Technology Evaluation for Chemical Demilitarization
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Preliminary Independent Assessment of General Atomics Speedy Speedy SCWO (S3) Proposal for NECDF *26 March 2002* *General Atomics*	If SCWO is chosen to treat VX/caustic hydrolysate, the S^3 proposal recommends bringing up two small-scale SCWO units at NECDF while a third, and potentially a fourth larger scale units are being fabricated. The S^3 proposal recommends using a removable Pt HIP liner and a removable C-276 liner as a backup.	The S^3 proposal appears to be technically sound. It offers the potential for using SCWO as the primary or a backup treatment option for VX hydrolysate. It provides the ability to carry out fabrication and implementation on a shorter time scale than the full-scale system.
Application of Electron Beam for Decontamination of Chemical Agents *April 2002*	The proposed technology consists of a system to generate and direct a beam of electrons onto a material or surface causing transformation or destruction of chemical or biological agents.	The technology is at a research stage and may be more applicable to the decontamination of biological agents rather than chemical agents. A significant effort would be needed to optimize the system and develop process details in terms of hardware configuration, setup, operating conditions and procedures, reaction times, etc.
Destruction of Chemical Agents Included in Unexploded Weapons Using Low Pressure Pyrolysis *May 2002* *DCPR-CNRS*	The technology envisioned would involve injecting chemical agent gases and/or liquids into a low-pressure vessel that would be resistively heated in an inert atmosphere of nitrogen. The target compounds are expected to thermally decompose to reduced compounds.	Based on lab-scale work with HD, the technology appears basically sound. However, the low-pressure pyrolysis process has neither been scaled for the destruction of chemical agents nor used commercially for any other industrial hazardous wastes.
Preliminary Comparative Evaluation of Supercritical Water Oxidation (SCWO) and Silver II Processes for Treatment of VX/Water Hydrolysate at Newport *June 2002*	The principal option for NECDF incorporates SCWO as the technology of choice for onsite treatment of VX-NaOH hydrolysate. Mediated electrochemical oxidation (Silver II technology) was proposed by CH2M Hill/AEA to process VX-water hydrolysate from the INVX process at Newport. A comparison of these two technologies was conducted to provide input into ongoing discussions regarding the choice of onsite technology at Newport.	The comparison of the two technologies favors SCWO over Silver II in eight out of ten evaluation criteria. The Government has a considerable investment in bringing the SCWO technology to its current stage of development, where technical issues that still require resolution are well identified and appear to be well underway toward successful resolution. Consequently, any new technology proposed to replace SCWO must provide a significantly higher expectation of success.

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Preliminary Evaluation of the EXCELL Molten Salt Process *June 2002* *Excell Partnership*	The MSO process is a flameless, thermal oxidation process that destroys organic constituents of waste in a bath of molten salts. The process typically injects air with the waste stream into a molten salt bath of various mixtures of salts. Halide acids are precipitated as salts so the off-gas is a relatively clean mixture of carbon dioxide, nitrogen, and water vapor.	Progress made by the Lawrence Livermore National Laboratory (LLNL) and the Navy during the last three years should be reviewed to determine if previous conclusions warrant reconsideration. Also, more detailed information about the unique, proprietary aspects of the EXCELL design are needed in order to determine if there are advantages over other MSO units.
Assessment of Concept Document "Sonication and VX Neutralization/Destruction" *June 2002* *Furness-Newburge, Inc*	The general concept centers on placing a high power (kilowatts) ultrasonic probe directly in a ton container in order to accomplish two distinct objectives: (1) increase mixing to accelerate the *in-situ* hydrolysis of VX with water in ton containers, and (2) provide for the oxidative/hydrolytic destruction of EA-2192 using sonochemical destruction from acoustic cavitation.	Since the Army is no longer pursuing *in-situ* hydrolysis, the bulk of the assessment focused on whether sonochemical processes are effective and ready for large-scale operations for oxidizing and hydrolyzing organics in aqueous wastes (e.g. VX hydrolysate). A significant development program would be required to ensure safe, reliable, effective operation at full-scale and further consideration is not warranted.
Microwave Plasma and its Possible Use in Chemical Demilitarization *June 2002* *Physical Sciences, Incorporated*	Thermal plasmas create zones of very high temperature ionized gas, which will break down the most refractory chemical bonds. These plasmas are created through the very high power dissipation within the torch or between the arcing electrodes. Microwave radiation can also be used to produce plasma similar to plasmas produced by other energy sources such as radio-frequency induction or electrical arcs.	There are technical and/or economic issues that make microwave plasma unattractive for an industrial-scale application. The temperature limitations suggested by the analytical plasma generation methods may be the greatest limitation. This type of system may be useful in applications where lower temperature plasma is needed. It is not the optimal method of plasma production for large-scale destruction of agent or agent byproducts in an aqueous waste stream.

