Ionizing Radiation and Health: What we all should know today

O.I. Timchenko

Marzeyev Institute of Hygiene and Medical Ecology,
Ukrainian National Academy of Medical Sciences
Kiev, Ukraine

Foreword

What lessons should people learn from the Fukushima catastrophe? What message and heritage should be handed to future generations on the nuclear catastrophe?

The post-Fukushima issue is not a simple question of alternatives, such as pro- or anti-nuclear power generation. The catastrophe and post-catastrophe management critically raised a series of questions to rethink modernity, namely, the relationships between science-technology and civilization, science and politics, the natural environment and society, government and citizens, locality and the globe, international society and nation state, culture and spirit, and so on. These questions should be shared by overseas colleagues to look for answers.

The most urgent issue is the evacuees in Fukushima, whose number is still, at least, as many as 150 thousand according to the Reconstruction Agency of Japan. The number must be much more, including those who evacuated themselves voluntarily. The full account might be 190-200 thousand or more. Most of the evacuees, having been of large families in their rural homeland, now live separately in small temporary housing in urban or suburban areas with no certain perspective of their destiny, to the old homeland or a new one. Their destiny depends on the number of a so-far totally unknown unit of measurement, the sievert, milli-sievert, or micro-sievert.

A nuclear disaster is a war against an invisible enemy. People, seeing and hearing foreign accounts of the number of sieverts every day in the media, still remain almost illiterate about it, though having full information. Information must develop into knowledge.

Twenty-five years before the Fukushima accident, the Chernobyl disaster happened in the Soviet Union. Almost all Japanese were severely shocked at that time; however, as time passed, they forgot it. Focus on the catastrophe turned to other business. As a result, the people learnt no lessons from it. In the Chernobyl region, however, the people have been facing post-disaster aftereffects and radiation exposure all the time since the accident. Meanwhile, the SU collapsed, and the affected people's destiny altered according to their new national belonging, that is, Russia, Belarus, or Ukraine.

The Slavic Research Center at Hokkaido University recently launched a joint research project "Catastrophe and Rebirth of Regions after Disasters: Chernobyl, Ajka, and Fukushima," and the aim of the project is to draw lessons from the disasters for the rest of the world and the future generations to fight an invisible enemy. This booklet is the first joint product for the public between scholars in Ukraine and Japan answering practical questions in an era of nuclear civil protection from an invisible enemy: exposure to radiation.

The author of this booklet is Olga I. Timchenko, senior researcher at the Marzeyev Institute of Hygiene and Medical Ecology, attached to the Ukrainian National Academy of Medical Sciences in Kiev, Ukraine. Her details are in the first pages of the contents.

Here, I provide a brief history of the booklet. In March 2013, I visited several research institutions of radiology in Kiev. The aim of the visit was to have a complex bird's eye view on Chernobyl studies in Ukraine, and to pass the experience and knowledge to the Japanese, especially to the people affected by the Fukushima accident. Olga plays a leading role in the researches on the influence of radioactivity on the ecology at the Marzeyev Institute. She was the key person among those whom I met there, and I asked her to write a guideline essay on low-level exposure to radiation. Olga accepted it, saying, "With pleasure. The Ukrainian people are grateful to the Japanese people who helped the Ukrainian children. Now, it is the time for us to reciprocate."

The booklet is full of experience and knowledge of the Ukrainian people, living a quarter of century after the nuclear catastrophe. It is indispensable for us. However, we have to develop their knowledge further on the basis of our own local experiences, because individual peoples and lands have their own physical and mental characteristics. As Olga writes, for example, balanced nutrition is essential to prevent the effects of radioactive doses. Then, we have to take into consideration the fact that diet differs greatly from nation to nation, or from area to area, and it can chronologically change within a nation or an area. The old Japanese diet of seafood is declining among the younger generation. This booklet, in any case, serves as a basic guideline to develop literacy against radioactive exposure.

I hereby express my deepest gratitude to Olga I. Timchenko. I extend my gratitude to Masumi Takaragawa, who is in charge of Chernobyl affairs at the Japan Embassy in Kiev, for her kind arrangement of my visit to Kiev in March 2013. Without her help, my stay in Kiev would not have been successful. Her family's hospitality is unforgettable with Georgian cuisine, prepared by Uta, her husband.

Special thanks go to Tetsuji Imanaka, the Research Reactor Institute at Kyoto University, and David Wolff, the Slavic Research Center at Hokkaido University, for their many valuable comments on the Japanese/English translation of the original paper, written in Russian. The translation into Japanese and English from the Russian texts was conducted by Takashi Ieda, who otherwise helped me as an interpreter in Ukraine in March. All he did for this booklet was totally voluntary.

I, who supervised the translations, assume all responsibility, however. Any critical comments and suggestions are welcome.

