the second phase (3-16 days) is characterized by the retarded synthesis and intensified disintegration of glycogen in the liver tissue; the third phase (the end of the third and the beginning of the fourth weeks after irradiation) is characterized by the restoration of the liver's glycogenolytic and glycogen producing functions (B.M. Graevskaja, N.N. Zolotareva, 1991). A stimulating effect of radioisotopes upon the beta cells of the pancreas until a definite level of their accumulation should be taken into account when assessing how transformations of hydrocarbons change (L.V. Evets, et al., 1992). It is confirmed by the reduction of glucose concentration in the blood of the children aged 3-7 years when the concentration of ^{137}Cs in the organism exceeds 37 Bq/kg (Fig. 16).

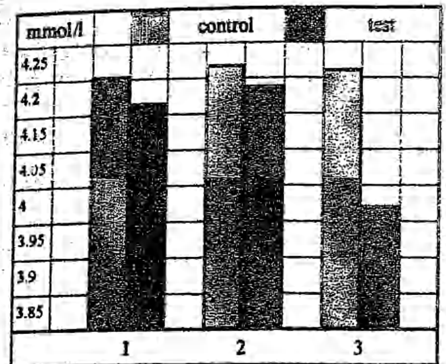

Fig. 16. Glucose concentrations in blood serum of children in test and control groups. Quantities of accumulated radioisotopes: *1* — 11 - 25.9 Bq/kg; *2* — 26 - 36.9 Bq/kg; *3* — 37 - 74 Bq/kg (* $p < 0.05$)

Glucose-6-phosphate dehydrogenase is one of the enzymes involved in the transformation of hydrocarbons, its suppressed reactivity has been observed among preschool children exposed to radioisotopes, primarily to ^{137}Cs (R.V. Trebukhina et al., 1993).

Radiation induces modifications of the protein metabolism in the organism. One of the earliest responses of the organism to radiation is protein synthesis acceleration and protein accumulation in the blood plasma (Martin et al., 1992; Racek et al., 1992). Also, males who were involved in the elimination of the Chernobyl aftermath, and children aged between 3 and 7 years exposed to radiation in the contaminated areas have manifested cases of hypoproteinemia and hypoalbuminemia (Fig. 17, 18).

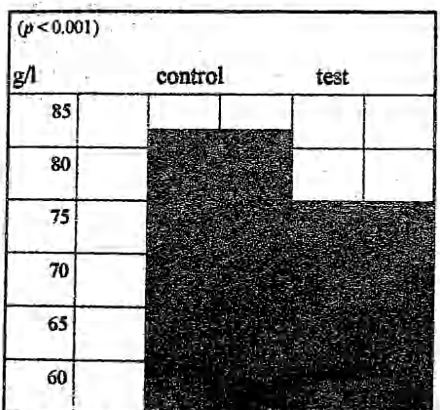

Fig. 17. Comparative values of general protein concentration in blood serum of children

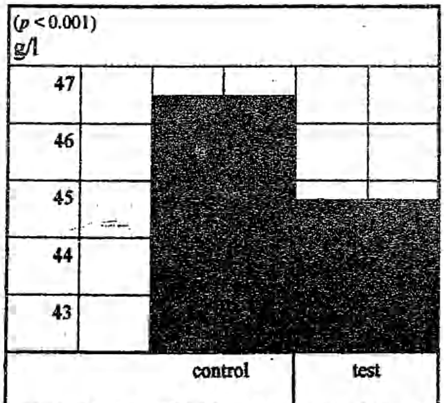

Fig. 18. Comparative values of albumin concentration in blood serum of children

It is possibly due to changes in the DNA concentration in the cells (L.G. Orlova et al., 1991) or to the activity of the mitochondrial and cytoplasmic enzymes. Gamma irradiation of rats with doses 4 Grays boosts specifically the activity of 5-nucleotidase and suppresses the activity of proteinkinase (J.V. Bezrodnyi, O.V. Bozhen, 1992; S.M. Jakubovskii, 1993). Single external irradiation of rats with one Gray doses induces oppositely directed changes in the ratio between isoenzymes of lactate dehydrogenase, malate dehydrogenase, esterase and sour phosphatase in the cytoplasm of brain cells during earlier terms (P.P. Chajalo, A.F. Protas, 1992). Suppressed activity of piruvate kinase and lactate dehydrogenase occurs in the early term of radiation disease (1-3 days) and during incorporation of radioisotopes (19) followed by their growing activity in later terms (5-10 days) (V.F. Sukhomlinov et al., 1993).

A drop of the concentration of cholesterol, creatinin in the blood reflects that incorporation of radioisotopes has upset the synthetic processes in the liver (Fig. 20, 21). Meanwhile calcium concentration exceeds that in the control group (Fig. 22).
It is possibly due to the fact that protein kinase in the liver of rats loses some of its responsiveness to Ca^{2+} ions already two hours after whole body X-irradiation (the dose is 7.76 Gy) (T.R. Andrejchuk et al., 1993).

Suppressed reactivity of alkaline and sour phosphatase, non-specific esterase in the zone of microfibrils, endothelial cells and crypts in the intestine, has been registered after prolonged irradiation (1.4 - 2.08 Gy/day) of chickens (Skardova, Lenhardt, 1992). Growing reactivity of alkaline phosphatase has been remarked among rats under the effect of 500 kBq **(N.M. Bagel, et al., 1990).**

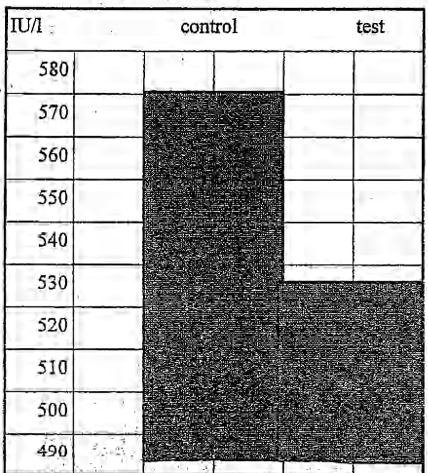

Fig. 19. Comparative values of LDH. activity in blood serum of children ($p<0.001$)

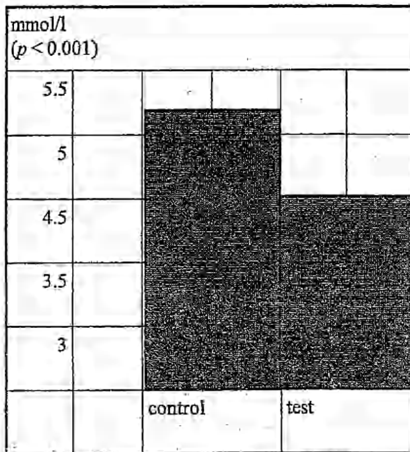

Fig. 20. Comparative cholesterin concentrations in blood serum of children

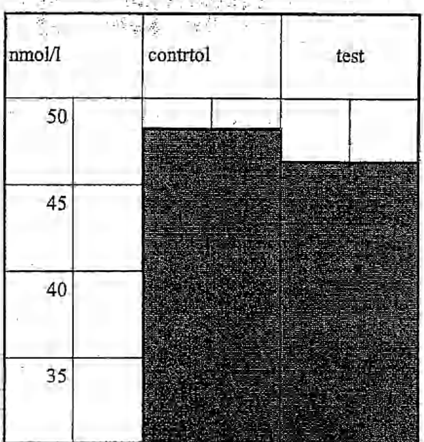

Fig. 21. Comparative creatinin concentrations in blood serum of children ($p<0.001$)

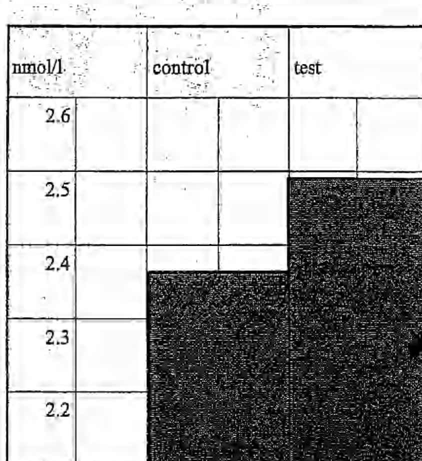

Fig. 22. Comparative calcium concentrations in blood serum of children ($p<0.001$)

The activity of enzymic systems relates to the changes in concentrations of regulating substances, such as cyclic adenosine monophosphate and guanine monophosphate (c-AMP and c-GMP). A higher ratio between c-AMP and c-GMP in the blood plasma of rats at later stages after irradiation (the total gamma - dose amounted to 10-20 Gy) evidences a predictably negative domination of adrenergic homeostatic mechanisms (E.I. Kiselgof, V.B. Shorokhova, 1992). It is confirmed by the studies accomplished by A.I. Dvoretskii, I.A. Kulikova (1993) who demonstrated that whole-body X-irradiation of the organism with doses 0.155 and 0.310 Ci/kg modifies the activating effects of noradrenalin and serotonin as well as the biphase effect of dophamin upon Na, K-pump of the membranes of neurons. Single-phase changes in the activity of adenylate cyclase should also be taken into consideration (L.V. Slozhenikina et al., 1992).

It has also been observed that the children in the area with the density of contamination 15-45 Ci/km^2 demonstrate a higher concentration of adrenalin in the blood (L.S. Baleva et al., 1992). Yet, S.V. Petrenko and V.A. Zajtsev (1997). Thus the children in the areas contaminated with radioisotopes manifest reduction of catecholamines as well as hyporeactivity of the hormonal response of adrenals to the stimulating effect of the endogenous adrenocorticotropic hormone (ACTH). V.A. Zajtsev also outlines these effects (1992). The individuals who participated in the elimination of the Chernobyl aftermath manifest a significant rise of histamine concentration, a stronger monoamine oxidant activity and a 4.5 time rise of serotonin in the blood (N.F. Ivanitskaja et al., 1991).

Disorders of the functions of adrenals are one of the key links in the pathology of metabolism under the effect of radiation. The children exposed to protracted small doses of radiation have manifested suppressed functional activity of adrenals, upset equilibrium between the concentrations of cortisone and ACTH in the blood plasma (S.V. Petrenko, V.A. Zajtsev, 1993). The children aged 3-7 years in the areas with the levels of ^{137}Cs concentration 1-5 Ci/km^2 have manifested a valid reduction of cortisone concentration in the blood compared with the control (Fig. 23). Suppressed capability of the liver to utilize cortisone is significant in the metabolic pathology leading to accumulation of metabolites in the organism (L.A. Litskevich, 1991).

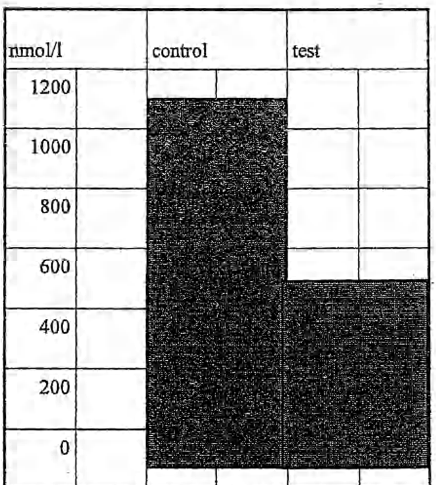

Fig. 23. Comparative concentrations of cortisone in blood serum of children ($p < 0.001$)

It should be noted that X-irradiation reduces the concentration of sex hormones, lutropin and testosterone specifically (S.V. Vjarga, 1993) which play a significant role in metabolism.

