Category 2 Chemical Weapons (precursors)
Universal destruction technology

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- Category 2 CW and reaction masses destruction technologies review
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Background

- **Article 16. of the Part IV(A) of VA.**
  For the purpose of destruction, chemical weapons declared by each State Party shall be divided into three categories:
  ....Category 2: Chemical weapons on the basis of all other chemicals and their parts and components;...

- **Article 17. of the Part IV(A) of VA**
  A State Party shall start:
  ...(b) The destruction of Category 2 chemical weapons not later than **one year after** this Convention enters into force for it and shall complete the destruction not later than **five years** after the entry into force of this Convention. Category 2 chemical weapons shall be destroyed in equal annual increments throughout the destruction period. The comparison factor for such weapons is the weight of the chemicals within Category 2;...
Aggregate Category 2 CW Destroyed as at 31 May 2014 (OPCW)

Declared (MT) 2,031.55
Destroyed (MT) 919.93
Progress 45.28%
To be Destroyed 1,111.62 MT
<table>
<thead>
<tr>
<th>Chemical name</th>
<th># SPs declared as Cat 2 CW</th>
<th>Destruction method</th>
</tr>
</thead>
<tbody>
<tr>
<td>PHOSGENE: CARBONYL DICHLORIDE</td>
<td>2</td>
<td>Reprocessed in chemical synthesis/TDC/SDC-neutralisation</td>
</tr>
<tr>
<td>DIPHENYLAMINOCHLORARSINE (DM)</td>
<td>1</td>
<td>Pyrolysis in N₂ atmosphere (600-800°C, 18 h) followed by incineration (1100°C)</td>
</tr>
<tr>
<td>CHLOROACETOPHENONE (CN)</td>
<td>1</td>
<td>Pyrolysis in N₂ atmosphere (600-800°C, 18 h) followed by incineration (1100°C)</td>
</tr>
<tr>
<td>PINACOLYL ALCOHOL</td>
<td>1</td>
<td>To be destroyed</td>
</tr>
<tr>
<td>2-CHLOROETHANOL</td>
<td>2</td>
<td>Mixing with HD-incineration</td>
</tr>
<tr>
<td>THIONYL CHLORIDE</td>
<td>1</td>
<td>To be destroyed</td>
</tr>
<tr>
<td>PHOSPHORUS TRICHLORIDE</td>
<td>2</td>
<td>To be destroyed</td>
</tr>
<tr>
<td>1-PROPYL ALCOHOL</td>
<td>2</td>
<td>To be destroyed</td>
</tr>
<tr>
<td>TRI-BUTYLAMINE</td>
<td>1</td>
<td>To be destroyed</td>
</tr>
<tr>
<td>SODIUM SULPHIDE</td>
<td>1</td>
<td>Mixed with concrete and buried</td>
</tr>
<tr>
<td>SODIUM FLUORIDE</td>
<td>1</td>
<td>Mixed with concrete and buried</td>
</tr>
</tbody>
</table>
Explosives use detonation technologies

TDC Transportable Detonation Chamber.

Simplified process flow diagram. Destruction of Old Chemical Weapons at Columboola (Image: Copyright CH2MHILL)

The TDC is a self-contained system, which includes a detonation chamber, an expansion chamber and an emission control system. It destroys munitions that are wrapped in explosive by detonating them within the fully-enclosed chamber. Applications of the TDC include destruction of recovered chemical weapons in Poelkapelle, Belgium, and at Schofield Barracks, Hawaii. TDC developed at Aberdeen Proving Ground, Md.
Explosives/high temperature use detonation technologies

