From Disaster to Recovery
How VOCs Can Ruin Your Day

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Prism Analytical Technologies

Agenda

- VOCs and IAQ
- Types of disaster
- Types of damage
- Critical concerns
- Before and After Assessments
- What is “Safe”?

Immediate Concerns

- Safety
- Possessions
- Insurance

- “Normal” life

- Structural damage
- Systems
  - Power, water
- Damaged items
  - Fire & smoke
  - Water
  - Phydical
- Hazardous materials

VOCs of …

- Disaster
  - Fire
  - Water
  - Physical
- Remediation
  - Cleaning
  - Encapsulate
  - Neutralize
  - Rebuild
- Hazardous materials

Exposure

- 1st responders
- Occupants
- Assessors
  - Insurance
  - Investigation
- Contractors

VOC Challenges

- Complexity
  - VOC types / chemical classes
  - Concentrations
  - Changing conditions
- Effects
- Odors
- Limits
- Sources
  - Building
  - Occupants

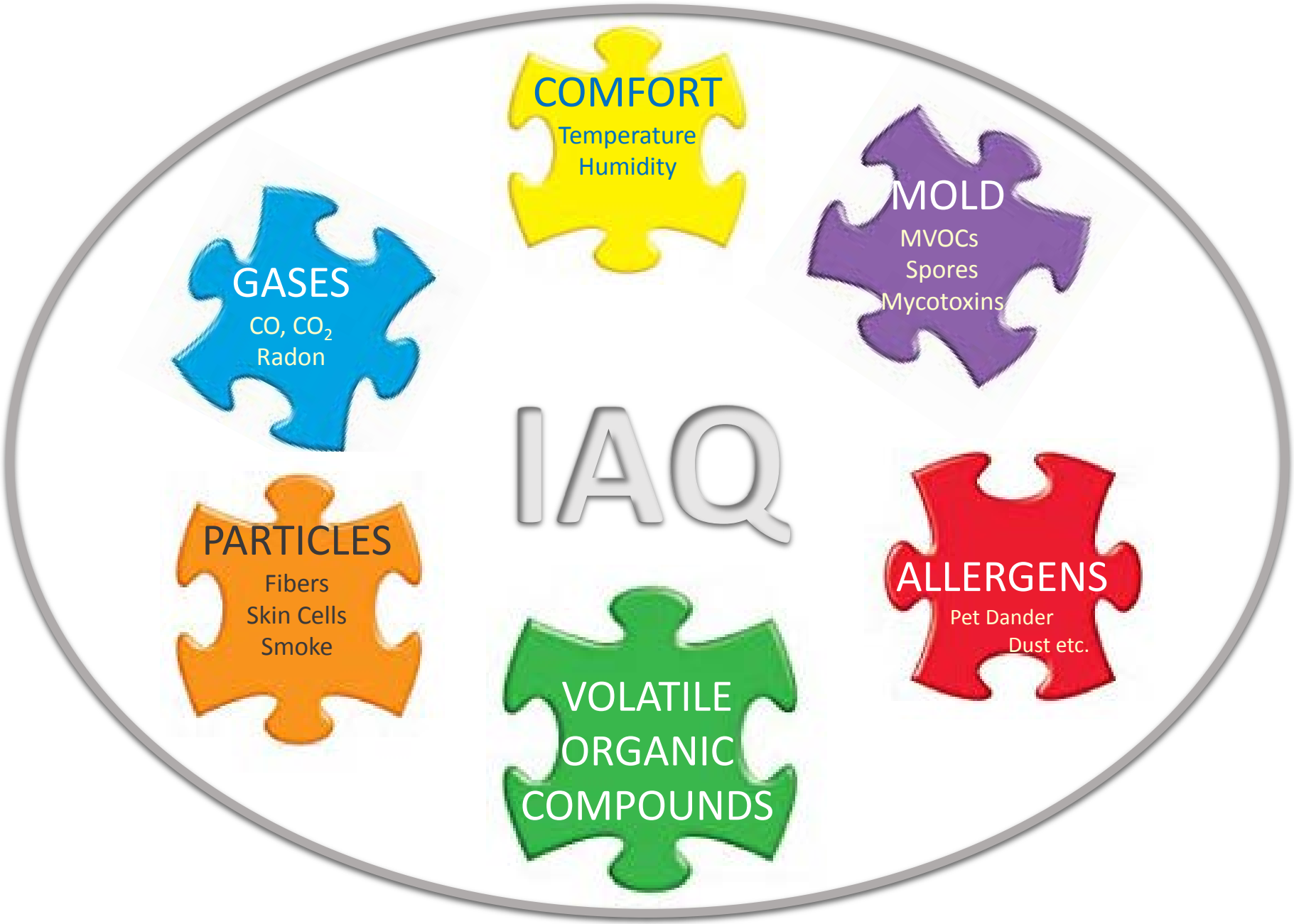
Indoor Air Quality

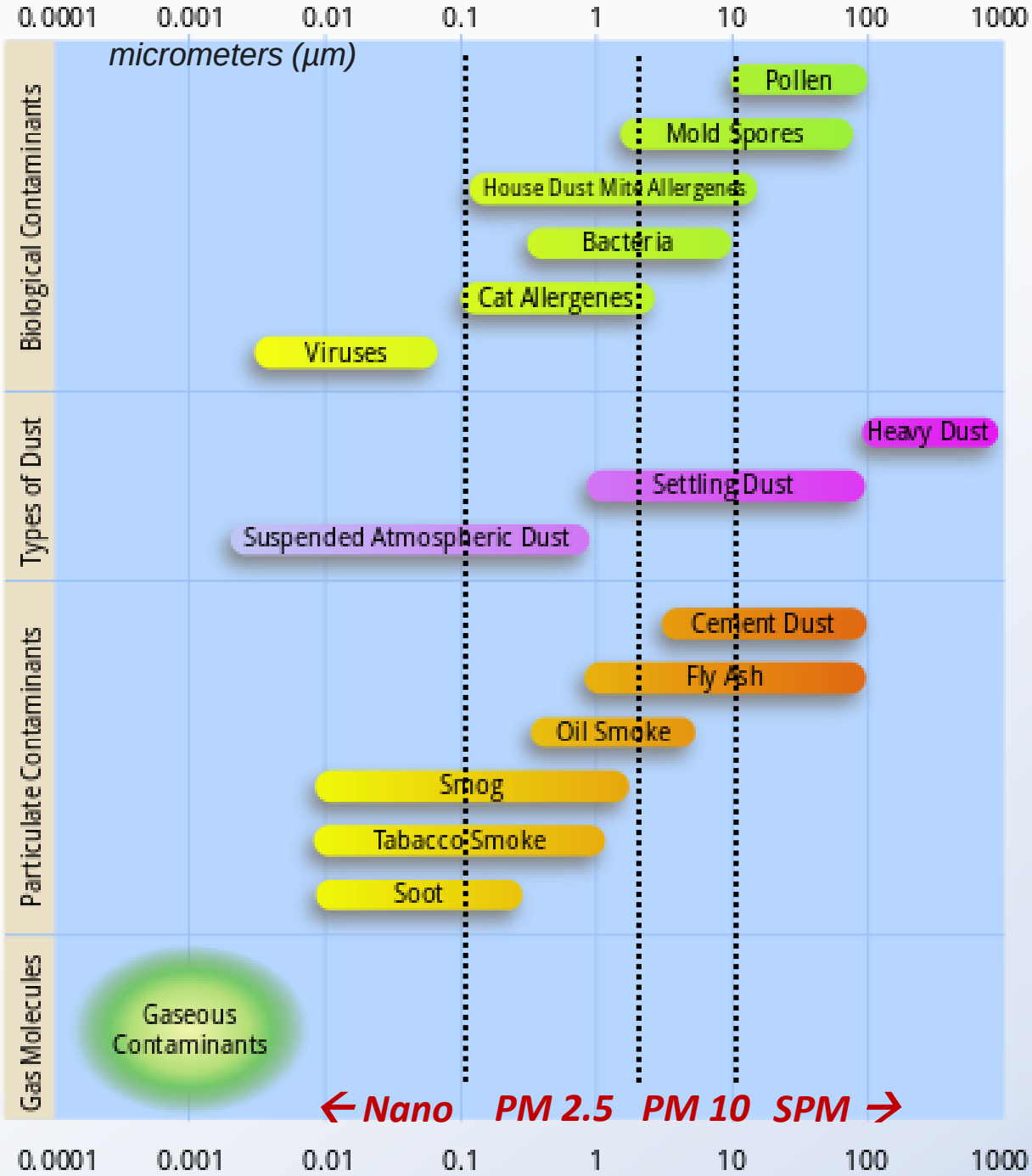
The air quality within and around buildings and structures, especially relating to health and comfort of the occupants.

Problems in IAQ

- Design and construction
- System installation and implementation
- Moisture in building materials
- Moisture and dirt in ventilation systems
- Ineffective filtration and air cleaning
- Inadequate ventilation
- Poor outdoor air quality
- Indoor equipment and activities
- Indoor contaminant sources

Indoor Air Quality Guide, ASHRAE 2013


COMFORT
Temperature
Humidity
MOLD
MVOCs
Spores
Mycotoxins
GASES
CO, CO_2
Radon
IAQ
PARTICLES
Fibers
Skin Cells
Smoke
ALLERGENS
Pet Dander
Dust etc.
VOLATILE
ORGANIC
COMPOUNDS



