

Electrochemical Decontamination System

Brian France (bfrance@tda.com), William Bell, Trudy Scholten and Joe Fredrickson
TDA Research, Inc.

12345 W 52nd Ave, Wheat Ridge, CO. USA 80033

TDA
Research

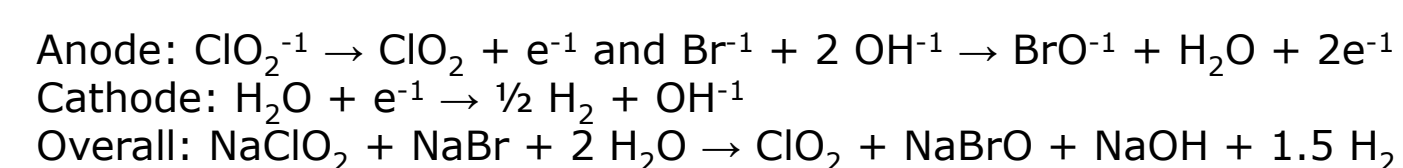
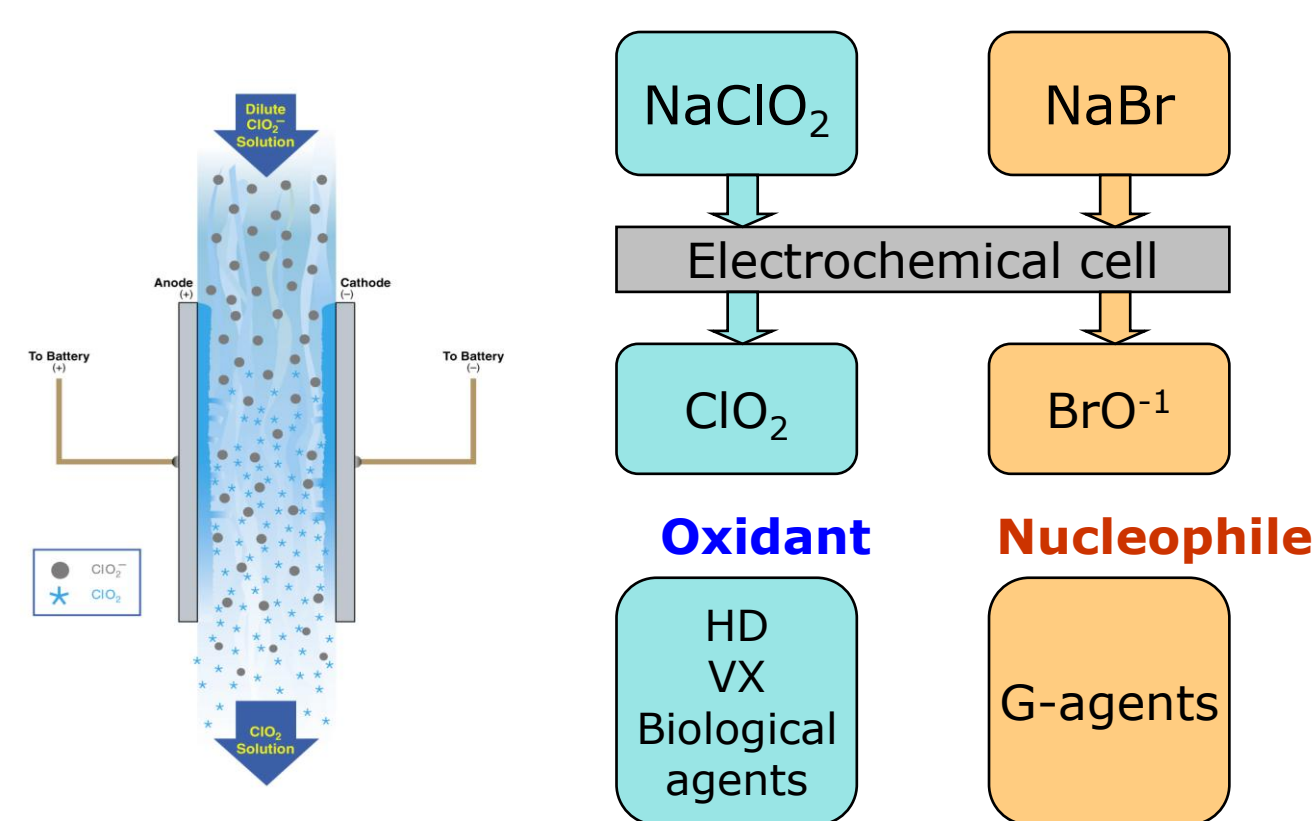
Larry Procell
Edgewood Chemical and Biological Center
Aberdeen Proving Ground, MD. USA 21010

