Research on Nuclear Emergency Capacity Building and Assistant Decision-making System under New Situation

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Abstract: In view of the complex and changeable international situation and the fact that nucleus and radiation emergencies threaten the people more severely than before, this paper discusses the main tasks of nuclear emergency under the conditions of nuclear facilities accidents and nucleus and radiation terrorism respectively, analyses some problems existing in China's nuclear emergency capability, and puts forward several aspects that should be strengthened in the future. Finally, we summarize the research status and key technologies of assistant decision-making system of nuclear emergency, and carry out a detailed design of the optimized system composition and functional framework, which provides new ideas for controlling or mitigating the consequences of nucleus and radiation incidents.

1. Introduction

The current international situation is turbulent and changeable, and risks are difficult to control. With the rapid development of the global nuclear industry and the increasingly serious threat of nuclear terrorism under the new situation, especially the nuclear leakage accident at Fukushima Nuclear Power Station in Japan since the 21st century and the network smuggling of Kadeer Khan's nuclear materials in the black market, how to deal with the nucleus and radiation emergencies in time and control or mitigate the harmful consequences of radioactive material leakage has become the focus of social attention, which puts forward higher requirements for national nuclear emergency capacity building.

2. Nucleus and radiation Threat Situation Analysis

At present, the application of nuclear technology in military and civilian fields has become more and more extensive, but with the continuous occurrence of nuclear accidents, nuclear terrorism has also emerged, greatly increasing the risk of nuclear leakage.

2.1 Nuclear Facility Accident

On March 11, 2011, a 9.0 magnitude earthquake and tsunami occurred in Japan, causing the cooling systems of four units of Fukushima Daiichi Nuclear Power Station to fail successively. Then, the hydrogen explosion triggered a large number of nuclear leaks, which forced tens of thousands of people within 30 kilometres of the Fukushima Daiichi Nuclear Power Station to evacuate. Because the situation was not effectively controlled for a long time, some areas, including Tokyo, have been exposed to varying degrees of nuclear contamination, which further led to panic in Japan and some neighboring countries. With the rapid economic development, China is accelerating its nuclear power expansion plan. By September 2018, 44 reactors had been built with a net installed capacity of 40.7GWe, accounting for 10% of the world's nuclear power installed capacity. As the scale of nuclear power continues to expand, the possibility of nuclear accidents continues to increase.

2.2 Nucleus and radiation Terror

At present, with the development of nuclear technology and the wide application of nuclear

materials, the nuclear-related industries and personnel tend to be gradually popularized. The circulation and dissemination scope of nuclear technology and nuclear materials will be wider and wider. The channels for terrorists to acquire radioactive materials will increase and the difficulty will be reduced. The possibility of artificially disseminating radioactive materials will keep increasing, which offer conditions and opportunities to create nuclear terrorist activities. And the risk of carrying out such nuclear terrorist attacks as "dirty bombs" is also rising.

2.3 Nuclear Material Leakage

At present, nuclear technology has been widely used in industry, agriculture, medicine, military and other fields. As far as nuclear reactor is concerned, there are more than 500 commercial reactors worldwide, which provide 16% of the world's electricity. There are also more than 300 research reactors and military reactors which are difficult to calculate. There are a lot of radioactive materials in factories, nuclear power plants, hospitals, schools, scientific research institutions and other places. The management conditions and emergency mechanism standards of these institutions, facilities and places are different, and it is difficult to completely avoid the "source loss" incident.

3. Major Tasks of Nuclear Emergency

Major issues demanding in-depth study involve how to strengthen the research of nuclear emergency mechanism and capability, formulate corresponding accident rescue plans and countermeasures, master scientific methods of dealing with consequences and minimize the likely consequent personnel and property loss. Nuclear emergency is an urgent action to control or mitigate the consequences of nuclear accidents and other nucleus and radiation emergencies. Nuclear emergency tasks are usually carried out under complex situation.

3.1 Dealing with Accidents at Nuclear Facilities

3.1.1 Emergency radiation monitoring.

It is mainly implemented by the national and provincial (municipal) nuclear emergency and disposal forces. Radiation monitoring networks are established by using fixed or mobile nuclear radiation monitoring and reconnaissance equipment. Radiation monitoring and reconnaissance are carried out in the atmosphere and the air, ground, the surface of water and overwater areas to determine the extent and scope of radioactive contamination, identify the types of nuclides and verify them. Real-time monitoring of radiation change and situation assessment products such as radioactive substances transport routes, concentration distribution and land subsidence in nuclear accidents serve as a reliable basis for timely protection evacuation or relief of protection for personnel.

