

# System and capability of public health response to nuclear or radiological emergencies in China

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## ABSTRACT

In order to respond to nuclear or radiological emergencies effectively and protect the physical and mental health of the public, the national-, provincial-, municipal- and county-level public health response systems for nuclear or radiological emergencies had been established in China by the end of twentieth century. The health administrative departments at all levels have established professional emergency response teams, continue to improve their own level of emergency response systems and operating mechanisms, enhance the capabilities of radiation injury treatment, radiation monitoring and protection through training and exercises and also pay attention to the logistical support for emergency response. In this article the organizations, management system and capabilities of public health response to nuclear or radiological emergencies in China are briefly introduced. We try to strengthen information exchange and cooperation with foreign counterparts in this field in the future, so as to jointly promote the development of preparedness and response for nuclear or radiological emergencies.

**Keywords:** radiation injury treatment; radiation monitoring; nuclear or radiological emergencies; public health response; international cooperation

## INTRODUCTION

The application of nuclear energy is developing rapidly in China. As of December 2020, 50 nuclear power units, distributed in nine provinces or autonomous regions of China, had been connected to generate electricity with a total capacity of 47.518 million kilowatts [1]. This accounts for 4.88% of the country's power generation (2019) [2]. There are also 12 nuclear power reactors under construction in China, which accounts for about a quarter of the number of reactors under construction in the world [1]. According to *The Annual Report of the Development of China's Nuclear Energy 2020*, the electricity generating capacity of operated nuclear power units will reach 70 million kilowatts, and those under construction will reach 30 million kilowatts by 2025 [2]. However, nuclear and radiation technology is a 'double-edged sword.' While it benefits mankind, once a nuclear or radiological accident occurs, it may cause not only serious health damage to the public in the surrounding areas, but also social psychological impact on a large area far beyond the accident location [3, 4]. The Chernobyl nuclear power plant accident in the former Soviet Union in

1986 [5, 6] and the Fukushima dai-ichi nuclear power plant accident in Japan in 2011 [7] have already sounded alarm bells for human beings. There are more than 100 nuclear power reactors in operation in neighboring countries of China [1]. If serious accidents occur at these nuclear facilities, they may also have an impact on the environment and the public in China, such as contamination of domestically produced food and drinking water, body surface radiological contamination of residents and evacuees and psychosocial effects [8–10]. In addition to nuclear power, China has also developed rapidly in the application of radiation technology. At the end of 2019, there had been 78 802 radioactive source users in China, with a total of 355 891 sources and 19 821 radiation-emitting devices [11] which were widely distributed in the fields of medical treatment, industry, agriculture and scientific research. According to the reports published by the National Nuclear Safety Administration of China, 185 radiological accidents happened between 2006 and 2019 in China [11], some of which caused serious radiation injury and even death for exposed victims [12, 13].

In order to deal with nuclear or radiological emergencies and carry out response actions effectively and promptly, China has established four levels of public health response systems for nuclear or radiological emergencies, from the national level to the provincial, municipal and county levels. Through continuous development in recent years, the response capabilities have been significantly improved. The response systems have played an important role in minimizing casualties and social impact caused by radiation accidents or events in China [12].

## EMERGENCY RESPONSE SYSTEMS

### Organizational structure for emergency response

In order to strengthen the leadership of nuclear accident prevention and rescue, the National Nuclear Accident Emergency Coordination Committee (NNAECC) was established in 1995. Led by the Ministry of Industry and Information Technology, the NNAECC coordinates and organizes the nuclear emergency preparedness and response activities at national level. In addition to the leading department, the main members of the NNAECC and their responsibilities are followed. The National Health Commission is responsible for the organization and coordination of public health or medical response to nuclear accidents. The Ministry of Ecology and Environment takes charge of radiation monitoring and identification of contaminated areas. The Ministry of Public Security is responsible for the organization and coordination of emergency area control, law enforcement, security guard and traffic control. The Ministry of Emergency Management takes charge of public transfer and salvation. All members in the NNAECC work together to fulfill the nuclear emergency response tasks in accordance with the requirements of *Regulations on Emergency Management of Nuclear Accidents at Nuclear Power Plants*, *National Nuclear Emergency Plan* [14] and other relevant regulations or plans. In terms of response to radiation accidents, according to the *Regulations on the Safety and Protection of Radioisotopes and Radiation-emitting Devices* [15], the ecology and environment authority is the leading department responsible for investigation, grading and emergency management of radiation accidents, and the health authority takes charge of the medical response to radiation accidents.

