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RADIATION PROTECTION

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Abstract. In this article the classification of incidents and accidents when working with sources of ionizing radiation (SIR) is discussed. Also are considered the important measures and actions laid down in the Bulgarian legislation for prevention of nuclear incidents and accidents, as well as for minimizing the consequences thereof for people and environment.

Keywords: radioactivity; radiation protection; classification of incidents; Bulgarian legislation; nuclear accidents; human error

Introduction

An attempt has been made to review the most common radiation accidents in the world since the first years of peaceful use of nuclear energy to date.

Bulgaria is a member of the European Union. In this respect, the Bulgarian legislation is harmonized with the European legislation in the field of peaceful use of nuclear energy.

Basic legislation

First of all, this is the Act on the Safe Use of Nuclear Energy (ASUNE)[1)] which governs the public relations connected with the state regulations of safe use of nuclear energy and the sources of ionizing radiation, safe management of radioactive waste and spent nuclear fuel, as well as rights and obligations of the persons, performing these activities to provide nuclear safety and radiation protection. The state regulation of these activities is carried out by the Nuclear Regulatory Agency. And Health Act which governs public relations connected with the protection of public health.

Regulations

Regulation on basic safety standards for radiation protection

.Subject matter of this Regulation are the basic requirements for radiation protection, criteria and levels of exemption regulation, measures for radiation protection in carrying out activities for use of nuclear energy and sources of ionizing radiation in the sense of the ASUNE.

Regulation for radiation protection during activities with sources with ionizing radiation

This regulation specifies requirements and rules for radiation protection of the personnel and the population during performing of activities with sources of ionizing radiation, as well as procedures for reporting and control of radioactive sources, categorization of the radioactive sources and the respective activities in relation to the radiation risk.

Regulation on emergency planning and emergency preparedness in case of nuclear and radiological emergences

The actions and measures for limitation and liquidation of the consequences of nuclear or radiation accidents are planned, defined and implemented on the basis of the radiation risk assessment and the type of facility, the category of the radioactive source, the site or the specific risk creating practice, as well as the emergency class.

Regulation pf the protection for using licenses and permits for safe use of nuclear energy

The regulation specifies the licenses and permits to be issued, amended, renewed, terminated and withdrawn by the Chairman of the Nuclear Regulatory Agency (NRA) in accordance with the principles and under the conditions set by the ASUNE.

Regulation on terms and conditions for the acquisition of professional qualification and for the rules of issuing a specialized training license and certificates for the use of nuclear energy

The physical persons who carry out activities which have an impact on the safe operation of the nuclear facilities and SIR shall have appropriate professional qualification in accordance with the requirements of the Regulation.

Regulation No. 30 from 31 October 2005 on terms and conditions for providing protection for medical exposure

This regulation provides the conditions and the procedures for protection of people in case of medical exposure.

Regulation No. 27 from 30 June 2010 on confirmation of the medical standard "Diagnostic Imaging"

The Diagnostic Imaging is a separate medical specialty and scientific discipline which, with the help of various physical methods and the anatomical structure, allows diagnosis and treatment of diseases.

Regulation No. 11 from 30 June 2014 on confirmation of the medical standard "Nuclear Medicine"

The Nuclear Medicine is a medical specialty and a scientific discipline that uses open radioactive isotopes for diagnostic and healing activity. The Medical Standard regulates the methodological and analytical principles to be followed in order to achieve high quality nuclear medicine while keeping safety and protecting the rights of the patients and the staff.

Regulation No. 6 from 29 January 2010 on confirmation of the medical standard "Radiotherapy"

Radiotherapy is a major clinical medical specialty that aims by use of ionizing radiation primarily to treat malignant tumors, some borderline malignancies and some non-cancer diseases. Radiotherapy is part of the multidisciplinary approach to diagnosis, treatment, and follow-up in oncology by use of medicinal products.

Review

The actions and measures for limiting and eliminating the consequences of radiation incidents and accidents are described in the Regulation on *Emergency planning and emergency preparedness in case of nuclear and radiological emergency*, issued in State Gazette, No. 94 of 29 November 2011.[1)]

The required measures are planned, determined and implemented on the basis of radiation risk assessment and the type of facility, the category of the radioactive source, the site or the risk creating practice, as well as the emergency class. All previously planned actions, measures and events are called "Emergency Planning".