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Preliminary Assessment of Chlorine Dioxide Technology for the PMCD Program *July 2002* *CDG Technologies*	Chlorine dioxide is a moderately strong oxidant. It does not chlorinate or alkylate chemical species, but oxidizes them. The residue after treatment of waste includes only chloride ion, plus the oxidation products from the treated material.	Chlorine dioxide-based chemical warfare agent decontamination reactions have only been studied at laboratory scale, so the technology should be estimated to still be at the applied research stage, or about 5 to 6 years from full-scale implementation and commercialization.
Preliminary Evaluation of Under Water Plasma Process for Solarwind Environmental *July 2002* *Solarwind Environmental*	The under water plasma process discharges 30 kV electrical pulses, which are claimed to have a number of effects, including creating supercritical conditions; dissociating organic molecules; separating air and water into oxygen, peroxy and hydroxyl radicals; and creating free-electrons and ions. The process appears to be similar to the more standard ozonation technique and claims improvement in effectiveness using a chemical "brew".	Although information provided by the vendor is incomplete, there appears to be credible work being pursued with this technology by other parties to enhance processes such as ozonation or hydrogen peroxide oxidation. If any of the chemical demilitarization waste streams are found to be amenable to treatment by these oxidation methods, this technology could be a possible enhancement.
Continuous Emission Monitors (CEMs) for Products of Incomplete Combustion (PICs) *September 2002*	PICs are byproducts of combustion devices that are formed as a result of partial combustion caused by incomplete mixing, insufficient residence time, or insufficient temperature. The report discusses the status of continuous emission monitors for the detection of polychlorinated dibenzodioxins and furans (PCDDs and PCDFs). Instruments evaluated include chromatographic methods, jet-REMPI and Cavity Ringdown Spectroscopy.	CEMS for PCDD/PCDFs (as well as VOCs and SVOCs) are not required under the MACT rules. Currently, there are no instruments available that have the required sensitivity. Development of such CEMS is an active task at both the EPA and DOE, and it is recommended that progress by these organizations be monitored at regular intervals. The status of the development of a field-deployable Jet-REMPI system by PMCD/EMO and EPA/NRMRL should be closely monitored.

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Multi-Metal Continuous Emission Monitors (MMCEMS) *September 2002*	This report discusses aspects of MMCEMs, including: instruments commercially available or under development; analytical technologies being used; level of technological maturity of various instruments; advantages and disadvantages for assuring environmental compliance; and, conclusions and recommendations for PMCD. Instruments evaluated include, Navy/Thermo Elemental ICP-AES, DIAL ICP, and the Cooper X-ray Fluorescence CEM.	None of the MMCEMs available meet the relative accuracy criterion of 20 percent required by current regulations. Improvements in calibration methods and in instrumental automatic correction for stack gas variables affecting accuracy are still needed. The more mature instruments are considered the most likely to be valuable to the PMCD program in the near future. Among those, the Navy/TE ICP-AES is considered the most promising.
Assessment of Plasma Arc Technology for Processing of Chemical Demilitarization Wastes *October 2002*	Plasma Arc (PA) technology sustains an electric arc by passing an electric current through a diatomic gas. The gases dissociate into their atomic state at 2,000 °C, and ionize, as electrons are stripped away at 3,000 °C. Organic constituents are volatilized, pyrolyzed, or combusted, while inorganic material and non-volatized metals are bound in a molten pool. The report provides a review of PA technology, and assesses its applicability for processing secondary and closure wastes.	It is recommended to continue to periodically monitor the status of PA technology in relation to PMCD needs. It is also recommended to develop a conceptual design and cost estimate for a small PA system to treat the metal waste for the Pine Bluff Non-Stockpile Facility to a 5X condition in the event that the planned chemical decontamination proves insufficient. Given the significant cost savings indicated by the preliminary economic analysis, it is recommended to perform a more detailed and definitive study of potential application to process closure wastes from demilitarization facilities.

