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Study on Biological Threat Faced by Surface Ships and Its Countermeasures

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Abstract: The current international and domestic biosafety situation is complex and diverse. With the progress of biotechnology, the use of biological weapons in the future battlefield may become a revolutionary and subversive means of warfare and determine the direction of war. It is necessary for surface ships to arrange in advance for biosafety protection. This paper discusses main biosafety challenges faced by surface ships from the perspectives of biological warfare agents in wartime and infectious diseases in peacetime. These challenges include increasingly fierce biological warfare, bioterrorism threat, increasingly frequent emerging infectious diseases, potential threats brought by the development of biotechnology and so on. Besides, the shortcomings of protection methods and equipment currently used by surface ships to deal with biological threat are analyzed, which include its weak ability of real-time detection and identification of microorganisms and the lack of isolation and disposal equipment for internal infectious sources. In view of the above deficiencies, the countermeasures are put forward from the perspectives of monitoring and protection. On the one hand, we should actively develop remote, non-contact, real-time and rapid-response biological monitoring equipment. On the other hand, based on the construction standard of biological laboratory, we should build the isolation and disposal cabins of surface ships. This paper aims to improve the response ability of surface ships to biological threats, and provide theoretical support and reference for the R & D and upgrading of nuclear, chemical and biological protective equipment of surface ships.

Keywords: Biological Weapon, Surface Ships, Infectious Diseases, Isolation Disposal

1. Introduction

Biosafety is an important part of the safety of surface ships, which directly affects the combat effectiveness of surface ships. At present, the biological threats faced by surface ships are complex and diverse, including both the direct threat brought by biological warfare agents in wartime and the indirect threat brought by infectious diseases in peacetime [1, 2]. From the physical structure of surface ships, the closed internal structure and personnel concentration are very conducive to enhancing the killing efficiency of biological warfare agents. From the perspective of protection equipment, surface ship forces mainly rely on gas masks, gas suits and ship collective protection system for personal protection and collective protection to prevent ship members who are not infected against biological warfare agents [3, 4]. However, for the internal suspected and infected personnel, there is no systematic and perfect isolation and disposal equipment at present. This is the obvious shortcomings and deficiencies of surface ships on its prevention against biological weapon attacks. In addition, infectious diseases have frequently appeared in recent years, such as severe acute respiratory syndrome, highly pathogenic avian influenza, influenza A H1N1, Middle East respiratory syndrome, Ebola haemorrhagic fever and global COVID-19 [5, 6]. These infectious diseases have become widespread in a short time, which has brought great troubles and security threats to the surface ship forces in the implementation of major military operations such as overseas peacekeeping, high-sea escort, Sino-foreign joint exercises and training, ship visits, foreign medical services and so on. In short, the biological threat faced by surface ships has never disappeared, but presents in a more complex and changeable way with the changes of the international situation, local regional turbulence, biotechnology development, the outbreak of external accidents and other factors.

By analyzing the complex biological threats faced by surface ships and their existing protective equipment and means, this paper demonstrates the shortcomings of surface ships in dealing with biological threats, and analyzes the countermeasures from the perspectives of monitoring and isolation disposal, so as to provide theoretical support for surface ships to improve their biological defense ability.

2. Biological Threat Faced by Surface Ships

2.1. Threat of Biological Warfare Agents to Surface Ships in Wartime

At present, the mainstream attitude of the international community towards biological weapons is to prohibit the production, development and use of biological weapons. So far, 183 countries have acceded to the Biological Weapons Convention (BWC), but the reality is inconsistent with the mainstream voice of the international community on biological weapons. The binding force of BWC on the prohibition of biological weapons on all countries is relatively limited. Some countries carry out military packaging of anthrax, botulinum toxin, yellow fever virus, Brucella and other biological warfare agents. In addition, it cannot be ruled out that some countries take advantage of the loopholes in the BWC to carry out biological weapons research and development under the pretext of preventing biological weapons and responding to bioterrorism and infectious diseases. In the process of fulfilling its mission-defending sovereignty over territorial sea, safeguarding maritime rights and interests and fighting enemies, the naval ship forces will directly face the threat and pressure brought by biological weapons. Unlike land operations, with surface ships as relatively independent units, operations on the sea do not have defense depth. Once attacked by biological weapons and infected by other ships and personnel, the combat effectiveness of ships will inevitably continue to decline. Because biological weapons have the characteristics of strong infectivity, strong permeability and incubation period [7], they are likely to break through the ship's defense line with the strong killing effect and indirectly affect the ship commander, even the rear port and base. Even if the surface ships are not attacked by biological weapons during the operation, the preparation for preventing biological weapons will inevitably reduce the operational efficiency and greatly increase the psychological burden of the crew.

