Science and Technology

Chemical Weapon Destruction

OPCW Member State Obligations

- *Each country that belongs to the OPCW must:*
  - *destroy all chemical weapons it owns or possesses;*
  - *destroy all chemical weapons it may have abandoned in another country; and*
  - *destroy facilities it owns or possesses which were involved in the production of chemical weapons.*

https://www.opcw.org/our-work/demilitarisation/destruction-of-chemical-weapons/

CWC Declared and Destroyed CW

- According to the OPCW, 84.95% of the 72,534 metric tons declared have been destroyed.
- Seven of the 192 member states declared chemical weapons stockpiles: Albania, India, Iraq, Libya, Russia, South Korea, and the United States.
- Russia largest stockpile…about 40,000 metric tons at seven arsenals
- U.S. – 28,577 metric tons at nine stockpiles

Three Ways of Disposing of Chemical Weapons

- Ocean dumping (no longer done)
- Incineration
- Chemical neutralization followed by various further treatments (now favored)

Challenges for Destruction of Chemical Weapons

- Choosing safest and most environmentally sound destruction techniques
- Paying high costs
- Meeting deadlines that were set before the process of destruction was determined.

Albania and South Korea

- Albania
  - With help from the U.S., Albania was first to destroy CW (16 metric tons of mustard agent and a small quantity of lewisite and other chemicals)
  - OPCW certified the completion of the destruction in 2007
- South Korea
  - Declared CW but details not made public
  - OPCW certified the completion of the destruction in 2008

India

- India
  - Declared 1044 metric tons of sulfur mustard
  - OPCW certified the completed destruction in 2009.

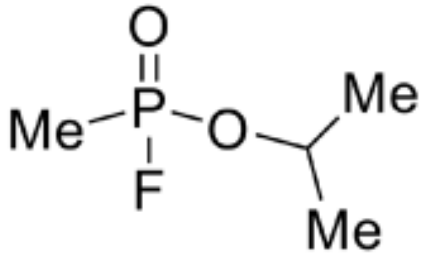
United States Destruction of Chemical Weapons

- When U.S. Senate ratified CWC on April 25, 1997, the articles of ratification specified, among other things,
  - Highest priority on protection of public health and the environment
  - Development of nonincineration techniques
  - National dialogue of stakeholders…federal, state, and local officials, environmentalists, public health experts, and military officials

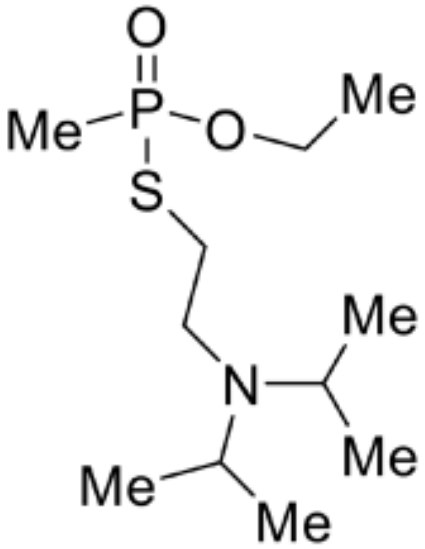
Ocean Dumping of Chemical Weapons

http://cns.miis.edu/multimedia/interactive_files/cw_dumping.htm

Incineration of Sarin and VX

2  $\xrightarrow[1480\ ^{o}C]{13\ O_2}$ $P_2O_5 + 8\ CO_2 + 9\ H_2O + 2\ HF$

GB (Sarin)

2  $\xrightarrow[1480\ ^{o}C]{38.5\ O_2}$ $P_2O_5 + 22\ CO_2 + 26\ H_2O + 2\ SO_2 + 2\ NO$