This kind of interdepartmental coordination mechanism, under the responsibility of a leading department, for response to nuclear or radiological emergencies is established by many countries in the world. In the USA, the Federal Emergency Management Agency (FEMA) chairs the Federal Radiological Preparedness Coordinating Committee (FRPCC), which consists of multiple federal departments and is responsible for the development and coordination of radiological emergency planning and preparedness activities [16]. As a member of the FRPCC, the Department of Health and Human Services takes charge of developing protective actions, providing guidance for human food and mental health [16], similar to the role of its counterpart in China (the National Health Commission).

China has established multilevel emergency organizations of public health or medical response to nuclear or radiological accidents, including the national, provincial, municipal and county levels (Supplementary Fig. 1). The organization structure of China applies the principles of territorial management and assignment of responsibility to different levels. Similar principles are also adopted by several countries, such as the USA and Japan. The emergency

system in the USA follows the guideline of tiered response and a four-level response system—at the community, local, state and federal levels—has been established [17]. In China, the health administrative department at each level leads the designated institutes for radiation injury treatment and institutes for radiological protection (generally centers for disease control and prevention or institutes for occupational diseases control) at the same level. In addition, the higher-level administrative departments or institutions guide the work of their lower-level counterparts. In terms of the coordination across the different departments, the National Health Commission organizes and carries out public health or a medical response under the unified coordination of NNAECC in case of nuclear emergencies, and also exchanges information and cooperates with other relevant departments.

### Institutes and teams for emergency response

In order to improve and maintain the nuclear emergency response capacities, in 2014 the NNAECC established the national medical rescue technical support center, 13 national medical rescue teams and two national medical rescue training bases for nuclear emergency (Supplementary Fig. 2).

The health administrative departments have also established multi-level medical rescue institutes for nuclear or radiological emergencies. At the national level, the Chinese Center for Medical Response to Radiation Emergency (CCMRRE) has been established (with three clinical departments, one monitoring and evaluation department and one technical support department); six national medical rescue bases for nuclear or radiological emergencies (in the cities of Beijing and Tianjin, provinces of Liaoning, Jilin, Jiangsu and Guangdong) and three national medical rescue teams for nuclear or radiological emergencies (in the city of Beijing and provinces of Jiangsu and Guangdong) have been founded or are to be founded. The national-level bases and teams are mainly responsible for off-site medical support for general nuclear emergencies, as well as in-hospital treatment of patients with very severe acute radiation syndrome (ARS) or severe internal contamination. Nineteen provincial-level medical rescue bases for nuclear or radiological emergencies have been established or are to be established, while provincial-level institutes for radiation injury treatment have been designated in other provinces. The main tasks of provincial-level rescue bases or designated institutes are off-site medical support for nuclear or radiological emergencies, as well as in-hospital treatment of patients with moderate to severe ARS or internal contamination. The organization of national- and provincial-level medical rescue bases for nuclear or radiological emergencies is shown in Supplementary Fig. 3. The health administrative departments of cities and counties, where the nuclear power plants or facilities are located, have designated the municipal- and county-level institutes for radiation injury treatment, respectively. The designated institutes or teams for public health or medical response to nuclear or radiological emergencies at each level are generally professional institutes or personnel devoted to scientific research, postgraduate training, technical supervision and technical support in the field of radiological protection and medical treatment for radiation injury. Under the leadership of the National Health Commission, those emergency bases or teams have played an important role in public health or medical response to multiple nuclear or radiological emergencies in the past.

