ABC

of

RADIATION PROTECTION
This brochure addresses radiation effects as well as outlines the simplest ways in which humans can protect themselves from radiation. It can be used as a manual for the public to be taught the fundamentals of radiation protection and to be trained in the appropriate actions in the case of on-site radioactive contamination. Apart from it, this brochure is intended for anyone who is interested in the issues of radiation protection.

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Where can one obtain essential information on nuclear facilities and the issues of radiation safety?

Internet site of the Russian Federation’s Federal Agency for Atomic Energy:
www.minatom.ru

Internet site of the Rosenergoatom Concern:
www.rosatom.ru

Internet site of the Ministry of the Russian Federation for Civil Defense, Emergencies and Elimination of the Consequences of Natural Disasters (EMERCOM):
www.mchs.gov.ru

Internet site of the Federal Service for Hydrometeorology and Environmental Monitoring (Roshydromet):
www.meteorf.ru

Internet site of the Nuclear Safety Institute of the Russian Academy of Sciences (IBRAE):
www.ibrae.ac.ru
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Both scientific and technological progress has created an environment in which both natural and manmade emergencies may occur. Since it is impossible to exclude the potential for radiation accidents completely, awareness of emergency procedures, realistic prediction of probable consequences, and adequate protective measures are critical to preventing or at least mitigating possible damage.

In 1995, the Russian Federation Government approved a special decree that created a unified system for public education and training in the case of a natural or technological emergency. The legislation stipulated that citizens be trained in emergency procedures and that they learn basic protective methods for use in emergencies. Arrangements for such training [for which the Ministry of the Russian Federation for Civil Defense, Emergencies and Elimination of the Consequences of Natural Disasters (EMERCOM) is responsible] require the development of appropriate teaching materials.

The present brochure can be used as a manual that provides the public the fundamentals of radiation protection and appropriate actions in the case of radioactive contamination. Additionally, this brochure can be utilized by all persons interested in issues pertaining to radiation protection.

The first chapter highlights basic facts and data pertaining to radiation as well as reviews the history of the nuclear era. Since a «dose» is the main radiation characteristic, this brochure will also describe the basic
idea in this area, as well as «dosimeter» units. This chapter also considers radiation effects which vary with a nature of exposure – acute or prolonged, total-body or partial, internal or external and discusses issues of low dose radiation effects. Items of regulation and radiation risk will be introduced.

The second chapter examines radiation accidents and outlines their classification. If the potential for reactor accidents is negligible nowadays due to strict safety measures, radiation sources utilized in industry and medicine may represent a certain risk when management procedures are not observed properly. This chapter also covers the issue of radiological terrorism known as a «dirty bomb». Safety provisions in the case of a «dirty bomb» are based on the same principles followed in the case of a radiation accident.

The third chapter describes the Automated Radiation Monitoring System (ARMS) which covers all Nuclear Power Plants (NPPs) and other nuclear facilities, and describes proper use of dosimeter equipment in obtaining accurate readings to determine appropriate radiation protection measures.

What should individuals do in a radiation accident? How can one find information about such an accident? What protective measures will be taken? The fourth chapter offers answers to these questions and examines public notification as an integral part of emergency plans. This chapter notes the critical importance of remaining calm, listening closely to emergency announcements, and adhering to all instructions. Protective measures are selected depending on the nature of an accident and serve to prevent excess public exposure.

Finally, the brochure offers a list of useful references concerning nuclear power and radiation environment safety.

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I. Basic Information and Facts

Having a basic understanding of radiation and radiation effects on the human body is critical to understanding the important fundamentals of radiation protection.

The Nuclear Era — A Brief Historic Outline

In 1895, Wilhelm Conrad Roentgen, the first Nobel Prize winner in physics, observed and recorded rays that had been previously unknown to science. Naming his discovery «roentgen rays» or «X-rays», Roentgen noted that these unknown waves demonstrated an impressive ability to penetrate paper, cardboard and wood. The discovery of uranium radioactivity and, subsequently, that of polonium and radium soon followed. This sequence of discoveries gave birth to the usage of ionizing radiation and, afterwards, the nucleus energy.

Following the discovery of X-rays, Roentgen radiation properties became important tools used widely in the field of medicine. Since humans did not see nor feel the immediate effects of radiation, the safe application of X-ray apparatuses and radioactive material was simply disregarded. However, it soon was discovered that long-term and intensive irradiation had negative effects on the human body. For example, researchers observed skin changes (reddening and even ulcers) following contact with radioactive sources. As research progressed, they also discovered that diseases could develop in other tissues and organs.
Ultimately, the pioneers of radiation research suffered considerable losses in terms of health and at times, life. Their efforts prompted the development of a system designed to protect humans from the negative effects of radiation. In the late 1920’s, specialists created an international working group to systemize data on radiation effects and to elaborate measures for radiation protection. This working group, the International Commission on Radiological Protection (ICRP), establishes both recommendations on radiation source management procedures and protective actions. Specialists from different countries formalize their national standards based on the Commission’s recommendations.

In 1945, the United States dropped nuclear bombs on Hiroshima and Nagasaki. This was the first and only case in which a nuclear weapon was utilized. Nevertheless, the events sparked a long, worldwide nuclear confrontation. In 1949, the Soviet Union conducted its first nuclear tests in the Semipalatinsk test area of Kazakhstan.

During the post-war period, a peaceful atom was also in development. On June, 27, 1954, a steam born in the «uranium boiler» turned the turbines of the world’s first nuclear power plant (NPP) in Obninsk, 100 km away from Moscow. The parting words of all scientists, engineers and workers who were present at this time, were unanimous, «Light Steam!» This event confirmed academician I. V. Kurchatov’s belief that nuclear power could be transformed into «a powerful energy source that gives welfare and joy to all people on the Earth».

In light of developments in nuclear power usage, the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) was created in 1955 with the objective of systematizing and generalizing data concerning the impact of radiation on the human body as well as evaluating and outlining radiation effects.

By the early 1980’s, NPPs had become an integral part of the nuclear power industry in developed countries. Currently, 423 NPP units operate worldwide. These units produce up to 18% of generated electric power, reaching 80% in some countries like Belgium and France. In Russia, for example, approximately 17% of the total electric power generated in the country is produced by its 10 operating NPPs.

It is important to note that nuclear power usage is not confined simply to nuclear power plants. Radioactive sources are widely used in many areas
of human activity, such as medicine, science, agriculture and industry. In utilizing these sources, it has become possible to: detect and successfully treat a lot of diseases early on, acquire new knowledge of substance structure, increase productivity of crops, test metal ware durability and perform many other functions. More than 15,000 Russian organizations (two thirds of which are medical ones) use radioactive sources and installations.

Approximately 20 nuclear fuel cycle facilities in Russia produce fuel for NPPs, mine ore and store waste and spent fuel. Facilities of the nuclear weapons complex are also important «nuclear» enterprises.

In examining new technological developments, the nuclear power industry has attracted the most acute and critical public attention. In light of the potential catastrophic consequences of a nuclear incident, the notion of nuclear power keeps the public on alert. The accident at Chernobyl in April 1986 has increased these concerns considerably.

Accidents at nuclear industry facilities that emit radionuclides are very rare. Following the onset of nuclear power utilization, a reliable and effective nuclear and radiation safety system was created. However, the Chernobyl accident illustrated that erroneous actions on part of personnel could still severely threaten system safety. After Chernobyl, the requirements for safe operation of NPPs and the nuclear industry’s facilities became more stringent. Since 1986, Russia has only witnessed one accident with a radioactive release. This accident occurred at the Siberian Chemical Complex (SCC) and it did not have a radiological impact on the public or on personnel.