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Continuous Steam Treater (CST)/Metal Parts Treater (MPT) Technology Assessment *November 2002*	The steam-based systems are designed to render agent-contaminated metal parts and secondary wastes to a 5X condition. They use superheated steam at a minimum of 1,000 °F for at least 15 minutes to treat the materials. The rotary MPT is designed to process drained projectiles; the batch MPT to process metal details. The CST is designed to decontaminate secondary wastes. Steam treatment of metal parts and secondary wastes is considered for the Newport Chemical Demilitarization Facility (NECDF).	The implementation of a batch MPT at the NECDF would severely affect schedule for agent operations and is not warranted given the current method planned for the off-site disposal of ton containers. There are several processes related to the CST system that remain undemonstrated, including the material feed system, mixing of secondary waste, and separation of processed wastes.
Munitions Access Systems *March 2003*	A munitions access system is typically a set of components for safely accessing the chemical warfare agent (CWA) fills of recovered chemical warfare materiel (RCWM). This report discusses several aspects of this equipment, including the systems and components under development, design variations, and their technological maturity. The units evaluated include the Drill Through Valve system, the chemical munition emptying system (CMES) and the Large Item Transportable Access and Neutralization System (LITANS). When fully developed, these systems may be capable of removing CWA from large or unstable munitions.	At the time of the report, the field trials of the LITANS had not been conducted yet. However, based on planned improvements, it was expected to be nearly field ready. The success of the trials depended largely on the new Monica drilling subsystem. The Safety-Kleen drill and tap fixture's potential value and maturity for PMNSCM operations cannot be assessed until technical data have been received. It may provide an alternative munitions access technology for emptying RCWM fills. Munitions access technologies should be closely tracked by PMNSCM, so that if advantages for particular situations arise, the options will be maximized.

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Wet Air Oxidation Technology Assessment *April 2003*	Wet air oxidation (WAO) is a moderate temperature, high-pressure, aqueous phase process in which soluble and suspended organic constituents are oxidized by dissolved oxygen. When the toxicity of agents has been significantly reduced by neutralization, WAO is considered to be suitable for the treatment of the products. This technology is a strong candidate for processing NSCMP neutralents and hydrolysates.	WAO is a viable technology option for non-stockpile neutralents and should be continuously monitored. Pilot testing of the WAO process for DF and QL neutralents was in progress at Zimpro at the time of the report and it was recommended that the test results be reviewed and captured in a supplemental report.
Transpiring-Wall Supercritical Water Oxidation Technology Assessment *April 2003*	Supercritical water oxidation (SCWO) involves the destruction of aqueous organic waste through rapid oxidation and hydrolysis by heating and pressurizing waste, oxidant and fuel (if necessary) above the critical point of water to convert them to carbon dioxide, water and inorganic salts. Two types of SCWO systems have been under investigation for the Assembled Chemical Weapons Assessment (ACWA) program: (1) solid wall liner and (2) transpiring wall liner. This report provides a technical evaluation of the latter, as tested under the ACWA program.	Based on available information and test data, it appears that TW-SCWO can be made to work at full scale at Blue Grass, KY. All of the technical and programmatic risks associated with scale-up cannot be eliminated, so additional time for shakedown, systemization and testing of the full-scale system will likely be necessary and may need to be accommodated in the schedule. Based on the available information for TW-SCWO and the lack of significant advantages over the current Newport Chemical Agent Disposal Facility (NECDF) SCWO process, it is recommended that TW-SCWO not be considered further for implementation at NECDF.
Wet Air Oxidation Development Chronology *April 2003*	The WAO development chronology was prepared in support of a review of the status of alternative technologies for the treatment of VX hydrolysate at Newport. The document covers the last 10 years of WAO development based on one programmatic and five National Research Council (NRC) reports.	The document describes the conclusions and recommendations from each report reviewed, but does not present any new opinions.

