Safety: Cured-in-Place-Pipe (CIPP) for Sewer Repairs

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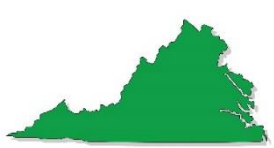
2. Grant by the US National Science Foundation
3. Donations by crowdfunding
4. Purdue University






Today, Transportation Agencies are Choosing to install Cured-in-Place-Pipes (CIPP)

Resin impregnated tube hardened inside a broken pipe

Curing methods: Hot water, Steam, UV light

Deliberate curing time: Hours to many days

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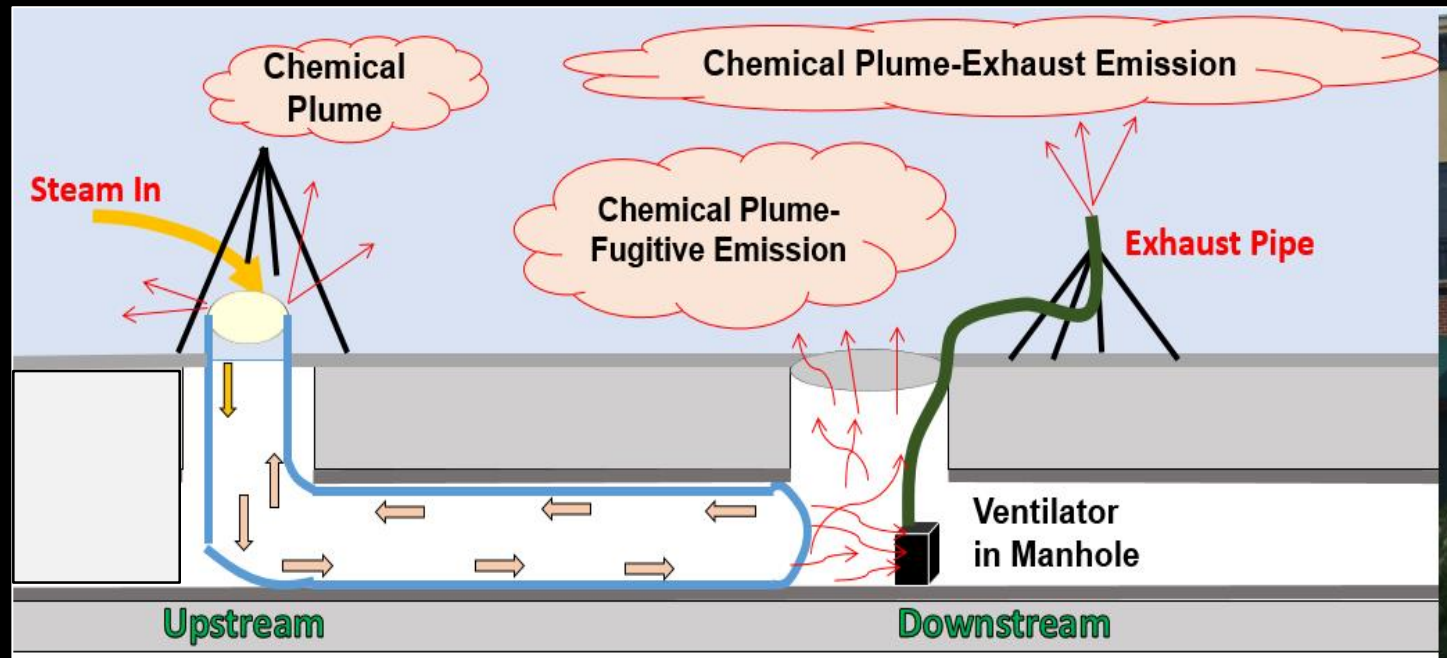
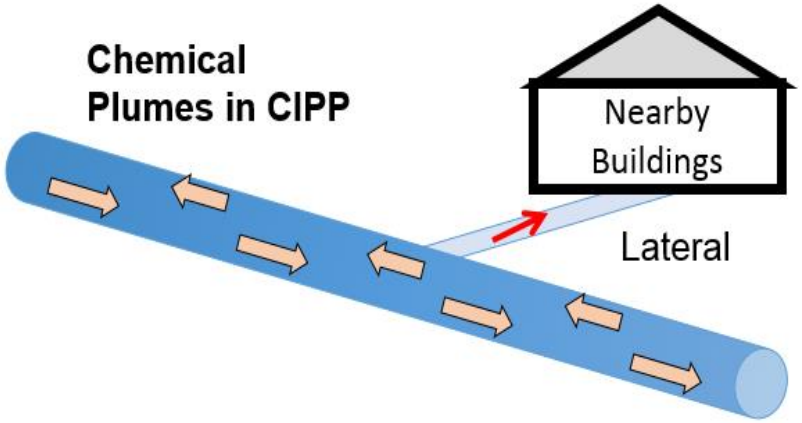
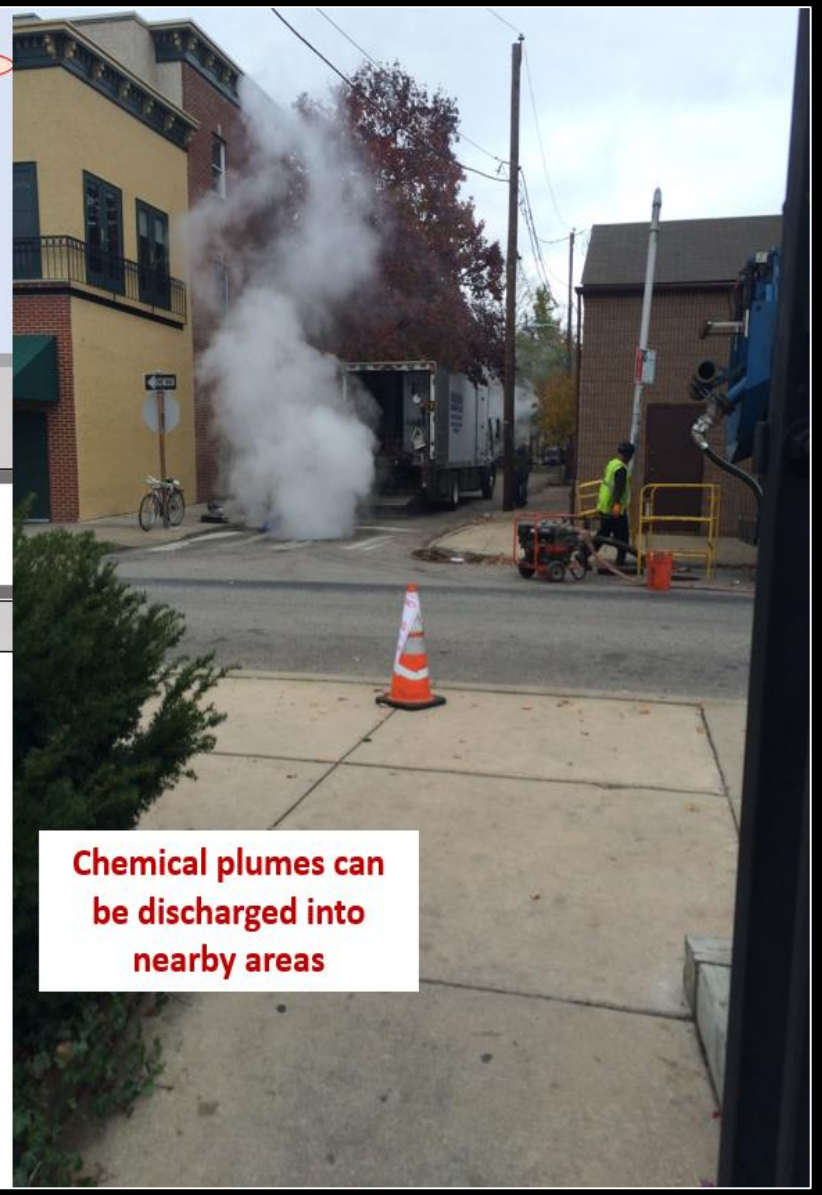
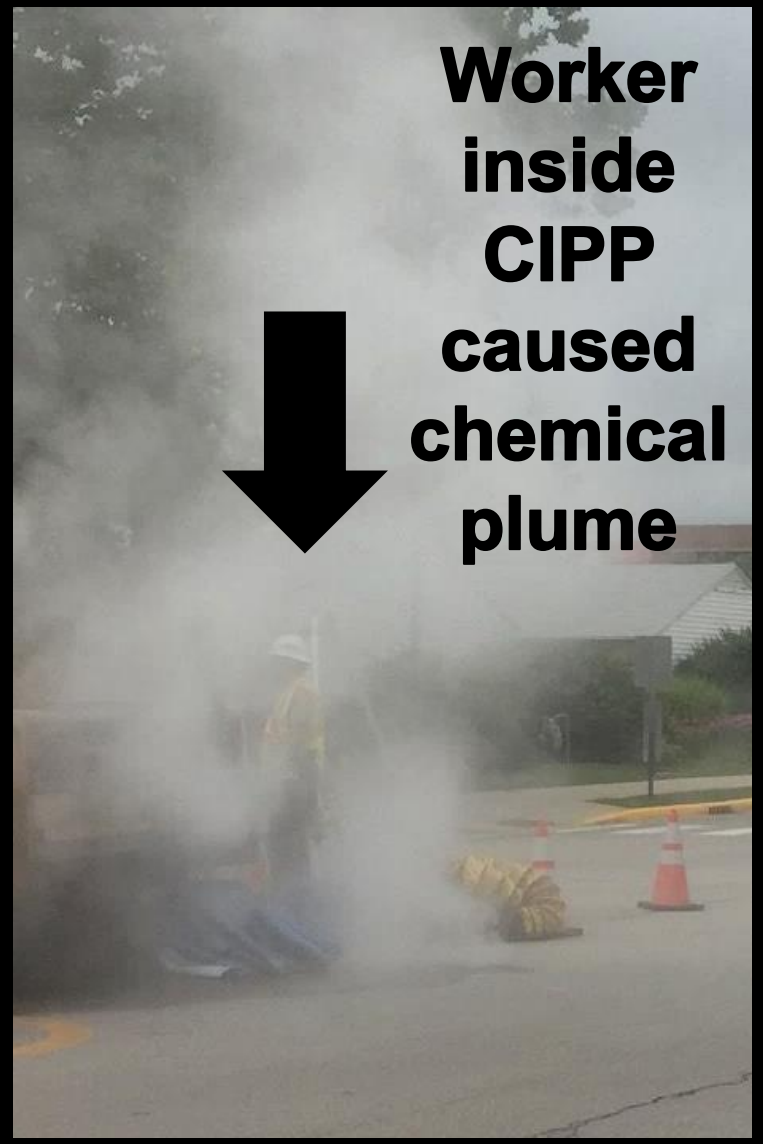