As for the safety of sources, matters stand quite differently in other non-nuclear industries. Incidents resulting in the excess of permissible exposure take place almost annually. As a rule, such an incident occurs when an ionizing radiation source goes beyond control. For example, a fault detector may become unsealed. To prevent excess exposure, it is essential that personnel use proper actions when managing a source. There can be no guarantees that all areas of human activity will be safe. Therefore, regardless of measures taken, the potential for radiation accidents cannot be completely ruled out. But, radiation protection is not only comprised of special technical systems, protectors and emergency-rescue teams. It includes safety rules for workers and the
public, i.e. those principles and protective measures to be followed in an extraordinary situation and in an emergency. Such measures provide a system to prevent, minimize and mitigate possible damage. For instance, the first and the most fundamental safety rule asserts that a person must refrain from touching foreign objects. Ultimately, this object could be a toxic agent container, an explosive or an ionizing radiation source.

Terrorism has become an attribute of everyday life for all countries. Today, transportation systems, trading centers, and other busy venues remain vulnerable to terrorist activities. The September 11, 2001 events have served as the impetus behind a growing anxiety concerning the possible malicious application of radioactive material for terrorist purposes. Recently, important measures have been taken to reinforce control over radioactive sources. Having been in operation for numerous years under the IAEA’s supervision, a special program for strict control over nuclear material has taken the forefront in implementing these measures.

**Units of a Dosimeter**

The word «radiation» (translated from Latin as «radiance») is used to signify an energy, which radiates and spreads as waves and particles. While there are numerous types of radiation (visible light, ultraviolet radiation, heat (infra-red) rays and radio-waves), the word «radiation» is most often used to signify «ionizing» radiation.

Radiation is defined as «ionizing» due to its capability to cause atom/molecule ionization (their splitting into negatively and positively charged particles) in a substance.

Electromagnetic ionizing radiation comprises roentgen rays as well as gamma rays emitted by radioactive elements. By nature, radio-waves, visible light and ultraviolet rays are also electromagnetic radiation, though their energy is insufficient for ionization. The rest of ionizing radiation is represented by particles. For instance, beta particles are electrons, alpha particles are helium nucleuses and neutrons are uncharged particles.

Penetrability is one of the most important characteristics of various kinds
of radiation. The higher the density of the particles’ energy transfer, the quicker the particles lose energy and cease to move. Such particles, for example, alpha rays, cannot penetrate deep into the material. Therefore, a sheet of paper is enough to protect oneself from them. Gamma and roentgen rays are the most penetrative, thus explaining the large number of protective shielding in an X-ray room.

The term «dose» is used to quantify a radiation impact. In assessing the health effects of radiation, a radiation dose is the most important characteristic.

The term «exposure dose» is used for radiation characteristics. Ionizing radiation causes an ionization effect in the air. The exposure dose shows how many ions occur in a certain airborne volume. For many years, a miscellaneous unit, roentgen (R), indicating a number of ions formed in 1 sm$^3$ of the air, has been used for these purposes. Though the unit is presently outside the list of dosimeter indices, in practice it is still widely used.

All types of radiation impact living organisms by transferring their energy to them. The absorbed dose is an ionizing radiation energy transferred to a substance (for instance, the human body). While the absorbed dose is measured in Grays (Gy), a miscellaneous unit rad (1 Gy = 100 rad) is sometimes used. These units show an amount of energy absorbed in a unit of the substance mass.

Various kinds of radiation affect living organisms differently. At one and the same absorbed doses, neutron radiation would have effects 10 times and alpha radiation — 20 times more severe than roentgen radiation. The term «equivalent dose» takes into account the factor. The equivalent dose unit is Sievert (Sv), the former unit being Rem (1 Sv = 100 Rem).

<table>
<thead>
<tr>
<th>Absorbed Dose (Units: Gy, rad)</th>
<th>Shows an amount of energy absorbed by the body.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Equivalent Dose (Units: Sv, Rem)</td>
<td>Takes into account different impacts of various kinds of radiation.</td>
</tr>
<tr>
<td>Effective Dose (Units: Sv, Rem)</td>
<td>Considers distinctions in radiation sensitivity of organs/tissues.</td>
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</table>
Even at an equally absorbed dose, the impact of irradiation on different organs and tissues can vary. Variance in potential impacts occurs in light of the fact that organs differ in their radio-sensitivity. For example, bone marrow is 10 times more radiosensitive than human skin. To assess possible bodily effects from non-uniform exposure, the term «effective dose» is used. The effective dose is also measured in Sieverts.

How do various dose units correlate with each other? Roughly speaking, it is possible to say that

$$1\text{ Sv} = 100\text{ Rem} = 1\text{ Gy} = 100\text{ rad} = 100\text{ R}$$

In other words, 100 Roentgen of the exposure dose approximately correspond to 1 Gy of the absorbed dose and to 1 Sievert of the equivalent dose.

In practice, such values as millisievert (1 mSv = 0.001 Sv) and centigray (1 cGy = 0.01 Gy) are used more frequently. It is more convenient to measure small doses (the most typical of an ordinary life) in millisieverts, the same as it is more suitable to measure small objects in centimeters and millimeters rather than in meters.

As was mentioned above, all kinds of radiation are characterized by energy transfer. However, in contrast to heat energy, radiation also has another mechanism to affect living organisms. Comparing their effects, it is possible to point out a surprising fact — the energy absorbed by the human body at a lethal dose of 10 Gy is equal to the heat energy contained in a glass of hot tea. If a human absorbs this energy as hot tea, it will entail a rise in body temperature to no more than one-hundredth of a degree.

Apart from the total dose value, the exposure intensity characterized by a dose rate is also of importance. The dose rate is a dose obtained within the time unit. It is measured, for instance, in millisieverts per hour or in millisieverts per year, depending on its value (the same as a velocity is measured in km/h, or m/s, or km/s, depending on how rapidly an object moves).

As a rule, dosimeters indicate not an accumulated dose but the dose rate. To get a value of the dose absorbed within a certain time period,
the mean dose rate for that period should be multiplied by the exposure duration. For example, if a dosimeter indicates the 0.1 microsievert per hour value, the dose obtained for 10 days will make up

\[ 0.1 \, \mu Sv/h \times 240 \, h = 24 \, \text{microsieverts or} \, 0.024 \, \text{millisieverts} \]

One should confirm that time was measured in the same units, namely in minutes, hours, years, etc. The calculation is true for the time periods, which are considerably less than the half-life of a radioisotope or mixed radioisotopes. Another parallel is the dose rate value-base calculated similarly to distance, namely by multiplying the average speed by the time of transit.

To measure a level of radionuclide contamination at various sites, a measure of radioactivity equal to the number of radioactive atom decays per the time unit is used. The value equal to the number of decays per second is called becquerel (Bq). Site contamination is measured as Bq/m²; that of foodstuffs – as Bq/kg or Bq/l; and air pollution – as Bq/m³. The former unit was called curie (Ci). 1 curie is equal to 37 billions of becquerels (1 Ci = 37\times10^9 \, \text{Bq}).

**Nature of Exposure**

By its nature, exposure can be external or internal, total-body or partial, uniform or non-uniform, acute or chronic.

