The University of Texas Medical Branch

2016 Hydrofluoric Acid Incident Preparedness: Symposium and Exercise – Oct 27

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UTMB Institutional Preparedness

utmb Health

HF Releases / Incidents

Nevada Test Site: HF Vapor Cloud

2012 South Korean HF leak / 12000 people seen

Where We Have Been: Year 1 (2014)

Exercise

Patient Type:

- **Occupational Exposure to liquid HF Acid**
- HF Exposure with **Trauma**
- Focus - **Decon and Triage**

Example of an HF Burn: New England Journal of Medicine

Year 2 (2015): Build on Year 1

- Year 2
  - Exercise
    - Patient Type: Decon and Triage/ HF combined with other chemicals/oils (**Acid Soluble Oil**). **Non-ambulatory**/unconscious patients with HF and Trauma
  - Symposium
    - What would a **National Model** for HF Response Look Like?
    - **Crisis Leadership** in Novel Situations (role of the Academic Medical Center in Incident Command response)
    - Occupational Exposures (model response)

- Began organizing community responders to attend the Hospital Emergency Response Team (HERT) training course at the **Center for Domestic Preparedness** in Anniston Alabama https://cdp.dhs.gov/find-training/healthcare/course/PER-902

Year 2: Model Response: Plant Incident

- Adequate Primary Decon in the Field
- (Plant Physician)Begin Treatment with Calcium Gluconate if waiting for Transport
- Communicate patient information to Hospital
- If supplied - EMS continue application of CG during transport
- Secondary (More Thorough if needed) Decon at Hospital
- Labs: Early/Often - especially Calcium and Magnesium
- Have supplies ON HAND to begin treatment (Calcium Gluconate (SurgiLube) (Skin, Respiratory Track, Eyes) Mineral Oil for ASO exposure
- Pharmacy and Supply Chain Support - continued supply of Calcium Gluconate

Where we are going 2016 (Today)

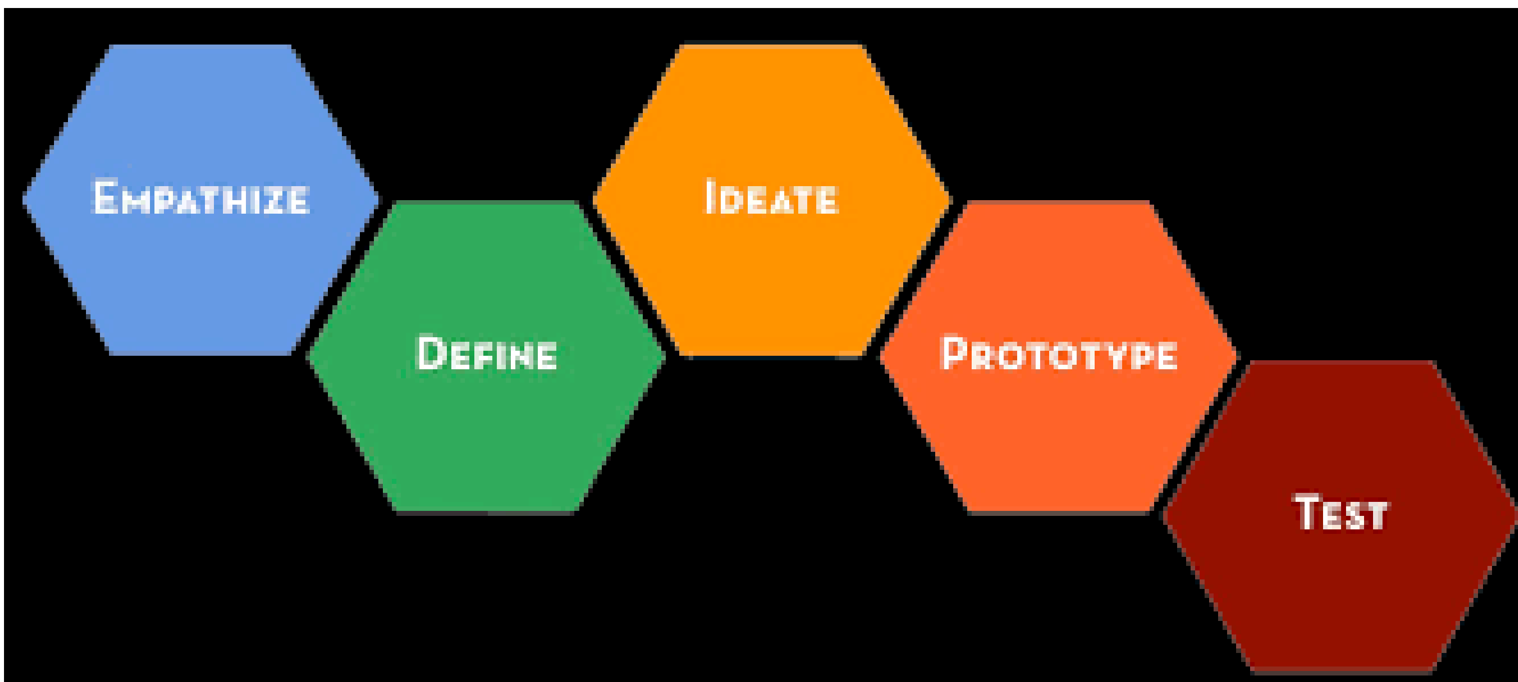
Flange that failed in Corpus Christi Release (21 tons)

- Year 3
  - Build on Year 2:
- Patient Type
  - Occupational exposure: HF, Blast, Trauma, Thermal Burn
  - Community Vapor cloud exposure (varying levels) skin, respiratory, eyes - Adult and Pediatric
  - A role for the Academic Medical Center (All Phases of Emergency Preparedness)
- Computational Modeling for Scenario Planning
  - Planning Scenarios based on release/weather/terrain/population
  - Validate Shelter-in-Place (e.g. Could be done at Dugway Proving Ground – mock urban area, vehicle movement)
- Whole Community Resilience - Building Community Linkages for Effective Preparedness (Build on based developed from Hurricane Preparedness)

Design Thinking: Building Linkages for a Healthcare Coalition

Hard to collect data about the future
Unbounded Problem
Population is constantly changing
Institutions Change

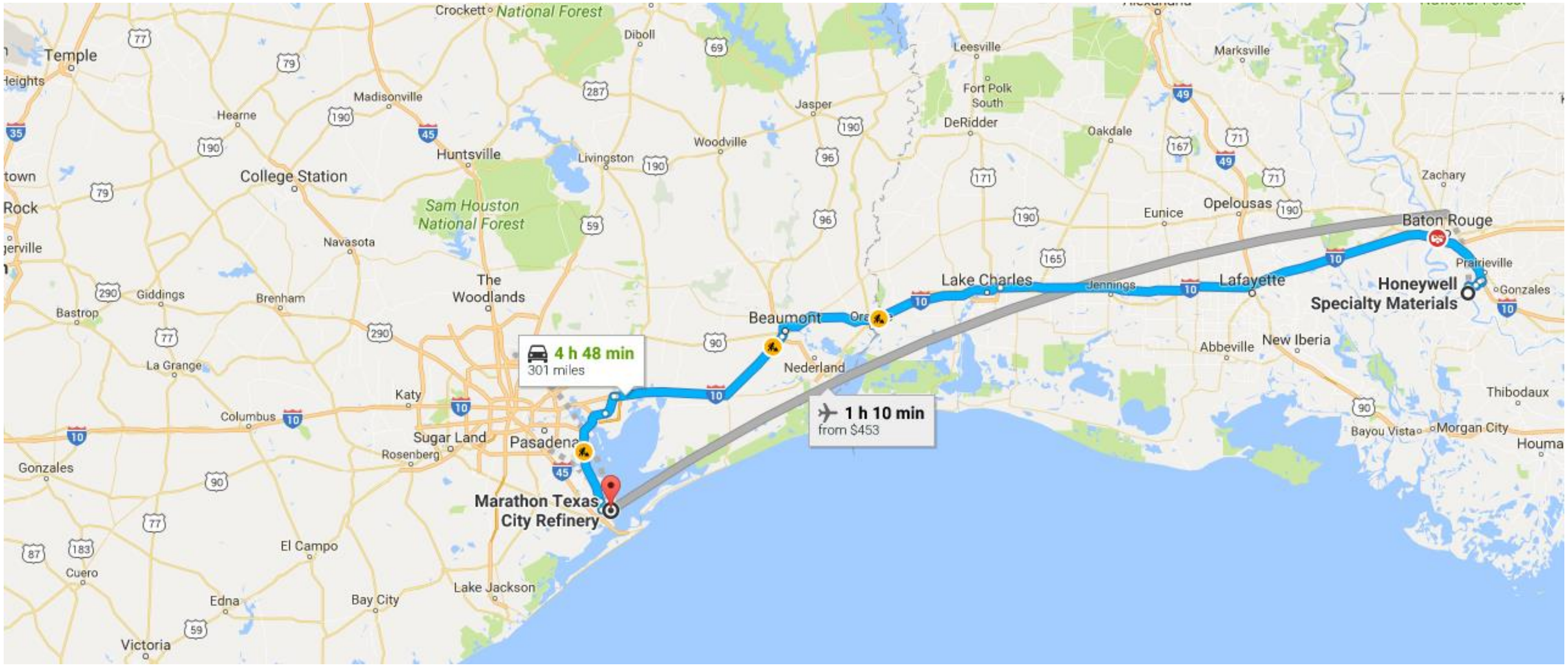
Bias Toward Action
Move Fast Through Failure
Build Your Way Forward



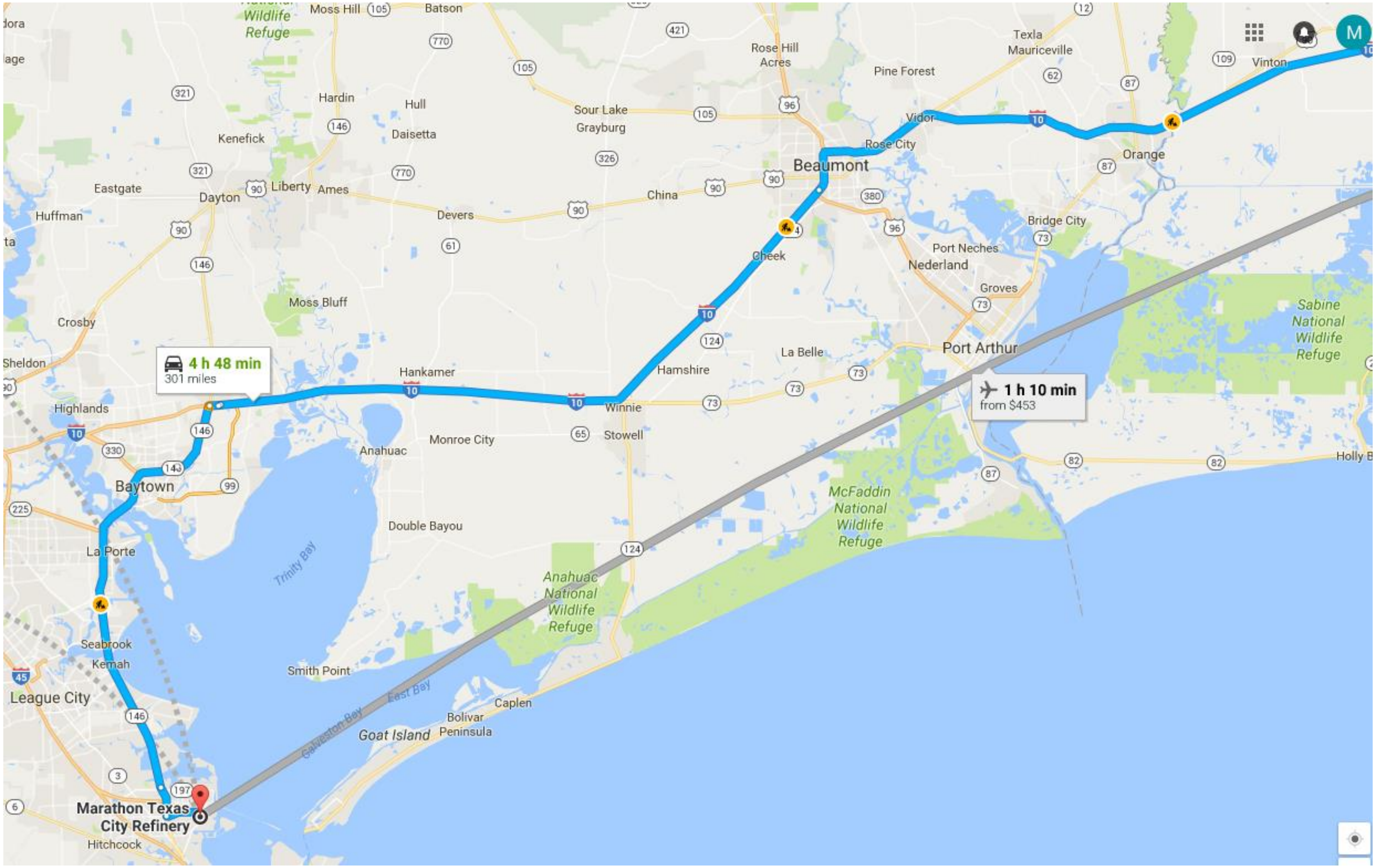
‘Design Thinking’ Process Flow from Stanford – can be applied to Whole Community Response

As part of our HF preparedness program, UTMB organizes a group of Community / Agency / UTMB staff to attend Center for Domestic Preparedness Training as a Response Community

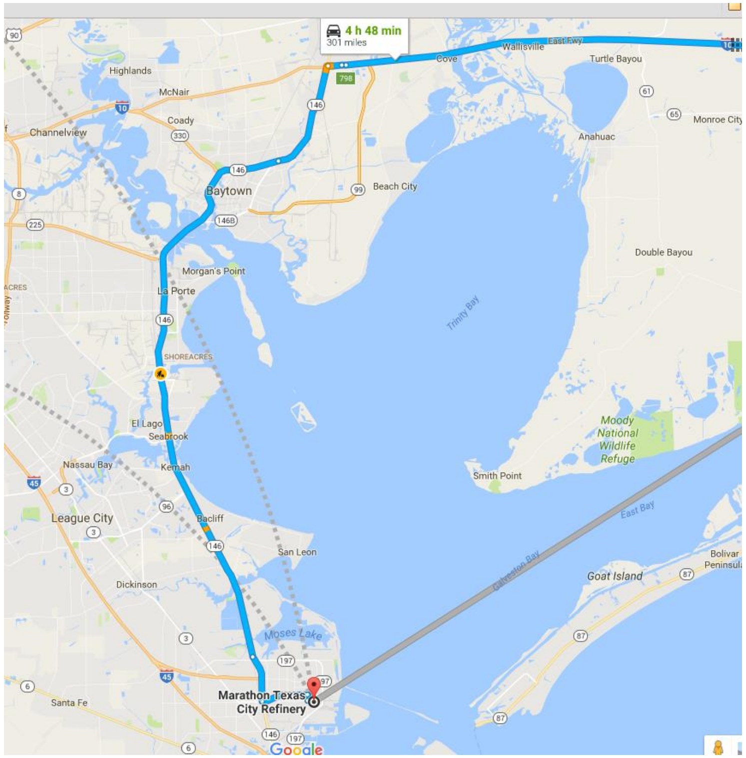
Major Transport Route: Geismar Louisiana to Texas City 3-4 times per week



See Southeast Texas Impact



HF Transport Route (3-4XWeek)



UTMB Locations in SE Texas

Sleeping Dragons (HF as Sleeping Dragon for our Region

Definition (Fat Tail incidents)

Black Swan Incidents

Low Probability / High Consequence Incidents

Adversarial Incidents (Terrorism)

Cascading Failures

(With Thanks to Dutch Leonard)

Comprehensive Risk Management

- If Risk Management Program is not comprehensive – start there
- Do a thorough assessment based on objective data
- Do you have any Fukushima Generators? (in hindsight, would be obvious to the general observer that there was a major problem
- External review – help locate Sleeping Dragons

Types of Emergencies

- Routine Emergencies
- Emergent Incidents (escalate from routine to crisis; e.g. cascading failures, Large-scale no-notice incidents)
- Novel / Crisis Emergencies (Disasters?)
- Existential Threats

Routine Emergencies

- Aware of Risk and Prepared (e.g. Utilities SOPs)
- ***Recognition Primed Decision Making***: you know what to do
- Make Routine - more emergency scenarios (Make HF Response as Routine as Possible with Training and Exercises based on modeling and visualization)

Emergent / Novel Emergencies

- Emergent – start as routine but then escalate (Need to recognize the change before too late)
- Unknown Unknowns
  - Make it known through risk analysis
  - If not possible
    - Have robust framework and processes in place; e.g., Incident Action Planning Cycle
    - In addition to scenario-based plans – address ***capabilities*** as well
- Existential Threats
- May require creativity and improvisation to resolve
- The *Problem of Knowledge* – **the more human knowledge brought to bear, the better the outcome in general**

Recognizing Novelty

- Novel (based on scale or scope) – may not have experience with large-scale incident / disaster
- Novel (based on scenario) – may not have anticipated that scenario in Risk/Emergency Management program
- Novel – may be an adversarial incident where adversary is seeking to optimize damage to your institution

Cognitive Biases to Watch For

- Overweigh own experience (e.g. Small HF/occupational exposure)
- Illusion on the amount of experience
- Overconfidence in ability to influence/predict/control the incident
- Failure to notice disconfirming evidence
- Over commitment to current strategy
- Conformance of observations to expectations
- Complacence

Modeling incidents can help here
Analysis of past incidents

Communications

Foster communications about risks from staff (unknown unknowns)

Be open to this information and analyze if appropriate (Space Shuttle O-Rings / Fukushima Generators)

Identify Sleeping Dragons

LEPCs:

- Tier 2 Reports
- Risk Management Plans
- Consequence Analysis

Communications

- Marine Corps – Maneuver Warfare: know the commander's intent at least 3 echelons down
- Marine Corps – Point of Effort / *Schwerpunkt*
- Communicate priorities in advance so that staff can act in accordance even if there is minimal or no communications available
- UTMB:
  - Protect Life
  - Protect Facilities
  - Continue key missions
- Give staff broad goals and let them figure out the details
- But confirm that they have done the detailed planning needed
- Ability to distinguish signal from noise

Communications

- Organizational Culture that supports and fosters open communication
- Clear communication and acknowledgement to assure understanding
- Recognize positive intentions of those bringing bad news

Industry / Response Agencies / Community

Mechanisms to Overcome Biases

- Broad participation in information collection and processing (esp Situation Unit Leader / Liaison)
- Form hypotheses about the future but look for disconfirming evidence. Hypothesis
  - Survives
  - Needs modification
  - Should be abandoned
- Communications from all levels (Space Shuttle O-Ring)
- Team B or Red Team
- **Exercises should be designed to truly stress capabilities and expand the level of expertise in your organization**

Signs that Plan is not Working

Outcomes from Actions ≠ Expected Outcomes

Distinguish or Reassess

Planning for Novel Incidents

- Scenario v Capabilities based planning
- Sample Capabilities:
  - Information collection and processing
  - Effective Two-way Communications (including Communications Technologies)
  - Staff planning to translate intelligence into action plans
  - Effective operations and implementation of plans
  - Use of specialized equipment (e.g. PPE)
  - General familiarity with CBRNE response

Planning for Novel Incidents

Concepts

- Common Terminology – Integrated Communications
- Modular Organization
- Management by Objective
- Incident Action Planning
- Manageable Span of Control
- Comprehensive Resource Management
- Command/Chain of Command/Unity of Command/Accountability

Nothing new here. Right?
Many of the tools are in place

When Stress is Good

- Mechanical (brittle) v Biological (adaptive) models
- Evolutionary competitive systems
  - Some level of stress causes system to become more resilient
  - At some point stress may exceed the threshold of resilience causing the system to fail

Planning for Novel Incidents

- Through all phases
  - Preparedness
  - Mitigation
  - Response
  - Recovery

Crossover Effect

Leadership for Novel Situations

What attributes of emergency planning cross over to Leadership:

- In general?
- For novel situations?

How might this affect the resilience / brittleness of the organization?