### Emergency management and operating mechanism

At the national level, the NNAECC has formulated the *National Nuclear Emergency Plan of China*, which stipulates the responsibilities of the health authorities as mentioned above. The National Health Commission has also formulated the *Health Emergency Plan for Nuclear and Radiological Accidents*, which specifies the responsibilities and tasks of the CCMRRE, the national-level and provincial-level medical rescue bases and institutes for radiological protection. The CCMRRE, established by the National Health Commission, undertakes nationwide technical management and support of medical or public health preparedness and response for nuclear or radiological emergencies. In addition, the National Health Commission has set up an expert panel for a public health response to nuclear or radiological emergencies. Consisting of experts in radiological medicine, radiological health, radiation protection and nuclear safety, the panel is responsible for providing suggestions on emergency preparedness and the response regarding nuclear or radiological accidents, participating in the revision of plans for a medical emergency and guiding the emergency response training and exercises.

The health administrative departments at the provincial, municipal and county levels also actively carry out the construction of the emergency management system and operating mechanism in accordance with their own responsibilities in medical response to nuclear or radiological emergencies. The survey in 2017 (see the details in the next section) showed that 64.5% of the provincial-, 67.3% of the municipal- and 56.1% of the county-level health administrative departments had established their own leadership group for public health response to nuclear or radiological emergencies; 64.5% of the provincial-, 59.2% of the municipal- and 53.7% of the county-level health administrative departments had formulated their own emergency plans for nuclear or radiological emergencies; 38.7% of the provincial health administrative departments had established the coordination mechanism with other relevant departments for nuclear emergency response at the same level (Table 1). Since the *Regulations on Emergency Management of Nuclear Accidents at Nuclear Power Plants* specifies that the provincial government where the nuclear power plants are located is responsible for the emergency management of nuclear accidents in their administrative areas (but do not stipulate for the municipal and county governments), the provincial health administrative departments are more proactive in formulating the emergency plans and establishing the coordination mechanism than the lower-level administrative departments. Besides, 61.3% and 93.5% of the provincial health administrative departments set up expert panels and medical rescue teams for nuclear or radiological emergencies, respectively, which showed that the provincial-level departments also paid attention to the role of emergency professionals. Although the proportion of the health administrative departments at the municipal and county level which had established the rescue teams for nuclear or radiological emergencies was lower than that at the provincial level, it reached more than 50% at the municipal and county level (Table 1).

### CAPABILITIES IN EMERGENCY RESPONSE

In order to assess the present status of medical or public health response capacities for nuclear or radiological emergencies in China, the CCMRRE carried out a nationwide survey in 2017 [18]. The survey covered

31 provinces (or autonomous regions, municipalities directly under the central government), 49 prefecture-level cities and 41 counties or key border areas where nuclear facilities are located; the subjects of the survey were national-, provincial-, municipal- and county-level health administrative departments, institutes for radiation injury treatment and institutes for radiological protection. The contents of the survey included the individual subject's responsibilities, financial support, professional personnel, training and exercises, materials and equipment, capabilities of radiation monitoring and radiation injury treatment, etc.

### Capabilities in radiation injury treatment

The national medical rescue technical support center (and sub-centers) and the national medical rescue bases for nuclear or radiological emergencies should have the capabilities of on-site first aid for those wounded by nuclear or radiological accidents, decontamination of the injured patients, in-hospital treatment of patients with severe ARS or internal contamination, guiding for iodine thyroid blocking, performing psychological assistance and medical follow-up, etc. Among them, the national medical rescue technical support center (and sub-centers) for nuclear emergency is composed of five units, each of which has advantages in certain specialized fields (Fig. 1) while they all have basic medical rescue capabilities. Therefore, when various types of nuclear or radiological emergencies occurred, they can be deployed for different tasks. The six national-level rescue bases are located in capital circle, north-eastern China (key border areas), and south-east coast region (where nuclear power plants are mainly distributed). The regional distribution of those bases is reasonable, which meets the needs of rapid deployment to key facilities or areas.