**SDC.** The boxed munitions are dropped onto a heated (550°C-600°C) shrapnel (scrap) bed at the bottom of the detonation chamber, resulting in deflagration, detonation, or burning of the munition’s explosive fill. The chemical agent in the munitions is destroyed by the shock wave from the detonation or by decomposition due to the high heat in the chamber (Anniston, USA), Libya.
<table>
<thead>
<tr>
<th>Nr.</th>
<th>Chemical name</th>
<th>Inorganic chemicals</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>TRIETHYLAMINE</td>
<td>HYDROGEN FLUORIDE</td>
</tr>
<tr>
<td>2</td>
<td>TRIMETHYL PHOSPHITE</td>
<td>PHOSPHORUS PENTASULFIDE</td>
</tr>
<tr>
<td>3</td>
<td>DIMETHYL PHOSPHITE</td>
<td>PHOSPHORUS TRICHLORIDE</td>
</tr>
<tr>
<td>4</td>
<td>MONOISOPROPYLAMINE</td>
<td>PHOSPHORUS OXYCHLORIDE</td>
</tr>
<tr>
<td>5</td>
<td>DI-ISOPROPYL AMINOETHANOL</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>2-CHLOROETHANOL</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>BUTAN-1-OL</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>METHANOL</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>PROPAN-2-OL</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>HEXAMINE</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>SODIUM-O-ETHYL METHYL PHOSPHONOTHIONATE</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>N (2-CHLOROETHYL)-N-ISOPROPYL PROPAN 2 AMINE (SALT)</td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>N (2-CHLOROETHYL)-N-ISOPROPYL PROPAN 2 AMINE (SOLUTION 23-64%)</td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>N (2-CHLOROETHYL)-N-ETHYL PROPAN 2 AMINE (SOLUTION 23-64%)</td>
<td></td>
</tr>
</tbody>
</table>
Hight temperature industrial waste treatment to be used for CWC purposes

Veolia Environmental Services Technical Solutions, LLC (U.S.A.)

CW disposal facility of GEKA mbH in Munster, Germany
Hight temperature industrial waste treatment to be used for CWC purposes

Veolia Waste disposal site in Ellesmere Port

Ekokem OY AB (Finland)
## Wastes required post treatment

<table>
<thead>
<tr>
<th>Waste (Schedule 2 chemicals)</th>
<th>Estimated Quantity of Effluent (liters)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fluorinated effluent</td>
<td>4,400,000</td>
</tr>
<tr>
<td>Aqueous solution containing o-ethyl methyl phosphonic acid</td>
<td>1,200,000</td>
</tr>
<tr>
<td>Sulfur containing effluent</td>
<td>300,000</td>
</tr>
<tr>
<td>Aqueous solution containing chloro-amines</td>
<td>1,800,000</td>
</tr>
</tbody>
</table>
Reaction mass post treatment

- Russian nerve agents neutralisation technology – incineration or bituminisation
- Newport VX neutralisation – mixing with the industrial waste and its incineration
- Pine Bluff BDF – neutralisation of DF and QL and its treatment at WAO
- Aberdeen HD neutralisation - biodegradation
The binary chemicals QL, diisopropyl aminoethylmethyl phosphonite, and DF, methylphosphonic difluoride have been neutralized at PBBDF and the resulting wastewater shipped to Texas Molecular, a permitted treatment, storage and disposal facility in Deer Park, Texas.

The WAO treated wastewater from the neutralization of the binary chemicals, the final step in the project to destroy binary chemical weapons.
Reaction mass biodegradation

Ensure safety and security
Category 2 CW (sodium sulphite & fluoride) destruction
Leaking $\text{PCl}_3$ and $\text{SOCl}_2$ storage tanks
PCL\textsubscript{3} destruction unit
Category 2 CW (PCl₃) hydrolysis/neutralisation
Needs for universal and mobile destruction technology

- Large varieties of toxic chemicals (precursors) and reaction masses (waste)
- Remote location
- Absence of commercial waste treatment facilities
- Limited technological and technical capabilities
- Limited timeframe and finance
Plasma arc technology

- Plasma waste treatment has over the past decade become a more prominent technology because of the increasing problems with waste disposal.
- Numerous technologies and approaches exist for plasma treatment of wastes.
- Cost of mobile plasma arc units for wastes management may vary between $1 - 10 mln.
Relevant research and application

- The Burns and Roe Enterprises, Inc. and technology partner MGC Plasma, AG of Muttenz, Switzerland, successfully completed a limited engineering scale testing of MGC's PLASMOX® plasma system for the U.S. Army's Non-Stockpile Chemical Material Program (NSCMP) in 2001
- The mobile application technology, RIF 2, was used to destroy chemical warfare agents in Switzerland. Based on its proven success, the RIF 2 unit has been shipped to Albania to destroy chemical warfare agents under the NATO Partnership for Peace program
- Russian Federal Agency for Safe Storage and Destruction of Chemical Weapons Stocpiles is utilising plasma technology for post treatment of reaction mass at three CWDFs
- German Ministry of Defence is using to treat chemical warfare materials and contaminated soils
- Modified Davinch unit is equipped with plasma oxidiser for off gasses after detonation chamber
PLASMA ARC WASTE DESTRUCTION SYSTEM (PAWDS) Mobile Units by PyroGenesis Canada Inc.
Typical technological scheme of plasma unit for toxic waste destruction

