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Significance of Different Risk Factors for the Occurrence and Consequences of Radiation Accidents and Incidents

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Abstract

The most important radiation accidents and incidents are considered from the point of view of the significance of risk factors of such events. The priority of the "human factor" in the occurrence and development of radiation events of any type is noted. Taking into account the nature of radiation incidents and the degree of significance of risk factors, a system of urgent measures in case of their occurrence is proposed

Key words: radiation accidents and incidents: risk factors for their occurrence, emergency measures in case of their occurrence.

Introduction. Relevance of the problem. Despite the widespread use of SIR, if all hygienic requirements are met in the design, construction and operation of radiological facilities, radiation hazard for any category of population is unlikely. However, there is no 100% guarantee in any country that there will be no disturbances in the management of an ionizing radiation source caused by equipment malfunction, improper actions of personnel, natural disasters or other causes. Such situations are referred to as a radiation accident or radiation incident of various levels. Such situations all over the world are considered to be among the most serious man-made accidents that can lead to violation of radiation safety of the population, both due to external exposure and internal exposure in case of radioactive contamination of the environment and RE incorporation[1,2,3].

The causes of radiation accidents and incidents are very diverse and are both objective and subjective in nature. However, despite the numerous publications concerning these events, there is still no exhaustive systematization of the causes and consequences of radiation accidents from the point of view of singling out the most problematic causes of radiation accidents.

Materials of the research. To conduct the research, we collected materials on characterization of the most important radiation accidents and incidents that took place in the world for the period from the first radiation accident (1944) to 2011: IAEA reports, expert opinions of specialists, analytical materials posted on the Internet. Analysis of these materials made it possible to identify the causes of the most significant radiation accidents and incidents, to systematize them, and to determine the consequences for personnel and population. A total of 39 situations at nuclear reactors and 22 situations at facilities using other sources of ionizing radiation were considered.

Results of the study. Out of 39 analyzed accidents (including 27 accidents of Levels 4-7), 2 accidents were classified as Level 7 (Chernobyl and Fukushima accidents), 2 accidents were classified as Level 6 (Kyshtym accident and Windscale accident), 7 accidents were classified as Level 5, and 8 accidents were classified as Level 4 on the INES scale. The rest of the analyzed events are classified as Level 2-3 radiation incidents. Thus, a significant part (64.1%) of radiation incidents at NPPs and nuclear reactors has the character of accidents. 66.6% of these cases were accompanied by release of radioactive substances into the environment and exposure of personnel and liquidators.

Radiation accidents with broad adverse consequences can also include events that occurred at smaller-scale facilities, including the use of sealed SRI and even radiation generators. We have analyzed 22 such situations, of which more than half (58.3%) had the character of an accident, mainly of Level 4, and 41.7% were radiation incidents of Level 2-3.

Researchers dealing with the problem of radiation accidents at nuclear reactors believe that the main risk factors of such situations are the "human factor", in particular, violations of technological discipline by operating personnel and deficiencies in their professional training.

We have analyzed the significance and specific nature of risk factors of radiation accidents (RA) in the considered situations (Table 1.).

Table 1

Factors determining the occurrence of radiation accidents and incidents

Nature of the situation	Number analyzed analyzed cases	Cause and number of RAs with a given causal factor factor, abs/%		The nature of the accident "trigger"
Accidents at nuclear power plants levels 4-7	27	Human factor	14/ 51,8	Lack of competence personnel - 3
		Technological failure, imperfection of technology	10/ 37,0	Equipment wear and tear – 1 Design flaws – 1 Cooling system failure – 8
		Natural processes	3/ 11,1	Hurricanes -1 Earthquake, tsunami – 1 Shoaling - 1
Accidents at nuclear power plants levels 1-3	22	Human factor	18/ 81,8	Lack of competence personnel -2 Mismanagement -6 Staff dishonesty – 4 Staff illiteracy -6
		Technological failure	3/ 13,6	Equipment wear and tear -2 Design flaws - 1
		Natural processes	1/ 4,5	Hurricanes - 1

It turned out that in 14 out of 27 analyzed cases, the main reason for the occurrence of RA of 4-7 levels was the human factor - 51.8%. Of these, errors in equipment management amounted to 42.8%, insufficient training of personnel - 21.4%, safety violations - 28.6%, and negligence of personnel - 7.1%.