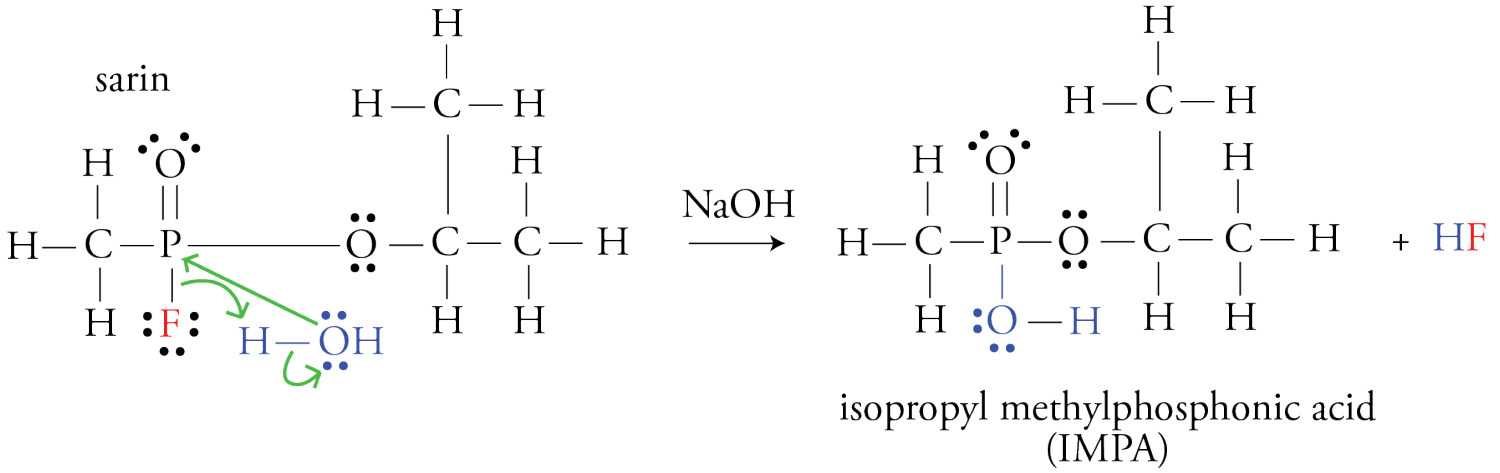
VX

Hydrolysis of Sarin

- In hydrolysis reactions, water molecules split into two parts, H and OH.
- The H forms a bond with an atom of a larger molecule (atom 1: for sarin, F or O), and the OH attaches to another atom of the larger molecule (atom 2: for sarin, P).
- When this happens, the bond between atoms 1 and 2 in the larger molecule is broken, dividing the larger molecule into two parts.

Hydrolysis of Sarin

Each arrow represents the movement of a pair of electrons as covalent bonds are broken and made.

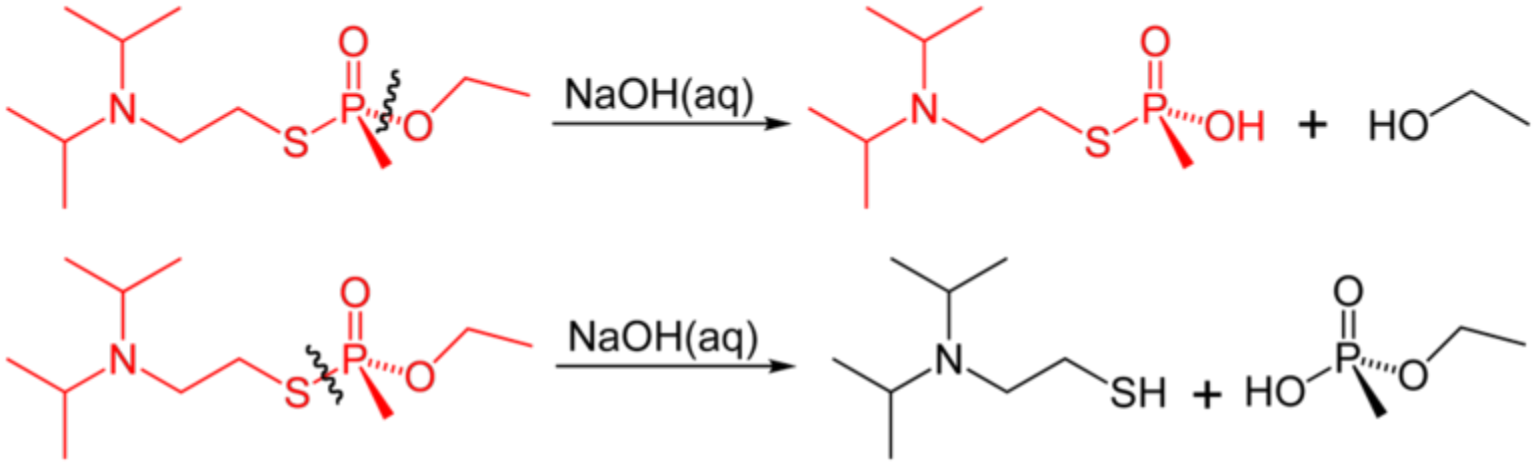


Hydrolysis of Sarin

- These hydrolysis reactions take place in the normal breakdown of sarin once it is released and in the destruction of sarin in what is often called chemical neutralization.
- The product of the first reaction (isopropyl methylphosphonic acid, IMPA) is unique to sarin, so if it is found in an area where sarin use is suspected, this indicates that sarin was present.
- Because the product of the second reaction (methylphosphonic acid, MPA) forms in the hydrolysis of other organophosphate compounds, it is a less reliable indicator of the presence of sarin.