Institutional Resources

If you are part of a university, university system, or Healthcare Coalition:

Make full use of the expertise represented in the faculty and research centers of that organization to improve resilience

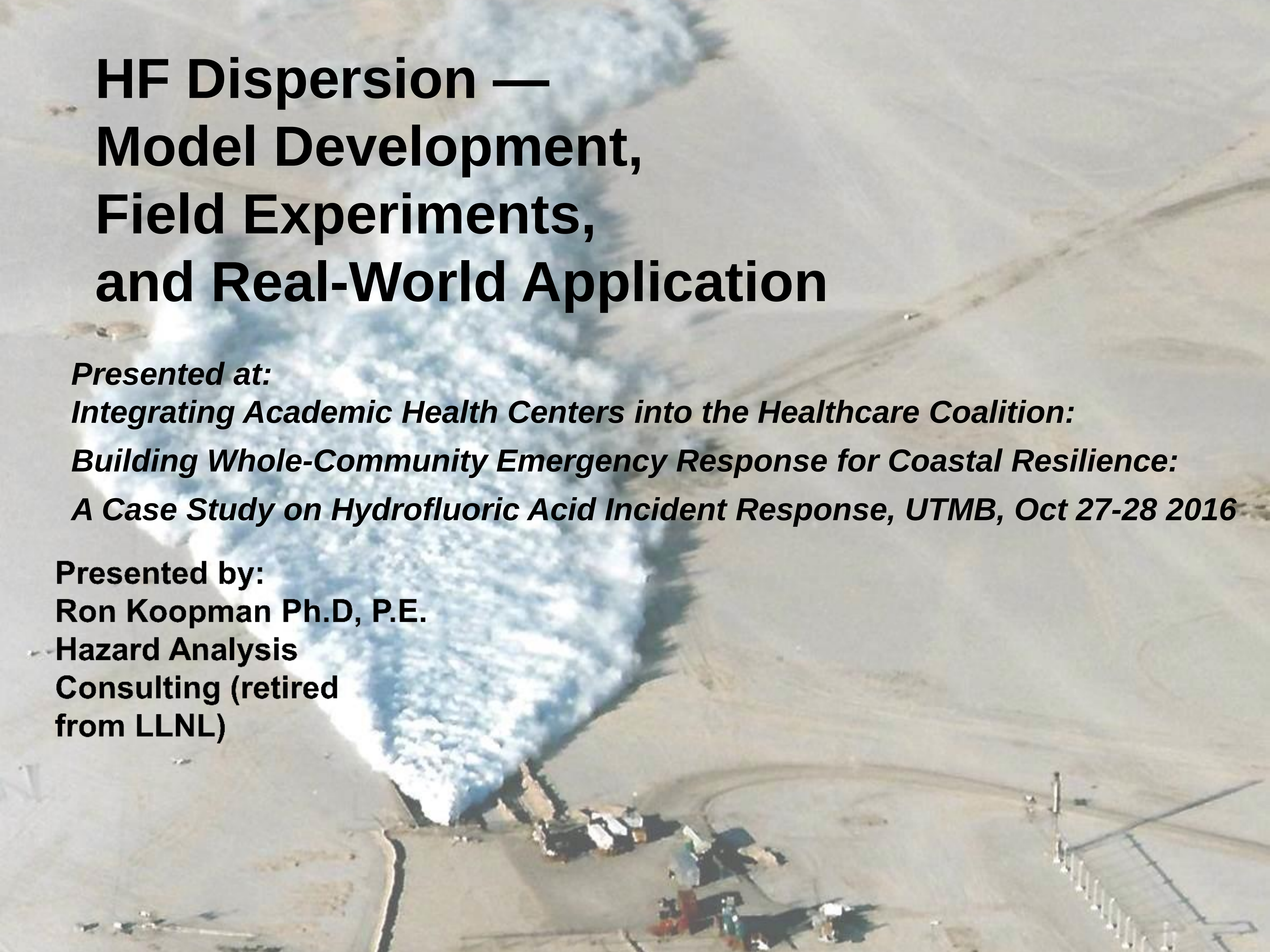
Make full use of the expertise represented in partnering response agencies and community

Innovation

- Make use of Modeling and Visualization Technologies
- No need to wait until after a disaster to see that there may be insufficient supplies
- Design Thinking applied to this problem?

Overview of the Day

- What can modeling and visualization tell us?
- How might we improve healthcare response?
- What is industry doing to improve safety?
- What role can the Academic Medical Center or Research Universities play? (Disaster Research Response)
- Work groups – What are your recommendations?

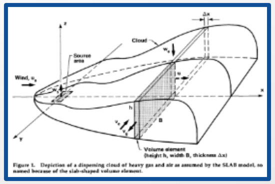


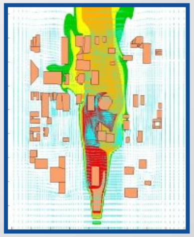
HF Dispersion — Model Development, Field Experiments, and Real-World Application

Presented at:
Integrating Academic Health Centers into the Healthcare Coalition:
Building Whole-Community Emergency Response for Coastal Resilience:
A Case Study on Hydrofluoric Acid Incident Response, UTMB, Oct 27-28 2016

Presented by:
Ron Koopman Ph.D, P.E.
Hazard Analysis Consulting (retired from LLNL)

Outline





Dense Gas Dispersion Models

- **SLAB** dense gas dispersion model
- **FEM3** computational fluid dynamics model

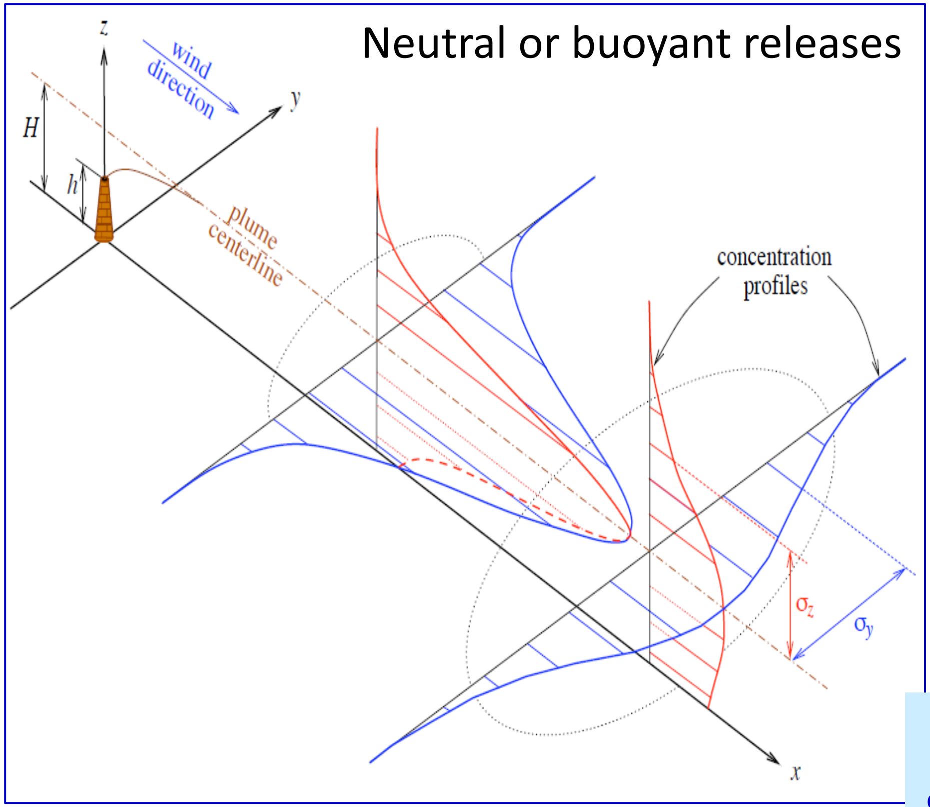
Field Experiments

- **HAZMAT Spills Center** at the Nevada Test Site
- **Goldfish** and **Hawk** experimental HF releases

Real-World Application

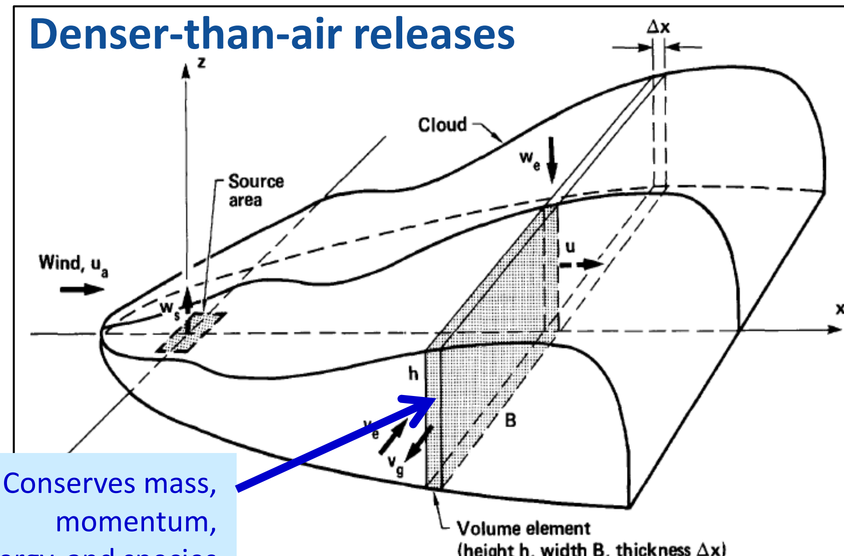
- **1987 accident** at Marathon Texas City Refinery

Analytical Dispersion Models



Gaussian plume model
for an elevated release from a “point source” at heights typically 10s of meters above ground

Analytical approach:
Plumes are dispersed horizontally and vertically according to distributions estimated from empirical field data.



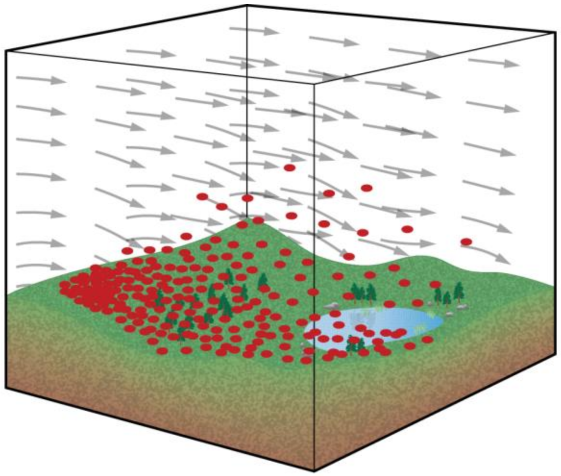
Conserves mass, momentum, energy, and species in each “**slab**”

SLAB model with a denser-than-air “area source”

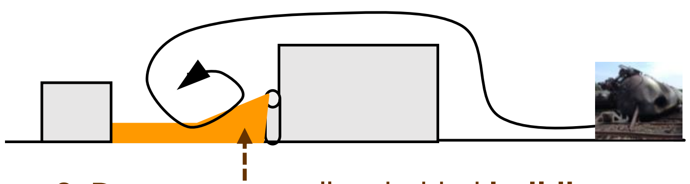
Dense gas dispersion models treat the special thermodynamic and phase-change aspects of **denser-than-air** releases as well as their unique dispersion initially driven by the dense cloud’s properties independent of ambient conditions

Numerical Dispersion Models

Computational Fluid Dynamics (CFD) approach:
A source is released as thousands of marker particles (shown as red dots) into a 3-D numerical grid of wind and turbulence calculated from full physics equations at each grid point, typically at 1 to 10 m resolution.

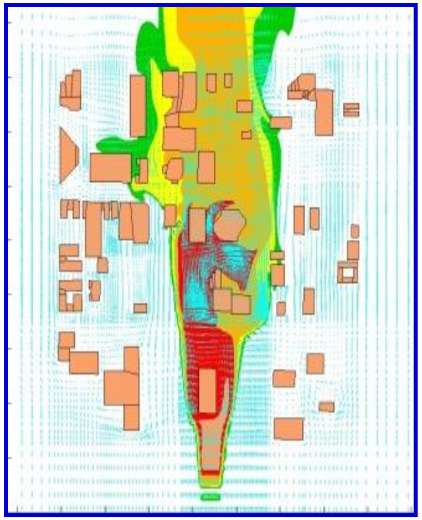


1. Dense gases follow **terrain** & pool in low areas

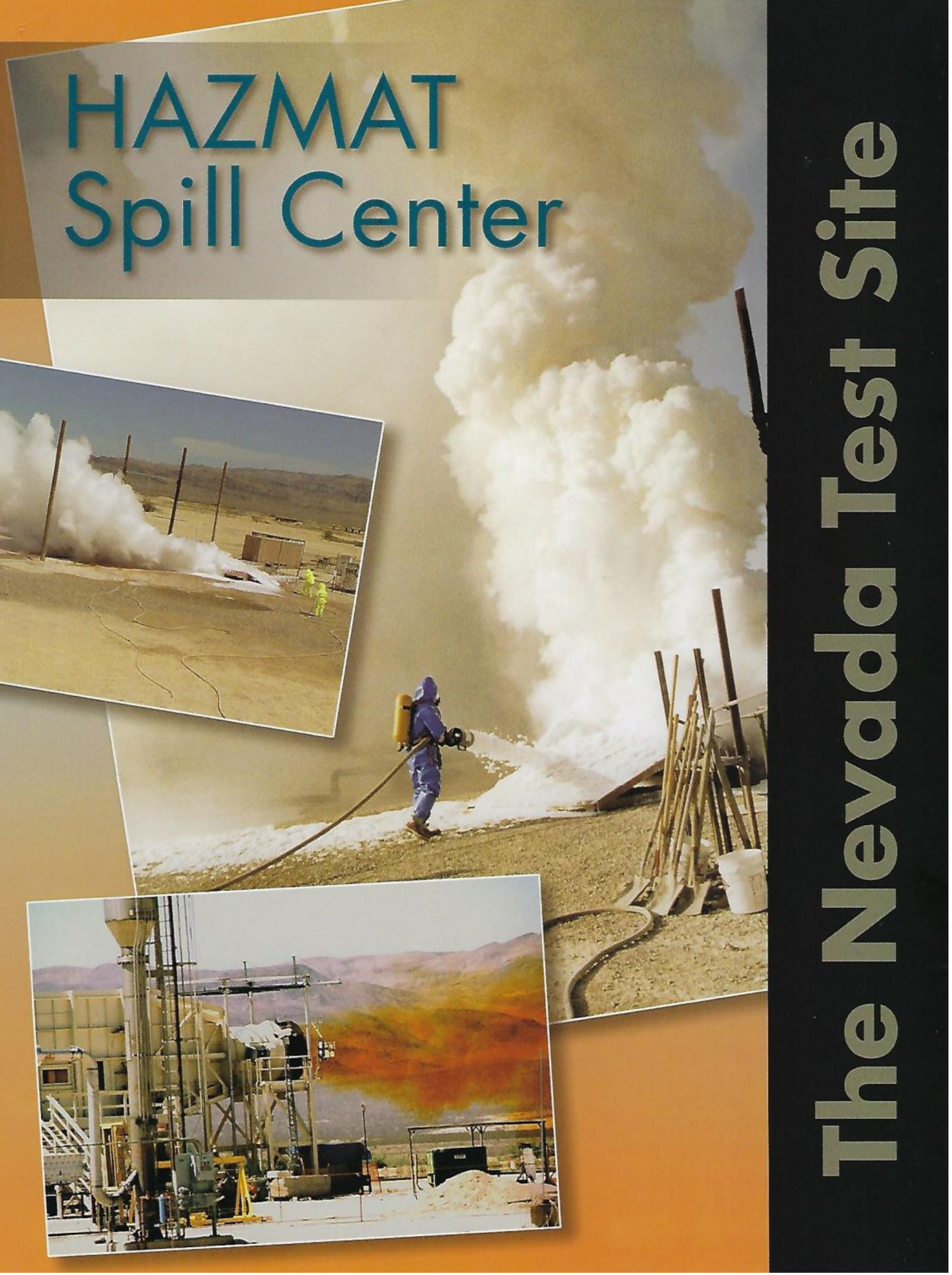


2. Dense gases collect behind **buildings**

CFD dense gas models explicitly treat two important aspects of dispersion:
Terrain and building effects



Example concentration plot from the LLNL Finite Element Model (**FEM3**) in an urban area



NTS provides an ideal location for atmospheric testing of hazardous chemicals, with controlled access and steady winds from the SW.

name	year	material	size m^3
Avocet	1978	LNG	5
Burro	1980	LNG	24-39
Coyote	1981	LNG	3-28
Desert Tortoise	1983	Ammonia	15-60
Eagle	1983	N_2O_4	1-4
Goldfish	1986	HF	4
Falcon	1987	LNG	20-66
Hawk	1988	HF	0.2

HAZMAT Spills Center Field Experiments

To understand dense gas releases, effects of water spray, and provide data to develop and validate dense-gas dispersion models, during the summer of 1987, LLNL and AMOCO conducted 6 releases of HF from a 5000-gal tank called the **Goldfish** series

Goldfish Release Data, Weather, and Purpose

Test	Spill Rate (gpm)	Duration (sec)	Wind Speed (m/sec)	Atm. Stability	HF Temp (°C)	Relative Humidity (%)	HF pressure (psi}	Purpose
1	469	125	5.6	D	40	5	111	Dispersion
2	175	360	4.2	D	38	11	115	Dispersion
3	172	360	5.4	D	39	19	117	Dispersion Humidity
4	68	840	6.8	D	36	15	116	Air & Water Spray
5	33	960	3.8	C/D	40	38	118	Up Water Spray
6	33	960	5.4	C/D	38	38	114	Down water spray

We will focus on the first and largest release, Goldfish 1

Test data came from a large array of gas concentration and atmospheric measurements

Each tower made measurements at 1 m, 3 m, and 8 m above grade

Typical arcs of instrument towers at 300 m, 1000 m, and 3000 m downwind

Goldfish 1

Comparison of SLAB and DEGADIS models with data from 3 Goldfish Experiments

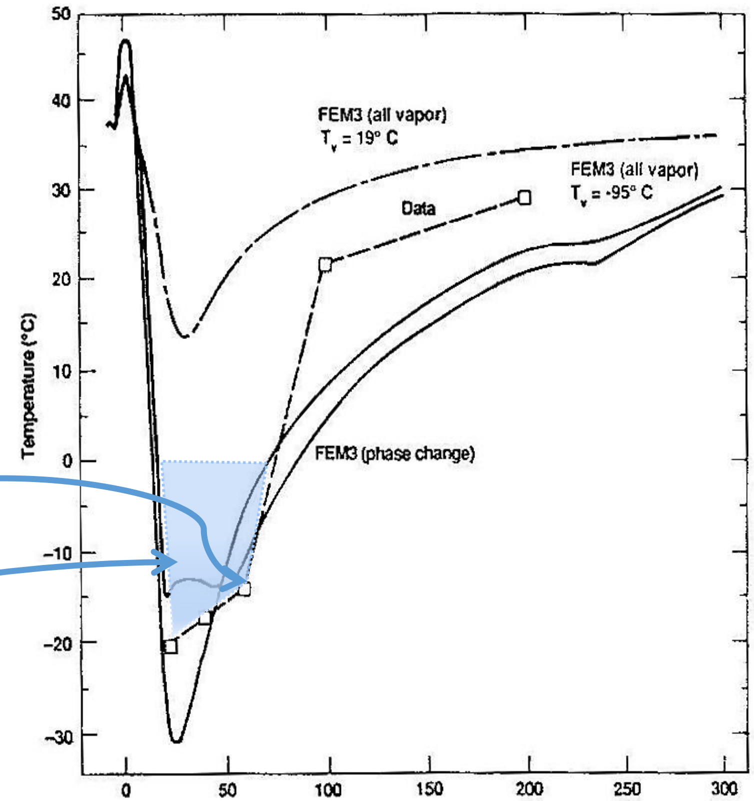
Goldfish Test		300 m	1 km	3 km
1	**Data (ppm)**	**25,473 (ppm)**	**3,098(ppm)**	**411(ppm)**
	SLAB	*25,000*	*2,580*	*400*
	DEGADIS	*21,000*	*1300*	*230*
2	**Data**	**19,396**	**2,392**	**96***
	SLAB	*12,500*	*1,250*	*200*
	DEGADIS	*6,800*	*820*	*110*
3	**Data**	**18,596**	**2,492**	**221**
	SLAB	*10,000*	*960*	*142*
	DEGADIS	*6,800*	*820*	*110*

Data from arcs of instruments at 300 m, 1000m, and 3000m downwind from the release point.

SLAB and DEGADIS model calculations (ppm) compared very well with plume ground-level centerline air concentration measurements (ppm)

Comparison of FEM3 Model with Goldfish 1

Release: 976 gal (469 gal/min for 2.08 min)
Weather: Wind at 5.6 m/s with D stability
37 °C or 99 °F at 5% RH



Downwind Distance (m)

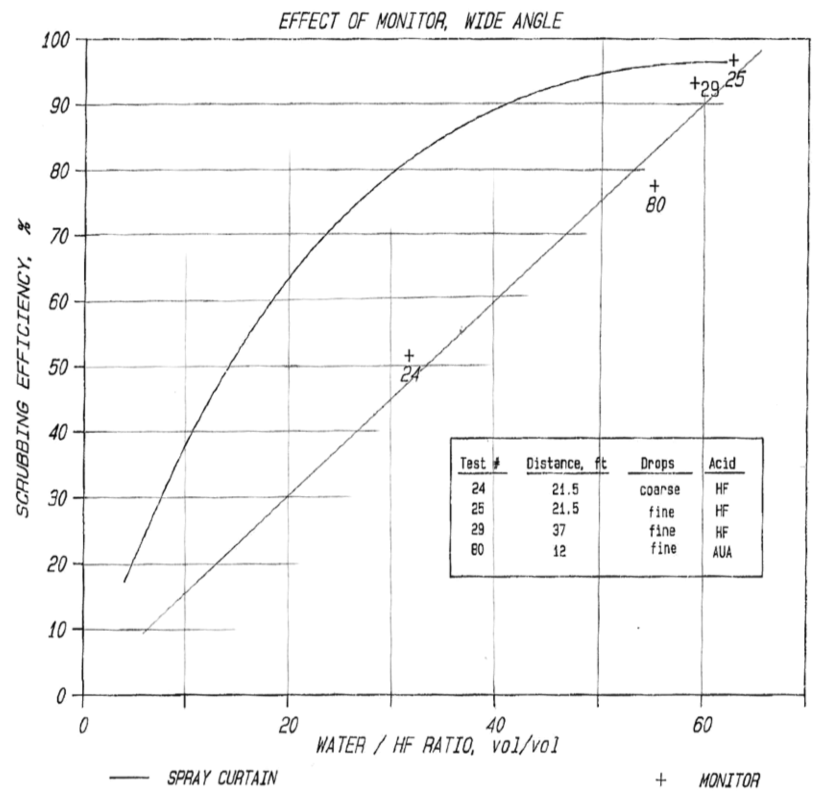
FEM3 recreated the cold cloud temperatures and horizontal dispersion well

Goldfish 1 cloud temperatures measured at 1 m above ground along plume centerline compared with several FEM3 model calculations

Goldfish 5 and 6 – Effects of waterspray

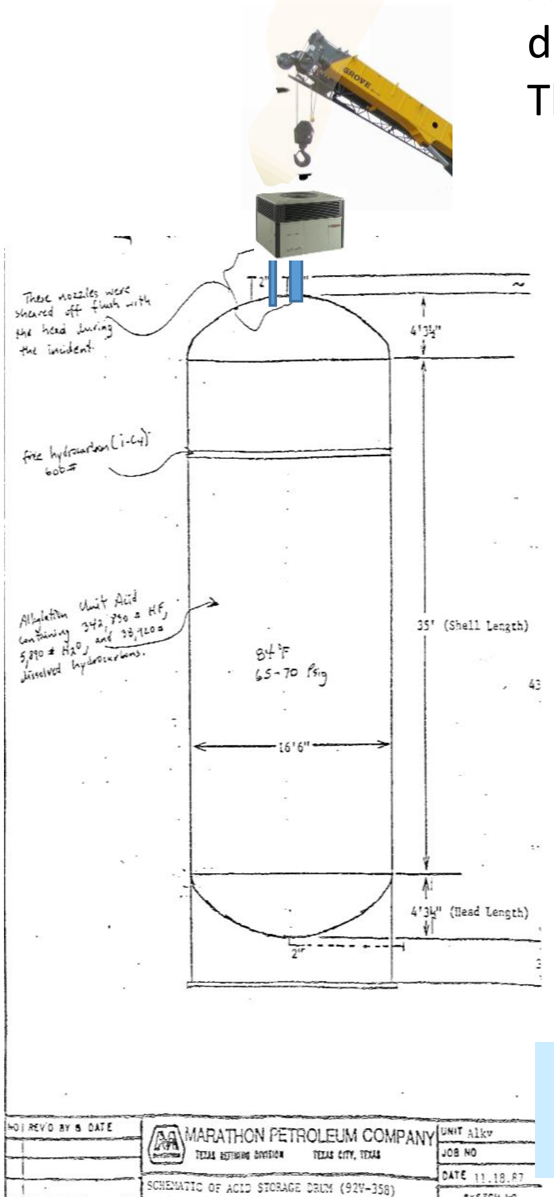
Tests 5 and 6 showed the net effects of water spray, both upflow and downflow, was to reduce air concentration of HF by 36 to 49%.

