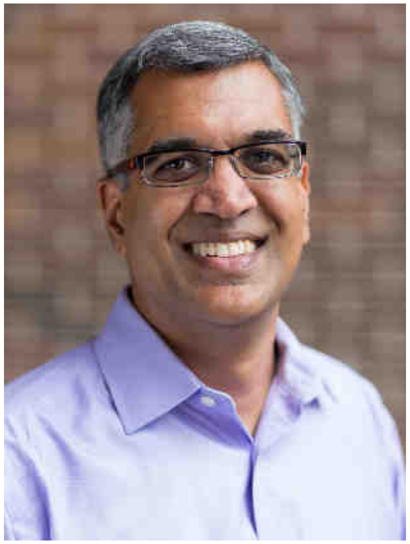
Making Safety Second Nature in an Academic Lab



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University of Minnesota, Minneapolis MN

*The contents of this presentation represent opinions and interpretations of the speaker and **do not** reflect those of his employers past and present*

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Safety Moment: Working from Home (a UMN Tradition)

- Close your eyes

- Ask yourself:
  - can you imagine the fastest route out of your home or apartment?
  - what is your second best exit?
  - if the threat is outside, do you have a place to hide?
    (maybe no windows: active shooter)
  - do you know whom to contact in case of emergency?
  - in case of roommates, can you contact them to ensure that they
    are safe?
  - are your important documents protected (e.g., fireproof box)?

Being at home provides a disarming sense of security, but we all need to plan for the unexpected

Personal Background

- B.A. in Chemistry & Mathematics, University of Colorado, 1997

  Research: inorganic synthesis
  *Most dangerous processes: t*BuLi in hexanes

- Ph.D., Chemistry, Stanford University, 2003

  Research: organometallic polymerization catalysis
  Most dangerous processes: perfluoroaryl lithiums, Me_3Al, high pressure reactions

- Postdoc, Chem. Eng. & Mat. Sci., UMN, 2003–2006

  Research: block polymer physics
  Most dangerous processes: large scale organolithium-initiated anionic polymerization (up to 3 L reactions), X-ray scattering, and polymer processing

- Faculty in Chemistry, UW-Madison 2006–2015
- Faculty in Chem. Eng. & Mat. Sci., UMN, 2015–*present*

Joining the Waymouth Lab in 1997

Prof. R. M. Waymouth

- Stanford University in the Silicon Valley
  - high regulated due to pollution from microchip manufacture
  - "surprise" monitoring of waste water and local/state EPA inspections (main focus on hazardous waste handling)

- After joining the group:
  - safety walk through with Lab Safety Officer (LSO)
  - Bob's oral safety exam based on lab manual (w/ R. Bittar incident report):
    a. fire extinguishers types and locations
    b. safety shower and eyewash location
    c. most dangerous steps of various reaction scenarios
    d. waste handling (segregation and reactivity)

- *Peer-assisted lab-specific safety training*
  - high pressure reactors: polymerization in liquid propylene (140 psig)
  - air- and water-sensitive organometallics (Et_3Al and Me_3Al)
  - high vacuum (Schlenk) lines with cryogens

