

Advancing Respiratory Protective Device Technology through Breathing Gas Chemical Research

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Proposed Project Goals

- (1) Demonstrate improved chemical performance using newly developed catalysts/ molecular sieves or distributed adsorbents in bench scale tests.
- (2) Standardize analytical test methods for evaluating breathing gas chemical processing to enable development or improvement of products that conform to The MINER Act of 2006 requirements.

Background

- Mine Escape Breathing Devices specified in 30 CFR 75.1714-1 indicate that the Self Contained Self Rescuer (SCSR) must be usable for not less than 1 hour or not less than 10 min (with access to 1 hour canister).
- The "Mine Improvement and New Emergency Response Act of 2006" (MINER act) requires duration improvement of closed circuit breathing devices (up to 4 hours) and filtering self rescuers (from 1 ---->2 hours).
- Self Contained Breathing Apparatus (SCBA) gas test conditions specified in 42 CFR 84.79, 84.97, and 84.103 (Subpart H) and in 84.126 (Subpart I).
 - Composition: >19.5 %O₂, O₂ to contain < 0.03% CO₂, < 0.001 % CO
 - CO₂ concentration: <2.5% (<30 min service), <1.0% (4 hr service)
 - Inspired air temp: < 43 °C (15-45 min, >50%humidity) < 35 °C (4 hr)
 - CO limit: <385 cm³ over minimum life and never > 500 ppm. (masks)

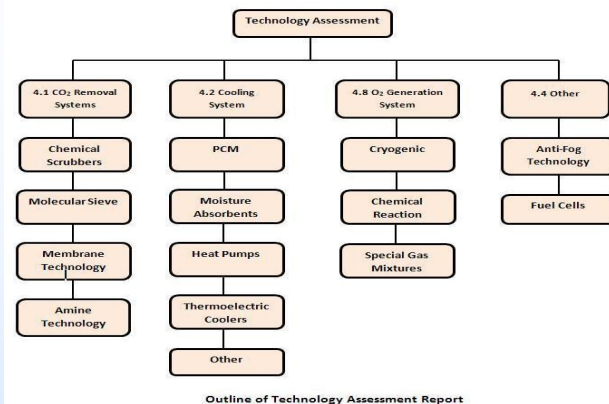


- Best review of SCSR design and canister chemistry in "Edgewood" report.
 - Devices built around concentrated O₂ sources, solid adsorbent traps.
 - Water and heat are byproducts which render breathing gas uncomfortable.
 - Devices incorporate physical or chemical agents for cooling or drying gases.
- Research is needed to explore potential applications of advances in chemical and materials science.

Canister Chemistry Options Today

- Oxygen (O₂) Generation
Tanks- Air (open circuit) or O₂ (closed) cylinders- 2000-4000 psig
Solids- $2\text{KO}_2 + \text{CO}_2 + \text{H}_2\text{O} \rightarrow \text{K}_2\text{CO}_3 + \text{H}_2\text{O} + 1.5\text{O}_2$ (+ heat)
Cryogenics- Liquid oxygen- low pressure, but fill right before use
- Carbon Dioxide (CO₂) Absorption
"Soda lime" or LiOH $x\text{M}(\text{OH})_y + \text{H}_2\text{O} + \text{CO}_2 \rightarrow \text{M}_x\text{CO}_3(\text{s}) + 2\text{H}_2\text{O}$
- Carbon Monoxide (CO) Oxidation
metal oxidants "Hopcalite" $\text{Cu}/\text{MnO}_x + \text{CO} \rightarrow \text{Cu}/\text{MnO}_{x-1} + \text{CO}_2$

Research Gaps Identified (Edgewood Report)



Material Types for Performance Improvements

New materials may demonstrate improved performance in different ways:

1. Improve chemical activity of active sites on solids
2. Improve gas-active site contact by distributing active sites in a 3-D molecular framework (zeolites, metal organic frameworks (MOFs))
3. Improve gas-active site contact by increasing gas access to solid surfaces- either by distributing on a support (fibers, membranes, resins, etc.) or by using fine or ultrafine particles (nanoparticles).

Literature Reports of CO₂ Absorbent Research

- Extensive references in review articles found in these journals- *Journal of Membrane Science*, *Separation Science & Technologies*, *Carbon*, *Energy*, *Science and Technology of Advanced Materials*, *Microporous And Mesoporous Materials*.
- Most prominent/active specific materials reported in these areas:
 - Basic amine functionalities on frameworks Amines in MCM-type silicas, silicoaluminophosphate (SAPO)-34, via various alkyl groups.
 - Basic polyethyleneimine (PEI) functionalities on frameworks PEI on glass fibers, mesoporous silica (MCM, SBA and KIT-6 types).
 - Novel adsorbent forms zeolites types (MFI, H-beta, FAU, EMT) CuMOF (Cu Hexafluoro isopropylidene bis benzoic acid), SAPO-34, amorphous silicas ASMS-3A or 5A, ionic liquid membranes.

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Literature Reports of CO Oxidant Research

Hopcalite improvements reported: syntheses or preparation methods yielding higher surface area or nanocrystals by redox or co-precipitation. Doping with Au, Ag, Co, or Ce as chemical promoters.

Novel 3-D frameworks reported: zeolite types FAU, MOR, ZSM-5, and MOF types- Au or Co @ZIF-8 (a Zn methylimidazole). These frameworks incorporate Cu, Pd, Ag, Co, Pt, H, or Au cations as active sites.

Proposed Project Milestones

1. Identify partners and collaborate to develop project plan. (2Q FY12)
2. Develop a bench scale test system- use it to collect pilot data on novel solid adsorbent/catalyst performance under constant gas flow and physiologic conditions. (3Q FY12)
3. Finalize full proposal and complete external scientific peer review. (4Q FY12).
4. Evaluate and add gas analysis instrumentation to bench system for comprehensive chemical analysis. Use improved system to determine chemical mechanisms and to provide improved measures of adsorbent /catalyst efficiency and degradation for promising materials. (2Q FY13)
5. Incorporate gas analysis instrumentation improvements into a BMS-type system (Breathing & Metabolic Simulator). Add breathing waveform controls and metabolic simulation control devices. Introduce as a full scale material evaluation device using industry-accepted testing protocols. (4Q FY14)

Wider Applications/ Future Work

- Consider subsequent projects in which chemical performance and testing improvements are incorporated into filtering respirator canisters, SCBA canisters used by firefighting, military, and first response professionals.
- **Your feedback on this proposed new research project is requested. Interested project partners should contact David Murray (DMurray@cdc.gov). Interested peer reviewers should e-mail Chris Coffey (ccc3@cdc.gov).**

Reference

- (1) "Final Report on Human Factors of Closed-Circuit Self-Contained Breathing Apparatus: Potential Areas for Improvement" Battelle Columbus Operations, to US Army Edgewood Chemical Biological Center, Aberdeen Proving Ground, MD. Authors DJ Winkel, AW Richardson, NE Knebel, DF Wourms, and KC Hofacre, (SP0700-00-D-3180- Task No. 505, Delivery Order 209), April 2006.