Chemical Neutralization of VX

- VX can be converted into safer substances by combining it with a concentrated solution of sodium hydroxide, NaOH.
- The reaction is called hydrolysis, in which water, H_2O, divides into H, which combines with one part of a molecule, and OH, which combines with another part of the molecule, splitting the molecule into two parts.

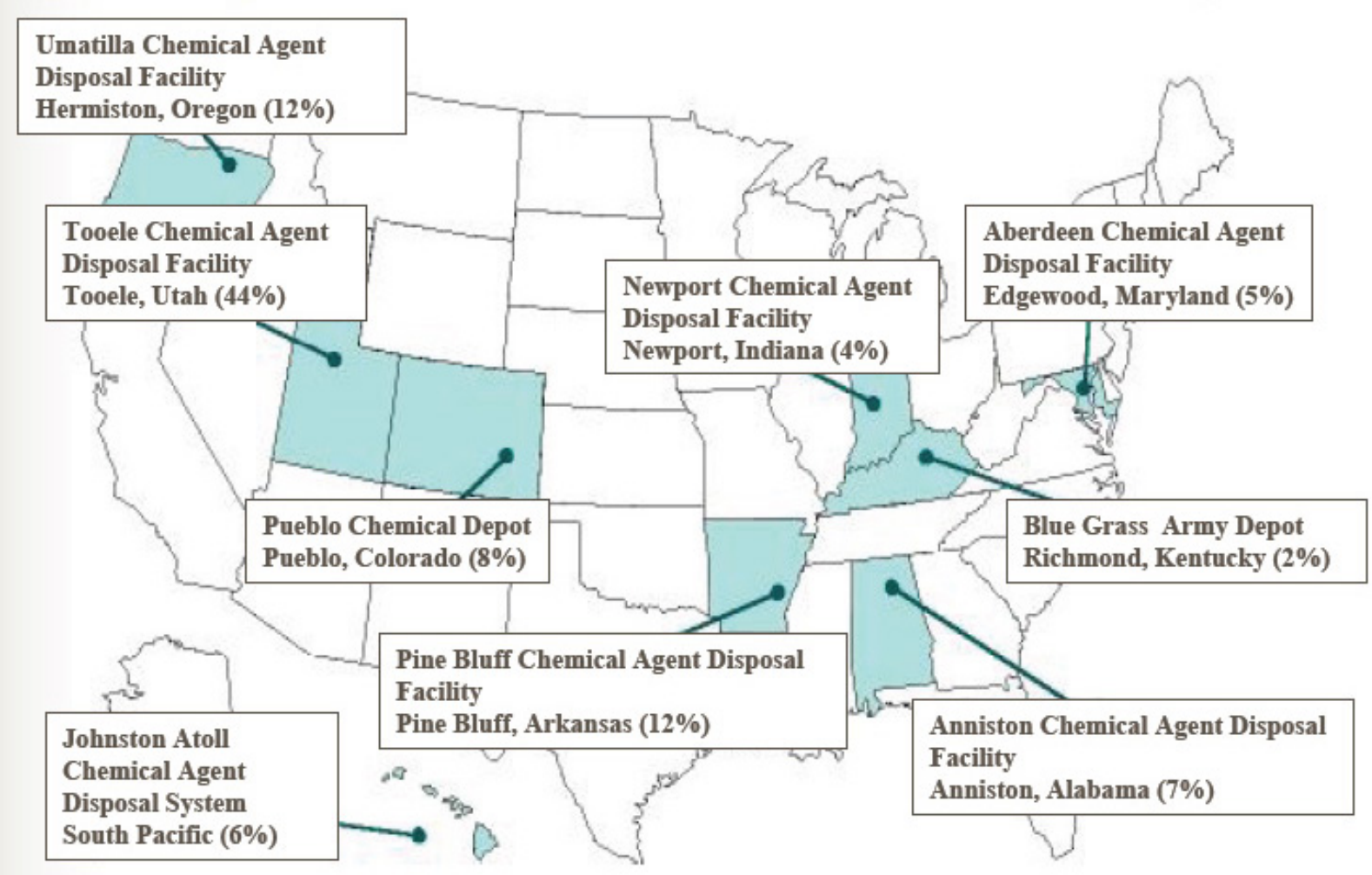


U.S. Army's Chemical Materials Agency (CMA)

- The CMA stores and destroys the U.S. chemical weapons.
  http://www.cma.army.mil/