3.1.2 Protection.

It is supposed to carry out dose surveillance for personnel entering and leaving polluted areas, offer emergency radiation protection equipment and material support and assist local governments in guiding mass protection.

3.1.3 Decontamination

Decontamination stations are mainly set up by the chemical prevention and rescue disposal forces with the support of the engineering rescue disposal forces. Pollution suppression and elimination are carried out on personnel and vehicles, key roads, buildings, equipment and related areas. Contamination inspection and decontamination are carried out on personnel, vehicles and vessels evacuated from the polluted areas. Recovery, disposal or transport of radioactive contaminants are in action.

3.1.4 Medical Rescue

The primary medical rescue mission is mainly carried out by the relevant medical rescue forces. It includes giving protection and treatment to the public and rescue workers, carrying out early

treatment for the nuclear contaminated casualties just engaging in emergency washout, conveyance of the more serious casualties in batches after preliminary treatment, registering and visiting the unlicensed and non-injured persons, participating in the national medical service and assisting in the treatment of non-radiation injury and health and epidemic prevention.

3.1.5 Engineering rescue

The rescue and disposal forces are largely responsible for the emergency repair of nuclear facilities, emergency disposal of collapse and bridge rupture occurring iat evacuation passages, landslides on mobile roads and other places, implementation of road, bridge, helicopter landing and landing site security, rapid recovery of traffic, and may also be responsible for clearing radioactive plume subsidence areas and dealing with areas of ground pollution exceeding the standard.

3.1.6 Meteorological and Hydrological Guarantee

It is mainly implemented by the meteorological and hydrological departments of the state and the army. It includes monitoring real-time meteorological and hydrological elements such as precipitation, humidity, temperature, wind direction, wind speed, solar radiation, ocean current, visibility, thunderstorms and gales in the accident-related areas and providing medium-term and short-term meteorological and hydrological forecasting in the accident-related areas and assessment of environmental impact scope and environment affordability.

3.2 Dealing with Nucleus and radiation Terrorist Attacks

3.2.1 Radiation Reconnaissance and Source Finding

It refers to the use of portable detectors carried by people to carry out walking measurement sampling, or the use of vehicle-borne nucleus and radiation detectors for the rapid detection of small-scale, low-intensity radioactive substances. For suspected high-risk targets, unmanned nuclear radiation reconnaissance equipment can be used to conduct mobile patrol and reconnaissance through radio remote control to designated areas. For the target of water reconnaissance, it is generally carried out in the order of overwater-surface-underwater, that is, to monitor whether the air over surface water or water body is polluted first, and then to sample the silt on the water bottom to assess if there is pollution.

3.2.2 Personnel Protection

It refers to the dose supervision of personnel suspected of being infected with radioactive substances, the provision of emergency radiation protection equipment and material support and guiding local people to implement protective action.

3.2.3 Contamination inspection and decontamination

Contamination inspection and washout refers to the use of radiometers or radiographic indicators to detect radioactive substance contamination in suspected areas or persons and vehicles suspected of being contaminated. In case of contamination, elimination operations will be carried out on personnel and vehicles. After elimination, contamination inspection should be carried out on the washed objects to ensure that the decontamination is thorough and the harm is removed. The purpose of removing radioactive contaminants can also be achieved by suppressing decontamination and controlled removing of radioactive contamination on the surface of impermeable media and in small space with elimination equipment.

3.2.4 Situation Assessment of Event Discovery Site

It involves predicting the hazard scope and harm extent of radioactive substance contamination, providing the public with protection guidance and presenting disposal suggestions according to the real-time meteorological and hydrological conditions of the sites of terrorist incidents, the radiation aerosol dose rate and ground contamination dose rate reported on the radiation monitoring network and other data.

3.2.5 Transfer and treatment of the wounded

Similar to medical rescue operations in response to accidents at nuclear facilities.