1998 Spring & the OSHA Lab Standard

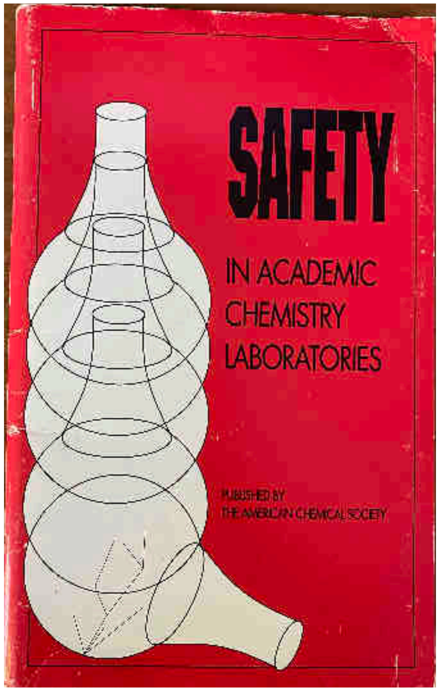
Prof. R. M. Waymouth

- Academic labs were behind on safety *and he knew it*

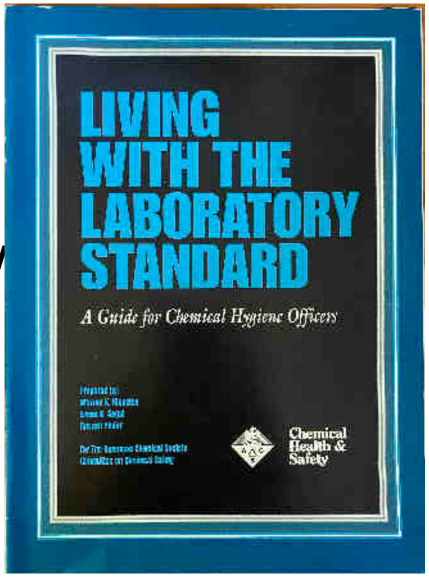
From the Federal Register, vol. 55, No. 21, Wednesday, January 31, 1990:

"Where hazardous chemicals are defined by this standard are used in the workplace, the employer shall develop and carry out the provisions of a written Chemical Hygiene Plan…

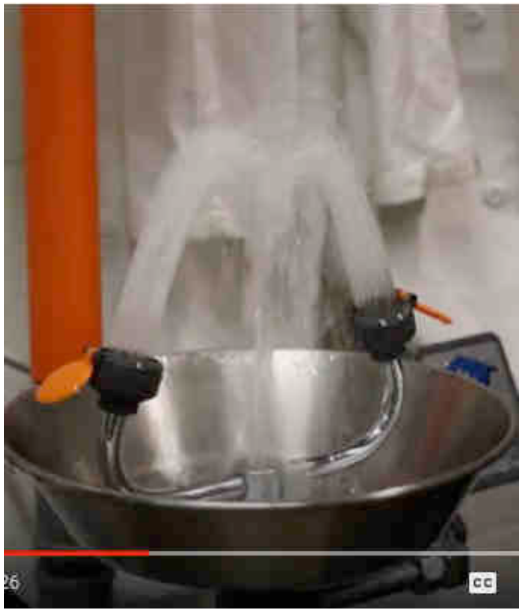
…The Chemical Hygiene Plan shall include each of the following elements…
(i) Standard operating procedures relevant to safety and health considerations to be followed laboratory work involves the use of the hazardous chemicals;
(ii) Criteria that the employer will use to determine and implement control measures to reduce employee exposure to hazardous chemicals…particular attention shall be given to the selection of control measures for chemicals are known to be extremely hazardous…"



- Limited implementation for perfluoroaryl lithium reagents (*e.g.*, C_6F_5Li) and a few other processes



Saved by my Training: Incident in the Lab



Moving to UMN the 1st Time: Postdoc

- Basic regulatory safety in place
- No lab-specific safety training uncommon
- Cryogen and reactive purification accidents in Summer 2003

Corrective actions by the MN Polymer Group:

- – Development of Standard Operating Procedures (SOPs) for widely performed anionic polymerizations
- – Uniform safety training protocols: watch once, assist once, do once with supervision
- – cryogen and reactive purification accidents in Summer 2003

Corrective actions in the Bates Group:

- – Lab-specific safety training, including safety walkthrough with LSO
- – Drafted SOPs and checked them with less experienced lab members
- – Hands on fire safety demonstrations
- – Demonstrations of (in)correct ways to quench reactive metals and organometallics (e.g., CaH_2, $LiAlH_4$, *n*BuLi, Bu_2Mg,Et_2Zn)
- – Initial sense of how to set up a culture of safety from a supervisory perspective

I'm Faculty at UW-Madison: Now What?

