Filter Testing-Performance Analysis and Performance Enhancement

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Objectives of Testing

Part 1: What to test?

Part 2: How to test it?

Part 3: How to translate laboratory testing to meaningful data to the user community.

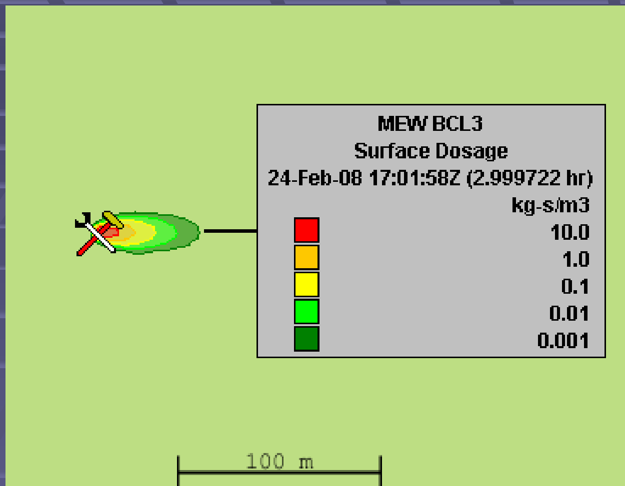
Industrial Chemicals

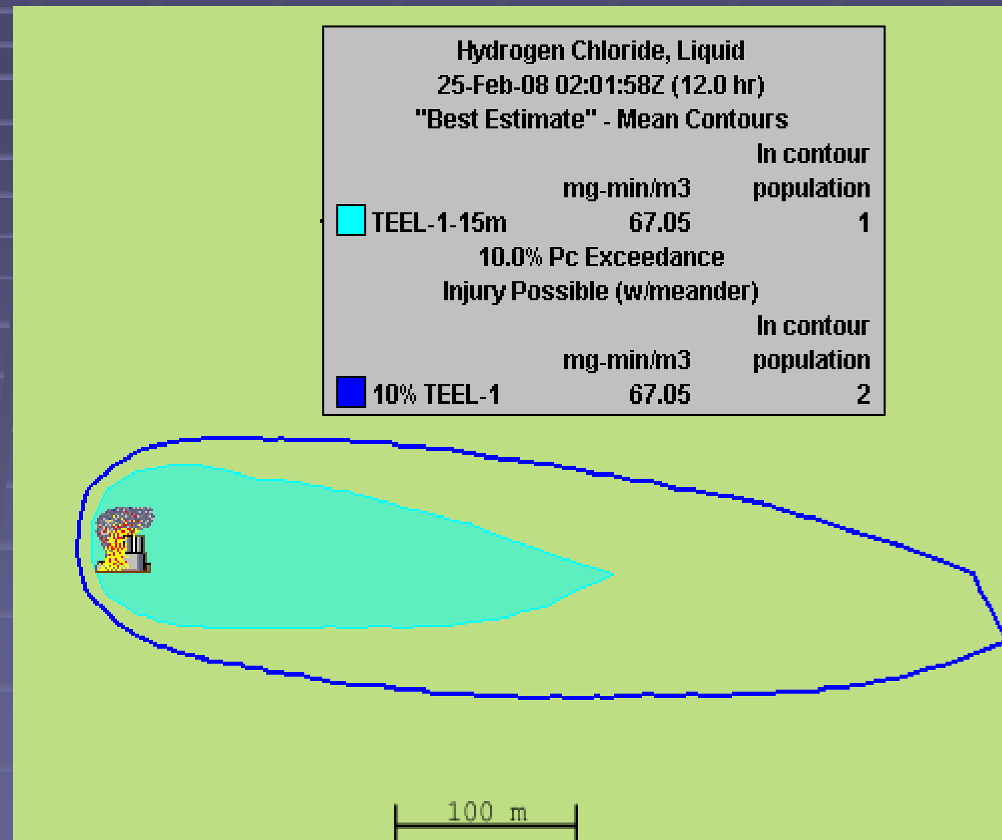
These few selected industrial uses are only a small subset of the over **5000** chemical manufacturing and processing facilities world-wide.

What to test?