**External exposure** is human exposure from a source situated outside of the human body; and **internal exposure** is that from radioactive isotopes (radionuclides) that have entered the human body.

In case of a radiation accident, a source of hazard can be external exposure from a radioactive cloud or on-site radioactive emissions. In addition, radioactive isotopes can also enter the human body through inhaled air, water and foodstuffs, thus forming internal exposure. Reduction of external and internal exposure levels will decline as radionuclides decay and are excreted from the human body.
Either the entire human body (total-body exposure) or its separate parts (partial exposure) can be subject to irradiation. Depending on the extent of body exposure, exposure effects will vary. For instance, the 10 Gy dose is lethal, in the case of total-body exposure. At the same time, the total exposure dose for a tumor treatment within a long period can be 5–7 times higher during the cancer radiotherapy treatment. These procedures, though highly focused, can damage nearby healthy tissue, though recovery occurs with time.

Radionuclides may spread uniformly inside the body (as, for example, radioactive natrium) or may accumulate selectively in its separate organs and tissues, namely: radioactive iodine in the thyroid, strontium in the bones and cesium in soft tissues. External exposure may also be uniform or may affect separate organs and tissues preferentially. Therefore, uniform or non-uniform exposure may occur.

Radioactive emissions may remain on-site for a long period of time. As a result, a human may be exposed to external radiation from on-site radioactive emanation and to internal radiation from radionuclides that have entered the human body for an extended amount of time. Such long-term low dose exposure is called chronic exposure. When it is a question of any exposure extended in time (by low or high doses), a more general term, «prolonged exposure», should be used.

It is known that if a person spends several hours under the burning sun, he or she may get painful sunburn. Similarly, if an individual spends only a few minutes a day under the sun, he or she will have a nice smooth suntan. The same is true for radiation effects. In a majority of cases, chronic exposure causes less damage than an acute exposure of the same dose. To a greater extent, it is explained by the impact of repair systems — recovery from the injuries suffered. Moreover, low dose chronic exposure may even stimulate repair systems activities, thus having a favorable impact on the organism.

But, when dealing with high doses, there is an exception to the rule. A fetus’s prolonged exposure to radiation will harm the future child more than a single exposure. Ultimately, prolonged exposure may occur during more than one of the «critical» periods of the fetus’s development, resulting in system and organ deformity.
Radiation has both deterministic and stochastic effects. Deterministic effects, i.e. certain ones, are 100% probable, if there is an excess in a certain dose limit. The extent of their severity depends on the exposure dose value. In particular, radiation sickness relates to deterministic effects.

Radiation sickness is either acute or chronic. Acute radiation sickness develops after a person has obtained a radiation dose above 1 Sv. The disease can have three degrees of heaviness: a light degree (1–2 Sv) at which all patients recover; a medium degree (2–4 Sv) at which a clinical outcome is quite favorable but requires special treatment; and a heavy degree (4–6 Sv) at which an unfavorable outcome may be. At doses exceeding 6 Sv, an extremely heavy kind of acute radiation sickness develops, the mortality being nearly 100%. At doses less than 1 Sv, clinical effects of the radiation impact are either lacking or are not evident and thus, do not require special treatment. Chronic radiation sickness is not a remote effect of acute radiation sickness. This disease develops as a result of long-term exposure in which doses reach 1–3 Sv in total. Developing from general or preferential exposure of separate organs, chronic radiation sickness has three degrees: light, medium and heavy. Upon termination of exposure, the recovery period begins.

Individuals, who receive radiation doses that are within hundreds of millisieverts, cannot develop radiation sickness. Even under radiation accident conditions, development of this disease among the population is practically impossible, as it is unrealistic to obtain the 1 Sv doses. According to established criteria, the probability that the public would be irradiated by doses of 1 to 5 mSv, requires strict radiation monitoring as well as relocation when exceeding the annual limit of 20 mSv.

The public often associates the dreadful disease of cancer with radiation. In fact, neoplasms may be directly linked to radiation. But, while radiation sickness is an unavoidable consequence of exposure to high radiation doses, cancer may or may not develop from such exposure. Such «probabilistic» effects are called stochastic effects. Furthermore, since neoplasms may take a number of years to develop, they are considered remote effects of radiation.
The **radiation risk** of cancer development is much less than the risk posed by chemicals or bad habits. The risk of developing cancer from toxic chemical agents at their concentrations of sanitary standard levels is more than a hundred times higher than a theoretically estimated risk from long-term extra exposure of the 1mSv/year level. When comparing the risk of smoking 20 cigarettes a day, this risk will be the same as the 1 Sv exposure dose. In everyday life, it is impossible to obtain such high doses. It is only during certain circumstances, such as the atomic bombings in Japan, in which individuals can obtain an extremely high dose.

In addition to the approximate 210,000 lives lost from all A-bomb damaging factors, roughly 86,000 survivors suffered consequences from radiation in the years following the 1945 bombings of Hiroshima and Nagasaki. Among the survivors, 82 «extra» fatalities from leukemia, which is blood cancer (1 case per 1,000 sufferers), were recorded as compared to the 162 atalities that would occur among those people without radiation (2 cases per 1,000 people). 420 people died from various forms of radiation cancer, their exposure doses being no less than 500 mSv. In comparison, there were 7400 cancer fatalities among the same population due to other non-radiation causes of cancer.

Risks of radiation cancer occurrence in everyday life are low. Nevertheless, when questions concerning the risk of extra exposure persist, adherence to essential safety measures is required. Both individuals living in contaminated areas and those who are in contact with radiation sources by profession should occasionally undergo a thorough medical examination. Even though the risk of radiation cancer is low, cancer can develop by other means. An early diagnosis could increase the probability that treatment will be successful.

The risk that radiation will have an **effect on genetics** is approximately 10 times less than the risk of developing cancer.

Among the offspring of individuals who received rather high doses of radiation from the Japan bombings, as a result of handling radiation sources, or from being exposed to radiation following an accident, genetic abnormalities have not been detected.

Unlike genetic effects, a certain risk may be associated with the so called **teratogenic** effects, such as prenatal exposure of the child, i.e. when the fetus itself is irradiated as opposed
to parents’ reproductive cells. When exposure doses for the fetus exceed 300 mSv, congenital malformations may develop. The fetus’s sensitivity to such radiation doses is extremely high. Moreover, age and sensitivity are directly correlated – the younger the fetus, the higher the sensitivity. However, one should remember that in examining the potential for teratogenic effects, it is important to note that radiation doses must exceed the exposure level both under ordinary conditions and in case of radiation accident more than a hundred times in order to cause such effects! Therefore, the probability that the future child will be irradiated by doses that can threaten the health of the fetus is practically zero. Stress experienced by the future mother may in fact become a greater danger to the child’s health.

It should be mentioned that as compared to radiation, many chemical agents, drugs and infectious diseases, like German measles, pose a higher risk to a child’s health in that they substantially increase the probability that a child will be born with heavy pathologies. In the 1960s, pregnant women living mainly in Europe were prescribed with a seemingly harmless sedative known as thalidomide. The consequences were monstrous – the entire generation of children had congenital defects of extremities. Moreover, it is known as well that children’s hereditary diseases are dependent upon the parents’ age, especially the mother’s. It has also been proven that children born to mothers who abused alcohol during their pregnancies were plagued with facial abnormalities, mental deficiencies and stunted physical development. Ultimately, among all the factors that may potentially impact a child’s health, it is impossible to ascertain which may be the exact cause of birth defects in newborns. However, advanced methods make it possible to diagnose many malformations long before the child’s birth.

