

Research and application of physical protection technology and equipment against biological contamination in mainland of China

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Abstract — Biological contamination is considered to be great hazardous and related to national security, it is very important to strengthen physical protection against biological contamination accordingly. Key technologies of physical protection against biological contamination were described in terms of isolation, positive/negative pressure, air filtration, antibacterial material and disinfection. Present situation of research and development about Chinese physical protection equipment against biological contamination were presented involving individual protection, collective protection, disinfections, quality control and ergonomics. Finally, Chinese and overseas status about physical protection equipment against biological contamination were analyzed and compared in the areas of administration, research and market. It was concluded that Chinese physical protection equipment against biological contamination fell behind in administration, research and industrialization. As a result, some suggestions with Chinese characteristics were presented to promote development of Chinese physical protection equipment against biological contamination.

Keywords — biological contamination, physical protection, technology, equipment, China

I. INTRODUCTION

Biological contamination is closely related to human life and health. Accompanied by the variety of natural ecological environment, international military and political situation, biological contamination has performed as various forms, such as biological warfare agents, biological terrorist attacks, emergent natural epidemic and biological incidents, etc. Therefore, biological safety has become a hot issue in the world. As an example of SARS epidemic in the spring and summer of 2003, involving 32 countries and regions, there were total 8422 cases around the world, 919 cases of death, 11% of mortality rate. Mainland of China had total 5,327 cases, 349 cases of death, and 6.6% of mortality rate. In particular, there were up to 1,016 cases of infection, 31 cases of death for the medical staff in the rescue of SARS patients, which respectively covered 19% of total domestic infection cases and 8.9% of death cases^[1]. This high infection rate caused a great panic among the people, which seriously influenced the social stability and economic development. The worldwide economic losses caused by

SARS were up to about 59 billion US dollars (17.9 billion US dollars of China)^[2]. Since the end of 2003, the avian influenza spread in the world, involving 13 countries and regions, which had 348 cases of human infection, 215 cases of death with 62% of mortality as well as 3 billion US dollars of economic losses^[3]. After entering the 21st century, the importance of national biological safety is nothing less than any other form of national security. Hence, developing protection technology and equipment against biological contamination to minimize people infections and deaths has become an important task for all countries.

II. THE CONCEPT OF PHYSICAL PROTECTION TECHNOLOGY AND EQUIPMENT AGAINST BIOLOGICAL CONTAMINATION

Protection against biological contamination mainly covers medical protection and physical protection. Physical protection technology refers to technology utilizing the physical means to prevent human body from biological contamination attack. Physical protection equipment mainly refers to equipment being used for individuals or groups to prevent and treat biological contamination, which is the specialized equipment to effectively eliminate or control the source of contamination, block the channel of transmission as well as carry out the protection or isolation of individuals and groups. Compared with the medical protection measures, physical protection equipment is provided with the characteristics of easy to use, immediate effectiveness and reliable protection, which acts as a powerful supplement to medical protection measures. Physical protection equipment mainly covers individual protection equipment and collective protection equipment.

III. KEY TECHNOLOGY OF PHYSICAL PROTECTION AGAINST BIOLOGICAL CONTAMINATION AND APPLICATION

A. Isolation

Isolation is the basic technology of physical protection against biological contamination. Many protection equipments achieve the protection for humans through the barrier and obstruction function of materials, which isolate the skin or mucosa of human body from biological contamination,

such as protective respirator, protective clothing, protective masks, protective gloves / shoe covers, etc.

It usually adopts the independent building or regional construction for the sites with high-risk biological contamination, which use walls and sealed doors to isolate and protect the external environment. It can improve the protection performance in these sites by setting up sub-area to achieve regional isolation. For example, BSL-3 laboratory sets up clean area, buffer area and contaminated areas (core area).

B. Positive/negative pressure

Positive/negative pressure environment is generated by comprehensive utilization of technologies of the enclosed structure, ventilation, air distribution and air filtration. The application of positive pressure can protect the personnel within from outside contaminated environment; the application of negative pressure can protect the personnel outside from inner contaminated environment. The facilities and equipments applied with positive pressure technology include biological protection tents, biological reconnaissance vehicle, and positive pressure clothing, etc. And the facilities and equipments applied with negative pressure technology include biological safety laboratory, biological safety cabinet, negative pressure isolation wards, and negative pressure ambulances, etc.

C. Air filtration

Air filtration technology includes air filtering material and air filter. Fiber filtering materials is the primary air filtering medium. The filtration efficiency of fiber filtering material can achieve 99.97% (HEPA) and 99.999% (ULPA).

Air filtration technology must be combined with ventilation technology, and the relationship between the parameters of flow volume, flow resistance and clogging capacity, and the filtering effect is the focus of the research. Most of biological protection facilities and equipments related to the ventilation are applied with air filtration technology, such as protection mask, biological protection tents, and BSL-3 laboratory, etc.

