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Reflections and Analysis on the Maintenance and Support of Nuclear Emergency Response Equipment

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Abstract: As the application of nuclear technology expands, nuclear safety concerns have become increasingly prominent. In response, countries around the world are intensifying their investment in and research on nuclear emergency response equipment, recognizing that maintenance and support are critical components for managing biochemical crises. The maintenance and support of nuclear emergency response equipment have thus emerged as key elements in ensuring preparedness for such emergencies. The Chemical Defense Unit of the Armed Police, being an elite force in disaster response and rescue, plays a vital role in managing chemical accidents. However, several challenges currently undermine the maintenance of nuclear emergency equipment within the Armed Police, including inadequate self-sufficiency in maintenance, excessive reliance on local resources, and difficulties in ensuring effective support during mission execution. To address these challenges and improve maintenance support capabilities, this study proposes several key strategies: enhancing the maintenance support system, advancing the informatization of equipment, and strengthening personnel training. These measures aim to improve both the efficiency and effectiveness of equipment maintenance and to bolster the overall capacity to respond to nuclear safety incidents, thereby safeguarding national and public security. Research findings underscore the importance of establishing a robust support system, which will positively influence future emergency response efforts.

Keywords: Nuclear Safety; Nuclear Emergency Response Equipment; Biochemical Crisis; Equipment Maintenance and Support; Emergency Support Capabilities

1. Introduction

Nuclear emergency response equipment encompasses various instruments [1], devices, and tools specifically designed to monitor, control, and manage radioactive leaks and radiation contamination during nuclear incidents. Currently, the maintenance and support model for such equipment within the Armed Police Force is divided into three main categories: military maintenance support, local maintenance support, and a military-civilian integrated maintenance support system. Although recent years have seen successful integration of military and local maintenance resources as part of the military-civilian fusion initiative, this has also led to an over-reliance on local resources. Consequently, several issues have emerged, including the Armed Police's diminished self-reliance in maintenance capabilities [2], increased risks from dependence on external contractors, and challenges in providing adequate support during critical missions. This reliance not only undermines the Armed Police's independent operational readiness but may also delay or weaken emergency responses at crucial moments. Therefore, it is urgent to enhance and optimize the internal support framework to ensure greater self-sufficiency and responsiveness.

2. Analysis of the Characteristics of Maintenance Support for Nuclear Emergency Response Equipment

2.1 High Timeliness

Nuclear emergency equipment often operates under extreme environmental conditions, such as high radiation levels, elevated temperatures, or high pressure [3]. These conditions can cause significant damage to the equipment, necessitating rapid repairs to prevent further

escalation of incidents. In the event of damage or malfunction, nuclear emergency equipment must be immediately restored to operational status to ensure swift and effective response to nuclear accidents and protection against radiation hazards [4,5].

2.2 High Degree of Specialization

The maintenance of nuclear emergency response equipment is highly specialized. Given the critical nature of nuclear safety, the standards for equipment maintenance are exceptionally stringent, requiring personnel with extensive professional knowledge and skills. Maintenance staff must undergo rigorous training and certification processes before being qualified to perform repairs on nuclear emergency equipment. Additionally, specialized tools and devices, such as laser rangefinders, megohmmeters, and rail verticality measuring instruments, are frequently used in these repairs, which are uncommon in regular maintenance tasks. This high level of specialization ensures the safety and reliability of nuclear emergency equipment.

2.3 Strict Safety Requirements

Since nuclear equipment involves radioactive materials, which pose severe and often irreversible threats to human health and the environment, the safety protocols during the maintenance process must be exceedingly stringent. Personal protective equipment (PPE) such as gas masks, radiation-proof suits, and protective gloves must be kept in perfect condition to guarantee the safety of personnel. Moreover, decontamination equipment like spray vehicles and shower vehicles must ensure the safety of both the objects being decontaminated and the surrounding environment [6,7].