The provincial medical rescue bases can carry out on-site and in-hospital medical treatment of the injured patients in nuclear or radiological accidents. Each provincial base should have the capacities and capabilities to simultaneously treat five patients with moderate to severe ARS, 20 patients with a radiation combined injury and 30 patients with mild ARS. The survey showed that 60–80% of the provincial-level institutes for radiation injury treatment had the capabilities of on-site first aid, medical classification, detection of radioactive contamination, treatment for ARS and radiation injury of the skin, guiding for iodine thyroid blocking and offering psychological assistance (see Table 2). On the whole, about 30% of the provincial-level institutes are relatively competent in professional capabilities, most of which are located in eastern China (generally developed areas), while the technological capabilities of provincial-level institutes in northern and western China (economically underdeveloped area) are relatively poor.

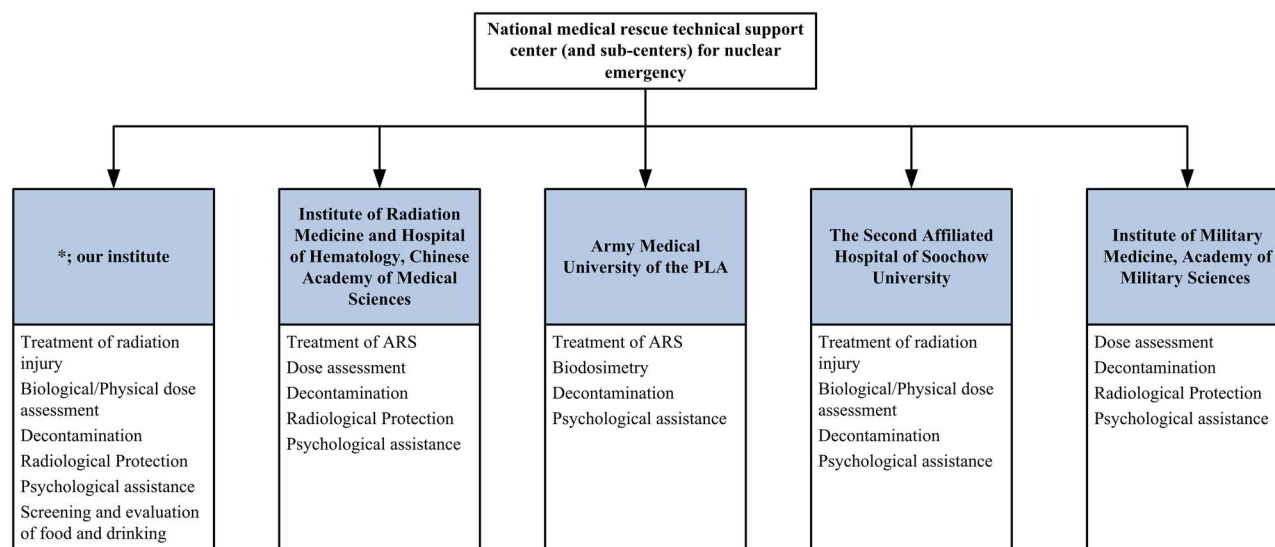
Regarding municipal-level institutes for radiation injury treatment, about 40% of them could provide medical support in nuclear or radiological emergencies (such as on-site first aid), and about 20% of them have the basic capabilities of radiation injury management, e.g. medical classification and transporting contaminated patients (Table 2). As for county-level institutes for radiation injury treatment, about 10–30% of them could perform on-site first aid and medical classification (Table 2), and thus they can only play an auxiliary role in a medical response to nuclear or radiological emergencies.