3.8. GASTROINTESTINAL TRACT

Gastrointestinal tract is one of the major paths of incorporation and excretion of radioisotopes. Strong ^{137}Cs doses, causing the appearance of acute radiation disease among experimental animals. induce the development of gastroenterocolitis with a pronounced disorder of blood circulation in all layers of the intestinal tube (J.I. Moskalev, 1995) and the edema of the mucosa (M.I. Jakubovskii, et al., 1997).

Incorporation of relatively slight amounts of ^{137}Cs by the organisms of children with food leads to chronic stomach inflammations. Over 80% of the children in the contaminated areas suffer from chronic gastritis and gastroduodenitis. Specifically strong contamination of the stomach mucosa with bacteria is noteworthy. Typical manifestations are the atrophied stomach mucosa and its intestinal metaplasia (Chernobyl, 1996).

The liquidators manifest more frequent erosive gastroduodenitis which typically evolves without symptoms, tends to relapse and combine with latent immunity deficit (O.J. Dementjeva, et al., 1997).

It can be due to the effect of internal irradiation of intestines with incorporated radioisotopes upsetting the final stage of the biogenesis of intestinal enzymes and their combination with the enterocytal plasmatic membrane (V.V. Lelevich, et al., 1995).

3.9. KIDNEYS

Kidneys are actively involved in metabolism. Incorporation of radioisotopes (^{137}Cs) by the organisms of experimental animals in the quantities over 100 Bq/kg and up produces pronounced changes in the glomerules in the form of proliferation of mesangial cells, infiltration of lymphoid histiocyte elements into the loops, fragmentation and death of glomerules (Yu. I. Bandazhevsky, N.E. Fomchenko, 1996). It results in the accumulation of urea and products of protein metabolism in the blood serum (Fig. 24).

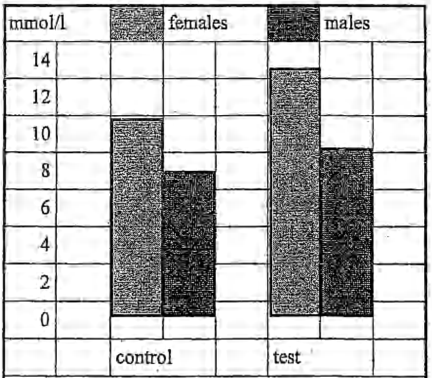

Fig. 24. Concentration of urea (*BUN*) in peripheral blood of male and female rates of Vistar line versus incorporation of radioisotopes

3.10. FEMALE REPRODUCTIVE SYSTEM

The female reproductive system is sensitive to ionizing radiation. Disorders of its functions are induced by different types of radiation and they are registered both clinically and experimentally.

Hormonal modifications occur typically in the hypophysis-ovary-uterus system leading to the disorders of ovulatory and menstrual functions.

Incorporation of radioactive elements by female organisms in the areas affected by the Chernobyl disaster leads to the inversion of the hormonal background resulting in the upset menstrual cycle. When accumulation of ^{137}Cs exceeds 30 Bq/kg, a valid reduction of estradiol and rise of progesterone concentration occur during the first phase of the cycle and
rise of progesterone concentration occur during the first phase of the cycle and
vice versa during the second phase (Fig. 25-28).

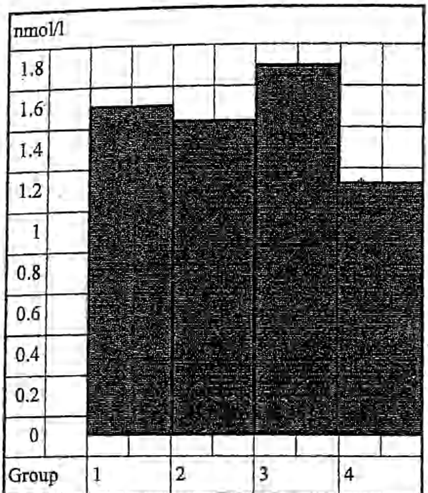

Fig. 25. Estradiol level during menstrual cycle phase I: *1* — ^{137}Cs accumulation up to 20 Bq/kg; *2* — 20-30 Bq/kg; *3* — 30-40 Bq/kg; *4* — over 40 Bq/kg. * — versus group 1 ($p < 0.05$)

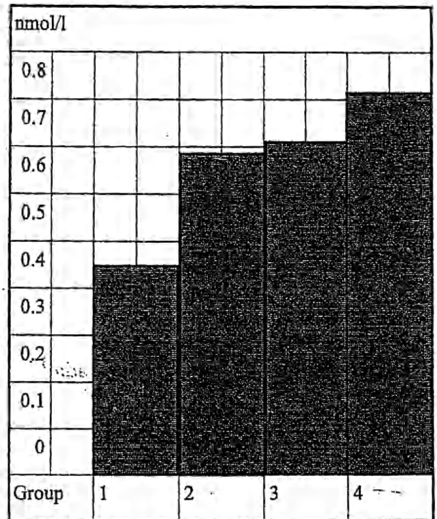

Fig. 26. Estradiol level during menstrual cycle phase II: * versus group 1 ($p < 0.05$)

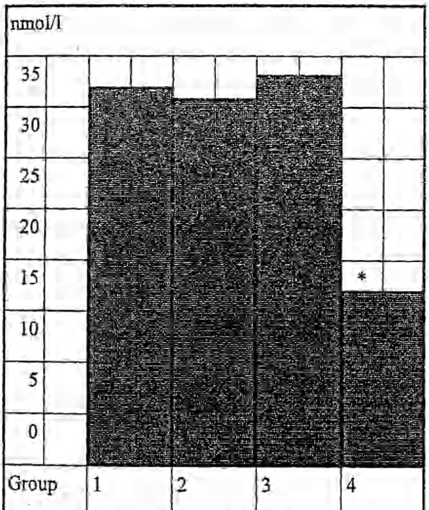

Fig. 27. Progesterone level during menstrual cycle phase II. * — versus group 1 ($p < 0.05$)

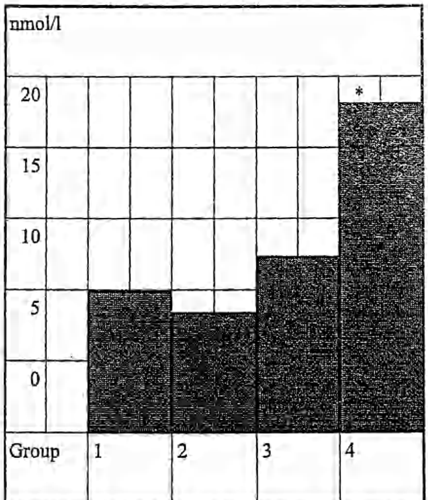

Fig. 28. Progesterone level during menstrual cycle phase I. * — versus group 1 ($p < 0.05$)

A similar relationship has been revealed in experiments with laboratory animals when the reduction of progesterone has been registered in the estrus cycle resulting in the thinning of the uterine mucus (Yu.I. Bandazhevsky, Yu.V. Antonova, 1995).

It should be remarked that accumulation of radioisotopes in the organisms of fertile age females intensifies generation of testosterone governing the appearance of masculine attributes.

3.11. EVOLUTION OF PREGNANCY AND FETUS DEVELOPMENT

Pregnancy is accompanied by a pronounced accumulation of ^{137}Cs in the mother's organism. Feeding laboratory animals 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 (Yu.I. Bandazhevsky, T.S. Ugolnik, 1995).

This radioisotope accumulates primarily in the placenta where its concentration can reach 200 Bq/kg and up in humans (Yu.I. Bandazhevsky et al, 1997).

Meanwhile, ^{137}Cs does not penetrate basically into the fetus organism (Yu.I. Bandazhevsky, T.S. Ugolnik, 1995). Since the functions of the placenta belong to the most essential among provisory organs, accumulation of radioisotopes definitely affects the functions of the fetoplacentary complex. Primarily it relates to the hormonal condition. In particular, the concentration of estradiol in the mother's and fetus' blood reduces by the end of pregnancy, while the concentration of testosterone increases compared with the control group (Fig. 29-30). Concentration of progesterone, thyroxin, triiodine thyronin, cortisone

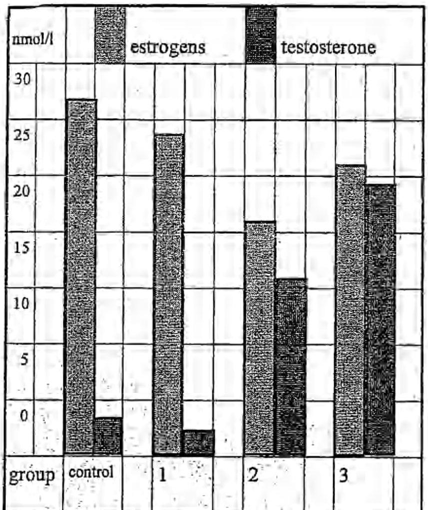

Fig. 29. Concentration of estrogens and testosterone in mother's blood, groups: *1* — 1—99 Bq/kg; 2 — 100 - 199 Bq/kg; *3* — 200 Bq/kg and more

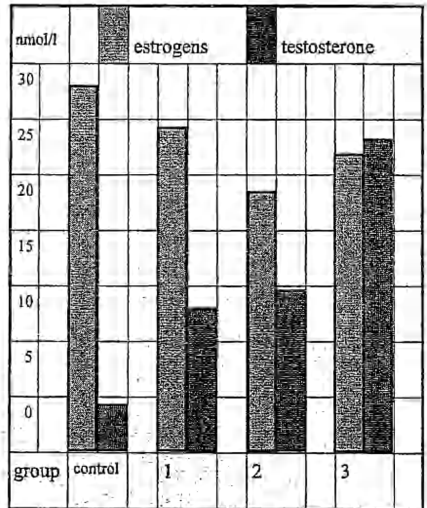

Fig. 30. Concentration of estrogens and testosterone in Fetus blood, groups: *1* — 1—99 Bq/kg; *2* — 100-199 Bq/kg; *3* — 200 Bq/kg and more

Meanwhile progesterone increases insignificantly in the fetus, thyroxin and triiodine thyronin are absent, the concentration of cortisone reduces progressively as the concentration of ^{137}Cs in the placenta increases (Fig. 31).

Intricate metabolic modifications are accompanied by structural changes of the placental villus apparatus when the number of intermediate villi increases and that of terminal villi reduces.

The surfaces of the villi manifest a significant number of trophoblastic cells evidencing their metabolic activity. Rise in the 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.

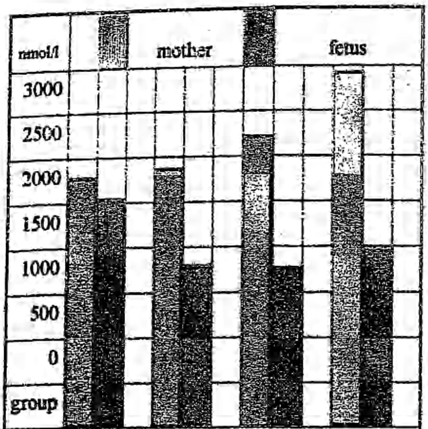

Fig. 31. Concentration of cortisone in response to accumulation of ^{137}Cs in blood of mother and fetus, groups: *1* — 1-99; *2* — 100-199; *3* — 200 Bq/kg and more

Metabolic modifications in the mother-fetus system affect the fetus development, increase chances of failed preimplantation, the process of bone system development, such as osteogenesis of tubular bones, is inhibited.

The count of leukocytes ad lymphocytes in the blood reduces, while that of eosinophil leukocytes increases (T.S. Ugolnik, 1996).

