MONITORING OF THE NATURAL RADIOACTIVE FUND AND RADIOACTIVE POLLUTION - AN IMPORTANT FACTOR OF NUCLEAR SECURITY IN BULGARIA

НАБЛЮДЕНИЕТО НА ЕСТЕСТВЕНИЯ РАДИОАКТИВЕН ФОН И РАДИОАКТИВНОТО ЗАМЪРСЯВАНЕ – ВАЖЕН ФАКТОР НА ЯДРЕНАТА СИГУРНОСТ НА БЪЛГАРИЯ

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Abstract: *The radioactive contamination has actual national and international importance. It is related to the increasing the prevention measures of accidents as consequences of exploring the nuclear energy for peaceful purposes, and in the military purposes as well. The optimization and management of operational systems for monitoring of radioactive background should bring the increasing of nuclear Bulgarian safety, and the quality of the population defense from expose to radiation, as a consequence of changing the characteristics of the natural radioactive background.*

Keywords: *radioactive contamination, measures of prevention, optimization, monitoring, radioacative background, population defence, expose to radiation*

1. Introduction

Nuclear power worldwide provides around 30% of global electricity production. Under normal operation of the NPP there is no major risk and the potential damage to the population and nature is much lower than in the areas around the TPP or the large chemical plants. Nevertheless, the danger of radiation and nuclear accidents should not be overlooked. In both cases we can expect significant radioactive contamination of the environment. Properly controlled control of possible radioactive contamination depends on the preservation of human, animal health and possible decontamination actions in the environment and food products.

At present, more than 510 Nuclear Power Units operate in the world. Of these, 163 are in Western Europe, 121 in the United States, 45 in Russia, and the rest in 29 other 5 continents.

2. NPP

It is known that atomic reactors are devices to maintain a controlled chain reaction. For fuel, the isotopes Uranus 233, Uranus-235 and Plutonium -239 are mainly used. The division of the kernels of these elements does not occur spontaneously, as with the nuclear weapon, but is controlled so that the separated heat is used to produce electrical energy. A stationary controlled chain reaction is carried out in the reactors. Critical chain reaction conditions are created, in which the neutron multiplication factor is close to one (K = 1). Therefore, for a stationary chain reaction, it is necessary for at least one neutron from the first division of the first generation to cause a second division and at least one neutron from the second division (second generation) to cause a third division, . When K <1 occurs under subcritical mode, the number of divisions gradually decreases and the reaction stops. At K> 1 counts of fission nuclei increase and the chain reaction is amplified. It is these conditions that make it possible to control the operation of each reactor, depending on the consumption of electrical energy. Thus, in case of shortage of electric energy, the velocity of the chain reaction increases, and in the case of excess energy, we reduce the rate of division.

It is known that all reactors consist constructively of: an active zone in which the fuel elements are located and which is surrounded by a neutron reflector. Fuel elements are made of uranium oxide or metallic uranium, placed in thin-walled metal sheaths (steel, aluminum and various alloys). The metal envelope must provide a high degree of sealing and long-term reliability of the fuel elements. Neutron retarder uses graphite, heavy water, plain water. Water, heavy water, liquid sodium, nitrogen, diphenylmethane and other combined liquids may be used as a coolant or cooler. An important element is the rate-control system of the chain-nuclear reaction. It provides a critical mode or the reaction can be delayed or stopped altogether. The larger number of reactors uses cadmium, boron and other materials that absorb the neutrons. They are removed or introduced into the core area, thereby regulating the chain reaction. Additionally, the reactor should have protective devices that reduce the dose of gamma rays and neutrons emitted from the core. This is the reactor casing, which consists of 3 layers - lead, cadmium and concrete. Synchronized operation of the reactor is accomplished by a remote control console.

The operating reactors at the Kozloduy NPP are of the 1000 W water-type type (ВВЕР-1000). The water of the so-called primary circuit serves as a retarder of neutrons and as a coolant. It is heated by the fuel elements to a high temperature and is under high pressure. Through it the heat is transmitted to the water of the second loop, which is converted into steam entering the steam generator and the turbine for generating electrical energy.