Unfortunately, healthy parents living under ideal conditions may give birth to children with hereditary diseases. For example, every 700th new-born is diagnosed with Down syndrome, one of the most disseminated diseases. This rate is even higher among children born to elderly women.

**Characteristics of Low Dose Effects. Natural Background**

Different approaches to the «low dose» definition exist. In the human radiation biology, the 100–200 mSv doses are considered low. Since such
doses are difficult to meet both in everyday life and in the case of a radiation accident, the doses similar to the natural background level are often called «low». These low doses are a level of several millisieverts. Therefore, when it is a question of «low doses» and their effects (what is more vital), it is important to clearly understand what level is under discussion.

Life on planet Earth, including the evolution of the human species, developed under the impact of natural background radiation. This radiation was born from the planet’s chemical elements and cosmic energy.

The average background dose makes up about 2 mSv per year. Radon, a natural radioactive gas found in all rocks, is the largest contributor to background radiation, contributing almost 2/3. In light of this, natural background is 2–3 times higher in countries like France and Finland where a large number of rocks can be found. Natural background is also associated with potassium-40. This potassium almost fully comprises the human body’s own radioactivity, and that of the world ocean and other elements. Cosmic radiation is mainly caused by particles of high energies coming from outer space. Since cosmic rays are absorbed by the atmosphere, only a small fraction reaches the earth surface. The cosmic rays’ dose at the sea level is low, about 0.03 µSv per hour. However, high in the mountains, it becomes much higher, already being 0.2 µSv/h at the 4–5 km height reached by the mountain-climbers; 5 µSv/h at the 10 km height reached during an aircraft flight, and 13 µSv/h — in the space orbit (220 km).

In Russia, as in the majority of the world’s countries, the share of natural radiation sources comprises more than 70% of the total radiation dose, and that of medical procedures is about 30%. Due to the operation of nuclear power plants and other nuclear industry facilities, extra dose loads do not exceed 1% of natural radiation background.

Theoretically, health effects of low doses can be detected only if comparing very large public groups with more than a million people. For instance, in order to obtain results that are 95% reliable a cohort of 10 million people and the same control group should be examined for the 10 mSv dose. Therefore, when assessing radiation health impacts, the
data obtained from observing people living in areas with high natural radiation background or on lands contaminated as a result of technogenic catastrophes, as well as those individuals who, by profession, are in contact with ionizing radiation sources is used.

It is known that certain areas on Earth like China, Brazil and India, have natural radiation levels that are tens or even hundreds of times higher than the average level. The health status of people living in these areas has attracted physicians’ attention. After many years of observations, physicians have not detected deviations in the world average indices for cancer or genetic diseases. In addition, long-term observations of people irradiated as a result of a technogenic activity have not revealed any authentic excess cancers or increase in a probability for the children to be born with pathologies at the doses below 100–200 mSv (10–20 cGy).

Nevertheless, as it is impossible to completely exclude harmful radiation effects, a linear non-threshold conception was adopted for the radiation protection system, according to which any radiation dose has the ability to cause negative effects. Moreover, risk evaluation is deliberately overestimated. This overestimation is justified as it directly pertains to public health.

Difficulties in detecting low dose effects are also complicated by the large number of factors that can have similar impacts on our everyday lives. On the other hand, an organism may respond to one and the same impact differently, depending on what other factors are affecting it at the moment. The fact is that as compared to other environmental factors, low radiation doses (of several millisieverts level) have mild impacts on the human body. Therefore, when predicting low radiation dose effects on a human organism, it is necessary to understand that it is a question of transferring the data obtained from major radiation doses to the area of low doses, rather than that of assessing actual impacts, which are practically impossible to detect reliably.
Radiation Regulations

A system of standards based on current knowledge and concepts concerning the nature of ionizing radiation’s biological effects have served as a source of protection for humans against radiation. As the knowledge of radiation effects developed, the level of permissible doses was steadily reduced. In 1920, the 100 R dose (thousands times higher than it is accepted nowadays) was considered quite safe. In 1934, the first international recommendations on maximum permissible radiation levels were established. These recommendations suggested 200 mR (about 2 mSv) per day for external exposure. In 1958, the maximum permissible dose of 50 mSv/year for professionals and that of 5 mSv/year for the population was offered. Finally, in 1990, the value of 20 mSv/year for professionals and that of 1 mSv/year for the population was recommended. Currently, these dose values are valid, including in Russia, and are based on the assumption that remote radiation effects (cancer and genetic malformations) do not have a threshold and may develop at any, even the lowest dose.

In 1953, the «Sanitary Rules/Standards for Work with Radioactive Isotopes» was first published in the Soviet Union. Following publication, these rules/standards were regularly supplemented and updated as advances were made in science and practice.

In this respect, it should be mentioned that radiation safety standards are established, proceeding from considerably stricter criteria and higher safety reserve than those for chemical agents. Nevertheless, the standards are regularly reviewed and are continually made more stringent. ICRP recommends that actual human exposure should be reduced to as much as possible below the limits approved when it is justified from the social or economic standpoints.

Currently, the basic dose limit for extra public exposure is equal to 1 mSv/year. This limit is quite comparable to the natural background level. To compare, when watching a TV three hours a day, one may obtain a yearly dose equal to one thousandth of the above value, and when in flight from Moscow to New York – one third of the annual dose. During an X-ray diagnosis procedure, patients obtain effective doses equal to 0.6 Sv at the fluorography; 1.3 mSv – at the radiography; 5 mSv – at the roentgenoscopy; and 3 mSv – at the computer tomography.
Permissible standards for human exposure do not reflect the actual risk that negative effects will manifest themselves, in particular, a risk of developing cancer. Exposure limits are not the limits beyond which a disease develops. If we compare a lethal dose with a height of the Ostankino tower, the occupational exposure limit will correspond to the human height, and the public dose limit — to the brick thickness. Should dose limits exceed, some risk increase is possible. In the case of low doses, such an increase is only a theoretical assumption. The Scientific Commission for Radiation Protection is responsible for issues pertaining to ionizing radiation regulations in Russia. Moreover, it is important to note that domestic standards correlate with international ones.

**Basic Documents Regulating Radiation Effects:**

- The Federal Law «On Public Radiation Safety»;

In compliance with the standards, radiation safety provision is based on the three principles:

1) Regulation principle, according to which permissible limits for public exposure to all radiation sources must not be exceeded;

2) Justification principle that prohibits radiation sources from being used, if a harm caused by extra exposure to these sources is greater than a public benefit from their using.

3) Optimization principle, i.e. keeping individual radiation doses and the number of irradiated people at a possible low and achievable level, taking into account economic and social factors.
The rights of radiation accident victims are protected by the Russian Federation’s special laws on social support for citizens who suffered from radiation impacts due to: the Chernobyl catastrophe, nuclear tests in the Semipalatinsk test area, the 1957 accident in the Mayak Production Association, and radioactive waste discharges into the Techa River.
Radiation accidents most often occur when operating the fault detector installations or medical gamma-therapy devices. For the most part, such accidents take place in light of a disregard for safety rules and regulations.

See below for some examples.

In 1983, a source containing a radioactive cobalt isotope was dumped into a lot of scrap metal in Mexico. The source contaminated the truck that transported scrap metal, road sides and the melted metal. 10 individuals were irradiated by doses that could sufficiently cause radiation sickness. In addition, hundreds of people obtained low doses.

