The SAFEST WATER In The World

Mixed-Oxidant Effectiveness against Biological and Chemical Warfare Agents

Dugway Proving Ground, a U.S. Government laboratory in Utah, started testing effectiveness of MIOX mixed-oxidant solution (MOS) in 2000 using potable water test solutions challenged with potential biological and chemical warfare agents. Current testing is being funded by the US Army TACOM/TARDEC in Warren, Michigan. Initial testing was funded by the Defense Advanced Research Projects Agency (DARPA). Tests were conducted in waters prescribed in the *US EPA Guide Standard and Protocol for Testing Microbiological Water Purifiers* in both "clean" (Type I) and "challenged" (Modified Type II) waters, using an MSR MIOX Purifier. Type I water is room-temperature, potable tap water, at a neutral pH and is not considered to be a challenge to the disinfectant. The Modified Type II water included high Total Dissolved Solids (1500 mg/L), high pH (9.0) and low temperature (4^{o}C), all of which challenge the effectiveness of a halogen-based disinfectant such as that generated by the MSR MIOX Purifier. In both types of waters, Purifier-generated MOS was very effective against biological agents, including Anthrax spores, plague bacteria, and smallpox virus surrogate (the vaccine strain Vaccinia). Tests on chemical agents in other solutions showed effectiveness against nerve agents and blister agents.

Biological Warfare Agents:

The disease **Anthrax** is caused by the bacterial spore *Bacillus anthracis*. The bacteria has a vegetative stage that is easy to inactivate, but the spore itself is much more resistant to disinfection. Purifier-generated MOS achieved 99.99% inactivation of the spore with a 20 mg/L dose in 20 minutes (leaving a Free Available Chlorine (FAC) residual of 10 mg/L due to the high oxidant demand of the challenge). MOS achieved a 4 log (99.99%) inactivation of the vegetative form of Anthrax in 15 minutes with a 5 mg/L dose. It should be recognized that addition of high concentrations of spore to a water supply would be unlikely in the event of a terrorist attack because large masses of spore would have to be prepared, transported, and dumped. Such large masses of spore would be impractical to prepare for even an advanced industrial country.

Klebsiella terrigena*,** one of the challenge bacteria required in the testing protocol (although not considered a biological warfare agent), was inactivated by Purifier-generated MOS to 6 logs in 10 minutes with only a 3 mg/L dose, for both Type I and modified Type II waters. Three other bacteria considered to be biological threat agents were tested as well. In tests on ***Yersinia pestis* (Plague)**, MOS achieved a 6 log inactivation in 20 minutes with a 10 mg/L dose (but a FAC residual of only 2.1 mg/L due to the high oxidant demand of the challenge). MOS achieved a 4 log inactivation of **Smallpox** Surrogate (the vaccine strain Vaccinia) in 20 minutes at a 5 mg/L dose (FAC residual 1.6 mg/L). For ***Francisella tularensis (the agent that causes tularemia), a 3 mg/L dose achieved 6 log inactivation in Type I water after 10 minutes and in modified Type II water after 20 minutes. The high oxidant demand of various challenges noted above arises from the composition of the culture media used to make the challenge microorganisms and would not be expected to be present in a potable raw water source or in treated water contaminated with the biological agents.

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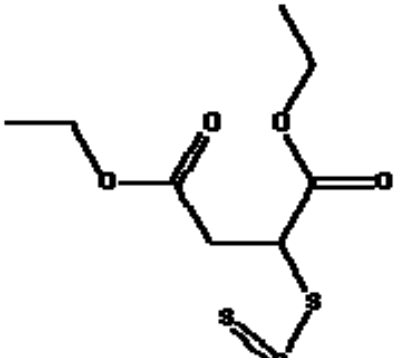
Inactivation of Bacteria and Viruses Using MIOX Mixed-Oxidant Solution

Bacteria	Inactivation	Contact Time (min.)	MIOX Dose (mg/L)
Bacillus anthracis spore (Anthrax)	4 log (99.99%)	20	20
Bacillus anthracis - vegetative	4 log (99.99%)	15	5
Klebsiella terrigena	6 log (99.9999%)	10	3
Yersinia pestis (Plague)	6 log (99.9999%)	20	10
Smallpox Surrogate (Vaccinia)	4 log (99.99%)	20	5
F. tularensis (Type I water)	6 log (99.9999%)	10	3
F. tularensis (Modified Type II water)	6 log (99.9999%)	20	3

The EPA rules on the Maximum Residual Disinfectant Level (MRDL) for chlorine and chloramines allows consumption of high levels of chlorine for short-term emergencies. Short-term exposure to high levels of chlorine is less harmful than contracting a disease. Even so, mixed oxidants were able to inactivate most biological agents at normal doses.

Chemical Warfare Agents:

The effectiveness of mixed oxidants against various chemical agents in water was also studied. Initial tests were conducted by Environmental Health Labs, using pesticides with chemical structures similar to nerve agents. The MOS showed effectiveness against the phosphorothioate (V-Agent is in this family) and phosphorocarbamate pesticides; these structures are similar to the phosphorocyanidate and phosphorofluoridate structures of several other nerve agents. Mixed oxidants at a 5 mg/L dose were particularly effective against Malathion (also a phosphorothioate), which is used as the primary surrogate for the nerve agents Tabun (GA), Sarin (GB), Soman (GD), and V-Agent (VX). Structural similarities suggested that mixed oxidants would inactivate the actual nerve agents as well.



Malathion Chemical Structure

Dugway Proving Ground completed additional testing against the actual nerve agents Soman (GD) and V-Agent (VX) and the blister agent Lewisite (L) in 2003. The Dugway tests were conducted with a Purifier-generated mixed-oxidant residual of 4 mg/L free available chlorine (FAC), which is the EPA's Maximum Residual Disinfectant Level (MRDL) for chlorine and chloramine solutions. Typically, the challenge concentration was 5-10 mg/L of nerve or blister agent, a very heavy concentration relative to the levels possible in an attack, even one directed at a water supply. The NATO standard is $\leq$ 4 μg/L for removal of chemical agents and $\leq$ 27 mg/L for removal of blister agents.

All three chemical agents were effectively decomposed by mixed oxidants. The original concentration of **Soman (GD)** was halved in 12 minutes. A 99% removal was achieved after 78 minutes. Soman concentrations went to non-detect (< 4 μg/L) in 150 minutes. The original concentration of **V-Agent (VX)** was halved in only 10 minutes. Approximately 99% removal was achieved in 130 minutes. Virtually total removal (< 23 μg/L) was achieved after 250 minutes. MOS removed **Lewisite (L)** to below detection in 30 minutes or less.

MIOX mixed oxidants have proven to be an effective technology to combat biological and chemical contamination in water supplies. The delivery method of the MSR MIOX Purifier will enable warfighters and individual consumers to effectively treat their non-salt water in the event of a contaminated water supply. Disinfectant doses from the Purifier can be adjusted to accommodate the varying demands of the different biological and chemical warfare agents. This customization enables the user to treat either normal water supplies or contaminated supplies on demand, ensuring that safe drinking water is available to them anywhere at any time.

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