Chemical Plumes Generated by CIPP can Escape the Pipe Being Repaired





Examples of Chemical Air Emissions



Safety Claims circa 2016 from Contractors & Municipalities

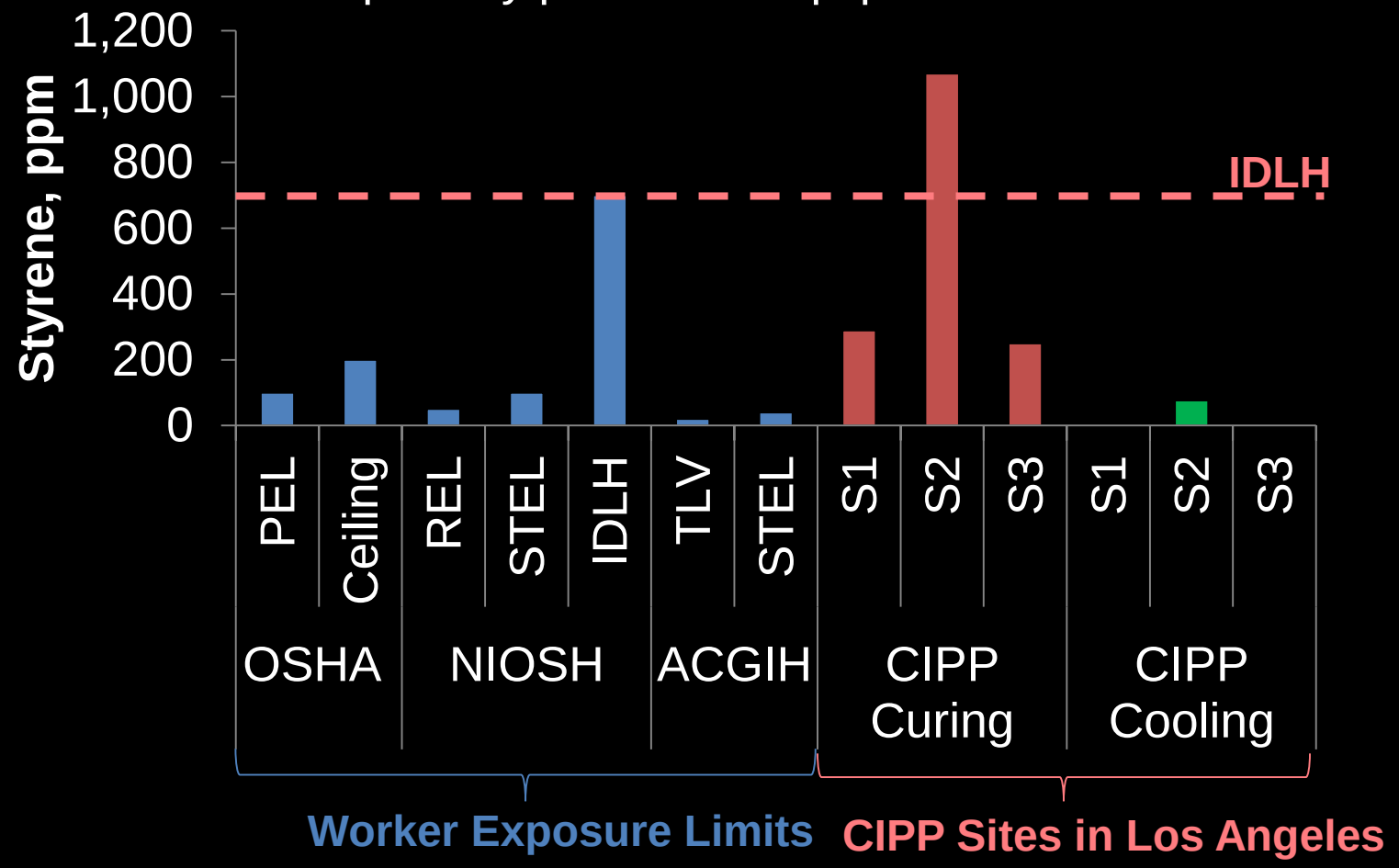
"Styrene vapor of at most few ppm"
"is not a human health risk"
"is safe for people and animals"
"it is harmless steam"
"no hazardous conditions posed"
"don't be alarmed"
"some people are offended by this odor and are fearful of it; even though the concentrations they smell present no harm"

Seems to be quite common in the US

No chemical capture
No formal setback distances
No formal respiratory protection
No formal air monitoring

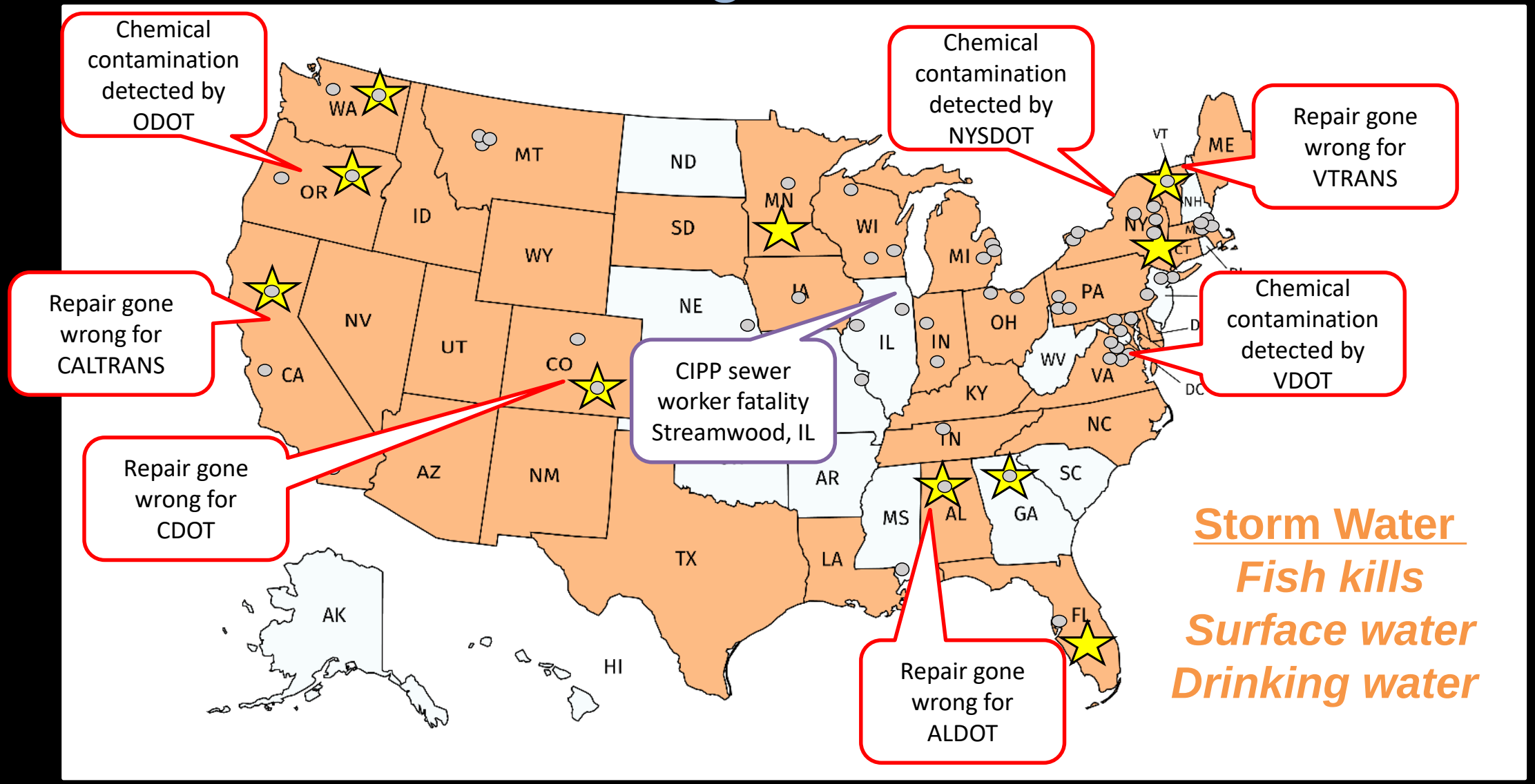
One STUDY: In 2015, Styrene was Discovered Exiting a CIPP Sewer Manhole that Exceeded the NIOSH IDLH Concentration of 700 ppm