- Valued safety and setting up a safe lab, but not sure how to build group safety infrastructure ***from scratch***
- Existing 1st year grad student course on chemical safety including drafting a Chemical Hygiene Plan (CHP) in January of each year
- Hands on training with all new grad and undergrad students, but no sustainable future plan

The Wake Up Call: Death due to Labwork on Jan. 18, 2009

Prof. Patrick G. Harran (UCLA) Sheri Sangji

– "I'm an industrial chemist, and if I did what he did, I'd be in as much trouble as him"

– "I agree … if someone under my supervision were killed on the job, I would at a *minimum* be unemployed"

https://cen.acs.org/safety/lab-safety/10-years-Sheri-Sangjis-death/97/i1#
https://publicintegrity.org/inequality-poverty-opportunity/workers-rights/landmark-worker-death-case-continues-against-ucla-chemistry-professor/

How I Built My Lab's Safety Culture

- Step 1: Wrote a safety manual with my expectations of personnel in my lab–*I am liable, therefore, I set the rules to the best of my knowledge and ability in compliance with local, state, and federal law*

- Step 2: I conduct initial safety orientations for all new lab personnel

- Step 3: I direct annual, OSHA-mandated lab-specific safety training on fire safety, basic lab safety, hazardous waste disposal, chemical safety, air- and water-sensitive reagent handling (documented and witnessed)

Record of Training for Laboratory Safety, Procedures, and general Awareness

Professor Mahesh K. Mahanthappa, Department of Chemistry, University of Wisconsin–Madison

Name: ____

Position: ____

Date of Training: _____________________________________

Length of Training: 60 minutes

Safety Officer:
Frank Speetjens
fspeetjens@chem.wisc.edu

Prof. Mahesh K. Mahanthappa
Assistant Professor of Chemistry
mahesh@chem.wisc.edu

Researcher Contact Info:

Office: ____________________________

Phone: ____________________________

e-mail: ____________________________

Emergency Contact: __________________

EC Phone: _________________________

Topics covered in this training refresher program:

- General Lab and Chemical Safety
  - Minimum required protective measures
  - Location of safety showers / eye washes / phones
  - Accessing MSDSs and general chemical awareness
  - Compatibility of chemicals for storage
  - Safety Considerations in Planning Experiments
  - Flammable and Pyrophoric Materials Handling
  - Limits for safe chemical handling
- Chemical waste management
  - Waste collection
  - Packaging waste for pick-up

Assertion that above named has completed this **annual** refresher

______________________________ ______________________________
Researcher signature Date

______________________________ ______________________________
Safety Officer signature Date

______________________________ ______________________________
Advisor signature Date

This form is to be kept on record with Professor Mahanthappa, and must be produced upon request by County, State, Federal, or University of Wisconsin Environmental Health and Safety inspectors. Please make a **copy** for your own records.

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- Step 4: Group meetings started with lab safety discussion catalyzed by a Lab Safety Walkthrough performed by the person giving group meeting.

This is a brief laboratory walkthrough that should take **<u>no more than 15 minutes</u>**. Its intent is to promote better laboratory safety and keep all of us vigilant.

Please take pictures of any egregious violations and share these during group meeting.