I do hope that the booklet will help develop radioactive literacy everywhere in the world to fight the invisible enemy successfully.

Sapporo, November 2013

Professor Osamu Ieda
The Slavic Research Center, Hokkaido University

Content

Dear Reader in distant Japan,

Let me express to you and your compatriots my condolences for the severe disaster that befell your country in 2011. I hope and believe that the inherent resistance, diligence and self-discipline of the Japanese people, which I have seen in books and films, will help you to weather all troubles and to withstand the many centuries ahead.

With my utmost sincerity,

O. I. Timchenko

1 . Introduction

Please allow me to briefly introduce myself. I was born in southern Ukraine, in the Zaporizhia region, during the Second World War. At that time my mother was studying at a medical institute, whereas my father was working as an agronomist, so I lived with my mother's parents, who were both teachers of the Russian language. After high school, I worked for two years. Then I attended a medical institute and completed it in 1969, majoring in therapeutic treatments. For the last 35 years I have been working at the Institute of Hygiene and Medical Ecology of the National Academy of Medical Sciences of Ukraine. I received the degree of Candidate of Medical Sciences in 1981, in "radiobiology," and became a Doctor of Medical Sciences in 1992, in "genetics" and "hygiene". I believe that it is the very combination of specialties which truly allows us to have manifold ideas and to obtain scientific and practical results on complex questions at the intersection of the sciences.

Since 1992, to the present, I have been the head of the Laboratory of Genetic Epidemiology. We specialize in studies of genetic processes of the Ukrainian population, and its impact on health: specifically, determination of frequency of birth defects in newborns and research on possibilities to prevent reproductive losses due to genetic disorders. Results of our laboratory studies have been published in 19 monographs. Fourteen of them comprise a series called "Gene Pool and Health." As an educational institution, the laboratory has graduated 16 Candidates and 7 Doctors to date.

2 . Chernobyl Days- A Personal View from Kiev

As generally known, until 1986, the Soviet Union did not allow for the possibility of a major accident at a nuclear power plant. Information on the radionuclide contamination of the River Techa (1948) and the nuclear accident at the Mayak Production (1957) had been carefully concealed from the public. Thus, atom's peaceful reputation and the general public's ignorance were both maintained.

In the afternoon of April 28, 1986, the director of the institute, in which I was working, told the employees that an accident had occurred at the Chernobyl

nuclear power plant, however, "although the reactor has been destroyed, the situation is still manageable and, luckily for the inhabitants of Kiev, the radioactive cloud has gone to the west." I somehow focused on the comforting words about the "manageability of the situation at the destroyed reactor". Then, a few hours later, I realized that the information was untrue, simply impossible, so something had to be done.

At that time, my daughter and her husband were in Crimea on a trip. However, my brother had two children aged 4 and 7. I immediately got in touch with my brother and quickly had four children (my nephews and their close friends) moved out to my parents' house in the south of Zaporizhia. Thus, these children were not exposed to radioactive iodine.

I found, at my work place, stocks of potassium iodide so I distributed them to my colleagues and relatives. However, as with Cassandra, the prophets were not appreciated: some of my relatives refused to take the potassium iodide, thinking that I was sowing panic. Instead, they believed the radio or watched the television, which showed people resting on the banks of the Dnieper River in Kiev with their children. My relatives believed, as the bulk of the population did, that nothing serious had happened. Again, the population was not informed properly. Or, I could even suppose that the authorities, like my relatives, did not fully understand the degree of danger of the accident.

However, later, when children began to be evacuated from Kiev, people, who had once ignored the danger, began to stare at any woman walking on the street with a child, saying that she was not fulfilling her duty as a mother to protect the child from the danger.

For decontamination, people often cleaned the streets (as did I my apartment). It is said that, at that time, vegetables were imported to Kiev from the southern uncontaminated areas.

Now, many years have passed since the accident. However, in my heart, the feeling of distrust in official reports, even on other accidents, has never disappeared. Subsequent events in our country (change of life style, collapse of the Soviet Union and the economy, etc.) confirmed that I have every reason to believe that, in a time of danger to my well-being (or possibly to my life), the

authorities would betray me again, if it served their interests.

Conclusion: Try to get the information you need from different sources. Consult with independent experts. Only then, make your own decision.

3. Ionizing Radiation as an Influence on the Human Body

According to the Resolution of the General Assembly of the United Nations (1979) human health is the only criterion of appropriateness and effectiveness applied to all, without exception, spheres of human activity. Furthermore, in Agenda 21 (Rio de Janeiro, 1992), which was signed by representatives of almost all countries of the world, it is stated that people have the right to their health and creative lives, in harmony with nature, to satisfy environmental and economic requirements of the current and future generations.