In radiation incidents, the "human factor" was even more significant: out of 22 analyzed situations, it occurred in 18 cases (81.8%). Of these, 33.3% were caused by errors in source management and elementary sanitary illiteracy of people, 22.2% - by bad faith (theft of radiation sources), 11.1% - by insufficient competence of personnel.

Technological causes of NPP accidents are mainly represented by reactor cooling system failure (80%), but in some cases (10%) there was equipment wear and tear or design deficiencies (10%). Occurrence of radiation incidents of Level 1-3 only in 13.6% was caused by technical reasons, and mostly (66.7%) - by equipment wear and tear. However, even in the case of technological failures, the trigger of such failures was most often (76-80%) incorrect actions of personnel.

The possibility of the impact of natural factors should not be discounted, but in comparison with other factors they are of much less importance: in the studied situations of NPP accidents they played the role of a trigger factor in 3 accidents (11.1%), and in radiation incidents of 1-3 levels - in 1 case (4.5%).

When analyzing the development of emergency situations, it was noted that at the time of an accident at nuclear reactors and immediately after it, the main danger is posed by high-power radiation, which causes the personnel and liquidators to receive high radiation doses. In accidents at non-nuclear facilities, the doses received are significantly lower, but the danger of receiving doses above the established limits remains throughout the emergency period

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In accidents at nuclear reactors, radioactive contamination of the environment is an almost obligatory consequence; in accidents at other facilities, the probability of radioactive contamination of the environment depends on the type of source used.

In the event of a radiation accident or incident, a number of actions should be taken urgently to prevent exposure of both personnel and the public. The nature of these measures should depend on the type of radiation event. Thus, in the case of Level 1-3 radiation incidents, the following measures are suggested (Table 2)

Table 2

Recommendations on the system of urgent measures in case of Level 1-3 radiation incidents

Type of radiation event	Immediate measures
Loss of SIR or discovery of unknown SIR	-informing the SAICM authorities -determination of the location of SIR - Measurement of radiation dose rate in the area where the SIR is located -Establishment of security guards and perimeter -Removal of people from the security zone -identification of radiation sources -Determination of individual doses to persons in the area of the incident -Source removal and decontamination
Disruption of shielding of continuous IIRs (isotopic IIRs)	-removal of people from the area of suspected exposure -Measurement of the radiation dose rate and establishment of the perimeter of the safety zone -Measurement of individual doses received -Removal from work of persons exceeding the established dose limit -Restoration of shielding
Safety violation when using an IR generator	-disconnection of the power supply to the IR generator -calculation of the estimated radiation dose received by personnel -dismissal from work of persons who have received a radiation dose above the established limit
Damage to the sealing of the isotope SIR	-Removing people from the incident area -Measurement of the radiation dose rate in the incident area and establishment of the perimeter of the safety zone -Identifying signs of RE dispersion and the level of radioactive contamination of facilities -in the presence of contaminated facilities -decontamination operations -control of individual radiation doses of persons in the zone of radioactive contamination -removal of radiation sources, their isolation, temporary storage with subsequent burial or reuse, provided that the source is fully restored to its tightness.
Cross-border movement of sealed SIR	-identification of the location of radiation sources -measurement of radiation dose rate, determination of the perimeter of the protection zone -identification of radiation sources -Measurement of individual radiation doses of persons within the protection zone -Retrieval of the SIR and its safe placement

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Transboundary transfer of radionuclides from RA in other countries as a result of natural processes	-measurement of the level and nature of radioactive fallout on soil, establishment of protection zones -determination of the level and identification of radioactive contamination of water and foodstuffs -calculation of external and internal radiation doses to the population -If necessary, making proposals to limit the consumption of contaminated water and foodstuffs.

Conclusions:

1.In a radiation accident of any level, the "human factor" plays a decisive role: the probability of technological failures, the speed and quality of response to the emergency depends on this factor

2.At the moment of an accident at nuclear reactors and immediately after it, the main danger is posed by high-power radiation, which causes the personnel and liquidators to receive high radiation doses; in case of emergency events at non-nuclear facilities, there may be no high radiation doses, but the danger of exceeding the radiation dose limit remains during the entire period of the emergency situation.

3.In an accident at nuclear reactors, one of the almost obligatory consequences is radioactive contamination of the environment; in accidents at other facilities, the probability of radioactive contamination of the environment depends on the type of source used.

4.In the event of radiation accidents or incidents, a number of actions should be taken urgently, the nature of which depends on the type of radiation event

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