**(First Applied Sorbent Treatment - Against Chemical Threats)**

## CHEMICAL HAZARD CONTAINMENT AND NEUTRALIZATION SYSTEM

# TECHNICAL REPORT

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## ABSTRACT

FAST-ACT® is a proprietary formulation of non-toxic high-performance specialty materials effective at neutralizing a wide range of **toxic chemicals** with the added capability to destroy **chemical warfare agents**. The FAST-ACT formulation is non-flammable, non-corrosive, and significantly reduces both liquid and vapor hazards. Since the dry powder neutralizes threats upon contact, on-site incident management and clean up times are reduced.

FAST-ACT works quickly to significantly reduce hazards associated with common industrial chemicals including: acids, acidic/caustic gases, organic compounds, phosphorus and sulfur compounds, and many industrial solvents. By the nature of FAST-ACT's innovative chemistry, hazards are chemically bound to the surface of the powder minimizing off-gassing.

Tested by U.S. Soldier Biological Chemical Command (SBCCOM) and Battelle Memorial Institute (Battelle), FAST-ACT is proven to remove over 99.6% (detection limit) of VX, GD (soman) and HD (mustard "gas") from surfaces in under 90 seconds, converting them to safer by-products.

FAST-ACT is offered in pressurized cylinders capable of addressing both liquid and vapor hazards, manually dispersed containers, kits for liquid hazard treatment, and mitts for equipment and small scale decontamination. FAST-ACT can be safely applied to any liquid spill or vapor release enabling Emergency Responders to utilize one technology when faced with a wide variety of known or unknown chemical hazards. Once the hazard has been treated with FAST-ACT, disposal should be in accordance with local, state, and government regulations.


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# I. *INTRODUCTION*

FAST-ACT is a non-toxic, non-corrosive, non-flammable dry powder formulation effective against a wide range of toxic chemicals with the added capability to destroy chemical warfare agents. FAST-ACT's efficacy against such a wide range of chemical hazards is due to the high surface area, large porosity, small crystallite sizes, defect sites, and electronically altered chemical structure of its components.

**FAST-ACT Advantages**

- Effective against a wide range of toxic chemicals including
  - Acids
  - Halogenated compounds
  - Phosphorus compounds
  - Acidic and caustic gases
  - Organic compounds
  - Chemical warfare agents
- Neutralizes both liquid and vapor hazards
- Rapid-acting upon contact
  - Life-safety threat reduction
  - Reduces on-site management time and cost
- Non-toxic, non-corrosive, non-flammable
- Dry powder formulation
- Safe to apply to all liquid and vapor releases
- Easy to operate delivery systems
  - No premixing is required
  - All units are portable
- No special training required
- Effective over a wide range of temperatures and environmental conditions
- Compact containers for easy storage

FAST-ACT rapidly (under 2 minutes) treats a wide range of acids (e.g., hydrochloric, nitric, phosphoric and sulfuric), acidic and caustics gases (e.g., sulfur dioxide, nitrogen dioxide, chlorine, anhydrous ammonia), oxidizers (ethylene oxide), organics such as alcohols (e.g., methanol, ethanol), aldehydes (i.e., acetaldehyde), fuels (e.g., diesel, gasoline), aromatics (e.g., p-cresol), organic compounds containing heteroatom such as: sulfur (e.g., mercaptans), phosphorus (paraoxon, dimethyl methyl phosphonate) and nitrogen (4-vinyl pyridine, acetonitrile) and halogenated compounds (chloroacetyl chloride, acetyl chloride).

FAST-ACT's efficacy against nerve agents GD, VX and blistering agent HD has been tested at Battelle and SBCCOM. The formulation was found to remove over 99.6% (detection limit) of these agents from surfaces within 90 seconds. In a subsequent step the agents are destroyed producing much safer products. In addition to the chemical warfare agents, FAST-ACT was found to destroy simulants of chemical warfare nerve, mustard, blood, and choking agents.

# II. *TECHNOLOGY DEVELOPMENT*

**Toxic Industrial Chemicals**

The toxicity of a substance is its ability to cause harmful effects to humans, plants, and animals. When only a very large amount of the chemical can cause damage, the chemical is considered to be relatively non-toxic. When a small amount can be harmful, the chemical is considered toxic. The toxicity of a substance depends on three factors: its chemical structure, the extent to which the substance is absorbed by the body, and the body's ability to detoxify the substance (change it into less toxic substances) and eliminate it from the body.

Toxic industrial chemicals (TICs) can contaminate the environment during industrial activities or accidents, during research and development efforts, or even be purposely released by terrorists. An effective response to such situations typically requires a broad range of measures starting with personal protection of personnel involved in the effort (gas masks, protective suits, gloves), air filtration devices intended for building or equipment protection, and ending with means of decontamination/cleanup of released chemical. Due to high volatility, about 100 out of 150 TICs are not effectively physisorbed on activated carbons or similar high surface area adsorbents and zeolites. For compounds that inadequately physically adsorb, a chemical reaction with the adsorbent is necessary in order to immobilize the agent. Clearly such a strategy is needed for numerous TICs possessing very different chemical properties including acidity, basicity, functional groups, etc. In contrast to physisorption, that to a large extent neglects chemical structure, finding chemically active adsorbents that target such a broad range of chemical agents is very difficult.