Natural environment, in which electromagnetic fields occupy a special position, can be considered as one of the significant factors of formation of health. The concept of “health” includes, of course, reproduction. According to the World Health Organization (1984), electromagnetic field of the civilization, in which we live, is several orders of magnitude higher in intensity than the natural one. Thus, since every cell in the whole body, itself, too, is a source of electromagnetic radiation, the present electromagnetic environment, following the nuclear accident, can be considered as an obstacle to the proper functioning of the human body and other biological systems.

According to the definition given by the UN Scientific Committee on the Effects of Atomic Radiation (UNSCEAR), the term "ionizing" refers to electromagnetic waves and particles that can ionize (that is to hit or excite) electrons in atoms and molecules of the environment, in which they are distributed (2000).

The origins of ionizing radiation are divided into electromagnetic (X-rays and gamma rays) and particle (beta particles [such as electrons and positrons], protons [hydrogen nuclei and deuterons] and nuclei of heavy hydrogen deuterium [alpha particles, heavy ions, etc.]). Particle radiation also includes neutrons,

which themselves have no charge, causing, however, indirect ionization.

The exact physical definition of dose of ionizing radiation became possible in the years 1928-1929 due to the introduction of dosimetry and the international X-ray unit (roentgen). This led to the collection of data showing that influences of different kinds of ionizing radiation in equal doses have quantitatively, or sometimes qualitatively, different effects on biological objects, due to spatial distribution of energy in the volume of an irradiated biological substance. For quantitative comparison of biological effects of different types of ionizing radiation, the concept of relative biological effectiveness (RBE) was introduced - a ratio of effectiveness of one type of radiation relative to another (compared to X-ray irradiation) to cause radiation damage of varying severity for an equal absorbed dose.

According to the recommendations of the International Commission on Radiation Protection, basic unit of dosimetry is considered to be the unit of absorbed dose (D): The energy, measured in joules, is absorbed by the mass measure in kilograms, and it has a specific name "Gray" (Gy).

There are the concepts of equivalent and effective doses. Equivalent dose is an absorbed dose averaged on a tissue or an organ and weighted by quality of exposure (type of radiation), for which a special coefficient is introduced – “radiation weighting factor” (Wr). The unit of equivalent dose is J / kg, which has a special name “Sievert” (Sv).

It is established that relation between probability of effects and equivalent dose depends on the irradiated tissue or organ. To account for this factor, the concept of tissue weighting factor (Wt) is introduced. Thus, the twice weighted absorbed dose (taking into account both the type of radiation and the nature of each organ being irradiated) is called “effective dose” (E). Effective dose is also measured in J / kg (Sv) and is the sum of the weighted equivalent doses in all tissues and organs of the body.

To measure dose of a radionuclide, the concept of activity (A) measured in Becquerel (Bq) is applied, which is the average quantity of spontaneous nuclear decay per unit of time (second).

Currently a very large number of people are in contact with ionizing radiation,

in every country, and this number can only increase in the future.

A few words about natural background radiation are in order. At the very first moment of the birth of the Earth, radioactive elements became part of it, thus natural background radiation (radiation caused by natural radionuclides and cosmic sources) has always been present on our planet. It is considered that the origin of living beings and the evolution of species, including humans, occurred in the ocean of electromagnetic waves. All living beings on Earth have constantly been under the influence of natural ionizing and non-ionizing radiation.

Levels of natural background radiation vary depending on geological structure of a site. The average global radiation exposure is 2.4 mSv per person per year. Up to ¾ of its dose is formed by radon. Indoor radon (especially on basements and the ground and first floors of buildings) accumulates due to its emission from the soil, building materials, gas combustion etc. Surface water or groundwater can also be sources of natural radiation.

Up to 15% of radiation load is formed by radioactive potassium (40K), which is a component of many vegetable and animal products. In animal products a small amount of radium (226Ra), polonium (210Po) and lead (210Pb) can also be found. Radioactivity of the human body is formed by the presence, therein, of radioactive isotopes found in the biosphere - primarily potassium, carbon and hydrogen. Outer space and the surface of the sun are also sources of ionizing radiation.

Human activities have created additional sources of ionizing radiation beyond the natural ones. Occupational load is observed in industrial processing of natural raw materials such as coal, petroleum, phosphates etc. Use of coal generates radiation load, not only at the mine, but also in the whole population. Sources of ionizing radiation are also widely used in medicine for diagnostic and therapeutic procedures.

Fallout from nuclear weapons tests and accidents at nuclear power plants also add ionizing radiation to the environment.

Systematic study of biological effects of ionizing radiation began with the discovery of X-rays. Evidences of mutagenic effects (changes in genetic

structures of living cells), under the influence of radiation, were discovered in the first third of the twentieth century. At present, it is confirmed that biomedical effects of absorbed dose depend on dosage, form of radiation, dose distribution (in time and the body) and duration of exposure.