Introduction

U.S. forces require a liquid decon solution that could be quickly applied to equipment contaminated with chemical warfare (CW) or biological warfare (BW) agents. No approved system is currently in service with U.S. forces. The use of DS2 has been discontinued due to environmental issues, but no replacement has been approved and fielded. The key criteria for a replacement are that it be effective against both CW and BW agents, readily stored, transported and operated, environmentally friendly, compatible with materials in military equipment, and economical.

In this project, a team including researchers from Procter & Gamble (P&G), Edgewood Chemical Biological Center (ECBC), and TDA Research, Inc. (TDA) is developing a new liquid decon solution based on electrochemical technology originally developed at P&G. The system consists of a dispenser with an electrochemical cell, in which electrical power applied to an aqueous solution of sodium chlorite produces chlorine dioxide (ClO₂), an effective decontaminant of CW agents that is also highly effective against biological threats, including bacterial spores. The addition of sodium bromide to the salt solution leads to the electrochemical generation of hypobromite ion (BrO⁻¹), which decomposes the G-agents. Both ClO₂ and BrO⁻¹ are highly reactive and not persistent: they react quickly with any CW or BW agents present, and decompose in a short period of time, leaving no hazardous residue.

Because we only need to transport and store a salt (as the solid) rather than a reactive species, systems using this approach are highly shelf stable and readily transportable. The electrochemical system is safe for the operator because we generate the active component only as needed, so the operators are not mixing or carrying any highly reactive toxic material. The chlorine dioxide and hypobromite will react and decompose within a few hours, leaving no hazardous residue. This system will benefit the warfighter by providing an effective decon solution that is readily transported, easy to use, environ-mentally friendly and safe for the operator.