4. Strengthening nuclear emergency capacity building

From the above analysis, we can see that the nuclear emergency task expected to be achieved is arduous and in a complex background. Capacity-building should be in accordance with the principle of civil-military integration and integration of peace and war, based on not only domestic situation but also potential cross-border support. It requires related staff to deal with not only accidents of military nuclear facilities of civil nuclear power plants and other clear objects but also threats from unknown targets such as nucleus and radiation terrorist attacks. With the rapid development of nuclear industry, a three-level nuclear emergency system for national and local nuclear power plants in China.But at present, there are still some problems in nuclear emergency capability, which are mainly reflected in the following aspects: the system and mechanism for the effective utilization of various related resources within the country have not yet been formed; the command and management situation of "offensive-defensive integration" has not yet been formed; the material preparation, personnel reserve, equipment reserve and technical reserve for dealing with nuclear threats to territorial security are not yet in place, which makes it difficult to play the role of emergency forces at all levels, such as the state, the army and the local government. In addition, China's nuclear emergency field has been relatively closed for a long time, and the comprehensive benefit of "military to civilian" is low, and the enthusiasm of "civilian participation" is not high, which not only affects the independent and controllable construction of emergency capacity, but also restricts the healthy and orderly development of emergency industry. As far as the current situation is concerned, the following aspects should be emphasized in order to improve the nuclear emergency capability and prevent possible nuclear accidents or nuclear-related emergencies in the future.

4.1 Establishing a Normalized and Smooth Nuclear Emergency Accusation Mechanism

It is necessary to set up a nuclear emergency and coordination committee at the national level to coordinate the emergency, decision-making, organization and command of the national nuclear radiation incident. At the same time, it is necessary to establish a mechanism of information exchange and cooperation between military and locality for nuclear radiation monitoring, reconnaissance and early warning, which is composed of military and local nuclear radiation information processing systems. For military nuclear radiation information processing system, there should be a reference to the existing military command system and a system structure of “tactical nuclear radiation information processing center-campaign nuclear radiation information processing center-strategic nuclear radiation information processing center”. For nuclear biochemical information processing system of department, there should a reference to the functional classification of the existing emergency system of the relevant functional departments of the state and a system structure of “enterprise-county(town) functional department-provincial (city) functional department-national functional department”. Joint operation command system should be integrated to realize the integration and share of information between military and locality, so that it has the functions of data receiving and storage, information fusion and release.

4.2 Formulating scientific and reasonable nuclear emergency plan

At present, China's nuclear safety management system is divided into different levels. The management of local nuclear radiation incident response matters at the provincial level has not been unified to the national level, lacking complete capacity and plan support. The compilation of nuclear emergency plan involves many specialties and departments, and needs extensive division of labor and cooperation. According to the main work, it can be divided into seven subsystems, including rescue and recovery subsystem, radioactivity monitoring, protection, decontamination and medical rescue subsystem, crisis public relations subsystem, evacuation, conveyance and

arrangement subsystem, life service and market supervision subsystem, security subsystem and training and popularization subsystem. In addition, three areas need to be set up, namely, evacuation emergency plan area, smoke plume emergency plan area and eating emergency plan area, and emergency evacuation preparations should be made in stages.

4.3 Strengthen the Construction of Complete Nuclear Emergency Equipment System

For the nuclear emergency needs in complex situations, it is supposed to base on not only the needs of normal response to nuclear accidents but also diversified nuclear emergency tasks in various complex situations. At present, although nuclear emergency equipment has formed a system of "reconnaissance, inspection, elimination, prevention and treatment", it is difficult to meet the needs of completing diversified nuclear emergency tasks because of the relatively single type. This requires relevant departments to focus on the whole process of nuclear emergency, establish dimensional emergency concept and improve the existing nuclear emergency equipment system. In terms of equipment types, in view of the whole process of nuclear emergency, it is supposed to increase equipment for "removal, transportation and storage", i.e. equipment for eliminating nuclear contamination, transporting and temporary storage of nuclear waste; in terms of equipment platform selection, it is supposed to highlight the dimensional nature and properly increase air, overwater and underwater nuclear emergency equipment; in terms of equipment performance, "point-to-surface integration" should be realized to enable handling both single target and massive nuclear contamination; in terms of equipment development, it is supposed to adhere to "combining general use with special use" and make breakthroughs in key equipment and technology to meet the needs of nuclear emergency capacity-building.

4.4 Constructing a Professional and Complete Rescue Training System

It is necessary to should strengthen the learning of theoretical knowledge about the modes, principles, characteristics and tasks of emergency rescue operations in accordance with the requirements of nuclear emergency rescue operations and focus on typical nuclear emergency rescue operations, lay emphasis on actions involving the nature of nuclear rescue and master the procedures, contents and methods of rescue operations. It is necessary to strengthen the professional action training of radiation monitoring and reconnaissance skills, protection skills, decontamination and disposal skills and check and rescue skills and improve the professional response ability. It is supposed to organize centralized separate training for the same specialty according to the type and profession composition of rescue personnel and combine it with field training and professional training. It is necessary to distinguish the types of emergency rescue operations according to the harmful nature of nuclear and radiation incidents and construct corresponding training content system. It is necessary to improve professional accomplishment and disposal capability, organize professional nuclear emergency teams and technical supporting forces at regular intervals, implement nuclear emergency safety disposal exercises and enhance the combat-oriented nuclear emergency disposal capability.