IDLH: a concentration from which a *worker* could escape without injury or without irreversible health effects in the event of respiratory protection equipment failure



Adjari (2016)

Our 2017 Study: Uncontrolled Chemical Emissions Are a Problem During and After CIPP Installs



Storm Water

Fish kills

Surface water

Drinking water

Purdue University (2018)

This is a Multiphase Chemical Mixture, **NOT Steam**
(particulates, droplets, partially cured resin, etc.)

Purdue University (2017)

It's NOT just styrene. Many compounds have NOT been listed on the SDSs have been found and have exposure limits.

Acetone
Acetophenone
Benzaldehyde
Benzene
Benzoic acid
Benzyl alcohol
BHT
2-Butanone (MEK)
tert-Butyl alcohol
tert-Butyl benzene
4-*tert*-Butylcyclohexanone
4-*tert*-Butylcyclohexanol
Chloroform
o-Chlorotoluene

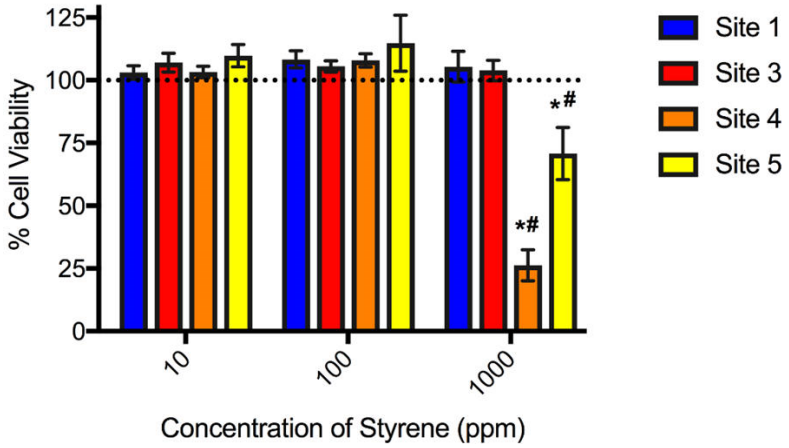
Diallyl phthalate (DAP)
Dibutyl phthalate (DBP)
Diethyl phthalate (DEP)
Di(2-ethylhexyl) phthalate (DEHP)
4-(1,1-Dimethyl) cyclohexanol
4-(1,1-Dimethyl) cyclohexanone
1-Dodecanol
Ethylbenzene
3-Heptanol
Isopropylbenzene
p-Isopropyltoluene
Methylene chloride
N-Propylbenzene
Styrene

Phenol
1-Tetradecanol
Tripropylene glycol diacrylate
Toluene
1,2,4-Trimethylbenzene
1,3,5-Trimethylbenzene
Xylene (total)
And more…

Purdue University (2018)

Exposures can be toxic

Purdue University (2017)



Mouse lung cell experiments indicated that toxicity occurred and future health impact investigations are necessary

Streamwood, Illinois
2017 CIPP sewer worker fatality. OSHA reported 220-270 ppm_v styrene exposure based on blood analysis

More than 68 incidents of illness reports from persons exposed to emissions or near CIPP installation sites: 25 States + elsewhere
Respirators worn when collecting contaminated water and air samples

Some information from past studies

USA, Canada, The Netherlands, Germany, and more…

TRUE STATEMENTS

- More chemicals than styrene can be released
- Styrene was released into air during a non-styrene CIPP installation
- Mouse lung cell toxicity was found for some emitted materials

Recommendations from Europe

- A 5 m (16.4 ft) setback distance was recommended at worksites
- Chemicals should be captured during and for 24 hours after CIPP installed
- Only a certain amount of styrene is permitted to be left inside a new CIPP

UNTRUE STATEMENTS

- ❑ MSDS's will identify all the chemicals emitted during installation
- ❑ Styrene is the only chemical emitted
- ❑ A PID only responds to the chemical styrene
- ❑ Contractors know what chemicals are emitted and their magnitudes