**Table 1. The emergency management system and operating mechanism established by health administrative departments at the provincial, municipal and county levels in China**

Level	Established the leadership group of medical response to nuclear or radiological emergencies		Formulated the emergency plans for nuclear or radiological emergencies		Established coordination mechanism with other relevant departments of nuclear emergency response at the same level		Set up the expert panel for nuclear or radiological emergencies		Set up the medical rescue team for nuclear or radiological emergencies	
	Number <sup>a</sup>	% <sup>b</sup>	Number <sup>a</sup>	% <sup>b</sup>	Number <sup>a</sup>	% <sup>b</sup>	Number <sup>a</sup>	% <sup>b</sup>	Number <sup>a</sup>	% <sup>b</sup>
Provincial level	20	64.5	20	64.5	12	38.7	19	61.3	29	93.5
Municipal level	33	67.3	29	59.2	9	18.4	21	42.9	28	57.1
County level	23	56.1	22	53.7	7	17.1	11	26.8	21	51.2

<sup>a</sup>The number of the health administrative departments at each level having established corresponding emergency management system or operating mechanism.

<sup>b</sup>The ratio of the number listed on the left to the total number of the departments being surveyed (31 for the provincial level, 49 for the municipal level and 41 for the county level).

**Fig. 1. The respective advanced specialties of the five constituent units of the national medical rescue technical support center for nuclear emergency.**

### Capabilities in radiation monitoring and protection

The national-level institute for radiological protection has the capabilities of on-site radiation monitoring and protection, personnel radioactive decontamination, internal and external dose assessment for radiation injury or those who have been contaminated, health effects evaluation for the affected population, screening and evaluation of potentially contaminated food and drinking water, etc.

The provincial-level institutes for radiological protection continuously have been improving their capacities in recent years. The survey showed that over 70% of the provincial-level institutes could carry out on-site radiation monitoring, surface radiological contamination monitoring,  $\gamma$ -ray spectrum analysis, individual X/ $\gamma$  dose measurement and dose estimation by on-site simulation, 67.7% of them could perform biodosimetry estimation with

chromosome aberration assays, and 35.5% of them had the capability for radioactivity analyses for Sr-89/90 and H-3 (Table 3). Most of the provincial-level institutes for radiological protection had the capabilities of on-site radiation monitoring, dose assessment and screening of food and drinking water, while about 30% of them can carry out more superior tasks, e.g. carrying out the assay of key radionuclides.

The capabilities of the municipal- and county-level institutes for radiological protection need to be further enhanced. The survey showed that about 30% of the municipal institutes have the basic radiation monitoring and protection capabilities, such as on-site radiation monitoring, surface radiological contamination monitoring, and food and drinking water sample pre-treatment, while about 10% of the county-level institutes could perform on-site radiation monitoring

**Table 2. Capabilities and facilities of the institutes for radiation injury treatment at the provincial, municipal and county levels in China**

Capability/facility	Provincial level		Municipal level		County level	
	Number <sup>a</sup>	% <sup>b</sup>	Number <sup>a</sup>	% <sup>c</sup>	Number <sup>a</sup>	% <sup>d</sup>
On-site first aid	26	76.5	22	39.3	10	26.3
Rescue for critical patients	26	76.5	N/A	N/A	N/A	N/A
First aid for contaminated patients	20	58.8	N/A	N/A	N/A	N/A
Medical classification for radiation injury	21	61.8	10	17.9	5	13.2
Detection of radioactive contamination	21	61.8	5	8.9	2	5.3
Management of contaminated wounds	19	55.9	N/A	N/A	N/A	N/A
Transportation of contaminated patients	20	58.8	11	19.6	5	13.2
Treatment for ARS	22	64.7	N/A	N/A	N/A	N/A
Laminar flow wards	21	61.8	9	16.1	4	10.5
Treatment for radiation injury of skin	22	64.7	N/A	N/A	N/A	N/A
Treatment for internal contamination	20	58.8	N/A	N/A	N/A	N/A
Whole body decontamination	15	44.1	N/A	N/A	N/A	N/A
Dedicated decontamination room	12	35.3	N/A	N/A	N/A	N/A
Guiding for iodine thyroid blocking	23	67.6	9	16.1	3	7.9
Offering psychological assistance	23	67.6	12	21.4	6	15.8

<sup>a</sup>The number of the institutes for radiation injury treatment having the corresponding capability/facility.