Timilon has shown that its proprietary nanocrystalline metal oxides are excellent adsorbents of multiple toxic industrial chemicals. Through chemical reaction these chemical hazards can be converted into much safer and easier to handle products. Acids such as hydrochloric, nitric, phosphoric, and sulfuric are converted into the corresponding metal salts upon contact with the metal oxide sorbents. Organophosphorus compounds, such as toxic insecticides, are destructively adsorbed and rendered safer through disruption of the P-O bond. Hazardous halogenated compounds are also readily adsorbed and converted into the corresponding metal salts. In addition, a wide range of organic compounds, such as alcohols, aldehydes, and commonly transported petrochemicals are effectively absorbed by selected materials.

**Chemical Warfare Agents**

Chemical warfare agents (CWAs) are chemicals designed to incapacitate, seriously injure, or kill people through their physiological effects. They can be deployed as either liquid aerosols or vapors. There are three major routes of exposure to chemical warfare agents: skin (liquid and high vapor concentrations), eyes (liquid or vapor), and respiratory tract (vapor inhalation). Chemical agents are usually divided into four categories: nerve agents (e.g., sarin, VX, tabun), blister agents (e.g., sulfur mustard, nitrogen mustard, Lewisite), choking agents (e.g., phosgene, chlorine), and blood agents (e.g., hydrogen chloride, arsine).

**Nerve agents**, discovered by the Germans in the 1930’s and developed during World War II, are the most dominant chemical warfare agents. They affect the transmission of impulses in the nervous system by blocking acetylcholinesterase enzyme. Nerve agents have an organo-phosphorus chemical structure, similar to the insecticides and pesticides from which they were developed. The "G" agents tend to be non-persistent whereas the "V" agents are persistent. Nerve agents are highly toxic, easily dispersed, highly stable and rapid acting when adsorbed through the skin or through the respiratory system. They are 100 to 1000 times more lethal than blister, choking or blood agents. They are most useful to terrorists because of the small quantity needed to inflict a substantial amount of damage. It has been said that sarin and VX (the most toxic nerve agents) can be synthesized by a moderately competent organic chemist with limited laboratory facilities.

**Blister (vesicant) agents** such as mustard were extensively used during WWI. They produce painful burns of the skin and respiratory track by rapidly generating a highly toxic intermediate episulfonium ion, which irreversibly alkylates DNA, RNA, and protein, disrupting cell function and causing cell death. Within two minutes, a drop of mustard on the skin can cause serious damage. They are intended to incapacitate rather than kill; however, respiratory exposure to these agents can be fatal.

**Blood agents** are not suited for use on large numbers of people, and so their primary role is in assassinations. **Choking agents** were the agents most used during WWI, but have lost much of their usefulness since the development of nerve agents.

## III. *EFFECTIVENESS OF THE FAST-ACT FORMULATION*

FAST-ACT is effective at neutralizing a wide range of **toxic chemicals** with the added capability to destroy **chemical warfare agents**. Table 1 summarizes groups of compounds and classes that can be effectively treated with FAST-ACT. The tests with select compounds were conducted using infrared spectroscopy (gases and high vapor liquids), gravimetric measurements (chlorine), UV-Vis spectroscopy (paraoxon), and gas chromatography coupled with mass spectrometry (remaining organics) as detection techniques.

**Table 1: List of Compounds Successfully Removed/Destroyed by FAST-ACT**

| Acids | Phosphorus/Sulfur Compounds | Organic Compounds |
|---|---|---|
| Hydrochloric Acid | 2-Chloroethyl ethyl sulfide | Acetaldehyde |
| Hydrofluoric Acid | Dimethyl methyl phosphonate | Acetone |
| Nitric Acid | Paraoxon | p-Cresol |
| Phosphoric Acid | Parathion | Diesel |
| Sulfuric Acid | Methyl Mercaptan | Denatured Ethanol |
| **Caustic/Acidic Gases** | **Industrial Solvents/Refrigerants** | Ethylene Oxide |
| Anhydrous Ammonia | Acetonitrile | Gasoline |
| Chlorine | Chloroacetyl Chloride | Methanol |
| Hydrogen Chloride | Acetyl Chloride | Toluene |
| Nitrogen Dioxide | **Chemical Warfare Agents** | 4-Vinylpyridine |
| Sulfur Dioxide | GD (soman) | |
| | VX | |
| | HD (mustard gas) | |

FAST-ACT is effective against these chemicals and many more.

For uniformity, tests were conducted at 1 to 50 agent to sorbent ratio by weight (unless indicated otherwise) at 2 and 10 minute contact times. However, for many hazards complete neutralization could be realized at much lower sorbent to agent ratios.