3. Issues in the Current Maintenance Support Model for Nuclear Emergency Response Equipment

3.1 Weak Self-Support Capability

Currently, the training of maintenance support personnel within the military primarily relies on centralized training, supplemented by institutional education and manufacturer field training. However, due to limited training time and personnel at various units, most of the training focuses on general equipment maintenance, with limited attention given to the specialized skills and theoretical knowledge required for chemical defense, nuclear, and biochemical equipment maintenance. This has led to a shortage of skilled professionals in the field of nuclear emergency equipment maintenance support. Moreover, there is a widespread issue of personnel shortages and a lack of specialized staff across maintenance roles. For example, repair units at the brigade level may have teams for vehicle repair, ordnance repair, and engineering machinery repair, but often lack professionals in chemical defense, special operations, engineering machinery, and explosive-proof armor repair. In some cases, there are even vacancies in these specializations, as shown in Figure 1. This undermines the military's capability to maintain nuclear emergency response equipment adequately.

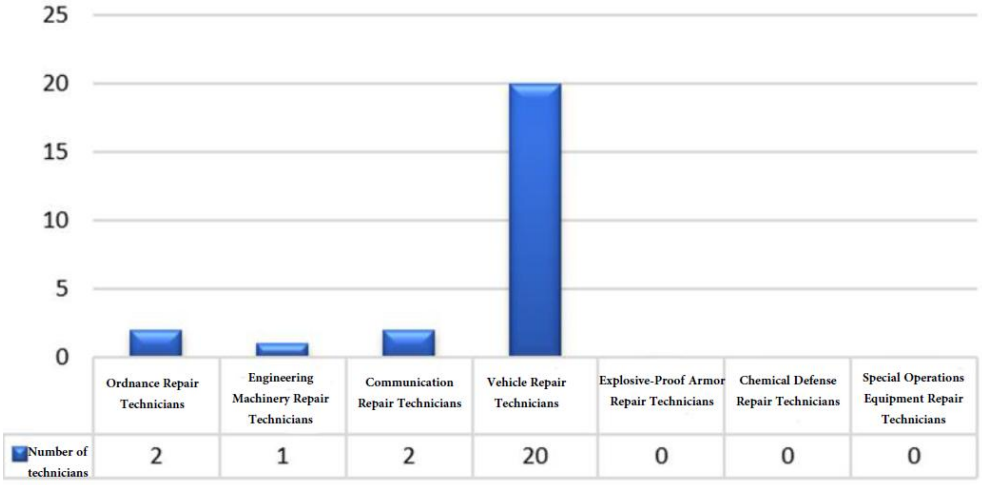

Figure 1. Allocation of Specialized Repair Technicians in a Repair Unit

3.2 High Dependency on Local Support

Due to the specialized nature of nuclear emergency equipment, some of it relies heavily on the original manufacturers and research units for maintenance. This not only significantly increases maintenance costs but also poses risks such as contract breaches by suppliers. Additionally, the procurement of certain equipment from single-source suppliers leads to market monopolies. This results in complicated procurement processes, extended timeframes, high costs of monopolized repair parts, limited procurement channels, and frequent bidding failures.

3.3 Challenges in Mission Execution Support

The procurement process for equipment maintenance involves multiple steps, including submission of needs, approval, pricing inquiries, and bidding. This complex procedure spans a long period, making it difficult to ensure timely maintenance of emergency equipment. Moreover, some equipment has been in use for extended periods, even nearing the end of its service life, and spare parts for these items are no longer available in the market. This further complicates the repair process, preventing timely maintenance and jeopardizing the functionality of emergency equipment when it's needed most.

3.4 Low Level of Information Integration

Leading military powers, such as the U.S., have introduced innovative maintenance support models that integrate various elements, including task planning, maintenance training [8], and support operations, through a real-time information system. This system enables continuous monitoring of the status of weapon systems, allowing the autonomous determination of appropriate maintenance plans based on real-time data. Maintenance tasks can be planned and resources allocated in advance, ensuring that repairs are carried out at the optimal time to keep the equipment in prime condition. While the Armed Police Force has made some progress in information technology construction, its maintenance support system still lags behind, especially in areas like real-time monitoring and remote diagnostics, limiting the efficiency and effectiveness of maintenance operations.