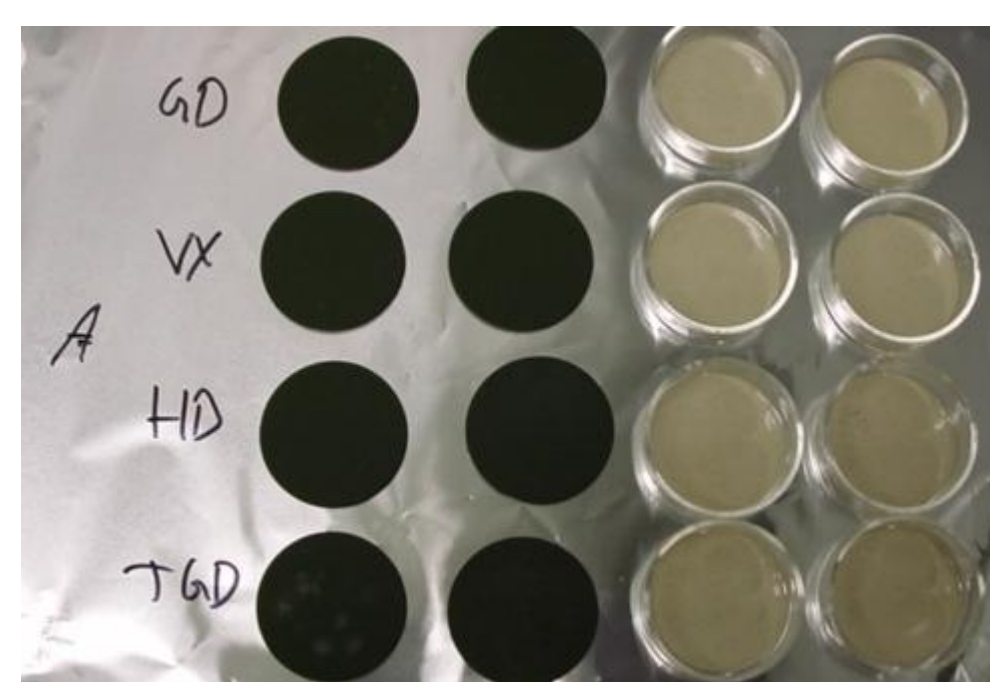


Chemical Efficacy

Operational Decon:
Decontaminate G, V, and H agents of operational significance at a 10 g/m² challenge to below detection levels of M8 and M9 detector papers within 5 minutes contact time.

Five-minute decontamination period assessment with M8 detector paper. Each circle is a test, green indicates below limit of detection. Data collect at ECBC (Identical results with M9 paper)

Agent	CARC	Butyl Rubber	Polycarbonate	Aluminum	Glass
HD	Green	Green	Green	Green	Green
VX	Green	Green	Green	Green	Green
GD	Green	Green	Green	Green	Green
TGD	Green	Green	Green	Green	Green



Vertical Decon Orientation on CARC Panels, all panels decontaminated. Data collected at ECBC

Polycarbonate with VX M8 - green for V agent
Polycarbonate with HD - HD penetrates and damages substrate

Thorough Decon:

Preliminary contact hazard testing has been performed with VX and HD. Initial data indicates that nonsorptive surfaces such as aluminum and glass panels are decontaminated below threshold requirements. HD on CARC results are near the 100 mg/m² threshold. Vapor hazard testing has not been performed yet. A testing program to measure thorough decon performance of the electrochemical decon technology is currently being planned.

Conclusion: Electrochemical decon system meets operational decon of classical agents on surfaces that do not absorb the chemical agents. Preliminary contact hazard assessment on hard surfaces is good, testing continues.

Biological Efficacy

- Two different testing series have been performed:
- (1) TDA tested with *B. atrophaeus* spores using ASTM standards E 1153, E 2111, E 2197, E 2315, E 2414
 - (2) The Naval Surface Warfare Center Dahlgren Division (NSWCDD) tested with *B. anthracis* Δ Sterne inoculation on large panels (12 x 12 in), surface samplings using swabs and wipes were performed.

TDA test with *B. atrophaeus*, ~2.6x10⁶ initial spore count

NSWCDD test with *B. anthracis* Δ Sterne ~1x10⁷ initial spore count

Small Coupon Studies:

- 1 cm disc inoculated *B. atrophaeus* spores totaling 2.6x10⁷ spores/area
- Samples treated and filtered through sterile two micrometer membrane
- Filters sent to SGM biotech (Bozeman, MT, USA) for culture and analysis
- 3 control samples (water-water, decon-neutralizer, shipping control)

Results:

- 2 minute exposure resulted in average CFU count of 0-3 (N=5 test replicates).
- No growth observed after 5 minute exposure to electrochemical decon
- Based on these results, an approximate D-value of 0.3 minutes can be calculated based on the Stumbo-Murphy-Cochran method.
- Fifteen minute exposure showed no growth on samples of glass, styrene butadiene rubber and CARC coated aluminum (N=10 test replicates)

Conclusion: Electrochemical decon is effective against bacterial spores, including *B. anthracis* simulants.

Materials Compatibility

Testing completed in accordance to Test Operating Procedure (TOP) 8-2-061 (2002), Chemical and Biological Decontaminant Testing

- Corrosivity, Sorption and hardness measurements require 24 immersion at 30C
- Haze and transmittance uses a 48 hour wet patch exposure

Corrosivity

- Materials Tested: stainless steel, 6061 aluminum, 6061 anodized aluminum and two different 4140 steel sources have been tested.
- Test solutions: DI water, seawater, active decon solution and salt solution
- Results: Only bare 4140 steel showed an increase in corrosion rate with immersion in decon solutions.