4.5 Deployment of a Rapid and Effective Nuclear Emergency Assistant Decision System

In the case of serious accidents or sudden nuclear and radiation terrorist attacks in nuclear power plants and other nuclear facilities, with the aid of evaluation models and relevant environmental monitoring information, the risk of radioactive release to the environment and the public can be analyzed and predicted by nuclear emergency assistant decision-making system, and the decision makers can acquire useful technical support to adopt scientific and reasonable emergency and protection measures. In addition, emergency actions can be implemented timely, which plays an important role in mitigating the consequences of accidents and protecting the public and the environment.

5. Analysis of Nuclear Emergency Assistant Decision System

Nuclear emergency assistant decision-making system defined in this paper refers to assisting the

command and decision-making organs of emergency forces to implement emergency plans for the state, locality and accident areas, carrying out timely emergency response actions when serious accidents or sudden nucleus and radiation terrorist incidents occur in nuclear power plants, nuclear fuel depots and other nuclear facilities. The system can offer specifically nuclear radiation monitoring and reconnaissance station layout, radioactive material transmission path, concentration distribution, land subsidence status and environmental affordability assessment, personnel concealment and evacuation path selection, accident area control and rescue team entry path, washout mode selection and other auxiliary decision support.

5.1 Research Status

Many countries in the world have developed their own decision support system for off-site emergency response to nuclear accidents. In the 1970s, United States Department of Energy carried out a large number of simulation research projects and applied them in the field of emergency response to nuclear accidents, such as ARAC system. The integrated use of three-dimensional atmospheric diffusion model, meteorological and hydrological data acquisition model and geographic information database can offer real-time prediction of dose rate level, surface contamination and water pollution regarding nuclear power plant accidents and nuclear power platform reactor accidents occurring at/above sea level.Finland has developed RADICAL system, which can collect radiation monitoring, pollution distribution, meteorological data and emergency actions, and display the panoramic situation of accidents. The EU has developed RODOS system, which has real-time online decision support capability for nuclear accidents. It is similar to open source system. It provides the basic prototype of nuclear accident emergency decision support system. Users can customize it according to specific circumstances. In the mid-1990s, China began to work on the research of assistant decision-making system for nuclear emergency. With RODOS system as the development platform, in light of the actual situation of our country, nuclear emergency system and accident consequence evaluation system have been established for the state, locality and nuclear power station respectively.

5.2 Key Technologies

When nucleus and radiation incidents occur, in order to quickly complete the radiation dose/dose rate estimation of radioactive materials, predict the direction and area of radiation plume diffusion and provide scientific basis for personnel protection and evacuation, the following key technologies need to be further studied: (1) radiation monitoring and reconnaissance in the field and related areas; (2) on-site real-time meteorological and hydrological information and medium-term and short-term meteorological and hydrological forecasting for related areas; (3) radioactive material transmission path, concentration distribution, land subsidence status and environmental affordability assessment; (4) monitoring station layout, personnel concealment and evacuation path selection, emergency area control and rescue team entry path, decontamination method selection, etc.

5.3 System Composition and Function Block Diagram

The decision support system for nuclear emergency is based on support network and legal standards. It consists of nuclear emergency radiation monitoring subsystem and assistant decision-making subsystem for nuclear emergency. The functional framework of the system is shown in Figure 1. The former provides the latter with multi-source and wide-area monitoring data for the latter, which includes fixed station radiation monitoring, personnel walking radiation monitoring, vehicle mobile radiation reconnaissance, UAV radiation reconnaissance, ground robot radiation reconnaissance, surface patrol boat/underwater submarine radiation reconnaissance, space-based (space borne) radiation monitoring and early warning modules.For example, space borne monitoring can realize universe land monitoring of extensive nuclear and radiation events by carrying effective detection load and relying on the three-generation BeidouNavigation Satellite Constellation, Early Warning Satellite Constellation or Medium Orbit Satellite in China. The latter is used to process the monitoring data and output the processing results in a simple and intuitive way. It mainly consists of analysis and processing module, model base module, database module,

digital map module and display module. It can automatically acquire, storage, output and verify radiation data, terrain data, meteorological data, etc. It has situation awareness and various function including display and check, model calculation, processing and analysis, hazard assessment, decision support, submission and publication, and can realize the scientific and reasonable nuclear emergency assistant decision-making function.

