Improving Occupational Exposure Assessments: Generation Rate Estimation of a Disinfectant

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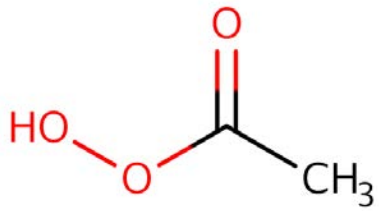
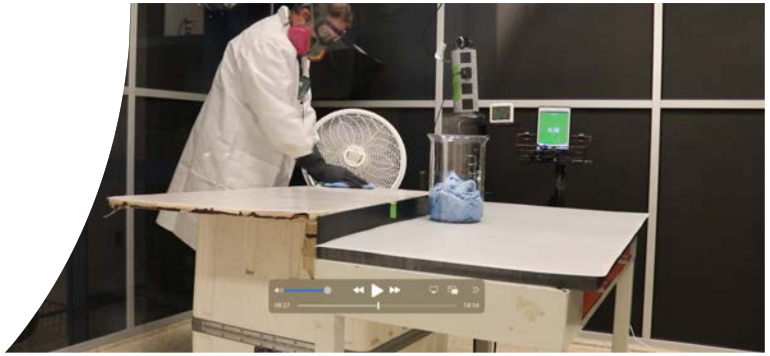
Outline

- Problems / Opportunities in Improving Exposure Assessments
- Case Study: Peracetic Acid (PAA) Disinfectant
  - Background
  - Regulatory Status
  - Highly-Controlled Exposure Scenarios
  - Decay Rate of PAA
  - Estimation of Evaporation Rate
- Conclusions





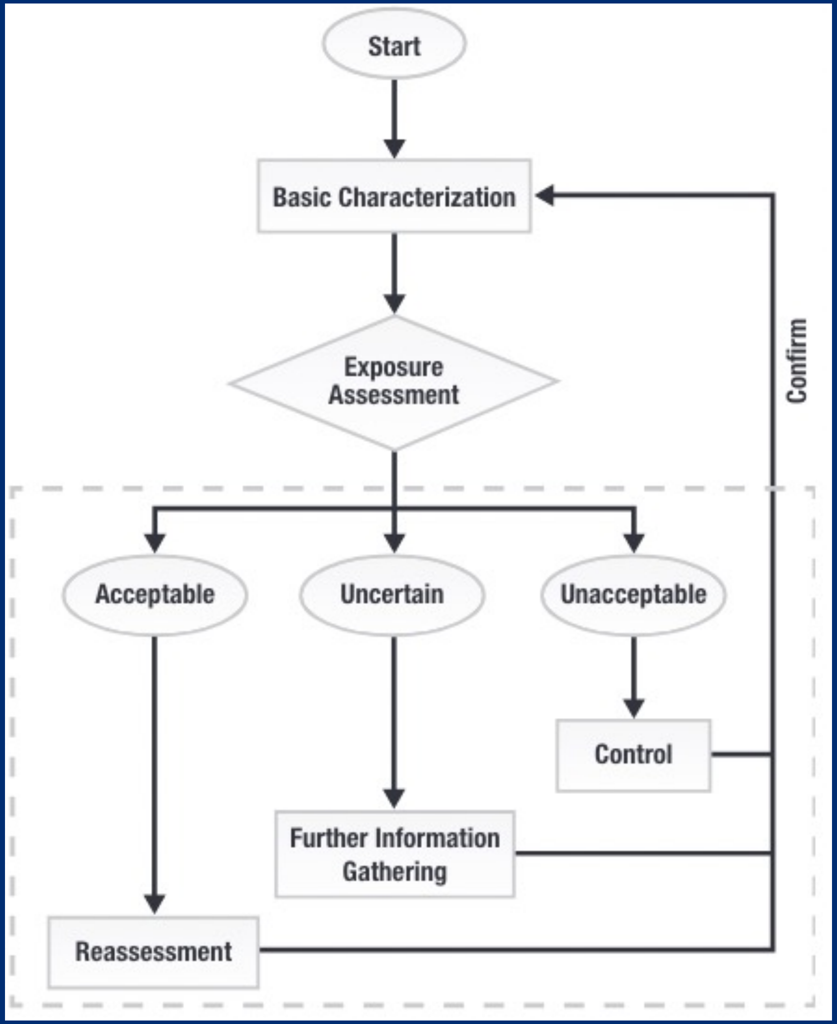
AIHA Exposure Assessment Strategy

- Motivation of PhD Dissertation

Management and Exposure Control Categories

	SEG Exposure Control Category**	Applicable Management/ Controls
	0 (<1% of OEL)	no action
	1 (<10% of OEL)	procedures and training, general hazard communication
	2 (10-50% of OEL)	+ chemical specific hazard communication, periodic exposure monitoring
	3 (50-100% of OEL)	+ required exposure monitoring, workplace inspections to verify work practice controls, medical surveillance, biological monitoring
	4+ (>100% of OEL, Multiples of OEL; e.g., based on respirator APFs)	+ implement hierarchy of controls, monitoring to validate respirator protection factor selection

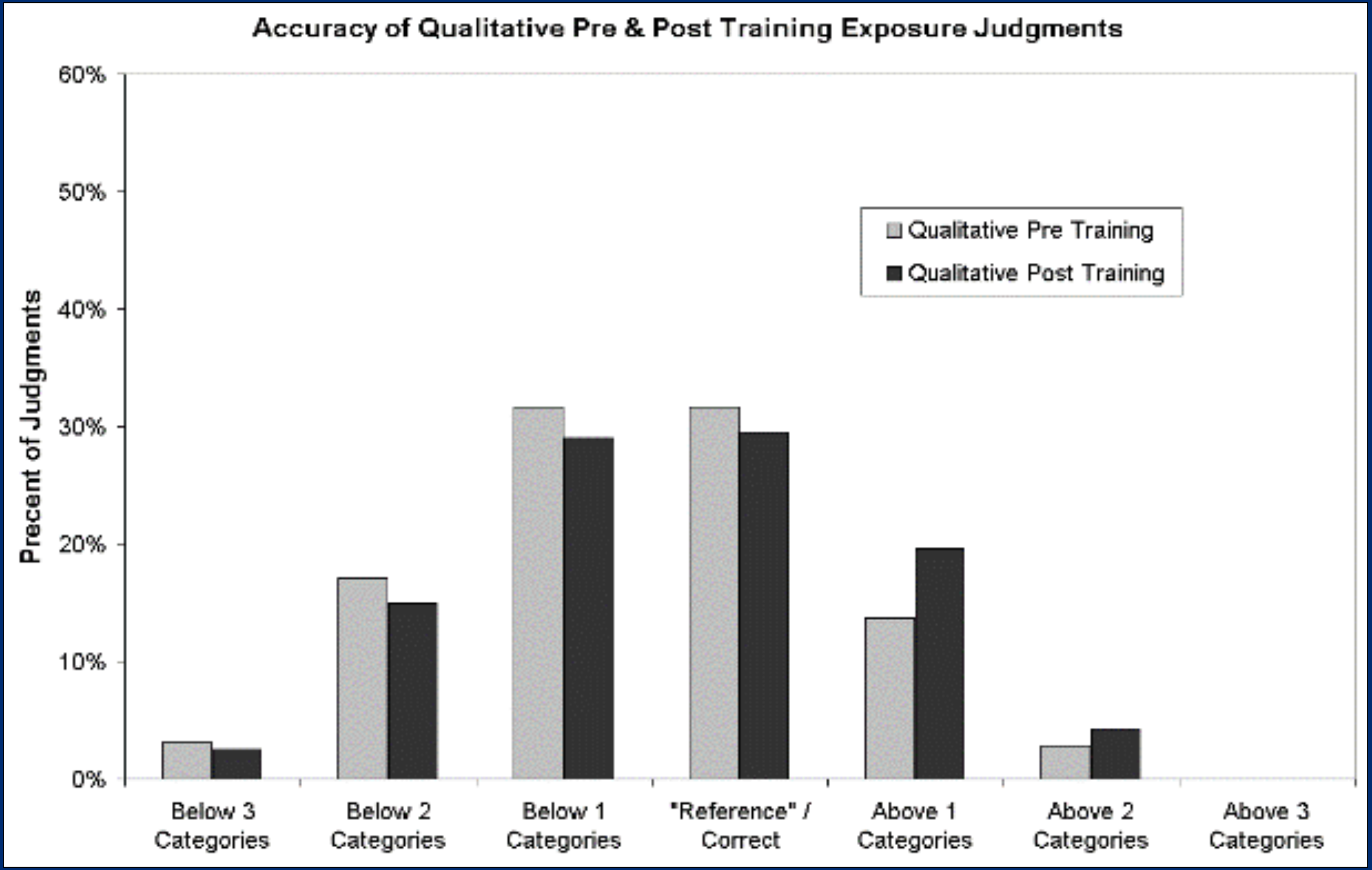
***Upper Tail Statistic decision = 90th, 95th, 99th percentile*



AIHA Exposure Strategy Handbook, 4th Ed.

Improving Exposure Assessments

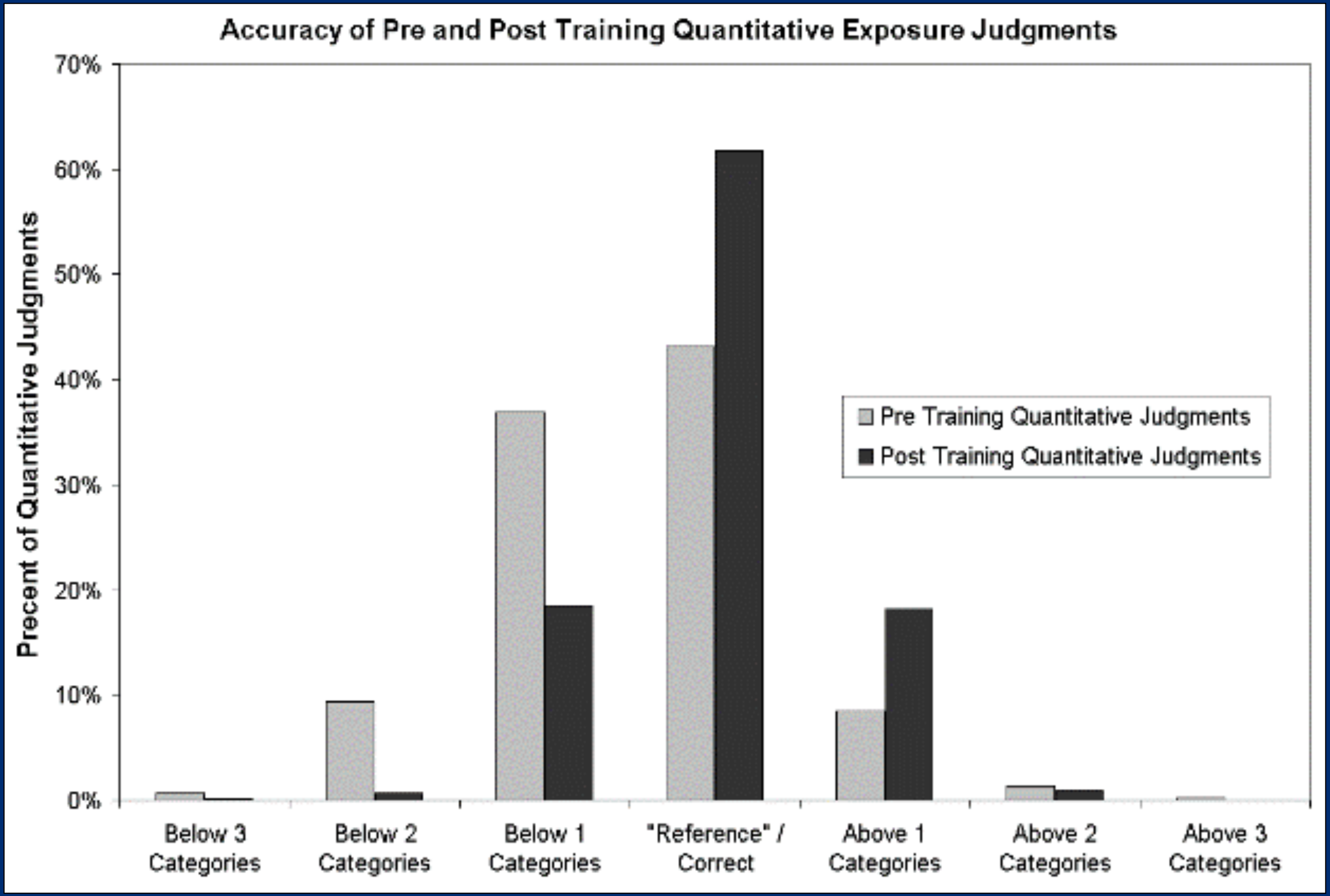
- Qualitative Assessments: >90% of all exposure assessments



Arnold et al., 2016

Improving Exposure Assessments

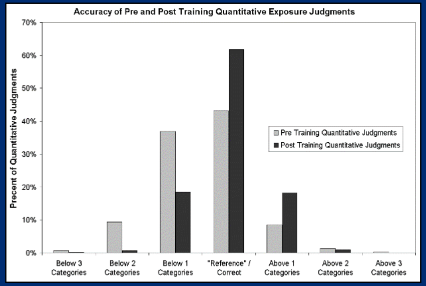
- Quantitative Assessment of Monitoring Data