To explain the mechanisms of observed effects, target theory was first proposed, which was based on ideas of “direct” effects of radiation. It was believed that accidental hit of quanta, of ionizing radiation, to sensitive microvolumes of cells (the "target") caused ionization, which resulted in mutation of the gene. That is, long before the discovery of the role of deoxyribonucleic acid (DNA), the theory suggested that genes were macromolecules. Later it turned out, however, that being hit by quanta does not lead to an immediate rupture of the chromosome. Primarily, local potential damages appear in the chromosome, and only a part of them, secondarily, after a certain amount of time, result in mutations or chromosomal damages.

In parallel, during the second half of the twentieth century, evidences of indirect effects of radiation were revealed. It was then demonstrated that DNA damages are caused by action of water radiolysis products, namely hydroxyl radical and hydrated electron, with which simultaneously develops a chain reaction of oxidation, of free radical type, whose products affect both chromosome and cell membranes.

Nonetheless (or, in addition) we should know that nonspecific adaptive responses develop in response to any adverse effect. The body tries to adapt to the changing conditions of existence. Therefore, according to the abovementioned, injury of the cells is the result of both the damage by ionizing radiation (or other factors) and the reduction processes developing thereunder. It is believed that, in the range of low-dose ionizing radiation, adaptive processes eliminating primary radiation damages to DNA prevail over reactions aimed at preventing reinforcement of these damages.

It should be noted that, from the point of view of evolution, due to the necessity to maintain genetic continuity throughout the succession of generations, the organism has developed a multi-component antimutagenic system, whose function is to prevent genetic damage and to recover therefrom.

Its first level belongs to the enzymatic system of cells (for example, catalase and superoxide dismutase), protecting the hereditary structures from damages caused by free radicals, arising under unfavorable effects such as irradiation.

The second level is the correction of these damages (reparation system of DNA). It is considered that about 200 types of genes are involved in the repair of DNA damages.

Then, in the end, stability of the genetic structures supports those systems, which function at the level of organism (ceruloplasmin, interferon etc.).

Thus, the system of anti-mutagenesis in the body operates fairly reliably. However, these systems cannot repair all damages. There are so-called "non-repairable" damages. Besides, the restoration of genetic structures can occur with errors.

Notwithstanding, thanks to the immune system, a large part of unrepaired cells are removed from the body.

Nonetheless, it should also be borne in mind that the capacity of antimutagen systems of the body is not designed to withstand long-term anthropogenic impacts and can be exhausted. In this case, the rate of mutagenesis can increase.

An important position in the activities of antimutagenic systems, at the level of organism, is occupied by the thyroid gland. We know that thyroid hormones are involved in providing cells and tissues of energy that are necessary for the repair of DNA and in processes of reproduction and anticarcinogenesis: these hormones affect realization of potential damage to chromosomes, caused by ionizing radiation, by reducing frequency of cells with damaged chromosomes. It is also shown that in response to external factors of low and medium intensity occurs an amplification of hormonal function of the thyroid gland (1.5-2.0 times the usual), which forms an integral part of adaptive reactions.

On the other hand, it seems fair to note that, over the past decades, evidences have accumulated that pre-exposure to ionizing radiation in low doses causes decrease in the number of genetic damage and increase in the viability of mammalian cells under repeated exposures. At the same time, adaptive response, cell proliferation and stimulation of metabolism are considered to be within the concept of nonspecific reactions that occur in response to external influences. Adaptive response of the immune system is observed in the range of 0.2-0.3 Gy

of total body irradiation and 1-2 Gy of local irradiation.

At present, it is assumed that impacts of radiation on the body should be distinguished into two types, regarding their medical effects.

First is non-stochastic (deterministic) effect, which has a threshold of dose (to this concept belong sicknesses such as radiation burns, radiation sickness and cataracts). Birth defects in children exposed in utero are also referred to this concept. In this concept, strength of the effect is in direct proportion to a received dose and its power.

The second type is stochastic (probabilistic) effect, which includes occurrence of tumors and genetic diseases. It is believed that such effect has no threshold and it can be caused by an influence factor of any low dose. In this concept, dynamics of dose is in relation with frequency of occurrence of effects (not the strength (scale) of its manifestation, as it is with the non-stochastic type).

However, taking into account the existence of basic mechanisms of each individual organism that ensure sustainability of living systems against the action of negative factors, with adaptation abilities to changing environmental conditions (function of anti-mutagenesis systems, nonspecific adaptive response etc.), it seems reasonable to consider that there is an individual threshold of manifestations of negative impact of radiation (that is, each organism has its own threshold). Its value may depend on the individual's genetic sensitivity to influences by negative factors, including ionizing radiation, functional condition of the body, at the moment of being affected by these factors (degree of coherence of enzymes repairing DNA, nonspecific protection factors, the immune system etc.) or some other elements that are unknown to us at present.