The water from the first circuit in the water-water reactors is always contaminated with radioactive substances. This is due to the neutron irradiation of metal corrosion products as well as the impurities and contamination of the liquid coolant in the core and become secondary radioactive. In addition, in the case of impaired leakage of fuel elements, nuclear fission products may be introduced into the first loop. Water contaminated with radioactive substances from the first contour is subject to decontamination and purification by means of ion exchange filters. In modern types of NPPs, such purification is also provided for water from the second contour. The radioactive elements emitted from the heat carrier are fed into the atmosphere through high chimneys where they are diluted in a large volume of air. It is obvious that the normal operation of the NPP is related to a certain, low level of environmental pollution with radioactive substances. For the most common reactors - water-water, the major radiological pollutants are the radioactive isotopes of noble gases and iodine. In the radioactive mixture were found the isotopes of the crypton, 15 of the xenon and 20 of the iodine. More important for the formation of the radiation environment around the nuclear power plants are crypton - 85, xenon - 133 and xenon - 135, iodine - 131 and iodine - 133. They have a small half-life and are in insignificant quantities. It should be noted that atmospheric discharges in the normal operation of the reactor, the so-called controlled discharges, do not pose a risk of environmental pollution. This process is technically controlled, resulting in completely safe dilutions that do not lead to an increase in the radiation background.

Much more dangerous for the radioactive contamination of the biosphere are the accidents that can occur at the NPP.

A radiation accident is called a breach of safe operating ranges, where radioactive products or ionizing radiation go beyond the norms, and disruption of normal operation of devices and equipment containing sources of ionizing radiation is required.

A nuclear accident is called the damage to the nuclear reactor fuel elements and emergency exposure to personnel.

For normal NPP operation it is assumed that up to 1% of the fuel element cladding has gas permeability (micro cracks) with respect to isotopes of cryptone, xenon and iodine and up to 0.1% non-hermetic, allowing contact of coolant with nuclear fuel. The magnitude of the accident and therefore the environmental consequences vary widely. The majority of previous accidents are small and have caused increased contamination with radioactive elements in restricted areas near the reactor. The worst and most dangerous accidents in the nuclear power plant have so far been due to a sharp increase in reactor power due to the acceleration of the chain steam explosion, which could destroy various installations and dehumidify the system. From the information related to some major accidents in the NPP, the reasons are the following: Operator errors, failure of the equipment and deficiencies in the construction. The most frequent cause of past accidents is the mistakes of the personnel servicing the installations of the individual reactor.

3. Radionuclides

A characteristic feature of the discharges is that the majority of the radioactive aerosols are deposited by the mechanism of local deposits near the plant itself. Another part, depending on the magnitude of the accident, may fall into the troposphere and fall to the ground as tropospheric deposits.

From the character of the distribution of radionuclides in the atmosphere and their deposition on the Earth's surface will also be the individual doses of irradiation of the people, located on the radioactively contaminated territory. Formation of dose of gamma- and beta-emitting isotopes from discharges under emergency conditions at NPPs has a direct and indirect impact. The direct path refers to external radiation with gamma-quanta and beta-particles of radioisotopes contained in the atmosphere or fallen on the Earth's surface. This fact suggests the relevance of this study as it is directly related to the proper organization of radioactive contamination control.

It should be noted that in the period 1945-1991 the total number of nuclear explosions on our planet is 2059, including 508 in the atmosphere. The largest number of such outbreaks were committed in the United States - 1085 and 205, respectively. Secondly, Russia 715 and 215 respectively. France 182 blasts (45 in the atmosphere). Britain, respectively 42 (21 in the atmosphere). China respectively 35 (22 in the atmosphere). It is known that until 1962, the main source of environmental contamination with radioactive substances was nuclear weapons. After the conclusion of the treaty banning nuclear experiments in the air, on the Earth's surface and under water, the radioactive contamination of the Earth significantly decreased. Despite the 1962 ban, separate nuclear blasts were committed by France, India, Pakistan and North Korea.

On the other hand, the widespread adoption of modern technologies in the national economy, medicine, science and industry using sources of ionizing radiation creates a risk of radioactive substances being released into the external environment. The most important prerequisite for radionuclide dissipation in the biosphere arises in the disruption of the mode of operation and in accidents in the constantly increasing number of atomic reactors, which leads to the release of radioactive aerosols into the atmosphere.