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Supercritical Water Oxidation Development Chronology *April 2003*	The SCWO development chronology was prepared in support of a review of the status of alternative technologies for the treatment of VX hydrolysate at Newport. The document covers the last 10 years of WAO development based on eight programmatic and six National Research Council (NRC) reports.	The document describes the conclusions and recommendations from each report reviewed, but does not present any new opinions.
Assembled Chemical Weapons Assessment Technologies Monitoring Report *August 2003*	This report gives a programmatic overview of the Assembled Chemical Weapons Assessment (ACWA) program, including major milestones achieved and technologies evaluated. It provides descriptions of the technologies evaluated for implementation at Blue Grass Army Depot (BGAD) and the Water Hydrolysis of Explosives and Agent Technology (WHEAT) awarded for the destruction of assembled chemical weapons at Pueblo Chemical Depot. The technologies evaluated for implementation at BGAD included: hydrolysis followed by supercritical water oxidation (SCWO), SILVER II – electrochemical oxidation, and hydrolysis followed by transpiring wall-SCWO. This report also documents the results of the overall ACWA test program and communicates the National Research Council's (NRC's) position on testing. It provides process descriptions, conclusions, and recommendations for the following ACWA treatment units evaluated in the past year: Plasma Arc (PA), Continuous Stream Treater (CST), Transpiring Wall-SCWO (TW-SCWO), and Projectile Washout System (PWS).	(1) Plasma Arc: The major conclusion was that there was no apparent benefit in using the PA technology at any of the stockpile facilities for processing secondary wastes. The technology evaluation, however, did identify that there may be some economic advantages for processing closure waste along with the metal parts furnace. (2) Continuous Stream Treater: It was strongly recommended that the CST not be considered for implementation at a stockpile facility until the material handling system for the secondary waste and carrier is improved and tested. (3) Transpiring Wall-SCWO: It was recommended that the TW-SCWO process not be considered for implementation at Newport. This recommendation was based on the lack of any identifiable or quantifiable significant advantages of TW-SCWO to current destruction processes already being implemented or designed for implantation. (4) Silver II: Based on test results, the NRC recommended that this technology not be implemented at BGAD. The increasing complexity of the overall process and uncertainties in handling and stability of certain process materials are indications that Silver II is too immature and therefore not ready for implementation. None of the unit operations have been integrated and tested as a complete system. The NRC feels that this is a major concern and may pose significant obstacles to full-scale implementation.

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Conference	Date and Location	Synopsis
Plasma 2002 CBD Decon Conference	March 20, 2002 Aberdeen Proving Ground, MD	Presentations covered laboratory tests on the use of low-temperature, atmospheric plasma discharges predominantly for the surface decontamination of biological hazards. The thrust of the efforts has been to develop a mobile system capable of decontaminating sensitive areas.
Projectile Washout System by PMACWA/Parsons	April 4, 2002 Aberdeen Proving Ground, MD	Parsons presented a summary of the projectile washout system that was developed under the ACWA program. The technology has potential application for non-stockpile recovered munitions in addition to the stockpile at Pueblo.
21st International Conference on Incineration and Thermal Treatment Technologies	May 13-17, 2002 New Orleans, LA	The plenary session focused on the upcoming changes to the hazardous waste combustor MACT standards. A number of papers attended were of specific interest to NSCMP. A unique portable plasma system, manufactured by PyroGenesis, was presented.
2002 Global Demilitarization Symposium and Exhibition	May 20-24, 2002 Lexington, KY	The National Defense Industrial Association, in cooperation with the Joint Ordnance Commanders Group, organized this tenth annual meeting. The US Army Defense Ammunition Center (DAC) sponsored a significant portion of the work described. There were over 400 attendees and about 50 government and industry exhibits.
ACWA Dialogue Meeting Summary	June 5-6, 2002 Edgewood, MD	This was the last ACWA dialogue meeting. Presentations included a program overview; technical updates including testing summaries for the four technologies and future ACWA testing; CATT oversight; NRC update; environmental update for Pueblo Chemical Depot (PCD) and Blue Grass Army Depot (BGAD); Report to Congress; Defense Acquisition Executive (DAE) review process; Colorado update; and a Kentucky update. The meeting summary addresses the four technologies in particular.