Debunked Safety Claims Based on Today's Evidence

- "Styrene vapor of at most few ppm"
  - 1070 ppm is not a "few ppm", exceeds NIOSH IDLH
- "is not a human health risk"
  "is safe for people and animals"
  - Can be a health risk, fatality in Illinois, injury in Pennsylvania, reports of illness elsewhere
- "it is harmless steam"
  - Not steam. It's solid + liquid + gases and can contains VOCs and SVOCs
- "no hazardous conditions posed"
  - Hazards do exist
- "don't be alarmed"
  "some people are offended by this odor and are fearful of it; even though the concentrations they smell present no harm"
  - When you smell something, yes it can mean that you are in a harmful environment

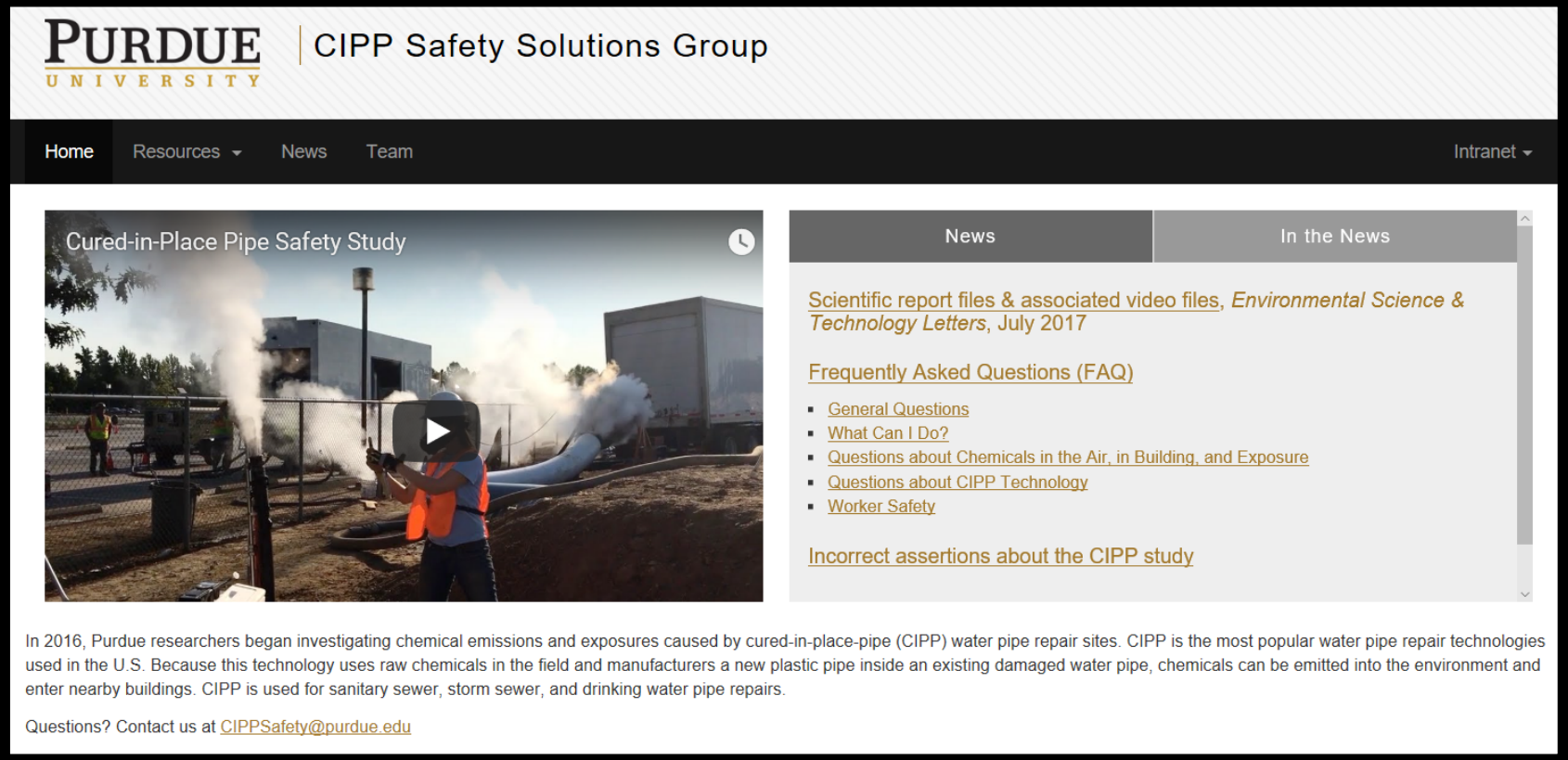
What are some Pipe Owners doing about CIPP?

1. Nothing but using CIPP and waiting for CIPP companies and the organizations they fund to tell them if the process they have been using and their past and ongoing chemical exposures were/are safe.
2. Using CIPP and telling employees to avoid CIPP job sites during construction.
3. Using CIPP and conducting their own PID testing at select job sites.
4. Using CIPP and considering a revision to specifications and special provisions.

How can transportation agencies find solutions?

- Learn more about how your employees can be or have been already affected.
- Require that specifications and special provisions state that all CIPP companies must show proof of a –free– NIOSH Health Hazard Evaluation *(Some companies are already working on this. It is not unreasonable.)*
- Require contractors capture chemicals and conduct monitoring.
- Pooled Fund independent efforts to identify best practices to minimize chemical emission for occupational and public safety through independent testing and recommendations.

1. Learn More. Freely downloadable information and videos at *www.CIPPSafety.org*



- ✓FAQs
- ✓Links to studies
- ✓Links to resources

Visit http://CIPPSafety.org or https://engineering.purdue.edu/CIPPSafety

You can access FREE worker and public safety resources

WATCH THE FREE CIPP SAFETY STUDY WEBINAR (Oct 2017)
neha.http://neha.org/node/59333

To help local, state, and county health professionals better understand public health and occupational exposures with CIPP. Results of a July 2017 Purdue University CIPP safety study were presented as well as lessons learned from a NIOSH workplace Health Hazard Evaluation, and options for health officials, agencies, companies, and workers to gain technical assistance.