Radioactive aerosol split products fall onto the earth's surface in the form of local, tropospheric or stratospheric deposits. As a result, they accumulate in the soil, plants, animals, water of open waters and their flora and fauna. This undoubtedly calls for a stable organization of radioactive contamination control. This organization should also include the study of the migration patterns of radio stones important in terms of radio storing strontium-90 and cesium-137 in the different sites of the biosphere. For example, strontium-90 is distributed in objects similar to the calcium element and the second (albeit to a lesser extent) potassium. Here are the group chemical similarities of these radioactive elements. This has important practical implications both for the intelligence of contaminated sites and for the elimination of the consequences of degraded nuclear power plants. Under the same conditions in the biosphere sites contaminated with radioactive substances, the maximum concentration of strontium-90 in them is always found in the organs physiologically rich in calcium (bones, egg shells) and the maximum concentration of cesium-137 in sites rich in potassium (muscles).

The formation of radioactive contamination depends largely on the state of atmospheric air. Radioactive aerosols by degree, area of distribution, fall and radiochemical composition form radioactive contamination in the local spaces around the accident, in the troposphere, as well as in the stratosphere.

Local radioactive contamination is formed in the area of the accident and forms different zones of contamination, which can be tens and hundreds of kilometers in size. The shape and contours of the radioactively contaminated area are mainly determined by the energy of the explosion, the weather conditions (the complex system of winds at different heights and their velocity), the relief of the area, the particle size, the duration of the discharges, the physico- the chemical status of the dividing products.

Local radioactive contamination settled on the Earth's surface within 24 hours. They are dry, ie. fall regardless of the rain. The speed of their fall is under the influence of gravity. Chemically, they are a mixture of nuclear fission products, with the predominance of short-lived isotopes. The major radioisotope is iodine-131, which has a half-life of 8 days. Depending on the level of radioactive contamination in the area, a gamma-field of different power is formed. Due to the rapid decomposition of the short-lived radioisotopes, the activity of the area relatively quickly diminishes.

Danger of increased local fall of radioactive products after a radiological emergency occurs under adverse weather conditions. Thus, in the event of heavy clouds after the blast, rain may fall as radioactive particles become condensation centers. When the radioactive cloud mixes with a rainy front, it can take a significant amount of split products together to produce rays and a high level of radioactive contamination of a limited area together with raindrops. Similarly, snow attracts radioactive products and can cause severe radioactive contamination of the Earth's surface. This requires particular attention in predicting accidents as well as in conducting intelligence to delineate areas of actual contamination.

In more powerful blasts (like the Chernobyl nuclear power plant), dividing products can fall into the troposphere. A characteristic feature of these radioactive contamination is that they fall very slowly, on average for about 30 days. There is a large radioactive trace, sometimes sometimes up to several thousand kilometers. The density of soil contamination with them, compared to local deposits, is much smaller. In the troposphere, the main meteorological processes occur - cloud formation, precipitation, air currents, cyclones, etc. The radioactive cloud in the troposphere from which the tropospheric deposits form, changes its original volume under the influence of gas and turbulent diffusion. Gradually the air currents tear it apart. Vertical displacement of atmospheric layers may lead to intensive deposition of radioactive substances in separate areas of the Earth's surface. Of much greater importance for the rapid displacement of radioactive particles in the troposphere have the dominant horizontal air currents.

The most important factor to purify the troposphere from the radioactive particles is precipitation. Especially important is their importance in moderate latitudes. Atmospheric precipitation changes the three main characteristics of radioactive contamination: density of 24-hour deposition, specific activity of rainwater and concentration of radioactive products in the ground air layer.

In the absence of rainfall, only the nearest air layer is subject to the removal of radioactive particles. It is in constant contact with the Earth's surface and as a result of the turbulent motion is constantly being renewed. Increased deposition of dividing products is observed with an increase in atmospheric pressure when air masses from the top of the troposphere begin to move in the direction of the ground. The amount of radioactive particles that fall as a result of the above processes varies considerably on days.

Radioactive aerosols form different fractions in the troposphere, which are removed from there at different rates. A late fall (1-2 years after the accident) of radioactive products was found. This is explained by the presence of aerosol fractions smaller than 5 micrometers, which due to their physicochemical properties are washed less than the rain.

The radioactive substances that fall on the soil and form the pollution zones depend on the following factors: the physico-chemical properties of the isotopes, the type of chemical compounds, some parameters of the external environment, etc.