About 100 Hawk series HF water spray tests were conducted in the NTS wind tunnel to explore details of water spray mitigation



With a water to HF ratio of 60 to 1, water sprays were 95% effective at removing HF

October 30, 1987 Texas City Marathon HF Accident



A crane drops a heater unit shearing two pipes (4" & 2" diameter) on top of the Alkylation Unit HF storage tank.
The HF plume rises about 200' above ground before returning.

Estimates of released amounts

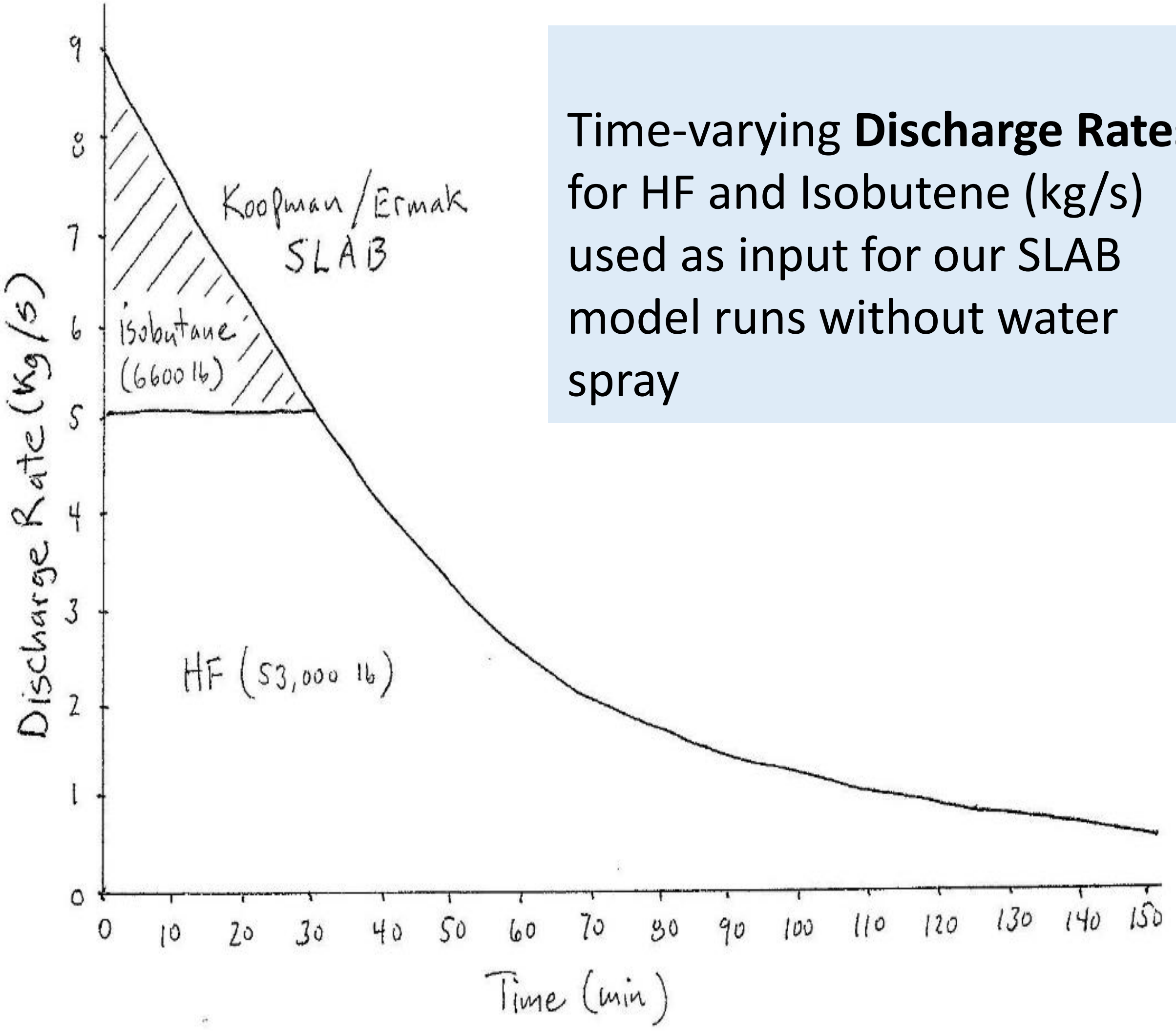
Inventory (pounds)	HF 342,829	Hydrocarbon 9,521
Reported Release		
Total	53,236	6,643
First 100 minutes	"most"	"all"
Calculated release		
Total	53,000	6,600
First 100 minutes	44,000	6,600
Remainder	9,000	0

Flashing inside the tank released a mixture of HF and hydrocarbon two-phase flow out of the broken pipes.

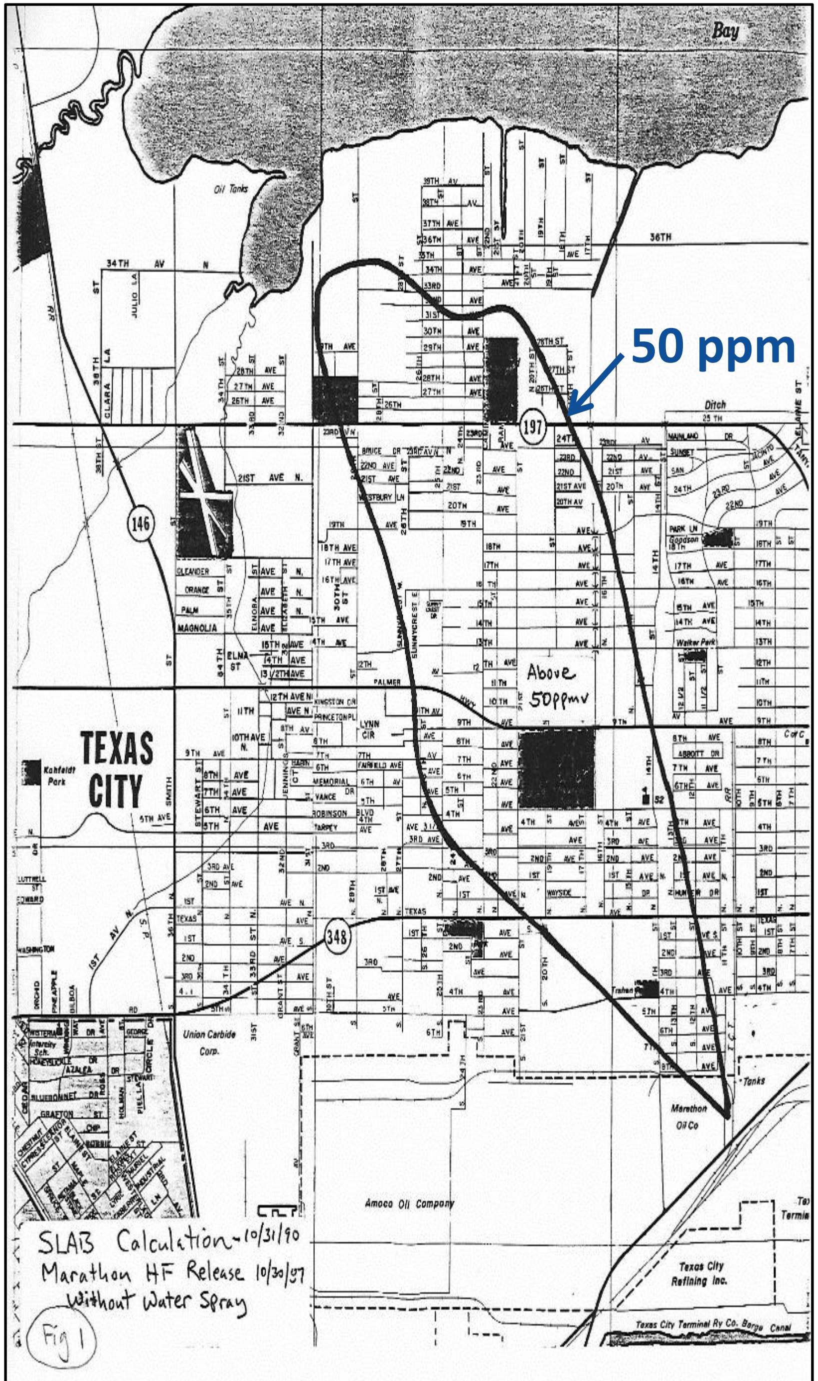
A "champagne effect" occurred where the vapor bubbles form throughout the liquid and carry much of the liquid out with them.

The post-accident modeling involved analyzing a complex set of conditions resulting in several estimates of released amounts.

Marathon Texas City Accident Release Rate



Time-varying **Discharge Rates** for HF and Isobutene (kg/s) used as input for our SLAB model runs without water spray

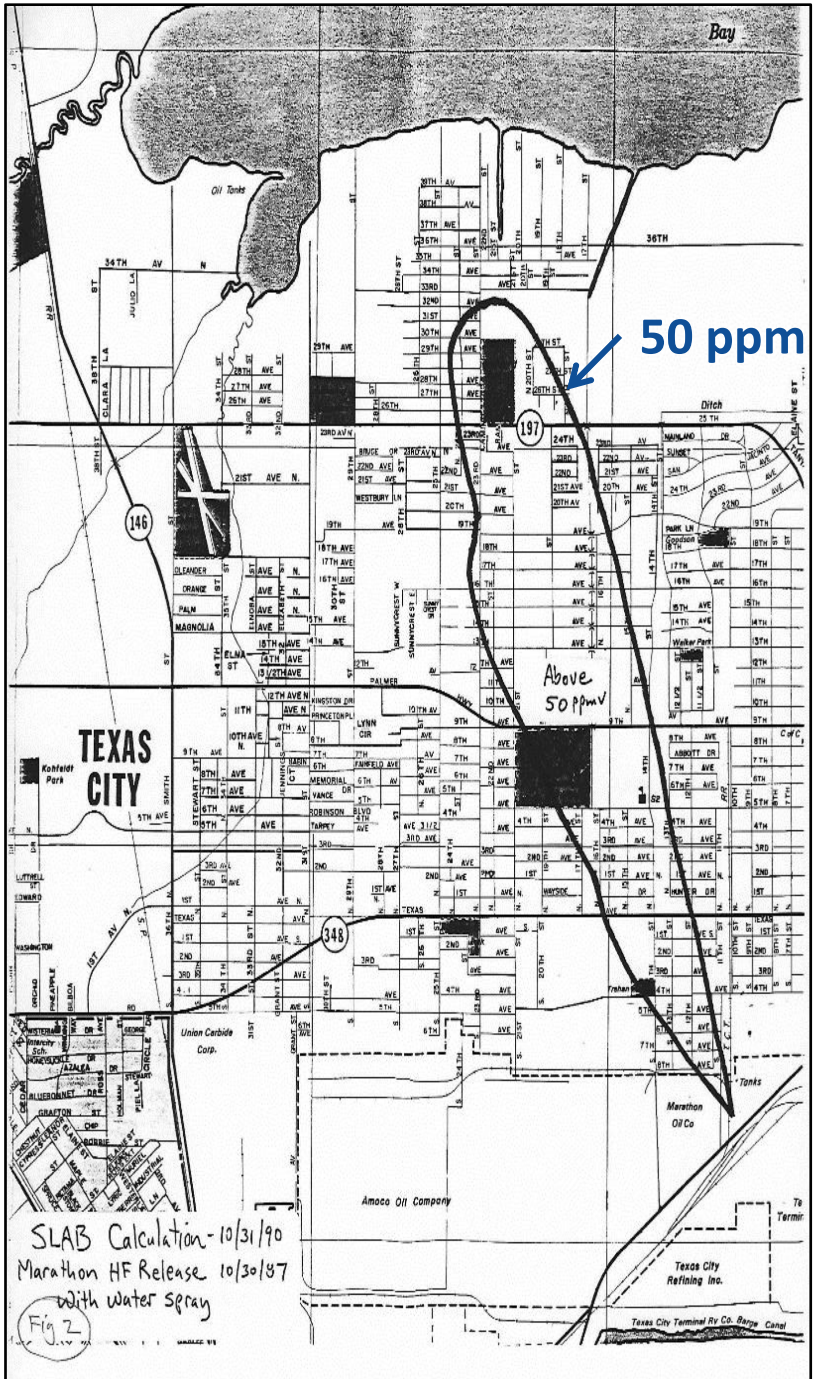


Marathon 1987 accident

SLAB average HF air concentration without water spray (worst case)

The 50 ppm contour extended 3.2 km

For reference:
The 60-min Acute Emergency Guideline Levels (AEGLs):
AEGL-3 = 44 ppm Threshold for lethality
AEGL-2 = 24 ppm Serious health effects
AEGL-1 = 1 ppm Mild health effects



Marathon 1987 accident

SLAB average HF air concentration with water spray started 25 minutes after release began

The 50 ppm contour extended 2.8 km

- 5,800 people on 85 city blocks were evacuated.
- 1,037 people were treated at hospital for respiratory problems and skin and eye irritations.
- Health effects would have been significantly greater were it not for the height and the vertical orientation of the initial plume which shot 200 ft over the neighborhood adjacent to the refinery before returning to ground level.

Ground Level HF Concentration Downwind (ppm) (without water spray)

TIME (MIN)	TOUCH DOWN (M)	400 M	800 M	1600 M	2400 M	3200 M	4800 M	6400 M	8000 M
0	356	5	194	122	63	39	21	12	7
12.5	368	5	164	114	66	40	19	13	9
25	400	1	111	117	75	48	26	17	1
37.5	370	4	140	128	79	49	27	17	12
50	274	28	118	70	41	25	14	9	6
75	207	133	150	62	32	19	10	7	5
100	155	238	150	47	23	14	8	5	
150	117	114	50	15	7				
200	100	50	19	6					

Ground Level HF Concentration Downwind (ppm) (with water spray)

TIME (MIN)	TOUCH DOWN (M)	400 M	800 M	1600 M	2400 M	3200 M	4800 M	6400 M	8000 M
0	356	5	194	122	63	39	21	12	7
12.5	368	5	164	114	66	40	19	13	9
25	400	1	71	75	48	31	17	11	1
37.5	370	2	81	74	47	28	15	10	7
50	274	13	53	32	18	11	6	4	
75	207	13	15	6	3	2			
100	155	0	0	0	0	0			
150	117								
200	100								

Ground Level HF Concentration Downwind

TIME (MIN)	TOUCH DOWN (M)	WATER SPRAY RATE (GPM)	HF RATE (GPM)	PERCENT REDUCTION
0	356	0	84	0
12.5	368	0	84	0
25	400	2000	84	36
37.5	370	2000	70	42
50	274	2000	54	55
75	207	2000	33	90
100	155	2000	20	100
150	117	2000	7	100
200	100	2000	2	199

Concluding remarks

After 38 years of research on hazardous gas releases to the atmosphere, what have we learned?

- We have learned a lot about the science and engineering standards necessary to run refineries and chemical plants safely, but not so much about how to improve those standards or how to assure compliance.
- Four years ago, Chevron's failure to maintain corroding pipes in it's massive crude unit in Richmond,CA, in spite of 6 engineering reports identifying the problem, resulted in a catastrophic explosion and destruction of the unit.
- Similarly, in Torrance, CA, mismanagement at the Exxon-Mobil refinery resulted in an explosion in the plants electrostatic precipitator, exposing 330,000 residents of the surrounding communities to the possible release of toxic hydrofluoric acid from a nearby storage tank.
- CAL OSHA issued six "willful" violations against ExxonMobil because, like Chevron, the company had failed to "take action to eliminate known hazardous conditions at the refinery."
- The regulations governing these plants have not been updated since the early 1990's when they were adopted in response to the Bhopal methyl isocyanate gas release in 1984 which killed thousands of people in India.
- On a smaller scale, each community can continue to review past accidents to inform current planning but the problems are complicated and communities need expert help. The US Chemical Safety Board can and does provide some of this help but they have no regulatory authority. Joint responsibility with EPA and OSHA would help.
- Communities could prohibit housing within 1-2 miles of the HF units but have failed to do this.
- Simpler tasks, such as establishing shelter-in-place procedures, training and equipment would help, along with evacuation procedures if appropriate.
- And, at the most basic level, all emergency response personnel should be equipped with appropriate PPE.

Dispersion Modeling for Emergency Planning and Response

Integrating Academic Health Centers into the Healthcare Coalition:
Building Whole-Community Emergency Response for Coastal Resilience:

A Case Study on Hydrofluoric Acid Incident Response

University of Texas Medical Branch, Galveston, TX, October 27, 2016

Lawrence Livermore National Laboratory

Presented by Ronald L. Baskett
Atmospheric Scientist and
Deputy Division Leader for Operations
Atmospheric, Earth, & Energy Division

LLNL-PRES-706664

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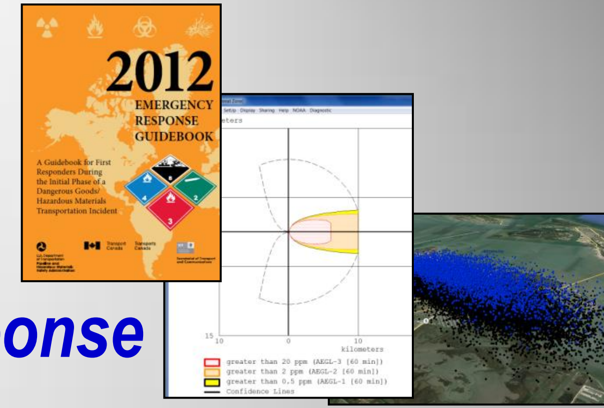
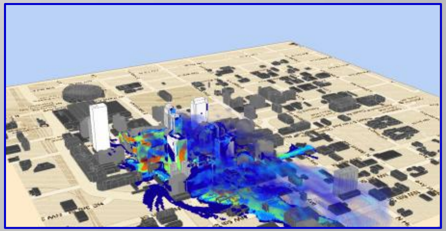
Outline



Dispersion modeling for emergency response

Issues with operational dispersion models

Illustration from Chlorine spill in Graniteville, SC



Advanced models improve realism

Planning studies assist preparedness

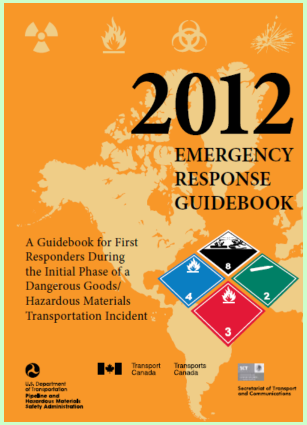
Dispersion modeling for emergency response - Initial guidance and modeling tools

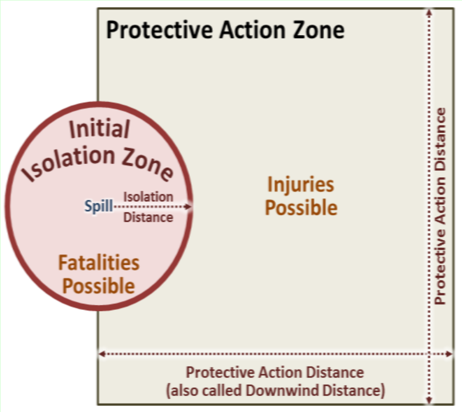
Accident

Photo credit: Transportation Safety Board of Canada - All rights reserved

Source: Key Response Factors and Considerations for the Aftermath of a Catastrophic Chemical Incident, FEMA P-1013, Dec 2013 [FOUO]

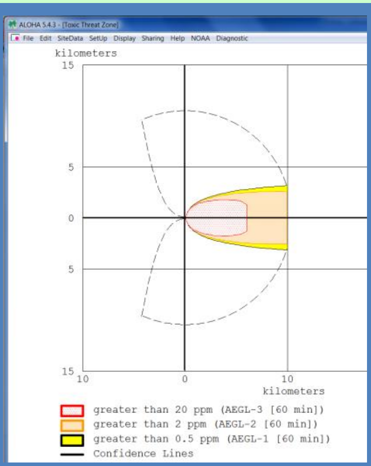
First Responder





NOAA NWS Incident Meteorologist

CAMEO/ALOHA model



Extensive studies have shown that models accurately reproduce concentrations downwind along the plume centerline to within a factor of 2 more than 50% of the time