**<u>Acid Neutralization</u>**

Strong acids, such as hydrochloric acid, phosphoric acid, nitric acid, and sulfuric acid are listed as hazards on Top 25 Hazardous Commodities 1998 and/or USACHPPM Toxic Industrial Chemical Lists. FAST-ACT is very effective at adsorbing and neutralizing acids with the formation of metal salts.

Neutralization of acids upon exposure to FAST-ACT was determined based on pH measurements after water addition to the treated powder. The formulation has been tested with hydrochloric, nitric, phosphoric, and sulfuric acids and the data is presented in Table 2. Upon treatment with FAST-ACT the pH is brought up to a safe range within 2 minutes of contact. Blank represents a sample with no treatment.

**Table 2: Neutralization of Acids by FAST-ACT**

| *Agent* | *Formula* | *pH after Treatment with FAST-ACT* | |
|---|---|---|---|
| | | *2 min* | *10 min* |
| Blank (no FAST-ACT) | | 1 | 1 |
| Hydrochloric Acid | $HCl$ | 11 | 11 |
| Hydrofluoric Acid | $HF$ | 11 | 11 |
| Nitric Acid | $HNO_3$ | 11 | 11 |
| Phosphoric Acid | $H_3PO_4$ | 11 | 11 |
| Sulfuric Acid | $H_2SO_4$ | 11 | 11.5 |

## Liquid Hazards

Organic compounds ranging from alcohols through aldehydes, mercaptans, organophosphates, nitrogen containing compounds to aromatics and fuels have been absorbed or neutralized by FAST-ACT.

For high vapor pressure liquids (4-vinyl pyridine, acetyl chloride, chloroacetyl chloride, diesel, gasoline, and acetaldehyde) the absorption of the agent was determined by vapor phase IR experiments. For the remaining hazards the spent powder was extracted with an inert solvent and the amount of undecomposed hazard was quantified by gas chromatography and mass spectrometry. For quantifying the amount of undecomposed paraoxon, UV-Vis was used as the detection technique. A data summary is presented in Figure 1 and Table 3. The absorptive capability ranged from 84% (acetonitrile) to 100% (acetaldehyde, acetyl chloride, chloroacetyl chloride, p-cresol, diesel, ethanol, methanol and 4-vinylpyridine).

**Figure 1: Effectiveness of FAST-ACT Towards Liquid Hazards**

Percent absorbed/neutralized after 2 minutes.

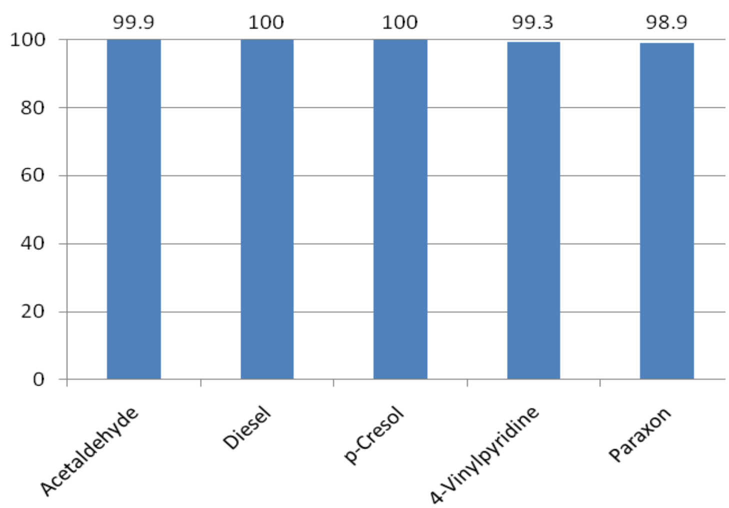


**Table 3: Decontamination of Liquid Toxic Industrial Chemicals by FAST-ACT**

| *Agent* | *Formula* | *% Agent Removed* | |
|---|---|---|---|
| | | ***2 min*** | ***10 min*** |
| Acetaldehyde | $CH_3CHO$ | 99.9±0.0 | 100±0.0 |
| Acetonitrile | $CH_3CN$ | 88.1±4.7 | 83.9±13.7 |
| Acetyl Chloride | $CH_3COCl$ | 100±0.0 | 100±0.0 |
| Chloroacetyl Chloride | $ClCH_2COCl$ | 100±0.0 | 100±0.0 |
| 2-Chloroethyl Ethyl Sulfide | $CH_3CH_2SCH_2CH_2Cl$ | 91.1±0.9 | 91.2±2.8 |
| p-Cresol | $C_6H_4CH_3OH$ | 100±0.0 | 100±0.0 |
| Diesel | hydrocarbon | 100±0.0 | 100±0.0 |
| Denatured Ethanol | $C_2H_5OH$ | 100±0.0 | 100±0.0 |
| Dimethyl methylphosphonate | $(O)P(OCH_3)_2(CH_3)$ | 99.5±0.4 | 98.3±1.7 |
| Gasoline | hydrocarbon | 96.8±1.3 | 97.0±0.1 |
| Methanol | $CH_3OH$ | 99.7±0.6 | 100±0.0 |
| Paraoxon | $(C_2H_5O)_2P(O)C_6H_4NO_2$ | 98.9±0.3 | 97.6±0.1 |
| 4-Vinylpyridine | $NC_5H_4C_2H_3$ | 99.3±1.1 | 100±0.0 |