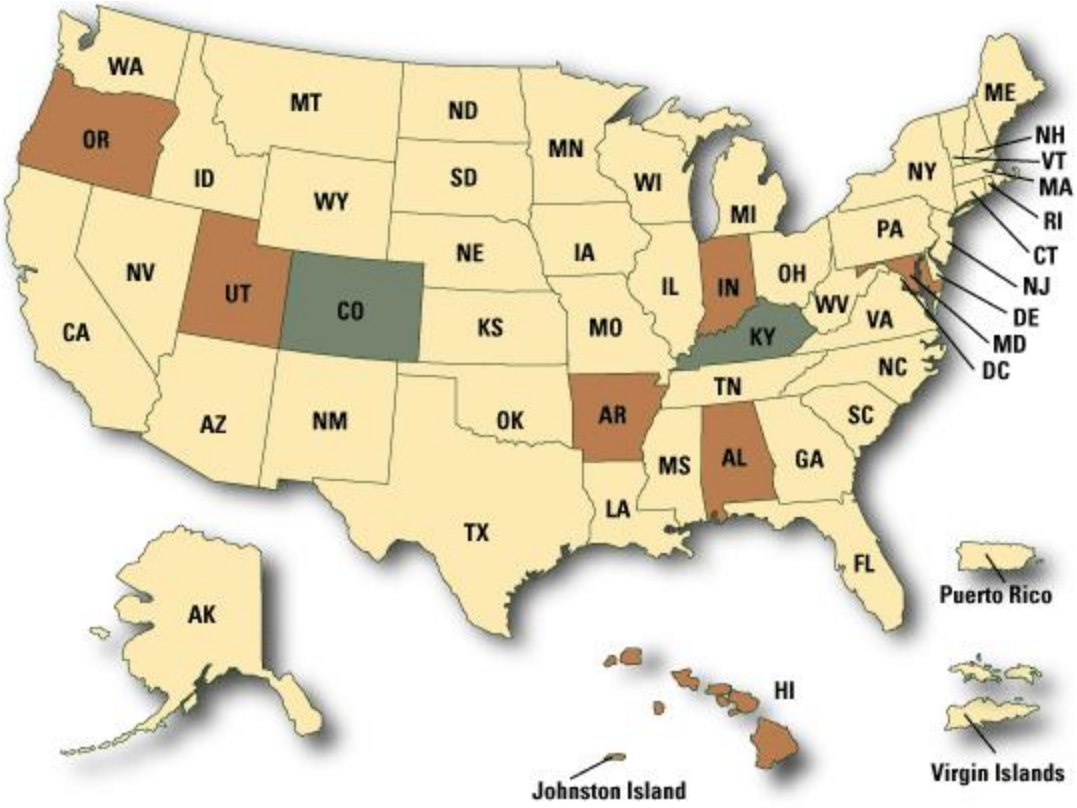
A student fully encapsulated in a protective suit at the Chemical Demilitarization Training Facility at Aberdeen Proving Ground, Md., rolls a simulated waste barrel in the Demilitarization Equipment Room.

United States CW Disposal Facilities



Status of CW Disposal Facilities

Green - States and Regions with Chemical Weapons Stockpiles
Yellow - States and Regions without Chemical Weapons Stockpiles
Brown - States and Regions that had Chemical Weapons Stockpiles



http://www.cma.army.mil/map.aspx

United States Destruction of Chemical Weapons

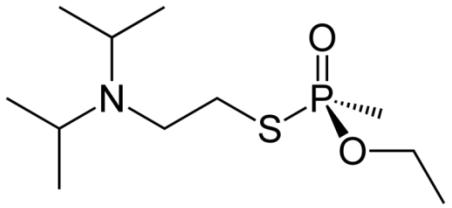
United States Destruction of Chemical Weapons

- Johnston Atoll
  - 800 miles southwest of Hawaii
  - Chemical weapons have been stored on Johnston Island since 1971.
  - CW formerly held in Okinawa
  - 1990 – CW from the Federal Republic of Germany were transferred to Johnston Atoll for destruction
  - 1991 - range-recovered chemical munitions were brought from the Solomon Islands.
  - 1981-2000 - world's first full-scale facility built to destroy chemical weapons.
  - Incineration of CW finished in 2000

United States Destruction of Chemical Weapons

- Newport, Indiana
  - August 2008 – 100% of VX neutralized by mixing with water and sodium hydroxide and heating to 194°F (90°C)