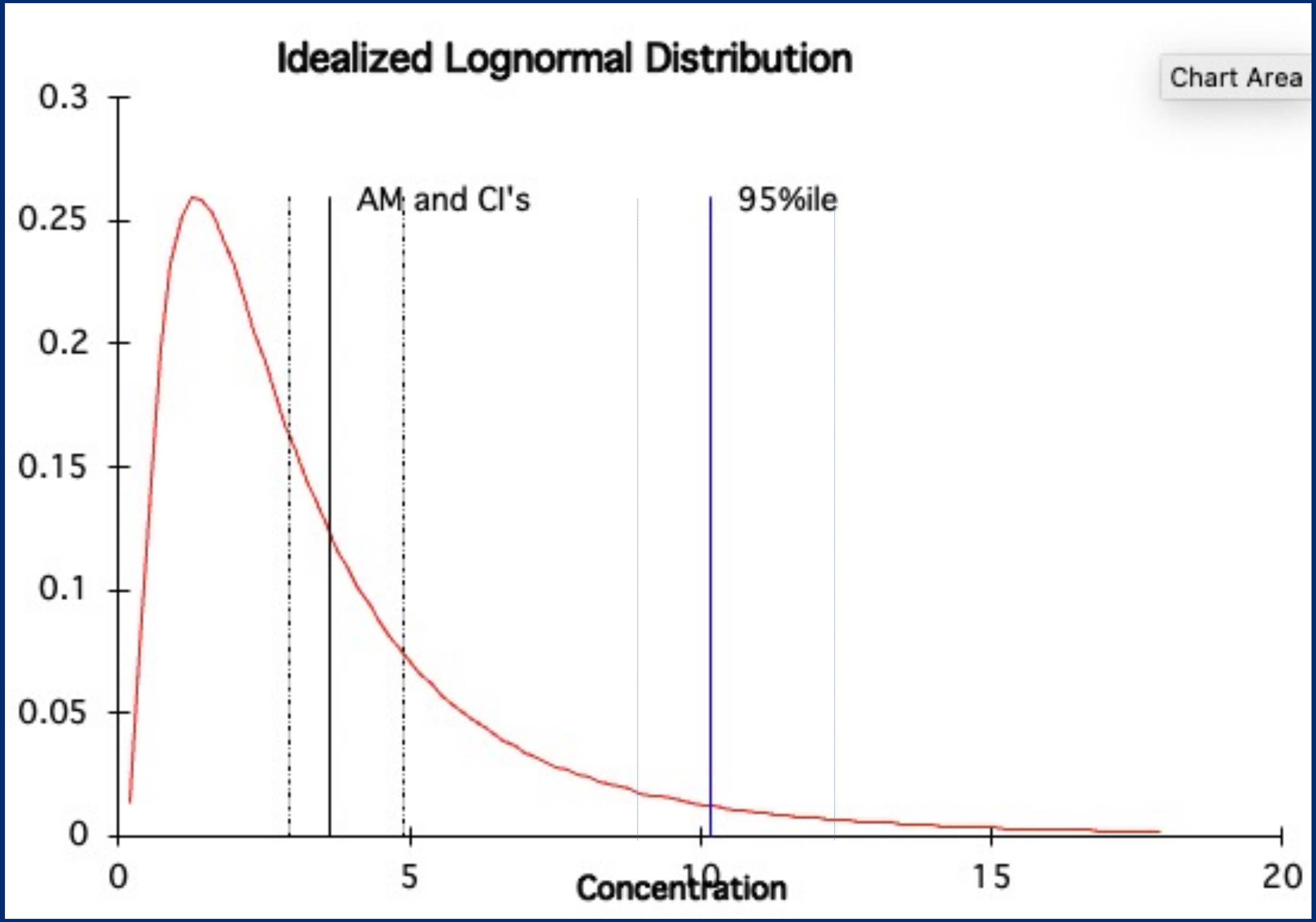


Logan, et al., 2009

Improving Exposure Assessments

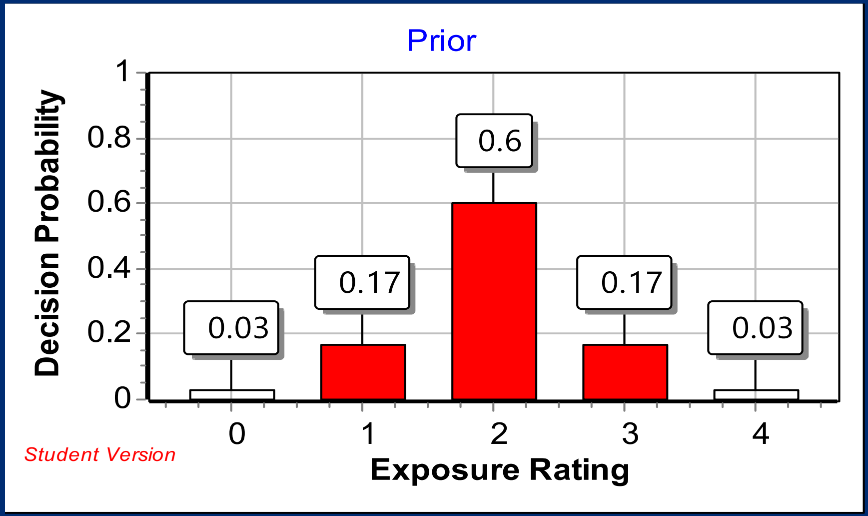
- Quantitative Assessment of Monitoring Data



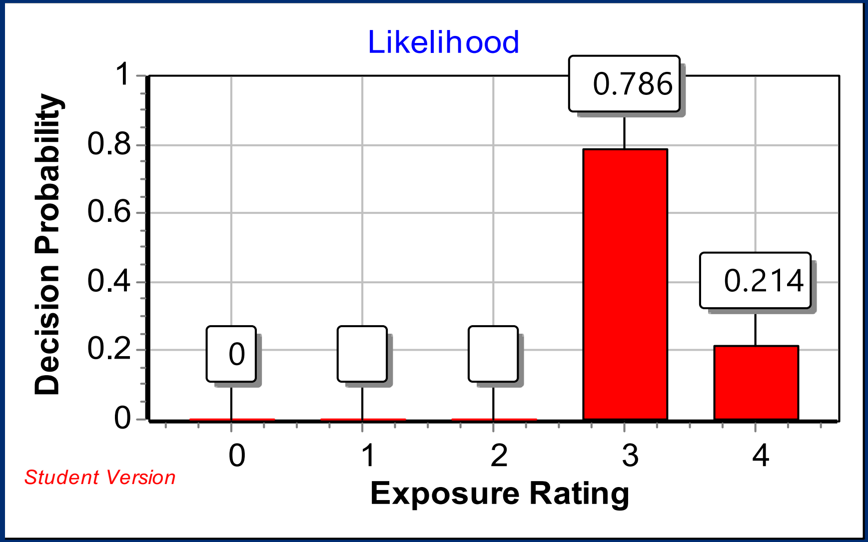


Bayesian Decision Analysis

- Informed Priors
  - Professional Judgments
  - Qualitative Assessments – Checklist
  - Modeling



- Likelihood – available Monitoring Data



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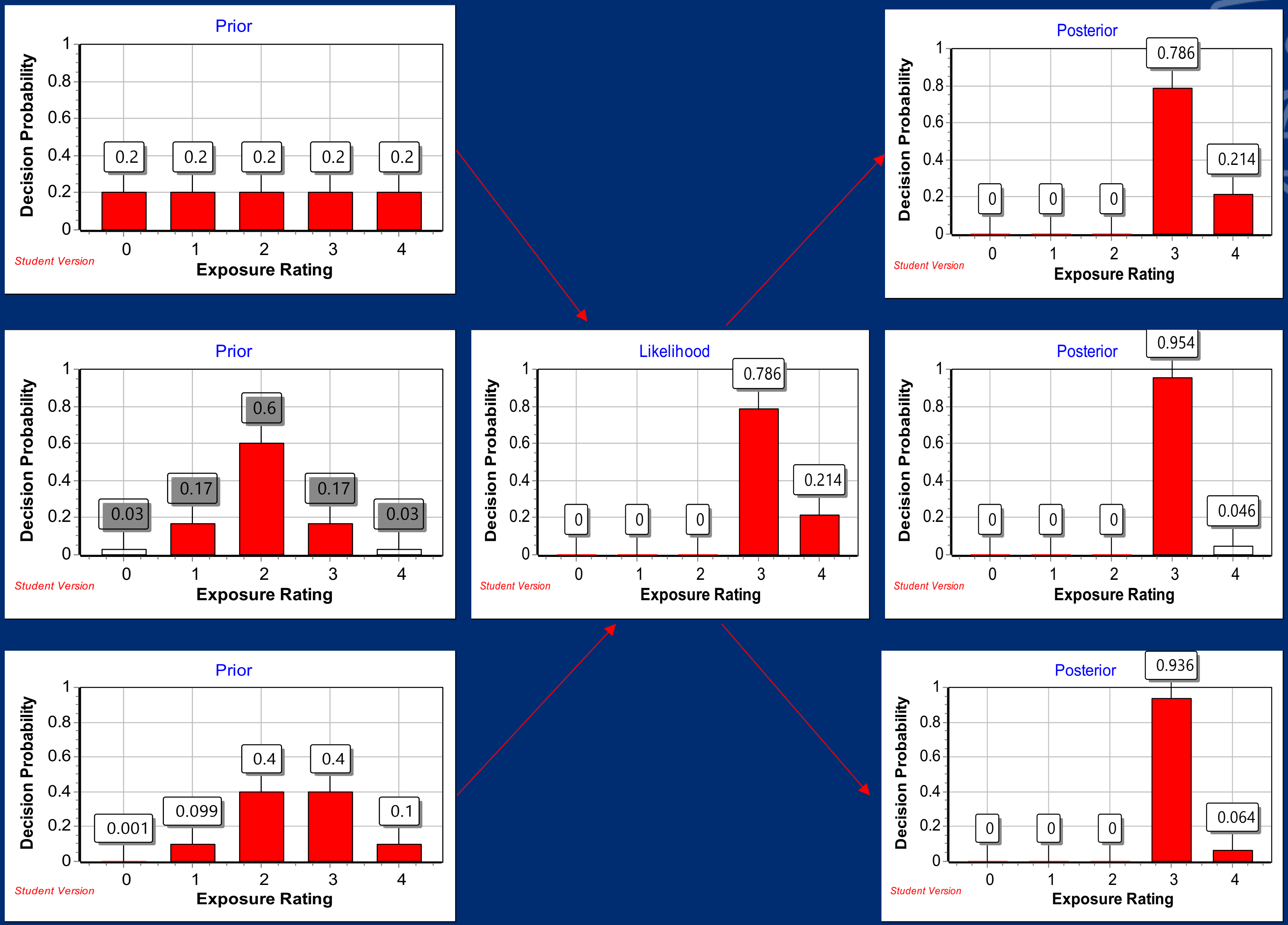
Hewett, 2023

Uniform Prior

Qualitative Informed Prior

Qualitative and Quantitative Modeling



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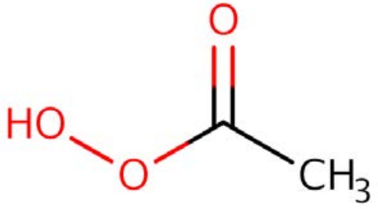
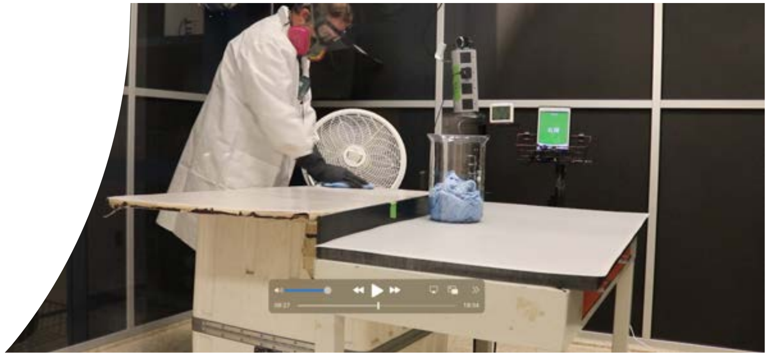
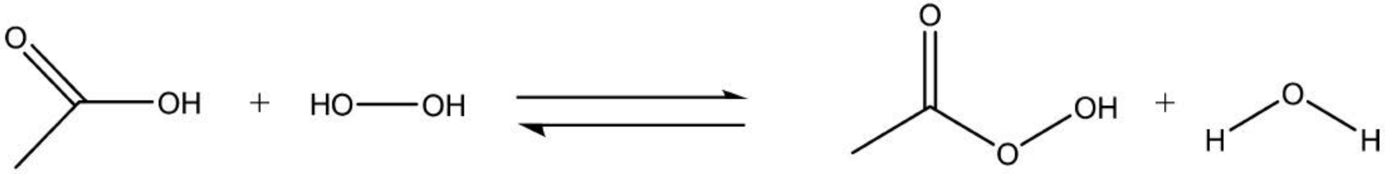
Peracetic Acid Case Study