**Vapor Hazards**

FAST-ACT was tested for the removal of vapor hazards such as anhydrous ammonia (USACHPPM Toxic Industrial Chemical List, Second Hand Smoke Component, considered as a choking agent); chlorine (TOP 25 Hazardous Commodities 1998 List, choking agent); ethylene oxide (USACHPPM Toxic Industrial Chemical List), hydrogen chloride (USACHPPM Toxic Industrial Chemical List, also considered a blood agent); nitrogen dioxide (USACHPPM Toxic Industrial Chemical List) and sulfur dioxide (USACHPPM Toxic Industrial Chemical List).

Adsorption of gases by FAST-ACT was determined using FT-IR spectroscopy and gravimetric measurements. In the IR experiments, the disappearance of the agent, upon exposure to FAST-ACT, was monitored based on the decrease in the intensity of the most prominent agent peaks. Since chlorine is a symmetrical molecule, IR spectroscopy could not be employed. Therefore, the amount of adsorbed chlorine was calculated based on the weight gain of the FAST-ACT formulation upon exposure to chlorine gas.

The percent of hazard removed at 2 and 10 minutes is illustrated in Figure 2 and Table 4. The gases are adsorbed very rapidly (2 minute data) and they do not outgas from the powder as indicated by the 10 minute data.

**Figure 2: Effectiveness of FAST-ACT Towards Vapor Hazards**

Percent removed after 2 minutes.

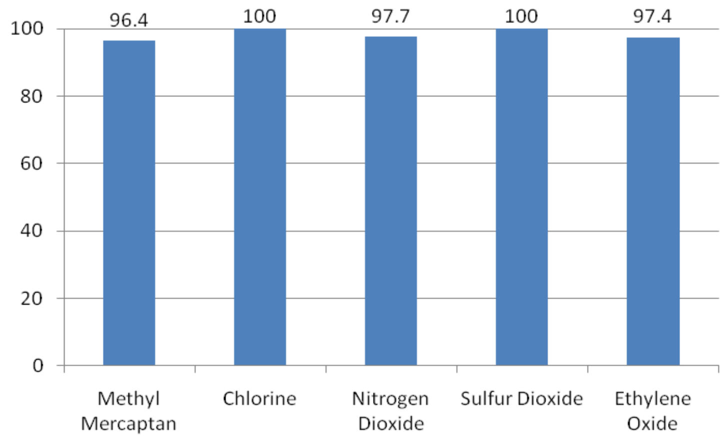



**Table 4: Removal of Gaseous Toxic Industrial Chemicals by FAST-ACT**

| *Agent* | *Formula* | *% Agent Removed* | |
|---|---|---|---|
| | | *2 min* | *10 min* |
| Anhydrous Ammonia* | $NH_3$ | 97.9±0.4 | 98.6±0.1 |
| Chlorine | $Cl_2$ | 100±0.0 | 100±0.0 |
| Ethylene Oxide | $CH_2OCH_2$ | 97.4±2.4 | 99.8±0.2 |
| Hydrogen Chloride | HCl | 100±0.0 | 100±0.0 |
| Nitrogen Dioxide | $NO_2$ | 97.7±0.4 | 97.8±0.5 |
| Sulfur Dioxide | $SO_2$ | 100±0.0 | 100±0.0 |
| Methyl Mercaptan | $CH_3SH$ | 96.4±1.4 | 99.1±0.6 |

*****100 to 1 sorbent to agent ratio was used.

In summary, FAST-ACT is very effective at neutralizing toxic industrial chemicals in vapor and liquid phase. The 2 minute data indicated immediate reaction with these toxic compounds creating a much safer working environment within a short period of time.

**<u>Destruction of Chemical Warfare Agents</u>**

Chemical warfare agents can only be destroyed if their chemical structure is modified. Nerve agents, such as sarin, soman, tabun, and VX all are phosphorus containing compounds, which can be chemically detoxified through breakage of the P-O, P-CN, or P-S bond. FAST-ACT destroys these agents by supporting immediate reactions such as hydrolysis and dehalogenation. Blistering agents are also neutralized by FAST-ACT through hydrolysis and dehydrohalogenation reactions.