VX at Newport



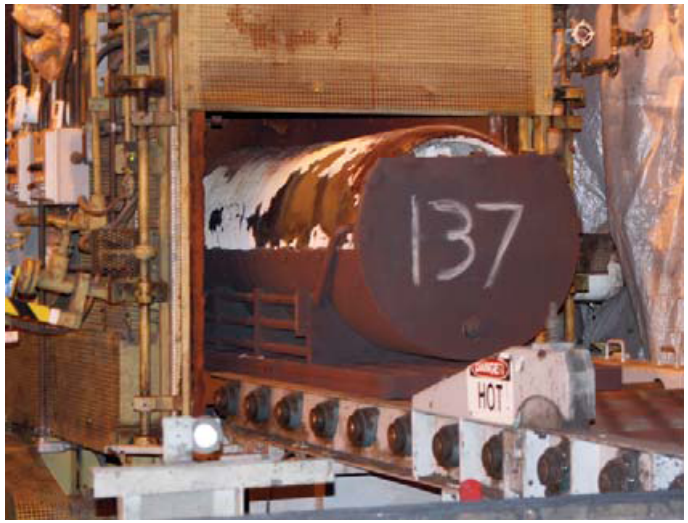
- Edgewood, Maryland
  - Agent destruction operations began in April 2003 and were completed in February 2006.

United States Destruction of Chemical Weapons

- Pine Bluff, Arkansas
  - Completed destruction of sarin, VX, and blister agents by incineration on April, 2010
- Anniston, Alabama
  - Completed destruction of sarin, VX, and blister agents by incineration on September 22, 2011

United States Destruction of Chemical Weapons

- Umatilla (yü-mə-ˈti-lə), Oregon –
  - 10/25/11 - Completed incineration at 2,700 degrees Fahrenheit of 3,717 tons of nerve gas and blister agent



Destruction of mustard agent at Umatilla

Umatilla, Oregon CW Destruction Facility

United States Chemical Weapons Destruction

- Tooele (tü-ˈe-lə), Utah
  - Destruction facility for chemical agents stored at the Deseret (de-zə-ˈret) Chemical Depot
  - The last chemical agent munitions were destroyed on Jan. 21, 2012.

United States Remaining Chemical Weapons

- Blue Grass Army Depot - Richmond, Kentucky
  - Chemical weapons will be destroyed by chemical neutralization followed by supercritical water oxidation.
  - Has 523 tons of sarin, VX, and mustard agent in projectiles, warheads, and rockets.