NIOSH, HHE 2014-0196-3254



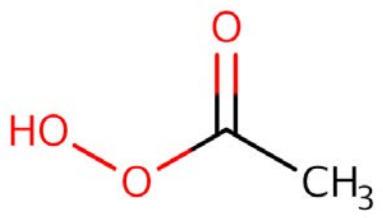
acetic acid   hydrogen peroxide   peracetic acid   water

Fig. 1. Reaction chemistry of peracetic acid.

https://www.google.com/url?sa=i&url=https%3A%2F%2Fwww.marsden.com%2F4-essential-evs-practices-to-improve-patient-outcomes%2F&psig=AOvVaw1daSpfs8kKLd6jbQ38tUqq&ust=1678762952240000&source=images&cd=vfe&ved=0CBAQjhxqFwoTCOCioL311_0CFQAAAAAdAAAAABAG

Basic Characterization - Background

- Peracetic Acid (CAS# 79-21-0)
  - Synonyms: Peroxyacetic Acid, PAA



- Effective Disinfectant – no rinse ~5 min contact time:
  - Food processing – poultry
  - Water/Wastewater Treatment
  - Healthcare
    - Cleaning equipment – endoscopes
    - General Disinfection
  - Outbreak / biological weapons decon

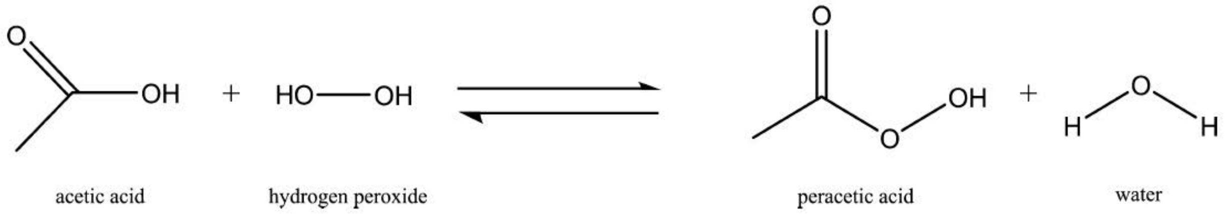


Fig. 1. Reaction chemistry of peracetic acid.

- 40 million pounds used annually in the United States

Basic Characterization - Background

- Disinfectants:
  - Concentrated form
    - PAA < 40% (general use, <15%)
    - Hydrogen Peroxide (HP): <30%
    - Acetic Acid: <10%
  - Dilution for Use:
    - PAA < 0.5%
    - HP <1%
    - Acetic Acid <1%

- Health Effects:
  - Skin Irritation (concentrated form)
  - Eye Irritation (burning eyes)
  - Upper Respiratory Irritation
  - Occupational Asthma(?) – at least one case

Regulatory Background

- Occupational Exposure Limits (OELs)
  - ACGIH – TLV
    - 15-min STEL = 0.4 ppm
  - US EPA AEGLs
    - AEGL-1 – 0.17 ppm (discomfort/irritation in general population, acute/reversible)
    - AEGL-2 – 0.5 ppm (serious adverse health effects / impaired ability to escape)
    - AEGL-3 – 60 mg/m^3 (10 min) – 4.1 mg/m^3 (8 hr) (life-threatening health effects)

    - Based on human (AEGL-1/2) and animal (AEGL-3) tox studies
      - AEGL-3 based on aerosol exposures, so not directly converted to ppm.
  - Proposed
    - NIOSH IDLH – 1.7 mg/m^3 (0.55 ppm)
    - CAL OSHA-HEAC – 0.4 ppm STEL; 0.15 ppm 8-hr PE

Sampling Methods

- Table recreated from NIOSH presentation by Dr. Kevin Dunn, CIH

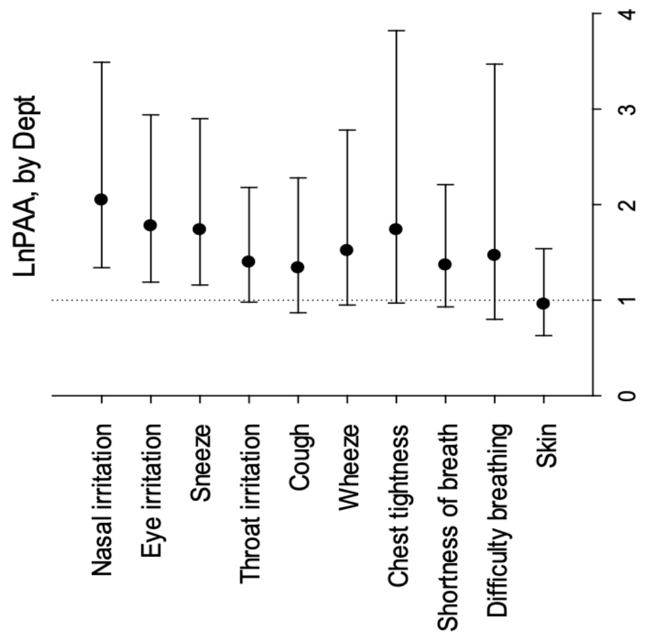
Method	Chemical Measurement	Manufacturer	Range	LOD
Direct Reading Methods	PortaSens II	Analytical Technology, Inc.	0 -2 ppm 0-20ppm	0.05 ppm 0.1 ppm
	SafeCide Portable Monitoring	ChemDAQ, Inc.	0-3ppm	0.01 ppm
	4000 Series Compact Portable Analyzer	Interscan Corp.	0-5 ppm 0-50 ppm	0.05 ppm 0.5ppm
Analytical Laboratory Methods	Impinger (colorimetric)	CHEMetrics, Inc.	0-1.6 ppm (per 15 L)	0.016 ppm
	Impinger (Hecht liquid analysis)	Reagents purchased directly	0.02 – 16.2 ppm (per 15 L)	0.003 ppm 0.013 ppm
	Sorbent tubes (Hecht)	SKC, Inc.	At least 0.47 ppm (per 15 L)	0.005 ppm

ChemDAQ Safecide Portable Monitor

- Range: 0-3ppm
- Accuracy: ±5%
- Resolution: 0.01 ppm
- Response Time (T90): < 120 sec
- Bluetooth output to tablet

Previous Exposure Assessments - 1

- AIHA Healthcare Working Group (HCWG) Data:
  - 23 Sampling Events – no reported adverse health effects
  - Range (21 events)– sampling times ≤45 minutes: < 0.12 ppm – 0.33 ppm
    - 2 other reports of full shift exposures
- NIOSH Health Hazard Evaluations:
  - Hospital Employees (Report No. 2017-0114-3357), 2019
    - Full-shift monitoring: Max = 28 ppb (n=56)
  - Health Effects Questionnaire Hospital Cleaning Staff that used disinfectant (PAA, HP, AA):
    - Eye Irritation – 44%
    - Upper Airway – 58%
    - Lower Airway – 34%



https://www.cdc.gov/niosh/hhe/reports/pdfs/2017-0114-3357.pdf

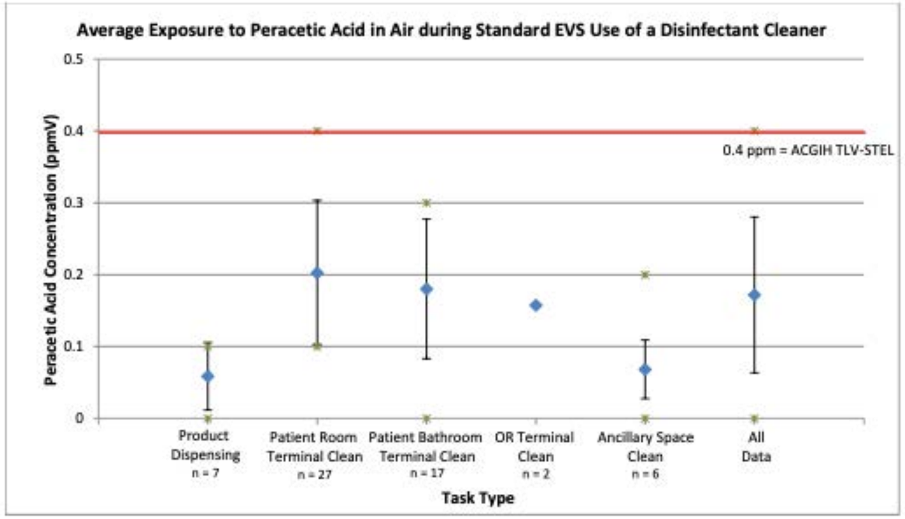
Hawley, B, et al. “Respiratory Symptoms in Hospital Cleaning Staff Exposed to a Product Containing Hydrogen Peroxide, Peracetic Acid, and Acetic Acid.” *Annals of Work Exposures and Health* 62, no. 1 (January 1, 2018): 28–40. https://doi.org/10.1093/annweh/wxx087.

Previous Exposure Assessments - 2

- Hospital Trial of PAA-based disinfectant: (n=11 samples)[1]
  - Range: 0.21 – 0.49 ppm
  - GM (GSD): 0.32 (1.24)
  - $X_{0.95}$ = 0.45 (ECC Class 4 - $X_{0.95}$ > OEL)
  - Exceedance Fraction = 14%
- The Peroxy Compounds Task Force Comments[2]:
  - Scenario 1 – Healthcare Application (n=59)
  - Range: ND - 0.4 ppm
  - Calculated Values from data plot (approx.)
    - Mean / SD = 0.18 (0.11)
    - GM / GSD: 0.15 (1.76)
    - $X_{0.95}$ = 0.39 (ECC Class 3 – 50% OEL < $X_{0.95}$ <OEL)
    - Exceedance Fraction = 4%

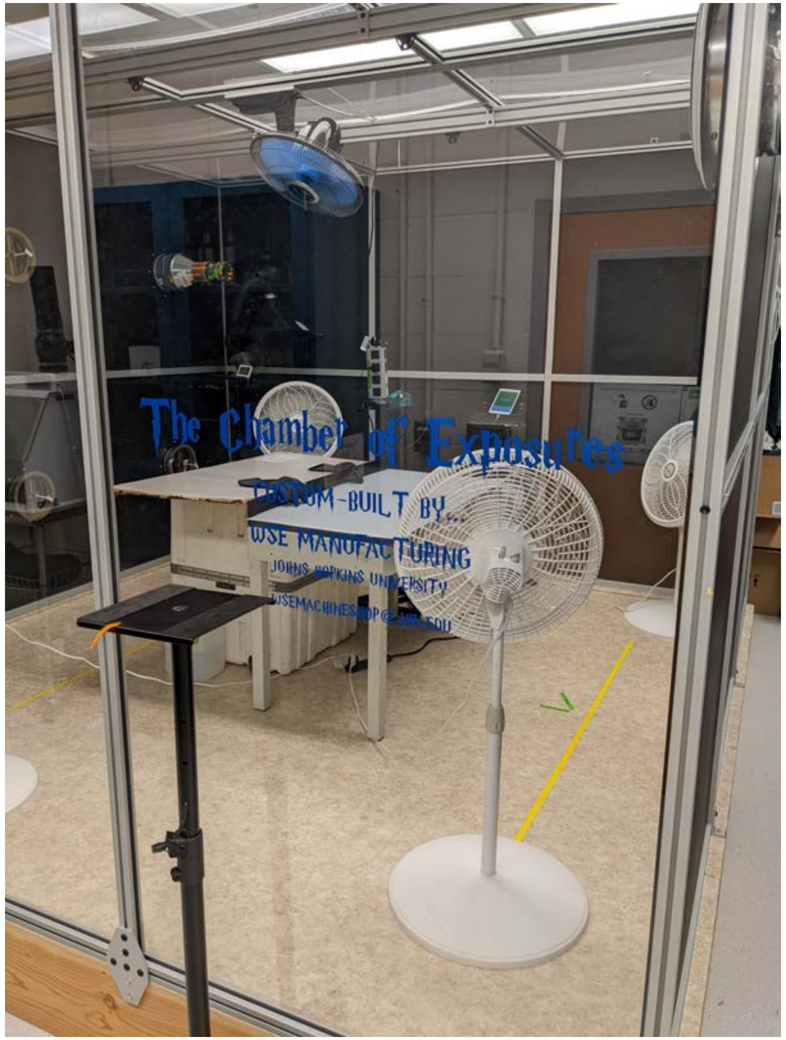
Peracetic Acid Results (15 min)

Average concentration, standard deviation, and range



1.Regions Hospital. Information on Peracetic Acid Monitoring submitted in response to NIOSH Request For Information on Peracetic Acid IDLH (NIOSH 2017-0015-RFI (CDC-2017-0015-0007_attachment_2.pdf). https://www.regulations.gov/document/CDC-2017-0015-0001
2. The Peroxy Compounds Task Force Peracetic Acid Group. Comments Submitted in Response to the Request for Information on Health Risks to Workers Associated with Occupational Exposures to Peracetic Acid, October 1, 2017. CDC-2017-0015-0012_attachment_1_data.pdf. https://www.regulations.gov/document/CDC-2017-0015-0001

