GAO | Science, Technology Assessment, and Analytics

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SCIENCE & TECH SPOTLIGHT:

TRACING THE SOURCE OF CHEMICAL WEAPONS

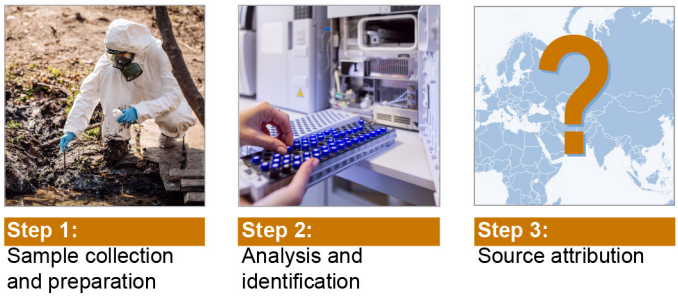
Accessible Version

WHY THIS MATTERS

Some governments are suspected of using chemical weapons despite international prohibitions under the Chemical Weapons Convention. For example, sarin and VX nerve gas have been identified in attacks. Most recently, Novichok nerve agent was used in 2020. Technologies exist to identify chemical warfare agents and possibly their sources, but challenges remain.

/// THE TECHNOLOGY

What is it? According to the Global Public Policy Institute, there have been more than 330 chemical weapons attacks since 2012. Such attacks are prohibited under the Chemical Weapons Convention. A set of methods called forensic chemical attribution has the potential to trace the chemical agent used in such attacks to a source. For example, investigators could use these methods to identify the geographic sources of raw materials used to make the agent, or to identify the manufacturing process. Such information can aid leaders in deciding on whether or how to respond to a chemical weapons attack.



Sources (left to right): kaninstudio/stock.adobe.com; Sodel Vladyslav/stock.adobe.com; GAO illustration. | GAO-21-271SP

Figure 1. Forensic chemical attribution process

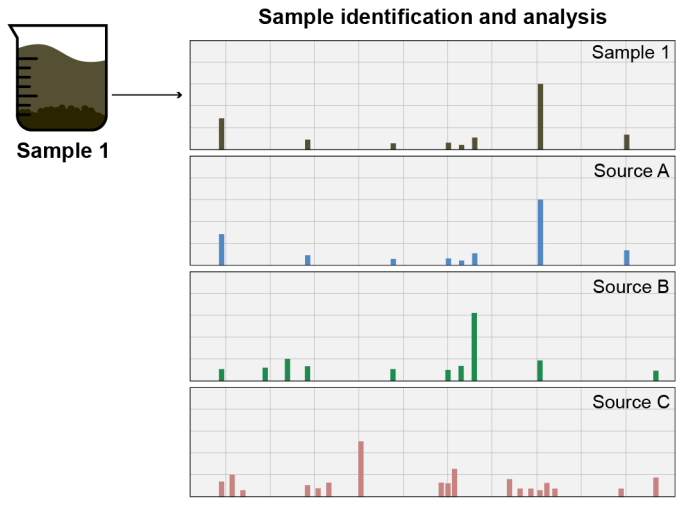
How does it work? Forensic chemical attribution is a three-step process, though the third step is being developed (see Fig. 1). First, a sample is taken from a victim or the site of an attack. Second, the sample's chemical components are analyzed and identified (see Fig. 2) either at a mobile lab or at one of 18 authorized biomedical labs worldwide. Common identification methods are:

- Gas chromatography, which separates chemical components of a mixture and quantifies the amount of each chemical.
- Mass spectrometry, which measures the mass-to-charge ratio of ions (i.e., charged particles) by converting molecules to ions and separating the ions based on their molecular weight.
- Nuclear magnetic resonance (NMR), which can determine the structure of a molecule by measuring the interaction between atomic nuclei placed in a magnetic field and exposed to radio waves. NMR is the same principle as magnetic resonance imaging (MRI), used in medical diagnostics.

In the third step—still under development—investigators use the data from the forensic chemical identification and analysis methods from step two to develop a "chemical fingerprint." The fingerprint can be matched to a database of information on existing methods or known source to identify chemical agents (i.e., Source A matching Sample 1 of Fig. 2). However, a comprehensive database containing complete, reliable data for known agents does not exist.