Models can be useful for many emergency decisions

- ✓ Determine where to:
  - Safely approach to the incident location
  - Locate the incident command site
  - Control access to incident
  - Take field measurements
- ✓ Decide what personal protective equipment (PPE) to use
- ✓ Estimate how many injuries or casualties to expect to triage, treat, or transport to hospitals
- ✓ Decide where to shelter-in-place (SIP) or evacuate
- ✓ Use as a means to communicate decisions to the public and allay concerns

*Model products need to be **timely and accurate** as well clearly provide the **relevant information** on a map*





Modeling can assist key decisions such as when to end temporary shelter and initiate evacuation

Need to consider:

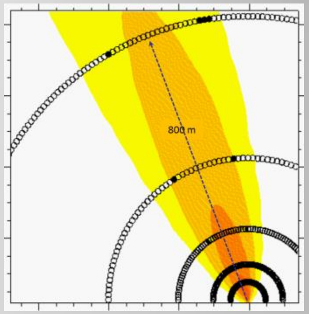
- *Lingering hazards*
- *Scene management*
- *Mass care*

When evacuating, need to direct people:

- *Outside of plume or contaminated areas*
- *To safe routes for triage or medical care stations*

Need: Current as well as ***future*** *plume locations, i.e., a forecast capability within the dispersion modeling system*

Issues with operational dispersion modes

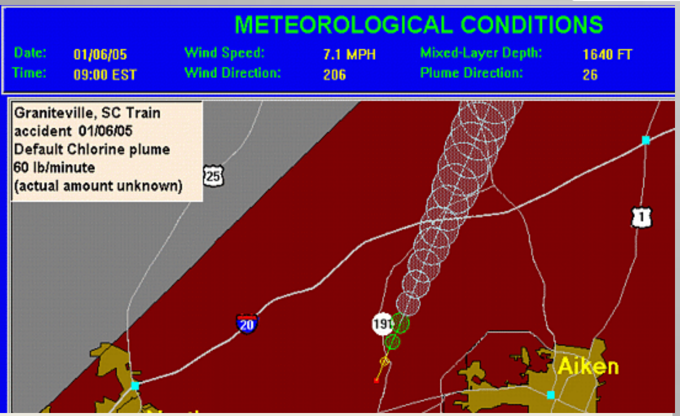


- Extensive field studies have shown **models accurately reproduce *concentrations*** along the plume centerline generally to within a factor of 2
- However, models typically over-predict the magnitude of the ***effects***
  — *Models show 100s to 1000s of people in AEGL-3 lethal or AEGL-2 serious health effect contours*
  — *Actual accidents have resulted in <20 casualties and <1,000 injuries*
- **Conservative assumptions** contribute to over-prediction:
  — *When source is unknown we model with worst case amounts*
  — *Steady-state models assume winds are constant*
  — *Some models do not include terrain and building effects*
  — *We assume that everyone is **outdoors** and stays still for the duration*
- **Indoor** concentrations are 100 to 1000 or more times less than outdoor
  — *Probably the biggest factor why models over-predict effects*

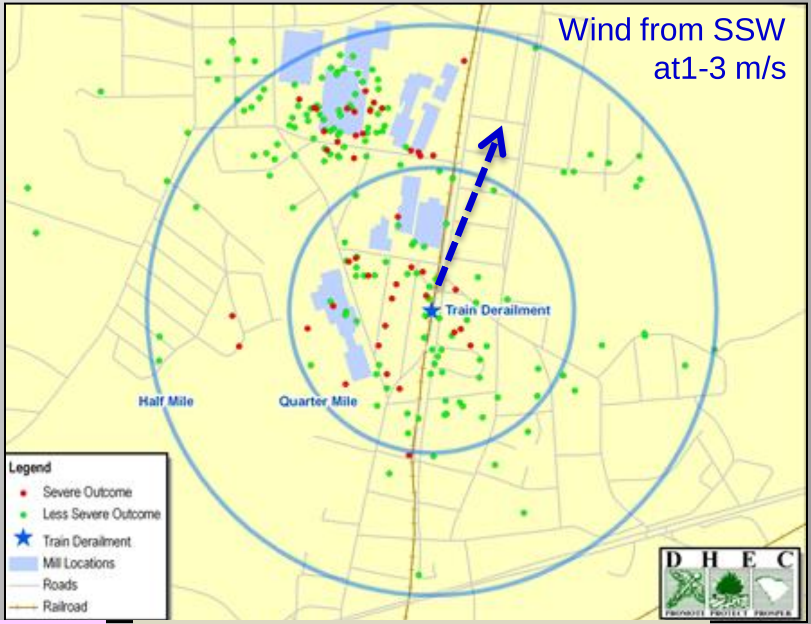
Illustration from Chlorine spill in Graniteville, SC, January 6, 2005

Gash in 90-ton tank

2:40 am Train derailment from head-on collision
3:00 am First patients arrive at hospital
6:42 am Reverse 911 call to community
8:00 am DHS provides IMAAC accident info
8:15 am IMAAC provides initial worst case plot
12:00 pm Emergency declared
4:20 pm Aiken Co. EMA orders 1-mi radius evacuation
Evening: Estimated ~5400 residents evacuate
Day 3: Tank hole is sealed
Day 5: 1000s remained sheltered outside evac. zone



Deaths	**9**
Hospitalizations	**72**
<u>Outpatients</u>	**<u>525</u>**
Total Cases	**605**



8 am: Savannah River Natl Lab plot: 3 ppm at 1 mi for 2-ton release over 1 hr

ERG: Isolation Zone of 800 ft & Protective Action Zone of 4.6 mi

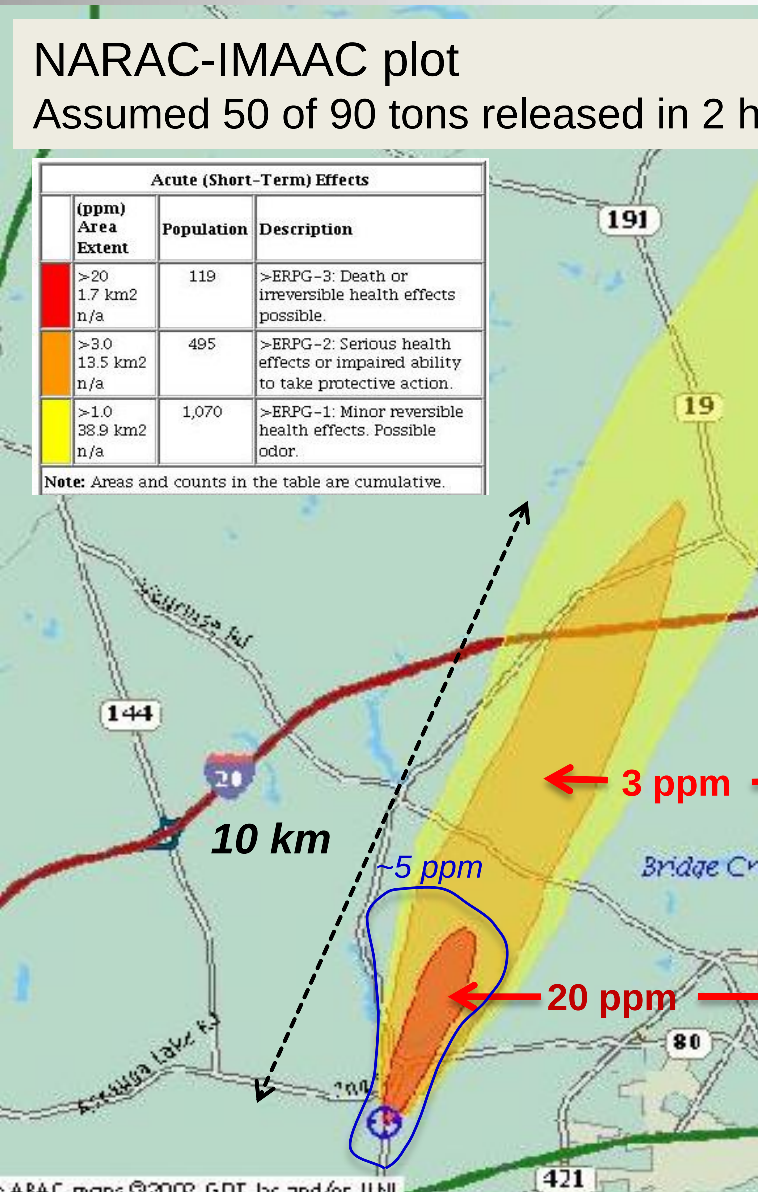
Significant injury occurred in a ~1 mile (1.6 km) diameter including upwind

Treating dense gas, terrain, buildings, and water bodies all mattered when modeling the Graniteville accident

Terrain and dense gas effects were included in some operational models

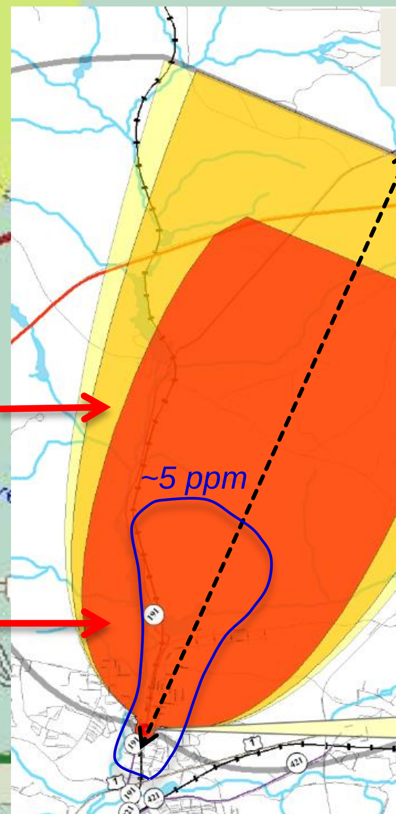
Models overestimated effects at Graniteville

NARAC-IMAAC plot
Assumed 50 of 90 tons released in 2 hr

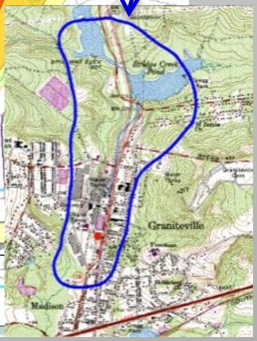


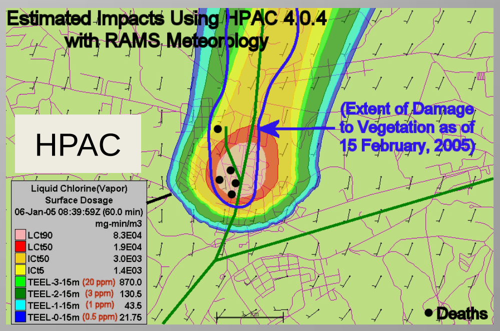
Acute (Short-Term) Effects			
	(ppm) Area Extent	Population	Description
(red)	>20 1.7 km2 n/a	119	>ERPG-3: Death or irreversible health effects possible.
(orange)	>3.0 13.5 km2 n/a	495	>ERPG-2: Serious health effects or impaired ability to take protective action.
(yellow)	>1.0 38.9 km2 n/a	1,070	>ERPG-1: Minor reversible health effects. Possible odor.
Note: Areas and counts in the table are cumulative.			

ALOHA

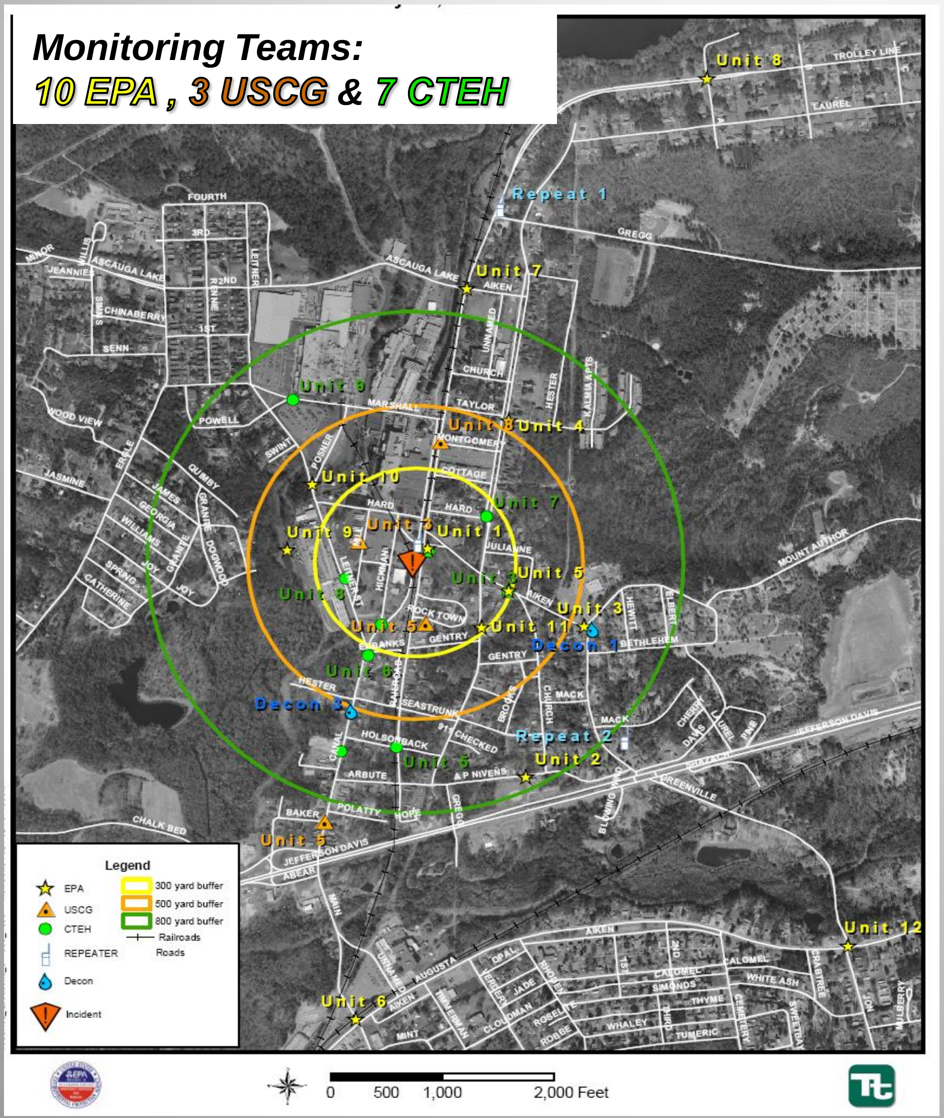


Dead pine needles was evidence that **~5 ppm** extended 4 km downwind



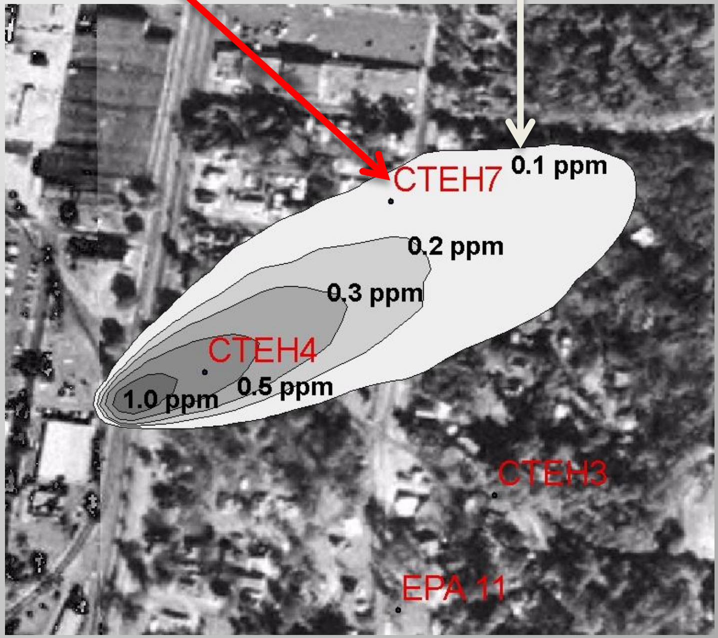


Forecasted plumes proved useful to the monitoring teams during cleanup operations



MEASUREMENTS

Plume forecasted by IMAAC

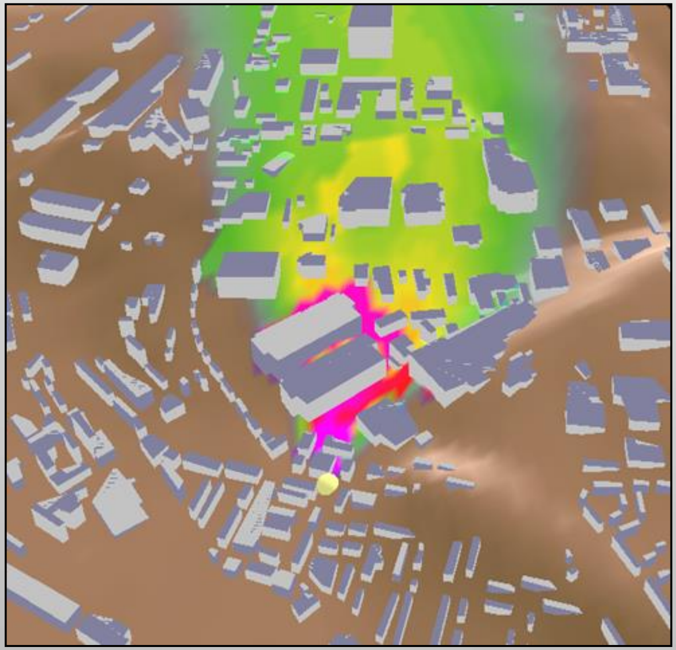


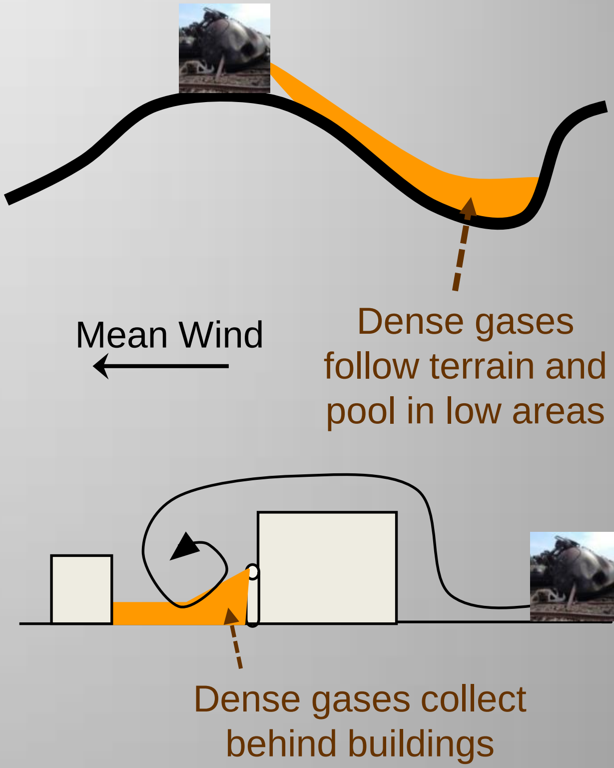
The tank leaked for 3 days until the hole was finally sealed, but cleanup operations took 2 weeks

Advanced models improve accuracy and realism

3-D numerical models produce lower air concentrations than simpler dispersion models when they include:

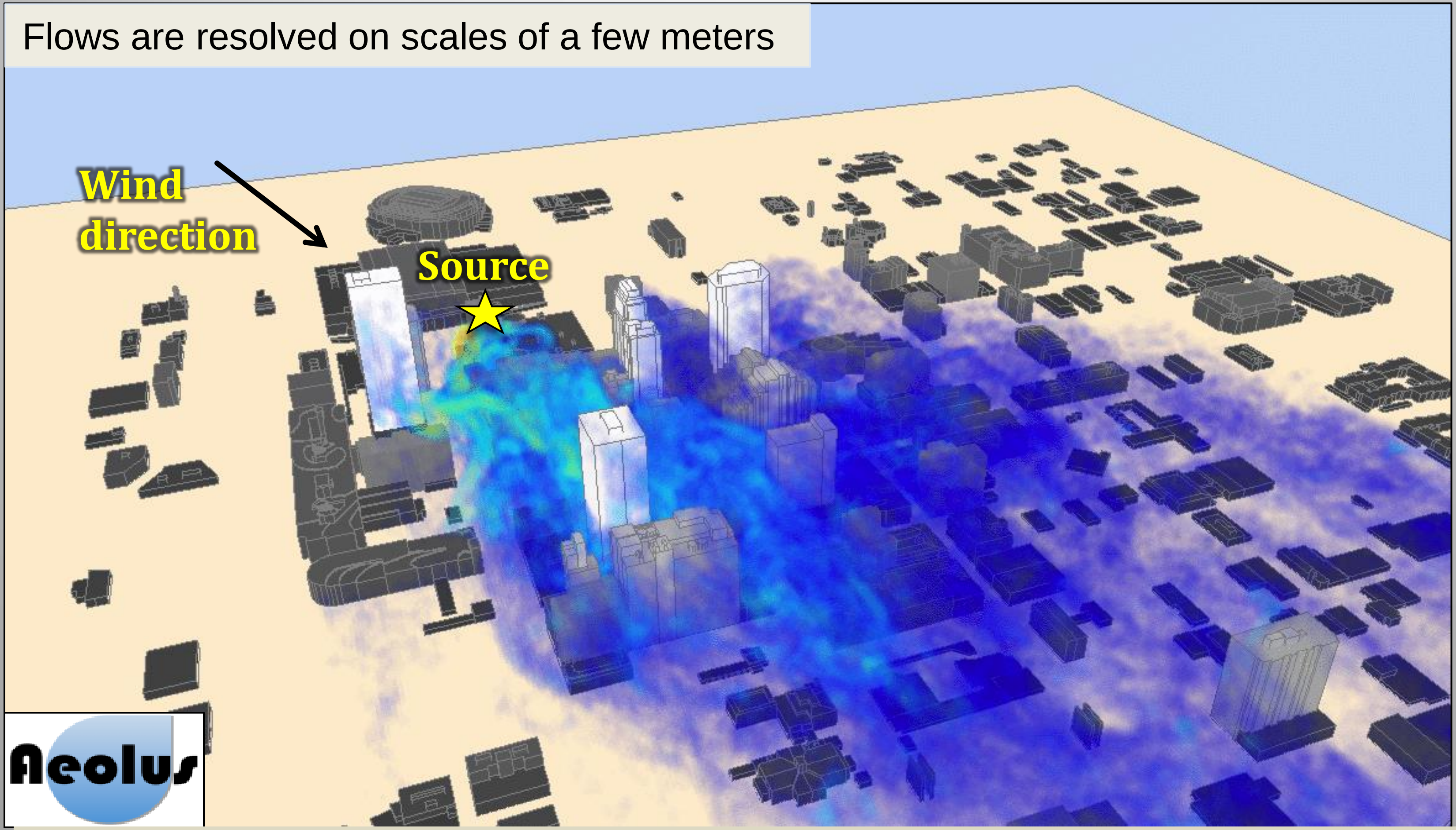
1. Time and space variations in meteorology
2. Effects of terrain
3. Effects of buildings