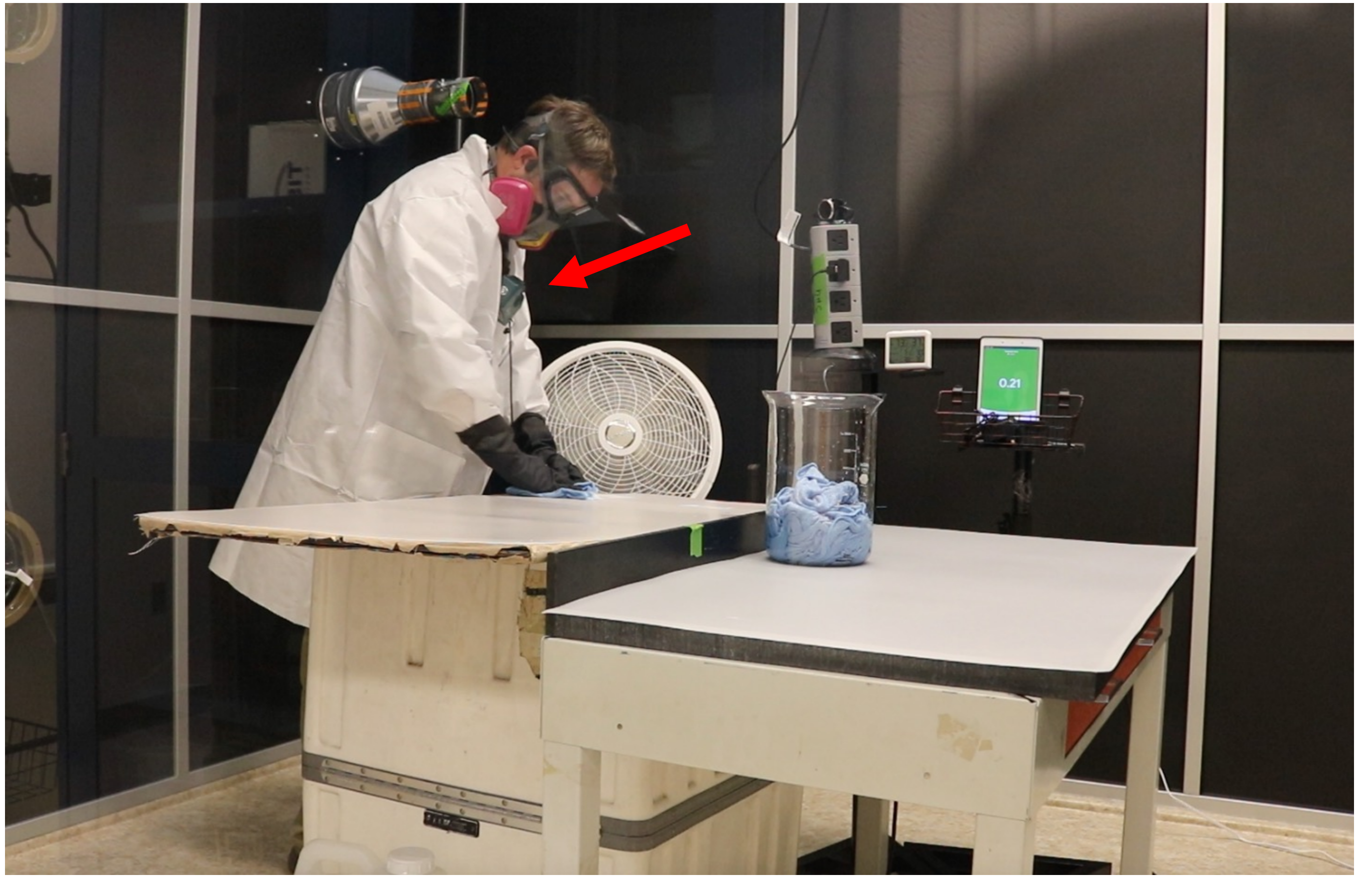
Highly-Controlled Exposure Scenarios



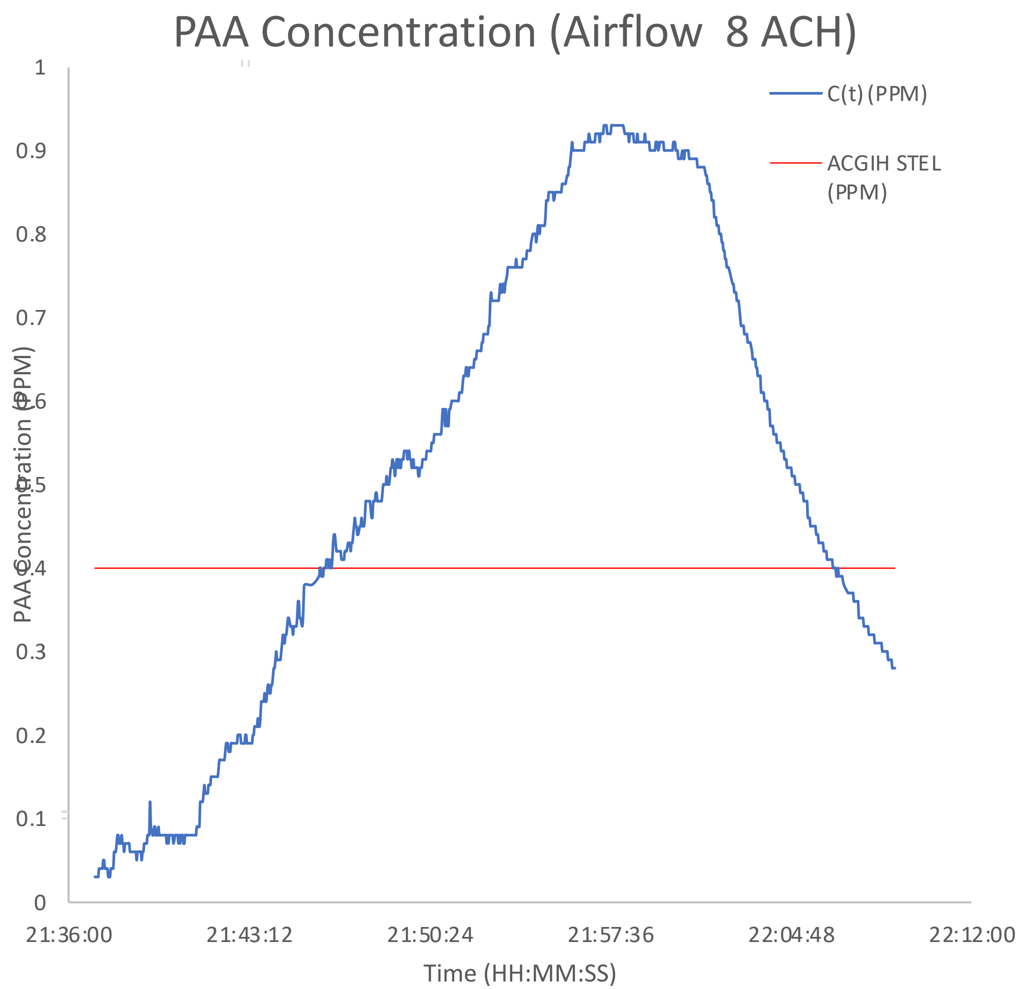
- 27.4 m^3 (11'x11'x8') Exposure Chamber
- Control Airflow (Q): 0-20+ ACH
  - w/ dedicated exhaust fans
  - Flow meter
- Conditioning Pre-Chamber
  - Temperature 70 ° -100°F
  - RH: 20%-75%
  - MERV-14 air filter

Highly-Controlled Exposure Scenarios

- Wiping Scenarios performed in a highly-controlled Exposure Chamber
- Wiping: 6 Wipes / 15 minutes
- ChemDAQ Meter
- Floor Fans (4x) set to low
  - Well-Mixed Room Model
- T = 70-75 ˚F / RH = 32-69 %
- ACH: 2 – 8 ACH
- Dilute Disinfectant to 3% w/ DI Water
  - Concentration of PAA = 0.13%



Results

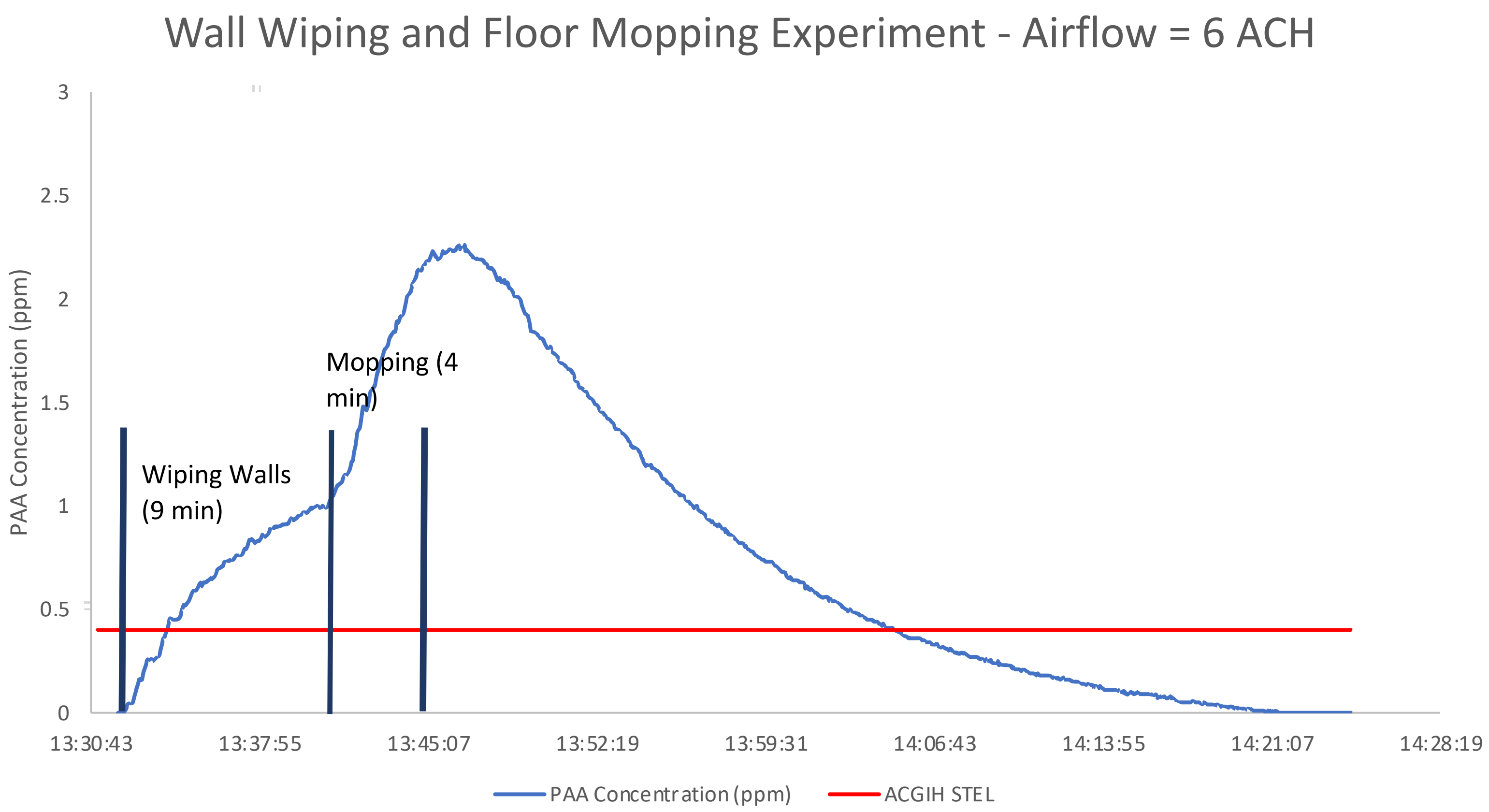


ACH	Mean Airflow (cfm)	Mean 15 minute TWA Concentration (ppm)	Mean of Maximum Concentration (ppm)
2		0.67 ± 0.10	
4		0.64 ± 0.19	1.37 ± 0.22
8			

Wall wiping / Floor Mopping

Wall wiping / Floor Mopping

Results



Wall Wiping and Floor Mopping Experiment - Airflow = 6 ACH
PAA Concentration (ppm)
3
2.5
2
1.5
1
0.5
0
Mopping (4 min)
Wiping Walls (9 min)
13:30:43
13:37:55
13:45:07
13:52:19
13:59:31
14:06:43
14:13:55
14:21:07
14:28:19
PAA Concentration (ppm)
ACGIH STEL