Biological attacks by terrorist organizations have become a real threat [8]. Compared with conventional weapons, biological weapons have greater social harm and social impact. As subversive weapons, once used in wars, biological warfare agents can break the rules of wars only using conventional weapons. They can break through the gap between the economic strength and conventional combat strength of the two sides. The side, like terrorist organizations, with less money and military strength can even cause more mass destruction to the other side, like forces from United Nations. In addition, biological weapons are easy to make and obtain, the signs of their uses are not easy to detect, and the effect is delayed. These characteristics make biological weapons a favor of terrorist organizations. They mainly pose biological threats to the surface ship forces in the ports, shipyards and other important military bases. In wartime, this will seriously affect the concentration of the combat forces and contain the forces of specialized personnel on nuclear, chemical and biological protection, resulting in the shortage of nuclear, chemical and biological protection forces in the frontal battlefield. Even if terrorists carry out biological attacks that does not directly affect the base and shipyard but on the city where the surface ship forces are stationed, the biological threat control and disaster rescue carried out by the forces after a disaster occurs will also pose a threat to the safety of the surface ship forces and contain the combat energy.

2.2. Biological Threat of Infectious Diseases to Surface Ships in Peacetime

In peacetime, the biological threat of infectious diseases to surface ship forces mainly comes from naturally occurring infectious diseases, infectious diseases caused by accidental leakage of biological laboratories and infectious diseases caused by man-made biotechnology.

Throughout history, human beings have never stopped being hurt and threatened by infectious diseases. In recent years, infectious diseases like severe acute respiratory syndrome, highly pathogenic avian influenza, influenza A H1N1, Middle East respiratory syndrome, Ebola haemorrhagic fever in West Africa and COVID-19 sweeping the world have shown the trend of normalization. These diseases, both traditional and new, have brought great challenges to human security and social stability. Modern and convenient means of transportation and transportation technology connect people closely and make it possible to explore every corner of the earth more deeply, but at the same time they also make viruses and bacteria spread around the world more quickly. For these reasons, naturally occurring infectious diseases present themselves with wider transmission, faster transmission speed and greater social harm. For surface ship forces, "going out" has become the norm. The implementation of major military operations by surface ship forces such as overseas peacekeeping, high-sea escort, Sino-foreign joint exercises and training, ship visits, foreign medical services and so on has become more and more frequent. Visiting and passing through epidemic related areas and contacting high-risk epidemic related people, the forces will pose a threat to the biological safety of surface ships and also a test to the biological defense ability of surface ships.

Infectious diseases can also be caused by accidental leakage in biological laboratory [9]. With the development of biotechnology and people's attention to biosafety, the number of biological laboratories has been increasing in recent years. In 1990, there were only 12 level 4 biosafety laboratories in

the world. Today, this number has increased to 58. These laboratories store pathogens that can cause serious diseases in humans and animals, typical of which are smallpox virus, anthrax, Vibrio cholerae, Ebola virus, etc. With the increase of the number of level 4 biological laboratories and the number of laboratory related personnel, the possibility of laboratory pathogen leakage also increases. The safety accidents of biological laboratories are often reported on the Internet, which shows that there are hidden dangers in the safety of biological laboratories. Once they are leaked, they will immediately pose great threats to the surrounding environment and people. Those resulting threats, with great harm, complex infectious sources and high mortality, are bound to pose a bad influence on the whole society, including surface ship forces.