IT IS THE RESPONSIBILITY OF THE PERSON(S) PRESENTING TO PERFORM THIS WALKTHROUGH ON GROUP MEETING DAY

1. Are all researchers in the lab space wearing correct PPE and attire? *Required for **<u>all researchers</u>** in Amundson 349: long pants, close-toed shoes, natural fabrics, lab coat, lab glasses, gloves if handling chemicals*
2. Are aisles and walkways clear of chemicals and clutter? *At least 3 feet of clearance is required in all walkways for egress.*
3. Are hood sashes lowered when not in use? *This will help save energy and protect everyone from chemical fumes.*
4. Are hoods organized and uncluttered? *A messy hood can exacerbate any dangerous situation!*
5. Are solvent wash bottles (squirt bottles) in secondary containers? *Secondary containment is essential to spill mitigation*
6. Are reaction cards up-to-date? *These help anyone quickly assess the hazards in a fume hood.*
7. Are all samples and chemicals labeled with name, notebook page, and hazards? *Ideally, this should be written on a paper label attached to the flask or vial.*
8. Are chemicals and/or reactions in secondary containment where appropriate? *This is one of the simplest measures you can take to mitigate any incident.*
9. Are common spaces and instruments (balances, rotovaps, ovens, GPC, solvent system, glovebox, centrifuge, PLM, Autolabs) well-maintained? Do any of these require attention?

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Step 5: Hazard discussions with group regarding existing and new procedures identified safe handling limits versus "unusual experiments" (requiring documentation and additional safety checks)

Safe Handling Limits and Unusual Experiments

- Class I: Reaction Size and Scale Up
  - *≥ 750 mL flammable reaction solvent*
  - *≥ 125 mmol of an organolithium reagent*
  - *≥ 10 g of NaN3*
  - *≥ 1 g of an organic azide with [C]:[N] < 2:1*

- Class II: Poisonous Chemical or Toxicity Hazards
  - HMPA
  - $RuO_4(s)$ or $OsO_4(s)$

- Class III: Pyrophoric Chemicals
  - Et_2Zn, ≥ 2 g of Na or K

- Class IV: High Pressure Reactions (any reaction at ≥ 2 atm)

- Class V: High Temperature Reatcions ($T \geq 200$ °C)

- Class VI: Unusually Corrosive Materials (strong acids and superacids)

There could be more depending on your lab environment

Mahanthappa laboratory “Unusual” Experiments –Form

Title of Procedure: ____

Prepared By: ________________________________ in ___________________ hood space

Procedure/Apparatus Reviewed By: ______________________________ Date:____________

Involves Use of Particularly Hazardous Substance (PHS)? Yes No

List:

Brief Description of Procedure (Include main hazards, reaction conditions, quench procedure)

Contingency measures (include spill, fire contingencies, and disposal information)

Chemicals Involved:

Chemical	Physical or Health Hazard(e.g., carcinogen, corrosive)

Secondary hazards (e.g. allergies):

Exposure Controls required (PPE): *(circle all that apply)*

Face shield Chemical apron Gloves (type):

Lab coat Respirator (type): Other_________________

Engineering Control: Fume hood Glove box

Other (pressure relief valve, blast shield, automatic shut-offs, etc.)______________________

Safety Considerations in Planning Reactions

Recognition and Assessment of Risk

Physical Properties of Reagents:

- Vapor pressure
- Boiling Point
- Flash Point
- Auto-Ignition Temperature
- Explosion limits in air
- Explosion temperature?

Chemical Reactivity

- Peroxide former?
- Strong oxidizer or reductant?
- Water reactive?
- Readily decomposes
- Affected by light, heat, or pressure?
- Reacts exothermically with other materials
- Potential energy stored in the molecule

Health Effects

- Corrosive, irritant, sensitizer
- Carcinogenic, mutagenic, teratogenic, biohazard
- Acute or toxic properties
- Lachrymator or inhalation hazards (can you handle the reagent outside of a hood?)
- Regulated by government agencies?
- Established permissible exposure limits

Combinations of Chemicals

- Incompatible Materials
- Heat of Reaction
- Undesirable byproducts
- Gaseous products
- Energy released?
- Health hazards
- Certainty of Material Composition (purity and impurities?!)
- Consequences of inadequate mixing

ASKING WHAT IF???