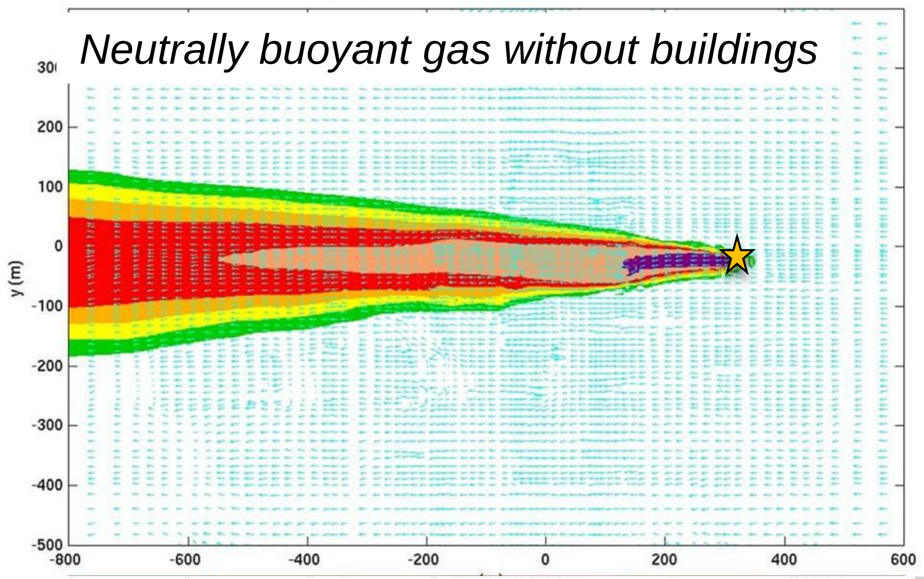
However, dense gases can create locally high concentrations

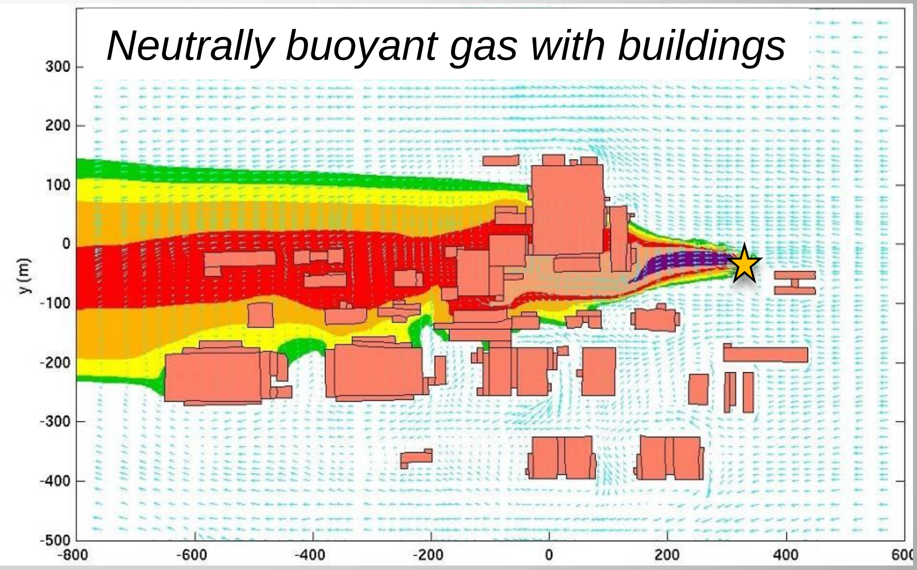
Turbulence created by buildings enhances horizontal and vertical dispersion

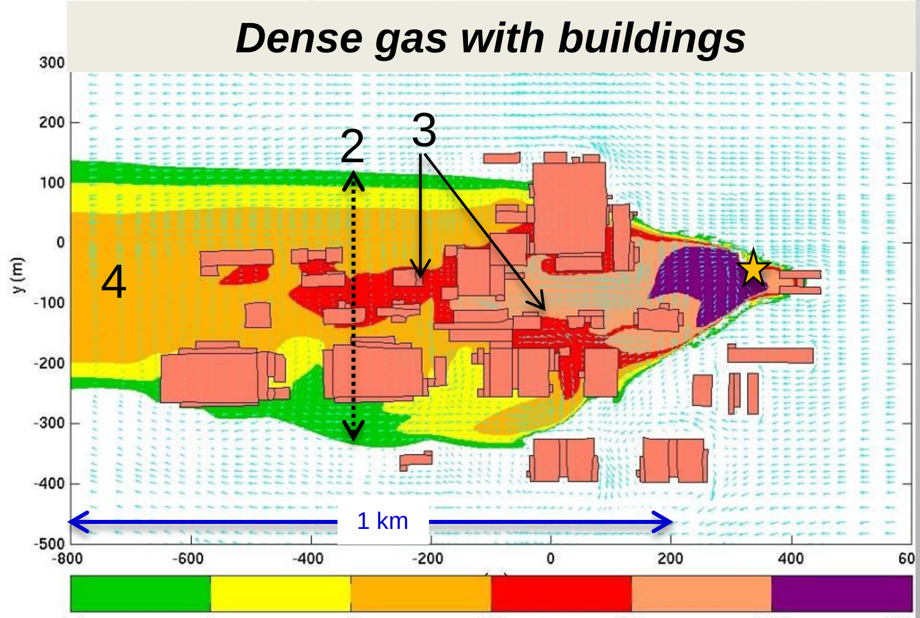


LLNL AEOLUS 3-D Computational Fluid Dynamics (CFD) numerical model

CFD models show how dense gases disperse in the presence of buildings



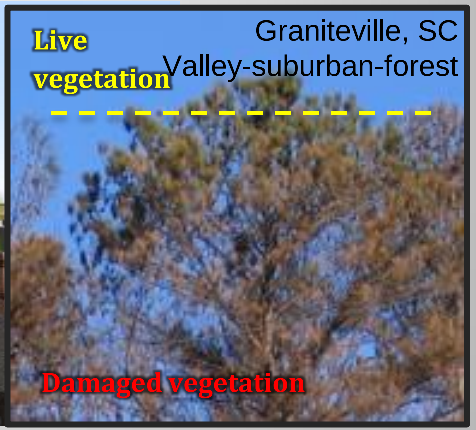


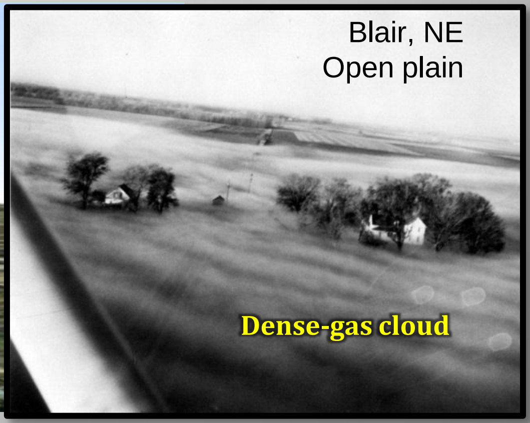


Building effects on dense gas dispersion:

1. Buildings increase vertical mixing
2. Buildings increase lateral spreading near the source
3. Dense gas is trapped gas behind buildings
4. Net effect is to reduce concentrations farther downwind and result in fewer population exposures

Plumes can mix up above buildings

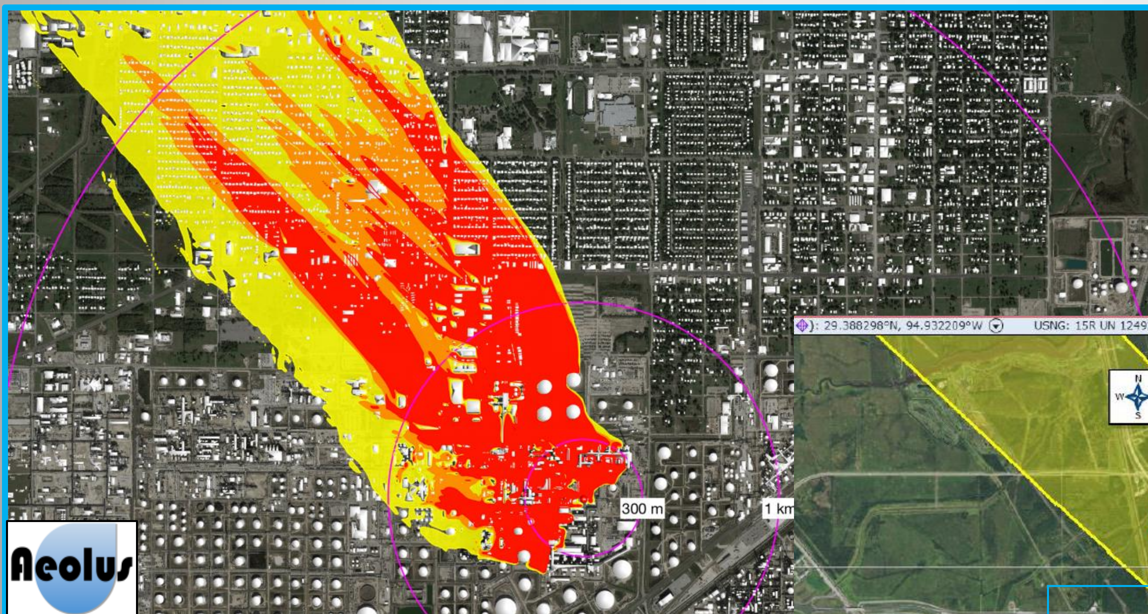




Going up to escape the plume may not be effective in urban environments

Top photo credit: Copyright 2005 Savannah River Nuclear Solutions, LLC
Bottom photo credit: Enterprise Publishing Company, Blair, N.E.

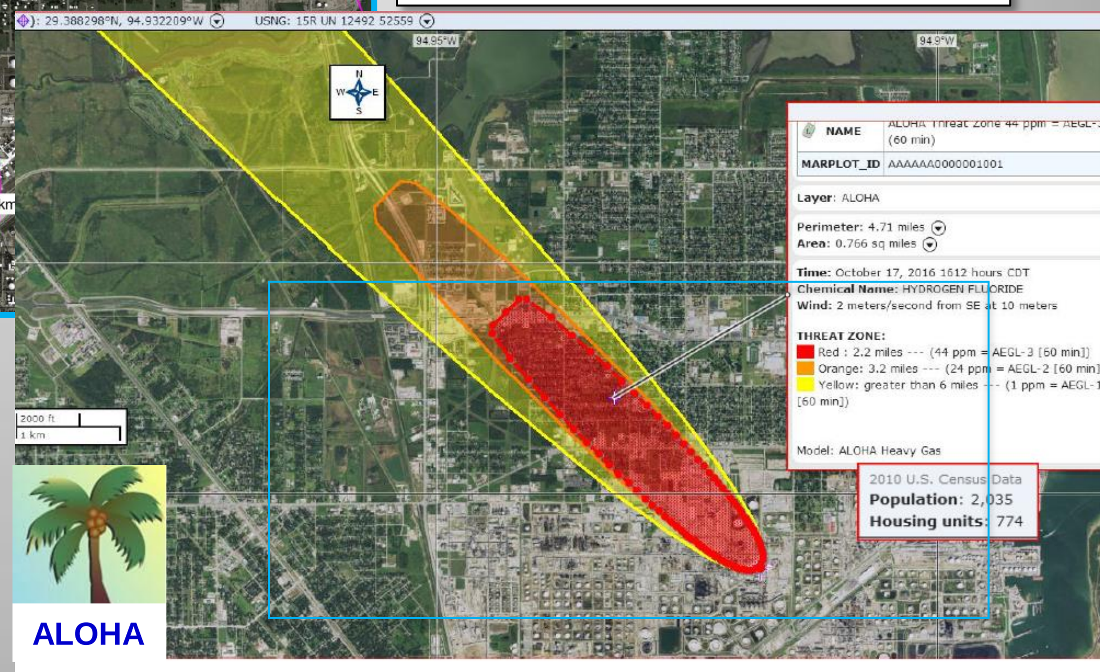
Comparison of operational and research models for refinery exercise in Texas City



Indoor night population
AEGL1 = 5794
AEGL2 = 2268
AEGL3 = **1121**

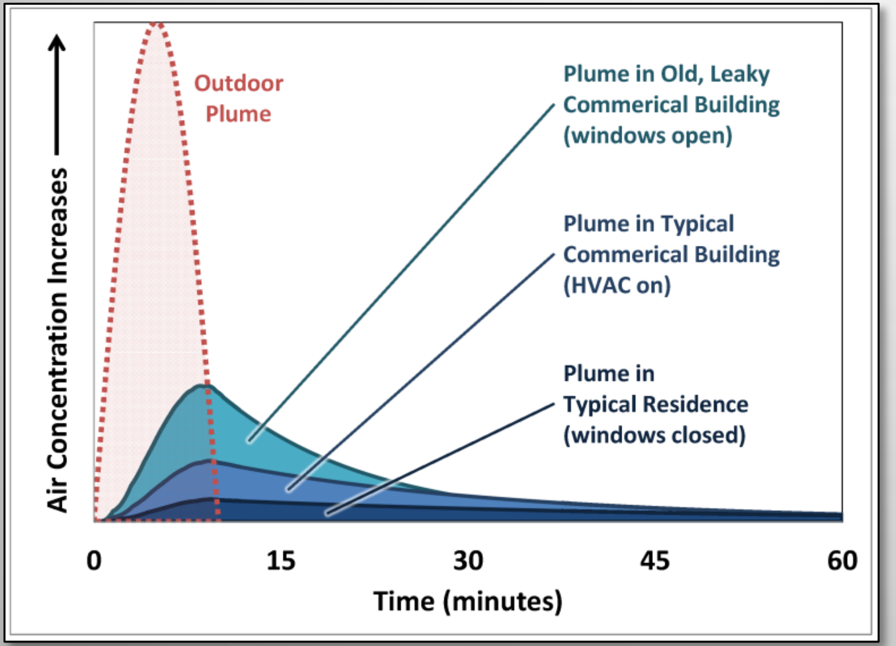
AEOLUS 3-D video illustrates building effects

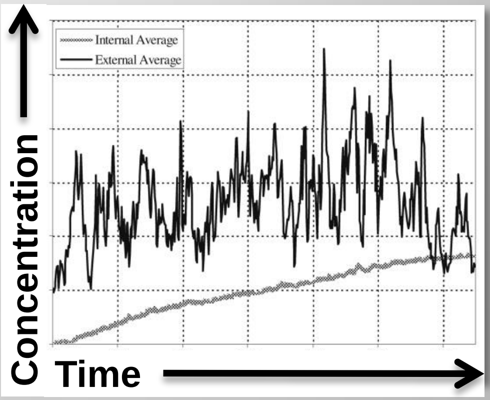
Scenario
- General source location
- 1987 accident release amount
- Single 4” pipe source
- Release start at 5 am
- Clear stable night
- Steady winds from SE at 2 m/s



ALOHA estimates about twice the affected population than AEOLUS (all assumed to be outdoors)

Because people are indoors ~90% of the time, including the substantially reduced indoor air concentrations due to building protection is a major step for improving realism





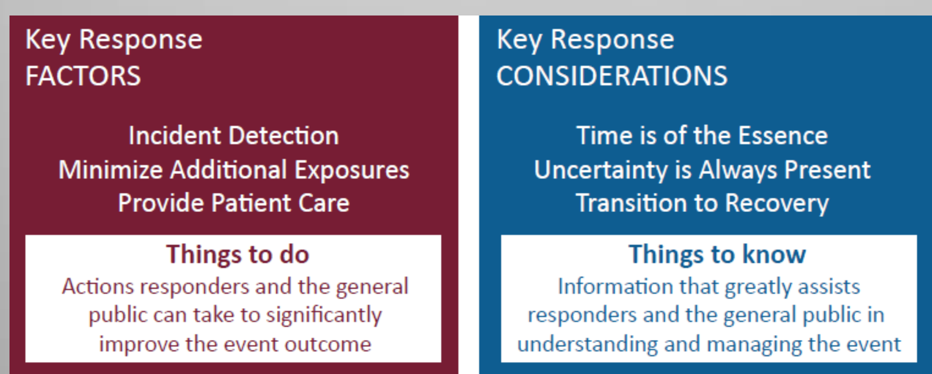
Actual measurements of outdoor versus indoor concentrations

Credit: DOI 10.1016/j.atmosenv.2011.08.049 with permission from Elsevier

Integrating a database of building type by census tract is the key to including building protection and accurately estimating health effects for indoor populations

Planning studies assist preparedness

- **Studies by industry**
- **Response Risk Assessments for key scenarios in specific cities**
  - ✓ Greenwalt, R, et.al., 2016: Response Risk Assessment and Recommendations for Response to a Mass Casualty Chemical Incident in Houston, Prepared for Department of Homeland Security Office of Health Affairs by Lawrence Livermore National Laboratory, LLNL-TR-684249 [FOUO].
- **Risk Management Program (RMP) plans** required by Clean Air Act
  - ✓ Identify a worst-case and alternative release scenarios
  - ✓ Can use basic dispersion modeling tools such as CAMEO-ALOHA
- **FEMA Key Response Factor Studies**
  - ✓ Catastrophic event generic scenarios
  - ✓ Use state-of-the-science models and analyses



The common goal is to identify preparation needed to minimize casualties

Concluding remarks

- Dispersion models have shown to be accurately reproduce air <u>concentrations</u> in a variety of settings, but conservative assumptions lead to over-predicting <u>health effects</u>
- Advanced models that treat terrain, buildings, and dense gas physics will reduce over-prediction when compared with simpler more conservative models
- Calculating indoor air concentrations will result in more realistic estimates of health effects
- Treating the spatial variation in indoor protection factors by building type will assist in deciding when to lift shelter-in-place and to proceed with an evacuation
- Using advanced models in planning studies can assist developing realistic local strategies

HF Symposium
UTMB-Galveston
October 27, 2016

CURRENT INDUSTRY PRACTICES

Daniel J. Buchanan, MS, CSP, TEM

Emergency Services Training Institute

Texas A&M Engineering Extension Service

College Station, Texas

American Chemistry Council

Hydrogen Fluoride Panel (formed in 1988)

Promotes safe manufacturing, use, handling, transportation, emergency response, and disposal of AHF and HF Acid.

Mission conforms with ACC's *Responsible Care Program* and Codes of Practice.

Published "*EMERGENCY RESPONSE GUIDELINES FOR ANHYDROUS HYDROGEN FLUORIDE (HF)".*

Medical & Toxicology Task Group and Mutual Aid Task Group (HF Mutual Aid Network…activated through CHEMTREC).

American Chemistry Council

Responsible Care

Guiding Principles

Product Safety Code

Process Safety Code

Security Code

Performance Measures

Management System and Certification (RCMS)

Hydrogen Fluoride Industry Practices Institute (www.hfipi.org)

Publishes recommended practices specific to the Hydrogen Fluoride (HF) Industry.

Established in 1994.

Four active Task Groups:

- Storage Systems Task Group
- Transportation Task Group
- Materials of Construction Task Group
- Personal Protective Equipment Task Group

Hydrogen Fluoride Industry Practices Institute

Recommended Practices on……

- Tank Car Guidelines
- Materials of Construction
- Personal Protective Equipment (PPE)
- Bulk Storage of AHF
- Cargo Tank Trailer Unloading
- Inspection/Evaluation of Vessels

American Petroleum Institute

HF Acid Working Group

API Process Safety Site Assessment Program ***(includes an emphasis on HF Acid Alkylation)…*****in partnership with the American Fuel & Petrochemical Manufacturers (AFPM)**

API Recommended Practice (RP) 751: Safe Operation of Hydrofluoric Acid Alkylation Units

HF Acid Aerosol Reducing Additives ***(R&D)***

American Petroleum Institute

API RP 751 Table of Contents:

Hazards Management

Operating Procedures and Worker Protection

Materials, New Construction, Inspection, and Maintenance

Transportation and Inventory Control

Relief and Utility Systems

Risk Mitigation – Options and Techniques

Regulatory Arena

29 CFR 1910.119 – Process Safety Management of Highly Hazardous Chemicals (OSHA)

29 CFR 1910.120 – Hazardous Waste Operations and Emergency Response (OSHA HAZWOPER)

40 CFR Part 68 - Risk Management Plan (RMP) Rule (EPA)

Regulatory Arena

- **OSHA Voluntary Protection Program (VPP)**

- **Emergency Planning and Community Right-to-Know Act of 1986 (EPCRA):**

  - **Created Local Emergency Planning Committees (LEPC) as *public-private sector partnerships* to plan for chemical emergencies.**

“Family of Plans”

Fixed Facility Response Plans

Company/Corporate Emergency Response Plans *(to include transportation)*

City/County/State Emergency Management Plans
(Annex Q – Hazardous Materials & Oil Spill Response)

Hospital Emergency Operations Plans (UTMB)

School District Emergency Operations Plans

Mutual Aid Networks (Industry, EMS, Medical Care)

“Family of Plans”

“How do we blend these plans during an actual HF incident?”