The activities, sites and facilities are given below.

Threat groups

Threat category I – nuclear facilities in which postulated initiating on-site events, including events of very low probability, could lead to an accident with significant release of radioactive substances in the environment and cause severe deterministic health effects off-site.

Threat category II – nuclear facilities in which postulated on-site emergency events could lead to an accident for which the projected dose could exceed the dose limits for the population off-site, which requires implementation of urgent protective measures onsite

Threat category III – nuclear facilities and sites with radioactive sources in which postulated on-site emergency events could lead to an irradiation or radioactive contamination of the environment above the permitted thresholds, which requires implementation of urgent protective measures only within the borders of the site.

Threat category IV – practices with nuclear materials and sources of ionizing radiation (SIR) that could lead to an accident in place, which cannot be foreseen or determined in advance, such as transport of nuclear materials and radioactive substances, practices with gamma ray detectors and other portable dangerous sources, including practices with dangerous sources which are illegally obtained.

Threat category V – facilities and practices which are not directly related to sources of ionizing radiation, but for which there is high probability of contaminating the production and uncontrolled spread of radioactive substances during their exploitation as a result of accident in threat categories I and II, or in other matters which can require implementation of protective measures.

Following, specific sites are described in the Regulation, which are classified in the respective category.

Depending on the possibility of control the processes during an accident and the severity of its consequences, for the purposes of emergency response, a given emergency in facilities, sites and practices is classified into one of the following classes.

General emergency class - This is an accident including actual or potential release of radioactive substances and exposure of the personnel and population, which requires implementation of urgent protective measures for the population; pronouncement of general emergency requires urgent protective measures to be promptly taken to reduce the accident's consequences and to protect the personnel and population.

Site area emergency class - This is an accident including a significant reduction of protection level of personnel and persons in the radiation protection area; pronouncement of a site area emergency requires immediate actions to be promptly taken to mitigate the consequences of the accident and to protect the personnel and also requires preparation for taking immediate protective measures for the population.

Facility emergency class - This is an accident including a significant reduction of the protection level of personnel without any risk for the population; pronouncement of a Facility Emergency requires immediate actions to be promptly taken to mitigate the accident's consequences and to protect the personnel.

Alert class - This is when events occur, the result of which is that protection level is uncertain or significantly decreased; pronouncement of an alert requires actions to be taken to evaluate the situation and measures to be taken to increase the preparedness for implementation of the emergency plans.

Other emergencies class - Such as find, loss or theft of a dangerous source of ionizing radiation, including re-entry of satellites containing dangerous sources of ionizing radiation.

To assure promptly and adequate response when an emergency occurs, according to the threat category and the emergency class, emergency planning zones are defined.

Emergency planning zones referred to the thread categories I, II and III are following: (1) On-site emergency planning zone – protected area; (2) Precautionary protective action planning zone; (3) Urgent protective action planning zone; (4) Long term protective action planning zone.

The boundaries of these zones are determined according to the following criteria: (1) for the *On-site Emergency Planning Zone* - the boundaries are the boundaries of the facility according to the project of the facility where sources of ionizing radiation are used; (2) for the *Precautionary protective action planning zone* – the annual effective dose in case of accident should not exceed 5 mSv outside the boundaries; (3) for the *Urgent protective action planning zone* – the estimated maximal individual doses per person at the border of the zone and outside for a beyond-design- basis accident are following: (a) effective dose of 5 mSv for the first year after the accident; (b) absorbed dose of 50 mGy in the thyroid gland; (4) for the *Long term protective action planning zone* – based on the results from the monitoring of the environment after the accident and the intervention levels for foodstuff and fodders.

The zones are divided into 16 sectors of 22.5° each, named with the first 16 letters of the Latin alphabet starting from North clockwise.