A larger incidence of congenital defects in the radiation contaminated areas is noteworthy. (*Chernobyl: Consequences for the Environment, Health and Human Rights* , Vienna, Austria, pp. 155, April 12 - 25, 1996.

3.12. THE ORGAN OF VISION

The organ of vision is highly sensitive to radioactive emission. External irradiation with 3-5 Gy damages the lens and induces cataracts.

Similar results are registered among humans after exposure to an external source of radioactive emission (Yu.I. Moskalev, 1991).

Incorporation of radioisotopes by the organism also leads to significant structural modifications, specifically of the lens. A direct proportionality is clearly observed between the quantity of accumulated radioisotopes (^{137}Cs primarily) and the incidence of cataracts (Fig. 32). It is manifested by the individuals living in the areas with significant radiocesium contamination (over 15 Ci/km^2).

In addition to cataracts other morphofunctional disorders of the vision apparatus are registered, such as destruction of the vitreous body, cyclastenias, abnormal refraction.

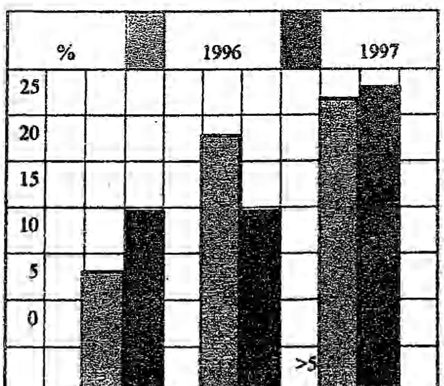

Fig. 32. Incidence of cataracts among children in Vetka district as function of incorporated dose

Reduction of the quantity of radioisotopes in the organism eliminates the above pathological conditions as it is evidenced by the results of population screening in the Vetka district (Yu.I. Bandazhevsky, A.N. Kurilenko, 1997).

Experiments with laboratory animals (albino rats) have manifested that radioactive cesium causes disorders in the development of the cornea when it loses fibers and becomes vascularized (Yu.I. Bandazhevsky, A.N. Kurilenko, 1997).

CHAPTER 4. PATHOMORPHOLOGY INDUCED BY INCORPORATED RADIOACTIVE EMISSION

4.1. Morphofunctional modifications induced by incorporated ^{137}Cs in the organisms of experimental animals

The present study has been endeavored with a view to investigate the effect of radioactive cesium in the food upon the structure of vital organs of laboratory animals. The experimental group included 116 male and female rate of the Vistar line which daily from 3 to 5 weeks received grain containing radioactive cesium in the concentration 373 Bq/kg.

The grain fed to the animals of the control group (oats) contained 17 Bq/kg of ^{137}Cs. Accumulation of cesium was registered regularly throughout the experiment. After the experiment the animals were decapitated, pieces of liver, myocardial and renal tissues 0.5 - 1.0 cm thick were fixed with a 10% formalin solution, cast into paraffin and histological sections 5 - 8 m thick were made and stained with the hematoxylin and eosin for microscopic studies.

Radiological studies have manifested that the concentration of radioactive cesium in the organisms of experimental male rats amounted to 100.4 8.0 Bq/kg against 5.4 1.9 Bq/kg in the control group. The concentration of radioactive cesium in the organisms of female rats was much lower amounting to 48.1 5.0 Bq/kg against 10.4 2.7 Bq/kg in the control, $p < 0.001$.

Histological studies of the tissues of kidneys of the male and female rats after dieting on the grain with radioisotopes manifested pronounced pathological modifications of glomerules in the form of proliferation of mesangiuml cells, infiltration of lymphoid histiocytary components into the loops, fragmentation and death of the glomerules (Fig. 33).

The epithelium of the straight and convoluted tubules showed granular and hyaline droplet dystrophy.

Microscopic studies of the liver tissues of the male and female rats after dieting on the grain with radioisotopes have revealed granular and vacuole dystrophy, dilatation of the perisinusodial spaces. Plethoric central interlobular veins reflected moderately pronounced disorders of blood circulation were demonstrated (Fig. 34).

The myocardial tissues of the experimental animals manifested diffused myocytosis, masses of lymphoid histiocytary infiltrates, plethoric vessels (Fig. 35).

The aqueous solution (5 ml) of radioactive cesium 180 Bq was injected daily during six days to 12 male common albino rats weighing 180 - 220 g in order to detect specific modifications induced in the organism by the "pure" radioactive cesium.

During the same period 12 animals received intragastrically a saline NaCl solution of the equivalent volume. The animals were kept in the vivarium. Throughout the experiment accumulation of radioactive cesium was checked with a radiation counter RYG-2.

The animals were decapitated on the 8th day of the experiment, the internal organs were extracted, pieces were fixed in the 10% formalin solution, cast into paraffin and histological preparations were made.

The accomplished study has revealed that daily intragastric introduction of ^{137}Cs leads to its accumulation with the concentration on the 8th day amounting to 991 76 Bq/kg (against 6.70 2.36 Bq/kg in the control group, $p < 0.01$).

It is noteworthy that 5 animals in the experimental group died on the 5th or the 6th day of the experiment when accumulation of radioactive cesium in their organisms exceeded 1,000 Bq/kg.

Microscopic examinations revealed pronounced hemorrhages in the internal organs, manifestations of venous congestion in the liver and lungs.

Microscopic examinations of the issues of kidneys have manifested injuries of the elements of glomerules, the necrosis of the epithelium and the vascular network, the ultimate injury was their complete disappearance. The tubules showed vacuole and granular dystrophy and pronounced necrosis of epithelial cells (Fig. 36).

The liver manifested venous congestion, more pronounced in the central compartments of lobes, the dystrophy and necrosis of hepatocytes, the lungs had pronouncedly plethoric vessels, penetration of erythrocytes in the lumens of alveoli, inflammatory modifications of the pleura (Fig. 37).

The myocardium manifested pronounced signs of the intermuscular and intracellular edema, the majority of myocytes where undergoing cytolysis with disintegration of the nuclei (Fig. 39). The adrenal glands showed hemorrhages in the medulla.

It should be emphasized that the peripheral blood system did not manifest any pronounced changes compared with the control animals.

Thus, penetration of radioactive cesium (primarily ^{137}Cs) into the organisms of laboratory animals induces injuries of internal organs, specifically of the kidneys, the myocardium, lungs, liver. Structural disorders of the kidneys are noteworthy in particular. When radioactive cesium penetrates into the organism in large amounts it kills the cellular components of glomerules and tubules producing voids. This pattern is specific for penetration of radioactive cesium. When radioactive cesium is incorporated with food diffused dystrophic processes evolve in the myocardium inducing a pronounced immunological response in the form of lymphoid histiocytary infiltrates. Introduction of large amounts of radioactive cesium produces a total dystrophy of the myocardium without any morphological manifestation of responses on the part of the immunity system.

The evolution of inflammatory processes in the epicardium and pericardium, in the pleural shell are noteworthy, they are accompanied by severe injuries of kidneys. In our view, it is a morphological manifestation of the renal deficiency.

Once the myocardium is injured, hemorrhages occur in the internal organs, in the pulmonary tissues, specifically.

These results evidence a directly proportional relationship between the concentration of radioactive cesium in the organism and the severity of structural modifications of the internal organs.

4.2. Accumulation of radioactive cesium and structural modifications of internal organs revealed by autopsies in Gomel

After 123 autopsies of individuals who permanently lived in Gomel and in the region and died between 1996 and 1998 of various diseases, the brain, lungs, the myocardium, the thyroid, kidneys, the liver, the spleen, the walls of the stomach, large and small intestines, the uterus, the skeletal muscles were studied radiologically using a counter RYG-2 for measuring the concentrations of radioactive cesium.

The results were processed in two large groups of 52 children (0-10 years) and 71 adults. Each group was subdivided into subgroups based on the nosological units as causes of death. After that the statistical analytical methods were employed for mathematical processing. For radiological measurements pieces of tissues were fixed in a 10% formalin solution, than they were treated with stronger and stronger alcohol solutions and histological sections were made using common methods.

The histological preparations were stained with hematoxylin and eosin and then with special methods using the Schiff base, silver impregnation and the Van-Gison method of MAG staining.

The preparations were examined under microscope using the qualitative methods of evaluating structural modifications.

The results manifested that the individuals who died in Gomel and the region between 1996 and 1998 their organs contained radionuclides (basically radioactive cesium).

It should be remarked hat the parenchymatous tissues, particularly the myocardium, the liver, the kidneys, the spleen, the brain, the thyroid, the skeletal muscles, the large and small intestines and the stomach of adults, contained the highest concentrations of radioisotopes (Table 1).

Comparison of the figures of accumulation of ^{137}Cs between the adult and children groups shows that the juvenile internal organs accumulate much more radioisotopes than adult organisms. The average statistics are validly higher for the heart, lungs, small intestine, pancreas and thyroid of the children. Other organs of the children would tend to accumulate ^{137}Cs stronger compared with adults(Table 2).

Table 1

Concentration of radiocesium in the internal organs of adults

Organ	Mean radiocesium concentration, kBq/kg
Heart	0.4778 ± 0.1061
Brain	0.3848 ± 0.0715
Liver	0.3468 ± 0.0609
Thyroid	2.0537 ± 0.2883
Lungs	0.4286 ± 0.0832
Kidneys	0.6453 ± 0.1349
Muscle	0.9019 ± 0.2337
Pancreas	1.3588 ± 0.3499
Spleen	0.6082 ± 0.1091
Large intestine	0.7582 ± 0.1817
Small intestine	0.8798 ± 0.1397
Stomach	0.5668 ± 0.1309
Thymus	1.5755 ± 0.2903
Adrenal gland	1.5755 ± 0.2903

Two most frequent causes of death have been identified among the children based on these patterns, vis. infections and congenital development defects. Meanwhile among the adults four groups have been identified: cardiovascular diseases, gastrointestinal diseases, infections (including septic conditions), tumors of various localization. The radiological results were processes individually for each group. Tables 3 and 4 show the results Comparison of the pattern of accumulation of radioisotopes among the nosological subgroups of the adult group has revealed the following features. The hearts of the adults who died of cardiovascular pathologies contained validly more ^{137}Cs on the average than among those who died of gastrointestinal diseases. The liver, the stomach, the small intestine and the pancreas would accumulate more ^{137}Cs in case

Table 2

Concentration of radiocesium in the internal organs of children

Organ	Mean radiocesium concentration, kBq/kg
Heart	0.4778 ± 0.1061
Brain	0.3848 ± 0.0715
Liver	0.3468 ± 0.0609
Thyroid	2.0537 ± 0.2883
Lungs	0.4286 ± 0.0832
Kidneys	0.6453 ± 0.1349
Muscle	0.9019 ± 0.2337
Pancreas	1.3588 ± 0.3499
Spleen	0.6082 ± 0.1091
Large intestine	0.7582 ± 0.1817
Small intestine	0.8798 ± 0.1397
Stomach	0.5668 ± 0.1309
Thymus	1.5755 ± 0.2903
Adrenal gland	1.5755 ± 0.2903

The skeletal muscles of the children manifested valid differences in the concentrations of ^{137}Cs in the organs. In case of infections the children would accumulate more ^{137}Cs than the children with congenital development defects (Table 4).

Hence, the results manifest that the autopsied internal organs of the children and the adults who died between 1996 and 1998 and who resided in Gomel and in the region contained gamma emitting radioisotopes.

The internal organs of the children would accumulate much more radioisotopes than the adults. Accumulation of radioactive cesium in the internal organs has different rates and depends upon the nature of a disease.

It should be noted that a number of the internal organs of the children and the adults who died in 1997 contained more ^{137}Cs than of those who died in 1996.