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Air and Waste Management Association (AWMA) Annual Conference	June 23-27, 2002 Baltimore, MD	A number of projects, processes, and products were reviewed during technical sessions and in the vendor exhibition. The main areas of interest for the conference were: • Monitoring and control of mercury • Treatment of gas-phase VOCs by innovative technologies
Non-Stockpile Chemical Materiel Project Air Monitoring Lessons Learned Workshop	June 26, 2002 Aberdeen Proving Ground, MD	The workshop focused on agent air monitoring methods and technologies. Topics included reports of recent Chemical Weapons Materiel field operations experience with unknowns that included volatile organic compounds in the environment, as well as contaminants or non-agent fills in munitions. Supporting systems (e.g. Data Management System) were also topics of discussion.
Bitler Plasma Technologies and Kinetrics Plasma Arc Technology Presentation	July 24, 1002 Abingdon, MD	Bitler Plasma Technologies and Kinetrics presented their plasma arc technology to representatives from SAIC, NSCMP, PMCD and the Environmental Monitoring Office (EMO).
Joint Services Pollution Prevention and Hazardous Waste Management (HWM) Conference and Exhibition	August 19-22, 2002 San Antonio, TX	The scope of the conference was predominantly in the areas of pollution prevention (P2) options and broad site environmental management. There were more than 200 speakers for eight different concurrent technical breakout sessions that generally involved waste management issues or technical solutions to very specific site remediation or P2 solutions. The exhibition included over 250 vendors for P2/Hazardous Waste Management and CADD/GIC technologies.
Chemical Biological Defense Industrial Base Symposium	October 7-8, 2002 Pittsburgh, PA	The issues discussed related to “Individual and Collective Protection Supporting Homeland Security and Army Transformation”. The theme of the symposium captured two major initiatives affecting the nation and the Army: individual and collective protection in a chemical and biological (CB) defense environment. The goal of the meeting was to capture the perspectives, solutions, and concerns of industry using an interactive discussion-based forum.

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Program Manager Non-Stockpile Chemical Materiel (PMNSCM) Technology Evaluation Panel II Briefing	October 16, 2002 Aberdeen Proving Ground, MD	The Technology Evaluation Panel (TEP) II evaluated nine technologies tested by Stone & Webster on behalf of NSCMP to provide recommendations for the treatment of feed types and quantities specific to the program. Further testing was recommended for DF and QL hydrolysis, persulfate oxidation, photocatalytic oxidation, solidification/stabilization, and wet air oxidation. Testing was also recommended for batch-SCWO and plasma technologies if justified for specific applications. CerOx and GPCR were not recommended for application to the treatment of NSCM.
11th Demil Users Group Meeting	October 29-30, 2002 San Diego, CA	The meeting provided a forum to address the challenges associated with disposition of energetics and demilitarization of the conventional weapons stockpile. The agenda involved program reviews, installation overviews, and presentations of ongoing research and development efforts. Technologies presented include Plasma Arc systems, SCWO, continuous emission monitors, Molten Salt Oxidation, Munitions Items Disposition System, Waterjet Cutting, Actodemil Technology, and a Transportable Flashing Furnace.
Non-Stockpile Air Monitoring Lessons Learned Workshop	December 03, 2002 Aberdeen Proving Ground, MD	The goals of the workshop were to: (1) provide a lessons learned vehicle for sharing experience; (2) ensure that the air monitoring policy appropriately supports the Non-Stockpile mission; (3) open a forum for discussion of air monitoring methodology and policy strengths and weaknesses; and (4) establish a continuing vehicle for examining progress. There were approximately 50 people in attendance, predominantly from NSCMP and their subcontractors. The agenda included review of the status of action items from the last workshop, followed by ten technical/programmatic presentations and open discussion of issues.

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Phoenix Solutions Company Plasma Arc Technology Presentation	January 15, 2003 Abingdon, MD	SAIC hosted the plasma arc (PA) technology presentation by Phoenix Solutions to representatives of CSDP, ATAP, and NSCMP. Phoenix has about 40 units in Japan. The largest unit to date at 10 megawatts is under construction; expected throughput is 150 to 160 tons per day. All of the reactors use water-cooled, copper electrodes and can be run in either oxidizing or reducing mode. The discussion confirmed that there were no apparent opportunities for the application of PA for the destruction of dunnage, other than the ACWA facility at Blue Grass.
PMCD Technology Workshop	January 29-30, 2003 Abingdon, MD	The workshop was hosted by SAIC on behalf of PMCD to facilitate the identification of technology systems, subsystems, and components that may contribute to the effective implementation of PMCD's mission. The purpose was to (1) clarify the technology needs, and (2) enable technology owners/developers to present technologies that may be useful as potential solutions. There were 29 talks scheduled in 8 technical sessions over the two-day workshop and a total of 111 people attended. There have been a number of inquiries to the Technology Evaluation team requesting additional information about technologies presented.
Pittsburgh Conference – Pittcon 2003	March 10-14, 2003 Orlando, FL	Pittcon is the world's premier annual conference devoted to laboratory science. This year there were over 20,000 attendees, 1000 exhibiting companies and 20 concurrent technical sessions with approximately 2,000 presentations. There were a number of papers and posters on the analysis of chemical warfare agents, particularly in the area of field detectors and first responder applications. In addition, numerous vendors were exhibiting CWA-related technologies.