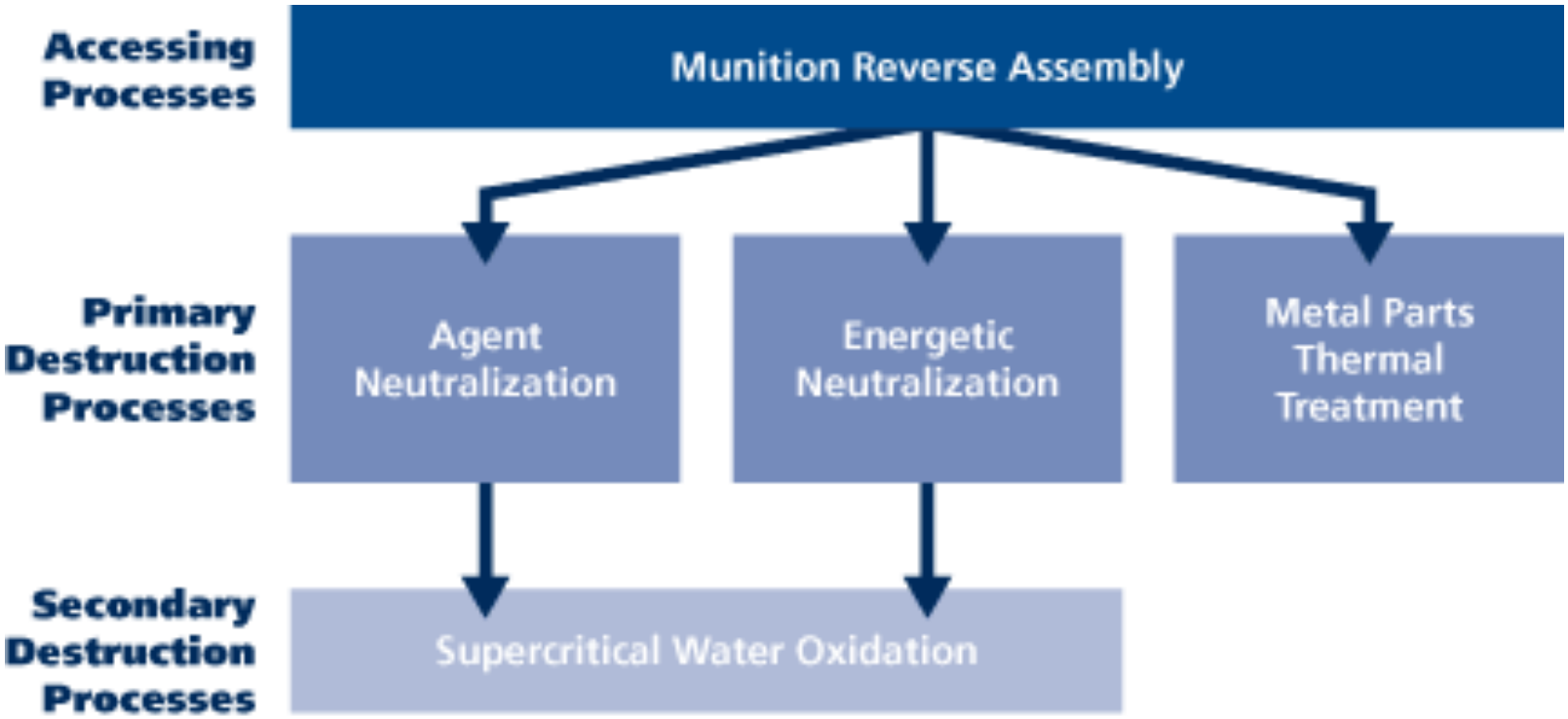
http://www.cma.army.mil/bluegrass.aspx

Supercritical Water Oxidation (SCWO)

- The chemical agent and energetics are separated.
- Hydrolysis of chemical agent and energetics
- The hydrolysis products are separately fed to the supercritical water oxidation units to destroy the organic materials.
  - SCWO subjects the hydrolysis products 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.
- Gases are filtered through a series of filters before being released to the atmosphere.
- Water is recycled into the pilot plant facility and reused as part of the destruction process.

http://www.peoacwa.army.mil/bgcapp/bgcapp-destruction-technology/