FAST-ACT's effectiveness against CWAs has been validated by two independent laboratories:

- Battelle in Columbus, OH – Surface Decontamination
- SBCCOM (ECBC) in Edgewood, MD – Chemical Reactivity

Two types of nerve agents, GD (Soman, 1,2,2-trimethylpropyl methylphosphonofluoridate) and VX (O-ethyl S-diisopropylaminomethyl methylphosphono-thiolate), and a blistering agent, HD (Distilled Mustard, bis(2-chloroethyl) sulfide) were used. In these tests 50 parts of the FAST-ACT to 1 part of the chemical warfare agent were used in controlled protocols at ambient room conditions (temperature, pressure and humidity).

**Battelle Surface Decontamination Testing**

The objective of Battelle testing was to determine surface removal ability and reactivity of FAST-ACT by measuring reduction in chemical warfare agents under ambient conditions. An inert surface (glass) was spiked with CWA, FAST-ACT was applied to the surface and mixed/agitated with the agent. After 90 seconds the powder was removed from the surface, the surface extracted with an organic solvent, and the amount of agent in the extract determined by GC/FID. After 10 minutes for VX and GD and 60 minutes for HD, the powders were extracted and the amount of extracted agent quantified by GC-MS.

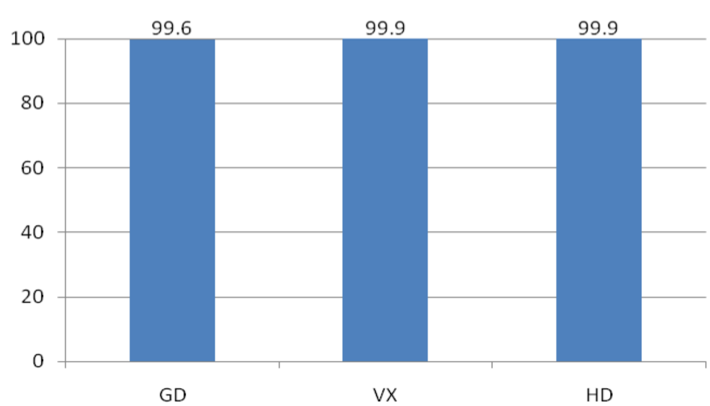
**Figure 3: Real Agent Testing at Battelle: Agent on the Petri Dish (Left) and Agent with FAST-ACT (Right)**

***Results***

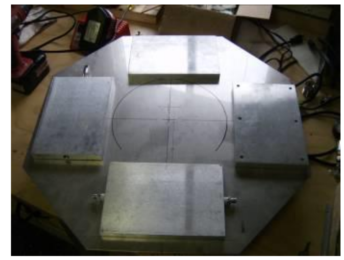
Within 90 seconds FAST-ACT removed over 99.9% of HD and VX and over 99.6% (detection limit) of GD from the surface as indicated in Figure 4. Over time the adsorbed agents were destroyed by FAST-ACT.

**Figure 4: Effectiveness of FAST-ACT Towards Removal of Chemical Warfare Agents from Surfaces**

Percent removed after 90 seconds.



Upon complete destruction of agents, the treated powder is not a listed hazardous waste nor is it considered as having hazardous waste characteristics.[1]



In advanced surface decontamination studies, large surface panels contaminated with chemical warfare agents under various operational conditions were tested. Agents included GA, GD, TGD, L, HD, and VX. Test methods included reactivity, large panel testing/contact hazard, large panel testing/vapor off-gassing, and vapor decontamination. Lexan polycarbonate, stainless steel, and CARC-painted steel, were all contaminated with agent and the panels were successfully decontaminated with FAST-ACT.

**SBCCOM Chemical Reactivity Testing**

The objective of SBCCOM testing was to determine the reactivity of FAST-ACT and identify reaction products. In these tests FAST-ACT was placed on the agent contaminated metal surface. After a short agitation the powder was placed in a solid state NMR tube and the amount of undecomposed agent, if any, as well as reaction products were determined by $^{13}C$ and $^{31}P$ MAS NMR.

***Results***

Upon contact with FAST-ACT the agent is quickly adsorbed (as seen in Figure 4) and then destroyed. The destruction is confirmed by changes in the NMR spectra (SBCCOM) and by inability to extract the agent from the powder (Battelle). In 10 minutes 99% of GD and over 99.9% of VX is destroyed. After 60 minutes 70-80% of HD is destroyed.

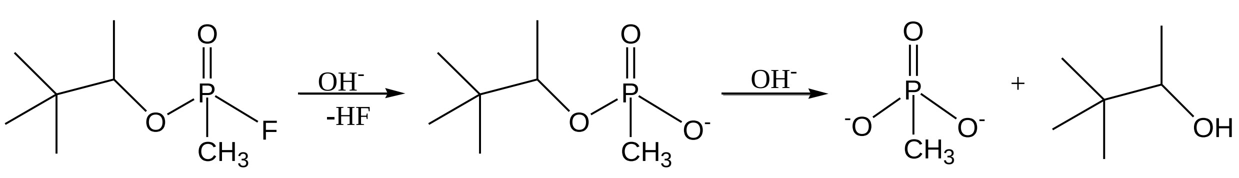
**Mechanisms of Agent Destruction**

FAST-ACT destroys chemical warfare agents through hydrolysis and/or dehydrohalogenation. Nerve agents are hydrolyzed with the formation of surface bound metal phosphonates. Mustard agent undergoes hydrolysis to form surface bound metal alkoxides or dehydrohalogenation to form vinyl and divinyl HD.