NATIONAL ENVIRONMENTAL HEALTH ASSOCIATION

Promoting productive workplaces through safety and health research NIOSH

PURDUE UNIVERSITY

2. Evaluate, Ask Questions

1. Who is making the decisions about employee chemical exposure safety at CIPP Sites at your organization for construction inspectors or the nearby public?
2. What air testing data does your organization have being used to make those decisions? Are they credible? i.e., PID only?
3. Review your construction specifications and special provisions
4. Visit job sites, not just one. Each material and contractor can be different.
5. Compare your findings against our suggested recommendations
6. Upgrade your organization’s approach to protecting workers

3. Get Help and Implement

- Contact us for advice or direct assistance
- Contact NIOSH for a HHE or advice
- Require your CIPP contractors to have proof of a NIOSH health hazard evaluation, which should better protect your employees
- Revise specifications to require chemical capture, monitoring, setback distances, and PPE based on work task

DOT EMPLOYEES as well as CURED-IN-PLACE-PIPE (CIPP) Employees OR Employers OR Unions should

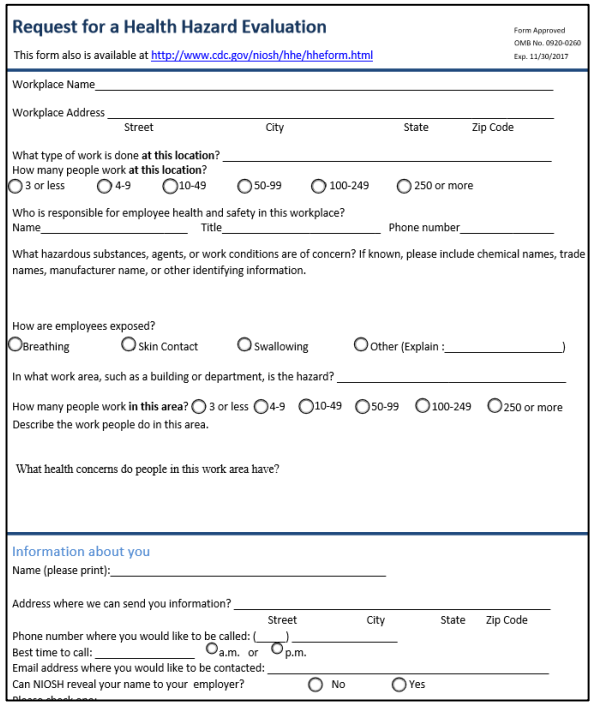
Request –FREE– Help from NIOSH

National Institute of Occupational Safety and Health

Right now you can…

- Request feedback about what PPE to wear
- Request a **-FREE-** Health Hazard Evaluation from NIOSH

Health Hazard Evaluations help workers learn what health hazards are present at their workplace and recommends ways to reduce hazards and prevent work-related illness.



Request for a Health Hazard Evaluation

Form Approved
OMB No. 0920-0260
Exp. 11/30/2017

This form also is available at http://www.cdc.gov/niosh/hhe/hheform.html

Workplace Name_____

Workplace Address _____
Street City State Zip Code

What type of work is done **at this location**? _____

How many people work **at this location**?
○ 3 or less ○ 4-9 ○ 10-49 ○ 50-99 ○ 100-249 ○ 250 or more

Who is responsible for employee health and safety in this workplace?
Name_____ Title_____ Phone number_____

What hazardous substances, agents, or work conditions are of concern? If known, please include chemical names, trade names, manufacturer name, or other identifying information.

How are employees exposed?
○ Breathing ○ Skin Contact ○ Swallowing ○ Other (Explain :_____)

In what work area, such as a building or department, is the hazard? _____

How many people work **in this area**? ○ 3 or less ○ 4-9 ○ 10-49 ○ 50-99 ○ 100-249 ○ 250 or more

Describe the work people do in this area.

What health concerns do people in this work area have?

Information about you

Name (please print):_____

Address where we can send you information? _____
Street City State Zip Code

Phone number where you would like to be called: (____) _____

Best time to call: _____ ○ a.m. or ○ p.m.

Email address where you would like to be contacted: _____

Can NIOSH reveal your name to your employer? ○ No ○ Yes

Requests can be made in writing or online:
https://www.cdc.gov/niosh/hhe/hheform.html

CONTACT THESE PEOPLE TO DISCUSS WHAT COULD BE INVOLVED:

Dr. Ryan LeBouf, CIH (igu6@cdc.gov)
Dr. Rachel Bailey (feu2@cdc.gov)

Thank You.

Please contact us if you have any questions.

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The contents of this presentation reflect the views of the authors and do not necessarily reflect the official views or policies of the sponsoring organizations. This presentation is does not constitute a standard, specification, or regulation.

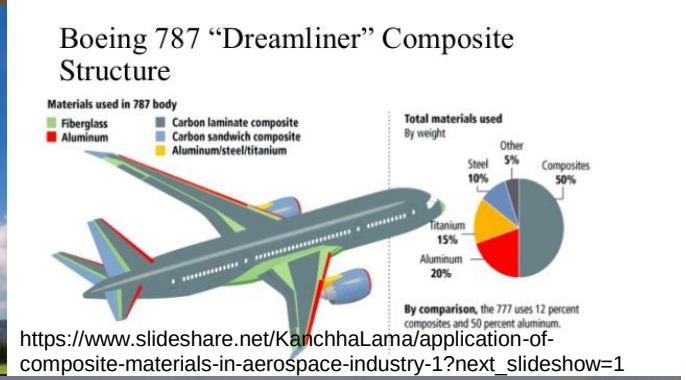
A Primer on Fiber Reinforced Polymer Composites

Coastal Engineering 98 (2015) 16–25

https://www.tes.com/lessons/pcQxUYMrDAPjKw/bridges

http://www.kcautoacc.com/AUTOart-76027-McLaren-P1-Matt-Black-with-Red-Accents-118-Scale-Composite-Car-_p_18280.html

http://www.shridhanalakshmi.com/wind.php



https://www.slideshare.net/KanchhaLama/application-of-composite-materials-in-aerospace-industry-1?next_slideshow=1

http://www.luxury[illegible]displacement[illegible]

https://www.usatoday.com/story/news/nation-now/2016/02/24/army-combat-shirt-body-armor-2019/80851048/

http://www.onur.net/en/references/mobile-air-traffic-control-towers-project-for-turkish-airforce-8/

What are fiber reinforced polymer composites (FRPCs)?