Modeling Information – Well-Mixed Room

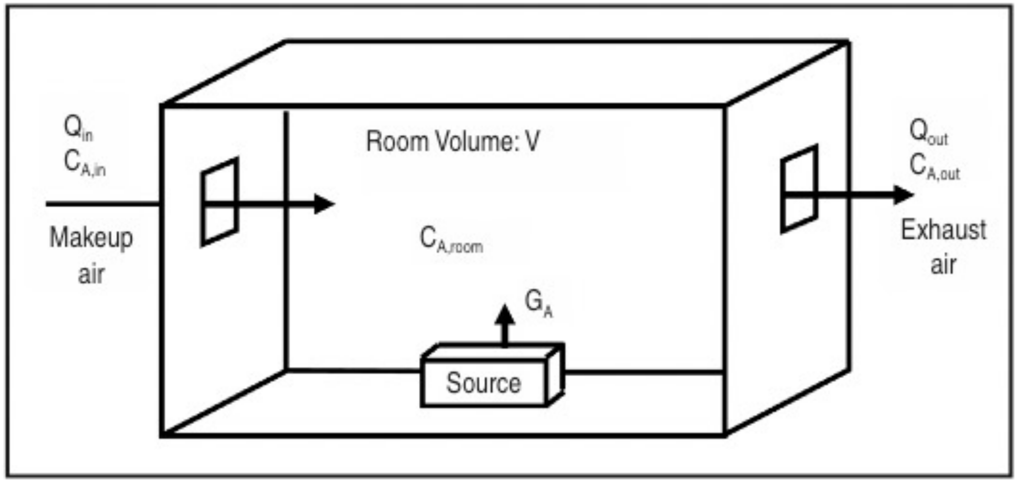
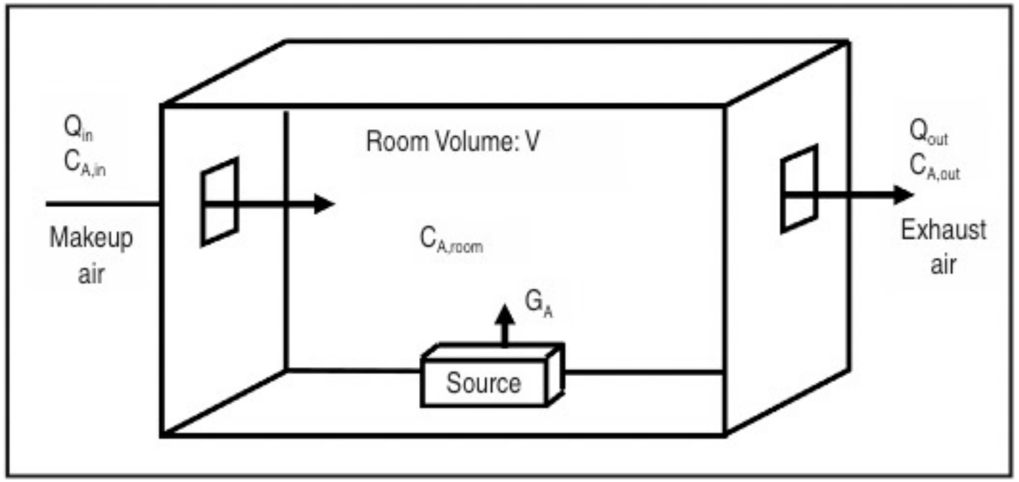


Figure 4.1 — Conceptual Model of the Well Mixed Box.

$$C(t) = \frac{G_{n(t)} + C_{in} * Q}{Q + k_L * V} * \left[1 - e^{\left(-\frac{Q+k_L*V}{V}*t\right)}\right] + C_0 * e^{\left(-\frac{Q+k_L*V}{V}*t\right)}$$

Modeling Information – Well-Mixed Room



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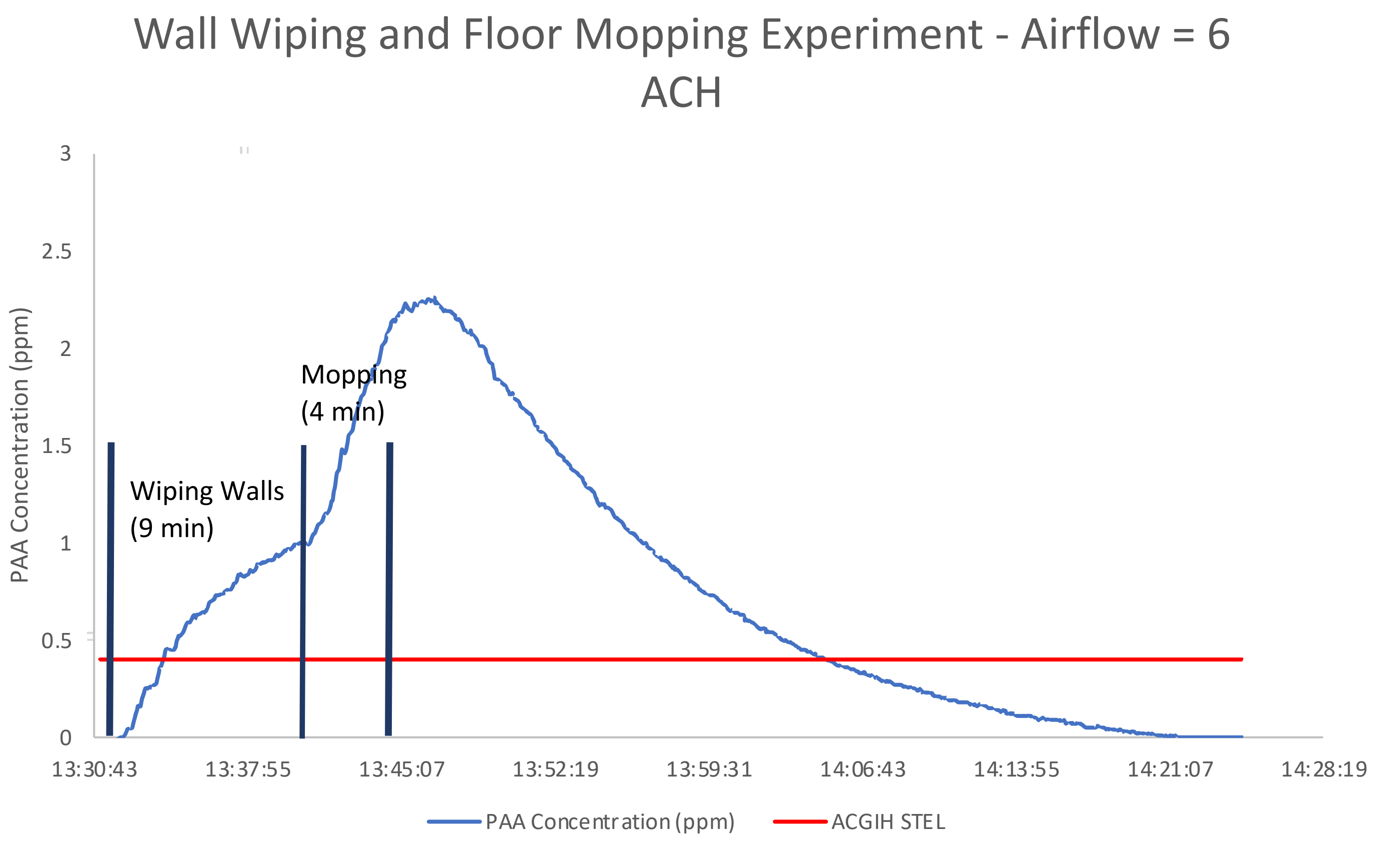
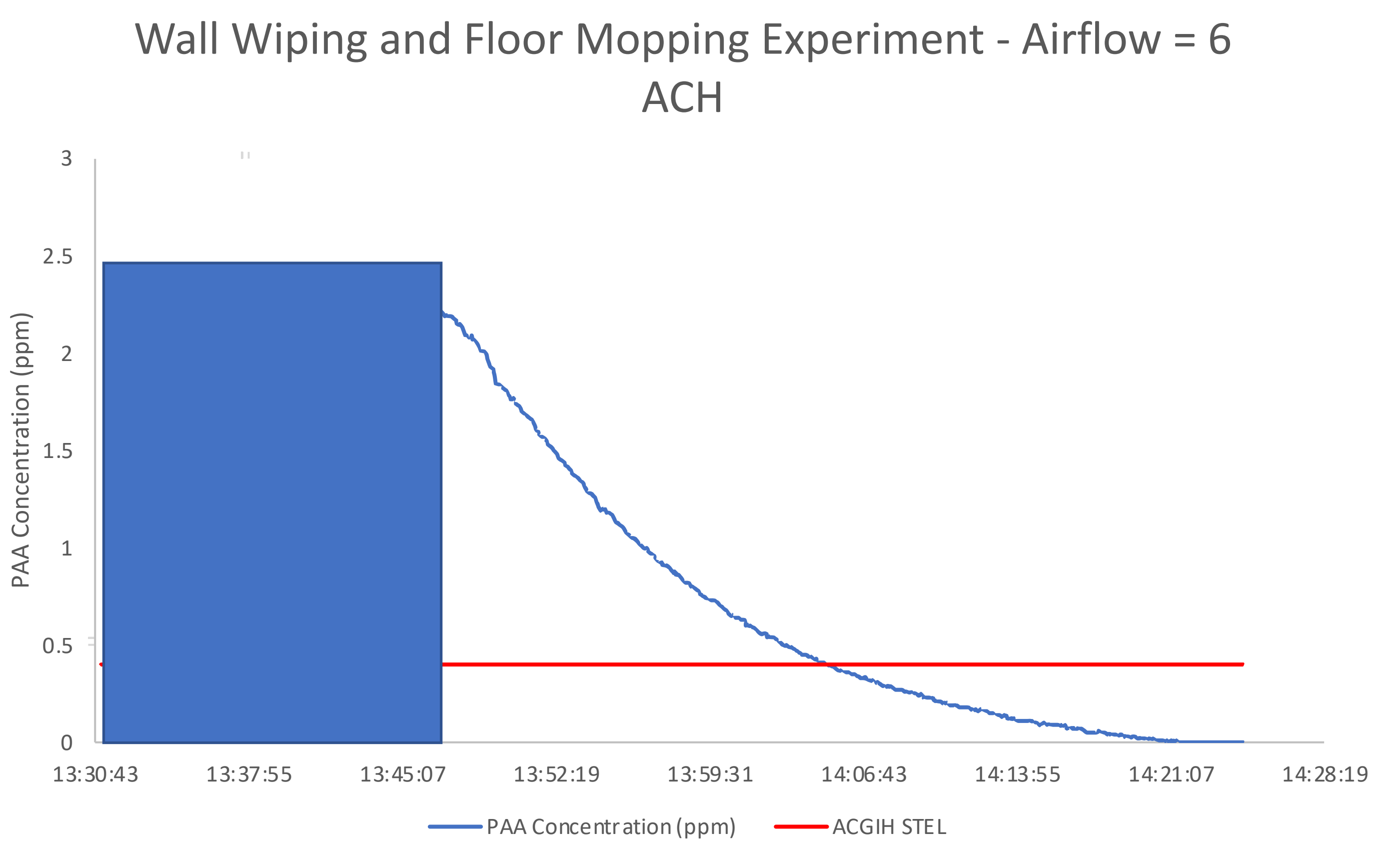
Assume, $K_L = 0$, Good Assumption?