Considering the population as a whole, in a fairly large group there are always persons who have heightened sensitivity, with low resistance, to outer damages (including ionizing radiation). The origin of the sensitivity is either genetic or acquired during one's life. Therefore, at the level of population, stochastic effects can be considered non-threshold.

Under chronic low dose exposure to low power radiation, however, threshold plays a particular role. In relation to human health, doses up to 0.2 Sv used to be considered "low", supposed to cause no apparent risk to health. During the

last decade, nevertheless, the range of “low dose” has been reduced to 0.1 Sv and less. Thus, equivalent dose that causes less than 0.1 Sv / year is considered "low-power". The equivalent dose accumulated during one’s life time should not exceed 1 Sv.

It should be noted that the public may be exposed to high doses of radiation, of a significant power, mainly during a nuclear war and in early stages of major accidents at nuclear power plants or factories producing/processing nuclear materials and nuclear waste. Otherwise, the public and professionals are only exposed to radiation in low doses.

Currently, evaluation of significance of radiation effects on the human body in low doses is based on a linear no-threshold model. It takes effects of low doses into account, which are extrapolated from data obtained by radiation effects of high doses, assuming that any increase of absorbed dose increases probability of occurrence of oncologic diseases (cancer) or congenital pathologies. However, in this concept, possibilities of adaptive and compensatory processes occurring in cells, tissues, organs and, finally, at the level of organism are not taken into account. Yet, it is, indeed, the very recovery processes and the ratio of damage to reduction, which are responsible either for development of the damage or return to the normal state. However, notwithstanding its problematic aspects, the use of no-threshold model is considered “humane” as it admits the risks of long-term (remote) effects.

Research results of molecular-cellular effects of exposure to low doses suggest that chronic exposure is less damaging when recovery systems are activated. The basis of effects of ionizing radiation at low doses is a reaction initiated by free-radical processes in the membranes of cytoplasm and nucleus. However, long-term effects may eventually lead to tension and exhaustion of the nervous, endocrine, immune and hematopoietic systems. Results of studies further indicate that the body's response to a factor such as exposure to low doses is similar to changes occurring as a result of chronic stress.

Depletion of the hypothalamic-pituitary-adrenal axis can lead to diseases of adaptation, as evidenced by the significant proportion of endocrine pathologies among people affected by the accident at the Chernobyl nuclear power plant.

The nonspecific nature of radiobiological effects and the wide range of living objects in which the effects are observed, indicate their common biological characteristic. Their occurrences show fundamental mechanisms of ensuring stability of living systems and possibilities of living beings' adaptation to changing conditions of existence. The answers of the organism are within the law of Arndt-Schulz: weak stimuli stimulate the body's reserves and increase the level of non-specific positive response to the influencing impact; medium-strength stimuli do not cause reactions, but put pressure on the body; strong stimuli destroy the organism.

What are the main worries for people who have been exposed to chronic irradiation in low doses? Fear of tumors, birth defects, infertility…
At present, a series of reports of UNSCEAR summarizes results of correctly implemented epidemiological studies on incidence of malignant tumors of groups who have fallen, for one reason or another, under irradiation. However, the basis of almost all cancer risk assessments, used for establishing criteria for hygienic regulation, are epidemiological data obtained from studies of morbidity and mortality among the exposed population of Hiroshima and Nagasaki, where doses were of very high strength (risks per dose unit were evaluated in terms of linear no-threshold dependence).

As a result, statistically significant increase was found in the occurrence of tumors (in general and in several varieties thereof). The link between leukemia and radiation exposure was also demonstrated. At the same time, at least a threefold decrease is witnessed in carcinogenic risks resulting from exposure, in comparison with the dose strength of the irradiated populations of Hiroshima and Nagasaki (although in subsequent risk assessments, coefficient equal to 2 was adopted).

UNSCEAR, according to its own analysis, suggests to accept that for the conditional population of men and women of different ages, who have been affected by acute exposure of 1 Sv (under low RBE such as X-ray and gamma-irradiation), magnitude of risk of death from cancer in their lifetime can be 9 % for men and 13% for women. Uncertainty of such data may be within the range of up to two times in directions of both increase and decrease of the risk. Hence, under chronic exposure, risks could also be reduced by 50% according

to the same dimensions of uncertainty: That is, under chronic exposure, within the intervals of dose and dose strength inducing effects of low doses, risk of oncogenic transformation may even decrease.

They also admit that risk of getting cancer is twice as high as that of dying from it. However, if one is irradiated in childhood, risks can be twice as high as for the mixed-age population.