How mature is it? Forensic chemical analysis and identification (i.e., Step 2 of Fig. 1) is mature for known chemical agents. For example, investigators determined the nerve agent sarin was used in an attack on civilians in 2017. The methods can also identify new agents, as when investigators determined the chemical composition of the Novichok nerve agent after its first known use in 2018.

Forensic chemical analysis and identification methods are also mature enough to generate data that investigators could use as a "chemical fingerprint" – that is, a unique chemical signature that could be used in part to attribute a chemical weapon to a person or entity. For example, combining gas chromatography and mass spectrometry can provide reliable information about the chemical components and molecular weight of an agent. To achieve Step 3, scientists could use these methods in a laboratory experiment to match impurities in chemical feedstocks of the weapon to potentially determine who made it. In an investigation, such impurities could indicate the geographic origin of the starting material and the process used to create the agent.



Source: GAO. | GAO-21-271SP

Figure 2. Example of forensic chemical identification and analysis, showing a match between Sample 1 and Source A.

Once investigators generate a chemical fingerprint, they would need to compare it to a database of existing fingerprints. University researchers have developed a framework for creating such a database, but the effort remains in the early stages.

/// OPPORTUNITIES

An effective international system for forensic chemical attribution could open up several opportunities, including:

- **Defense.** Knowing the source of a chemical agent could help nations better defend against future attacks and, when appropriate, take military action in response to an attack.
- **Legal response.** Source attribution may provide information to help find and prosecute attackers or to impose sanctions.
- **Deterrence.** The ability to trace agents to a source might deter future use of chemical weapons.

/// CHALLENGES

- **Chemical database.** Creating a comprehensive international database of chemical fingerprints would require funding and international cooperation to sample chemicals from around the world.
- **Finding perpetrators.** Matching a chemical to its source does not reveal who actually used it. Almost all investigations require additional evidence.
- **Samples.** Collecting a sufficient sample for attribution can be challenging, as can storing and transporting it using a secure chain of custody—potentially over great distance—to one of the 18 authorized biomedical labs worldwide.
- **International cooperation.** Lack of cooperation can delay investigations, may compromise sample quality. Cooperation is also essential for creating an international database.
- **Standardization.** Attribution methods are complex and require standardized, internationally accepted protocols to ensure results are reliable and trusted. Such protocols do not yet exist for attributing a chemical weapons attack.

/// POLICY CONTEXT AND QUESTIONS

The following questions are relevant to building an effective, trusted system for tracing attacks using forensic chemical attribution:

- How can federal agencies promote and contribute to the international standardization of scientific methods for forensic chemical attribution? Which agency or agencies should lead this effort?
- How can the international community create and implement a framework for cooperation and trust in forensic chemical attribution?
- What actions could promote or incentivize creation of an internationally accepted database of unique chemical fingerprints for attributing chemical agents to their sources?
- What can be done to fully identify and address the scientific and technological gaps in current capabilities for attributing a chemical agent to its source?

/// SELECTED GAO WORK

- National Security: Long-Range Emerging Threats Facing the United States as Identified by Federal Agencies, GAO-19-204SP.
- Anthrax: Agency Approaches to Validation and Statistical Analyses Could be Improved, GAO-15-80.
- Anthrax Detection: Agencies Need to Validate Sampling Activities in Order to Increase Confidence in Negative Results, GAO-05-251.
- Nonproliferation: Delays in Implementing the Chemical Weapons Convention Raise Concerns About Proliferation, GAO-04-361.
- Chemical and Biological Defense: U.S. Forces Are Not Adequately Equipped to Detect All Threats, NSIAD-93-2.

/// SELECTED REFERENCES

Library of Congress. Congressional Research Service. *Resurgence of Chemical Weapons Use: Issues for Congress.* IN10936. Washington, D.C.: Updated Sept. 18, 2020.

Organisation for the Prohibition of Chemical Weapons. *Report of the Scientific Advisory Board's Workshop on Chemical Forensics.* July 14, 2016.

GAO SUPPORT:

GAO meets congressional information needs in several ways, including by providing oversight, insight, and foresight on science and technology issues. GAO staff are available to brief on completed bodies of work or specific reports and answer follow-up questions. GAO also provides targeted assistance on specific science and technology topics to support congressional oversight activities and provide advice on legislative proposals.

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