“What brings us together and organizes our response efforts during an actual HF incident?”

YOUR THOUGHTS?

NIMS/ICS

Standardization

- Common Terminology

Command

- Establishment and transfer of command
- Chain of command and unity of command

Planning/Organizational Structure

- Management by Objectives
- Incident Action Plan (IAP)
- Modular Organization
- Manageable span of control

Facilities and Resources

- Resource Management
- Incident locations/facilities

Communications/Information Mgt

- Integrated communications
- Information/intel mgt

Professionalism

- Accountability
- Dispatch/Deployment

NIMS/ICS

The “Family of Plans” comes together through joint training and exercising!

A <u>major</u> HF incident could be equivalent to the “Super Bowl” for the affected emergency response community.

Hence, let’s make sure we have a “Game Plan” and that we’ve “run the plays” numerous times via live scrimmage!

Thank you!

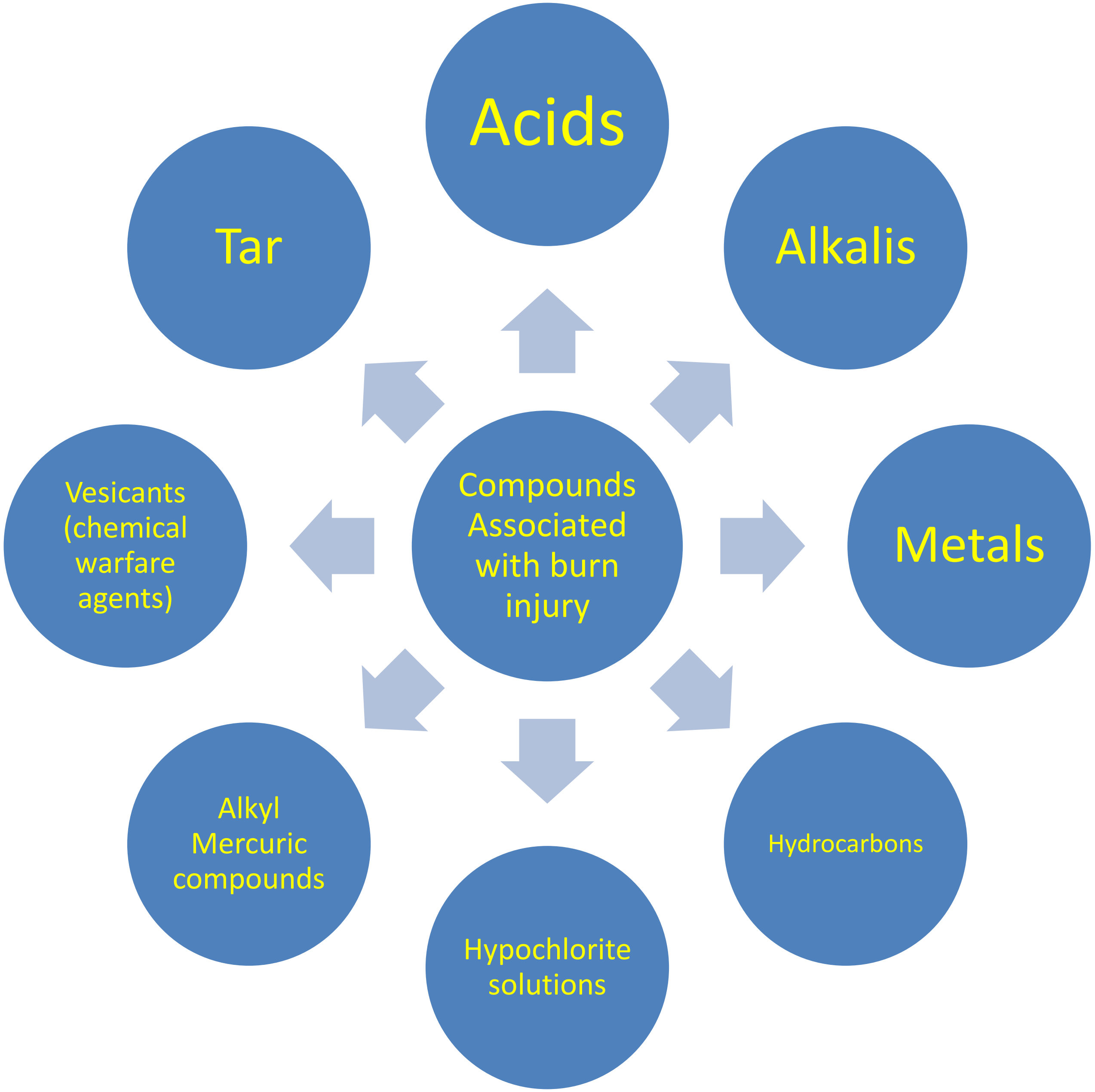
QUESTIONS?

Burn Care
Chemical Injury

Carlos J Jimenez, MD, FACS
Associate Professor
Critical Care Surgery

Shriners Hospitals for Children™

UTMB
The University of Texas Medical Branch


Acids
Tar
Alkalis
Vesicants (chemical warfare agents)
Compounds Associated with burn injury
Metals
Alkyl Mercuric compounds
Hydrocarbons
Hypochlorite solutions

Frequent Offenders

Acids

- Hydrofluoric acid
- Acetic acid
- Carbolic acid
- Chromic acid
- Epichlorohydrin acid
- Formic acid
- Hydrochloric acid
- Nitric acid
- Oxalic acid
- Phosphoric acid

Alkali

- Cement (calcium oxide)
- Calcium hydroxide
- Sodium hydroxide
- Ammonium hydroxide
- Lithium hydroxide
- Sodium hypochlorite
- Calcium hypochlorite
- Tar (asphalt)

Texas City

Texas Gulf Coast

- The petrochemical processing and services sectors dominate the private-sector economic landscape of Galveston County.
- Industrial development remains the area's top priority, with petrochemicals continuing to be the major base of the economical sector.
- The largest employers are the petrochemical companies there suppliers and/or distribution facilities.
- Dow is the largest producer of epichlorohydrin acid in the world, with a capacity of 1 billion pounds/year (~453,000 metric tons/year) from plants in Freeport, Texas, and Städe, Germany. Annual global production is about 2 billion pounds/year (903,000 metric tons/year)

Galveston History in Burn Trauma

1947 the freighter SS Grand camp exploded in Texas City killing 653 and injuring thousands
Under the leadership of Dr. Truman Blocker, MD, one of the world's first designated burn units opened at UTMB

In 1966 first Shriners Burns Hospital opened
Dr. Blocker developed the design and philosophy of SBH interdisciplinary research and care.

- Formed interdisciplinary research teams and collaborative projects to improve the care of burn injuries
- Clinical and basic science disciplines resulting in interactions between clinicians, basic scientists, allied health specialists and students (nursing, psychosocial, OT/PT, RT, prevention)

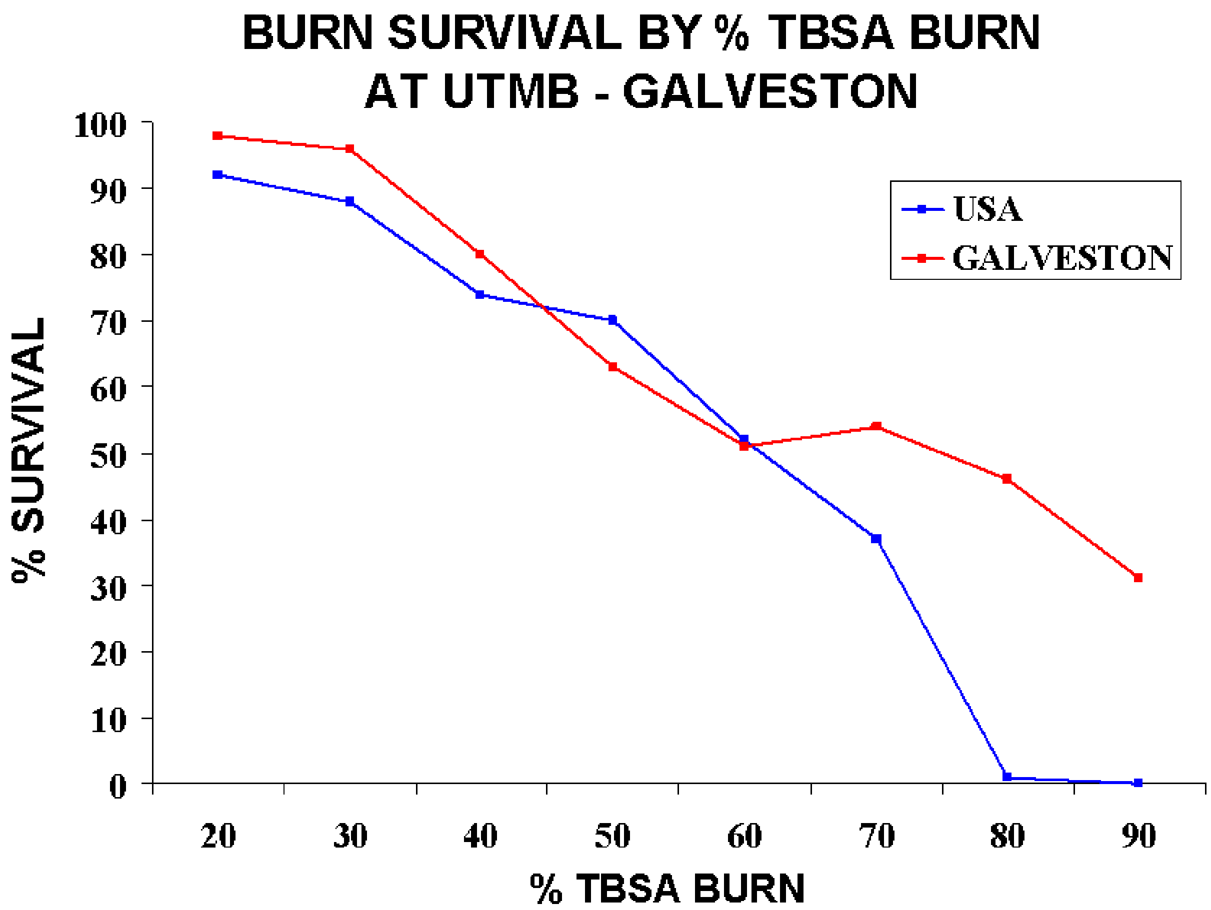
UTMB Blocker Burn Unit

Specializes in treatment of thermal, chemical and radiation burns, as well as research related to burns, trauma, sepsis and tissue repair. It has the highest survival rate of patients with major burn injury (greater than 80%) of all hospitals in the U.S.

In 1996 UTMB became the first burn center in the U.S. to be certified by both ACS and ABA.

UTMB is closely affiliated with Shriners Burns Hospital.

Burn Severity – Depth determinites



Chemical Burns: Introduction

The most commonly affected areas: face, eyes, and extremities

Hospital length of stay and duration of healing - greater compared to thermal burns

Chemical burn injuries compose only 3% of all burns and 30% of burn deaths

Severity of a chemical burn injury is determined by several factors:

- strength (concentration),
- quantity of chemical agent,
- manner and duration of skin contact (progression),
- extent of penetration,
- mechanism of action,
- phase of agent (liquid, solid, gas)

Pre-Hospital Scene

Burn Wound Care & Stabilization

Cover with clean, dry sheets

Protect from heat loss
- Thermal insulating blanket
- Do not use wet dressings or sheets

Stabilize all associated injuries
- Chest
- Potential spine injury
- Fractures / dislocations

Initial Assessment and Scene Management

- **Agitation (hypoxia)**
- **Facial burns, singed nasal hairs**
- **Carbonaceous sputum**
- **Tachypnea, intercostal retraction**
- **Excessive coughing**

- **Airway is at high risk for obstruction due to edema, from the injury or from resuscitation.**
- **Establish airway early, secured and maintained appropriately.**

Disability

Refers to Level Of Consciousness.

- Even a 99% burn is awake and talking at the scene. Good time to get a quick history.

- If they are not, look for other reasons:
  - inhalation injury
  - drugs/medications
  - alcohol use
  - head injury
  - CVA (stroke)
  - preexisting medical condition
  - **Chemical exposure**

Pre-hospital Scene

Establish IV & initiate Ringer's Lactate fluid replacement when:

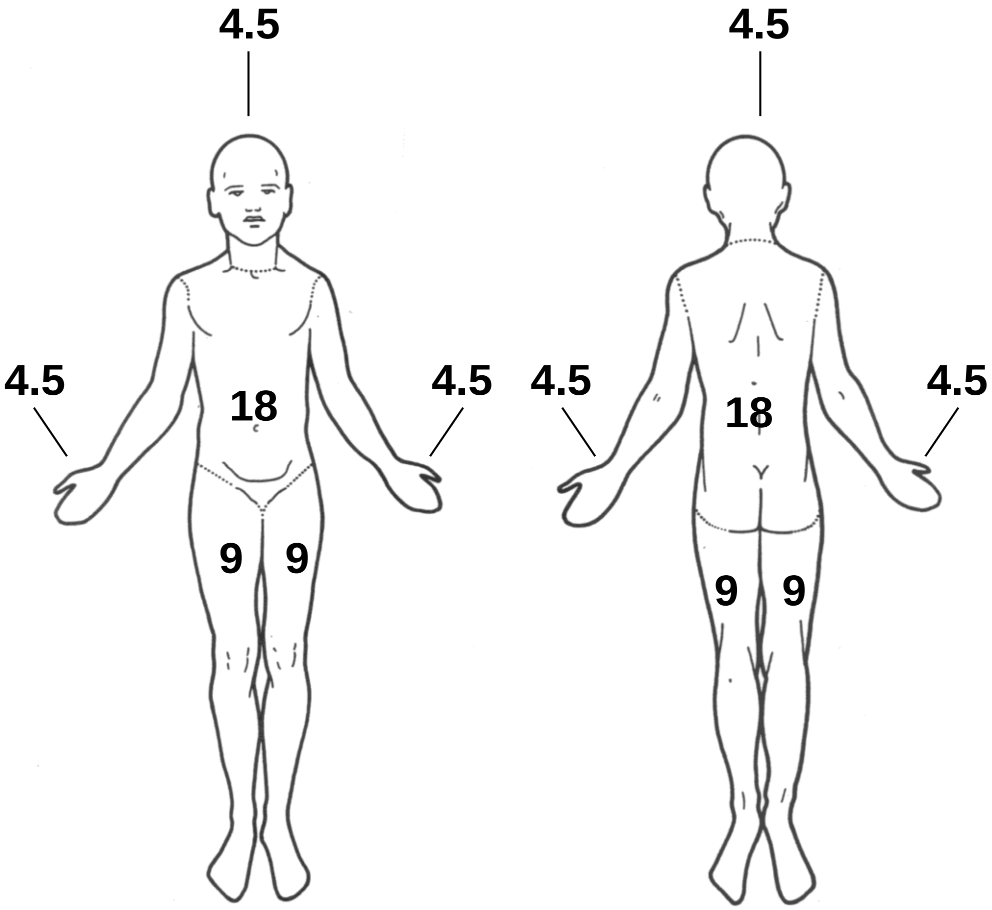
- **TBSA burn > 20%**
- **Associated injuries results in hypovolemic shock**
- **Life-threatening ventricular dysrhythmias are present**
- **Airway obstruction or cardiac arrest is a potential**

Estimating burn size (adult)

Rule of Nines

Clinically competent initial gross assessment

The palm of the hand with fingers together is equal to approximately 1% of that person's Total Body Surface Area



Chemical Burns: Pathophysiology

Chemical burns are often described as acidic or alkalinic.

Alkaline materials cause more injury than acidic compounds, in general

Acids

- Acids act as proton donors.
- Strong acids have a pH < 2
- Cause coagulation necrosis with precipitation of protein

Alkali

- Basic material, injury typically occurs with pH > 11. 5.
- Cause ‘liquefaction’ necrosis, allowing deeper penetration
- Dissolve and unite with the proteins of the tissues to form alkaline proteinases, which are soluble and contain OH ions

Chemical Burns: Pathophysiology

Organic solutions tend to dissolve the lipid membrane of cell walls

- Mechanism of action via disruption of cellular architecture

Inorganic solutions tend to remain on the exterior of cells

- May act as vehicles to carry agents that denature proteins or form salts with proteins themselves.

Chemical Burns: Pathophysiology

Mechanisms of action for chemical agents in biological systems:

Reduction: Reducing agents act by binding free electrons in tissue proteins, causing denaturation. Examples include hydrochloric acid, nitric acid, alkyl mercuric agents, ferrous iron, and sulphite compounds.

Oxidation: Oxidizing agents are oxidized on contact with tissue proteins. The by-products are often toxic and continue to react with the surrounding tissue. Examples of oxidizing agents are sodium hypochlorite (Clorox), potassium permanganate, chromic acid, and peroxide.

Corrosive agents: Corrosive substances denature tissue proteins on contact and form eschar and a shallow ulcer. Examples of corrosive agents include phenols, cresols, white phosphorus, dichromate salts, sodium metals, lye, sulphuric acid, and hydrochloric acid.

Chemical Burns: Pathophysiology

Protoplasmic poisons: These agents produce their effects by binding or inhibiting calcium or other organic ions necessary for tissue viability and function. Examples of protoplasmic poisons include ‘alkaloidal’ acids, acetic acid, formic acid, and metabolic competitors/inhibitors such as oxalic, hydrofluoric, and hydrazoic acid.

Vesicants: Vesicant agents produce ischemia with anoxic necrosis at the site of contact. There is associated tissue cytokine release and blister formation. Examples include cantharides, dimethyl sulfoxide (DMSO), mustard gas (sulphur and nitrogen), and Lewisite.

Desiccants: These substances cause damage by dehydrating tissues and exothermic reactions causing the release of heat into the tissue. Examples include sulfuric and muriatic acid, calcium sulphate, and silica gel.

General Management Principles

- The most important aspect of first aid for chemical burns is removal of the offending agent from contact with the patient
- Irrigation of chemical burns: early, copious lavage has been shown to reduce the extent and depth of injury.
  - Wounds should not be irrigated by placing the patient into a tub (contains chemical and spreads the injury)
- Irrigation should be large volume and drained 'to the floor,' or out an appropriate drain
- Monitoring of the pH from the effluent can provide quantifiable information as to adequacy of lavage
  - 30 minutes, 2 hours (or more) of lavage time may be necessary.

Cement

– Acts both as a desiccant and an alkali

– Cement is calcium oxide, which becomes calcium hydroxide upon exposure to water (exothermic reaction)

– Injury results from the action of the hydroxyl ion

– It usually contains lime, sand and other metal oxides

– The dry powder is very hygroscopic and will cause desiccation injury if not hydrated or washed away

Tar, Crude Oil

- Tar, crude oil, and asphalt are various names for mineral products created from long-chain petroleum and coal or fossil hydrocarbons
- This compound should be removed from the skin immediately
- Once cooled, the tar produces liquefaction injury and should be debrided from the skin, especially if obvious burn, blister, or tissue loss is apparent
- Antibiotic ointments and household items such as baby oil, mineral oil, mayonnaise, and butter have been found to aide in its removal

Hydrofluoric acid

- An acid and a metabolic poison
- Lethal in small size burns (<5% TBSA)
- Chelates calcium/magnesium- Producing lethal cardiac arrhythmias (Q-T interval prolongation)
- Severe soft tissue necrosis- IV and arterial calcium replacement may be necessary
- Cardiac and electrolyte monitoring is mandatory on all HF exposures.
- Reactive airway dysfunction on inhalation (inhaled/nebulized calcium gluconate)

Hydrogen Sulphide

- Highly toxic lethal substance with strong odor of rotten eggs
- Exposure to concentrations as little as 50ppm can cause loss of consciousness, death at 500ppm
- Industrial hazard in well drilling and gas refining
- Sulphur is reduced to H2S under the degradation process of organic material that forms natural gas and petroleum
- Inhaled it enters the circulation and dissociate into sulfide ions
- Sulfide disrupts cytochrome oxidase activity at a cellular level producing (cyanide like) lethal cellular anoxia and marked metabolic acidosis

Hydrogen Sulphide

- Rapid and <u>safe</u> removal from exposure site is key to survival
- Trauma (ABCDE) protocol
- 100% FiO2 oxygen delivery
- Prompt administration of (inhaled/IV) nitrites with creation of methemoglobin that would displace the bound sulfide molecule
- Theoretical benefits from administration of Sodium Thiosulphate, cyanocobalamin tox-kit, IV vitamin C and the use of hyperbaric O2

Survival from a lethal dose of hydrogen sulfide gas using an inhalation injury protocol

Sherman WC, Hughes BD, Voigt J, Mosin (PhD), Capek K, Herndon DN, Jimenez C

Hydrogen sulfide gas is a highly toxic and lethal substance. As little as 50 ppm **may** cause a loss of consciousness and a level of 500 ppm has been known to be fatal. There are no reported cases of survival with exposures greater than 1000 ppm. A recent victim from an industrial accident presented to our institution after an exposure level recorded at 1250 ppm via a hydrogen sulfide gas detector worn by the patient. He was working on an electrical transformer when a valve to a pipeline containing the hydrogen sulfide gas overpressurized and became a projectile. The valve impacted his chest and knocked him off a ladder onto a concrete slab causing a scalp laceration. The patient arrived intubated and non-arousable with a GCS of 5T. Cardiac echocardiogram demonstrated a reduced ejection fraction to 45% and bronchoscopy demonstrated mucosal sloughing and bloody exudate within the main bronchi as well as secondary branches. Cyanocobalamin was immediately administered followed by the initiation of our inhalation protocol. The medications included in the protocol consist of inhaled heparin, racemic epinephrine, n-acetylcysteine, and nebulized albuterol as needed to reduce the mucosal inflammatory response, preservation of bronchial mucosa, and prevention of fibrinogen cast formation and airway obstruction. CT imaging of the thorax demonstrated substantial injury to the parenchyma of the lung in the upper lobes and posterior dependent sections. The patient became arousable on hospital day 2 and was extubated on hospital day 3. His neurological status improved over the next few days and he was deemed stable for discharge by hospital day 7. Pulmonary function tests obtained prior to his discharge demonstrated a depressed FEV1 to 71% and an FEV1/FVC 63%. It is suspected that the victim survived by being forced away from the source of the gas leak after the valve impacted his chest. The exposure was still considerable as evidenced by his depressed neurologic, cardiac, and pulmonary status. We believe that the initiation of our inhalation injury protocol limited further damage and sequelae of the hydrogen sulfide gas and advocate the institution of a similar protocol in any treatment regimen for hydrogen sulfide inhalation injuries.