UNSCEAR accepts the risk of leukemia, for life time, after acute exposure at a dose of 1 Sv per 1% for both sexes, with the same uncertainty of up to two times (increase or decrease).

When considering stochastic effects of radiation, in relation to reproductive health, it may be noted that most embryos with complex genetic disorders, as a result of both external and internal reasons, are eliminated by natural selection in the early stages of development, by increased frequency of spontaneous abortion and infertility. However, violations passing through the filters of natural selection may result in some congenital malformations and micro-anomalies.

People who took part in the liquidation of the Chernobyl accident have an increased risk of cancer, whose magnitude depends on the absorbed dose. Likewise, the connection between irradiation and thyroid cancer of children exposed to radioactive iodine is undeniable.

At the same time, epidemiological studies of populations living in areas contaminated with radionuclides have not given indisputable evidence of increased reproductive failures arising as a result of exposure. These studies have some shortcomings and, for some features, do not conform to the rules of evidence based medicine. Moreover, as mentioned above, it is nearly impossible to separate the effect of chronic stress from that of chronic exposure to radiation in the range of low doses.

At present, the international community recognizes that the assessment of radiation risks contains significant uncertainties associated with population differences. Thus, it is likely that different population groups have different degrees of expression of adverse effects of exposure. It seems that under an exposure of equal dose and strength, in the range of low doses, the population of Japan should experience less adverse health effects than the irradiated population

of the Polessye region in Ukraine, at least thanks to some aspects of lifestyle and diet.

Analyses of studies aimed at identifying the relation between radiation and adverse pregnancy outcomes among residents of the territories contaminated as a result of the Chernobyl accident are inconclusive. These analyses were made by experts from UNSCEAR, but do not prove the link of increased level of stillbirth, premature birth and birth defects (which were detected in other studies) with radiation influence. However, taking into account the magnitude of doses accumulated in the population, as a result of the accident, such conclusion may seem logical.

The dynamics of radiation doses received by the residents of Ukraine due to the accident (even assuming that the official sources diminish the dose, that is, the actual doses were higher than the officially reported ones) suggest that the contribution of radiation factors to the deterioration of health in the population living in contaminated areas should not be so great and certainly not fatal. On the other hand, public perception of the threat of radiation effects on their health, especially on reproductivity, is clearly inadequate. Even in some medical circles, ideas of extreme danger of exposure to low doses, unsupported by scientific evidences, are current. Such opinion is convenient for the authorities, the public, in some ways, and, perhaps, some medical personnel: it relieves their responsibility for the poor state of public health and for other harmful factors distributed in the environment, which may affect the organism. It is much easier to consider that almost all diseases are results of radiation: It means that there is no need to improve and change your lifestyle nor to give up bad habits etc. - whatever you did, you would, anyway, become sick as a result of elevated levels of radiation!

Conclusions.

1.Ionizing radiation is one of the environmental factors, which may considerably affect one's health condition. In all countries, having a technological civilization of a certain high level, populations are exposed to higher levels of ionizing radiation compared to that of the natural environment. Irradiation in the range of low doses, under low power, arouses adaptive responses in the organism. The

nonspecific nature of the radio-biological effects and the wide range of living objects, on which the effects are observed, indicate their common biological nature. Their occurrence is the evidence of fundamental mechanisms for ensuring the stability of living systems and the possibility of adaptation, of living beings, to the conditions of existence.

2. Authors of works, bearing witness to one or another negative effect on health (this applies to our own studies), resulting from residing in territories contaminated by the accident at the Chernobyl nuclear power plant, fix the effects of living in these territories as chronic influences by radiation, chronic stress, poor nutrition and, finally, poverty. Indeed, much, if not most, of the population of the area has been living in poverty. However, to an ordinary person, after all, the reason of the cause of an illness, on its own, is of little importance. He or she wants to be healthy, and for this, one needs to know how he or she should and could act and behave.

4. Strategies for Preventing Negative Health Effects

Taking into consideration the statements above, there are several ways to prevent the effects of chronic exposure to low-dose radiation.

A.

Since such exposure leads to arousal of nonspecific adaptive response in the organism, one should enhance one's own endogenous background of radiation stability, applying rational diet and adaptogens of preferably natural origin. According to the existing views of today, “rational” nutrition is considered to be as such, which possesses a physiologically wholesome nutrition for a potentially healthy individual, providing the body with necessary amounts of nutrients and energy in response to the norm of physiological needs. Healthy diet is a part of a healthy lifestyle, which presents an optimal ratio of consumed products to regular physical activities.