The following schemes indicate destruction mechanisms based on SBCCOM work with NanoActive materials.

**GD**

Destruction products: pinacolyl methylphosphonic acid (GD-acid) that converts to surface bound methylphosphonic acid (MPA); eliminated HF is also neutralized by FAST-ACT.

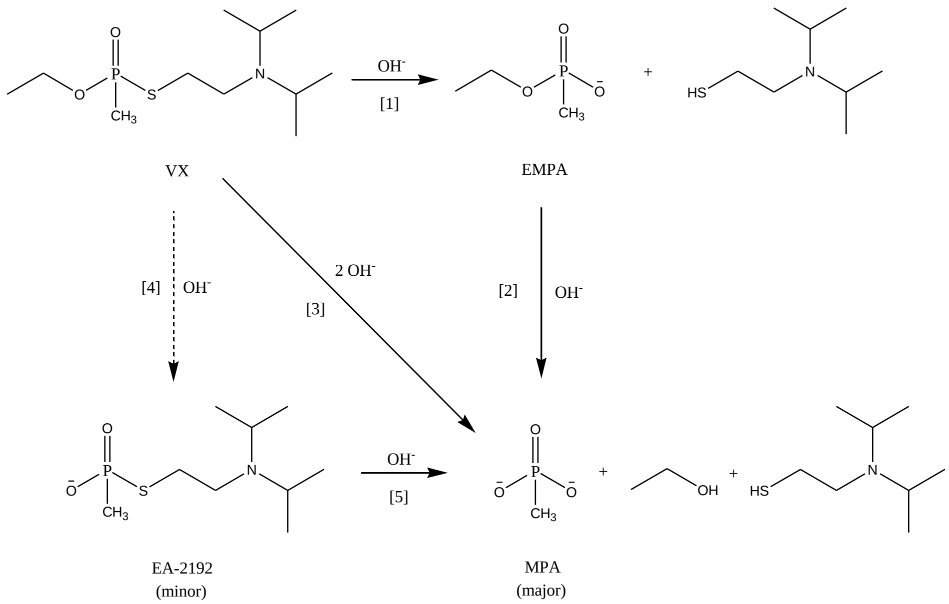



**GD** **GD-acid** **MPA**

[1] 40 CFR (Code of Federal Regulations) 261, Subpart C and D

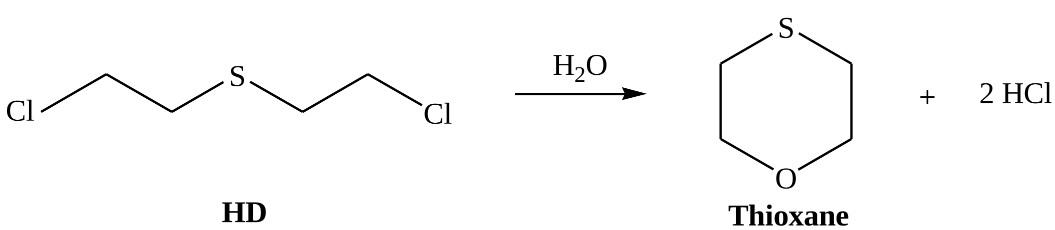
**VX**

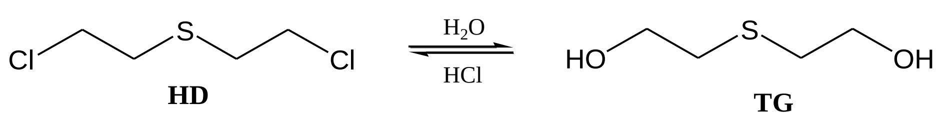
Destruction products: ethyl methylphosphonic acid (EMPA) that converts into surface bound methylphosphonic acid (MPA).



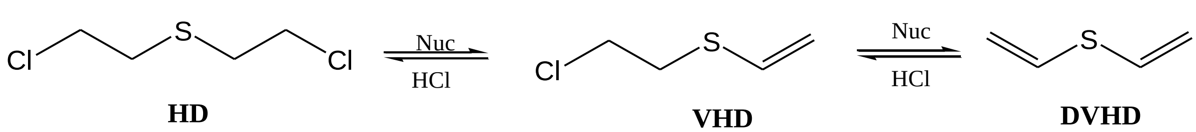

**HD**

Decomposition products through hydrolysis: thioxane and chlorohydrin (CH) that forms surface bound thiodiglycol (TG)




Decomposition products through elimination: 2-chloroethyl vinyl sulfide (CEVS) and divinyl sulfide (DVS)



In addition, Battelle has conducted off-gassing experiments for FAST-ACT after exposure to HD, GD and VX. The results indicate, through the absence of any major chromatographable peaks, that the reaction products are either low molecular weight (less than 60 amu), small gaseous materials that were eluted with the air peaks, or compounds that are tightly bound to the materials.