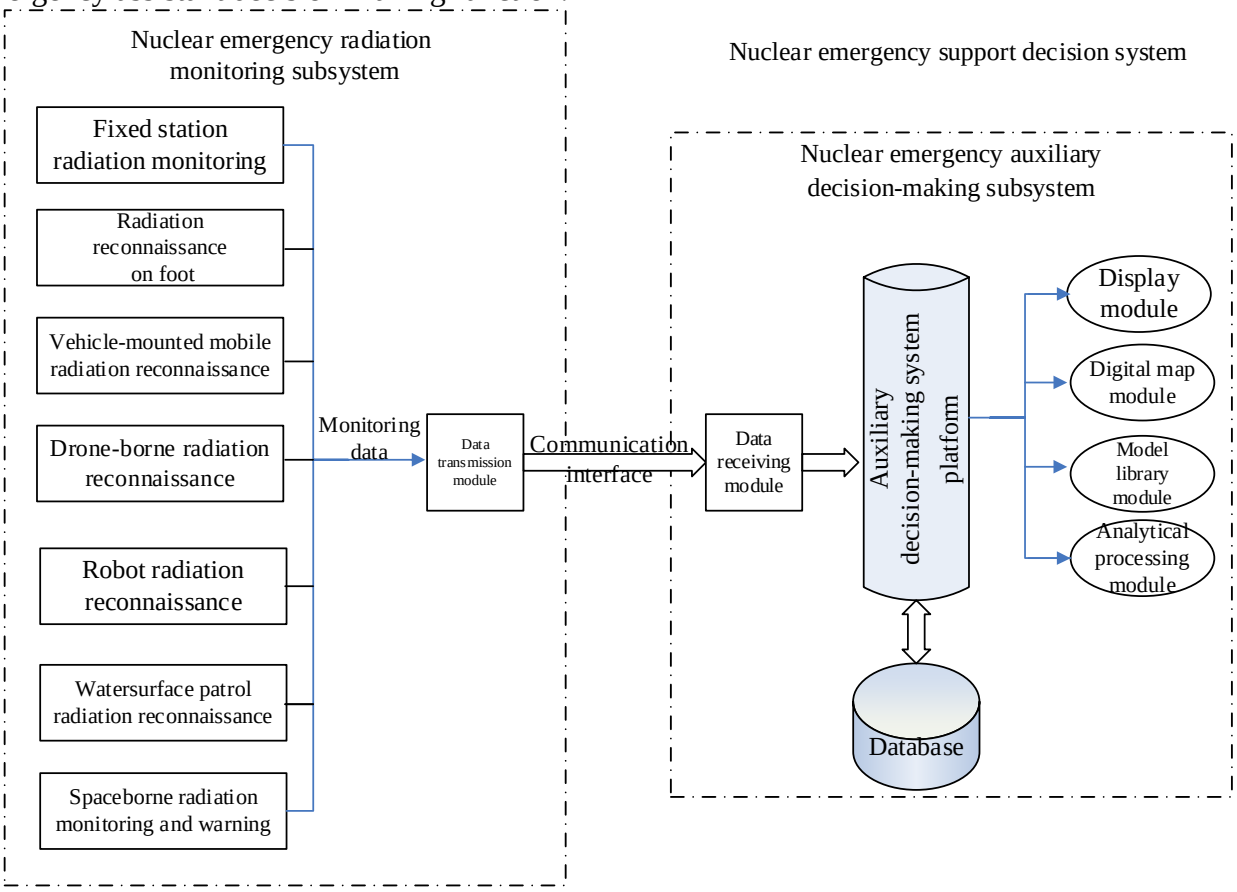

Figure 1 Functional framework of nuclear emergency support decision-making system.

6. Conclusion

In the face of nucleus and radiation threats in the new situation, it is necessary to take precautions against possible disasters, take precautions, optimize and improve the construction auxiliary decision-making system construction while strengthening the nuclear emergency capacity building, so as to effectively respond to sudden nuclear facilities accidents, quickly deal with nucleus and radiation terrorist attacks and fulfill the sacred responsibility of nuclear emergency forces.

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