Well-Mixed Room Model – Decay Rate



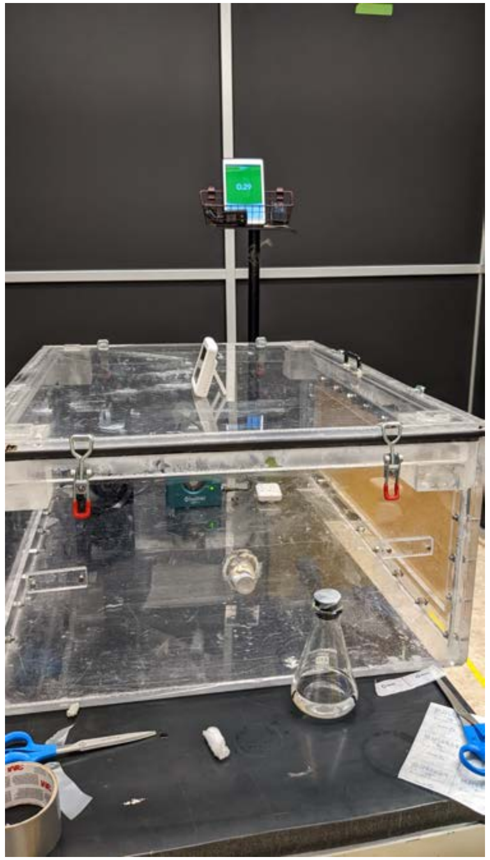
Well-Mixed Room Model – Decay Rate

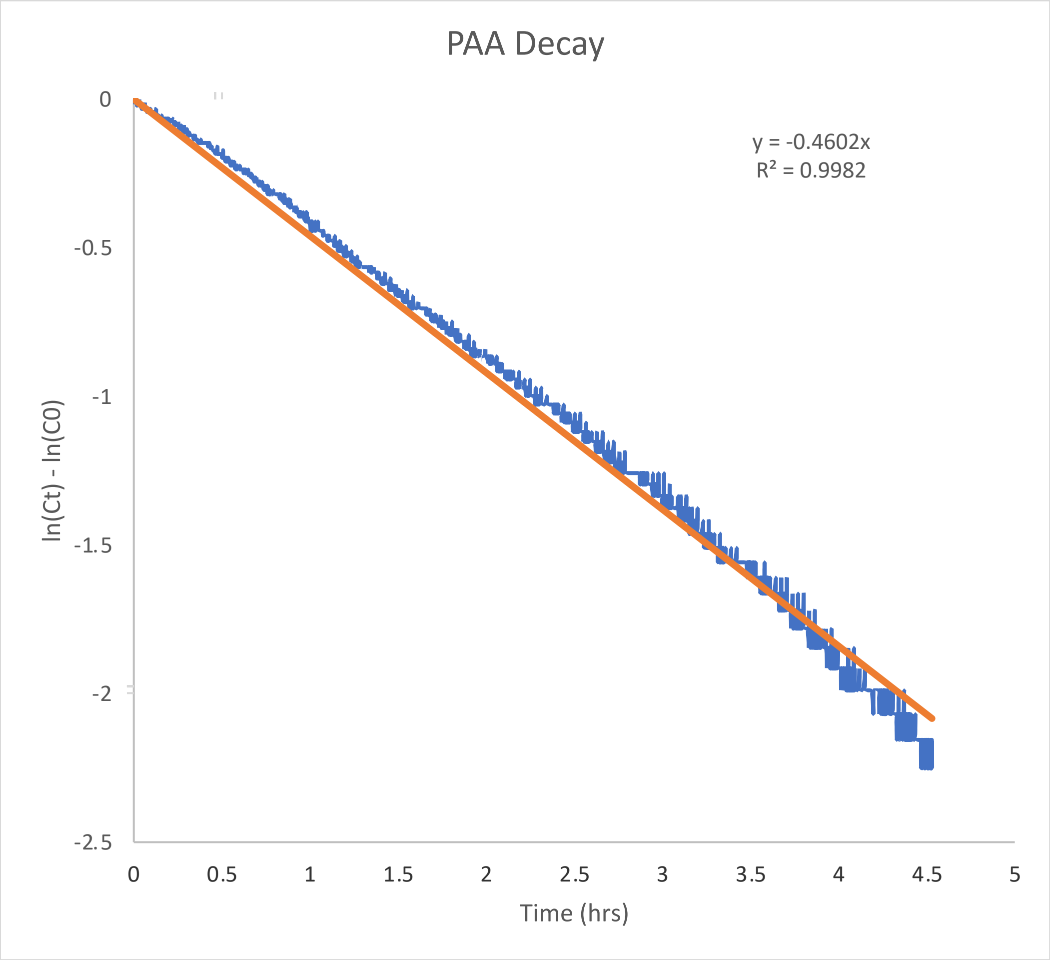


$$C(t) = C_0 * e^{\left(-\frac{Q}{V} * t\right)}$$

Modeling Information – Decay

- First Order Decay:
  - First Order decay in water
  - $C(t) = C_0 * e^{\wedge -\alpha * t}$
  - α – decay rate coefficient
  - Closed small chamber exp
    - Fan in chamber
    - 12 experimental runs
  - α (hr^{-1})= 0.5 ±.07
    - Half-Life = 83 min
    - Previous report – 22 min
  - Over 15 min, loss is <10%



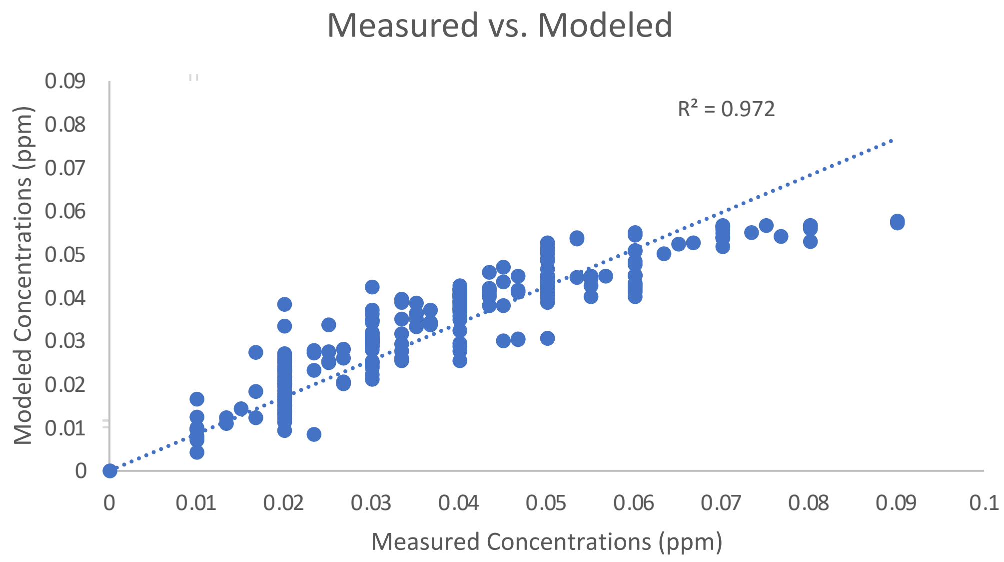


Modeling Information – Well-Mixed Room

- In our case, G(t) is from evaporation – assumption that evaporation rate is from Small Spill Model
  - Iteratively solve for k (evaporation constant)
  - Method presented in paper by Arnold et al., 2019

Small Spill Model:

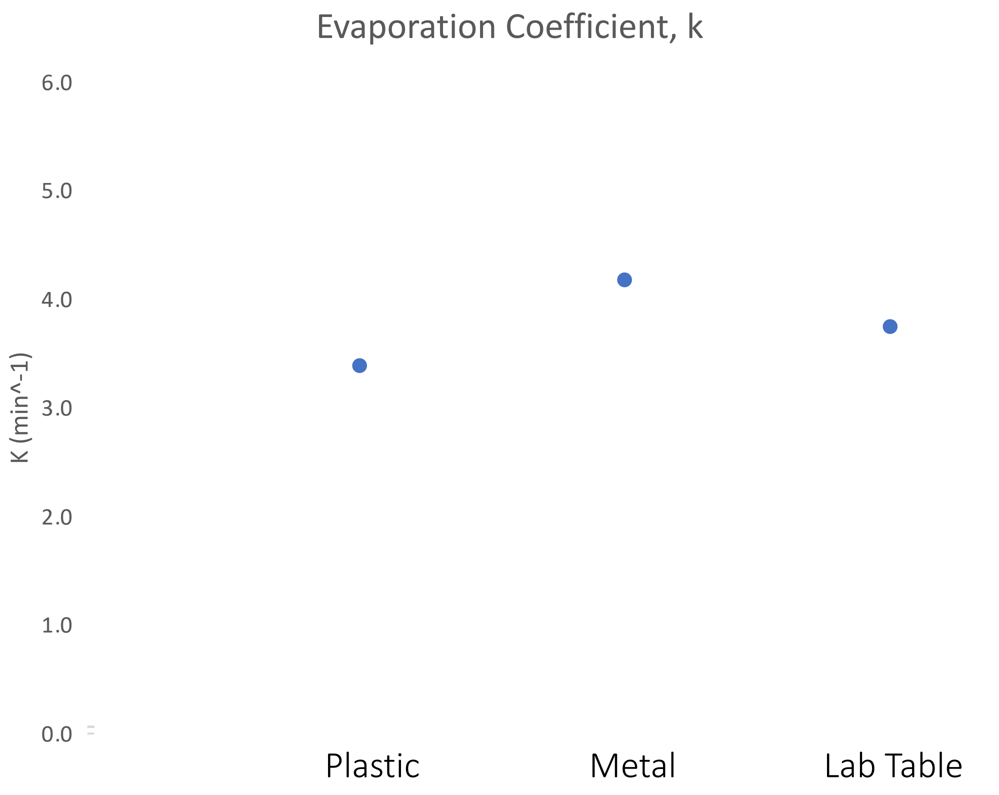
$$G(t) = M_0 * k * e^{-kt}$$



Modeling – Evaporation Constant

- Surface (Roughness):
  - Plastic (HDPE)
  - Metal Shelving
  - Composite Lab Table
- Wind Speed
- Volume / Surface Area
- Concentration

$$G(t) = M_0 * k * e^{-kt}$$



Modeling – Evaporation Constant

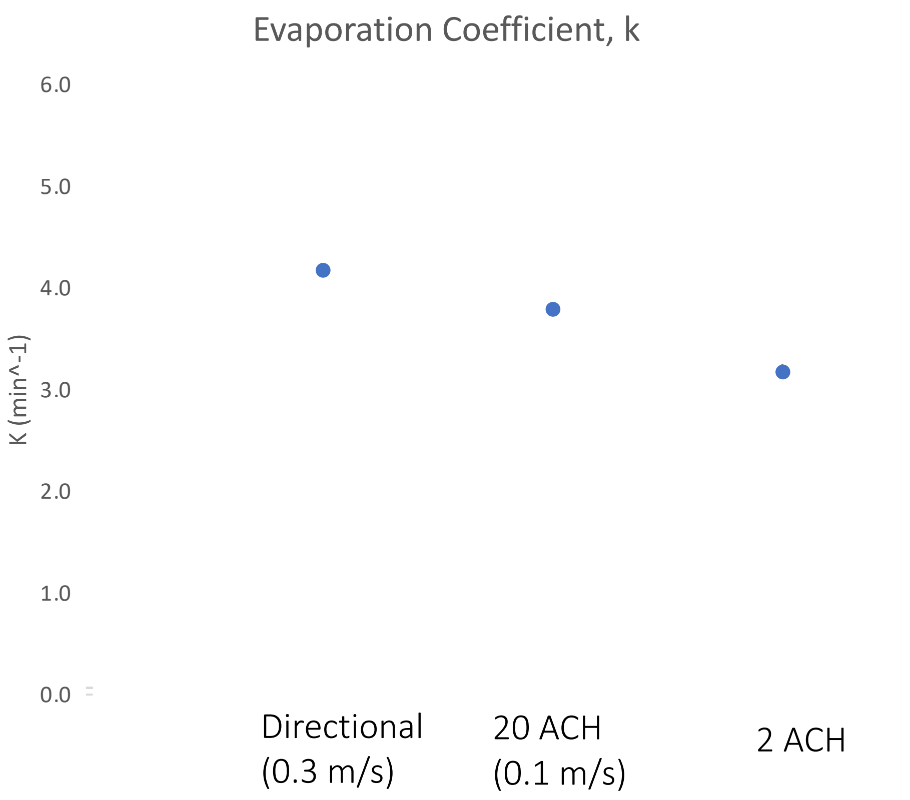
- Surface Roughness:
  - Plastic (HDPE)
  - Metal Shelving
  - Composite Lab Table

- Wind Speed

  Local (Directional Flow)

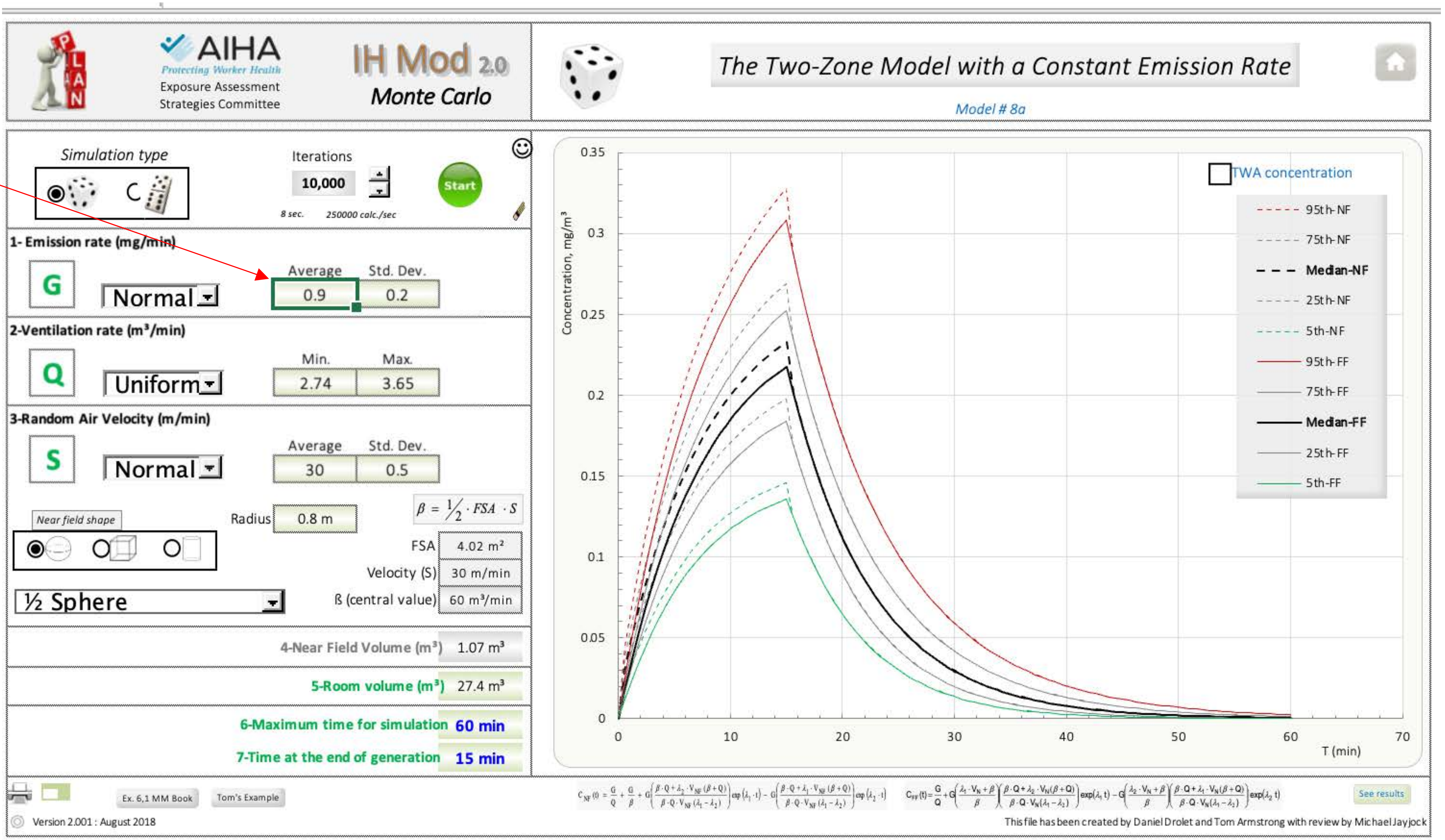
  Q (ACH)