The diet should consist of 45-65% of carbohydrates (vegetables, fruits, whole grains such as brown rice, whole wheat bread etc.), 10-35% of protein (fish, lean meat such as poultry, egg, bean products, nuts etc.), 20-35% of fat: basically it

should be unsaturated fat found in fish, olive oil, nuts etc. At the same time, we should know that some people do not accept cereal protein gluten. With such individuals, consumption of cereal protein gluten results in development of celiac disease.

Instead of whole milk one should consume more low-fat fermented milk products. Dairy products are considered to be one of the best sources of protein, calcium, vitamin D and potassium. Avoid products that contain artificially processed red meat and hydrogenated vegetable oils, such as confectionery products, margarines, spreads, semi-finished products etc. Do not abuse sweet carbonated beverages.

The simplest way to assess one's nutritional status is the assessment of body mass index (BMI), which is determined by dividing the body weight (in kilograms) by the square of height (in meters). The following is considered according to BMI:

underweight: less than 18.5 kg/m2;
normal: 18.5-24.9 kg/ m2;
increased (overweight): 25.0-29.9 kg/ m2;
obese class Ⅰ: 30,0-34,9 kg/ m2;
obese class Ⅱ; 35,0-39,9 kg/ m2;
morbid obesity: more than 40.0 kg/ m2
(scale may vary from time to time and country to country).

According to existing ideas, diet of the population in areas contaminated with radionuclides should include:

-reduction of daily intake of radionuclides through food;
-inhibition of absorption of these substances by the gastrointestinal tract and acceleration of their excretion;
-well-balanced diet in terms of energy and vital substances.

To reduce intake of radionuclides through food, one should:

-thoroughly wash fruits and vegetables;
-clean vegetables and fruits as up to 40% of radionuclides may concentrate on surface layers.
-follow some rules of cooking: in conditions of radioactive contamination, “boiling” should be preferred among other cooking methods; since a large part of radionuclides flows into broth, it is advisable to boil a product in water for 10 minutes, pour out broth, and then cook the product in a new portion of water; mushrooms are to be boiled twice for 10 minutes, pouring out the broth after each boiling, before final cooking; in case of suspected contamination of meat or fish, they are recommended to be soaked in water for 1.5-2.0 hours before boiling.

Reduction of absorption in the gastrointestinal tract and acceleration of excretion, of radionuclides, can be done by applying special diet or artificial enterosorbents. It is known that lack of protein in diet contributes to accumulation of radioactive cesium, whereas, increase of its content, on the contrary, accelerates elimination of the radionuclide.

Increased intake of potassium (not less than 5 g per day), found in grain products, potatoes, apricots etc., can reduce intestinal absorption of radioactive cesium.

A sufficient supply of calcium (up to 800 mg/day) reduces absorption of radioactive strontium. For women entering the age of menopause, intake of 1,200 mg of calcium/day is recommended to prevent osteoporosis.

Use of dietary fiber, pectin, from fruit and vegetables, and salt of alginic acid, from seaweeds, not only enhances peristalsis of the intestines, but also promotes binding of radionuclide and metal ions for formation of complexes that are not absorbed by but excreted from the organism.

Daily requirement of dietary fiber is 20-25 g for women and 40 g for men – it is believed that intake of dietary fiber should be up to 14 g for every 1000 calories. Diet should contain pectin of 2-4 g/day.

Synthetic enterosorbents can be taken only for a short time.

Under conditions of radiation exposure it is appropriate:

-to saturate diet with protein products (especially those containing amino acids, such as cysteine and methionine that contain sulphydryl groups, which react to active radicals formed during irradiation. These products are, primarily, dairy products.)
-to increase intake of unsaturated vegetable fats of antisclerotic effects (which reduces hardening of tissue) to withstand effects of ionizing radiation; animal fat should not exceed 10% of the total fat in the diet;
-to provide non-starch polysaccharides (pectin and dietary fiber), according to the above-mentioned daily requirements;
-to increase intake of vitamins of groups A, B, C, E and P by 30-40%, compared to the usual daily dose;
-to saturate the body with a sufficient amount of iodine (150-200 μg/day). Lack of iodine leads to violations of the thyroid gland. Note that the requirement of iodine for pregnant women is higher;
-to control daily intake of copper (2-3 mg), zinc (up to 15 mg), manganese (5 mg), cobalt (up to 100 mg) and selenium (up to 100 mg).

B.

The public's inadequate perception of health risks of chronic exposure to low doses should be taken into account, which can be explained by:

-unsatisfactory health education,
-fear for future radiation accidents, based on those already experienced,
-exaggerated information from the media or other sources. Studies conducted by our institute have shown that women living in the contaminated territories, having given birth to children with birth defects, consider that the most significant factor of formation of the children’s pathology (among 16 different factors) is radioactive exposure. However, women who live in the same area, having given birth to healthy babies, consider radiation as only the third most significant among the factors. Nonetheless, among factors that threaten their own lives all women consider radiation exposure as the most significant.