The pathological modifications induced by radioisotopes typically manifest domination of alterative processes, disorders of blood circulation, disorders of regeneration processes, and immunopathological responses. These manifestations become stronger as the content of radioactive cesium in the internal organs goes up.

Structural modifications of the myocardium have been observed in the studied cases, irrespective of the cause of death, typically they are the processes of alteration in combination with rather strained responses of compensation and adaptation.

Dystrophic and necrotic modifications of cardiomyocytes of various intensity reflect the destructive pattern of myocardial injuries.

The evolution of the degenerative phenomena was evidenced by the spots of adipose and protein dystrophy alternating with finer necrotic spots. The fibers would become homogenized, fuxinophilia would appear after diffused eosinophil coloring. A variegated pattern of histological modifications would appear. Some fibers would be colored more intensively, some would be less sensitive to staing and striation would disappear along their entire stretch. In the majority of the cases the structural injuries of the myocardium were determined by the contractile modifications of myofibrils, in the first place, shown by the overcontraction of different extent when their optical features would change due to the reduction of dacromers and intensification of the anisotropy of fibers shown by double refraction of A-discs until a complete anisotropic conglomerate appears in the polarized light, some cardiomyocytes would become fragmented. The penetrability of the sarcolemma

Table 3

Concentration of radiocesium in the organs of adults as a function of nosology (kBq/kg)

Group / organ	Tumors	Infections	Cardio-vascular disorders	Gastro-intestinal disorders
Heart	0.1185 ± 0.820	0.0376 ± 0.0153	0.1368 ± 0.0331	0.0457 ± 0.0207
Brain	0.3020 ± 0.0728	0.4457 ± 0.3787	0.0870 ± 0.0389+	0.2100 ± 0.1011+
Liver	0.0844 ± 0.0625	0.2955 ± 0.1083	0.1445 ± 0.0240	0.1159 ± 0.0265
Thyroid	0.3912 ± 0.2749	0.2745 ± 0.0958	0.3257 ± 0.0844	0.2452 ± 0.1477
Lungs	0.1800 ± 0.0943	0.3133 ± 0.2394	0.1965 ± 0.0380	0.1142 ± 0.0374
Kidneys	0.1190 ± 0.0933	0.2365 ± 0.0924	0.2836 ± 0.383	0.2063 ± 0.0904
Skeletal muscles	0.1689 ± 0.2265	0.3280 ± 0.2015	0.1134 ± 0.0381	0.2202 ± 0.0697
Pancreas	0.1253 ± 0.0632	0.5278 ± 0.3664	0.0876 ± 0.0153+	0.0946 ± 0.0263+
Spleen	0.2050 ± 0.1063	0.1583 ± 0.0753	0.2046 ± 0.0545	0.0900 ± 0.0360
Large intestine	0.0545 ± 0.0174	0.0472 ± 0.0220	0.1078 ± 0.0315	0.0979 ± 0.0266
Small intestine	0.1418 ± 0.0757	0.2573 ± 0.0319	0.1180 ± 0.0372	0.0873 ± 0.0276
Stomach	0.0663 ± 0.0431	0.4185 ± 0.1863	0.1003 ± 0.0246	0.1357 ± 0.0325

would increase evidenced by the plasmatic saturation of the fibers detected as the diffused positive PAS-reaction (when sections were treated with the Schiff base).

Myofibrils would disintegrate due to the spots of mosaic lysis. Some cellular areas would contains portions where the structural elements would separate from aggregates, meanwhile the adjacent portions would preserve normal striation. In some case vacuole degeneration of the myocardial cells was observed whith whitened vacuoles locating in the perinuclear zone or expanding over the entire cell. The vacuoles would become larger and coalesce into larger optically "blank" spaces. The muscular tissues would become optically blank. The contours of the fibers would distort, pinpointed fragmentation of the muscular tissues evidenced also the process of myocyotolysis of the structural cardiac elements. An intensive edema of the stroma was observed together with ruptures and defibrillation of the argyrophil fibers in the zone of fragmentation of the fibers. It resulted in the appearance of passive centers of deparenchymation of the organ with the reticule "empty" network. The spots of necrotized cells dominated in the subendocardial layer of the myocardium and in the papillary muscles.

In this case a pronounced polymorphism was observed. Some cardiomyocytes near the vessels and around the destroyed spots showed typical signs of hypertrophy of the compensation and adaptation nature apparently. The muscular cells after secondary modification would also show atrophic changes.

Group / organ	Infections	Congenital development defects
Heart	0.6228 ± 0.2201	0.3786 ± 0.1815
Brain	0.4506 ± 0.1547	0.3382 ± 0.1561
Liver	0.2106 ± 0.0669	0.4272 ± 0.1920
Thyroid	2.1498 ± 0.6574	1.5052 ± 0.6150
Lungs	0.3502 ± 0.0899	0.2835 ± 0.0871
Kidneys	0.3519 ± 0.0976	0.5477 ± 0.2200
Skeletal muscles	0.7613 ± 0.2449	0.2248 ±0.1215*
Pancreas	0.9348 ± 0.5757	1.5782 ± 0.8324
Spleen	0.5321 ± 0.2021	0.4798 ± 0.1601
Large intestine	1.7703 ± 0.3825	0.8728 ± 0.4865
Small intestine	1.5771 ± 0.2137	0.8831 ± 0.3345
Stomach	0.2474 ± 0.1132	0.7546 ± 0.3234
Thymus	0.3808 ± 0.1392	0.8990 ± 0.3698
Adrenal glands	1.5853 ± 0.5580	1.2022 ± 0.3906

Table 4

Concentration of radiocesium in the organs of children as a function of nosology (kBq/kg) * — $p < 0.05$

Changes of the stroma looked like plethora and edema without any manifestations of cellular reactions. In the majority of cases the internal basal membrane of the vascular wall of the elastomuscular layer would split up forming an argyrophil framework and making spot plasmorrhage more pronounced. The vessels of the microcirculatory channel showed irregular blood content with erythrocytary stasis. The endothelium of most of the capillaries looked swollen with manifestations of the extramuscular edema. The reticular stroma showed manifestations of the muscular edema, fine spots of hemorrhages, fine spots of sclerosis of different maturity. The activity of local connective tissue elements predominantly in the left ventricle without connection to the vessels would be intensified. The liver would undergo strong structural modifications evidenced by the degenerative processes combined with blood circulation disorders. The cellular and nuclear polymorphism of the parenchymatous elements of the liver (nuclei of various shapes, size and intensity of staining, cells of various dimensions, among them a great number of bi- and multinuclear) drew specific notice. The proliferating and hypertrophied Kupffer cells were numerous among structurally modified hepatocytes. The beam structure remained in basically all the cases excepting the diseases causing the cirrhotic liver transformation under common conditions. The adipose dystrophy of hepatic cells was common with different extent of manifestation. Some autopsies revealed hepatocytes with fine droplet inclusions of fat in the peripheral segments of the lobes and in the zone of portal tracts. The adipose dystrophy would be predominantly subtotal or total governing the morphological pattern of the adipose hepatosis. In a number of cases the hepatic cells were fully affected by the dystrophic process, the liver would become an optically "blank" network with narrow interlayers of intact stroma. Different segments of hepatic lobes manifested fine spots of necrosis of the parenchyma having the argyrophil stroma destroyed. Hepatocytes manifested clusters of autophagic vacuoles, the cytoplasm of the hepatic cells would be swollen and show intensified fuxinophilia and signs of eosinophil degeneration. Some cells had larger numbers of lipofuxin grains occupying a considerable portion of the hepatic parenchyma.

The portal tracts were expanded with typical manifestations of edema and little pronounced cellular infiltration predominantly with macrophages and lymphohistiocytary elements. The portal stroma showed spots of diffused sclerosis. Sometimes, without any typical manifestations of inflammatory injuries of the liver, spots of interlobular infiltrates were observed as clusters of macrophages and lymphocytes which would stretch along the sinusoids, as a rule. The Disse's spaces were expanded.

Modifications of the microcirculation system were observed as strong plethora of the central lobular veins. The sinusoids were expanded, their lining was destroyed in some spots. Erythrocytary stagnations were observed. The endothelium of the capillaries was swollen with edemic signs. Pronounced hemorrhages are noteworthy, predominantly in the central lobular compartments.

Microscopic examinations of the tissues of kidneys showed pathological modifications in all the structural components, yet nephrons showed maximum damage.

The majority of the glomerules showed degenerative and atrophic changes in the forms of necrotic loops of capillaries. Nephrons degenerated differently. Some glomerules had a narrow strip of space between the capsule and the capillary loops filled up with the edemic fluid. Other glomerules would show a wider span between the capsule and the glomerule due to the latter's reduction because of the necrosis of vascular loops. The capillary lumen would reduce, the capillary walls would get thinner. The mesangium matrix would strongly reduce in size. These modifications created a pattern of individual formations within the capsule with reduced dimensions of glomerules. Finally the glomerule would become optically "blank", as mesangium cells and capillaries of the glomerule would undergo lysis without any sign of an inflammatory reaction, a structureless void would appear filled up with the eosinophil substance. The structural elements of the glomerules were not identifiable. The staged morphological modifications of the glomerule filter in the form of progressive destruction of the glomerule structures until their complete disappearance has allowed to characterize this phenomenon as a "melting icicle".

Individual glomerules had expanded and plethoric capillary loops, sometimes the walls of the capillaries were strongly thickened and manifested a double contour (when impregnated with silver). The basal membrane was thickened due to the accumulation of IR-positive substances. Erythrocytes and the fluid rich in protein compressing the capillary loops were observed in the lumens of the glomerules.

The walls of blood vessels were saturated with plasma. The lumens of the capillaries had clusters of blood cells.

Some glomerules had the mesangium matrix expanded with manifestations of moderate metarrhomasia constricting the lumen of the capillaries. The basal membrane of the vessels was irregular with alternating thicker and thinner portions, sometimes with ruptures, or sometimes the fibers would become structureless. These modifications were combined with the intraglomerular edema. The periglomerular fibrosis would appear in some glomerules, it would comprise concentric layers of collagen located outside the membrane and the glomerule capsule. Signs of sclerosis and hyalinosis of glomerules were observed.

The tubular structure would be basically modified in the proximal compartment of the convoluted tubules. The lumens of some tubules contained desquamated cells, hyaline cylinders, hemolyzed and fresh erythrocytes, proteinic fluid. Damaged tubules basically manifested severe types of the protein and adipose dystrophy. The hyaline-droplet dystrophy prevailed in the epithelial cells, hydropic dysproteinosis was occasional sometimes turning into the balloon dystrophy. Necrosis of epitheliocytes and destruction of the basal membrane were observed in a number of cases together with the signs of rejection of the wall. The nephrothelium delaminated into the lumens of tubules. Some tubules would undergo atrophic modifications with the flattening of the epithelium.

The morphological modifications of the interstice are manifested by the edema of the loose connective tissue. Staining with Sudan reveals lipophil inclusions in the stroma. The cellular infiltration of the stroma would be irregular presented by the spots of clustered lymphocytes, eosinophils, plasmatic cells and mononuclears localizing mostly in the perivascular spaces. The leukocytary infiltration was rare in the spots of destroyed tubular structures. All the histological sections manifested signs of regeneration of the epithelial lining of the tubules and the stroma of the kidney. The interstitial vessels were expanded, as a rule, containing abundance of blood. Some arteries showed the hypetrophied medium with detached muscular framework of the wall. No fibroplastic processes in rhe tubule interstice were observed unless they related to the renal pathology.