- Volume / Surface Area
- Concentration



Bayesian Decision Analysis – Modeling Prior

$$G(t) = M_0 * k * e^{-kt}$$



- Q = 6 to 8 ACH
- S(random air velocity)
- V = 27.4 m^3
- Gen. Time = 15 min

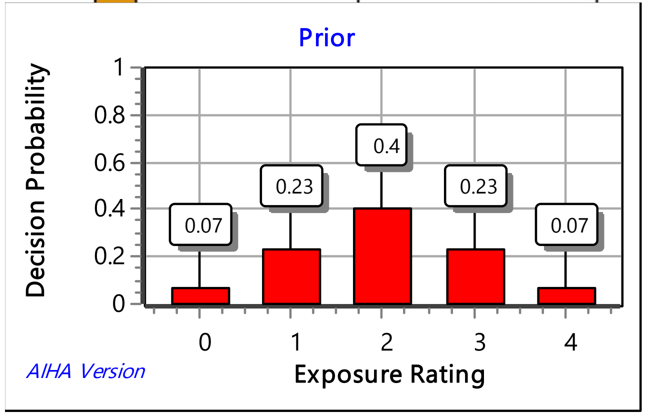
Armstrong, Drolet, Jayjock, 2018

Bayesian Decision Analysis – Modeling Prior

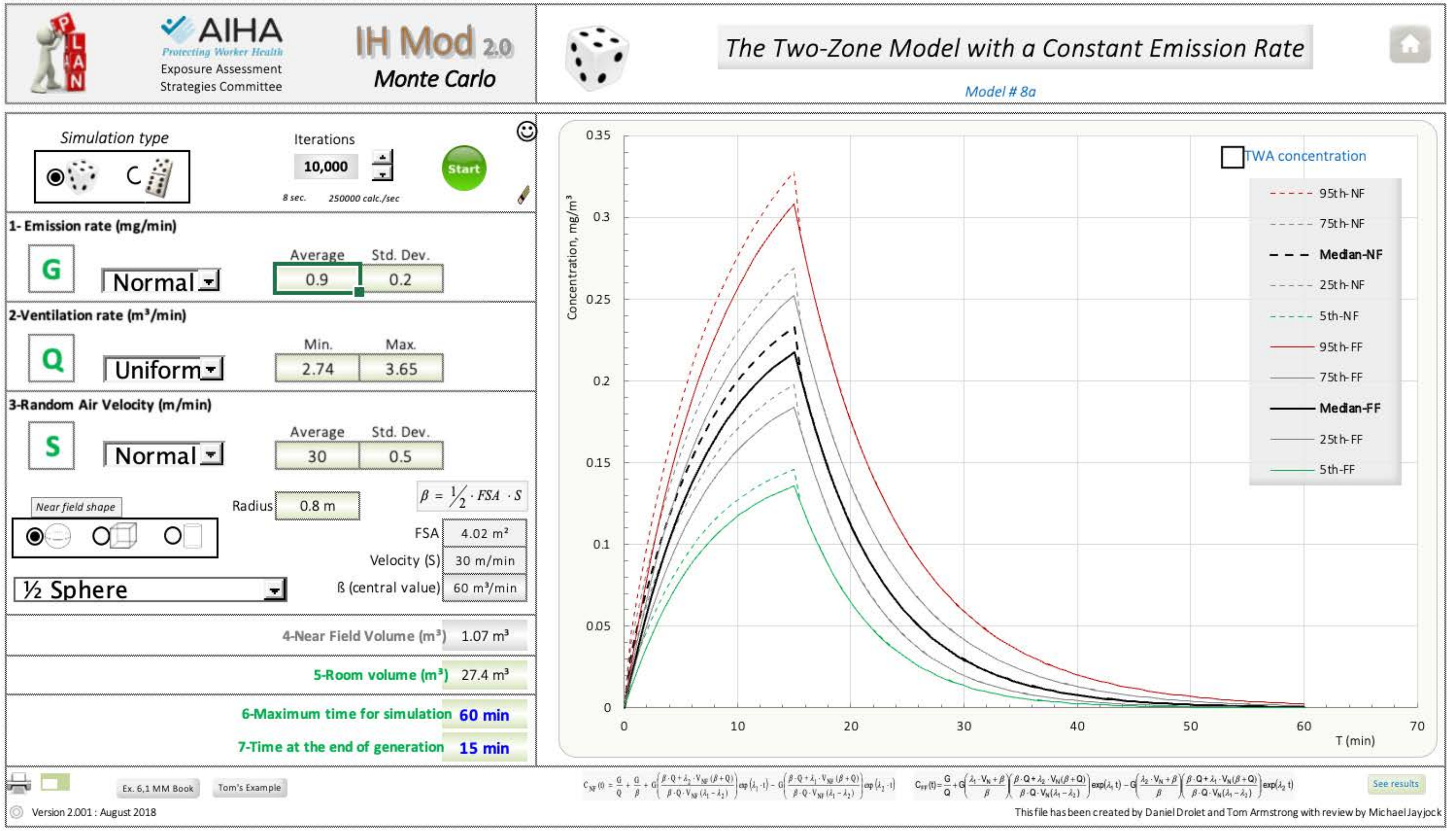
C_{max} = 0.33 mg/m³
= 0.11 ppm

ACGIH STEL = 0.4 ppm

Management and Exposure Control Categories		
	SEG Exposure Control Category**	Applicable Management/ Controls
	0 (<1% of OEL)	no action
	1 (<10% of OEL)	procedures and training, general hazard communication
	2 (10-50% of OEL)	+ chemical specific hazard communication, periodic exposure monitoring

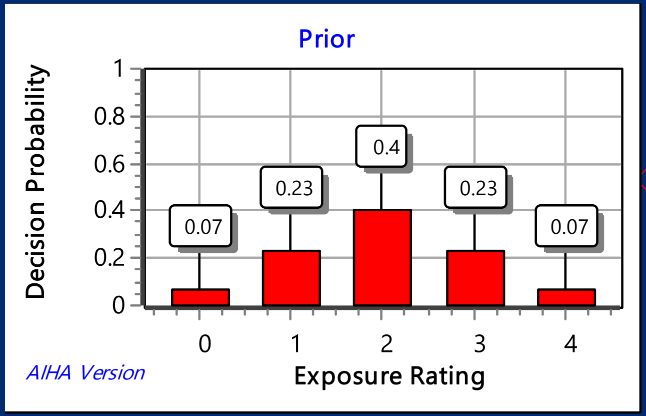


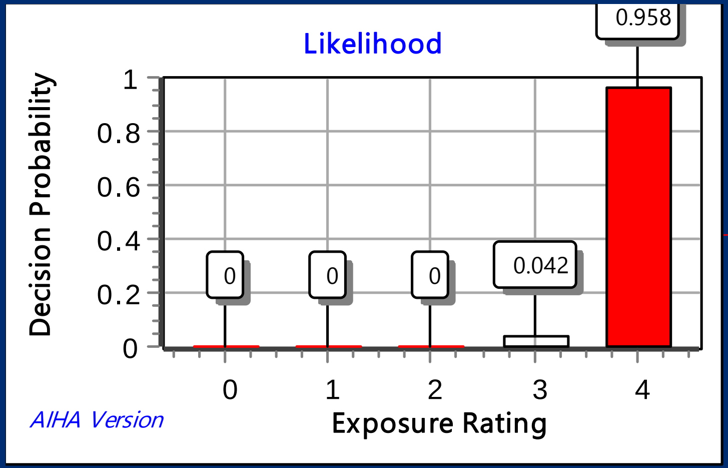
IHMod 2.0

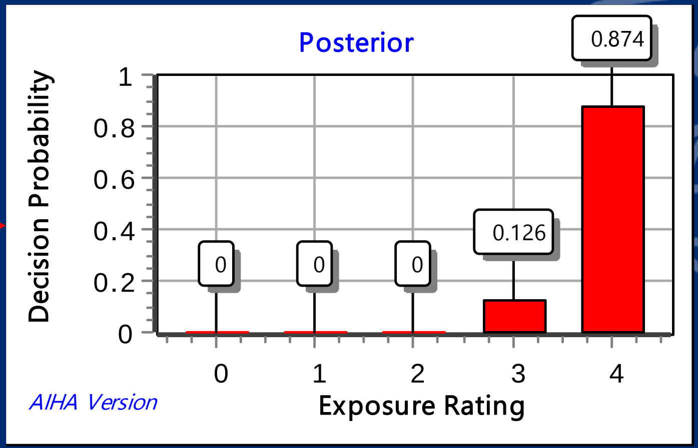


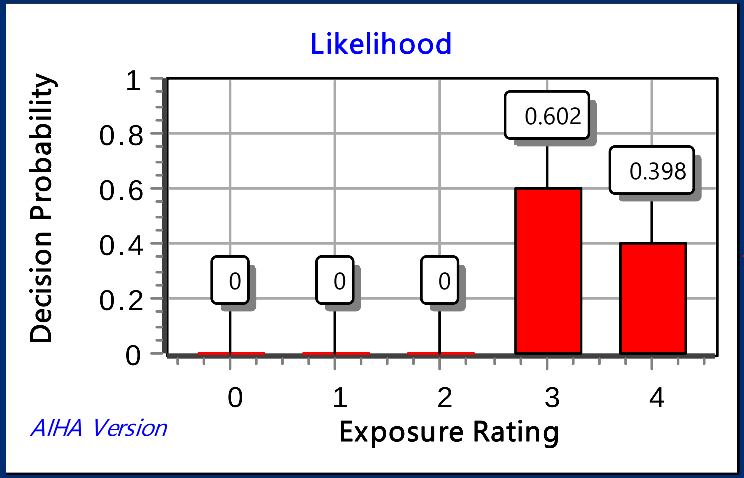
Armstrong, Drolet, Jayjock, 2018

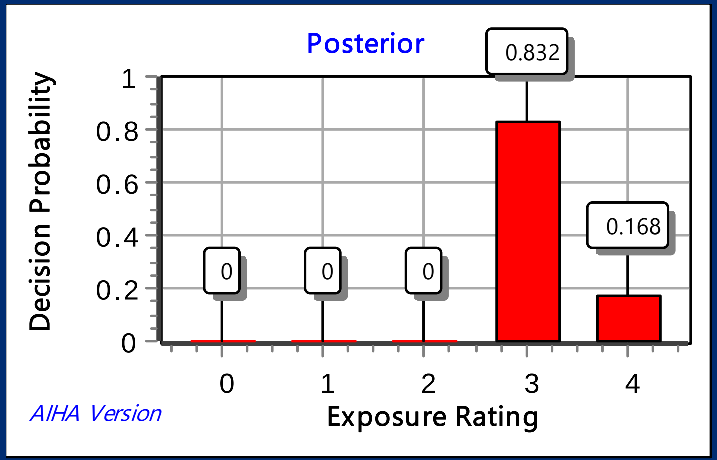
Quantitative Modeling Prior











AIHA IHDA
Hewett, 2023

Modeling Information – Likelihood

- Previous Assessments – submitted in response to NIOSH IDLH

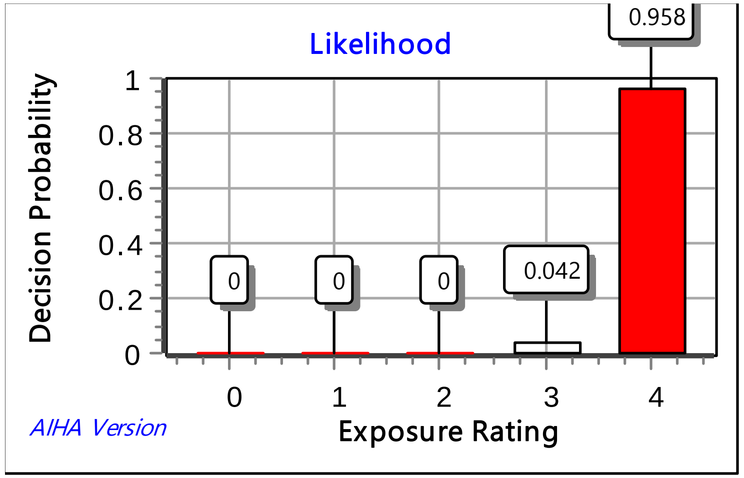
Hospital Trial of PAA-based disinfectant: (n=11 samples)

Range: 0.21 – 0.49 ppm

GM (GSD): 0.32 (1.24)

$X_{0.95}$ = 0.45 (ECC Class 4 - $X_{0.95}$ > OEL)

Exceedance Fraction = 14%



Scenario 1 – Healthcare Application (n=25)

Range: ND - 0.4 ppm

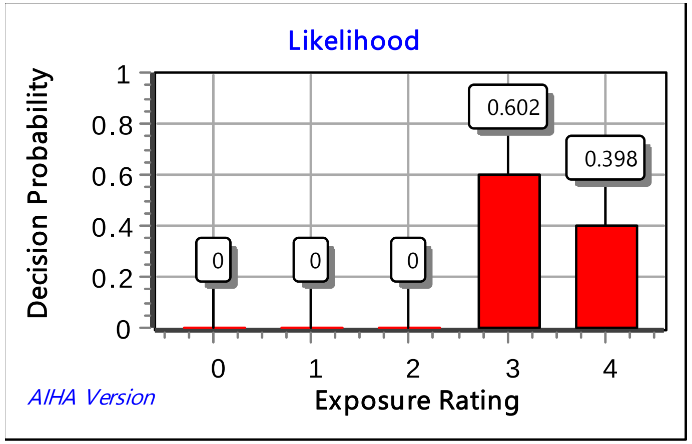
Calculated Values from data plot (approx.)