The apparent hopelessness of a situation (impossibility to completely decontaminate the area to the last bit of radionuclide, actual high level of threat etc.) generates chronic stress in the population fallen under irradiation. Such stress can exacerbate existing pathologies or cause new ones.

Results of currently available studies give reason to believe that chronic stress is an important source of induced mutagenesis, carcinogenesis and teratogenesis that can lead to malignant diseases and birth of children with congenital malformation.

Prevalence of chronic stress among the affected population requires prevention of its adverse effects. Such prevention can be implemented in several directions. The first direction is correction of diet. It is acknowledged that development of stress (as much as chronic exposure) is accompanied by increased intensity of free radical oxidation, whose negative impact can be neutralized by applying antioxidants of natural origin, which are found in food and natural supplements. Such diet is, at the same time, useful against chronic irradiation.

Attention should also be paid to the fact that, with the increasing globalization of the surrounding world and strengthening of the flow of information, a problem of inadequate formation of mental health has been increasing. Therefore, society must address this problem and look for ways to resolve it.

Thus, the second direction of preventing the negative effects of stress is the strengthening of mental health, which is possible only through interdisciplinary actions, covering activities that are aimed at creating living conditions and environment, which would allow one to live a healthy lifestyle and maintain one's mental health.

On the other hand, a quite important direction (as the third direction) of prevention of chronic stress is reinforcement of acts aimed at developing adequate psychological reactions against stress-causing factors. Such mental reinforcement can be done through development of psychotherapy possessing meditation techniques: there are specific ways to conquer (manage) one's personal individuality and social variables, the use of which allows one to avoid health disorders. Human capabilities to restructure psychological system of personal perception of oneself and the environment, in a way as to include

measures and adaptation to illnesses, are also closely related to courses of already existing diseases. In this process, the role of psychologists, including clinical psychologists, is undeniable.

C.

Radiation protection of the population living in contaminated areas should seek reduction of radiation dose. However, it can be noted that for the population, especially for women contemplating pregnancy, measures to reduce the level of radionuclides in the body (direct countermeasures) are insufficient. To reduce the risk, particular attention should be paid to indirect actions. Our own studies have shown that residence in the contaminated areas does increase a woman's chance of spontaneous abortion (1.2-1.4 times). However, if a woman smokes, the probability of spontaneous abortion increases up to 3.8 times, and if she has chronic infections - up to 4.6 times. Hence, it is important for expectant parents to stop bad habits such as smoking, excessive consumption of strong alcoholic beverages etc.

The whole family should be sanitized in terms of chronic infections (especially sexually transmitted diseases) and noninfectious diseases. In this, especially during pregnancy, medication should be taken only with the prescription of a doctor.

Avoid stressful situations and physical exhaustion.

Particular attention should be paid to radioprotective diet (2-3 months before and during pregnancy).

As noted above, the role of thyroid hormones is determinant in the realization of radiation effects. Phenomenon of tissue insufficiency in triiodothyronine (one of the thyroid hormones) is observed in cancer patients. Malignant tumors, of different localization, are encountered 14 times more often in patients with thyroid disease. Thyroid disease in pregnant women is considered as one of the significant factors influencing the occurrence of birth defects in their children. It should be noted that thyroid disease in modern society is widespread.

Considering the cytogenetic meaning (significance) of the imbalance of thyroid hormones, normalization of activities of the thyroid gland, when living in contaminated areas, turns out to also be a way to prevent adverse effects of ionizing radiation.

Medical assistance to the people affected should include monitoring of their endocrine systems, particularly of the thyroid gland.

5 .Conclusion.

1. Among preventive activities, special attention should be paid to enhancement of endogenous background of radiation-resistance, applying a balanced diet rich in natural antioxidants.

2. We should address prevention of stress, which occurs not only due to a nuclear disaster. This can be done by the same correction of diet, creation of living and environmental conditions, which would allow one to live a healthy lifestyle and maintain mental health, and formation of adequate psychological reaction, of the individual, to the stress-causing factors.

3. Considering the important role of the thyroid gland in reproductive processes, carcinogenesis and preservation of integrity of chromosomes, as well as the fact that residents of the contaminated areas have been exposed to radioactive iodine during the accident, normalization of the thyroid gland should be given the highest priority. It seems appropriate to recommend a mandatory endocrinology test, at least once every two years for healthy individuals, and once a year for those having previous illnesses.

4. Preservation of health of the population depends on the position of each injured individual and the role of the government in social and medical rehabilitation and adaptation. Under current circumstances, regular education and public enlightenment, in terms of evaluation of influences of radiation effects and possible measures to prevent negative medical consequences, are an important and presumably feasible task for the whole society.