The zones for emergency planning for threat category IV and in case of emergency in a random or undetermined place are following: (1) *Secured zone* – the territory around the place of emergency occurrence, which is denoted with tapes and signs or in other suitable way and stays under direct control of the licensee or the relevant permit holder until arrival of the authorities of the Ministry or Interior; (2) *Zone with supervised access around the secured zone.*

In case of emergency of the Threat Category IV: (1) The outer boundary of the Secured Zone is differentiated as follows: (a) dose rate lower or equal to 100 µSv/h; radiation control is required when leaving it; (b) surface contamination which does not exceed 1000 part./cm^2.min for betaradionuclides and low radiotoxic alpha-emitters and 100 part./cm^2.min for all other radiotoxicity groups of alpha-emitter; (2) The outer boundary of the Zone with supervised access is differentiated where the dose rate is less or equal to 1,0 μSv/h; no humans or animals are allowed to enter the zone;. (3) No food and drink consumption or smoking is allowed for the personnel and the emergency teams, working within the zones.

Emergency planning is an activity of establishing a system of measures for mitigation and liquidation of the consequences of an accident and for creating and maintaining an emergency preparedness.

Emergency planning is based on the analyses of potential scenarios of occurrence and development of accidents and assessment of risk of the radiation consequences due to these accidents for the personnel, population and environment.

Implementation of measures in the emergency plan targets mitigation and reduction of emergency's consequences on human's health, quality of life, property and environment, and is also a base of recovering the normal conditions for social and economic life after liquidating the consequences of an emergency.

Nuclear accidents

Already in the early 20th century the first nuclear bombs began to produce nuclear accidents. And then others came.[2-4)]

1 September 1944, USA, Tennessee – Explosion in a uranium enrichment facility at the Oak Ridge National Laboratory. Five victims: two died, the other three were seriously injured.

19 June 1948, USSR, Site A at the Mayak Plant in Chelyabinsk district – Overheating of several uranium blocks of a nuclear reactor producing plutonium. All men working on the reactor and the soldiers helping to liquidate the accident were irradiated.

3 March 1949, USSR, Mayak Plant in Chalyabinsk District – Leakage of radioactive wastewater into Lika River. Irradiated are 124,000 people from 41 settlements in the district. Occurring of radiation illness is recorded.

12 December 1952, Canada, Chalk River Nuclear Power Plant, Ontario - Melting of the core due to overheating. Radioactive contamination of air and soil. About 4,000 cubic meters of radioactive water is poured into the soil near the Ottawa River.

29 November 1955, USA, Nuclear Reactor EBR-1, Idaho – The reactor suffered unintended meltdown, burning 40% of the active core.

29 September 1957, USSR – Radioactive waste repository of the Mayak plant in the Chelyabinsk district, near the town of Kichim. Explosion of a tank with radioactive substances. The power rating of the explosion is 70-100 tons of TNT equivalent. The resulting radioactive cloud covers Chelyabinsk, Tyumen and Sverdlov districts of an area of 20,000 square kilometers. Seriously suffered more than 5,000 people. The consequences of the accident were removed in the period 1957 to 1959 by more than 30,000 soldiers.

10 November 1957, UK, Nuclear reactor for plutonium in Windscale – Fire of the active zone burning for 4 days. Radioactive contamination spread across Great Britain and Ireland, and later also in Belgium, Denmark, Norway and Germany.

April 1967 USSR, Mayak Plant, Chelyabinsk district **-** Due to drought, the water of Lake Karachay, where the plant is dumping radioactive wastewater, is decreasing. The wind spreads the residual radioactive powder. Radioactive contamination over a territory of 1800 square meters with a population of 40 000 people.

1969, Switzerland, underground nuclear reactor in Lucens – Nuclear accident in the Lucens reactor with radioactive contamination of the whole cavern. The entrances of the reactor were filled with concrete and blocked forever.

1969, France, Saint-Laurent Nuclear Power Plant – Explosion of a reactor.

18 January 1970, USSR, Krasnoe Sormovo Plant in Nizhni Novgorod **-** Uncontrolled start of a nuclear reactor during the construction of a nuclear submarine. The reactor is running for 15 seconds. There are 1,000 workers in the workshop. Six of the victims were taken to Moscow. Three of them die. The accident is kept secret for 25 years. Thousands of people are working to eliminate the accident by April 24, 1970. Of these, only 380 people are still alive in January 2005.

22 March 1975, USA, Browns Ferry Nuclear Power Plant, Alabama **-** The fire in the reactor lasts for 7 hours and the power plant remains out of operation for many years.