Mean / SD = 0.18 (0.11)

GM / GSD: 0.15 (1.76)

$X_{0.95}$ = 0.39 (ECC Class 3 – 50% OEL < $X_{0.95}$ <OEL)

Exceedance Fraction = 4%



IHDA-AIHA Version
Hewett, 2022

BDA Results – Posterior

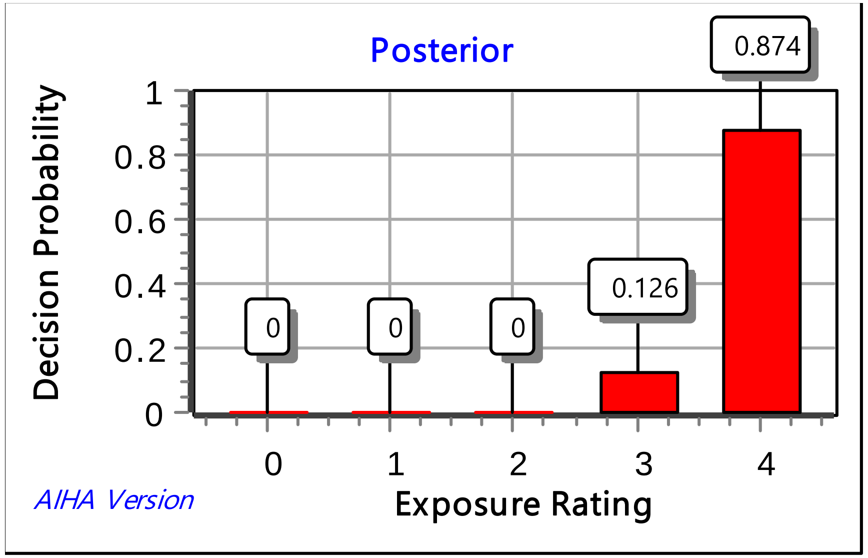
Hospital Trial of PAA-based disinfectant: (n=11 samples)

Range: 0.21 – 0.49 ppm

GM (GSD): 0.32 (1.24)

$X_{0.95}$ = 0.45 (ECC Class 4 - $X_{0.95}$ > OEL)

Exceedance Fraction = 14%



Scenario 1 – Healthcare Application (n=25)

Range: ND - 0.4 ppm

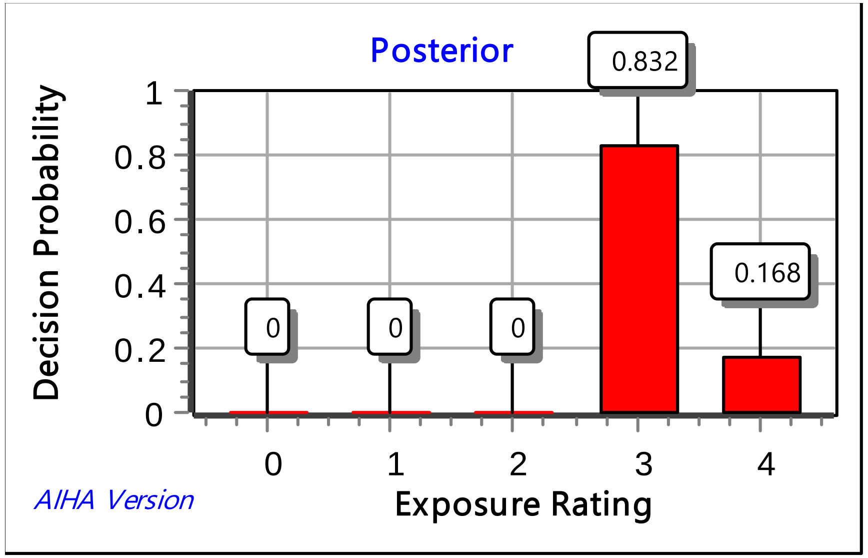
Calculated Values from data plot (approx.)

Mean / SD = 0.18 (0.11)

GM / GSD: 0.15 (1.76)

$X_{0.95}$ = 0.39 (ECC Class 3 – 50% OEL < $X_{0.95}$ <OEL)

Exceedance Fraction = 4%

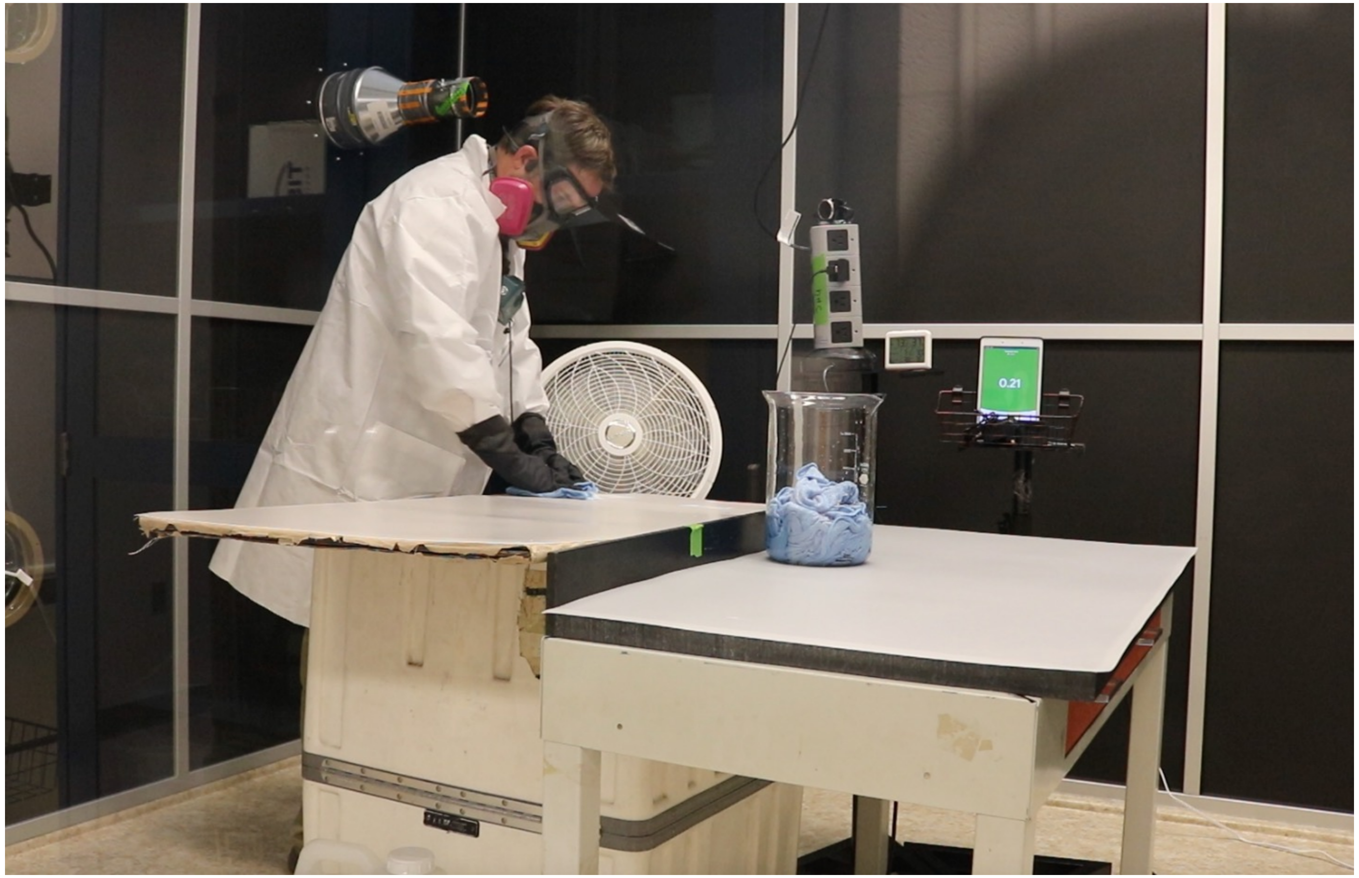


IHDA-AIHA Version
Hewett, 2022

Conclusions and Next Steps

- PAA Additional Work on other factors in Evaporation Constant
  - Volume / Surface Area
  - Concentration
  - ACH Range
- Guidance Values of M_0
- Regression Analysis

- Decay Rate of PAA
- Evaporation Coefficient
- Model for wiping scenario



Improving Exposure Judgments

AIHce 2023: PDC 704

PDC 704: Improving Inhalation Exposure Assessments – Day 1

Sat, 5/20: 8:00 AM - 5:00 PM MST
P704

CM Credit Hours: 14
Professional Development Course
Phoenix Convention Center

Course Level

Intermediate

Topics

Engineering Controls and Ventilation
Hazard Recognition/Exposure Assessment
Risk Assessment and Management

Description

Industrial hygienists (IHs) need strategies and tools to make effective and efficient decisions in rapidly evolving domestic and international environments. U.S. and international regulations are impacting large and small businesses alike. Pressure from stakeholders has motivated many IHs and their organizations to identify more efficient, comprehensive methods for assessing and managing exposure risk. AIHA's exposure risk assessment and management strategy provides a solid foundation for gauging occupational and environmental exposure risks. The strategy empowers IHs to make more accurate, efficient exposure risk judgments. During this two-day workshop, participants will learn how to: 1) make qualitative and quantitative exposure risk judgments using the newly revised Structured Deterministic Model 2.0 (SDM 2.0), and 2) apply these new skills and tools within their organization. Hands-on exercises with local exhaust ventilation units will help to visualize the impact of different types of controls on contaminant concentration and connect these controls with the terms used in the SDM 2.0. The capstone of the workshop will be a facilitated discussion reviewing the results and lessons of each workshop, providing direct feedback to each participant. A six-month follow-up scenario will be emailed to each participant, eliciting an exposure judgment to evaluate sustained learning.

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https://www.aihceexp.org

Courses » Making Accurate Exposure Ri...

Making Accurate Exposure Risk Decisions (2023)

AIHA UNIVERSITY eLearning | Courses

Course Description:
Accurate exposure risk decisions are critical to risk management programs that protect workers and optimize the use of limited resources. This video series will teach you a basic understanding of the properties of lognormally distributed exposure profiles and how to use traditional and Bayesian statistical analysis tools to make accurate exposure risk decisions based on monitoring data. The use of several freely available statistical tools will be demonstrated using multiple examples. Upon completion of the webinar video series, you will have the knowledge needed for the successful completion of the exam for the AIHA Exposure Decision Analysis Registry.

Target Audience
This course is relevant for anyone seeking to improve their exposure risk decisions, including students, early-career professionals, and experienced practitioners.

http://learning.aiha.org/

Questions?

- If you or your organization is willing to participate in creating well-documented exposure scenarios that can be used for modeling and validation/training, please get in touch:
  - Ryan Hines: rhines12@jhu.edu
  - Dr. Ram Ramachandran: gramach5@jhu.edu
  - Chun-Yu Chen

Hierarchy of Controls

Elimination	Not Applicable – need for reasonable disinfection
Substitution	High potential – considerations for other disinfectants with less acute effects should be considered, but must be balanced with potency and contact time. Consideration for occupancy of areas (non-patient)
Engineering Controls	For general wiping – ventilation should be better than good general (>6 ACH) LEV/Capture for concentrate
Administrative Controls	1. Work practices should limit entry into room for times following wiping 2. Wipes should be pre-wet so damp but not dripping/saturated 3. Limit surface area of cleaning (no floor mopping / wall wiping) 4. Chemical/product specific training
PPE	Full Face Respirator, gloves (nitrile or rubber gauntlet), goggles or face shield 3M Technical Bulletin #185: Organic vapor/acid gas multi-cartridges Solvay: 8-hr (150 ppm of PAA @ a flow rate of 32 L/min and up to 80% RH)

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