Case 1. Female patient, 67 years old, resided in Kalinkovichi. The clinical diagnosis: micronodular liver cirrhosis, portal hypertension. Died after aggravating phenomena of cardiovascular deficiency. Pathoanatomic diagnosis: poorly differentiated papillary adenocarcinoma of the pilloried department of the stomach with metastases into the liver, the small and the descending intestines, the diaphragm, the ovaries, the abdomen. The radioactive cesium concentration in the liver was 0.33 kBq/kg, in the heart— 0.94 kBq/kg, in the thyroid— 1.00 kBq/kg. The myocardium and the thyroid manifested he gravest structural modifications.

The myocardium (Fig. 40). The morphological pattern typically featured the phenomena of pronounced intermuscular edema, transforming in some spots into the chromophobic edema due to the combination of sour glucosaminoglycanes. Cardiomyocytes manifested irregular structural modifications. The majority of the simplastic cells were in the state of hydrophilic dystrophy, sometimes reaching the ballon dystrophy. Some cardiomyocytes manifested signs of myocytolysis and cariopicnosis, the lysis of nuclei and spots of deparenchymation. The cell nuclei typically manifested pronounced polymorphism and strong mitotic activity, hyperchromia in some fibers, atrophic modifications in others. The stroma manifested fine fibrotic spots primarily localized perivascularly. Clusters of cells of the macrophage-histiocytary system with the signs of autophagia, segmented vague leukocytes were observed around the fibers with minor destructive modifications, most eosinophils and obese cells evidence intensification of the inflammatory reactions as a strive to eliminate damage. The vessels manifested hyperplastic changes of the muscular layer with the signs of elastofibrosis and division of the internal basal membrane of the vascular framework. The endothelium was typically swollen with manifestations of the alterative productive endovasculitis, with thrombi in some spots.

The walls of the vessels manifested plasmorrhagia, when stained with MAG the vessels and the perivascular stroma would become deep-red.

The thyroid (Fig. 41). The morphological modifications were typically characterized by the destructive processes with active involvement ofthe repairing mechanisms and stress of the immunity response system.

The follicles manifested desquamation and delamination of the epithelial cells into the lumen. The "exposed" basal membrane underwent destruction up to complete rupture and discontinuity. No immunogenesis was detected morphologically in the tissues with pronounced dystrophic modifications or such signs were very weak. The interstitial round cell infiltration was observed , the infiltrated cells were of the hematogenic origin, vis. eosinophils, lymphoid elements. Macrophages and plasmatic cells were detected in some spots. The infiltration occurred in spots without tending to coalesce. Appearance of lymphoid infiltrates directly adjacent to the thyroid epithelium in the region of the basal membrane drew attention. The blood vessels contained excessive blood with the manifestation of stasis, sludging was observed in some spots. The walls of the vessels were thickened irregularly due to extravasates, the muscular framework was edemic. Spots of destruction of the epithelium were observed with the appearance of erythro- and leukodiapedesis. No extensive hemorrhages in the tissues of the gland were observed. The stroma was modified insignificantly. The fibrosis of the interstice was not strong with some spots of the perivascular edema.

Case 2. Female patient, 71 years old, resided in Gomel. She was hospitalized with the signs of pulmonary deficiency. The clinical diagnosis: intestinal obstruction, she underwent operation on the 1st day, acute bilateral pneumonia, acute cardiovascular deficiency. The pathoanatomical diagnosis: basic combined diseases: 1) commissures in the abdominal cavity; 2) acute dextral draining fibrinopurulent spot pneumonia of the upper lobe complicated with the bilateral edema of the lungs. The internal organs manifested significant accumulation of radioactive cesium (Table 5).

The Table shows that the liver, kidneys, brain and thyroid incorporated most of radioactive cesium, kidneys are included as an example.

Kidneys (Fig. 42). The injuries of nephrons were manifested by a massive edema of the glomerules constricting their components. The latter manifested degenerative changes, The glomerule would crumple due to the necrosis of the vascular loops, the atrophia of the mesangium, the thinning of the capillary walls. The spacing between the glomerule and the capsule would increase and would be filled up with the eosinophil substance. The mesangium matrix was strongly reduced and finally disappeared leaving a void. The lumens of the tubules contained erythrocytes, protein cylinders. The epithelial cells were in the state of profound (hyaline-droplet and hydropic) dystrophy. Some spots manifested the necrosis of epitheliocytes and the destruction of the basal membrane, signs of rejection of the wall. Evolution of the edema of the interstice was manifested by the signs of separation of the proximal tubules as loose edemic connective tissue. In addition to the edema the interstice manifested spots of cell infiltration: lymphocytes, eosinophils, plasmatic cells and polynuclears localized around vessels and most severely injured tubules. The vessels changed little, capillaries had manifestations of plasmorrhage, edema of the intima, individual spots manifested loosening of the muscular wall layers. Erythrodiapedesis and perivascular inflammatory infiltration were observed.

Table 5

^{137}Cs accumulated in the internal organs of dead A.

Organ	^{137}Cs concentration, kBq/kg
Heart	0.18
Lungs	0.09
Kidneys	0.30
Brain	0.60
Small intestine	0.30
Thyroid	0.47
Skeletal muscle	0.60
Stomach	0.30
Large intestine	0
Uterus	0
Liver	0.43

Case 3. Infant D. Born after the 1st pregnancy in due term by cesarean section with gluteal presentation weighing 2,790 g. The Algar scale was 7/8 points. The mother lives in the village Pokalyubichi of the Gomel district. The infant manifested multiple congenital defects of the backbone, internal hydrocephalia, bilateral pes varus, including complete lumbosacral rachiscisis of the backbone, defective kidneys. He died after 12 days due to the purulent meningoencephalitis. Radiology revealed significant concentration ofradioactive cesium in the internal organs (Table 6).

Table 6

^{137}Cs accumulated in the internal organs of infant D.

Organ	^{137}Cs concentration, kBq/kg
Heart	2.33
Lungs	1.33
Kidneys	0.30
Pancreas	9.00
Thymus	0
Thyroid	7.50
Spleen	0
Brain	2.05
Liver	0
Adrenal gland	3.00
Stomach	0

The pattern of histological modifications in the kidneys and adrenals is shown as an example.

Kidneys (Fig. 43). Pathological modifications were pronounced and combined with the morphological immaturity. The globules manifested irregular plethora of the capillaries: collapsed capillaries alternated with expanded capillaries overfilled with blood, frequently with the phenomena of stagnation. The walls of the capillaries underwent plasmatic saturation, the endothelium looked swollen, it contained small spots of diapedetic hemorrhages. Destructive modifications in the glomerules were various, from fragmentation of the glomerules and atrophy to the disappearance of structures and formation of voids.

The basal membrane of the glomerules was thinned and structureless in some spots. These modifications were combined with the intraglomerular edema. The nephropthelium of the tubules was in the state of the hyaline-droplet and hydrolytic dystrophy transforming into the balloon dystrophy. The epithelial cells of the tubules were destroyed in some spots, the contours of the cell nuclei were poorly identifiable. The alterative changes in the form of dystrophy were combined with rexisis and lysis of the nephrocytes, they would separate into the lumen of the tubules. Some spots manifested destruction of the basal membrane. The lumens of the tubules contained also protein cylinders, erythrocytes and leukocytes. The morphological modifications of the interstice were manifested by edemas and the appearance of lymphocytes, plasmatic cells, less often eosinophils and leukocytes infiltrated into the perivascular spaces and around the destroyed tubules in the cortex and the medulla. The vessels of the stroma were expanded, they contained excessive blood, some showed blood stagnation. The walls of the vessels were swollen, edemic and showed saturation with plasma.

Adrenals (Fig. 44). Morphological modifications were manifested by the strong plethora of the vessels with hemorrhage into the medulla, it was located in fine spots with the necrosis of tissues and hemosiderosis. No hemorrhage into the cortex was observed. The adrenal cells were in the state of protein dystrophy, more often vacuole, the cells looked swollen, edemic. The nuclei were polymorphic, hyper- and hypochromous. Strong edema of the interstitial tissue was typical.

Case 4. Infant aged 7 months, from the Korma district, was hospitalized with the signs of acute respiratory virulent infection. After that respiratory and cardiovascular deficiency developed, intoxication. Died of septicemia on the 8th day after hospitalization. The internal organs manifested significant accumulation of radioactive cesium (Table 7).

The severest structural modifications were observed in the organs with the maximum accumulation of radioactive cesium, vis. the liver, the thyroid, the myocardium.

Table 7

^{137}Cs accumulated in the internal organs of infant L.

Organ	^{137}Cs concentration, kBq/kg
Lungs	0.45
Heart	2.41
Stomach	0.25
Small intestine	1.25
Large intestine	1.20
Kidneys	0.71
Pancreas	0.24
Thymus	0.08
Thyroid	4.70
Spleen	0.13
Brain	0.65
Liver	0.67
Adrenals	2.50

Liver (Fig. 45). The center-lobular hepatocytes were in the state of the hyaline-droplet and hydropic dystrophy transforming into the balloon dystrophy. The parenchymatous protein dystrophy was combined with the adipose dystrophy, fine- and large-droplet adipose dystrophy of hepatocytes was most pronounced over the perimeter of the lobe. The centers of coagulatory necrosis were observed predominantly in the centers of the lobes. The hepatic cells were reduced in dimensions, they had indistinct contours, their nuclei were polymorphous, irregular in size, hypo- and hyperchromous, the signs of cariorexisis and cariolysis were observed with certain regularity. The disorders of blood circulation were manifested by the plethoric central and interlobular veins and the centers of plethora in the interlobular capillaries accompanied by elevated vascular penetrability, diapedetic hemorrhages and expansion of the Disse's spaces due to the edema. The vascular walls manifested plasmatic saturation, swollen endothelium and evolution of endovasculitis. Modifications of the stroma were shown by the swelling of the intravoid substance due to the edema, by the expansion of portal tracts and the appearance of the infiltrate of lymphocytes, plasma cells, eosinophils and neutrophils. The biliary channels manifested atrophic processes and the thickening of the epithelium. Kupffer cells manifested pronounced proliferation. Sclerotic processes in the stroma of the liver were little pronounced.

The thyroid (Fig. 46). The morphological modifications included a combination of alterative changes and vascular disorders. The ferrous follicles had irregular dimensions (mostly moderate), their colloids were mostly light-colored, diluted, sometimes with large numbers of resorptive vacuoles, the follicular epithelium was flattened. Alongside with theese signs the spots of dystrophic and mildly pronounced necrobiotic changes of the epithelium were observed: the cells were reduced in size, the cytoplasm had a fine granular structure, the nuclei were stained mildly, some follicles manifested cariopicnosis and lysis. The epithelium of some follicles was desquamated. The vascular disorders included pronounced venous plethora, stagnation, finespot diapedetic hemorrhages. The walls of the vessels were swollen with the signs of plasma saturation. The stroma was edemic, the amount of the interfollicular tissue was somewhat increased, moderate spots of lymhophysiary infiltration of the interstice and some follicles were observed.

The myocardium (Fig. 47). Modifications of cardiomyocytes were manifested by the alterative modifications in the form of the hyaline-droplet and spot hydropic dystrophy. The muscular fibers were loose and had indistinct contours, mildly pronounced cross strip striation. Spot lysis of myofibrils and their fragmentation were observed. The nuclei of the cardiomyocytes showed polymorphism and hyperchromia, some spots showed cariopicnosis and cariolysis. The myocardial vessels were strongly plethoric. In addition to the swelling and proliferation of the vascular endothelium, plasmorrhagia and smallspot diapedetic hemorrhages were observed.

The stroma manifested a pronounced intermuscular edema, perivascular cellular infiltration with the cells of the lymphocytary and plasmatic series.