## Deployment Methods

FAST-ACT can be delivered to the contaminated area using several methods of deployment. In the event of a liquid spill, the powder can be manually placed onto the hazards (shaker bottle for small spills, bulk pail for larger spills, or pressurized cylinders for a quick coverage of the entire spill). If both liquid and vapor hazards exist, a fogging hose attachment can be employed so that the powder can be sprayed into the air to neutralize any vapor threat and still be directly applied to the liquid threat. The use of an optional applicator wand allows the operator to maintain a safe distance while quickly applying FAST-ACT from a pressurized cylinder to a liquid hazard. Below guidelines for unit size selection are given based on type and amount of the spill.

### Neutralization of Acids

FAST-ACT neutralizes a broad range of acids including phosphoric, sulfuric, nitric hydrochloric and hydrofluoric. Using concentrations at which the acids are commonly transported, the amount of spill that can be neutralized using various FAST-ACT units is shown in Table 5.

**Table 5: Guidelines for Maximum Acid Spill Sizes that can be Neutralized by Various FAST-ACT Units.**

| *Type of Acid* | *500 grams* | *1-Kg* | *2-Kg* | *4-Kg* | *5-Kg* |
|---|---|---|---|---|---|
| | **Liters** | **Liters** | **Liters** | **Liters** | **Liters** |
| 85% $H_3PO_4$ | 0.35 | 0.76 | 1.42 | 3.03 | 3.41 |
| 94% $H_2SO_4$ | 0.30 | 0.57 | 1.23 | 2.27 | 3.03 |
| 70%$HNO_3$ | 0.95 | 1.89 | 3.79 | 7.57 | 9.46 |
| 37% HCl | 1.24 | 2.27 | 4.54 | 9.84 | 12.49 |
| 39% HF | 0.65 | 1.32 | 2.55 | 5.30 | 6.44 |

### Absorption of Organic Spills

FAST-ACT absorbs a wide range of organic compounds such as alcohols, aldehydes, chlorocarbons, and petrochemicals. Table 6 gives recommendations for unit selection based on the spill size.

**Table 6: Guidelines for Maximum Amount of Organic Spill that can be Absorbed by Various FAST-ACT Units.**

| *Type of Organic Spill* | *500 grams* | *1-Kg* | *2-Kg* | *4-Kg* | *5-Kg* |
|---|---|---|---|---|---|
| | **Liters** | **Liters** | **Liters** | **Liters** | **Liters** |
| Acetone | 0.50 | 1.04 | 1.99 | 4.16 | 5.30 |
| Alcohols | 0.35 | 0.71 | 1.32 | 2.84 | 3.56 |
| Chlorinated hydrocarbons | 0.65 | 1.23 | 2.46 | 4.92 | 6.44 |
| Petrochemicals | 0.38 | 0.76 | 1.42 | 3.03 | 3.79 |

### Destruction of Phosphorus and Sulfur Compounds including Chemical Warfare Agents

FAST-ACT neutralizes phosphorus and sulfur containing compounds, such as insecticides and even chemical warfare agents. Table 7 provides information on the amount of agent that can be destroyed using various FAST-ACT units.

**Table 7: Guidelines for Maximum Amount of Liquid Chemical Hazard that can be Destroyed by Various FAST-ACT Units.**

| *Type of Liquid Chemical Hazard* | *500 grams* | *1-Kg* | *2-Kg* | *4-Kg* | *5-Kg* |
|---|---|---|---|---|---|
| | ***Ounce*** | **Ounce** | **Ounce** | **Ounce** | **Ounce** |
| Paraoxon | 0.6 | 1.2 | 2.5 | 5.0 | 6.0 |
| DMMP | 0.7 | 1.4 | 2.9 | 5.8 | 7.3 |
| 2-CEES | 0.8 | 1.6 | 3.1 | 6.2 | 7.8 |
| VX | 0.3 | 0.7 | 1.3 | 2.6 | 3.3 |
| GD | 0.3 | 0.7 | 1.3 | 2.6 | 3.3 |
| HD | 0.2 | 0.5 | 1.0 | 2.1 | 2.6 |

Table 8 indicates what size of delivery system is required to completely remove a chemical warfare agent assuming 50 to 1 FAST-ACT to CWA ratio and a NATO contamination standard of 10 g/m$^2$.

**Table 8: Coverage Areas Based on the Removal of CWAs from a Surface. Results from Battelle, 90-second Contact Time, Ambient Conditions.**

| *Delivery System* | *Coverage Areas* | |
|---|---|---|
| | *m$^2$* | *ft$^2$* |
| Shaker Bottle | 1.0 | 10.8 |
| 1 kg Pressurized Cylinder | 2.0 | 21.5 |
| 2 kg Pressurized Cylinder | 4.0 | 43 |
| 4 kg Pressurized Cylinder | 8.0 | 86 |
| 5 kg Bulk Pail | 10.0 | 107.5 |

**Vapor Threats**

FAST-ACT effectively neutralizes or adsorbs acidic and caustic gases as well as oxidizers. Table 9 provides agent concentration in parts per million (ppm) that can be successfully treated (at least 95% reduction) in a 1,000 ft$^3$ room using various FAST-ACT units. The safety levels for immediate danger and time-weighted average, based on NIOSH, are given as a guide.