Sorption, Haze and Transmittance of Thermoplastics

- Materials Tested: Polycarbonate and Acrylic
- Test Solutions: DI water, active decon solution and salt solution
- Independent lab, Intertek Plastics Technology Laboratories measured haze, transmittance on polycarbonate and acrylic.
- Results: Largest sorption changes seen with acrylic, 0.74%. No change in Haze or diffuse transmittance. Change of 0.20% in polycarbonate and -0.10% in acrylic total luminous transmittance.

Conclusion: Electrochemical decon has good materials compatibility with military surfaces. There is an increased corrosion rate observed on unpainted steel, however painted steel is not effected and CARC coatings are not softened.

Large Coupon Studies:

- 2 x 5 cm areas inoculated with five 10 microliter spots of *B. anthracis* Delta Sterne spores totaling 1x10⁷ spores/area
- 16 experimental areas sampled from six repeat panels for each material
- 3 control areas sampled (water-water, water-neutralizer, decon-neutralizer)
- Six replicate 12x12 inch panels run for each material (glass, CARC, steel, polycarbonate, butyl rubber)

Results:

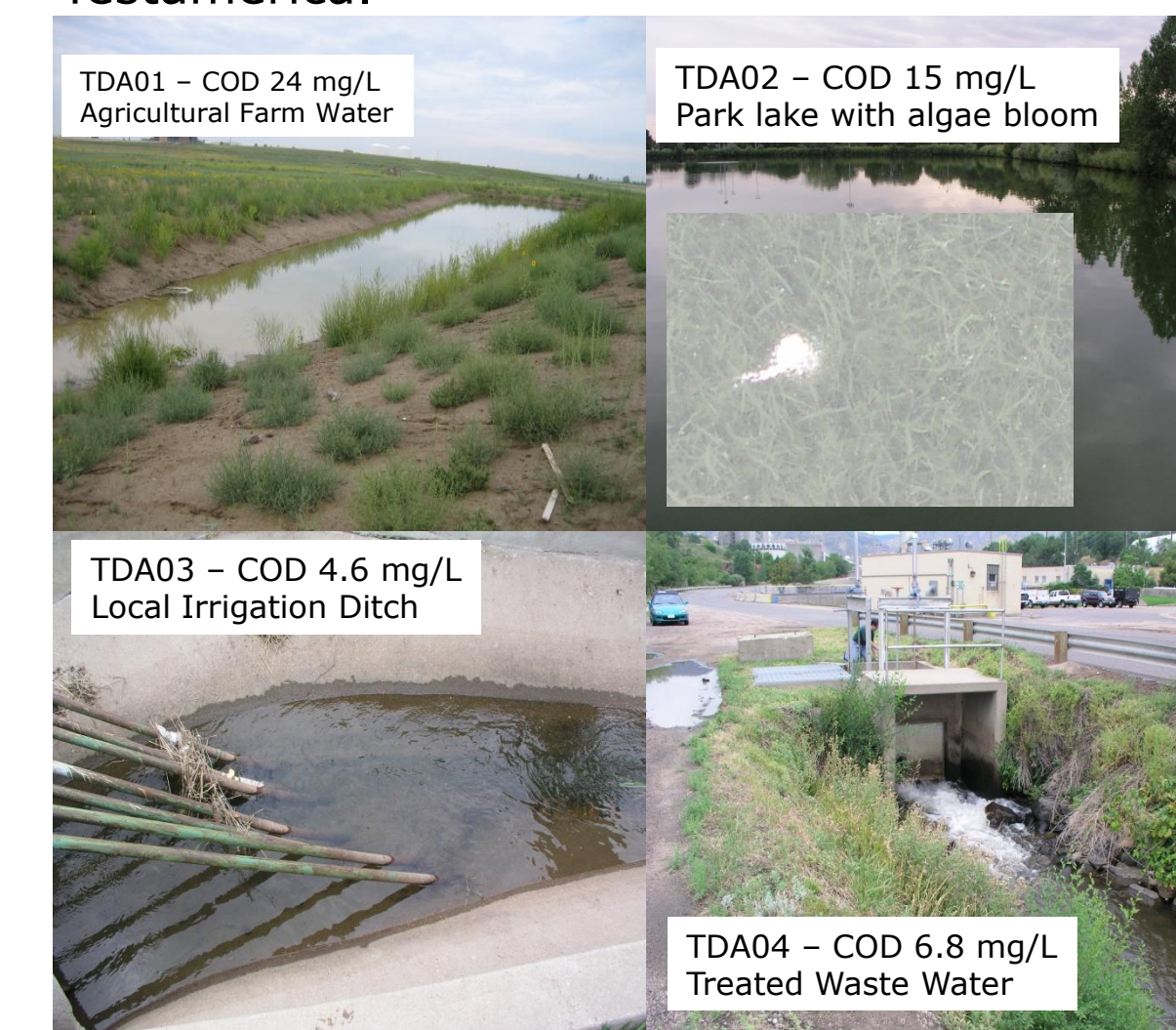
- 5.42 log reduction on CARC surface
- 5.35 log reduction on polycarbonate
- 4.9 log reduction on glass
- 4.9 log reduction on steel
- 4 log reduction on rubber