Funding: SHC 84080 and 80100

Chemical Burn Treatment Summary

- Many chemical compounds can cause burn injury
- The principal idea behind the treatment of chemical burns is early, copious irrigation (safe elimination of offending agent)
- Wound care is the same as with thermal burns (once the agent is removed)
- Chemical burns tend to be deeper than they initially appear, often requiring skin grafting for management
- The use of specific antidote agents is limited to the industry and in those cases where the agent is clearly identified (MSDS/CAS numbers or SDS)

Early Excision and Grafting

Early Excision Mortality vs Conservative Therapy

Treatment Group	n	Age (yrs)	Mortality (%)
Early Excision Conservative	22 11	17-30	9 45*
Early Excision Conservative	7 16	31-55	57 75

*Significant difference at p<.03

DNH-61

Length of Hospital Stay; Serial Debridement vs Early Excision

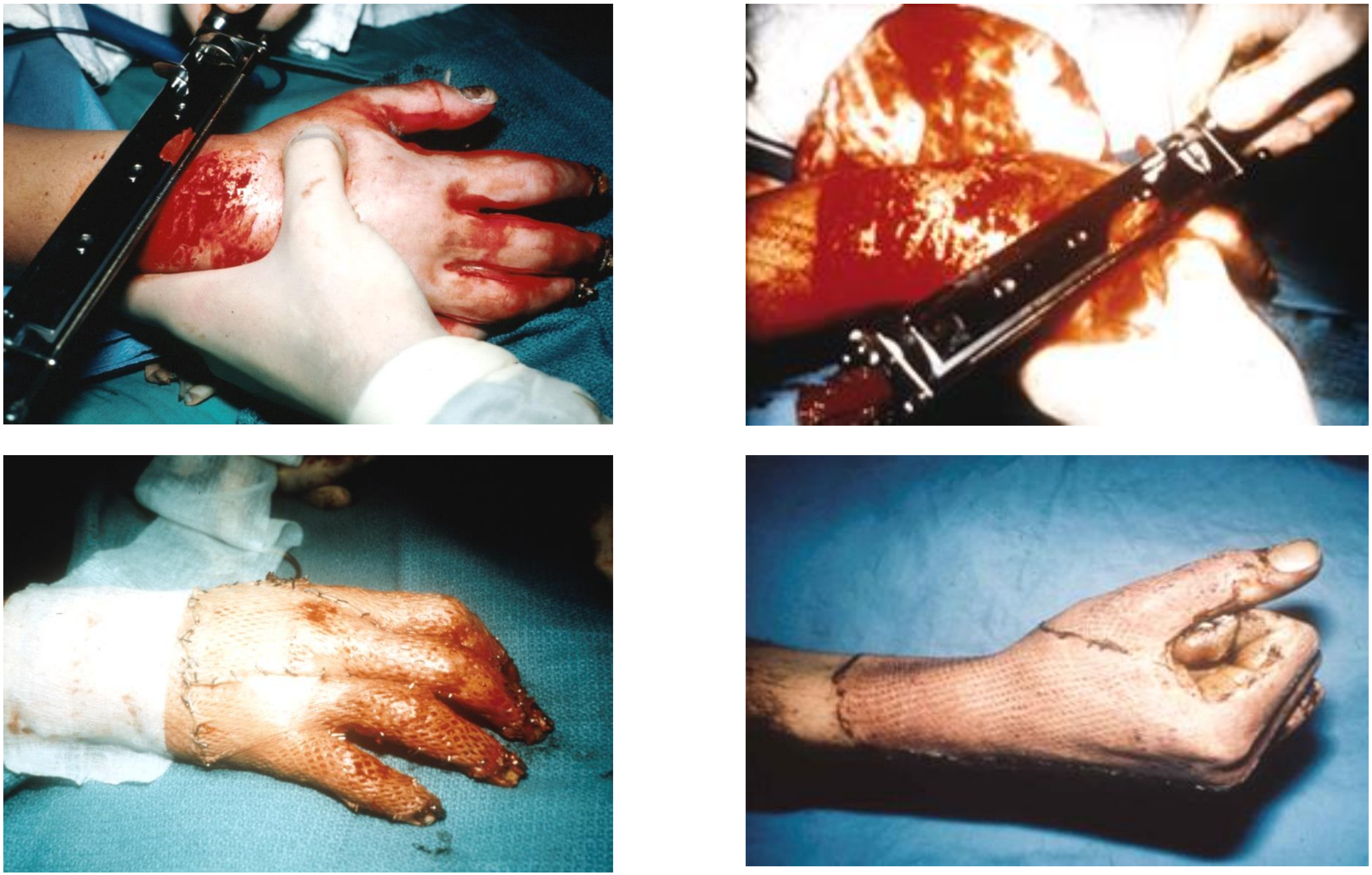
	Days Postburn Final Coverage	Length of Hospital Stay
1977-1981 Serial Debridement n = 25	67 ± 6	97 ± 8
1981-1984 Early Excision n = 25	44 ± 4*	57 ± 5*

Means ± SE

*Significant Difference between groups, p<.01

DNH-60

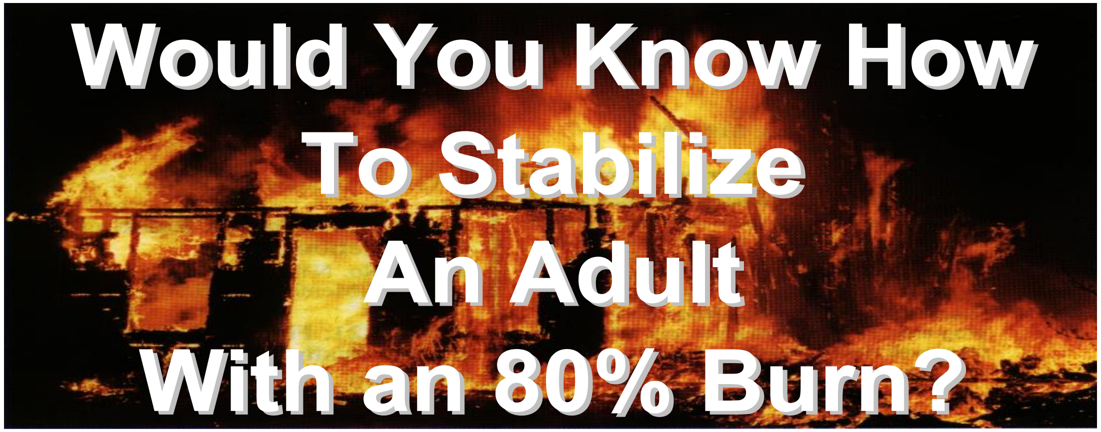
Early Excision of Full Thickness Burn Wound



Referral Criteria

ABA criteria for referral and admission to a Burn Center

- 2nd degree burns > 10% TBSA
- Burns to face, hands, feet, genitalia, perineum, major joints
- 3rd degree burns
- Electric injury (lightning included)
- **Chemical burns**
- Inhalation injuries
- Burns accompanied by pre-existing medical conditions
- Burns accompanied by trauma, where burn injury poses greatest risk of morbidity or mortality
- Burns to children in hospitals without pediatric services
- Patients with special social, emotional or rehabilitative needs



Advanced Burn Life Support Courses

- Goal to train medical professionals in emergency care of burn victims, adults and children
- A joint presentation between Blocker Burn Unit and Shriners Burns Hospital
- Over past 3 years we have educated over 1000 personnel in Texas and surrounding areas.

PRE-HOSPITAL AND EMERGENCY BURN CARE COURSES

- Scene Management
- Pathophysiology of the Burn
- Initial assessment and Scene Management
- Stabilization and Transport
- Inhalation Injury
- **Chemical Injury**
- Electric Injury
- Radiation Injury

Burn Center of Excellence

Burn Clinical Care, Education and Research

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Disaster Preparedness and Response: Research and Public Health

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Objectives

- UTMB Center in Environmental Toxicology's ongoing role in disaster preparedness and response to natural and manmade disasters
- NIH vision for Disaster Research Response
- Whole Community Approach to Disaster Preparedness and Community Resiliency
- Exploring opportunities for integration of healthcare response, research, and education

Why is the Center in Environmental Toxicology so focused on Disaster Research Response?

(otherwise known as, what a long, strange trip it's been)

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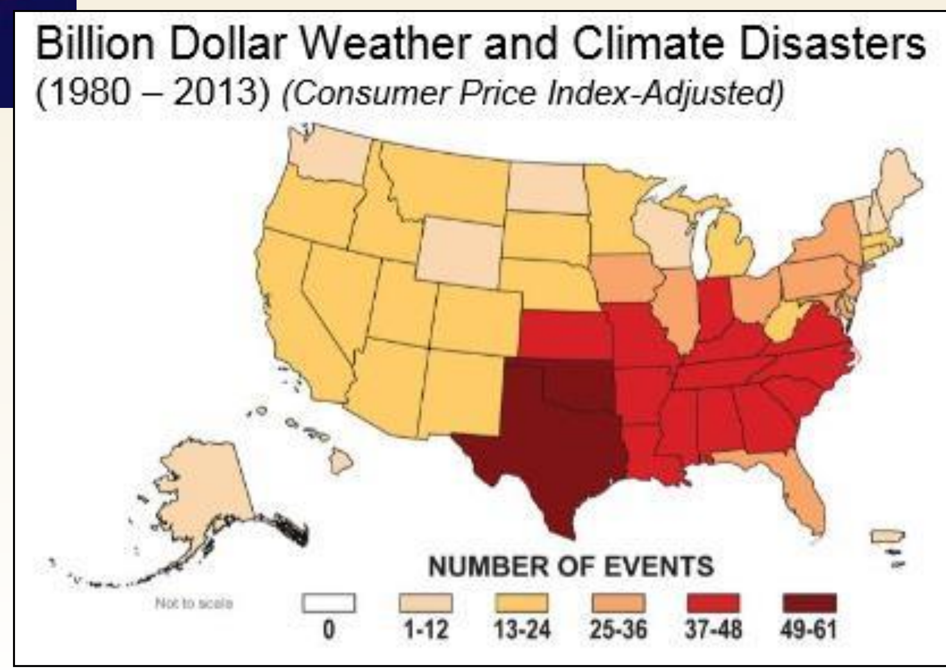
When Disaster Strikes. . .

Texas is likely to be involved. . .



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Hurricanes Katrina, Rita, and Isaac

- Needs Assessments
- Relief and Response:
  - Collecting and delivering essential relief supplies
  - Partnering and assisting to provide clean-up materials, PPE, and safety protocols
- Planning and Response:
  - Year-long assessment of community resiliency and preparedness

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Ike

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Hurricane Ike

- Up close and personal
- Expected to provide relief and response
- Urgent Need for Community-Based Participatory Research:
  - Sediment sludge deposited in 75% of island residential and commercial buildings
  - Collected and analyzed sediment samples for toxicants
- Urgent Need for Education and Training:
  - Thousands of college students and other volunteers came to help
  - Thousands of contractors including non-English speaking workers

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Deep Water Horizon Oil Rig Explosion and Fire / BP Oil Spill

NIEHS U19 Gulf Coast Health Alliance: health Risks related to the Macondo Spill (GC-HARMS)

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Goals and Objectives

- Assess PAH contamination of Gulf seafood
- Determine the toxicity of petrogenic PAH
- Evaluate exposure and health outcomes in a longitudinal cohort study involving community partners
- Disseminate findings to community stakeholders

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Lessons Learned

- Response is necessary but insufficient to accurately identify risk to human health—**need for integrated multi-agency and multi-institutional response that includes research** as a complementary effort
- Valuable to partner with existing public health and Emergency Management to respond effectively, immediately, and appropriately to disaster situations
- Must develop capacity to capture and analyze samples and provide results to affected community agencies and groups to drive evidence-based programs
- Must establish infrastructure and policies to enable rapid approval of Disaster Research Response and IRB protocols
- Need for baseline studies of high risk communities

Impetus for Integration

- Presidential Policy Directive on National Preparedness
  - NIH's Disaster Research Response Initiative
  - FEMA's Whole Community Approach to Emergency Management
  - Health and Human Services' National Guidance for Healthcare System Preparedness
  - CDC's Public Health Preparedness Capabilities

Rapid Acquisition of Pre- and Post-Incident Disaster Data (RAPIDD)

Get in the field sooner by:

- Pre-reviewed by IRB and OMB
- Standardized methodology with previously used instruments
- Pre-positioned study documents and questionnaires
- Pre-positioned field guides and training materials
- Pre-approved protocols for clinical assessment and biospecimen collection

Mobile Clinical Research Clinic

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What are we approved to do?

- Capture exposures in air or water through passive samplers
- Biomarker analysis
- Cohort registration and follow up
- Survey research
- Biometrics
- Spirometry
- Phlebotomy
- Other biospecimen collection (urine, hair, nails)
- Potentially help with triage

A Whole Community Approach to Response and Resiliency

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What is it?

- Brings to bear the full capacity of private and nonprofit sectors to prevent, protect against, mitigate, respond to, and recover from multiple threats or hazards effectively
- Focuses on identifying opportunities for engaging diverse groups and organizations: clinicians, scientific investigators, community and volunteer groups, industry, local and regional jurisdiction and emergency response officials, and policy makers
- Intent: integrate efforts for maximum efficacy, guide development of policies and best practices, increase the resiliency of Gulf Coast communities

Conclusions

- Much consensus that we should work together
- Little infrastructure for doing so
- Must resist temptation to remain in our organizational and disciplinary silos
- Must actively engage all stakeholders
- If we can reduce risk, we must
- Gulf Coast Health Alliance: achieving Resiliency Together through Disaster Response, Research, and Recovery (GC-HART)

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Public Health Emergency Response

Randy Valcin, GCHD Manager of Diseases and Disasters

Tyler Tipton, GCHD Public Health Planner

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1. Immediate Response: Assessment

- Should public health become involved? If so, how?
- What public health function have or may be adversely impacted?
- What geographical area(s) have or may be adversely impacted? Does it fall within your health department's jurisdiction?
- How many people threatened, affected, exposed, injured, or dead?
- What are the exposure pathways?
- Have critical infrastructures been affected? If so, how?
- Have medical and healthcare facilities been affected? If so, how?
- Have public health operations been affected? If so, how?
- Are escape routes open and accessible?
- Will current/forecasted weather conditions affect the situation?

1. Immediate Response: Assessment

- What other agencies/organizations are currently responding?
- What response actions have already been taken?
- Has information been communicated to responders and the public to protect public health? If so, in what way(s) and by whom?
- Does your health department have existing mutual-aid agreements with other agencies, organizations, or jurisdictions?
- Has an Incident Command Post (ICP) been established? If so, where is it?
- Who is the Incident Commander (IC)? How can the IC be contacted?
- Has the local, state, or tribal Emergency Operations Center (EOC) been activated? If so, where is it operating?

HFA Incident

Existing Protocol and Roles for Public Health in a Large-Scale Event

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What roles do you see for DR2 or Public Health Response in the context of an HFA release?

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Respiratory Management of Hydrofluoric Acid Inhalation Injury

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Objectives

- Describe the pathophysiology of HF inhalation injury
- Describe signs and symptoms of HF exposure
- Discuss current treatment guidelines
- Discuss limitations of the current guidelines
- Long-term outcomes of an inhalation injury
- Case studies
- Future needs

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HF Inhalation

- The use of Calcium Gluconate in cutaneous HF exposure is well documented and supported by the literature, but its use in HF inhalation exposure has not been studies experimentally in great detail.
- There are case reports reporting the use of nebulized Calcium Gluconate in treating HF inhalation starting with Trevino et al in 1983.
- Experimental research on HF inhalation injury treatment is lacking and thus the need for investigation.

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Symptoms of HF Exposure

- Coughing/Choking
- Inability to breathe / Chest tightness
- Chills/Fever
- Cyanosis
- Delayed reactions can occur and cause:

  Laryngeal edema

  Bronchospasm

  Pulmonary edema

  Respiratory arrest

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HF Inhalation Injury Pattern

HF Inhalation Clinical Symptoms

- Irritation to the nose
- Sore throat
- Burning sensation
- Cough
- Dizziness
- Nausea/vomiting
- SOB
- Severe respiratory distress

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Clinical Findings

- Facial burns
- Rales
- Dyspnea
- Hoarseness
- Tachypnea
- Cough and hypersecretion

Lower Airway Involvement

- Edema of airway
- Erythema
- Mucosal Sloughing
- Decreased Mucociliary Activity
- Bronchospasm

Parenchymal Injury

- Endothelial Cell Injury
- Alveolar Cell Injury
- Bilateral congestion
- Pulmonary edema
- Acute respiratory distress syndrome

Physiological Effects of HF Inhalation

- Decreased thoracic compliance
- Increased airway resistance
- Increased work of breathing
- Hypoxemia

Pathophysiology

- Cilia loss, respiratory epithelial sloughing
- Cast in airways
- Atelectasis, occlusion by debris/edema
- Pseudo membranes
- Bacterial colonization at 72 hrs.

Hubbard et al. J Trauma 1991; 31:1477-1486

Major considerations for the clinical diagnosis

Exposure characteristics:

- Closed space, Entrapment
- Duration of exposure
- Concentration of HF
- Unconscious
- Other known inhaled agents

Objective Diagnostic Test

- Frequent Measurements of Labs (Calcium, Magnesium, Potassium)
- Arterial Blood Gas Analysis
- Chest X-Rays
- Direct Airway Observation (Bronchoscopy if indicated)

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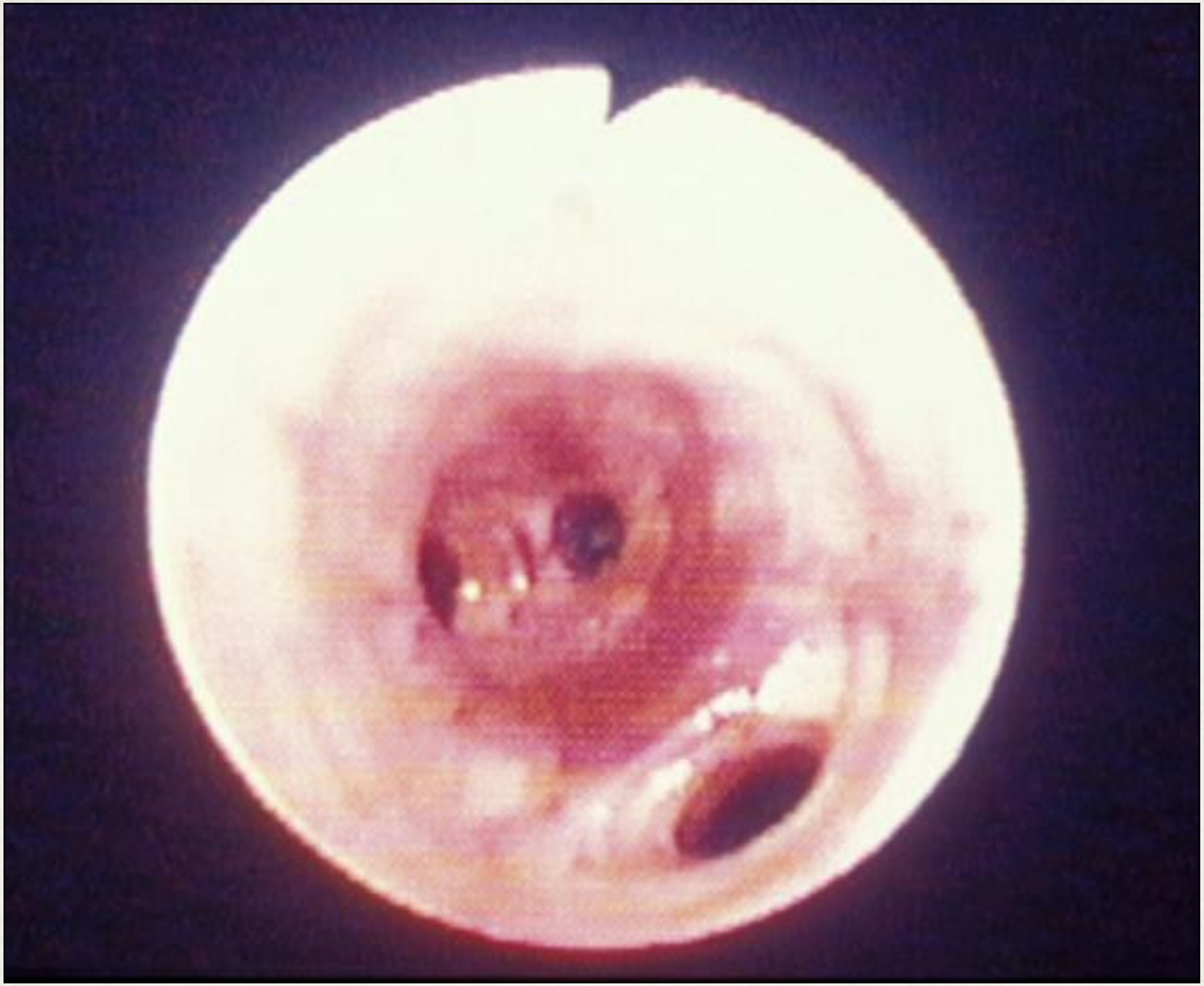
Bronchoscopy Findings of HF Inhalation Injury

Categorization of Involvement:

- Mucosal: erythema, edema, ulceration, hemorrhage
- Sub mucosal: hemorrhage
- Extra mucosal: carbonaceous material, cast, blood



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TREATMENT GUIDELINES FOR HF INHALATION INJURY

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HF Inhalation Treatment

- Trevino et al. J Occupational Medicine 1983, suggest giving 100% oxygen by mask and 2.5-3% calcium gluconate solution by inhalation, preferably by IPPB utilizing a nebulizer or by nebulizer alone.
- Trevino et al also suggest admitting these patients to an ICU and observing for 24-48 hours.
- Case reports in the literature further suggest following this initial recommendation. However there is little mention of how often and how long this recommendation should be continued.