One of the main properties of radioactive substances determining their soil behavior is their water solubility. According to the literature, about 1-10% of the division products that are formed in a radiation accident are soluble. These include the compounds of strontium, cesium and iodine. The rest of the radioactive substances fallen to the ground is practically insoluble. It is noteworthy that about 60-70% of strontium-90 deposited on soil is in soluble form available to plants.

The large insoluble particles of the dividing products are retained in the top layer of the soil. They have a very limited ability to penetrate into depth. The smaller ones adhere to the soil components. The quantity and qualitative composition of humus also influence. The rate of migration and depth of penetration depend not only on the type of soil but also on its water regime (groundwater level). Severe clay soils retain more heavily radioactive substances than sandy ones.

It is estimated that 80% of the radioisotope deposited on the ground is retained in the upper layer (from 0 to 25 cm) of the clay soils. In softer soils, they penetrate to a few tens of centimeters. It is known that the major part of the radiochemistry is located in the soil layer 0-10 cm thick. This is the area in which the root system of the pasture plants develops. 40-80% of the isotope were in the 0-5 cm layer, and 20-60% penetrated deeper. The movement of the radioisotope in depth on the precipitous sandy soils takes place alongside the downstream waters. In hardly permeable clay soils, the transfer in the same direction is mainly due to ionic and molecular diffusion.

We must take into account the special moments in the cesium-137 movement, which is radionuclide-important radionuclide. Not all of its ions are equally tightly bound to the soil. Some of them are attached to the soil particles by cation exchange and form the exchange fraction of the isotope. Another part is fixed for the mineral constituents of the soil and it is an unchanged fraction. Over time, the quantitative ratio of the two fractions changes as part of the non-variable fraction becomes available to plants. Compared to clayey, sandy soils are more easily attributed to the non-quench fraction.

Radioactive strontium retains well from the soil, but unlike radioactive cesium, its relationship to soil elements is not stable. Under the influence of the neutral salts contained in the soil solutions, it is easily distributed in groundwater and plants. The amount of strontium-90 that comes to the plants through the roots depends on many factors: the radioisotope concentration in the soil, the presence of free calcium, the plant species, etc. Like radioactive cesium, it translates into larger quantities of sandy than clay soil and rich in organic impurities. There are known examples showing that the amount of radioactive strontium passed to the plants is about 3% of the total amount of soil occupied by the root system.

As noted, the main pollutant of the NPP biosphere is iodine-131. It has a relatively short half-life, and its absorption from plants through the roots is a slow process. Therefore, soil contamination with iodine-131 is of no practical significance for the implementation of the air-soil-plant-animal-human migration chain.

Pollution of water in open waters - rivers, lakes, dams, with radioactive substances can be different. Most important is the release of liquid radioactive waste or the accidentally discharged from the NPP aerosols, which are subsequently precipitated under the water surface. It is also dangerous to wash out the rains of radioactively contaminated terrestrial areas.

Radioactive elements infiltrated into the pond may have different behavior depending on their concentration in water, the nature of the pollution and the radiation situation on the shore. The following factors are important: type of joint, water composition, temperature, etc. The isotopes retained on the solid particles floating in the water are gradually deposited at the bottom of the pond. The rate of precipitation depends on the particle size, the nature and magnitude of the electrical charge, the velocity of the water flow, the presence of a turbulent motion. The majority of radioactive substances are deposited at the bottom of the basin, and a smaller part on the aquatic plants. The distance that radionuclide passes into the pool is determined mainly by its solubility and its half-life. Soluble long-lived radioisotopes can pass enormous distances.

As a result of the precipitation of radioactive substances, the surface layer of the bottom is most intensively polluted. Very important in this respect is the type of soil from which it is formed. Highest sorption capacities have bottoms that are made of clay particles and organic matter. The long-term contamination of long-lived isotopes leads to their penetration into depth of the lower deposits and to the soil forming the bottom of the basin. Depth of penetration depends largely on water permeability of soil layers. Reverse entry into the water of radioactive substances retained by the bottom depends to a large extent on the alkaline-acid equilibrium. In an acidic environment, up to 50% of all radionuclides contained in the sludge are released into the water. This process runs much slower in a neutral or alkaline environment. It is easiest to leave the muddy radio station - up to 84-87% of the total radioactivity. Neutral salts also accelerate the release of radionuclides sorbed by the bottom.