Storage, Transport and Use

- Stored equipment: (1) electrochemical decon sprayer, (2) solid salt packet, (3) battery.
- Transported equipment: All components, including chemicals, can be safely transported on commercial aircraft, for quick response during a time of need.

This system simplifies military logistics with longer shelf lives and ease of transport. The oxidants on demand capability resolves the conflicting decontaminant requirements, allowing the decontaminant to be stored for long periods while being very reactive when required as well as not producing an environmental hazard. The extremely active species are generated only when and where they are needed; we store and transport only a stable salt (water is combined on site to generate the starting decontaminant). The active species are highly reactive, so it does its job quickly, then degrades and does not persist in the environment. The energy to generate the active species is stored in a battery; readily available lithium batteries can provide the current and voltage required, and have a 10-year shelf life.

Solid salts can be reconstituted with any surface water, including seawater. Samples including actual surface waters have been tested, each test solution generated oxidant concentrations within one standard deviation of the control. COD values were measure by independent laboratory, Testamerica.



Surface Water Testing Results:

- All tested water sources yield oxidant concentrations within one standard deviation of DI water control.
- Water samples tested:
 - Water containing nitrate/nitrite fertilizer
 - Artificial seawater
 - 100mg/L, 1000mg/L, 10000mg/L chemical oxygen demand (COD) water
 - "Real world" water sources: See photo on left

Design and Scalability

The electrochemical decon technology has the capability to have application devices created on differing scales. Devices from small handheld units to large skid mounted systems can be produced without changing the fundamental technology. Any size system will operate starting with a salt solution and generating the active decon solution as needed through an electrochemical cell. This highly versatile technology is readily transportable based on the requirement. Small areas requiring decon can utilize handheld devices, for larger multi-vehicle systems, skid or truck mounted systems can be generated. In all cases, systems can be produced to achieve the desired capacity and rate of decontamination.



The photo above shows three different, fully operational prototype sprayers. Plans are in place for larger, skid mounted units.

Summary

- The electrochemical decon technology has demonstrated operational decon efficacy against classical chemical warfare agents. The technology has also demonstrated efficacy against bacterial spores, simulants for *B. anthracis*.
- The decontaminant solutions are compatible with materials used in military equipment.
- Bare steel corrosion has been shown to increase with submersion in the decon. Painted steel is not effected and CARC coatings are not softened.
- Perhaps the most significant benefit of the electrochemical decon technology is its ease of storage, long shelf life and ability to be quickly and simply transported. The reduction in logistical burden and minimal cost of storage without sacrifice in effectiveness makes this technology very beneficial to the warfighter.
- The versatility of the technology allows applicators to be made at differing scales, allowing a single technology to meet many different decontamination requirements.

Acknowledgements

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