Technical Inquiry

Sarin/GB Overview

Developed by:

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HDIAC Contract Number: FA8075-13-D-0001

Technical Inquiry Summary:

HDIAC received an inquiry to provide overview and analysis on the destruction and neutralization/hydrolysis of Sarin, or GB.

Background Information:

HDIAC processed and analyzed scientific and technical information in internal databases as well as pertinent outside sources to prepare the following summary to the inquiry.

Analysis:

Overview

Sarin, also called by its NATO designation GB, was originally developed in Germany in 1938 for use as a pesticide. Today, it is known as a deadly, man-made, chemical warfare nerve agent, which is the fastest-acting and most toxic chemical warfare agents. Sarin is a colorless, odorless and tasteless liquid that can also be evaporated into a vapor in order to quickly spread into the environment.[1] This volatile chemical agent has been used as a weapon many times throughout history, including the Iran-Iraq War in the 1980s and the widely-known Tokyo subway sarin attack, which killed 13 people.

Exposure to sarin causes the disruption of the enzyme acetylcholinesterase, which restricts the breakdown of the chemical, acetylcholine. Acetylcholine allows muscle contraction. Symptoms of sarin vapor exposure appear within a few seconds and within a few minutes and up to 18 hours after exposure to the liquid form. Eventually, the nerve agent allows too much disruption in the body, causing violent muscle spasms, respiratory arrest and eventual death due to asphyxiation. Treatment of sarin poisoning can only be accomplished immediately after exposure with specific antidotes, atropine and pralidoxime chloride (2-PAM), along with supportive medical care.

Destruction

Any country belonging to the Organisation for the Prohibition of Chemical Weapons (OPCW) is required to destroy all existing chemical weapons under international verification. The OPCW is the implementing body of the Chemical Weapons Convention, which was established in 1997. The 190 member states included within the OPCW are working together in order to achieve a world rid of chemical weapons.[2] States possessing and maintaining chemical weapons are required to provide detailed plans of their destruction. These instructions include details of the destruction facility in addition to procedures to follow. Monitoring the destruction of chemical weapons would require more elaborate information processing, including remaining stock balances, preventing diversion of agents or weapons and analytical chemical data.[3]

[1] Facts About Sarin. (2004). Centers for Disease Control and Prevention.
[2] About OPCW. (2015). Organisation for the Prohibition of Chemical Weapons.
[3] United Nations Conference on Disarmament Geneva (Switzerland). (1991). Conference on Disarmament, Chemical Weapons Working Papers of the Ad Hoc Committee on Chemical Weapons., (p. 442). Ottawa.

In 1991, the Chemical, Physical and Biological Technical Center of Italy and the Nuclear, Bacteriological and Chemical (NBC) Defence Establishment proposed two different chemical methods for destroying the mixture by oxidation and hydrolysis, by means of using hydrogen peroxide as an oxidant and nitric acid. Due to economic considerations and environment protection, the Italian technical center proposed using H_2O_2, overlooking the reaction temperature was hard to control. Today, chemical agents can either be destroyed by neutralization/hydrolysis, incineration or supercritical water oxidation.[2]

Table 1: Overview of the destruction/decomposition processes for Sarin

Aqueous Hydrolysis[4]	Varies with pH and temperature; at 20°C, $t_{1/2}$ = 27 min @ pH 1; $t_{1/2}$ = 3.5 hr @ pH2; $t_{1/2}$ = 80 hr @ pH7; $t_{1/2}$ = 5.4 min @ pH 10; and $t_{1/2}$ = 0.6 min @ pH 11
Hydrolysis products	Chemical neutralization occurs which creates isopropyl methylphosphonic acid as its first reaction, which is unique to sarin. Methylphosphonic acid forms in the hydrolysis of other organophosphate compounds, which is a less reliable indicator of the presence of sarin.
Photo[5]	Strong UV
Thermal[6]	Complete decomposition occurs within 2.5 hr @ 150°C

Hydrolysis/Neutralization

The toxicity of most chemical weapons agents can either be eliminated or reduced to an insignificant level by chemical treatment. GB can be rapidly hydrolyzed by treatment with a 10 to 20 percent aqueous solution of sodium or potassium hydroxide. All similar nerve agents can be toxicologically neutralized in this manner. Once an agent has been hydrolyzed, the question of disposal of the hydrolysate arises. Solutions include sea disposal, incineration (including GB, even though it's non-flammable) and concentration followed by land burial.[4] Incineration is the more appropriate method of destruction because it leads to irreversible total mineralization of the toxic chemicals involved.