The accomplished studies have revealed that functional elements perish in the organs intensively accumulating radioisotopes. The injuries of the renal tissues are specifically noteworthy, since glomerules perish and leave voids. It is worthwhile to mention the absence of lympho- and macrophage elements involved in fibroplastic processes. The injuries of the tubular epithelium in the form of the hyaline-droplet and hydropic dystrophy followed by necrosis should be highlighted. As a rule, these kidney injuries were combined with pronounced modifications of the myocardial tissue. Destructive manifestations would appeare in case of strong concentration of radioactive cesium in the myocardium in the form of intermuscular edema, hydropic dystrophy, myocytolysis. The above modifications were observed both among children and adults. Possibly the injuries of kidneys during excretion of radioactive cesium from the organism are a major cause of is accumulation in the tissues with strong metabolic reactions, primarily in the myocardium.

It should be emphasized that the above modifications would definitely lead to fatal outcomes, mostly there were ignored in the clinical and pathoanatomical diagnoses.

4.3. Accumulation of radioactive cesium and structural modifications of internal organs in case of sudden deaths in Gomel

In order to obtain evidence about the role of radioactive cesium in the evolution of pathological conditions leading to fatal outcomes a morphological (macro- and microscopic) study of the organs of individuals residing in the area contaminated with radioisotopes after their sudden death (in Gomel and the region) has been accomplished.

The randomized study comprised 285 autopsies in the forensic morgue in Gomel. Radiological measurements were performed in 84 cases using a counter RYG-2.

The obtained results were processed statistically. Examinations of sections have manifested that the injuries of the myocardium are registered in 281 cases (98.6%) after deaths of various diseases.

Diffused damage of the muscular cells (myocytolysis or hydropic dystrophy) is noteworthy. The muscular fibers are loose, their contours are indistinct and have poor cross-strip striation. Spot lysis of myofibrils and their fragmentation have been observed (Fig. 48).

The above pathomorphological modifications have been accompanied with pronounced incorporation of radioactive cesium (its average concentration in the heart amounted to 26.1 Bq/kg).

The morphological modifications of the tissues of kidneys have been observed in 253 cases (88.8%) of sudden deaths. The damage of this organ manifested death of the structural and functional elements in 142 cases (49.8%) , primarily glomerules, evidenced by a typical histological pattern, such as appearance of voids (Fig. 49). Meanwhile, the fibroplastic processes almost did not evolve. The epithelium of tubules manifested signs of profound (hyaline-droplet, hydropic) dystrophy or necrosis. The tissue of this organ showed average concentration of radioactive cesium 36.5 Bq/kg.

Injuries of the liver were registered in 122 cases (42.8%) showing morphological signs of the adipose hepatosis or cirrhosis.

This organ manifested average accumulation of radioactive cesium 28.1 Bq/kg.

Hence, the accomplished study has manifested that in case of sudden death the individuals would manifest pronounced pathological modifications of vital organs, primarily the myocardium, as major causes of fatal outcomes.

Accumulation of radioactive cesium by these organs can be assumed to be the leading factor of evolution of the above pathological modifications.

CHAPTER 5. PATHOGENESIS OF DISORDERS INDUCED BY INCORPORATED RADIOACTIVE CESIUM

A huge quantity of radioisotopes released into the environment after the Chernobyl disaster has induced significant alterations in the organisms of people living in the affected areas.

It should be emphasized that radioactive elements had different half-lives. Hence, the duration of their effect and the features of their interactions with biological structures differently influence human and animal organisms. Therefore the periods of effects upon man of short-living (^{131}I and ^{89}Sr) and long-living (^{137}Cs and ^{90}Sr) isotopes last differently.

Radioactive ^{131}I is incorporated by the organism of man through the organs of digestion, respiration, through wounds and burns. Digestion and inhalation have most significance. After incorporation by the organism ^{131}I is quickly absorbed by blood, lymph and accumulates in the thyroid gland, in muscles, bones. The extent of its accumulation in the thyroid depends upon the gland's condition. In case of hyperthyreosis ^{131}I accumulates faster, and vice versa in case of hypothyreosis. When the thyroid functions normally 20% of iodine is combined by proteins.

Acute and grave radiation injuries lead to lethal outcomes in case the concentration of ^{131}I in the organism of man is 55 mBq/kg and 1,850 mBq/kg in the organism of rat. Smaller concentrations induce pathological modifications in the thyroid, blood system, immunity system and in a number of metabolic links.

Radioactive effects of iodine induce malignant pathologies in the thyroid, cancer in the first place. The latter is due to the strong modifications of the immunity system.
In addition to ^{131}I, there are grounds to believe that ^{137}Cs and ^{134}Cs play an essential role in inducing thyroid cancers. These elements negatively affect the thyroid tissue, the immunity system, meanwhile the latter is supposed to control the functions of thyroid cells and suppress those which go out of control. In addition to the plasmogenic effects, radioactive iodine induces hypo- and hyperfunctioning of the thyroid gland and autoimmune disorders.

The population in the affected areas is exposed to major negative effects of the long-living radioisotopes, primarily ^{137}Cs and ^{90}Sr. They are incorporated by the organism as components of food and their accumulation in the organism is determined by a number of factors:

(1) concentration in food;
(2) age;
(3) sex;
(4) blood group and rhesus;
(6) agents influencing incorporation of radioisotopes by the gastric tract or their excretion;
(7) structural and functional features of organs and tissues.

The highest concentration of gamma emitting radioisotopes (^{137}Cs) has been registered in the communities which consume forest berries and mushrooms in heavily contaminated areas. These radioisotopes are the main contributors to the radiation dose. A direct proportional relationship has been established between the age and accumulation of radioisotopes. Senior children manifest larger accumulation.

Experimental and clinical studies have revealed that female individuals accumulate less than males in the same conditions. A relationship has been revealed between the extent of incorporation of ^{137}Cs and the blood group. Individuals with the Rh- blood group accumulate radioisotopes less (Yu.I. Bandazhevsky et al., 1997).

Accumulation of radioisotopes increases is many times stronger inpregnancy, primarily in the placenta, upsetting the hormonal balance between both the mother's organism and the fetus which will definitely affect later development of the baby. Meanwhile, among mammals with the hemoxorial type of the placenta structure, like among humans, penetration of ^{137}Cs into the organism of the fetus is reduced to the minimum evidencing that this provisory organ acts a barrier. Damage of the placentary barrier causes death of the fetus.

Accumulation of radioisotopes strongly depends upon the environmental factors to which the organism is exposed, specifically when radioisotopes penetrate into the gastrointestinal tract. Among them the agents capable to sorb the radioisotopes and to excrete them from the organism occupy a specific place.

These preparations, or enterosorbents, have different chemical structures and different sorption effectiveness in respect to ^{137}Cs. Research at the Gomel Medical Institute have demonstrated that clayey-pectin compounds, petopal in particular, are most promising agents capable to protect the organism against enterally incorporated radioisotopes (Fig. 50).

The radioisotopes incorporated with food, primarily ^{137}Cs, accumulate differently in tissues and organs.

Studies of sections and laboratory samples have shown that parenchymatous tissues, primarily the heart and the thyroid are heaviest accumulators.

The incorporated radioactive cesium induces structural and metabolic modifications in

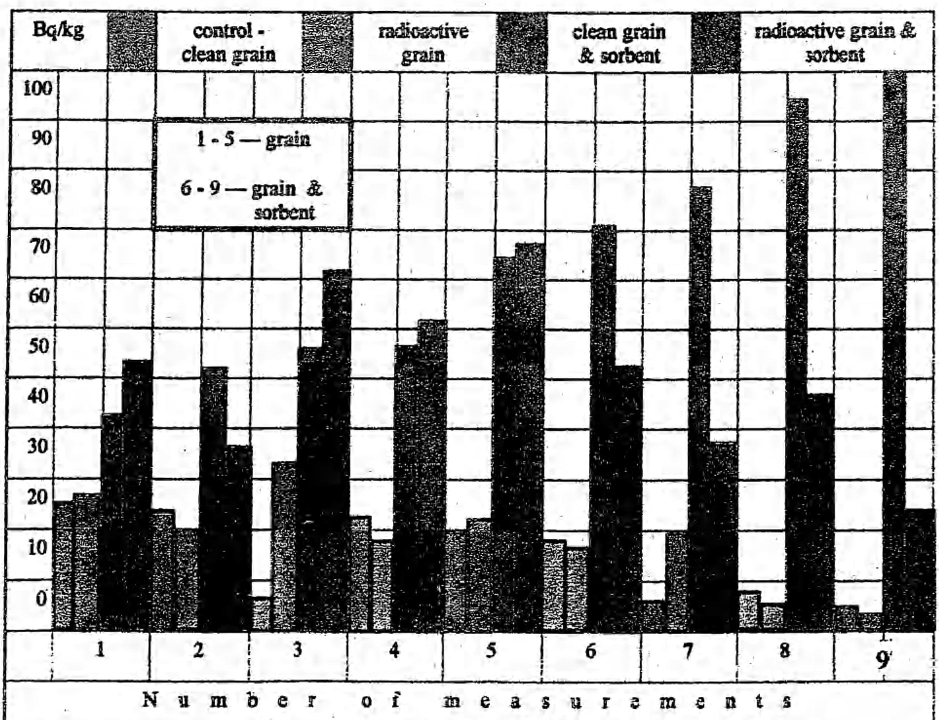

Fig. 50. Dynamics of accumulation of radioisotopes among rats in experimental and control groups

the organs and tissues, their extent is directly proportional to the amount of accumulated radioisotopes.

Clinical and experimental studies have revealed pathological effects in the heart, liver, kidneys, central and vegetative nervous, endocrine, immunity and reproductive systems.

A clear-cut relationship has been revealed between the structural and functional disorders of vital organs and the amount of incorporated radioactive cesium. The injuries of the myocardium, kidneys and liver are specially noteworthy.

The pathology of the cardiovascular system manifests itself by functional alterations already among preschool children which intensify as the concentration of radioactive cesium in the organism increases.

In particular, disorders of electric pulse conduction as various sorts of blockades have been registered. The frequency of the His bundle blockades among children in the affected areas is directly proportional to the amount of radioisotopes incorporated by the organism.

Examinations of sections have manifested that the injuries of the myocardium occur in 98.6% of the cases of death of various causes. The diffused damage of muscular cells typical for the toxic effects of radioactive cesium are noteworthy. Dystrophic modifications of the myocardium are due to pronounced incorporation of radioactive cesium. Accumulation of radioactive cesium would be many times larger in case of persistent cardiovascular disorders.

Injuries of the myocardium may be aggravated by the upset balance of generation of hormones by the thyroid gland and by the upset functions of the vegetative nervous system.

Pronounced injuries of kidneys have been registered in 88.8% of sudden deaths and among the individuals who died in Gomel hospitals. This conditions would not be diagnosed during the life time in the majority of cases.

Injuries of this organ typically result in the death of the structural and functional elements, glomerules in the first place, as a typical histological pattern.

The tissues of kidneys manifest significant accumulation of radioactive cesium. The results with experimental animals by injecting "pure" ^{137}Cs allow to assert that these changes are induced by the toxic effects of this radioisotope.

Injuries of kidneys are one of the main causes of accumulation of radioactive cesium and products of metabolism with their toxic effect upon the myocardium. It is the condition of the latter which determines extensive mortality among adults.

Grave pathological modifications of the liver tissues in the form of adipose hepatosis and cirrhosis are noteworthy.

Accumulation of radioisotopes in the internal organs and primarily in the liver, kidneys, endocrine glands, upsets metabolic processes in the organism and leads to the alterations of the biochemical blood parameters.