Supercritical Water Oxidation (SCWO)



United States Remaining Chemical Weapons

- Pueblo, Colorado
  - Will destroy 2,371 metric tons of mustard agent stored in different types of projectiles and mortars by neutralization.
  - Started March 2015

http://www.cma.army.mil/pueblo.aspx

Steps for Neutralization Followed by Biotreatment

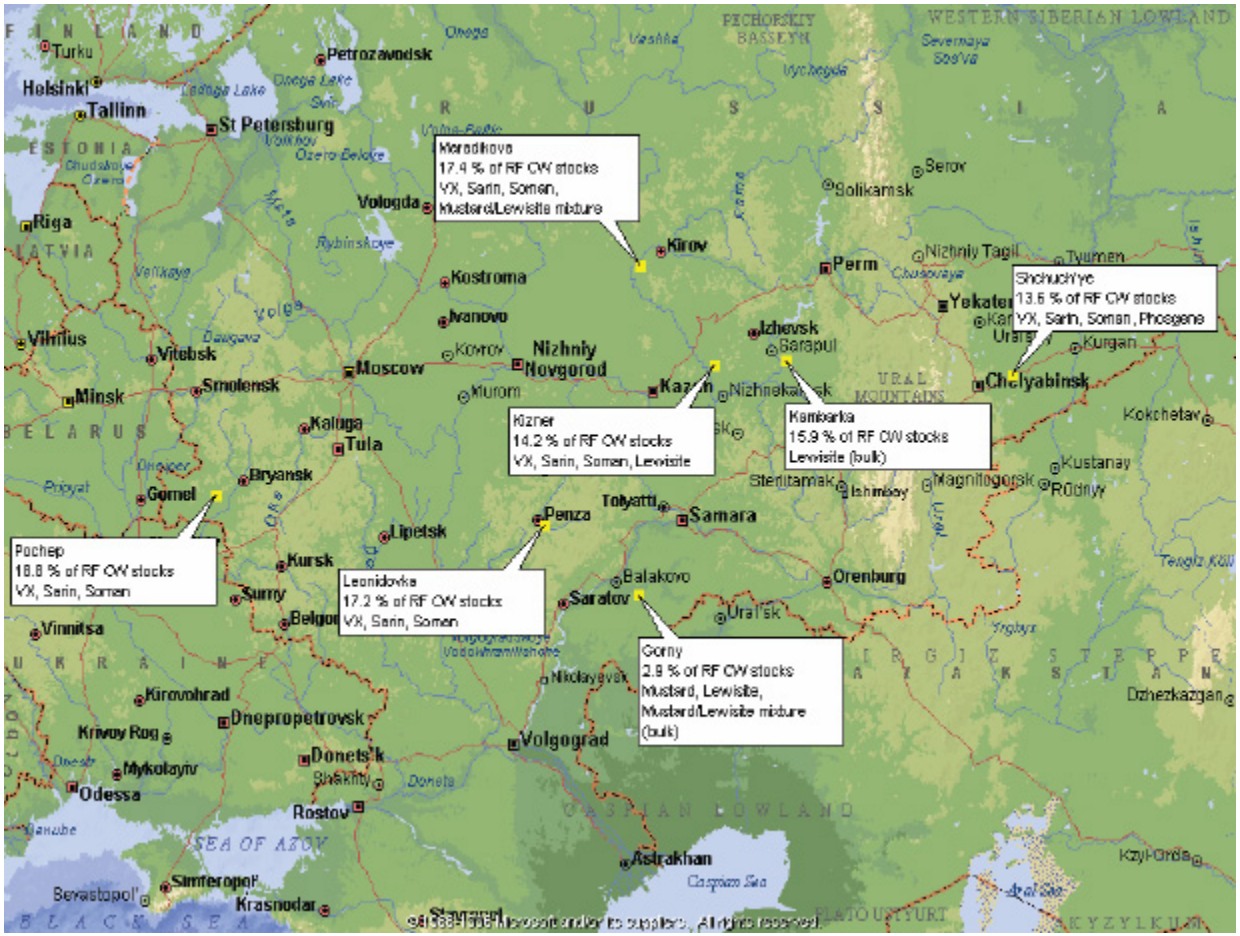
- Robatically removing the energetics, including the fuse and burster
- Robatically removing the mustard agent
- Hydrolysis of mustard agent
- Biotreatment of remaining organics (mostly thiodiglycol) with microbes (ordinary sewage treatment bacteria)
- Disposal of metal parts after heating to high temperature to complete the decontamination