D. Antibacterial protection material

Traditional air filtering material, which could only passively obstruct contamination, can not extermination microorganism. Therefore, it's significant to develop the protection materials with antibacterial function. At present, the main antibacterial protection materials include biological antibacterial materials, electret filtering material, and electrospinning materials, etc.

National Biological Protection Equipment Engineering Center (short as NPEC) had carried out the research of lysozyme filtering material, and found that sterilization efficiency could be up to 95%^[4]. NPEC had also carried out the research of polypeptide antibacterial filtering material, and found that it not only had a high sterilization rate up to 99%, but also had a good stability and long effectiveness^[5].

Electret air filtering materials achieve the filtration through mechanical effect and electrostatic adsorption effect. At the same time, electret materials play a role of restraining and killing the microorganisms. Currently, electret antibacterial air filtering material has applied to some air conditioner.

Electrospinning technology can produce fiber with fine diameter, large surface area, high porosity, and good gas and vapor permeability. Non-woven fabric produced by electrospinning has the low resistance of air, and the strong protection ability against microorganism aerosols.

E. Indoor air disinfection

Indoor air disinfection technology can limit the microorganism concentration of indoor air in a certain range. The indoor air disinfection technology mainly includes ultraviolet disinfection, chemical disinfection, ozone disinfection, and air-conditioning disinfection, etc.

F. Outdoor air decontamination

Outdoor air decontamination refers to utilizing disinfection agent and equipment to kill pathogenic microorganism and vector insect in the outdoor environment. And the decontamination equipments include sprayer, spraying machine and fog machine, etc. They can be divided into backpack type, hand-push type and vehicle-mounted type. At present, the decontamination agent with multi-function, low corrosion, pollution-free and fast efficiency is the R & D hot spots, such as biological enzyme-catalyzed disinfectant, metal complex catalysts disinfectant, nano-metal oxide disinfectant, polymer adsorption reaction disinfectant and self-catalysis sterilizing coating, etc. At the same time, high temperature, high pressure and jet technology are the characteristics for the new generation of decontamination equipment. In order to protect some sensitive equipment, the water-free decontamination technology is also under development.

G. Remote Monitoring of body signs

To decrease the contact with the infectious disease patients can effectively protect the medical personnel. NPEC developed the remote body temperature signs monitoring

technology. It has about 150 monitors, and 1,000m monitoring region. It can solve the problem of remote real-time non-contact multipoint temperature monitoring for infectious disease patients.

IV. DOMESTIC R&D PROGRESS OF PHYSICAL PROTECTION EQUIPMENT AGAINST BIOLOGICAL CONTAMINATION

A. Individual protection equipment

In recent years, Academy of Military Medical Science researched and developed some individual protection equipment against biological contamination such as the biological protection respirator, the positive pressure medical protection hood, the PTFE biological protection clothing, the TPU protection clothing and the negative pressure isolated cabin for infectious disease patient, etc. Hereinto, the biological protection respirator has a filtration efficiency great than 99.5% for bacteria and virus.

B. Collective protection equipment

China has developed some collective protection equipment against biological contamination these years such as the negative pressure isolation wards and the negative pressure ambulance for infectious disease patients, mobile biological safety level 3 laboratory, field hospital system with NBC protection function, etc. Hereinto, the mobile BSL-3 laboratory is the first one that China independently developed. When public health incidents occur suddenly, it can arrive at the designated locations quickly, and carry out the separation, cultivation, detection and identification operation on the suspicious pathogens.

C. Disinfection and decontamination equipment

At present, there are relatively abundant types of disinfection and decontamination equipment in the domestic market including ultraviolet disinfection devices, ozone disinfections devices, fumigation disinfection equipment, and spray decontamination equipment, etc. Such as the sanitation and anti-epidemic vehicle developed by Academy of Military Medical Science is used for exterminating the field large-area pathogenic microorganism and vector insect. The vehicle is provided with the field mobility and equipped with high efficiency spray equipments. Its decontamination capacity is not less than 100,000m² per hour.

D. Quality control and monitoring equipment

Quality control and monitoring equipment of biological protection equipment includes particle and microorganism

aerosol filtration efficiency testing equipment, air microorganism sampling equipment, synthesized blood penetration testing equipment, etc. Such as the microorganism aerosol filtration efficiency test system developed by NPEC, which is designed according to ASTM standard F2101-01, is provided with the characteristics of variable flow, negative pressure, precise measurement, and easy operation. It can test the microorganism aerosol filtration efficiency of air filtration material, protection material, and protection respirator.

E. Ergonomics evaluation equipment

Ergonomic and comfort evaluation equipment is applied in the research of biological protection equipment developed by NPEC. The influences of microenvironment parameters of the equipment such as oxygen, carbon dioxide, temperature and humidity on the physiological indexes of user such as heart rate, respiration, blood pressure, and oxygen saturation, etc. were researched. The ergonomics evaluation equipment mainly covers: microenvironment quality monitoring equipment, personnel physiological status monitoring equipment and evaluation test platform, etc.