Design your experimental apparatus so that *even in the event of the worst possible scenario, no significant personal injury or damage would be possible.*

WHAT IF???:

- The reaction overheats
- The reaction over pressurizes
- Water leaks into the reaction
- The condenser becomes blocked
- The seals on the reaction fail
- Agitation is lost (stirrer stops working)
- There is Stoichiometric imbalance (too much of one of the reagents)
- A spill occurs
- Your fume hood fails?
- The electricity goes out
- The cooling water fails
- Refrigeration fails
- Instrument air flow fails

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Step 6: Junior students assigned senior safety mentors, which could include me and I still train people in hazardous procedures

Two Missing Ingredients

Stop Work Authority

1. If you see something, say something: ***if it looks unsafe, it probably is!***
2. Right to engage when you see something unsafe and discuss
3. If unresolved, bring other group members into conversation
4. Escalate to PI

Accident and Near Miss Discussions

Learning from accidents means understanding how and why they occurred to develop new procedures that avoid them

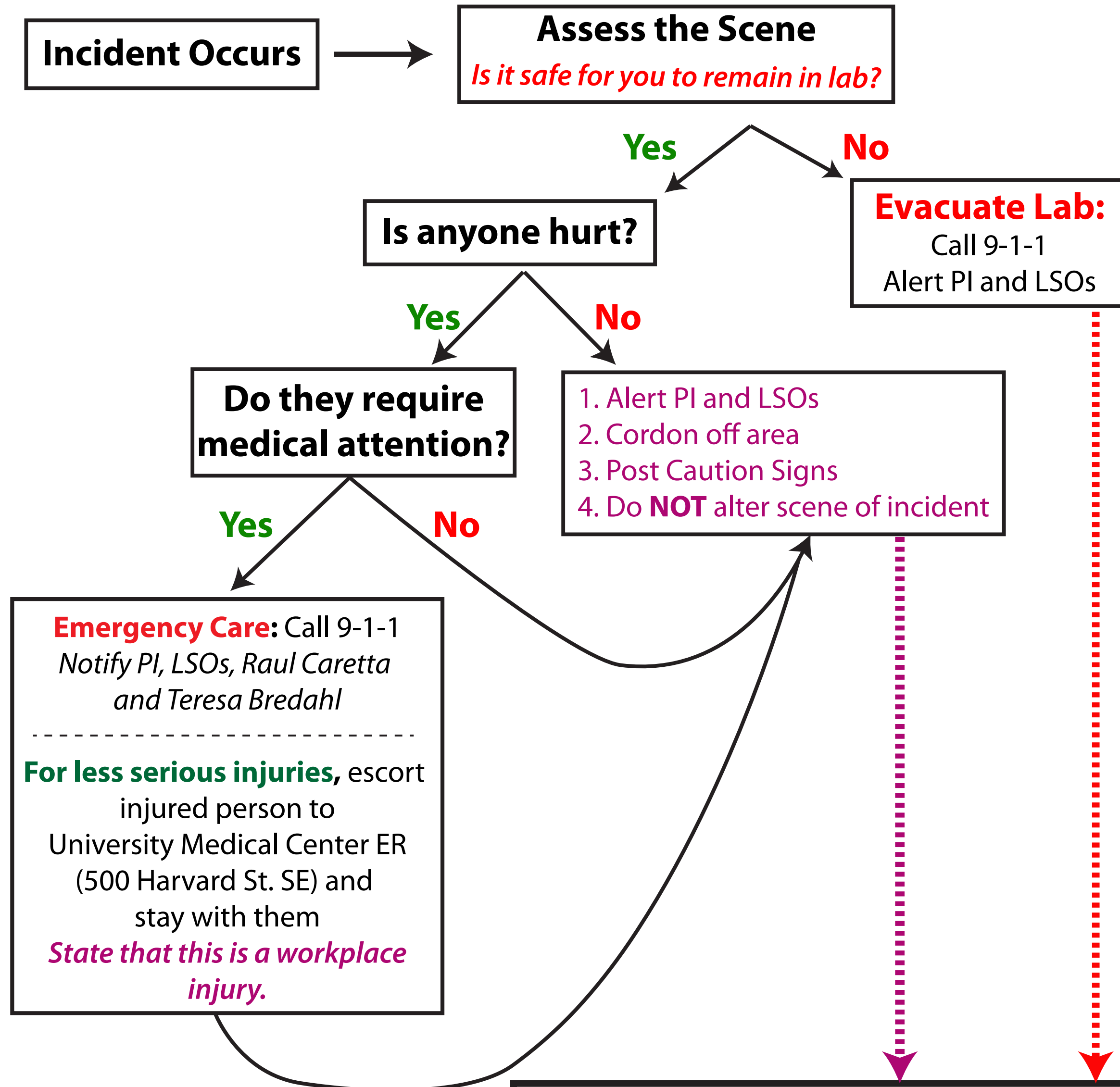
Evolving to Account for New Knowledge

- Lab coats: Nylon ⇒ Cotton ⇒ FR Nomex
- Glove types: chemical compatibility charts and considerations
- Banning fleece items in the lab (high surface = burns/melts quickly!)
- SOPs are living documents: they evolve and should changed, if incidents occur
- New SOPs as procedures become routine written by senior members and checked by junior ones
- Plan for emergencies: Emergency Evacuation Plan and Chain of Command List *(inspired by Bob Waymouth related to earthquake safety)*
- Incident Response flowchart (@ UMN)

Incident Response

- Each group should have a plan
- Steps to follow
- Important phone #'s
- For lab incidents, ***do not*** rush to clean up: forensic evidence is how we **learn from accidents** & ***prevent future ones***

Incident Response Flowchart **Mahanthappa Group 2016**



Post-incident Actions:

1. Meet with PI to review incident
2. With PI, file Incident Report Form and Worker's Compensation paperwork