Injuries of the tissues of kidneys affecting the apparatus of glomerules and tubules, alongside with the injuries of the liver tissues should be specifically highlighted, since they lead to the accumulation of the products of protein metabolism in the organism.

Pathology of the immune system manifests itself by the inhibition of functions of the immunity competent cells leading to a number of infectious and parasitic disorders, tuberculosis, in the first place. Inhibition of the fagocytary activity of neutrophil leukocytes and reduction of IgJa concentration in the blood are real manifestations of the process.

Disorders of the hemopoiesis should be noted specifically. Valid reduction of erythrocytes with normal concentration of hemoglobin in them have been registered among the children in the areas with heavy radioactive contamination (above 40 Ci/km^2) resulting in a significant accumulation of ^{137}Cs in their organisms (500 Bq/kg and more). No strong alteration of hemopoiesis has been observed among the children in the areas with level of

^{137}Cs contamination 1 to 5 Ci/km^2 when accumulation of this radioisotope stays below 50 Bq/kg.

Injuries of the endocrine system, the thyroid gland in the first place, are due to the effects of the iodine radioisotopes during the first days after the Chernobyl disaster. However, the effect of ^{137}Cs intensively accumulated by this organ should be also taken into consideration. A relationship has been revealed between the concentrations of T3 and T4 and ^{137}Cs in the organism.

A similar relationship has been established in respect to cortisone as one of the hormones of the adrenal cortex.

Injuries of the thyroid are strongly governed by the modifications of the condition of the immune system under the effect of ^{137}Cs. A correlation between IgJ and thyroid hormones is noteworthy among the children in the contaminated areas because these agents have an affinity to combine together.

It can be assumed that elimination of these hormones from the metabolic chain upsets the functions of the pituitary body-thyroid system intensifying the release of a significant amount of the thyreotropic hormone stimulating the thyroid gland. As a result the proliferation of the follicular epithelium is intensified favoring neoplastic transformations.

In our view, the effects of incorporated radioisotopes, 137Cs in the first place, upon the endocrine system should be treated as disorders of the immunal control over the functions of organs and tissues with the consideration of the pattern of proliferation and differentiation of their cellular elements.

Under these conditions the period of restoration of the thyroid gland after a short-term effect of ^{131}I occurs under a long-term effect of ^{137}Cs and ^{90}Sr both upon the tissues of these organ proper and upon the immunity system controlling the processes of proliferation and differentiation of the follicular epithelium and adjacent cells. These factors transform the structural components of thyroid cells into antigens for the immunity system. An immunological response evolves when autoantibodies and immunity competent cells damage the thyroid gland and cause autoimmunal thyreoditis as a factor of subsequent evolution of thyroid cancers.

Various vegetative disorders due to the upset balance between monoamines and neuroactive amino acids reflect the dysfunctions of the central nervous system when the organism incorporates radioisotopes.

The organs of senses are also affected by the incorporated radioisotopes.
High incidence of the pathologies of the organ of vision among children is most salient in the areas with stronger contamination (the Vetka district, above 15 Ci/km2 of ^{137}Cs), among them modifications of the lens in the form of cataracts are specifically noteworthy.

Pathologies of the female reproductive system directly relate to the endocrine dysfunctions. A definite upset balance between progesterone and estrogens among females of the fertile age has been registered, the extent of damage is determined by the quantity of incorporated radioisotopes. During pregnancy, in case of intensive accumulation of ^{137}Cs in the placenta, the hormonal disorders are manifested both by the mother and the embryo. In particular, the concentration of testosterone increases as the concentration of radioisotopes goes up. Mother would manifest larger concentration of thyroid hormones and cortisone in the blood.

Modifications of the hormonal status in the mother-fetus system extend pregnancy, cause complications in labors and post-natal development. In particular, the fetus manifests reduced concentrations of cortisone which possibly inhibits adaptation to the intrauterine environment.

Hence, natural incorporation of radioisotopes upsets the metabolic processes of vital organs. It is specifically noteworthy that main victims are the organs and tissues in which the physiological conditions dictate insignificant proliferation of cells or it is complete absence (the myocardium). These organs continuously accumulate ^{137}Cs, it presumably produces the negative effect primarily through intoxication by intervening into the metabolic processes and damaging the membrane structures of cells. Considering the affinity between ^{137}Cs and K+ its involvement into the K-dependent processes can be assumed, specifically into the electrolytic metabolism.

This process results in the disorders of the structures and functions of various vital systems, primarily of the cardiovascular system. At the same time ^{137}Cs does not induce pronounced damages of cells in the tissues with intensive proliferation . In our view, it is due to its quite long half-life, hence its ionizing effect at present is not so noticeable.

Hence, it should be admitted that disorders of the metabolic processes in the organism at present are basically due to the toxic effects of cesium and other radioactive elements with long half-lives and which are contained in huge quantities in the environment after they had been released by the Chernobyl disaster.

The ionizing effects of the long-living radioisotopes will become manifest after a considerable period of time, hence the priority task of the medical science and practice is to create conditions to eliminate these agents from the human organism.

Hence, the doses of ^{137}Cs producing weak ionizing effects so far may become strong if their toxic effect upon the vital organs and system is taken into consideration.

The pathological modifications they induce in the human and animal organisms can be integrated into the syndrome of incorporated long-living radioisotopes (SILR).

It appears among the individuals after incorporation of long-living radioisotopes (^{137}Cs, ^{90}Sr) by the organism with resulting structural and functional modifications of the cardiovascular, nervous, endocrine, immunity, reproductive, digestive, hepatobiliary and urine systems.

The concentration of the radioisotopes inducing the SILR may be different as a function of age, sex, physiological conditions of the organism. In particular, children manifest strong pathological modifications of the organs and systems in case accumulation of ^{137}Cs exceeds 50 Bq/kg.

The data above allow to conclude that radioactive cesium negatively affects the organisms of the people living in the areas affected by the Chernobyl disaster. It is primarily due to the toxic effect of this radioisotope upon the vital organs, such as the heart, liver, kidneys. Evaluation of the condition and opportune treatment should be properly effected in order to avoid inevitable death of the organism. The situation is aggravated by the effect of various accompanying negative factors, such as smoking, alcohol abuse, hypodynamism, infectious agents.

In our view, a system of actions to protect public health in the areas contaminated with radiation should include the following components:

1. Elimination of possible incorporation of radioisotopes by human organisms through tough monitoring of the quality of food, water and air.
2. Excretion of radioisotopes, ^{137}Cs and ^{90}Sr primarily, with harmless compounds (based on natural restorative agents) through the gastrointestinal tract. They may be pectin compounds which both excrete radioactive cesium from the organism and remedy the condition of metabolism.
3. Physical and therapeutical methods of purging the organism and eliminating the effects of radioisotopes and toxic products.
4. Development and implementation of the methods stimulating elimination of radioisotopes from tissues, organs and the organism as a whole.

3. Physical and therapeutical methods of purging the organism and eliminating the effects of radioisotopes and toxic products.
4. Development and implementation of the methods stimulating elimination of radioisotopes from tissues, organs and the organism as a whole.
5. Continuous radiological monitoring in order to identify groups with higher risk of incorporation of radioactive cesium followed by clinical examinations and laboratory tests.
6. Continuous monitoring of the condition of children and adults with relevant registration of the functions of the heart, liver and kidneys, general assessment of the health status and identification of risk groups.
7. Continuous correction of the metabolism and functions of vital systems by implementing actions of prevention and medication.
8. Continuous scientific validation of the results of the implemented actions of public health care in the radiation contaminated areas for perfecting methodological approaches.

The presented information allows to conclude that a comprehensive program of immediate implementation of safe life should be elaborated to protect from the effects of the long living radioactive elements.

LIST OF ABBREVIATIONS

ATP-ase	adenosintriphosphatase
AST	asparate aminotransferase
ALT	alanin amino transferase
T_3	triiodine thyronin
T_4	thyroxin
GAMC	gamma-amino oleic acid
GGTP	gamma-glutamat transpeptidase

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APPENDICES

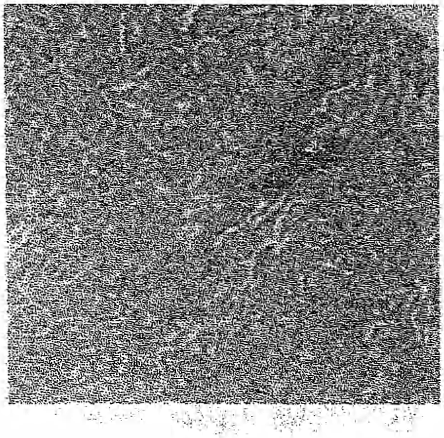

FIG. 33. HISTOLOGICAL STRUCTURE OF ANIMAL LIVER AFTER INCORPORATION OF RADIOACTIVE CESIUM WITH FOOD. LYMPHOHISTIOCYTARY INFILTRATE IN CORTEX COMPARTMENT, HYALINE DROP DYSTROPHY OF EPITHELIUM OF TUBULES, PROLIFERATION OF MESANGIUM AND GLOMERULES. STAINING WITH HEMATOXYLIN AND EOSIN. MAGNIFICATION X 125

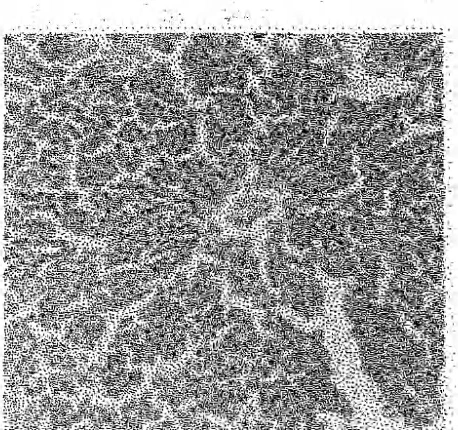

Fig. 34. HISTOLOGICAL STRUCTURE OF ANIMAL LIVER AFTER INCORPORATION OF RADIOACTIVE CESIUM WITH FOOD. BLOOD STAGNATION IN CENTRAL COMPARTMENTS OF LOBES WITH DILATATION OF CENTRAL VEINS AND DISSE'S SPACES. STAINING WITH HEMATOXYLIN AND EOSIN. MAGNIFICATION X 125

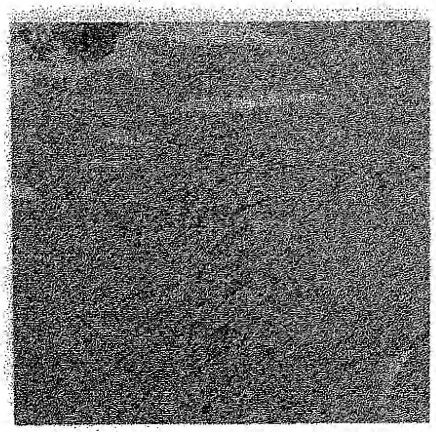

FIG. 35. HISTOLOGICAL STRUCTURE OF ANIMAL MYOCARDIUM AFTER INCORPORATION OF RADIOACTIVE CESIUM WITH FOOD. DIFFUSED MYOCYTOLYSIS. SPOT INFILTRATION OF LYMPHOHISTIOCYTARY ELEMENTS. STAINING WITH HEMATOXYLIN AND EOSIN. MAGNIFICATION X 125

