On-Site Detection as a Countermeasure to Chemical Warfare/Terrorism

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ABSTRACT: On-site monitoring and detection are necessary in the crisis and consequence management of wars and terrorism involving chemical warfare agents (CWAs) such as sarin. The analytical performance required for on-site detection is mainly determined by the fatal vapor concentration and volatility of the CWAs involved. The analytical performance for presently available on-site technologies and commercially available on-site equipment for detecting CWAs interpreted and compared in this review include: classical manual methods, photometric methods, ion mobile spectrometry, vibrational spectrometry, gas chromatography, mass spectrometry, sensors, and other methods. Some of the data evaluated were obtained from our experiments using authentic CWAs. We concluded that (a) no technologies perfectly fulfill all of the on-site detection requirements and (b) adequate on-site detection requires (i) a combination of the monitoring-tape method and ion-mobility spectrometry for point detection and (ii) a combination of the monitoring-tape method, atmospheric pressure chemical ionization mass spectrometry with counterflow introduction, and gas chromatography with a trap and special detectors for continuous monitoring. The basic properties of CWAs, the concept of on-site detection, and the sarin gas attacks in Japan as well as the forensic investigations thereof, are also explicated in this article.

KEY WORDS: Chemical warfare agents, detection performance, on-site detection.

INTRODUCTION

Chemical warfare agents (CWAs) [38,77,134] were used in World War I and World War II as well as during the ensuing Cold War period, and their production and stockpiling continued after those conflicts ended [130]. In the 1980s, Iraq used sarin (GB) and mustard gas (HD) in the Iran–Iraq War [5]. In 1992, a treaty prohibiting the development, production, stockpiling, and use of CWAs, and mandating their destruction, was ratified, and it came into force in 1997 [14]. The Japanese cult Aum Shinrikyo used GB in Matsumoto in 1994 and in the Tokyo subway in 1995 [88] (*see* Appendix), and many defenseless people were poisoned or killed [113,120], bringing the threat of chemical terrorism to worldwide public attention.

Just after the September 11, 2001, terrorist attacks in the United States, letters contaminated with anthrax spores were sent to a number of addresses, and five people were killed [51], highlighting the threat of biological terrorism. In addition, various CWAs have been discovered in former Japanese military facilities during excavations [91]. Injuries have been reported from direct contact with CWAs leaking from containers in Samukawa [40], and some complaints were received about damage to health (neurological disorders) resulting from contaminated drinking water in Kamisu, which was probably caused by arsenic vomiting-agent degradation products [54].

To achieve a safe and secure society, the authorities should establish a stronger crisis management system at the national level [110,128]. *Crisis management* in cases of the deployment and/or disposal of CWAs involves measures to protect against terrorism and to protect workers' health, such as monitoring CWAs in public places, and security checks at territorial borders, airports, large event venues, executive facilities [28,42,127], and chemical weapon demilitarization zones. *Consequence management* involves on-site detection by first responders (for personal protection), and samples then being transported to laboratories for analysis so that the incident can be investigated and emergency lifesaving measures can be taken. *Incident management* includes performing laboratory analysis to provide evidence for court proceedings and to prevent future crimes (**Figure 1**). Forensic science laboratories analyze specimens taken from the site and from exposed casualties. Current methods used in the laboratory to identify toxic substances from on-site and exposure-victim specimens consist of a preliminary rapid screening test, sample pretreatment, and instrumental analysis by hyphenated mass spectrometry (MS). Analytical technologies have been developed and used for a number of CWAs [6,20,48,67,109,115,116,156], their degradation products and metabolites [59,147], and adducts with biological components [90,143].

Rapid on-site detection is extremely important in counterterrorism/detection schemes to minimize a given disaster, because the time it takes to transport specimens to a laboratory for analysis is saved. Various analytical technologies have been used for on-site detection [109–111, 116,118,122]. Analytical performance criteria required when choosing on-site methods for use by first responders include sensitivity, accuracy, response time, recovery time, and operational performance. A detector that provides satisfactory performance for all criteria is not currently available. Low alarm sensitivity, frequent false alarms, and

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ABOUT THE AUTHOR

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Yasuo Seto was born and grew up in Kagawa, Japan. He obtained his B. Sc. and M. Sci. degrees in agricultural chemistry from the University of Tokyo (Bunkyo, Tokyo, Japan) and his Ph.D. degree, featuring a cholinesterase inhibition mechanism study, at the same university. In 1992, he worked at Vanderbilt University (Nashville, TN) as a postdoctoral fellow, under the supervision of Prof. Guengerich, studying cytochrome P-450 chemistry. Dr. Seto is currently director of the Third Department of Forensic Science, National Research Institute of Police Science (Kashiwa, Chiba, Japan).

Before joining the National Research Institute of Police Science in 1985 as a researcher in forensic toxicology, Dr. Seta worked for three years at the Kagawa Medical School (Takamatsu, Kagawa, Japan) as an assistant professor in biochemistry. Dr. Seta's current duties include research and development, forensic investigation into special cases, and training local forensic science laboratory members. He was involved in the forensic investigations into the sarin gas attacks and the Wakayama Curry poisoning case. After the sarin gas attacks, he worked on R&D of the laboratory's analytical technologies for chemical warfare agents and biological toxins. Since 1999 he has worked extensively on R&D of countermeasure technologies for chemical terrorism, such as on-site detection and decontamination, as national projects.

Dr. Seto is a member of the Japanese Association of Forensic Toxicology (JAFT) and The International Association of Forensic Toxicologists (TIAFT). He received an award for excellence from TIAFT in 2007.