1 – air compressor, 2 – plasma reactor, 3 – burning camber, 4 – plasma torch, 5 – power supply system, 6 – centrifugal bubble apparatus (scrubber), 7 – ion-exchange filter, 8 – smoke-stack, 9 – tank with scrubber water, 10 – radiator, 11 – water supply system, 12 – tank with waste
**Mobile compact plasma system (MCPS) for disposal of liquid wastes - AMK-1X**

- Main Unit size 1100x1100x1350mm
- Four sequence plasma arc chambers
- Plasma flow mass average temperature – 3500-5000 ºC
- Temperature in combustion (pyrolysis) zone – 1200-1800 ºC (depending on waste composition)
- Pyrolysis products residence time in reaction zone – more than 2 seconds
- Waste processing degree – 99.98%
Plasma unit contains special equipment to control all technological parameters such as:
- plasma torch power, plasma forming gas consumption, waste consumption, quenching air consumption and others
- Air pressure for plasma unit supplied by autonomous air compressor with fine filter and air-preparation unit. Waste materials are loaded and dispersed by pneumatic injector.
- After burning and cooling of exhaust gases is in the three section quenching module by addition air supplying. temperature in gas purification system is 150 – 520 ºC

Portability of the unit (reactor, gas purification module, supply modules and control system are placed in shipping container) provides ease in transport, minimize installation work. It also allows correcting technological parameters of the unit to adapt it to any special conditions (waste composition and consumption)
MCPS - AMK-1X test conditions

Plasma unit operating parameters:
- Electric arc current in plasma torch – 110-210 A
- Voltage – 200-320 V
- Plasma forming gas (air) consumption – 15-18 m³/h
- Cooling water in plasma torch and reactor consumption – 715 g/s
- Productivity (waste processing) – 8.0-50.0 kg/h (depending on waste composition)
- Quenching gas (air) consumption – 100 m³/h
- Off gas temperature at the inlet of scrubber – 120-500 ºC (depending on waste composition)
- Exhaust gas velocity – 14.7 m/s
- Consumption – 1 265 m³/h.

Design parameters of plasma unit are following:
- Electric power is 45-65 kW
- Heat power transferred to plasma flow is 35-40 kW
- Plasma flow temperature is 3500-5 000 ºC
## MCPS - AMK-1X test results

<table>
<thead>
<tr>
<th>Chemical composition</th>
<th>Analysis of exhaust gas composition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mixtures of toxic waste and manufactured sewage water from epoxide resin production.</td>
<td>300-390 mg/m³ NOₓ, 160-220 mg/m³ SO₂, 45-160 mg/m³ H₂S, 12-14 mg/m³ CH and doesn’t contain CO</td>
</tr>
<tr>
<td>Density is 1.1-1.2 g/sm³. It contains: toluene – 2 000 mg/l; epichlorhydrin – 400 mg/l; sodium chloride – 15 000 mg/l; tarry matters – 700 mg/l; suspended matters – 250 000 mg/l</td>
<td></td>
</tr>
<tr>
<td>Mixture of diesel oil and water at ratio 3:2</td>
<td>200-2 140 mg/m³ CO, 130-145 mg/m³ NOₓ, 240-280 mg/m³ SO₂, up to 54 mg/m³ H₂S, up to 284 mg/m³ CH</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>Mixture of isopropyl alcohol and water at ratio 1:1</td>
<td>730-1 500 mg/m³ CO, 190-360 mg/m³ NOₓ, up to 10-16 mg/m³ CH and doesn’t contain SO₂</td>
</tr>
</tbody>
</table>
Summary

- The plasma arc technology application in case of Category 2 CW (precursors) and wastes is the most universal one, possible cheapest one, most environmentally friendly and resulting with much less quantity of non-toxic wastes (salty waters).

- Depending on the decision taken all chemicals and wastes may be disposed on-site using mobile equipment without complicated transportation of aggressive/toxic chemicals for long distance to the stationary industrial facility.

- Hotzone solutions and CF LASO are planning to test MCPS - AMK-1X on Phosphorus trichloride and Thionyl chloride this summer. All process parameters for MCPS - AMK-1X to process these chemicals are calculated.
CBRN Security in the public sector

Ensure safety and security

Questions?

Ensure safety and security