- Composites materials are made by combining two materials where:
  - ❖ One of the materials is a reinforcement (fiber)
  - ❖ The other material is a matrix (resin).
- Fibers: glass fiber (fiberglass), carbon fiber, aramid, and polyester.
  - – The fibers come in veil mat, short fiber mat, woven cloth, unidirectional tape, biaxial cloth or triaxial cloth.
- Resins: Typically thermoset resins such as polyester, vinyl ester, epoxy, polyurethane and phenolic.
  - – The resins start as a liquid and polymerize during the cure process and harden.

FRPCs are high performance materials that are much higher cost than other structural materials

However, in construction, FRPCs have been considered as substitute for traditional civil engineering materials, namely concrete and steel.

This because FRPCs are:

- Lightweight and non-corrosive (polymer based)
- Exhibit high specific strength and specific stiffness (due to fibers)
- High durability (due to matrix)
- Can be tailored to satisfy performance requirements
- Are easily constructed, therefore cheap for low run size

Formula cars vs production cars!

Fiber type is dependent upon many factors

Aramid/UHMWPE

- Advantages: Moderate strength, High stiffness, Low density, High toughness
- Disadvantage: SUPER high cost, Difficult to

Carbon Fiber

- Advantages: High strength, High stiffness, Low density
- Disadvantage: High cost, Brittle

Glass Fiber

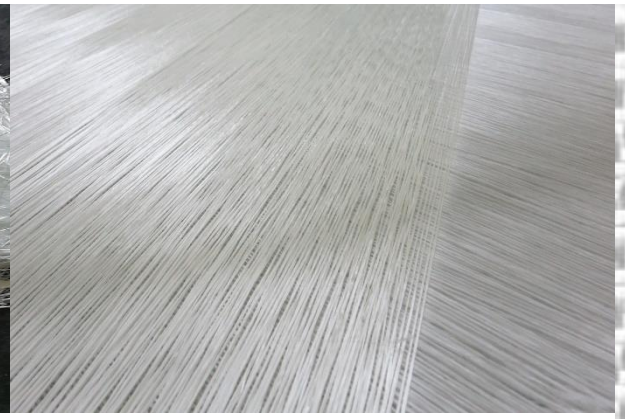
- Advantages: Low cost, High strength, Moderate stiffness,
- Disadvantage: High Density, Low fatigue resistance, Stress corrosion, brittle

Staple Polymer

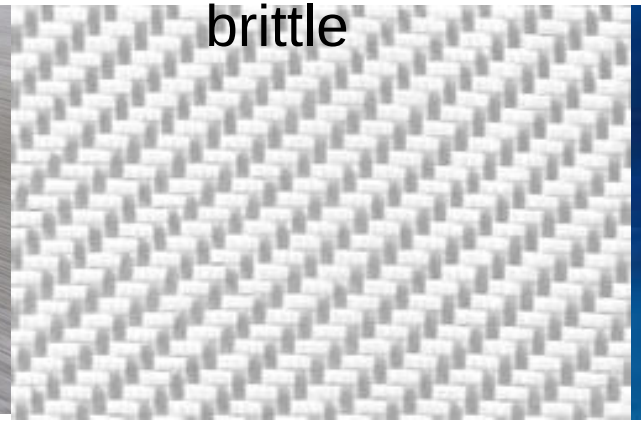
- Advantages: Extremely low cost, High toughness, Low density
- Disadvantages: Low stiffness, Low strength, low temp, poor solvent

https://www.alibaba.com/showroom/concrete-fiberglass-chopped-strand.html

http://vectorply.com/reinforcement-fibers/



https://www.uscompositesnet/ProductDetails.asp?ProductCode=FG-7725-38-10



https://www.jiffe.com/en/product/S-glass-fiber-needle-mat-850C/fiberglass_needled_mat-004.html

Fiberglass represents > 90% of the reinforcements used in infrastructure applications

While fibers are the focus for properties, there are many possible resins that also dictate performance

Unsaturated Polyester

- Cheapest resin
- Multiple types (Ortho- vs Iso-)
- Thermal (peroxide), Redox (MEKP), or UV (Irgacure) radical cure
- Good water performance

- Safety Issues:
  - Diluted 30-60% in reactive solvent (styrene)
  - Some initiators are explosive
  - Can be composed of Phthalates

Vinyl ester

- More expensive than UPR
- Better performance than UPR
- Thermal (peroxide), Redox (MEKP), or UV (Irgacure) radical cure
- Good water performance

- Safety Issues:
  - Diluted 30-60% in reactive solvent (styrene)
  - Some initiators are explosive
  - Has BPA