1. Over 5000 chemical facilities worldwide
2. An even greater number of distributors
3. TIC prioritization focused on a comprehensive risk management of what we do not know:
   - Absolute global production levels
   - Absolute global distribution amounts

Assess the actual environmental hazard





Inputs:
(1) Chemical Reactivity
(2) Decay rate fed into model
(3) Container Regulations

Outputs:
(1) Major By-product: Hydrogen Chloride
(2) Release Modeled as such

How to test?

1. **Challenge Levels**
   - Scenario Modeling (For T&E purposes)
   - Vignette Modeling (For operational analyses)
2. **Breakthrough Levels**
3. **Detection Approaches**
   - Multiple species may be present
4. **Chemical Class Analysis**
5. **Humidity Effects**

Scenario Modeling

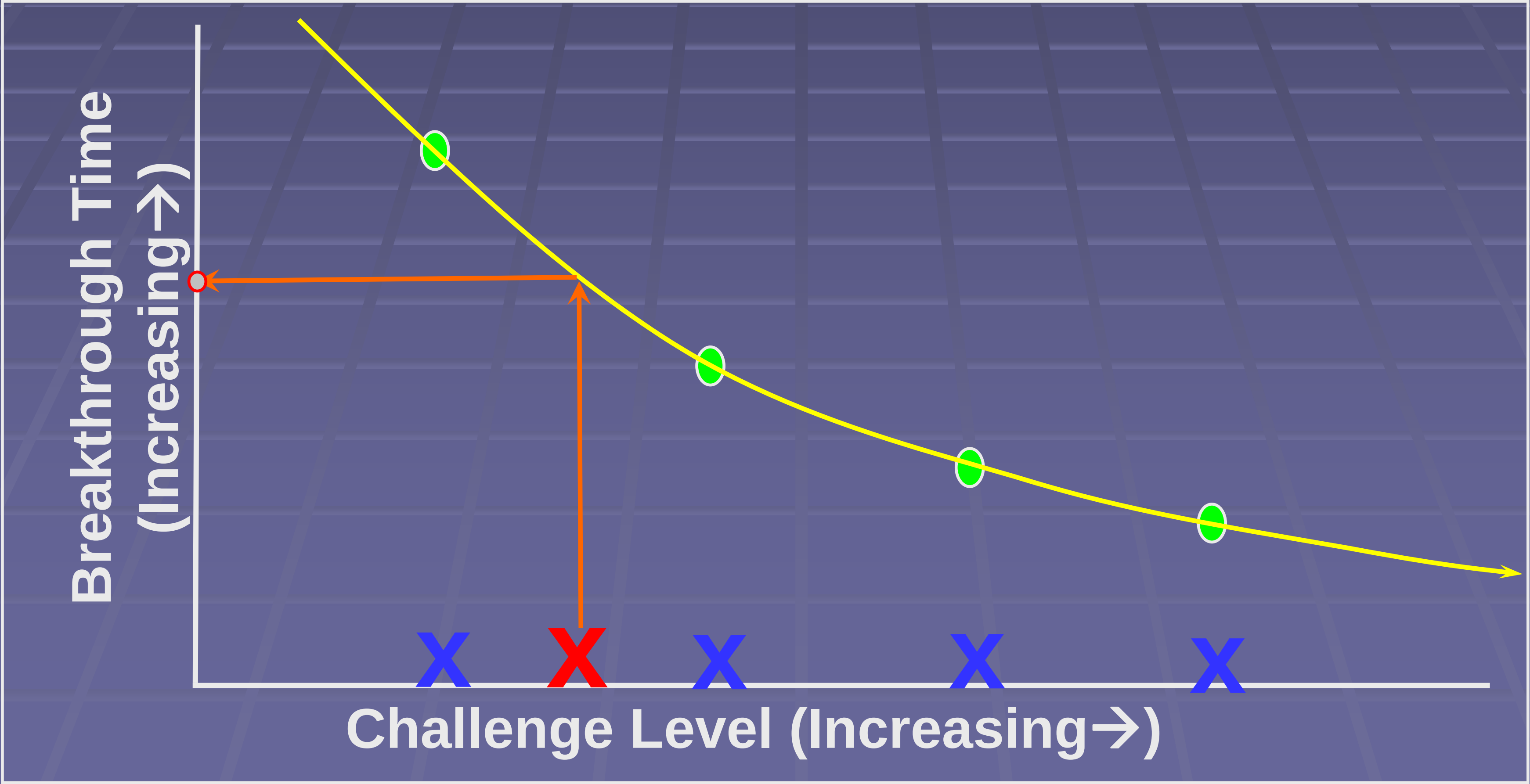
For each prioritized TIC:

1. **Utilize DOT/UN transport regulations to determine large, moderate and asymmetric releases.**
2. **Determine maximum challenge levels at set distances**
   - **(100, 500, 1000 meters)**
3. **Consider operational relevance to challenges.**
   - **At 100 meters from a large rail car explosion-is the threat an inhalation hazard or a blast hazard?**

Challenge Levels

Test a range of concentrations (Scenario Driven)

- Performance curve generated vs. single data point
- Extrapolation of performance for any vignette



How to detect?

Consider NO_2:

Humidity – partial conversion to HNO_3 and HNO_2

Reactions with different impregnates:

$ZnCl_2$ / $ZnBr_2$ + HNO_3 → $Zn(NO_3)_2$ + HCl / HBr

Develop capability for in-line detection of multiple species.

How to detect?

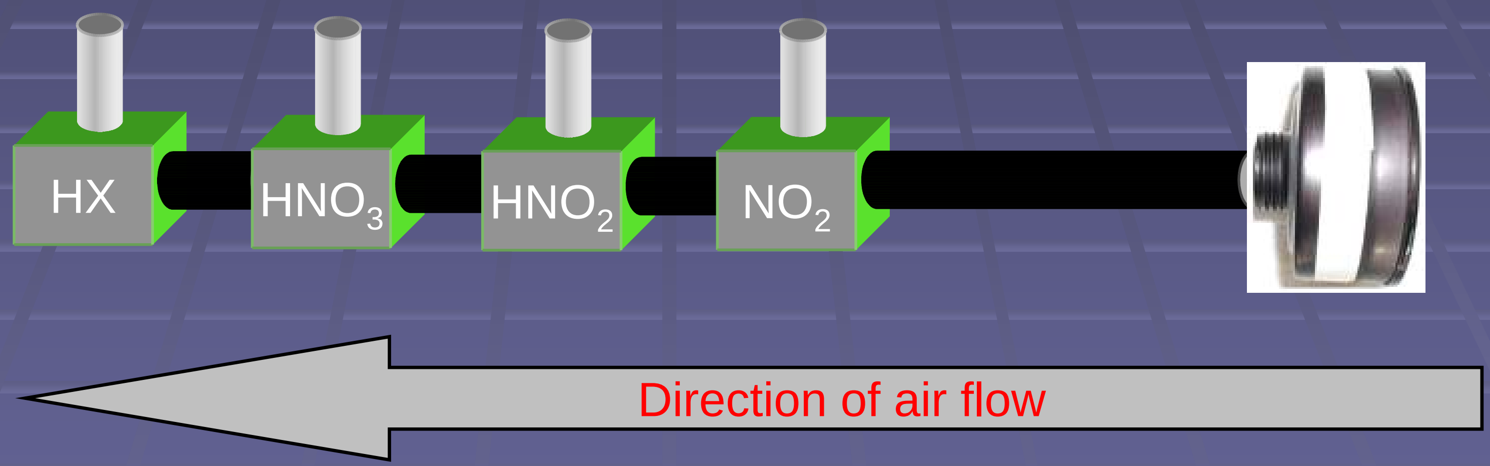
One example:

- Use of ion selective-electrochemical sensors
- Commonly available for industry
- Below lists a few of those with high sensitivity and limited cross interference

Acrylonitrile (AN)	**Fluorine (F_2)**	**Nitric Acid (HNO_3)**
Ammonia (NH_3)	**Formaldehyde**	**Nitric Oxide (NO)**
Arsine (AsH_3)	**Hydrazine (N_2H_4)**	**Nitrogen Dioxide**
Benzene (C_2H_6)	**Hydrogen Bromide**	**N_2O**
Bromine (Br_2)	**Hydrogen Chloride**	**Ozone (O_3)**
Butadiene (C_4H_6)	**Hydrogen Cyanide**	**Phosgene ($COCl_2$)**
Carbon Monoxide	**Hydrogen Fluoride**	**Phosphine (Ph_3)**
Chlorine (Cl_2)	**Hydrogen Sulfide**	**Styrene**
Cyclohexane	**MEK ($CH_3COC_2H_5$)**	**Sulfur Dioxide**
Ethylene Oxide	**Methyl Bromide**	**Vinyl Chloride**

How to detect?