3. Revise Standard Operating Procedure
4. Prepare Safety Moment for Group Meeting
5. File Learning Experience report with JST

Important Phone Numbers:

If you call 911 from your cell phone, immediately ask for UMN Campus Dispatch

Mahesh Mahanthappa (PI)	[redacted]
Gray Jackson (LSO)	[redacted]
Beth Dewing (LSO)	[redacted]
Raul Caretta	[redacted]
Teresa Bredahl	[redacted]

Making Hard Decisions

As a PI, consider how this applies:

Codes of conduct at many colleges universities do include clauses regarding students who willfully “endanger themselves or others”: these clauses can and should apply to laboratory conduct.

Motivating Factors @ Madison

- Recruiters' anecdotes: it takes 6–9 months to retrain the average chemistry Ph.D. regarding safety in an industrial setting
  ⇒ *safety is professional development*

- *Liability and responsibility*

- Industrial sabbatical: the case of the *spiral staircase training*

- Adopting the UMN JST Model: students and postdocs are powerful, self-interested advocates who genuinely value safer working environments.

- Faculty are important role models and sources of information, experience, and lab-specific knowledge

Moving to UMN a 2nd Time: CEMS Faculty

- Shared lab spaces are common in CEMS, but uniform safety standards across groups were not
- Discussions of liability, responsibility, and professional development
- Template for required safety plans developed based on components from our group’s 9-year effort
- Evacuation Plans and Lab Hazard Maps are now required
- Updated Group Safety Information is a compulsory part of faculty annual performance evaluations

Some Takeaways

- Personal commitment by the PI and all lab members
- *Stop Work Authority* and *lack of hierarchy* enables a safer culture
- Lab personnel are self-motivated in this topic and it is an important yet overlooked form of professional development
  Possible implications for ACS CPT
- Senses of safety evolve with knowledge: living documents
- Each lab can set rules that are more restrictive than local constraints

Educational (non-punitive) approach to safety
Practice makes safety concerns reflexive