In 1984, a casual passer-by in Morocco picked up and brought home a radioactive iridium source that was previously used to check welding seams in an industrial site. The source accidentally dropped out of the container fastening. As a result, the passer-by’s whole family of 8 people died from high doses of radiation.
In 1987, a cesium-137 source was dismantled in Brazil. Radioactive exposure caused the death of four people.

As technological advances were made, greater knowledge and experience shaped safety provisions. In fact, accidents played a large role in establishing needed changes to safety rules and regulations. As safety systems developed and became more reliable, the number of incidents steadily decreased.

How safe are Nuclear Power Plants (NPPs)? Following the Chernobyl accident, it has become almost an axiom that radiation is something awful and that every sufferer from its effects is doomed. This is indeed not the case. The nuclear power industry’s development has been suspended for many years. On the other hand, all safety aspects were given the most acute attention after Chernobyl. As a result, the operation of NPPs has been practically accident free since 1986.

It is possible to make the following figurative comparison. A fire in the fireplace, being a peaceful source of heat in the house, may become destructive due to carelessness or malicious intent. Therefore, it needs to be handled carefully. The NPPs’ technological systems are designed to practically prevent radioactive emissions into the environment, as well as to reduce possible leakages to the minimum. The NPPs’ special protective barriers serve these purposes. First, fuel is situated within slugs whose containments do not allow hazardous products to go outside. A reactive vessel and a pipeline serve as the next protective barrier. Finally, a protective containment made of reinforced concrete is situated over the reactor vessel (safety containment).

Today, safety requirements are so high that the probability for a large reactor accident that may entail human death from radiation exposure does not exceed one case for a million years of operation. This period is 20,000 times greater than the average term of operation for modern reactors. To better evaluate those figures, one can imagine that a factory warranty for trouble-free work of the car engine will make up two billions, rather than 100,000 km of run.

It should be mentioned that while an accident probability may be low, it can still happen. When we say «one case in a thousand», in fact, it does
not mean that it is a question of the thousandth case (after the nine hundred ninety ninth one.) It can also be the third case, thus making no difference to us as to what probability assessment has been under discussion. Here is an example. Let us assume that there are a thousand small balls in a bag. One of the balls is black while the other nine hundred ninety nine are white. If we remove one ball from the bag, the probability of taking out the black one is 1/1000. However, the black ball may be taken out during any attempt. If the event occurs, its consequences will be the same if it were one of the two possible events or one in a million.

**Radioactive waste** is substances with an increased content of radioactive elements that are of no further use. During the first years of the nuclear power industry’s development, the radioactive waste issue was not given proper attention, resulting in a large amount of accumulated waste.

When using state-of-the-art technologies, reliable isolation for radioactive waste is not a problem. Selection of disposal sites makes it possible to exclude the potential for radioactive impacts on the environment. When managing radioactive waste, creation and use of various artificial and natural protective barriers provide radiation safety standards. For waste disposal, basic protective barriers are a geological formation (natural rock properties are used); a physical and chemical form of waste (waste is transformed into a safer form by vitrification/cementation, etc.); and sealing properties of containers.

**Irradiated (or spent) nuclear fuel** is formed as a result of nuclear operations. It comprises radioactive elements, which can be retrieved and reverted to the nuclear cycle. The other part of elements is represented by radioactive waste.

**Grading of Radiation Accidents**

A heavy sea is measured in grades. At 1–2 grade roughness, a bathing is rather safe, but at a grade 5 storm, it is recommended that individuals refrain from entering the water. For earthquakes, the Richter scale is used to evaluate force in grades. A similar scale is used in the case of radiation accidents. The IAEA has established a 7 grade-scale, the International Nuclear Event Scale (INES), for radiation incidents and accidents in ac-
In accordance with their threat to personnel, population and the environment.

Apart from it, to describe insignificant deviations in NPPs’ operation that are of no importance to safety, such characteristic as a «zero level» is used. Also, incidents can be «below the scale values» or «outside the scale».

Levels 1 and 2 are considered events vital to safety. However, such violations will not entail radioactive contamination or represent any threat to the public or the environment.

Starting from level 3, violations may be considered accidents when a radioactive release outside the site is possible. The 1993 accident at the SCC in Tomsk is among such accidents when, as a result of the damage in one of the technological installations, the production premises, an industrial site of the plant and those ones being in immediate proximity to it became radio-contaminated. The personnel and the public were not exposed to the doses exceeding permissible levels.

In 1999, a level 4 accident took place in Japan. An uncontrolled chain reaction occurred at the facility and an insignificant radioactive release on the facility’s territory soon followed. The two workers who initiated the accident died.

The 1979 severe core melt accident at the Three-Mile-Island NPP in the USA can be categorized as a level 5 accident. The reactor containment was not damaged and no radioactive materials were released externally. However, due to the gravity of the situation and in order to protect human wellbeing, a partial evacuation was ordered offsite. The case showed that even a severe core melt accident did not have a negative health effect on both the public and the environment, as the final protective barrier,
the containment vessel, did not fail to function. The public protective measures taken in cases of this sort are often preventive, attempting to exclude any possible threat to the population.

In 1957, two accidents corresponding to level 6 took place. At the Windscale plant in Great Britain, a fire in a reactor that generated arms plutonium spawned a large radioactive cloud that reached Europe. In the South Urals of Russia, an explosion in a radioactive waste repository occurred at the Mayak Production Association. Based on the exposure dose evaluations, it was determined that nearly 11,000 people needed to be evacuated and relocated. The contaminated territory was called the East Urals Radioactive Trail (EURT).

The 1986 Chernobyl accident relates to the severest level 7, when an explosion and a fire occurred at the fourth unit. More than 300 people from among the plant’s personnel and firemen were exposed to high doses. Acute radiation sickness developed among 134 people. Soon after the accident, 28 of these individuals died. As a result of the accident, vast areas in Byelorussia and Ukraine were contaminated. Furthermore, in Russia, contamination affected lands in the Bryansk, Kaluga, Tula and Orel regions. Owing to protective measures, including evacuation, doses of extra public exposure did not reach a hazardous level. However, the criticality of human error must be mentioned. Due to the untimely and poor organization of protective actions during the first month after the accident, the irradiation dose for the thyroid from radioactive iodine turned out to be high, and the iodine insufficiency typical of these regions increased negative radiation effects.

Generally, it is accepted that remote consequences of radiation accidents may affect a great number of people. Radioactive contamination may cover considerable territories, as was the case at Chernobyl. However, in contrast to other industrial and transport accidents, radioactive contamination does not lead to the immediate deaths of a great number of people. For instance, 760 people died during the June 1989 oil pipeline explosion in Bashkiria while about 900 people lost their lives during a wreck of the «Estonia» passenger boat in September 1994. Moreover, the 1984 chemical accident in Bhopal, India, led to the death of 2000 people. 20,000 people died in the following 10 years, raising the total number of sufferers from that accident to 200,000.
To compare, among those who survived after the atomic bombings in Japan, an extra death rate from all radiation cancer types has made up 420 cases or 1 case per 200 people for 50 years.

The Chernobyl accident has become the worst case of a nuclear reactor accident: the reactor unit was destroyed; the core melted; and tens of millions of curie of radioactive agents was released into the environment. At the same time, only a significant increase in the thyroid gland cancer has been observed. As for the other indices, the health status of the public from affected regions does not differ from that in other Russian regions. The death rate indices for liquidators are the same as the indices for the male part of the country’s population. Overall, rumors that recount the birth of awful monsters or the agonizing death of thousands of liquidators from radiation sickness are simply unfounded for such things are impossible in practice.