<sup>b</sup>The ratio of the number listed on the left to the total number of the provincial-level institutes for radiation injury treatment being surveyed (34).

<sup>c</sup>The ratio of the number listed on the left to the total number of the municipal-level institutes for radiation injury treatment being surveyed (56).

<sup>d</sup>The ratio of the number listed on the left to the total number of the county-level institutes for radiation injury treatment being surveyed (38).

N/A: not applicable.

**Table 3. Capabilities of the institutes for radiological protection at the provincial, municipal and county levels in China**

Capability	Provincial level		Municipal level		County level	
	Number <sup>a</sup>	% <sup>b</sup>	Number <sup>a</sup>	% <sup>c</sup>	Number <sup>a</sup>	% <sup>d</sup>
On-site radiation monitoring	29	93.5	20	38.5	5	10.6
Surface contamination monitoring	29	93.5	17	32.7	1	2.1
Individual X/γ dose measurement	30	96.8	N/A	N/A	N/A	N/A
Dose assessment by on-site simulation	22	71.0	N/A	N/A	N/A	N/A
Dose assessment by chromosome aberration assays	21	67.7	N/A	N/A	N/A	N/A
γ-ray spectrum analysis	23	74.2	N/A	N/A	N/A	N/A
Radioactivity measurement for Sr-89/90	11	35.5	N/A	N/A	N/A	N/A
Radioactivity measurement for H-3	11	35.5	N/A	N/A	N/A	N/A
Internal dose estimation	9	29.0	N/A	N/A	N/A	N/A
<i>In vivo</i> radioactive measurement	1	3.2	N/A	N/A	N/A	N/A
Drinking water sample collection and pre-treatment <sup>e</sup>	N/A	N/A	20	38.5	5	10.6
Food sample collection and pre-treatment <sup>e</sup>	N/A	N/A	15	28.8	5	10.6
Radiation monitoring of food	22	71.0	N/A	N/A	N/A	N/A
Radiation monitoring of drinking water	24	77.4	N/A	N/A	N/A	N/A
Skin decontamination for affected individual	20	64.5	N/A	N/A	N/A	N/A

<sup>a</sup>The number of the institutes for radiological protection having the corresponding capability.

<sup>b</sup>The ratio of the number listed on the left to the total number of the provincial-level institutes for radiological protection being surveyed (31).

<sup>c</sup>The ratio of the number listed on the left to the total number of the municipal-level institutes for radiological protection being surveyed (52).

<sup>d</sup>The ratio of the number listed on the left to the total number of the county-level institutes for radiological protection being surveyed (47).

<sup>e</sup>It refers to sample collection capability for the county-level institutes.

N/A: not applicable.

and collect food and drinking water samples (Table 3). It revealed that the municipal- and county-level institutes could only engage in the

auxiliary work of the public health response to nuclear or radiological emergencies.

### Logistic and financial support, training and exercises

In 2020, the COVID-19 pandemic spread worldwide and impacted the effectiveness of most countries' health systems, which highlighted the importance of adequate assurance of emergency personnel and materials in response to public health emergencies. In coping with the pandemic, the multilevel health authorities in China coordinated to deploy professional personnel and critical equipment (such as ECMOs), originally in various provinces to severely affected areas, which played an important role in effective treatment of COVID-19 patients and successful epidemic control. Similarly, in public health or the medical response to nuclear or radiological emergencies, it is also necessary to effectively allocate various resources to ensure sufficient professional personnel, funds and materials for an emergency response.

