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# NOVEL TECHNOLOGIES FOR RAPID TRANSITION FROM INDIVIDUAL TO COLLECTIVE PROTECTION


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## ABSTRACT

History reveals that Soldiers are most likely to become casualties of chemical weapons when they are transitioning from individual to collective protection. Existing test reports reveal that with current practices in place, excess time is required for each person to enter or exit the protected area and some contaminants do enter the shelter. Whether entering via air exchange or via the Soldier, contaminant infiltration must be minimized as much as possible. The U.S. Army Natick Soldier Center has established a multi-directional, technology-based approach to eliminating these capability gaps and enable rapid entry/exit to collective protection systems.


## 1. INTRODUCTION

With the increasing threat of nuclear, biological, and chemical (NBC) weapons, adequate protection must be made available to the widest number of Soldiers as possible. This protected area provides relief from cumbersome protective suits and masks enabling the Soldier to carry out mission critical functions. It also provides a means of rest and relief during critical times. Although a clean environment is provided, history reveals that Soldiers are most likely to become casualties of these weapons while transitioning from individual to collective protection. Field Manual 3-4 recommends that commanders estimate 17 minutes for entry process time of each person, which is far longer than practical for military applications. This requirement negatively impacts the logistics and capabilities of collective protection systems, limiting their applicability. The U.S. Army Natick Soldier Center (NSC) has combined computational fluid dynamic modeling and simulation with novel neutralization technologies to allow for rapid entry and exit of collectively protected areas. These technological advances will make the benefits of collective protection applicable to the majority of the Warfighters rather than the minority.

## 2. COMPUTATIONAL FLUID DYNAMICS

Computational fluid dynamics (CFD) software was used to create a mathematical model of the existing protective entrance (PE) airlock. The filtered overpressure from the shelter was simulated and variables such as airflow velocity patterns, pressure differentials, and particle traces were analyzed. This model served as a baseline that revealed non-uniform airflow distribution and velocity patterns, as well as many zones of recirculation. These velocity patterns can carry airborne contaminants along all three axis around the body and into zones that were previously free of contamination. Several design iterations were created of the airlock to improve upon the efficiency of the airflow fed through the airlock from the pressurized protected area. Airflow behaviors were captured and analyzed in comparison to each other and to the baseline design in order to identify the most efficient configuration. The design of highest performance created laminar airflow inside the PE by spreading the supply air over the surface of the airlock/shelter interface. The simulation of this airflow pattern demonstrated reduced recirculation and dead zones. Although the supply enters at a lower velocity than the original PE, as the air travels through the airlock it gains velocity.

## 3. PHYSICAL TEST AND EVALUATION

In order to validate the mathematical modeling and evaluate the efficacy of improved designs, full-scale tests and evaluations were conducted on actual equipment. The PE was connected to a tent vestibule liner section, which was over-pressured with a single motor/blower unit through an M28 filter canister. These tests were conducted by generating an Emory oil fog inside the airlock chamber, introducing a clean air flow, and measuring the resultant simulant contamination over time using an optical photometer. Data collected did correlate well with data from previous tests conducted by Massachusetts Institute of Technology and the U. S. Army. This served as the baseline performance for comparison and validated the computer aided modeling and simulation.

Based on the design improvements of the modeling and simulation efforts, prototypes were constructed of the most promising designs. This prototype consisted of removable, reconfigurable panels that enabled flow/purge testing to be conducted on several design variants. This testing has shown promising capabilities to redirect the air flow, increasing purge efficacy.

## 4. NOVEL NEUTRALIZATION

Although these advances are quite promising, the airlock would still require several air exchanges in order to reach the required three-log reduction in airborne contaminants. Driven to reduce this dwell time, the NSC investigated novel neutralization technologies. The intention was to incorporate a technology that could render chemical and biological agents, airborne or residual on personnel/supplies, harmless without causing harm to skin or sensitive equipment. A thorough investigation revealed a novel electrolyzed water technology of Procter and Gamble as the most applicable and beneficial.

Efforts in Procter and Gamble's Corporate New Ventures have taken advantage of the well-proven properties of $ClO_2$. Traditionally either an acid/catalyst reaction or electrochemical membrane process is used to create this neutralizing solution. Both processes produce a hazardous waste stream, utilize materials that the Department of Transportation (DOT) prohibits transporting, and the resultant solution is not stable over time. The E-$ClO_2$ method has been developed to safely produce $ClO_2$ on-demand with dial-in concentration capabilities, enhanced safety and stability, and minimal logistics. The product uses a stable salt solution (DOT accepted) with a small proprietary electrochemical cell that can achieve formulation flexibility for various applications. This was initially demonstrated in a spray bottle with the electrochemical cell placed in series with the spray mechanism. The only preparation required by the system is to introduce solid flakes of sodium hypochlorite (salt) to water. The salt is stable and transportable and water quality is not a concern. The amount of electricity to power the electrochemical cell is so small that it could be powered by a solar cell or mechanical energy from a hand-powered spray.

The antimicrobial efficacy of $ClO_2$ is well demonstrated in the literature. However, tests verified that the $ClO_2$ produced via this new approach was consistent with what was expected from $ClO_2$ produced by conventional means. The antimicrobial efficacy of a 1 ppm E- $ClO_2$ solution was tested in various solutions of microorganisms. The contact time was one minute and in all tests, total kill was achieved. Comparable tests were conducted against *Bacillus cereus* of five different strains. The E-$ClO_2$ treatment achieved total kill, in comparison to the hypochlorite benchmark which only yielded 1.5 log kill. Neutralizing chemical agents was more challenging than biological agents because of the methoxyl-phosphonate group and the hydrophobicity. The two primary objectives were to reduce interfacial tension between the hydrophobic chemical agents and the $ClO_2$ and also accelerate the hydrolysis of the phosphonate structure. Variations were made in the solution to the pH and surfactants to achieve these goals. Of the 120 formulations evaluated against Dimethyl Methylphosphonate (DMMP), the four best performers were chosen for live agent testing for performance validation.

Lessons learned are being applied to optimizing the delivery system for droplet sizes, particle sizes, velocities, and concentrations. This technology is being designed to provide a spray/fog of neutralizing solution to a protective entrance, eliminating the need for repeated air exchanges inside the airlock during entry and exit. The salt would be included in a collective protection system and the required water can come from a variety of sources including sea, swamp, or lake water.

## CONCLUSION

These technical efforts are currently being integrated to advance the state of the art of collective protection entry/exit to fill capability gaps of the current system. Reducing bottlenecks and time consuming steps, soldiers will be able to quickly get inside a protected area to carry out mission critical functions and gain relief from the burden of individual protective equipment. E-$ClO_2$ will be integrated into the system, rendering airborne contaminants harmless and reducing the threat of agents desorbing from personnel. This will increase the protection factor of the shelter and reduce the load on the recirculation filters placed on the shelter interior. Power savings will also be earned by reducing the volume of airflow requirement of the airlock purge. Supporting the Collective Protection Joint Future Operational Capability (JFOC), the success of this program would benefit the transportable, fixed site, and mobile collective protection systems and advance the state of the art towards the new Joint Expeditionary Collective Protection program.

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