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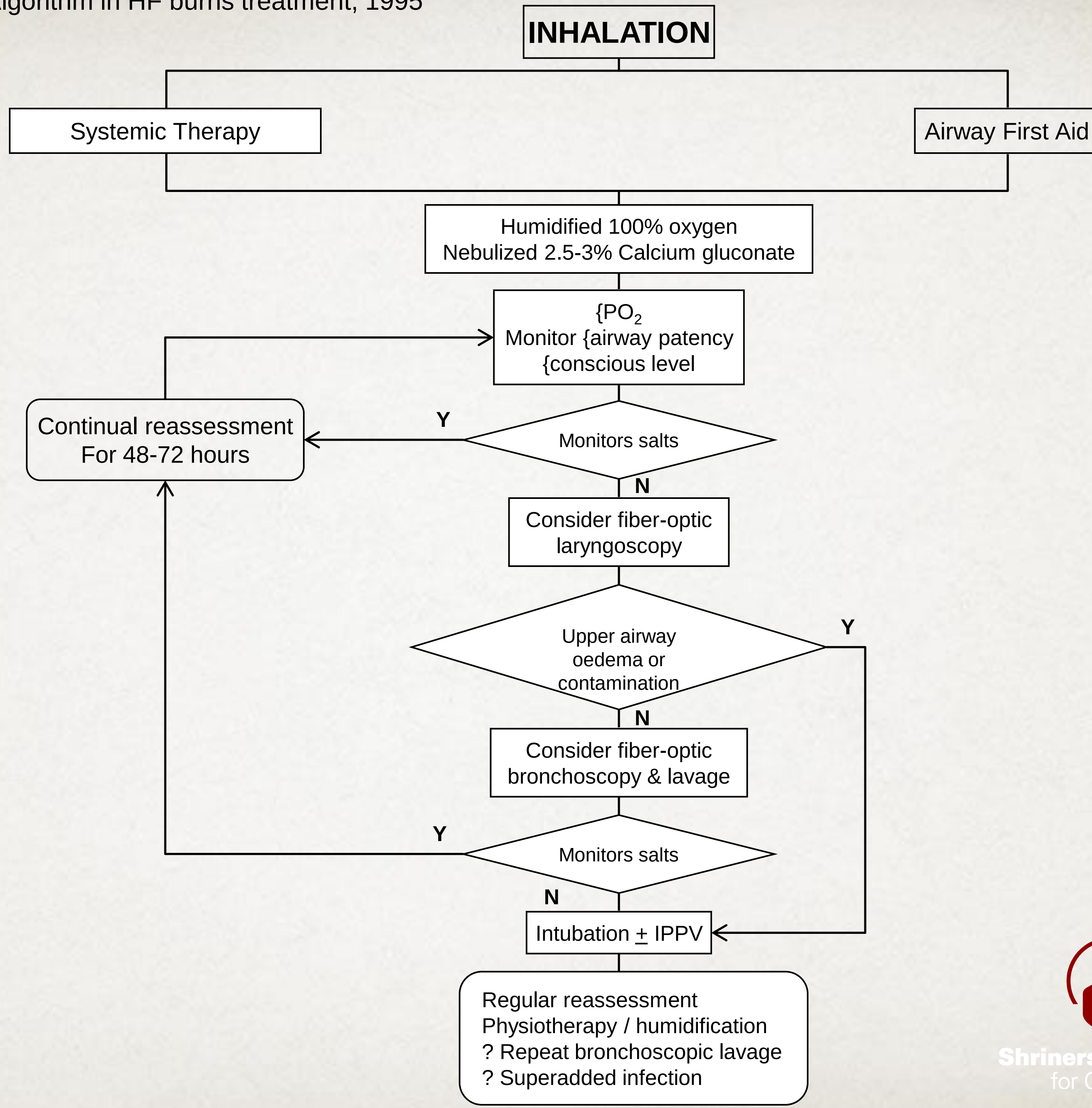
Kirkpatrick and Burd: Algorithm in HF burns treatment, 1995



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Recommended Medical Treatment for HF Inhalation Exposure : Honeywell

- Immediately remove victim to fresh air and get medical attention.
- Keep victim warm, quiet and comfortable.
- If breathing has stopped, start artificial respirations.
- Administer 100% Oxygen.
- Nebulize a solution of 2.5% calcium gluconate.
- Repeat use of nebulized calcium gluconate every 4 hours for 48 hours after a significant exposure has been described in the literature (Tsonis et al).
- Administer bronchodilators as necessary.
- The administration of inhaled steroids has also been recommended.
- Specific measures may be needed to treat pulmonary edema.
- Assess pulmonary function studies.

Suggested HF Inhalation Injury Treatment Guidelines

- High flow 100% humidified oxygen
- Nebulized 2.5-3% Calcium Gluconate by continuous nebulizer for the first 3 hours then Q 4 hours for 48 hours if needed.
- ICU support as needed.
- Ventilator support following ARDS guidelines.

HF Inhalation Injury Guidelines

- Airway clearance techniques Q 4 hours
- Cough deep breathing Q 2 hours
- Sputum cultures MWF
- Bronchoscopy evaluation as indicated
- Mechanical ventilation as needed
- Early extubation

Mlcak RP, et al., BURNS, 2007; 32: 2-13

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HF Inhalation Injury Guidelines

- Early ambulation
- PFT's prior to discharge and at scheduled OP visits
- Patient/family education

Mlcak RP, et al., BURNS, 2007; 32: 2-13

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Long Term Outcomes of Inhalation Injury

- Obstructive lung disease
- Restrictive lung disease
- Diffusion defects

Mlcak R.P., et al. J Burn Care Rehabilitation (2000)

Herndon DN. (2009) In Total Burn Care 4th edition. Chapter 21,pp.281-291

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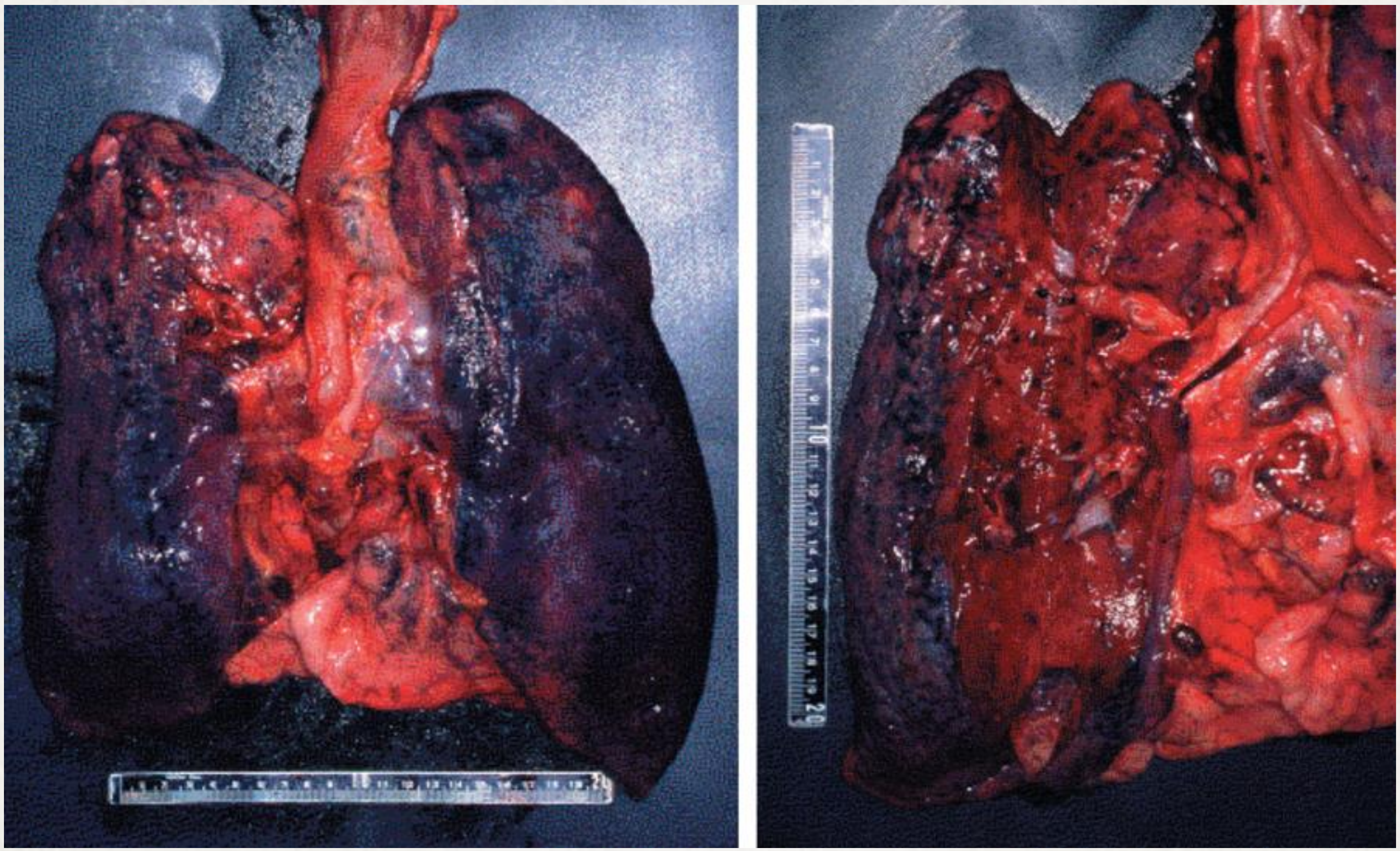
Case 1: History. Dote T, et al. Toxicology and Industrial Health 2003)

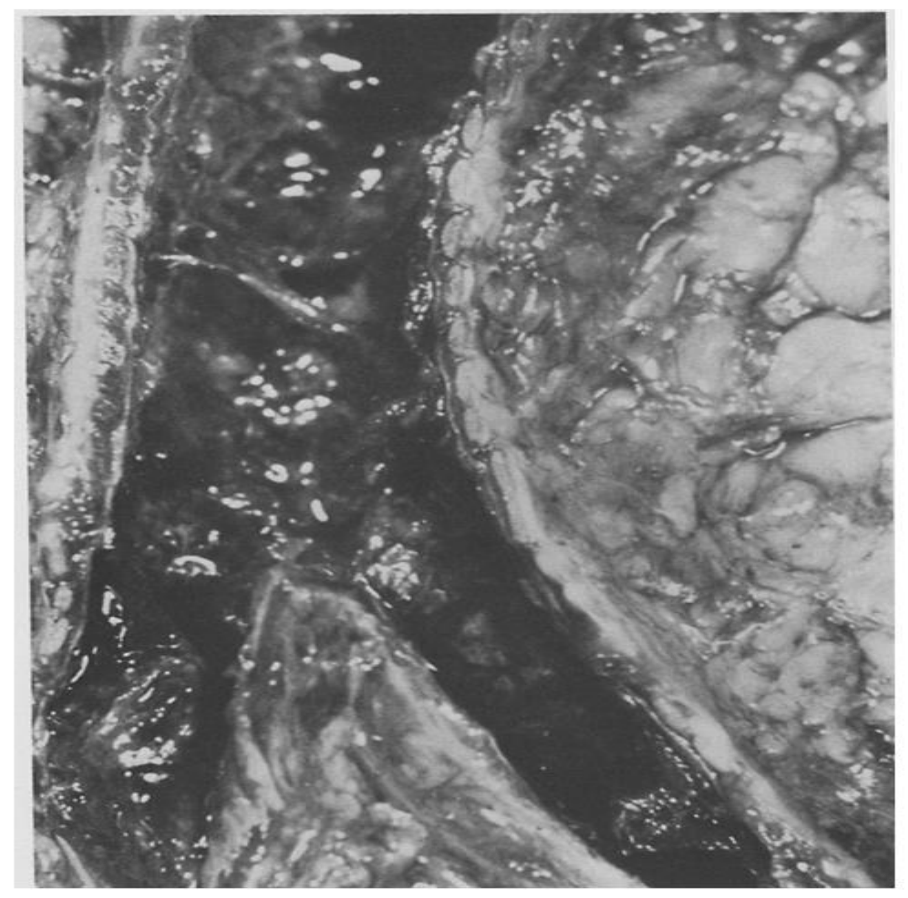
- 65 year old worker was severely sprayed on his face with HF acid.
- Immediately complained of dyspnea.
- His coworkers rapidly removed his helmet and raincoat to ease his breathing.
- He was immediately transported to the hospital and arrested ½ hour later.
- Death was confirmed an hour and 40 minutes later.

Case 1:

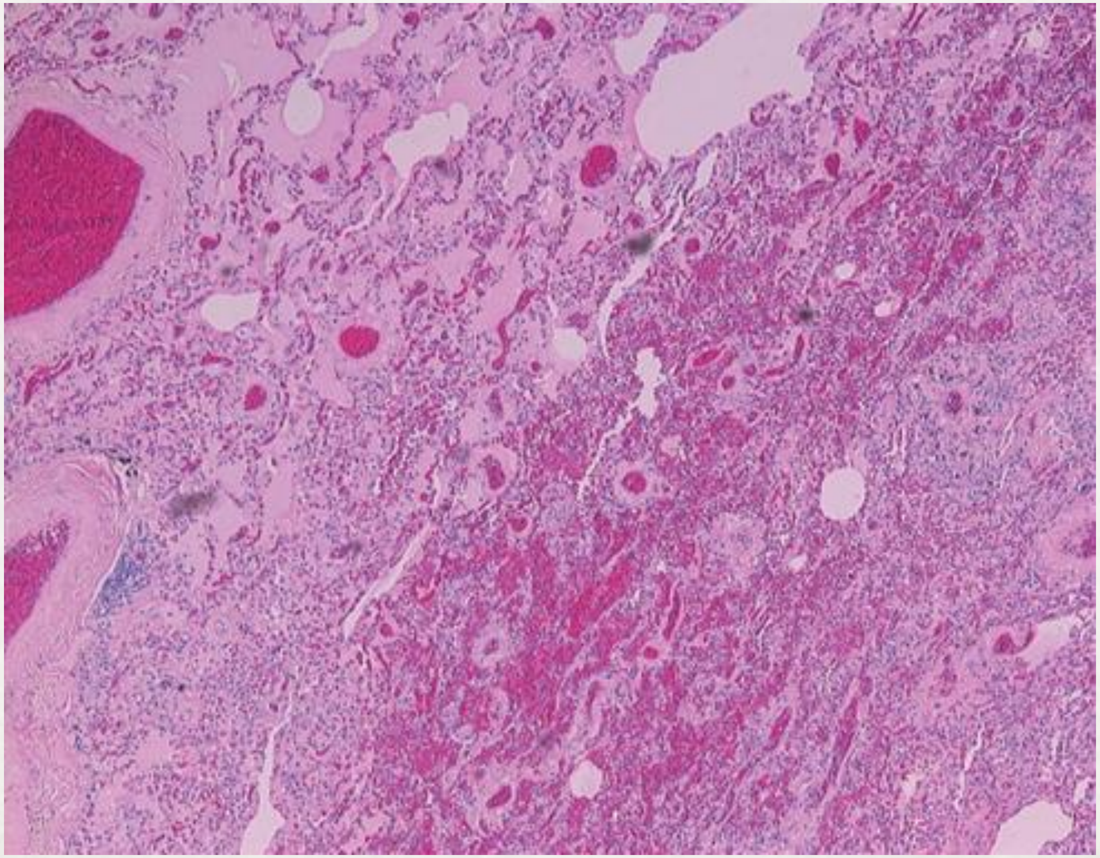
Case 1: Bilateral congestion and edematous lungs following inhalation of HF solution



Severe ulcerated and necrotized tracheobronchitis with pseudomembraneous coating and obstruction of the L main stem bronchus



Case 1: Histopathological findings showed severe congestion and massive eosinophilic substances within the alveoli



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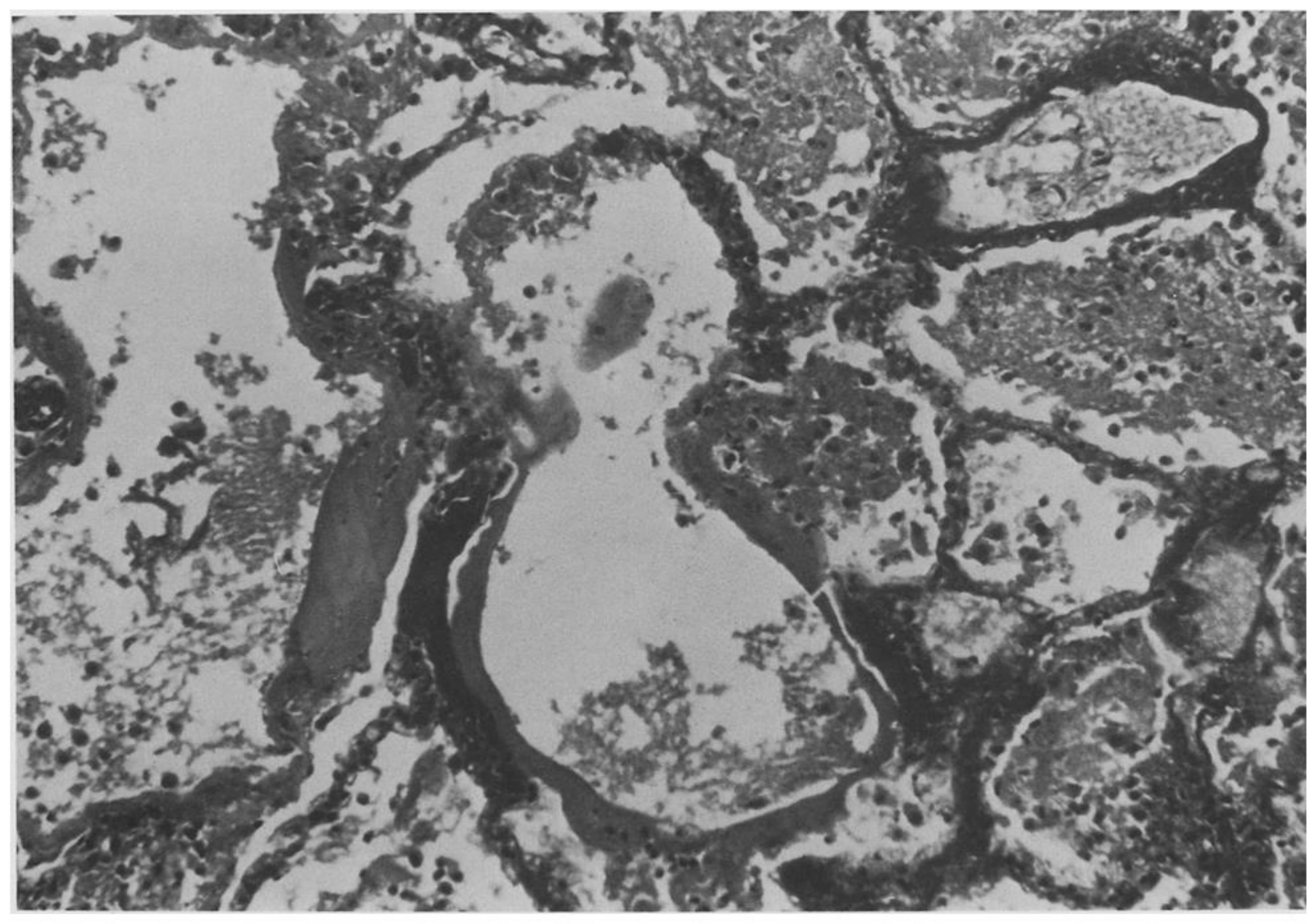
Fibrinous widening of the alveolar septa and hyaline membrane in the alveoli.



Case 2: Reported by Tsonis et al. J Burn Care and Research 2008

- 40 year old man working in metal etching factory dropped a machine part into container of HF and sulfuric acid and spent 10-15 minutes in retrieving it. It was reported that he was wearing a protective mask at the time.
- 9 hours after exposure he reported to the ED with respiratory distress and hypoxia.
- BS were decreased in all lung fields. Blood gases and X-ray exams was consistent with acute respiratory distress syndrome.
- He was immediately intubated, placed on mechanical ventilation and started on nebulized calcium gluconate 2.5%, given continuously for the first 3 hours and then every 4 hours for 48 hours..
- Subsequently developed pneumonia but was finally weaned from MV after 8 weeks.
- 5 months after the initial injury his lung function studies showed mild obstructive lung disease and a mild diffusion defect.

Case 2: HF Clinical Presentation

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Future Directions

- Expand and modify pharmacological therapy (inhaled use of Calcium Gluconate) based on best practice or evidence based medicine.
- Improve supportive modes of therapy.
- Determine level of residual effects.
- Develop a new treatment algorithm to include ICU standards of care.
- Support research on treatment of HF inhalation.

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QUESTIONS?

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