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Veckis Industries Limited Presentation of Biotechnology for the Destruction of Chemical Warfare Agents *April 2003*	April 15, 2003 Aberdeen Proving Ground, MD	Representatives of Veckis Industries Limited (Veckis) of Liechtenstein presented their technology for the biotreatment of chemical warfare agents to a group of people from the Program Manager for the Elimination of Chemical Weapons (PM ECW). The technology was described as an amino acid reagent that converts CWA to a "non-toxic" mixture (1st stage) that can then be further digested by commonly used microorganisms such as active silt (2nd stage). The final product is an organic and mineral mixture. The technology is claimed to be applicable to Soman, Sarin, VX, Sulfur Mustard, Lewisite, halogen-containing pesticides, and for the treatment of contaminated soil.
Presentation of Battelle's Acid Digestion Process for the Treatment of Chemical Munitions *April 2003*	April 23, 2003 Aberdeen Proving Ground, MD	Representatives of Battelle's Eastern Science and Technology Center presented their technology for the treatment of chemical and biological munitions by acid digestion to a group of people from the office of the Program Manager for the Alternative Technologies and Approaches (PMATA). The technology provider claims that it can treat a variety of munition types, maximizes worker safety, and is both mobile and cost effective. Acid digestion requires no mechanical disassembly, cutting or drilling, or other physical means to access munitions. The concept of the process involves (1) dissolving whole munitions with nitric acid and neutralizing the chemical agent, (2) filtering the reaction mixture to recover undissolved explosives and metals to be treated or recycled, and (3) neutralizing and disposing of the spent acid or recycling it.

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The International Chemical Weapons Demilitarization Conference *June 2003*	May 20-22, 2003 Prague, Czech Republic	Approximately 70 presentations were given in two concurrent sessions, divided into policy and technology topics. Selected technical presentations included: The Use of Wet Air Oxidation for the Destruction of Recovered Chemical Warfare Material and Binary Precursors, Pressurized Water Washout of 4.2 inch Mortar Rounds Containing Liquid and Frozen HT and Agent Solid Residues, Batch Super Critical Water Oxidation Evaluation Status, Demonstration/Validation Testing of the TC-25 Donovan Blast Chamber, General Atomics' Total Solution for Assembled Chemical Weapons at Blue Grass, Sequencing Batch Reactor Biodegradation of Hydrolyzed GB as Sole Carbon Source, and Acid Digestion of Recovered Chemical Warfare Material.
2003 Global Demilitarization Symposium and Exhibition ***June 2003***	May 19-22, 2003 Sparks, Nevada	Presentations included those on different stationary and portable Donovan Blast Chamber systems being used for demilitarization and conventional and chemical munitions, incineration and OB/OD emissions and risk evaluation analysis, Blue Grass neutralization/SCWO, and APG mustard pressurized water washout experience. A variety of technologies successfully used or undergoing study for conventional munitions demilitarization was also described, including biological, plasma, molten salt, mechanical/robotics, and chemical relation processes.
Chemical Biological Regenerative Air Filtration System Presentation/Discussion *August 2003*	July 28, 2003 Edgewood, Maryland	A presentation and demonstration of dominick hunter's (dh) chemical biological regenerative air filter system was addressed.
Veckis Industries Limited Presentation of a Concept for Testing a Biotechnology for the Destruction of Chemical Warfare Agents *August 2003*	August 4, 2003 Edgewood, Maryland	As a follow-up to their initial visit on 15 April 2003, representatives of Veckis Industries Limited presented an outline of the testing being planned to confirm the effectiveness of their bio process for the destruction of chemical warfare agents.