There have been reports of making biological weapons through gene editing technology [10]. This also proves that with the deepening understanding of microorganisms, any infectious disease has the possibility of being transformed into biological warfare agents, especially the pathogens widely existing in nature. In the future battlefield, it cannot be ruled out that the surface ship forces will face the threat of new biological warfare agents transformed by biotechnology. Such biological warfare agents are more infectious, more lethal, more difficult to find, and are ahead of current medical means.

3. Deficiencies of Surface Ships in Dealing with Biological Threats

At present, real-time and accurate monitoring of infectious microorganisms in the air cannot be achieved. What we can do is to monitor a large range of aerosols in the air by means of photoelectric technology. Such monitoring performance is suitable for judging whether the enemy has carried out large-scale biological weapon attacks on our surface ships in the battlefield environment. However, when it comes to monitoring small-scale biological warfare agent attacks and the transmission of infectious diseases from person to person or from the environment to person, there is not much we can do. The most traditional methods for microbial identification include pathogen culture, isolation and identification, as well as biochemical analysis. This method is highly selective and sensitive, and the results are accurate [11]. However, the disadvantages are also very obvious. The cycle is long, the process is time-consuming and laborious, and precision equipment and professional operators are needed. Therefore, the traditional identification methods are not suitable for surface ships. At present, the identification of biological threats is an obvious weakness in the biological defense of surface ship forces.

As for the disposal of biological threats, surface ship forces mainly rely on gas masks, gas suits and ship collective protection system for personal and collective protection. Surface ship forces can prevent against biological warfare agents by using the isolation effect of gas clothing and the filtering effect of gas mask on aerosols. The ship collective protection system utilize filtration and overpressure to create a relatively safe space with an airtight perimeter, so as to protect the crowd inside the space and avoid the threat posed by biological warfare agents. However, it should be noted that at present, various protection methods towards biological warfare agents on surface ships at home and abroad are all aimed at ship personnel who are not infected by biological warfare agents. For ship personnel suspected or already infected by biological warfare agents, so far, surface ships have not been equipped with isolation equipment and appropriate isolation disposal measures.

4. Countermeasures Against Biological Threat on Surface Ships

4.1. Develop New Microbial Detection and Identification Devices

Traditional biological warfare agent reconnaissance rely on contact sampling of detection personnel, on-site detection or taking samples back to the laboratory for cultivation, analysis and identification, which is not suitable for real-time and frequent monitoring of large population or environment. With the development of photoelectric technology, many countries, based on photoelectric technology and spectral monitoring technology, have developed relatively reliable laser-induced fluorescence detection equipment for biological warfare agents [12-14]. In 1999, the Canadian Department of Defense began to develop an integrated hyperspectral resolution active detection system, which can realize the real-time estimation of aerosol concentration. Through many field tests, the measurement results prove to be consistent with the actual situation. In 2004, the US military developed the joint biological standoff detection system, which uses 355nm laser to excite the fluorescence of the detected biological warfare agent aerosol. The maximum detection distance is 5km, and it has a high degree of automation. It can be carried on surface ships. In 2007, the CBRN center of Germany developed a multi-wavelength laser radar system for the remote detection of biological warfare agents. Through the statistical analysis of the optical parameter data such as the depolarization ratio of the backscattered light emitted by the laser to the cloud, the biological properties and types of aerosols are determined. The equipment can be carried on surface ships.

Remote, non-contact, real-time and rapid responses are the characteristics of biological warfare agent monitoring system. Based on the needs of surface ships for biological threat prevention and control, we can consider the relatively mature laser-induced fluorescence detection system on ships. Of course the laser-induced fluorescence system is not perfect, and there are still many technical problems, such as low signal-to-noise ratio and high false alarm rate in the daytime, on which we should focus our research in the future. In addition, biosensors are also developing in recent years, including aptamer biosensors, cell-based biosensors,

surface plasmon resonance biosensors, nano material biosensors and mobile phone biosensors. Relying on the advantages of high sensitivity and specificity of biosensors, the research and development of relevant monitoring equipment is becoming a hot spot in the field of biological warfare agent detection [15, 16].