Within sarin hydrolysis reactions, water molecules are split into two parts: hydrogen (H) and hydroxide (OH). The H is able to form a bond with an atom of a larger molecule, either fluorine or oxygen, and the OH is able to attach to another atom of a larger molecule (phosphorus). As a

[4] Epstein, J., Studies on Hydrolysis of GB I. Effect of pH and Temperature on Hydrolysis Rates. II. Observations on Hydrolysis of GB in Sodium Bicarbonate Buffered Waters, MDR 132, Chemical Warfare Laboratories, Army Chemical Center, MD, February 1948.
[5] Guo-Min Zuo et al., Photoassisted removal of sarin vapor in air under UV light irradiation Journal of Photochemistry and Photobiology A: Chemistry, 118, Pages 143-148, 20 May 2007.
[6] Perry, B.J., et al., The Chemistry of the Alkylfluorophosphonites and Related Compounds, Porton Technical Paper No. 258, Chemical Defense Experimental Establishment, Porton, England, 31 August 1951.

result, the bond between both atoms in the larger molecule is broken, which divides the larger molecule into two parts. Chemical neutralization occurs which creates isopropyl methylphosphonic acid as its first reaction, which is unique to sarin. Methylphosphonic acid forms in the hydrolysis of other organophosphate compounds, which is a less reliable indicator of the presence of sarin. See Figure 1 which depicts the hydrolysis of sarin.[7]