Simple t-cell detection set-up



Class Based Analysis

Dual Use of a chemically based Class Analysis

- Risk mitigation of the unknown absolute scoring of a chemical’s presence globally.
- Class based analysis to assess filter performance against other related chemicals not tested.

Chemical Classes in Prioritization

Oxidizers-includes "acid gases", and "acid forming gases" such as chlorine or fluorine.

Reducers-includes ammonia and the other hydrides, as well as the hydrazines and amines.

Lachrymators- self-polymerizing "tear causing chemicals"→ acrylonitrile, acrolein, allyl alcohol, methyl isocyanate and phosgene.

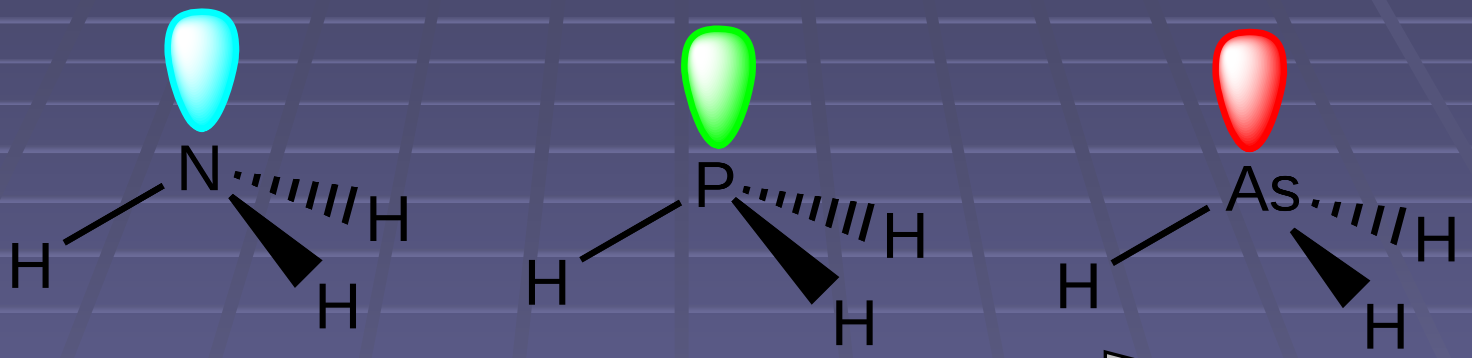
Volatile Organics- simple, volatile solvents such as carbon disulfide or carbon tetrachloride.

Pest/Herbicide-called due to toxicity, stability and current/past global distribution

From initial ranking, select those with the highest scores in each Class to ensure that all classes are represented.