**Table 9. Guidelines for Maximum Concentration (in parts per million) of Vapor Hazard that can be Successfully Treated with FAST-ACT Pressurized Cylinders in a 1,000 ft$^3$ room.**

| *Type of Vapor* | *Safety Levels (ppm)* | | *FAST-ACT Unit* | | |
|---|---|---|---|---|---|
| | **Immediately Dangerous** | **TWA* (8 hrs)** | *1-Kg* | *2-Kg* | *4-Kg* |
| | | | *ppm* | **ppm** | **ppm** |
| **Acidic** | | | | | |
| Hydrogen chloride | 50 | 5 | 865 | 1730 | 3460 |
| Hydrogen sulfide | 100 | 20 | 235 | 475 | 950 |
| Sulfur dioxide | 100 | 5 | 340 | 685 | 1370 |
| **Caustic** | | | | | |
| Ammonia | 300 | 20 | 215 | 430 | 860 |
| **Oxidizers** | | | | | |
| Ethylene oxide | 800 | 5 | 125 | 250 | 500 |
| Chlorine | 10 | 1 | 200 | 400 | 800 |

*TWA = Time Weighted Average

Because of the formulation's increased adsorptive ability, prolonged exposure to atmospheric conditions will begin to degrade the performance of the material toward chemical hazards.

**Product Safety and Disposal**

A rigorous toxicity evaluation of FAST-ACT components has revealed that there are no safety hazards. Dermal $LD_{50}$ (rabbit) was >2g/kg and oral $LD_{50}$ dermal (rabbit) was >5g/kg. The formulation has also been tested for inhalation toxicity and proven to be non-toxic to rats.

| **Test** | **Result** [Reference] |
|---|---|
| Acute Oral Toxicity | SAFE [1,2] |
| Acute Dermal Toxicity | SAFE [3] |
| Acute Dermal Irritation | SAFE [4,5] |
| Skin Sensitization | SAFE [6,7] |
| Acute Eye Irritation | SAFE [8,9] |
| Acute Inhalation | NON TOXIC [10,11,12] |
| Mutation Assay: Ames Test | SAFE [13] |
| Cytotoxicity | NON TOXIC [14] |
| In Vitro Dermal Absorption | SAFE [15] |
| Sub Chronic Inhalation | SAFE [16] |

References:

1. LD50 > 2 g/kg 928-006 (TiO2)
2. LD50 > 5 g/kg 5302-18-01-07-01 (MgO)
3. LD50 > 5 g/kg 03GG-23-05-09-02 (TiO2)
4. EPA Category IV Non-irritating 03GG-11-05-01-02C (TiO2)
5. EPA Category IV Non-irritating 85MA5302A-11-01-07-04 (MgO)
6. Non-sensitizer 03GG-13-05-01-03A ($TiO_2$)
7. Non-sensitizer 5302-01-04-02 (MgO)
8. EPA Category IV Non-irritating (minimal affects clearing in less than 24 hours) 03GG-10-02-09-03 ($TiO_2$)
9. EPA Category III Slightly irritating 85MA5302A-10-99-06-01 (MgO)
10. EPA Category IV Practically Nontoxic 2334 mg/m3 for 4 hours 03GG-24-05-01-04 (TiO2)
11. Nontoxic 259 mg/m3 for 4 hours 5302-24-02-10-01(MgO)
12. Nontoxic 825 mg/m3 for 4 hours 01BN-24-03-04-01
13. Not a Potential Mutagen 200532203-01
14. Non toxic to human immune cells
15. Absorption not detectable through intact skin
16. NOAEL:160 $mg/m^3$ 20 six hour whole body exposures at 160, 24 and 5.3 mg/m3 over a four week period 0ABF- 35-08-10-01

In addition, it was determined that the FAST-ACT components are captured in excess of 99.9% by standard NIOSH particle filters (Flat media, Model 200 Series, N95 NIOSH, 30981J and Pleated filter with flat media, NIOSH Pro-Tech respirator, PN G100H404 OVIP-100).

FAST-ACT that has not come in to contact with a hazardous chemical is safe for solid waste disposal and is non-hazardous. For chemicals neutralized by FAST-ACT, the EPA requires the materials be disposed of in accordance with the starting material hazards or per guidelines for the characteristic hazard present. Employed product should always be disposed of in accordance to local, state, and federal regulations. For federal regulations follow 40 CFR 261, Subpart C "Characteristic Hazardous Wastes" and 40 CFR 261, Subpart D "Listed Hazardous Wastes."