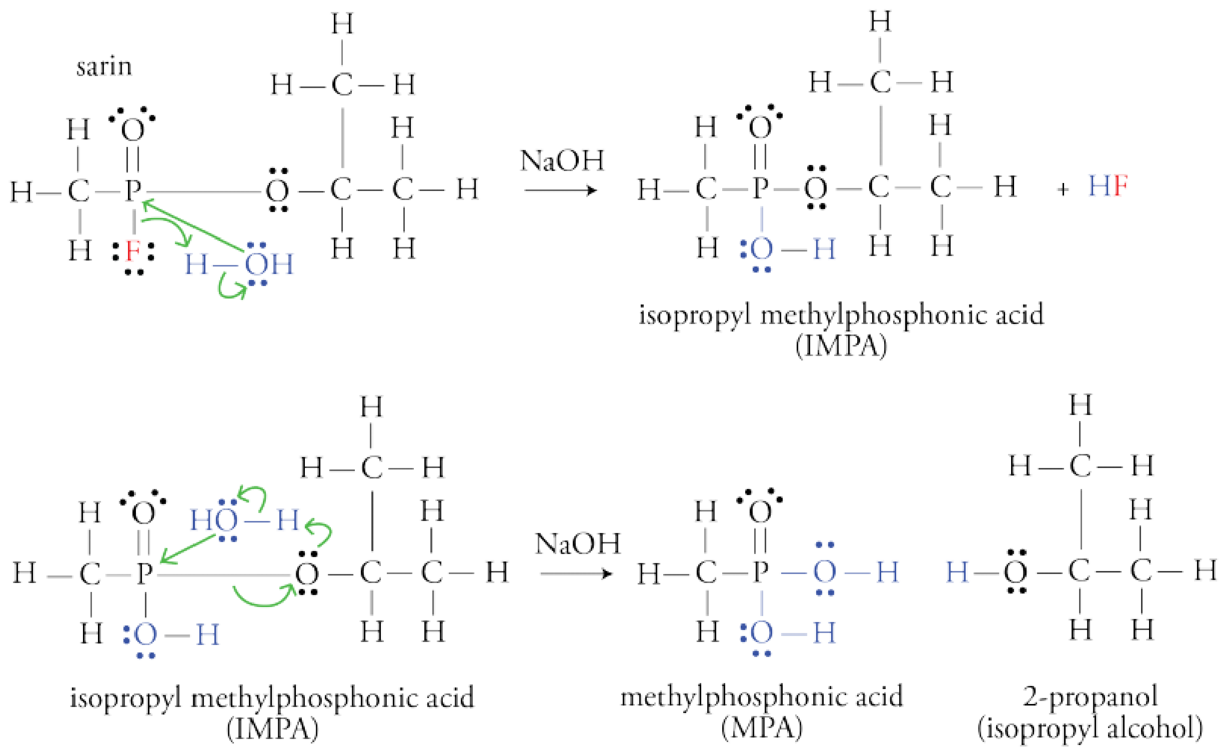

Figure 1: Hydrolysis of Sarin. Each arrow represents the movement of a pair of electrons as covalent bonds are broken and made.

The Blue Grass Army Depot, one of the remaining storage facilities for conventional munitions and chemical weapons, uses neutralization followed by supercritical water oxidation to destroy chemical weapons, including sarin, stored on-site. Stored munitions are disassembled by modified reverse assembly. After separating the chemical agent and the energetics, they are chemically mixed with caustic or water to destroy the chemical agent using hydrolysis, resulting in hydrolysates, as mentioned above. The agent and energetic hydrolysates are fed to the supercritical water oxidation units to destroy the organic materials. This subjects the hydrolysate to very high temperatures and pressures, breaking them down into carbon dioxide, water and salts. Metal parts are thermally decontaminated by high-pressure water washout and heating to 1,000 degrees Fahrenheit for a minimum of 15 minutes. The metal parts can then be safely recycled. Gas effluents are filtered through a series of HEPA and carbon filters before being released to the atmosphere.

[7] Bishop, M. (n.d.). *Chemical Weapon Destruction*. Monterey: Monterey Institute of International Studies.

Water is recycled into the pilot plant facility and reused as part of the destruction process.[8] See Figure 2 for a layout of this process.

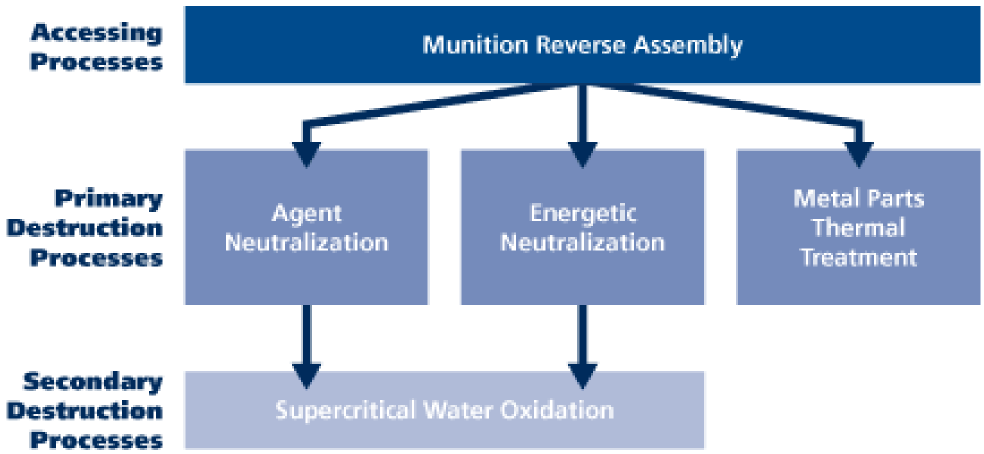

Figure 2: Layout of Chemical Agent Neutralization followed by Supercritical Water Oxidation used at the Blue Grass Army Depot.[5]

References:

See included bibliographies for additional references used in this analysis.

[8] Neutralization followed by Supercritical Water Oxidation. (2015). BGCAPP Destruction Technology. Retrieved from http://www.peoacwa.army.mil/bgcapp/bgcapp-destruction-technology/.