Class Based Analysis in Filter Testing

Ammonia Phosphine Arsine



Increasing reactivity (stronger reducing agent) →

← Increasing stability in the environment

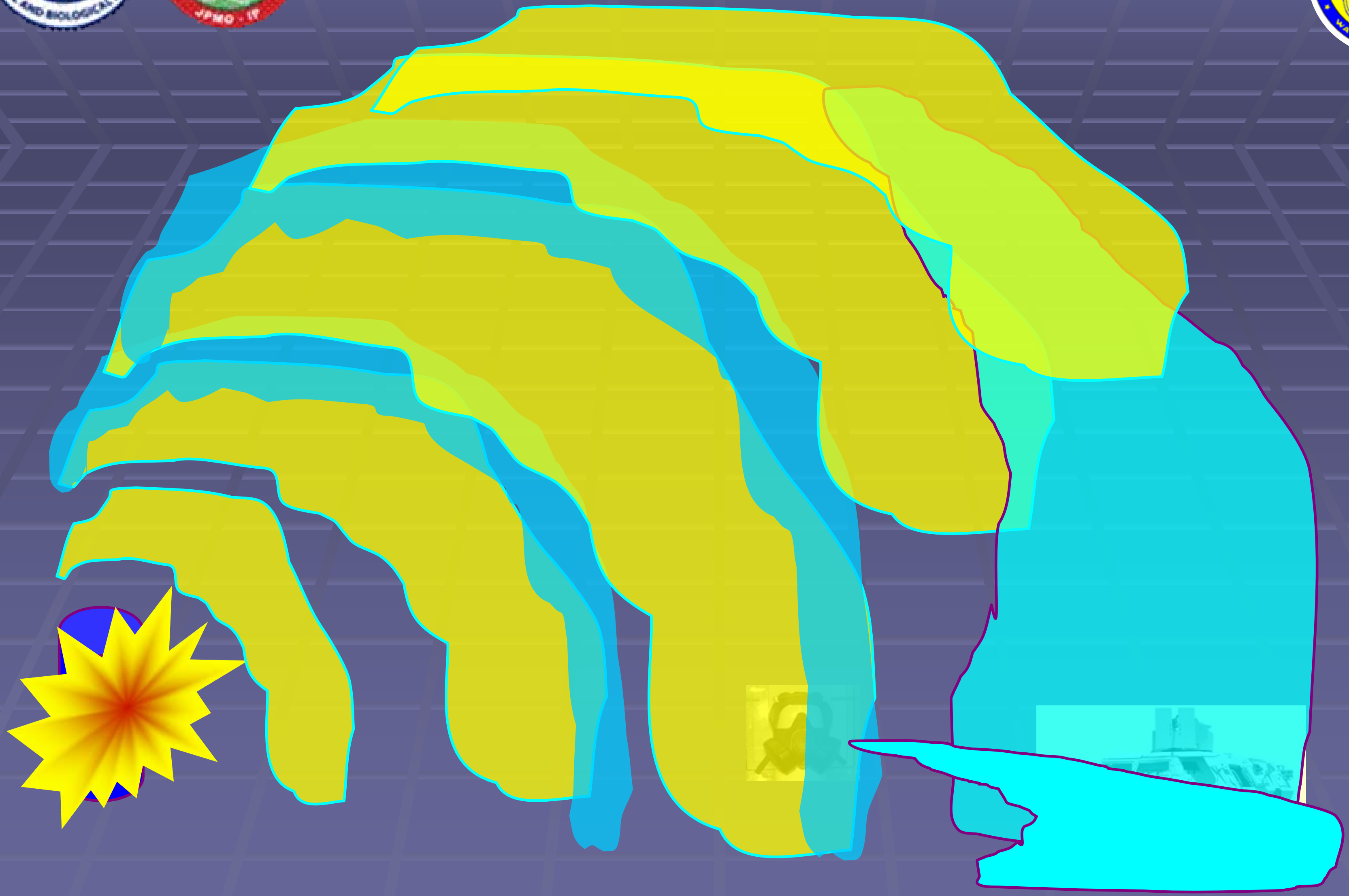
Increasing ability to filter (increasing capacity) →

Humidity Effects and Anhydrous Gases

Anhydrous gases present a two-fold challenge:

1. Upon release in the environment-conversion to an aerosol hazard
   - HCl gas to aerosolized hydrochloric acid
   - HBr gas to aerosolized hydrobromic acid
   - NH_3 gas to aerosolized ammonium hydroxide
2. Second hazard occurs behind this expanding aerosol hazard-a zero humidity challenge

Aerosol Hazard of Anhydrous Gases



HCl Vapor

Hydrochloric Acid Aerosol

Utilizing Filter Performance data for Operational Assessments

Based upon performance curve data:

- Estimate operational time at IDLH values or AEGL-3 values

Based upon scenario modeling and performance curve data

- Estimate operational time at specific distances for large, moderate and asymmetric types of releases.

Conclusions

1. What to test based on a comprehensive risk mitigation strategy
2. How to test-lessons learned from previous T&E as well as fundamental chemistry
3. Simple, low cost approaches to breakthrough detection
4. Two fold use of Class Based Analysis
   - Risk mitigation during prioritization
   - Performance assessment during T&E and operational analysis
5. Humidity effects-Test at the most challenging (zero humidity?)
6. Utilize performance curve data to translate laboratory test data to operationally relevant filter performance.