http://www.peoacwa.army.mil/media-toolkit/facts-pages/facts-page-neutralization-followed-by-biotreatment/

United States Destruction of Chemical Weapons

- United States has finished off about 90 percent of its original holding of close to 30,000 tons of warfare agents, along with hundreds of thousands of munitions. Disposal plants are still being readied in Colorado and Kentucky to complete the job, no later than 2023 according to current projections.
- Missed the April 29, 2012 deadline
- OPCW OK'd an extension in the December 2011 meeting.
- U.S. Congress has set 2017 as date for 100% destruction
- U.S. Army projects 2021 as a more likely end point
- Will have cost $40 billion

Russian CW Sites



Russia Destruction of Chemical Weapons

- 1987 – discontinued production of CW and stated intention to destroy and not replace CW
- 1989 – U.S. and Russia signed Wyoming MOU
  - Bilateral exchange of information
  - Verification inspections
- 1997 – ratified CWC
- 2002 – neutralization facility for destruction of lewisite
- By August 2011 – Five more destruction facilities

Russia Destruction of Chemical Weapons

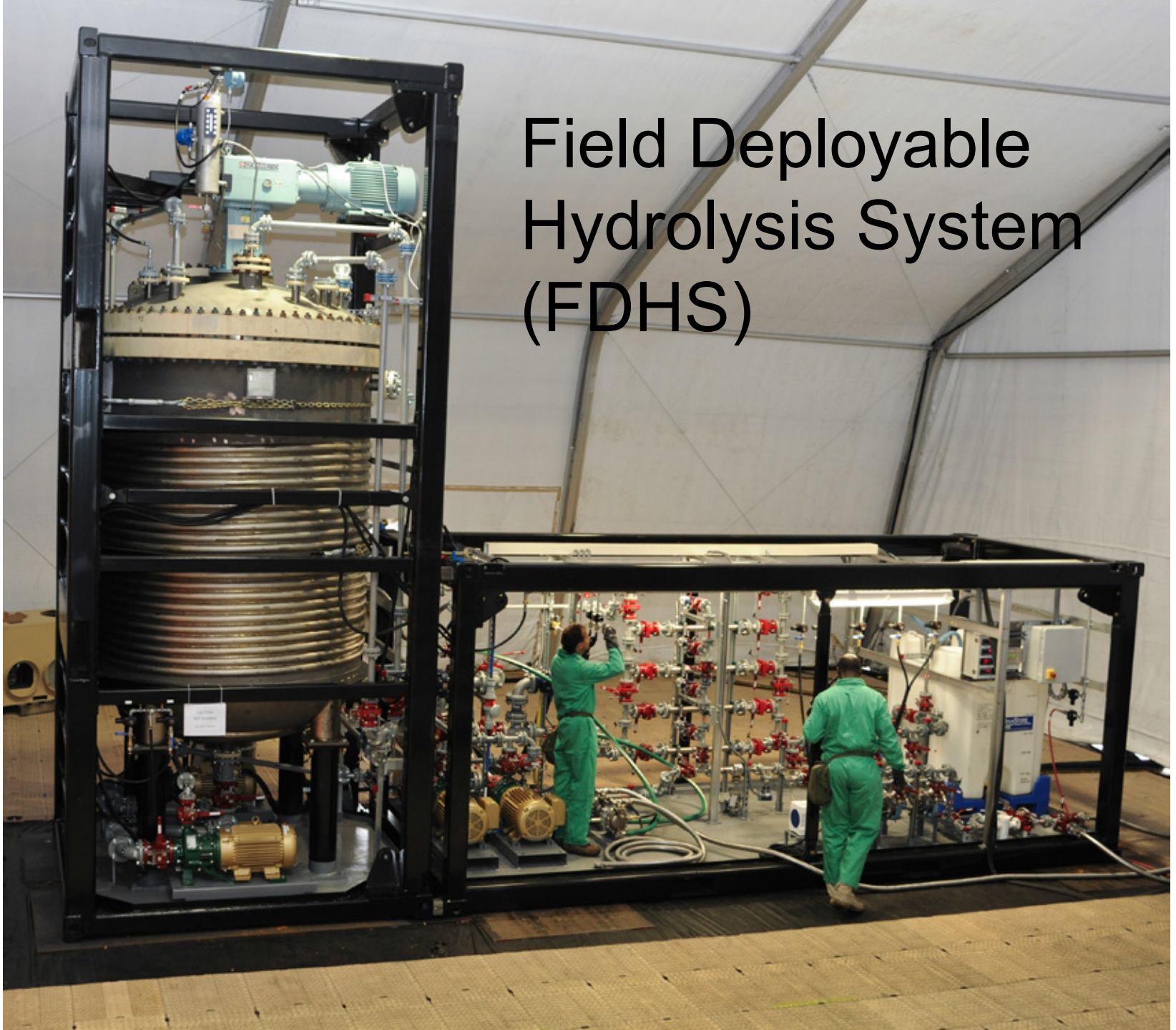
- U.S. through Cooperative Threat Reduction program has committed $1 billion to help
- OPCW OK'd an extension in the December 2011 meeting.
- September 2013 – Russia reported that they had destroyed over 76% of its stockpile (over 30,000 of 40,000 metric tons)
- Expect to be done by December 2020.

Destruction of Syrian Chemical Weapons

- 23 June 2014 - last *declared* chemical weapons were shipped out of Syria.
- The most dangerous chemical weapons destroyed at sea aboard the CAPE RAY, using an U.S. Army Field Deployable Hydrolysis System.
- 17 June 2015 – OPCW verifies that the last of the hydrolysis products of Syrian CW destroyed.

Field Deployable Hydrolysis System (FDHS)

- *Transportable, high-throughput modular demilitarization system designed to render chemical warfare materiel into compounds not usable as weapons.*
- *The system uses neutralization technology to destroy bulk chemical warfare agents and their precursors by heating and mixing with reagents, such as water, sodium hydroxide and sodium hypochlorite to facilitate chemical degradation resulting in a destruction efficiency of 99.9 percent.*


Field Deployable
Hydrolysis System
(FDHS)

Destruction of Syrian Chemical Weapons

According to the OPCW, as of 9 February 2015

	Total amount	Amount destroyed	Destroyed %
Category 1*	1,046,981 kg	1,046,981 kg	100.0%
Category 2**	261,040 kg	234,436 kg	89.8%
Total	1,308,021 kg	1,281,417 kg	98.0%

Only 29 metric tones of hydrogen fluoride remain to be destroyed at facilities in the United States and United Kingdom

http://www.opcw.org/special-sections/syria/destruction-statistics/

http://www.opcw.org/news/article/first-of-12-chemical-weapon-production-facilities-in-syria-destroyed/

Destruction of Syrian Chemical Weapons

- Some questions about the completeness of Syria's declarations and about how serious they were about the spirit of the CWC.
  - The Assad government forces have been accused of conducting illegal chlorine attacks in 2014.
  - Late disclosure in 2014 regarding Syria's ricin program

Destruction of Syrian CW Production Facilities

- As of 23 March 2015, of the 12 chemical weapons production facilities (five under ground), *three underground structures have been verified by the OPCW as destroyed, and destruction operations continue at one of the remaining two underground structures.*

http://www.opcw.org/index.php?eID=dam_frontend_push&docID=18558

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