**Nuclear and Radiation Terrorism**

In hit films, plots often depict bandits capturing nuclear missiles and blackmailing governments. In reality, these sites are extremely secure. Moreover, detonating a stolen bomb is not a simple task since modern weapons have many degrees of protection (special fuses, code devices, etc., which even a well trained criminal will hardly be able to «break open»). **Nuclear terrorism**, the criminal use of nuclear material able to cause a chain reaction, represents a great threat as a means of blackmail intended to illicit fear and panic.

**Radiological terrorism** is quite another matter. Unfortunately, it is more real. Terrorists threaten people with the so called «dirty bomb», which is an explosive device filled with radioactive agents that spread after the explosion. Most likely, an explosion of a «dirty bomb» will not entail a great number of «radiation» victims; trotyl that defines an explosive device power may bring more harm than the radiation content.

At present, drastic measures for control over nuclear and radiation material are being taken at the international level. A special accounting system that tracks all their movements has been developed.
Temperature and humidity can be felt. Furthermore, humans can make out a volume of sounds and the brightness of light. However, human sense organs cannot perceive radiation. Radiation can be revealed only by special devices called dosimeters.

All Russian nuclear power plants have the Automated Radiation Monitoring System (ARMS or ASKRO in Russian). Tens of sensors from the system are located in both the radiation control area and in the surveillance zone within a radius of up to 30 or more kilometers around the NPP. In localities situated in the immediate proximity to the NPP, the information boards entering the ARMS system show the real-time level of radiation background. Radiation monitoring over the territories is performed automatically. The sensors run measures every minute; they accumulate the result and hourly deliver the data to the NPP’s ARMS center.

Under normal operational conditions, the NPP’s activity is not detected by sensors; – the ARMS data reflects only small deviations in natural background. During emergencies, by obtaining the data during the radiation background increase, one can assess the radiation level, forecast the status development and define measures required for public protection.

When the radiation background level within the 30-km surveillance zone is increased by 0.1 µSv/h, a signal, «Emergency Preparedness», will be activated. If the dose rate makes up 20 µSv/h, the emergency plans shall
come into force and the status will be characterized as an «emergency»
The radiation monitoring data is delivered to the Rosenergoatom’s Crisis
Center where specialists on duty 24 hours a day can render assistance to
the NPP in extraordinary occurrences. The Situation-Crisis Center of the
Federal Agency for Atomic Energy (FAAE) also obtains such data.

The ARMS system covers many nuclear complex facilities. Information about
the current radiation level is freely available. Besides, the ARMS system of
the nuclear facilities is not the sole source of data on the radiation status.
Many regions have created their own systems of radiation monitoring. The
systems are being gradually integrated and, eventually, the Unified State
Automated Radiation Monitoring System will be established.

Various agencies perform extra radiation control. The Federal Service for
Hydrometeorology and Monitoring of the Environment (Roshydromet)
performs on-going radiation monitoring on the territory of the Russian
Federation, and the Federal Service for Consumer Protection and Human
Welfare (Rospotrebnadzor) controls the radionuclide content in the food-
stuffs and consumer goods. Furthermore, veterinary and agrochemical
laboratories run control over the radionuclide content in agricultural pro-
duction. Sanitary rules and standards contain strict requirements, which
serve to protect public health.

Currently, dosimeters can be purchased quite easily. Issues concerning
dose units, what is natural radiation background and what factors con-

<table>
<thead>
<tr>
<th>Unit</th>
<th>Dosimeter readings</th>
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<tbody>
<tr>
<td></td>
<td>Everything is O.K.; No reasons to worry</td>
</tr>
<tr>
<td>µSv/h</td>
<td>0.1–0.5</td>
</tr>
<tr>
<td>µR/h</td>
<td>10–50</td>
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<td>µrad/h</td>
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tribute to human exposure have already been mentioned above. So that readings of a dosimeter become as clear as those, for instance, of a room thermometer or a barometer, see the simple table below. It comprises one and the same values both in standard and outdated (though more usual to many people) units.
The Unified state system for emergency prevention/elimination operates in Russia. Its prerogative is to unite the efforts and capabilities of all authorities, organizations, enterprises and facilities in the area of prevention/elimination of emergencies and their consequences. It comprises branch systems, including the Branch system of emergency prevention/elimination at nuclear industry sites. The profile commissions and structures are created in the organizations, including the Rosenergoatom Concern which operates all Russian NPPs.

Regional organizations of the Unified state system have precise emergency plans that come into force during disruptions in operation of nuclear power plants and other radiation-hazard sites.

In compliance with the INES scale, incidents of a zero («outside the scale») level, as well as those of levels 1 and 2 have no consequences for the public. Nevertheless, the mass media is kept informed of such occurrences. The information contains the data on radiation background, which at such incidents, according to their grading, remains within the standard of which the public is secure.

In more severe cases, when a threat of public exposure arises, decisions on required protective measures from radiation are made. Measures depend on estimated dose values. The main concern during severe cases is to bar excess public exposure and to prevent environmental contamination.

During emergencies, radiation protection must prevent the occurrence of deterministic (predefined) effects of radiation and reduce the risk of
remote radiation effects, including the development of malignancies to the minimum.

**Keeping the Public Informed of Radiation Accident and Required Actions**

The Law «On Radiation Safety for the Public» requires that, in the case of a radiation accident, organizations working with radiation sources should inform public and local authorities as well as people from the lands where increased irradiation doses are possible. Binding public information concerning radiation accidents and the radiation level is envisaged by the Russian Federation’s legislation.

- From time to time, rumors of radiation accidents disturb residents of the areas located in the vicinity of nuclear power plants or facilities having nuclear reactors. Following a period in which information was often suppressed from the public, fear that incidents will once again be concealed has developed among the people. This fear can be explained by the fact that people have become aware of the true scope of the Chernobyl accident long after it. Distrust is difficult to fight — there are no arguments against the words «I do not believe».

- Let us assess the situation from the reverse. Imagine that the head of a facility tries to conceal the radioactive contamination of territory following a severe radiation accident. Such actions on the part of responsible persons are not only criminal, but illogical for the radiation accident will soon be revealed. Eventually, an increase in the radiation level will be detected. The ARMS system, Rosgidromet and the sanitary-epidemiological surveillance services run the radiation status monitoring with this aim in view. Moreover, dosimeters available to representatives of environmental organizations and the public will indicate actual radiation levels. Therefore, the simplest advice to those who fear nondisclosure of an accident is to buy a dosimeter.

**Public notification** in case of a health threat is an integral part of emergency plans. The basic means of notification are local radio, television and special sirens. It is important to listen attentively to the messages delivered. Messages will relay information concerning what actions to take to protect oneself and one’s family. If something is not clear or access to notification devices is not available, contact the persons on duty from the Ministry of Civil Defense, Emergencies and Elimination of the consequences of natural disasters (EMERCOM of Russia) or local authorities.