It is obvious that the bottom plays the role of a depot for the radionuclides that have fallen into the basin and ensures their return to the water after the radioactive contamination has ceased. Therefore, the discharge into the open waters of heavy and other radioactive waste containing long-lived radionuclides should not be allowed under any circumstances. The presence of such should be strictly controlled and limited to free access.

The magnitude of concentration of radionuclides in plants and their products depends on many reasons. There is a direct link between the amount of radioactive pollutants in a given locality and the concentration of radionuclides in plants. With equal other conditions in mountain areas, grass and crops contain a higher concentration of radioisotopes than in the plains. It is assumed that in the areas situated at 1000 m above sea level the activity of the grass is 3-4 times higher than in the lowlands. The vegetation exposed to open winds has been shown to be more active than the one found in wind-protected areas. The activity of vegetation also depends on the amount of rainfall. The availability of radioactive deposits for vegetation depends on the water bivalence of their compounds in the biosphere. There are two main pathways to radioactive contamination of plants - through the roots and directly through the surface of their organs. The importance of the former is determined by the extent and nature of the radioactive contamination of the soil, its species, chemical composition, water content, etc. An important factor is the ability of the radionuclide to saturate from the soil. As much as this property is more pronounced, the smaller the amount of radioactive element penetrates the plants. Through the root system, radioisotopes are converted into ionic form or as salts (carbonates, sulphates). The penetration of the radioisotopes through the exposed parts of plants is as intense as their higher concentration in the air. The absorption of radioactive substances from the soil flora also depends on the properties of the chemical elements, the type of plants, the conditions of their cultivation, etc. It is currently assumed that the foliar pathway of radionuclide penetration in plants is paramount and root is secondary. Besides the initial deposition of the radioactive deposits on the leaves of the plants is also observed secondary - by the wind. A known part of the surface parts of the soil, together with the radionuclides in them, rise into the air in the form of ground dust and then are deposited and fixed on the plants.

Cesium-137, Bari-140 and Iod-131 are almost entirely absorbed through the leaves. The remaining radionuclides are sucked through the leaves considerably less. It is interesting to know that the radiosynthesis is sucked into plants through the leaves several hundred times more than strontium and is very mobile ie. quickly spreads throughout the plant. In iodine, it has been found that in gaseous form the radionuclide is incorporated by plants better than the aerosol form that remains on the surface of the plants. A large part of a radio station, falling on the leaves, stays at the site of the attack and migrates a little inside the plants. For this reason, this radioisotope is found in the leaves in larger quantities, compared to the rest of the plants.

Strontium-90 is rooted twice as much as cesium-137, despite the fact that the last radioisotope is in a higher concentration in the soil. Typical of other nuclear cerium products such as cerium, ruthenium, zirconium, yttrium, tellurium, plutonium, which are normally absent in plants, are poorly absorbed in the process of mineral soil metabolism. They are retained by soil particles and only small quantities of them pass through the root system.

Different types of agricultural plants to varying degrees absorb radionuclides. These differences can be observed even in the different plant species of one family. This is mainly related to the construction of leaves and roots. Leaves with more pronounced relief hold more radio aerosols. The age of the plant has a significant impact on the accumulation of radionuclides in it. Perennials always have more activity than annuals. In this regard, the lichen example is very prominent. They are perennial, grow slowly, are devoid of roots and receive mineral substances only from falling aerosols. For this reason, the strontium-90 concentration is 20 times higher than in the surrounding pastures.

Between the various parts of the plants radionuclides are distributed unevenly. Grains, seeds and fruits have been found to retain fewer radioisotopes than in leaves and stems of plants. In the shell their concentration is greater than the core. For this reason, no more than 15% of the radioactive strontium contained in the wheat grain is present in the flour.

All mentioned radioactive contamination features require specificity in the organization of radioactive contamination control.

4.Conclusions:

1. The formation of radioactive contamination and its behavior is of interest for both preventive measures and after a nuclear or nuclear accident at the NPP.

2. Radioactive contamination in a radiological or nuclear accident will be determined by a wide range of factors that determine the contamination of tropospheric air, soil, water, plants and the overall environment.

3. Optimized control of radioactive contamination following an accident contributes to the proper organization of evacuation rescue operations as well as to the decontamination of contaminated areas and food products.

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