The national-level medical rescue bases for nuclear or radiological emergencies, which are located in Beijing and Tianjin (founded in 2005), have a total of 40 laminar flow beds for the treatment of severe ARS, 80 ordinary ward beds for the management of radiation diseases and 160 square meters of dedicated radioactive decontamination rooms. The newly founded national-level medical rescue bases, which are located in provinces of Liaoning, Jilin, Jiangsu and Guangdong, are under construction. About 20 million RMB (about US\$3.08 million) will be invested in each new base, mainly for purchasing special equipment or instruments for radiation monitoring, construction of a laminar flow ward, radioactive decontamination rooms and other facilities. Each national medical rescue team for nuclear or radiological emergencies consists of about 30 members, including professional personnel in medical classification, radiation protection, radiation monitoring, decontamination, psychological assistance and support personnel in logistics management and communication support. Each national rescue team will obtain the annual operating expenses approximately 900 000 RMB (about US\$138 000), mainly for the provision of consumables (e.g. protective suits), training or exercises and equipment maintenance. The national rescue team from the CCMRRE is composed of two groups, consisting of 30 members each. They can be deployed to the scene according to emergency tasks, so as to avoid fatigue during the situation. In recent years, the CCMRRE has organized and carried out a number of public health response exercises for nuclear or radiological emergencies (Supplementary Fig. 4) in Shandong province (2014), Liaoning province (2016), Jilin province (2017) and Jiangsu province (2018). Through those exercises, the practical skills and mutual cooperation among team members have improved and the emergency operation process has been standardized.

At the provincial level, the survey showed that six provincial health administrative departments had special funds for nuclear or radiological emergencies, not exceeding 5 million RMB (about US\$0.77 million) annually from 2014 to 2016. More than 65% of provincial-level institutes for radiation injury treatment were equipped with hematology analyzers, surface radiological contamination monitors and personal protective suits; 50% of them had equipment for chromosome analysis (applied in biodosimetry); about 52.9% of them had reserved radiation injury treatment (including decorporation therapy) drugs (Table 4), including estriol, nylestriol, potassium iodide and Prussian blue, etc. Five to seven national training courses relevant to the public health response to nuclear or radiological emergencies for personnel from provincial-level institutes were held each year, a total of more than 1000 people were trained. Provincial health administrative

departments hold provincial-level training or exercises of the medical or public health response to nuclear or radiological emergencies. The survey showed that 25.8% and 29% of the provincial health administrative departments held relevant training and exercises from 2014 to 2016, respectively.

Regarding the city and county or key border areas where nuclear facilities are located, the survey showed that three municipal- and two county-level health administrative departments had special funds for nuclear or radiological emergencies, ranging from 30 000 to 730 000 RMB annually from 2014 to 2016. In total, 64.3% of the municipal- and 39.5% of the county-level institutes for radiation injury treatment were equipped with emergency ambulances, while the proportion of municipal- and county-level institutes equipped with other professional instruments for medical response to nuclear or radiological emergencies was relatively low. For example, less than 17% of the institutes at those levels were equipped with digital personal dosimeters and personal alarm dosimeters (Table 4). It is necessary to provide more emergency equipment to the municipal- and county-level institutes in the future.

### PROSPECTS FOR THE FUTURE

In October 2019, the National Institute for Radiological Protection, also known as the CCMRRE, were officially designated as the World Health Organization Collaborating Center for Radiation and Health (WHO-CC), which is the first cooperation center between China and WHO in the field of radiological health. The WHO-CC will carry out the cooperation in medical preparedness and response for nuclear or radiological emergencies, including developing technical tools and guides, participating in relevant meetings and emergency exercises and implementing International Health Regulation (IHR) to provide technical support to WHO in case of emergency, etc. In addition, the WHO-CC will work in the fields of biodosimetry, radiation monitoring of food and drinking water, health risk assessment of radiation effects, etc. The WHO-CC will also consider exploring new fields of cooperation in the future, such as providing technical training courses for developing countries and regions such as south-east Asian countries, so as to share with the world China's achievements in the field of radiological health, and introduce Chinese solutions to international cooperation in the field of public health responses to nuclear or radiological emergencies.