In some instances, it may be difficult to obtain timely, official information about the accident. Having seen the first signs of an unusual situation,
for instance, a radiation threat sign on the road or having received word of the accident, one should remain calm. It is recommended that individuals stay inside, but if an individual learns of the accident while outside, it is best that he or she reach a place where detailed information is available. Children who are outside should be called home. The personnel from children’s institutions, such as schools, day-care centers, etc., will be informed as to what to do in each specific case. One should turn on a radio or a TV-set. If you have a computer at home and you are eager to obtain more information or find out the most up-to-date news, take advantage of the Internet.

Let us remind you once again that, in the case of a radiation accident, the public will be immediately informed of it. Those who suppress information about emergencies at nuclear sites will be prosecuted. The details about any, even insignificant, failures in the work of NPPs or other nuclear facilities are open to the public. You may access this information by visiting the official sites of Rosenergoatom (www.rosatom.ru) or FAAE (www.minatom.ru).

On Protective Measures, When Being in Contaminated Areas

As a result of radiation accident, the following may happen:

- Radioactive cloud formation. In this case, the threat is represented by external exposure at the moment of cloud passage, intake of radioactive agents by the human body along with the inhaled air and radioactive contamination of clothes and the skin.

- Radioactive contamination of the territory and the premises, as a result of fall-outs or mechanical transfer of radioactive agents. The threat factors will be: external exposure when being at the contaminated site, contamination of foodstuffs and radioactive dust formation.

- Surface water contamination due to immediate ingress of radioactive agents into the reservoir or their depositions at the moment of passage of a radioactive cloud. As a result, it may be hazardous to stay near the reservoir or use its water.

- Loss of control over the source. A radioactive source may turn
out to be «orphan». The main thing is not to approach it and, by no means, touch it. In avoiding the source, adverse health effects can be avoided.

Depending on the nature of an accident, radioactive substances can be of different kinds – gas or aerosols. Aerosols are particulates that deposit at the moment of cloud passage.

The composition of radioactive substances may differ as well. For example, it can be a damage to an isotope source which is one of a few radioactive isotopes whose properties, including the half-life period, are well-known to experts. In a more complicated case, for instance, during a nuclear reactor accident, tens of radionuclides from radioactive substances may enter the environment. The majority of them have a very short half-life period, namely minutes, hours or days. It is during that period that their radioactivity twice decreases. For some, the half-life period makes up tens of years (for example, for radioactive cesium). The more time has passed from the moment of radioactive contamination, the less radiation intensity will be. The first days or weeks are the most hazardous. The situation will then take a turn for the better.

All radionuclides have one property in common, namely that they decay. As a rule, during nucleus decay, energy is released as gamma quantum or beta particles; alpha particles are released during the fission of some nucleuses. These particles all may have a different energy and thus, different penetrability. Thick clothes or a polyethylene film are sufficient enough to protect an individual from alpha particles. However, a thicker material is required for protection from beta particles. To weaken gamma radiation twice, a protective layer of 12 cm thick concrete, 3 cm thick iron and 1 cm thick lead is required.

Naturally, it is possible to protect oneself from intake of radioactive agents through inhaled air, water and food. Depending on the form (soluble or insoluble) in which radionuclides have entered the human body, they either leave the organism or accumulate in the human body. Many radionuclides, like iodine radionuclides, react peculiarly in the body. Concentrated in the thyroid gland, iodine is of vital importance to a human since heavy diseases can develop as a result of iodine deficiency. The human organism absorbs iodine well. However, at the same time, the organism cannot decipher between stable or radioactive iodine. During
an accident at operating nuclear installations, it is important to be aware of this principal peculiarity since a large number of iodine radio-isotopes forms at the moment of uranium nucleus fission.

In the case of an emergency, radioactive iodine may enter the environment and human organisms, thus threatening the thyroid gland. Therefore, iodine prophylaxis is one of the early protective measures taken in the case of an emergency. Decisions to implement prophylaxis are made by local teams from EMERCOM and Civil Defense and brought to the public’s attention.

How one can be protected by shielding:

Iodine pills can help protect the thyroid gland from radionuclides. It is desirable that a room first aid kit have required medicines, such as potassium or sodium iodide, Iodine-Active or Iodomarin readily available. These medicines should be taken immediately upon the notification of an accident, before radioactive iodine gets into the human body. When medicines are taken in a timely fashion, 98% protection will be provided. Under other conditions, medicines should be taken as soon as possible. Iodine prophylaxis efficiency decreases with time, and 4–6 hours later it makes up only 50%. If pills are not available, it is possible to take a few drops of normal iodine spirituous solution dissolved in water or milk or to construct iodine net of 10x10 cm on the skin.

The radiation status may rapidly change in the initial phase of an accident. The passage of a radioactive cloud is the most hazardous moment. During this period, a shelter inside a building and isolated from the environment should be used for protection. If the information delivered over the
radio or by other means of communication prescribes heading to the nearest shelter, leave immediately. Upon arrival at the shelter, follow the instructions of those in charge closely and behave appropriately.

If you lack time or an opportunity to find refuge in a specially equipped shelter, an ordinary dwelling house will also provide reliable protection and reduce multiple radiation doses. Do not panic. Close the doors and windows tightly to bar radioactive dust from entering the house. If there are isolated rooms without windows in the house, it is better to take shelter within them. It is best not to leave the house, but one should take measures, if necessary, for individual protection. Upon return, it is recommended that an individual wash and change his or her clothing.

Children over 2 years old and adults should take potassium iodide by 0.125 g and children under 2 years – by 0.04 g once a day after meals, drinking it with kisel, tea or water. Children over 2 years old and adults may take the 5% iodine aqueous-spirituous solution 3 times a day after meals by 3–5 drops for a glass of milk or water, and the dose for children under 2 years makes up 1–2 drops for 100 ml of milk or nutrient mixture. Iodine prophylaxis is conducted for 7 days. Pregnant women should take into account that iodine medicines should be taken along with potassium perchlorate (0.75 g) to exclude the probability that iodine will have a negative impact on the fetus.

Clothing covering open parts of the body will help to protect the skin. It is possible to use gloves and gauntlets to protect arms, as well as rubber boots or any covered footwear (with galoshes, if any) for feet protection. It is recommended that women put on trousers. If parts of the skin and the hair remained unprotected and were exposed to radioactive contamination, it is required that they be cleansed with water and soap or a shampoo.

For lack of a gas mask or a respirator, one can manufacture fabric masks or bulky dressings on one’s own to protect respiratory apparatus. If you are in the street during an incident, use a handkerchief or thick piece of fabric to cover your nose and mouth.

To bar radionuclides from entering the human body along with foodstuffs, one should refrain from eating meals in the open air.
Your stay in the shelter will not be long, usually lasting a few hours or a day at the maximum. During this time, the radiation level will be specified and recommendations on future actions will be given. It is inexpedient and dangerous to take independent actions at the time. Being unaware of the radiation status when leaving the house may lead an individual to the most contaminated sites.

Most likely, it will soon be possible to leave the shelter and return to an accustomed lifestyle.

However, a decision to evacuate may be made. Such a decision is made in compliance with criteria that warrant safety provision. Nevertheless, evacuation means that the situation is, in fact, serious and it is necessary to behave oneself in the maximum organized way. The evacuation announcement will establish the assembly place, outline the evacuation route and contain all essential instructions. If you are at home and you have been informed of the evacuation, you should calmly and quickly collect your documents, money and the minimum of things you need, as well as turn off the lights and gas, lock the door and arrive timely at the assembly place. If you are already in the shelter, you need to consult the person in charge as to whether it is possible to manage without documents.