V. R&D COMPARISON OF PHYSICAL PROTECTION EQUIPMENT AGAINST BIOLOGICAL CONTAMINATION AT HOME AND ABROAD

Biological contamination outbreak will trigger people's panic, and even impact on social stability, which may result in tremendous losses of the national public security and economic development. Therefore, the developed countries have attached great importance to the development and application of biological protection equipment.

A. Management

In mechanism of preventing and treating bio-terrorism incidents and urgent public health events, the United States and other developed countries have drawn up a series of national biosafety plans involving action plans and a wide range of emergency measures.

In the biological safety management, the World Health Organization (WHO) issued laboratory biosafety manual in 2004 (3rd Edition). For the standards: the United States and Europe have established a comparatively complete standards system for protection equipment. For example, standards for product and test method of protection clothing involve 42 ISO standards, 24 ASTM standards, 20 ANSI standards, and 51 EN standards.

After SARS, the bio-safety issue attracts great importance of Chinese Government that 2005-2020 state biological safety strategic countermeasures was studied and formulated. At present, more than tens of biological safety laws and regulations as well as standards have been issued in China.

B. R & D

R&D institutions of biological protection equipment at abroad are mainly divided into three types: the first type is national R&D institutions, such as the National Protection Center (NPC) of the United States, and the National Personnel Protection Technology Laboratory (NPPTL), etc.; the second type is military R&D institutions, such as the Biological and Chemical Protection Bureau of U.S. Army, the Army Medical Research Institute of Infectious Disease, and Walt Terry Army Medical Institute, etc.; the third type is enterprise R&D institutions, such as 3M company and DUPONT company in the USA, Elwyn E. Roberts Isolation Equipment Co., Ltd in the UK, and BACOU company in France, etc.

It also established various academic organizations at abroad, which played an important role to guide the development of biological protection technology and equipment. For example, Biological Terrorism Incidents Nursing Research Group under the Emergency Nursing Association (ENA) of the United States established in 1970, American Biological Safety Association (ABSA) established in 1984, European Biological Safety Association (EBSA) established in 1996, International Biosafety Working Group (IBWG) Established in Canada in 2001.

Biological protection equipment research and development in China was almost blank before SARS, In December 2003, National Biological Protection Equipment Engineering Center (NPEC) was established based on Academy of Military Medical Science approved by the Ministry of Science and Technology.

In October 2007, NPEC, Academy of Military Medical Science, and China Disease Prevention and Control Center co-established the Biological Safety and Protection Equipment Branch of Chinese Preventive Medicine Association.

C. Marketing

The foreign biological protection equipments have the advantages of various types, full functions, reliable performance and advanced technology, etc. For example, N95 series of respirator, Air-Mate protection hood, M40 protection mask from 3M, Tyvek series of protection clothing from Dupont, JSLIST of US Army, NBC protection casualty bags and NBC protection tents developed by Finland

EGO company, MPD100 multi-functional decontamination system from Germany Kach company. The products from the main foreign companies of biological protection equipment have almost dominated the global military and civilian market.

In comparison, the product of domestic biological protection equipment is relatively small in variety, quantity of production and sales, and is incomplete in function, which does not come up to its own well-known brand.

VI. GAPS AND SUGGESTIONS

Compared with developed countries, China fell behind in administration, research and industrialization in the filed of biological protection technology and equipment. It is very important to vigorously strengthen the management and construction of biological protection technology and equipment, and form a complete system of national biological protection equipment as soon as possible.

A. Management

Biohazard events relate to social public interests, it is the important responsibility for all levels of governments to cope with fast and properly. The government shall establish a full range of management systems, mechanisms, policies and regulations, such as early warning, response plans, prevention education, technical research, equipment reserves, materials supply, medical aid, and reconstruction after disaster, etc. and become the leading strength for dealing with biohazard events. Suggestions: First, strengthen the scientific research input. Second, strengthen strategic reserves input. Third, establish the technology standard systems, setup quality testing platform and certification institutions, as well as strengthen trade supervision and management. Fourth, combine reserves with rehearsals, and fully exert the performance of biological protection equipment.

B. R & D

At present, the R & D of biological protection technology and equipment in China has obvious gap with developed counties in establishment of professional institutions, the number of staff, research levels, platform construction and funds input. Suggestions: First, earnestly support the key project research, Second, improve the scientific research conditions, strengthen the research infrastructure investment, Third, establish levels of academic organizations, launch professional journals, build domestic and international academic communication platform.

C. Industrialization

At present, the number of domestic enterprise that specialized in biological protection equipment is rarely small, which could hardly satisfy the demands of domestic biological safety protection. Therefore, it urgently needs to speed up the cultivation of domestic professional manufacturing enterprises that owned famous brands, so as to improve the market shares of domestic biological protection equipment. Suggestions: Firstly, implement the positive fostering policy for domestic enterprises. Secondly, carry out the promoting technology innovation policy for domestic enterprises.

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