28 March 1979, USA, Threemile Island Nuclear Power Plant, Pennsylvania – In case of a breakthrough in the equipment, 53% of the nitrogen zone of the reactor of the second power block melts. Radioactive xenon and iodine are spread in the atmosphere. 185 cubic meters of low-radioactive water flow into Squakahana River, 200,000 people are evacuated.

On the night of 25-26 April 1986, USSR (present-day Ukraine), the Chernobyl NPP – This is the largest to date nuclear accident. Partial destruction of the reactor core of the fourth power block. Approximately 200 tons of radioactive substances are dumped in the atmosphere. Eight of a total of 140 tons of the nuclear reactor fuel are spread in the air. The flames of the reactor burn for almost two weeks, spraying additional radioactive substances. Calculations show that people in Chernobyl are subjected to 90 times the radiation exposure of the Hiroshima bombing.

30 September 1999, Japan, Plant for production of fuel for the NPP in Tokaimura, Prefecture Ibaraki **-** An uncontrolled nuclear chain reaction has been triggered for 17 hours. 119 out of a total of 439 exposed persons receive irradiation several times above the permissible daily dose. Of the three critically ill patients, two die.

9 August 2004, Japan, Miamah NPP, west of Tokyo, Honsue – Steam discharge at a temperature of 200 ºC from the third reactor turbine. No radioactive contamination. There were 200 workers in the reactor building. High-temperature steam has burned people, of which 4 are killed and 18 are seriously injured.

11 March 2011, Japan, Fukushima NPP in Prefecture Okuma – The accident is caused by an earthquake and the following tsunami waves. During the earthquake, the first, second and third power units are switched off and remain on back up power supply. After 40 minutes the 14 meters high tidal wave flooded the plant. The protective wall can not stop the waves. The incoming water damages the power generators and the electronics of the units and interrupts the power supply. On 12 March, the population was evacuated within a radius of 10 kilometers around the plant. On 12 March, the first power block exploded, and on 14 March and 15, March the third and second blocks respectively. These explosions can not destroy the metal shells of the reactors. As a result, the radiation background increases sharply, but its value is still much lower than that which would have occurred if the integrity of the housings were destroyed. Japan's Nuclear and Industrial Safety Agency calculates the emitted radiation in the environment. These calculations show a value which is 15 times higher than the norm for a 7th grade accident. When comparing the values obtained from the Fokushima accident with Chernobyl, it was found that the radiation released was only 10 % of that in Chernobyl.[5)]

Conclusions

In all nuclear accidents described above, except the one in Fokushima, the main reason is a human error.

Specifically, for the Fokushima NPP there was a natural disaster – an earthquake with subsequent tsunami waves. But on the other hand, concerning the nuclear safety - the natural factor has been underestimated in this accident. The protective wall was designed to stop a 5.7 m wave. However, the tsunami wave, which flooded the plant, was 14 meters high. This fact could be seen as a human error – underestimation of radiation protection in the presence of natural disasters. Thus, knowledge of radioactive hazards is of the highest importance for safe radiation handling. Ultimately, it is very important that the personnel working in this field is highly qualified. However, this is not sufficient because science and technology develop and improve continuously. That's why the rules on radiation protection are updated all the time. In this connection, it is absolutely necessary to train continuously the personnel, working in the nuclear facilities. The purpose of this periodic training is to update the knowledge in accordance with the latest achievements of science and technology, as well as of the radiation protection.

In this connection, the Medical University of Varna holds a license issued by the Nuclear Regulatory Agency – Sofia, for specialized training of persons working with sources of ionizing radiation. The University is authorized to issue certificates for completion of such courses.

If we want to improve the life of the modern people, using the positive aspects of ionizing radiation, it is imperative and obligatory to observe the rules and measures for radiation protection. So we will protect ourselves and our world from the harmful effects of ionizing radiation.

Regarding radiation protection and nuclear accidents, it should be noted that the city of Varna is located by air at a distance of 340 km from the Kozloduy NPP, Bulgaria and about 120 km from the Cernavoda NPP, Romania.

Complying with stringent radiation protection measures and rules is also beneficial to our safety.

NOTES

1. http://www.bnra.bg/bg/documents/legislation/regulations/reg_empr.pdf
2. https://profit.bg/svetat/golemite-radiatsionni-avarii-i-katastrofi/
3. http://atominfo.ru/
4. http://atominfo.bg/
5. http://www.world-nuclear.org/

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