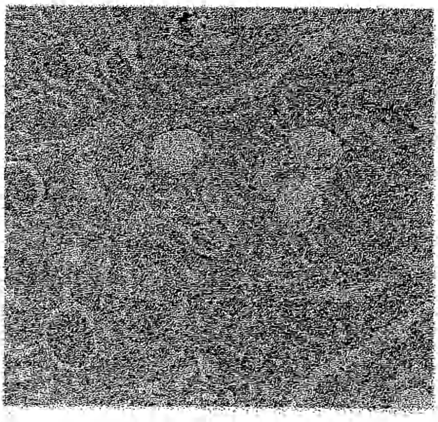

FIG. 36. HISTOLOGICAL STRUCTURE OF ANIMAL KIDNEY AFTER INCORPORATION OF ^{137}Cs. NECROSIS AND FRAGMENTATION OF GLOMERULES AND APPEARANCE OF VOIDS, NECROSIS AND HYALINE DROP DYSTROPHY OF EPITHELIUM OF TUBULES. STAINING WITH HEMATOXYLIN AND EOSIN. MAGNIFICATION X 200

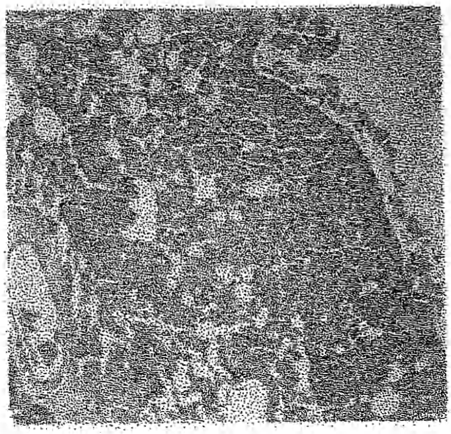

FIG. 37. HISTOLOGICAL STRUCTURE OF ANIMAL LUNG AFTER INCORPORATION OF ^{137}Cs. PLETHORA OF VESSELS, BLOOD LEAK INTO LUMEN OF ALVEOLI. INFILTRATION OF NEUTROPHIL LEUKOCYTES, LYMPHOCYTES AND HISTIOCYTES INTO VISCERAL PLEURA. STAINING WITH HEMATOXYLIN AND EOSIN. MAGNIFICATION X 125

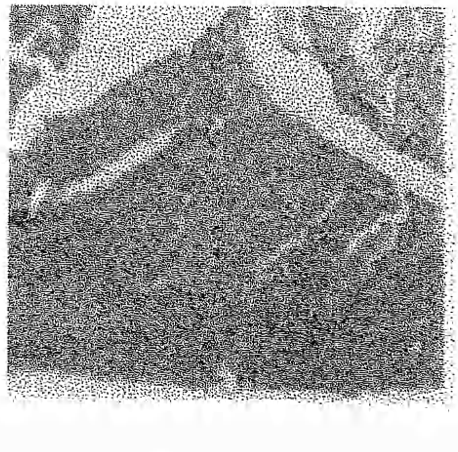

FIG. 38. HISTOLOGICAL STRUCTURE OF ANIMAL MYOCARDIUM AFTER INCORPORATION OF ^{137}Cs. DIFFUSED MYOCYTOLYSIS, PRONOUNCED INTERTISSUE EDEMA. STAINING WITH HEMATOXYLIN AND EOSIN. MAGNIFICATION X 125

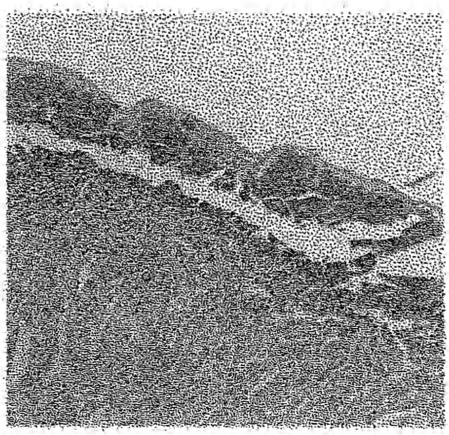

FIG. 39. HISTOLOGICAL STRUCTURE OF ANIMAL MYOCARDIUM AFTER INCORPORATION OF 137CS. INFILTRATION OF NEUTROPHIL LEUKOCYTES, LYMPHOCYTES INTO EPICARDIUM AND PERICARDIUM. PRONOUNCED MYOCYTOLYSIS. STAINING WITH HEMATOXYLIN AND EOSIN. MAGNIFICATION X

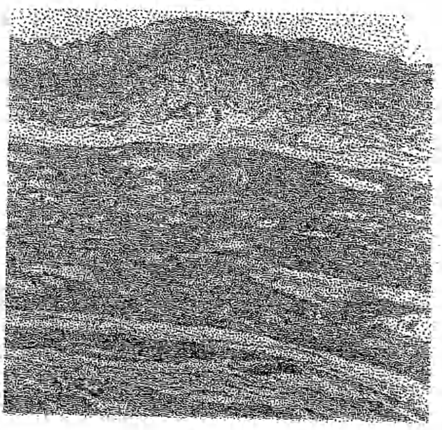

FIG. 40. STAINING WITH HEMATOXYLIN AND EOSIN. MAGNIFICATION X 250

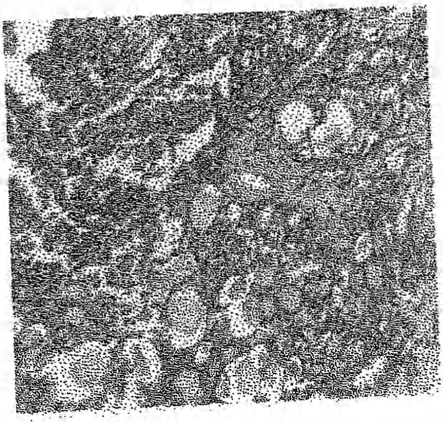

FIG. 41. STAINING WITH HEMATOXYLIN AND EOSIN. MAGNIFICATION X 250

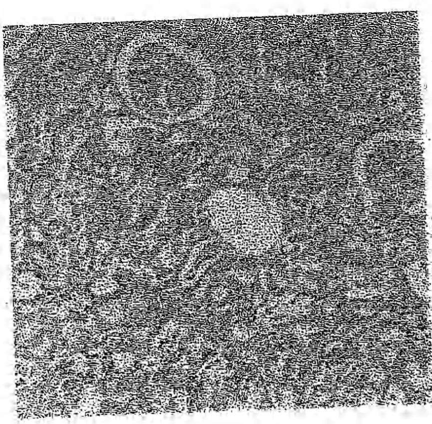

FIG. 42. STAINING WITH HEMATOXYLIN AND EOSIN. MAGNIFICATION X 250

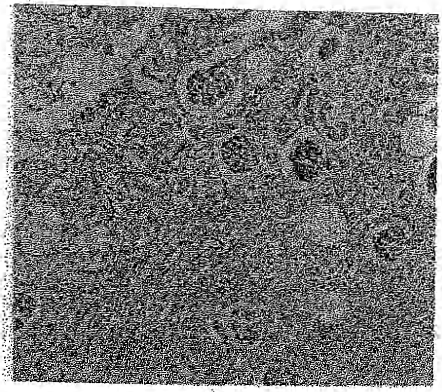

FIG. 43. STAINING WITH HEMATOXYLIN AND EOSIN. MAGNIFICATION X 250

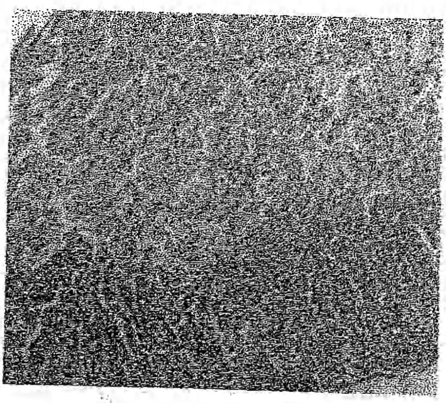

FIG. 44. STAINING WITH HEMATOXYLIN AND EOSIN. MAGNIFICATION X 250

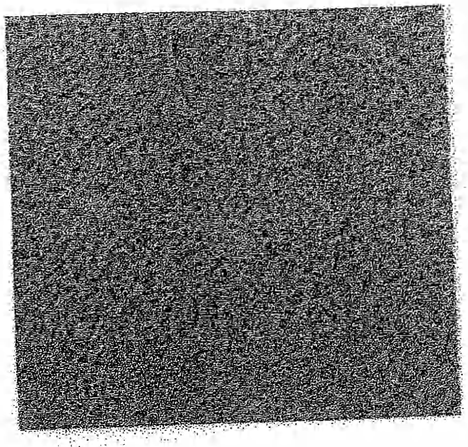

Fig. 45. Staining with hematoxylin and eosin. Magnification x 250

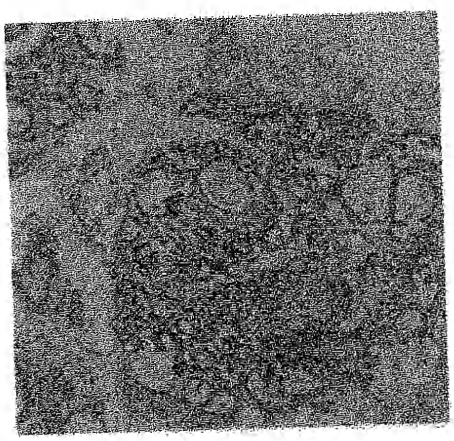

Fig. 46. Staining with hematoxylin and eosin. Magnification x 250

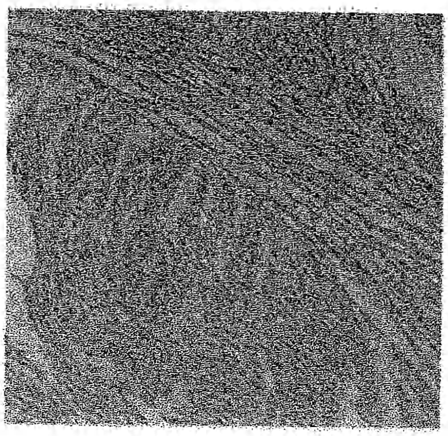

FIG. 47. STAINING WITH HEMATOXYLIN AND EOSIN. MAGNIFICATION X 250

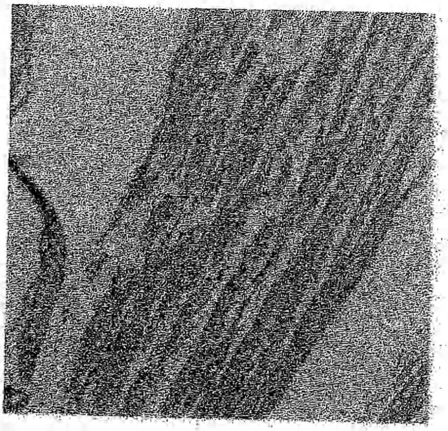

FIG. 48. STAINING WITH HEMATOXYLIN AND EOSIN. MAGNIFICATION X 250

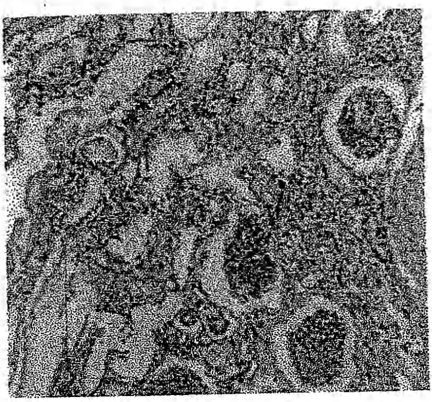

FIG. 49. STAINING WITH HEMATOXYLIN AND EOSIN. MAGNIFICATION X 250

Yuri I. Bandazhevsky

PATHOLOGY OF INCORPORATED RADIOACTIVE

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