A biodosimetry laboratory network, mainly composed of provincial-level laboratories, was established in China. The CCMRRE performs annual national biodosimetry intercomparison to evaluate each laboratory's capability of biological dose assessment. The biodosimetry laboratories in China also participate in the construction of the Asian Biodosimetry Network and joined, in 2017, the international biodosimetry comparison organized by the Asian Radiation Dosimetry Group (ARADOS) [19]. In the future, China will actively consider organizing regional biodosimetry intercomparison and performing biodosimetry training for professional personnel from developing countries under the framework of the WHO-CC, and continue to participate in the activities of the Asian Biodosimetry Network.

As for the domestic capacity-building of the medical response to nuclear or radiological emergencies, in order to significantly improve China's capacity to treat radiation injuries and monitor radiation for

**Table 4. Emergency equipment and reserved drugs of the institutes for radiation injury treatment at the provincial, municipal and county levels in China**

Equipment/reserve drugs	Provincial level		Municipal level		County level	
	Number <sup>a</sup>	% <sup>b</sup>	Number <sup>a</sup>	% <sup>c</sup>	Number <sup>a</sup>	% <sup>d</sup>
Hematology analyzer	25	73.5	N/A	N/A	N/A	N/A
Equipment for chromosome analysis	17	50.0	N/A	N/A	N/A	N/A
Surface contamination monitor	26	76.5	17	30.4	3	7.9
Personal protective suits	23	67.6	18	32.1	10	26.3
Digital personal dosimeter	15	44.1	9	16.1	3	7.9
Personal alarm dosimeter	19	55.9	9	16.1	4	10.5
Emergency ambulance	N/A	N/A	36	64.3	15	39.5
Satellite phone	5	14.7	1	1.8	2	5.3
Radiation injury treatment (including decorporation therapy) drugs	18	52.9	5	8.9	9	23.7

<sup>a</sup>The number of the institutes for radiation injury treatment having the corresponding equipment/drugs.

<sup>b</sup>The ratio of the number listed on the left to the total number of the provincial-level institutes for radiation injury treatment being surveyed (34).

<sup>c</sup>The ratio of the number listed on the left to the total number of the municipal-level institutes for radiation injury treatment being surveyed (56).

<sup>d</sup>The ratio of the number listed on the left to the total number of the county-level institutes for radiation injury treatment being surveyed (38).

N/A: not applicable.

human health, and achieve a reasonable geographical distribution of the bases (i.e. full coverage of key areas), the country will build new medical rescue bases—and also upgrade the existing bases—for any nuclear or radiological emergencies between 2021 and 2025. At the same time, some of the old equipment in the bases will be updated, and capability evaluation and supervision will be carried out for the existing and new bases, to ensure that the bases can play their part efficiently. China will also strengthen the capacity-building at the municipal and county level, provide basic equipment for radiation monitoring and radiation injury treatment to municipal- and county-designated institutes for radiation injury treatment and institutes for radiological protection, increase municipal- and county-level funding for nuclear or radiological emergencies, and carry out training courses for professional personnel. This will enable the low-level institutes to have the basic emergency response capabilities, such as first aid for radiation injuries, radiation monitoring, collection and pre-treatment of potentially contaminated samples and individual protection.

In summary, public health response systems for nuclear or radiological emergencies at the national, provincial, municipal and county levels have been established in China. From an overall perspective, the institutes for radiation injury treatment and radiological protection at all levels have certain capabilities to respond to nuclear or radiological emergencies, and continue to advance the construction of facilities, equipment and professional personnel. In the future, while continuing to improve its own capacities, China will pay more attention to international cooperation, especially with its Asian neighbors, in terms of development of key technologies, operation training, technique inter-comparisons and other cooperation projects, so as to promote the common development of public health or medical responses to nuclear or radiological emergencies.

#### SUPPLEMENTARY DATA

Supplementary data is available at *RADRES* Journal online.

#### CONFLICT OF INTEREST

The authors declare they have no conflicts of interest.

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