4.2. Establish Isolation and Disposal Compartments for Surface Ships

At present, surface ships at home and abroad generally lack the ability to deal with internal sources of infection. The construction of ship biological isolation and disposal cabin is a relatively good solution to this prominent problem.

4.2.1. Design Principle of Isolated Disposal Compartment

The design principle of isolated disposal compartment is to protect people and the ship environment. Therefore, it should be realized mainly through the effective combination of facilities, equipment, personnel and quality.

4.2.2. Airtightness Design of Isolation and Disposal Compartment

The core of the isolation and disposal compartment design is the air tightness design. The core equipment to realize the airtightness of the cabin includes: airtight door, airlock chamber, air source, pneumatic butterfly valve, poison filtering and ventilation system, filtered biological aerosol monitoring system, ventilation pipeline isolation switch, etc. The air-tight door of the isolation area shall integrate the performance of air tightness, thermal insulation, compression resistance, dust prevention, fire prevention and so on. For this, the switch on the door is both electric and manual, and to prevent people from being caught, the safety sensor is also used. What's more, to facilitate the centralized control of the opening and closing of the airtight door by the personnel on duty, the driving sensor and remote controller are also set.

The airlock chamber is set at the entrance and exit of the isolation area, which is a buffer room for blocking the polluted air flowing from outside or adjacent chambers by controlling the pressure difference. The airlock chamber is generally equipped with two doors that cannot be opened at the same time. They maintain the pressure gradient at a certain level to ensure the air flow direction is from a safe environment to an environment with risk factors.

The pneumatic butterfly valve is mainly used as a block valve. It can also be designed to have the function of regulation or both block and regulation. By adjusting the air supply volume, the pressure gradient of adjacent compartments can be adjusted.

Poison filtration and ventilation system is the core of safety protection system, which filters harmful gas containing biological warfare agent aerosol into clean and safe gas. At present, there are two main filtering principles of poison filtration and ventilation system based on different filter materials. One is based on the physical adsorption, chemical reaction and catalysis of anti-toxic carbon to filter toxic and harmful gases, and the other is based on the filtration of molecular sieve. The traditional filter material has stable anti-virus carbon filtration performance, but its continuous service life is limited. When molecular sieve is used for filtration, after adsorption saturation, it can be desorbed by heating, so as to realize recycling and prolong service life, but the filtration performance is not as stable as that of traditional materials.

The filtered biological aerosol monitoring system can display the filtered aerosol concentration in real time, therefore timely find out whether the filtration capacity of the poison filtration and ventilation system fail due to overload.

4.2.3. Airtightness Design of Isolation and Disposal Compartment

Good professional training and technical ability play an important role in ensuring the biological safety of the isolation compartment, which directly affects the generation of combat effectiveness. The crew responsible for managing the isolation and disposal compartment of the ship must receive professional training, including basic theoretical knowledge of biosafety, management, operation and daily maintenance of the isolation and disposal compartment of the ship.

4.3. Other Aspects Requiring Attention in Dealing with Internal Infectious Sources

After the ship establishes the isolation and disposal cabin, in the isolation and management of infected and suspected infected personnel, we should also consider the following issues, such as isolation implementation plan, activity route of other personnel on the ship, life support plan of isolated personnel, sanitary and epidemic prevention plan, etc. Even with perfect isolation and disposal cabin and other hardware facilities, if the above problems are not handled properly, the biological safety of the ship cannot be guaranteed.

5. Conclusion

The current international and domestic biosafety situation is complex and diverse. With the progress of biotechnology, the use of biological weapons in the future battlefield may become a revolutionary and subversive means of warfare and determine the direction of war. It is necessary for surface ships to arrange in advance for biosafety protection. In view of the current deficiencies of surface ships in biological threat protection, we should actively develop sensitive, accurate and high-throughput biological monitoring equipment. At the same time, combined with the ship structure and task requirements, we should consider the feasibility of constructing isolation and disposal compartments, and formulate relevant emergency disposal plans, so as to deal with the problems of internal infectious sources, improve the biological defense capability of surface ships, and provide a solid guarantee for surface ship forces to fulfill their missions.

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