When being evacuated by means of transport, one may pack prepared things and products into suitcases, bags or rucksacks. These items should not be extremely heavy. However, it is required to envisage all necessary things and take into account weather conditions. A small first aid kit will be an important item to bring, and it is better to take those products, which will not spoil in transit. Also, do not forget about the drinking water.

If the distances are short and you will have to go by foot, it is best to pack your things into a rucksack. Footwear should be comfortable and appropriate to the season. In transit, you ought to observe instructions given by authorized managers and responsible persons and you ought not to make a fuss or confusion.

Evacuation implies the return after the risk has passed. If the living in
contaminated areas or at sites turns out to be hazardous for public health, relocation of the inhabitants to safe regions is performed.

It may so happen that after the radiation accident, extra exposure doses will be low. In this case, relocation will not be required. However, to bar negative health effects, one must adhere to the simplest procedures. Estimations based on measurements of site contamination by radionuclides make it possible to assess the public exposure dose. Depending on a possible accumulated dose, contaminated lands are divided into zones. For instance, the average annual dose may make up 1.5 mSv at the 15 Ci/km$^2$ radioactive cesium contamination; and the 40 Ci/km$^2$ contamination level corresponds to the average dose of 4 mSv/year.

The information about exposure levels can be obtained from experts from the sanitary-epidemiological stations. The dosimeter data is highly essential for selection of correct protective measures. Radioactive fallouts have a non-uniform nature of dissemination, creating «spots». Meter men should be asked as to whether there are such spots in your garden plot or if the well is damaged. One should be aware of the current state of river water, which forests are better not to enter and which pastures can serve as grazing lands. It is desirable to abstain from walks and bathing, if data on the radioactive contamination of the forest and river is available. At the same time, being in the fresh air is useful for the health, and unwarranted restrictions will not bring benefit. It is mandatory that the checkpoints and the sanitary-epidemiological stations measure products, fish from the river and items from the forest such as berries and mushrooms.

In private life, you will be best protected if you adhere to the most ordinary hygienic measures, which are as follows: you are required to wipe your feet on a damp rug, when entering the house; not to walk in the street in your house shoes; and to clean your outer clothing. Finally, your house needs a damp cleaning.

After the accident, radioactive particles deposit on the soil or reservoir surfaces. On this soil, plants, which contain radionuclides, grow due to the processes of migration by biological chains. Agricultural animals eat these plants and, thus, radionuclides get into their systems. A human, the last link in the biological chain, lives on vegetable food, meat and milk.
A radical way to prevent radionuclide from entering an organism along with foodstuffs is to completely refrain from consuming local products. However, it is impossible to fully proceed to «imported» foods. Moreover, it is not required. For adequate nourishment, it is necessary to know what products can accumulate radionuclides and how their content can be reduced. Simple methods for product processing/making (for instance, washing of products with running water before making; their maceration; their boiling in a big amount of water which is discharged after that) will reduce the radionuclide content in the food several times and will prevent adverse effects.

**Urban conditions** have their peculiarities. Due to a high density of the population, radioactive contamination affects a greater number of people. On the other hand, the public lives mainly on the products that are bought in the shops, rather than raised in their own garden plots. This reliance on store bought items makes it possible to radically limit the internal exposure dose stipulated by «eating».

A distinguishing feature of cities is the high level of environmental contamination stipulated by non-radiological factors. This environmental contamination is mainly associated with industrial activity and motor transport releases. A health risk from non-radiological factors may exceed a radiation risk hundreds of times. Therefore, a decrease in environmental contamination is of great importance to the maintenance of health.

As a rule, the living standard in cities is higher than that in the rural area; the medical service is more available and its quality is higher. In light of this higher living standard, medical control over the status of health will promote the timely detection and successful treatment of diseases that develop from radiation exposure as well as from other causes.

So, in the case of a radiation accident, one should remember that **all measures required** should one be panic-seized or take medicines which «helped» a relative of your neighbor’s friend during a «previous emergency». Remember that hypertension stroke from unnecessary stress or drug poisoning, including an overdose from iodine pills, are hazardous as well.
You will make a mistake if you go from one extreme to another and fully ignore safety requirements. You should follow recommendations given by experts, listen to the announcements, pay attention to safety signs, refrain from entering contaminated sites and observe recommended safety measures. **Any, even incomplete, protective measures are better than the lack of any protection.**

**Expediency of Protective Measures**

It is necessary to distinguish between two different situations: an acute period immediately following the radiation accident and the subsequent living on contaminated lands. In both cases, the nature and volume of protective actions are defined by possible radiation effects. Protective measure efficiency should be considered, taking into account such factors as an averted dose, the cost of protective measures, social consequences, etc. Specific measures vary with the extent of accident severity and should be optimized in such a way that protective actions will bring more benefit than harm.

For instance, the decision to relocate will not be justified if public health will deteriorate at this new location from changes in usual surroundings and accustomed lifestyles or job loss. A risk of falling ill due to the impact of some local factors could conceivably increase at the new place. Mass resettlement may lead to a decline in the lifespan due to neoplasms. Public relocation at the average age of 35 years may take away up to 8 years of life due to changes in lifestyle and health, deterioration or stress. When living on contaminated lands, exposure will not entail such an effect on the human lifespan.

Unnecessary food restrictions may bring more harm than benefit. For example, even if people consume a small amount of «contaminated» mushrooms, it will not increase risk since the dose obtained will be negligibly low. In any case, increased risk from using such mushrooms will be less than the risk posed by alcohol consumption or smoking.

Exposure levels in the areas where living is permitted do not pose a threat to health. Risk underestimation is dangerous, but its
overestimation is no less perilous. It is known that stress is the cause of many diseases in that it reduces an organism’s general resistibility. Therefore, stress-entailed fear of radiation or any other factor may represent a greater hazard to the health than the radiation itself.

In no lesser extent than medical measures, reasonable social and economic measures are able to reduce the negative consequences of radiation accidents to a minimum. Human health is considered to be approximately 15% dependent upon heredity and environmental factors, 60% dependent upon lifestyle and another 10% dependent upon the status of medical care. Therefore, it is possible to reduce the total health risk by lessening the impact of other risk factors. Things such as balanced nourishment, the value of rest, regular medical examinations, physical activity and abstinence from smoking and alcohol will protect against possible radiation effects and will also strengthen overall health.

Besides, maintenance of good health is directly connected to the living standard. In this sense, not only medical actions but also regional economic development, including the creation of new jobs and the increase in public income level, should be regarded as of paramount importance.
This brochure addresses radiation effects as well as outlines the simplest ways in which humans can protect themselves from radiation. It can be used as a manual for the public to be taught the fundamentals of radiation protection and to be trained in the appropriate actions in the case of on-site radioactive contamination. Apart from it, this brochure is intended for anyone who is interested in the issues of radiation protection.

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Where can one obtain essential information on nuclear facilities and the issues of radiation safety?

**Internet site of the Russian Federation’s Federal Agency for Atomic Energy:**
www.minatom.ru

**Internet site of the Rosenergoatom Concern:**
www.rosatom.ru

**Internet site of the Ministry of the Russian Federation for Civil Defense, Emergencies and Elimination of the Consequences of Natural Disasters (EMERCOM):**
www.mchs.gov.ru

**Internet site of the Federal Service for Hydrometeorology and Environmental Monitoring (Roshydromet):**
www.meteorf.ru

**Internet site of the Nuclear Safety Institute of the Russian Academy of Sciences (IBRAE):**
www.ibrae.ac.ru