4. Strategies and Recommendations for Building a Maintenance Support System for Nuclear Emergency Response Equipment

4.1 Enhancing the Maintenance Support System

Improve the maintenance support system for nuclear emergency equipment by adjusting organizational structures and optimizing the integration of military-wide maintenance resources [9]. First, optimize personnel allocation, ensuring a balanced proportion of professionals in each maintenance specialization. This will guarantee swift supply, efficient repair, and precise support, continuously refining the maintenance capabilities at all levels. Second, optimize the specialization of maintenance fields. Given personnel limitations and the complexity of equipment classification, it is recommended to break down professional barriers and create modular combinations of specialties based on mission requirements, fostering versatile talent. Finally, optimize the talent structure by increasing the number of senior engineers and technicians, improving the direct recruitment of NCOs to ensure a proper professional match and higher efficiency. With the ongoing civilian personnel reform, moderately increase the proportion of non-active-duty civilian staff by recruiting or rehiring specialists in chemical defense and biochemical technologies.

4.2 Developing a Skilled Workforce

Building a team of skilled maintenance personnel is fundamental to strengthening the ability to maintain nuclear emergency equipment. The focus should be on cultivating talent and establishing a continuous training system, ensuring that maintenance personnel receive regular training to enhance their comprehensive skills. Additionally, it is crucial to create a platform that supports ongoing learning and hands-on practice. The Armed Police Force can organize an annual centralized training session, with field guidance from relevant equipment manufacturers, and the internal security brigades can strengthen specialized training for nuclear emergency maintenance during junior NCO training opportunities. Moreover, combining this with incentive policies can help

maintain team morale and provide growth opportunities for key technical personnel. This will not only improve maintenance efficiency but also provide the team with a sense of security, fostering the development of a skilled workforce.

4.3 Improving Equipment Configuration

With the advancement of technology, intelligent and automated equipment has demonstrated its superiority in many fields. For nuclear emergency response equipment, intelligent systems can not only improve operational efficiency but also provide more accurate data support and more effective risk assessment and control in emergency situations. By enhancing the intelligent systems of the equipment, automatic monitoring and maintenance of faults can be achieved, and maintenance and repair data can be analyzed to provide scientific evidence for future equipment efficiency improvements, ensuring timely and effective repair and maintenance.

4.4 Deepening Military-Civil Integration

As the model of military-civil integration in maintenance support continues to develop, local civilian maintenance support plays a significant role in military repairs. However, due to the specialized nature of nuclear emergency equipment, remote, small, and scattered units often face a shortage of qualified local manufacturers. To address the challenges of difficult repairs, it is necessary to further integrate military and civilian technology, resources, and information [10]. First, integrate military and civilian resources to improve resource utilization efficiency, sharing advanced technologies and facilities in the research and maintenance of nuclear emergency equipment. Second, establish a robust supplier database so that when maintenance tasks arise, the appropriate manufacturers can be quickly identified. Leveraging advanced civilian repair technology will improve the efficiency and quality of nuclear emergency equipment repairs. Finally, for single-source procurement equipment, sign maintenance contracts at the time of purchase and collaborate in training a workforce skilled in both technical and repair roles, providing the necessary technical support for maintaining nuclear emergency equipment.

5. Conclusions

The maintenance support system for nuclear emergency response equipment is a crucial component in ensuring the safety of nuclear energy. In light of the current issues within the maintenance support structure of the Armed Police Force's nuclear emergency equipment, effective and practical measures must be taken to improve it. By enhancing the maintenance support system, cultivating a skilled workforce, upgrading equipment configurations, and strengthening military-civil integration, the maintenance support capacity for the Armed Police Force's nuclear emergency equipment can be continuously improved. This ensures that in the event of a nuclear accident, rapid and effective emergency responses can be carried out, safeguarding the lives and property of the public. The findings of this study indicate that establishing a sound maintenance support system not only enhances the efficiency of existing equipment but also plays a critical role in responding to emergencies. However, there are limitations to this research, such as the relatively limited assessment of local support capabilities and an incomplete coverage of all potential risks. Furthermore, data collection and analysis require further improvement to ensure the scientific accuracy and validity of the research conclusions. Looking ahead, there is vast potential for development. It is recommended that the Armed Police Force strengthen its collaboration with research institutions to drive technological innovation and application. At the same time, continuous talent cultivation and recruitment should be emphasized to meet the increasingly complex demands of nuclear emergency response. By implementing regular training and drills, the emergency response capabilities can be enhanced, ensuring that in the event of a nuclear accident, the Armed Police Force can swiftly and effectively organize rescue operations, maximizing the protection of people's lives and property.

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