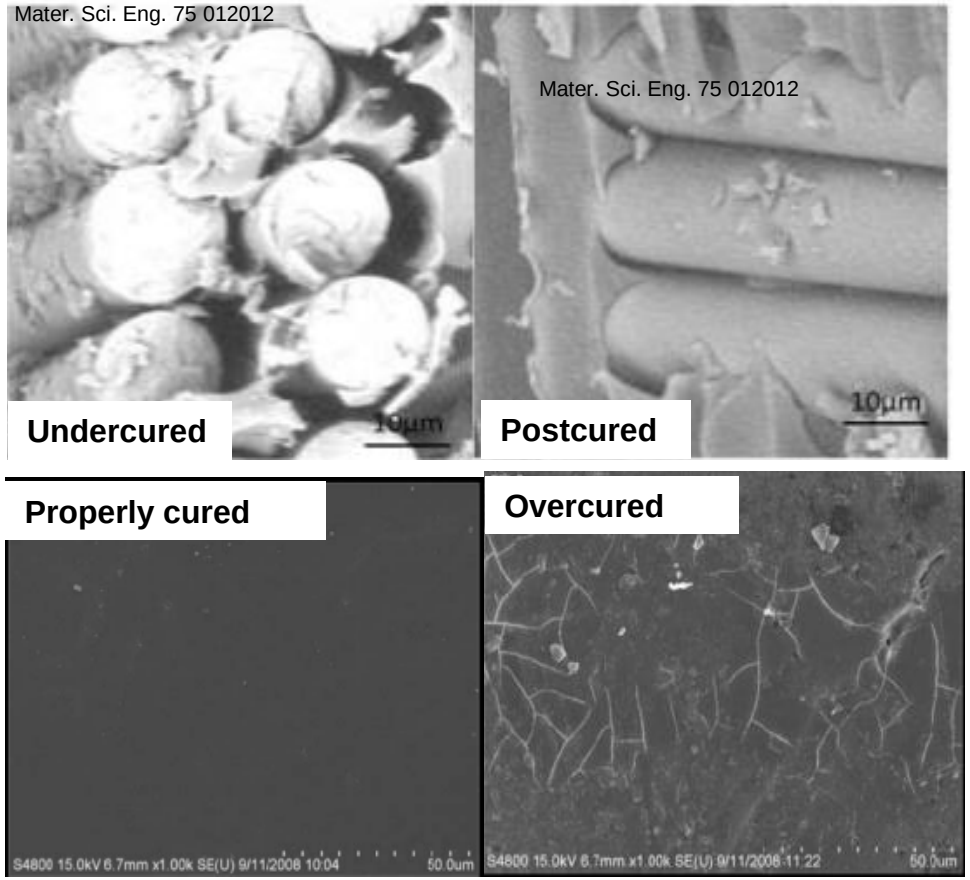
Epoxy

- Most expensive
- Best performance
- No reactive solvent
- Many types (BPA, BPF, CA)
- Can have poor water performance

- Safety Issues:
  - Has BPA
  - Can contain amines (hardeners)

Curing issues in FRPC

- The curing process plays a major role in achieving the final mechanical properties
- Aerospace industry has complicated time/temperature/pressure profile to reduce porosity and improve cure
  - Increases crosslink density, so T_g and ILSS increases
  - Can post-cure to improve
- Many possible issues with curing
  - Undercuring: Lack of complete reaction. Lowers Tg and ILSS and leaves residual monomer
  - Overcuring: Causes chain scissioning, matrix cracking and debonding at fiber/matrix interface. Lowers Tg and ILSS. Similar to UV exposure.
  - "Overtemp" (not a real term): can heat too high
    - Thermal runaway
    - Flash off monomer (styrene)
    - Cause too fast initiator (catalyst) decomposition



http://etd.fcla.edu/CF/CFE0002406/Tipton_Bradford_R_200812_MSME.pdf

Trying to speed up curing, or "force" complete cure will cause issues – If hot is good, hotter is not better!

Why does all this matter?

There are “free” small molecules in FRPCs after curing

- Impossible to achieve 100% cure in a thermoset
  - Highly dependent upon cure schedule and type
- Residual organic compounds will be leached out over time and may change mechanical properties of the composites.
  - Monomers such as cycloaliphatic amine and polyoxylalkyl amine (for epoxy resin), and styrene (for unsaturated polyester or vinyl ester resin) remain unreacted.
    - Will change properties over time and pick up water as monomer leaves
  - Plasticizers and additives such as butylated hydroxytoluene, 1-tetradecanol, diethyl phthalate are used to impart specific properties of the composites.
    - Become embrittled over time
  - Oxidation and degradation products of monomers, polymers, and initiators/catalysts remain.
- Commonly 1-6% residual monomer in UPR/VE
  - Quick calculation: L=10m, D=1m, T= 10cm, 50% resin, 1% residual monomer = ~14Kg
  - However, after initial burst comes out over years.

CFRP production can pose issues to fabricators

- Three main areas of concern: fiber handling, cutting/sanding, and resin use
- Fiber handling: mostly fiber skin penetration
- CFRP cutting: breathable dust, eye irritation.
  - 2016: "OSHA Issues $47k in Penalties to Manufacturer of Fiberglass Boats For Exposing Georgia Employees to Serious Hazards" (Hansford Lawfirm)
- Resin Use:
  - Exposure to monomers (styrene from vinyl ester and polyester)
  - Environmental emissions (VOC)
  - Flammability concerns

Styrene emissions were a huge issue for bathtub and boat manufacturers

- Large scale FG manufacturers were forced to change procedures due to lawsuits and regulations
  - OSHA, EPA, DHHS all issued reports regarding styrene release
- Possibly solutions:
  - Industrially, proper ventilation, such as a push/pull ventilation system is necessary to remove styrene from the work area
    - Lasco Bathware $2M investment 2008 to meet clean air standards (reduced emission by ~250,000 tons/year)
  - High transfer efficiency spray guns for gel coating applications
  - Reduced styrene content in resin
  - Styrene substitution with a less volatile monomer, such as p-methyl styrene
  - Vapor suppressant
- Controls reduce exposure below threshold limits, still concerns about chronic exposure

1. Industrially, ventilation/emissions control is necessary
2. Proper PPE are needed (especially for small fabricators

Thanks

Any Questions?