Size is Everything

SPM > 10 µm
Suspended particulate matter

PM 10 2.5 µm → 10 µm
Coarse; respirable

PM 2.5 0.1 µm → 2.5 µm
Fine; gas exchange

Nano < 0.1 µm
Ultra fine; pass beyond lungs

Wikipedia – Particulates (GFDL)
ttps://en.wikipedia.org/w/index.php?curid=48987967

Volatile Organic Compounds

Volatile

Size:

6 – 16 Carbons

OR

Boiling Point:

50 – 250 °C

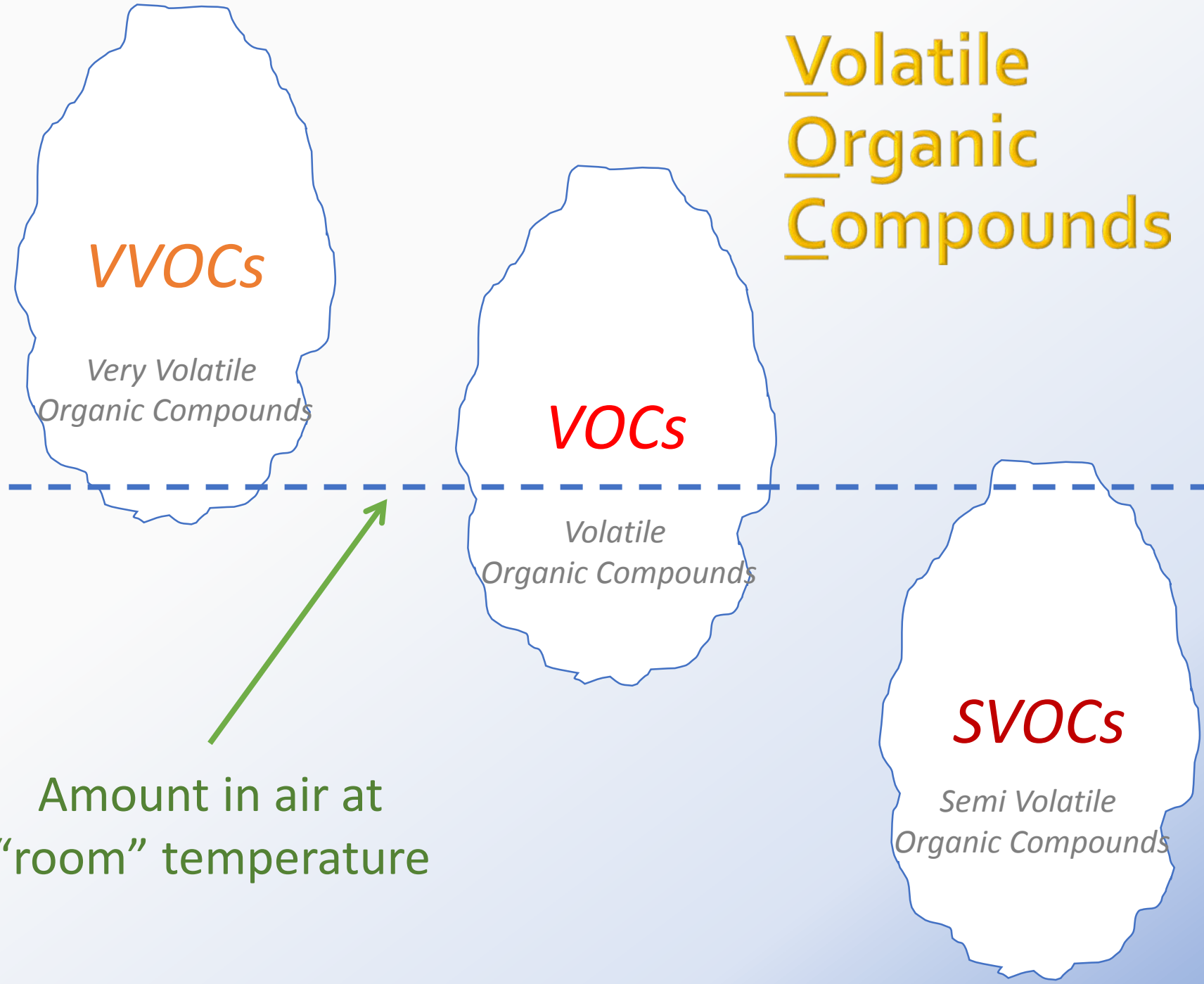
Organic

Contains:

Carbon (C) & Hydrogen (H)

Gas at room temperature

Volatile Organic Compounds



Volatility

Particle-Bound Organic Matter
Non-Volatile Organic Compounds

PAHs (~370-500)
Phthalates (~280-380)
Pesticides (~100-450)
Flame Retardants (~220-)

Semi-Volatile Organic Compounds

- BP 240-260 to 380-400 ºC
- Primarily semisolid/solid state

Hexane (68)
Benzene (80)
Acetone (56)
MEK (80)
Limonene (176)

Volatile Organic Compounds

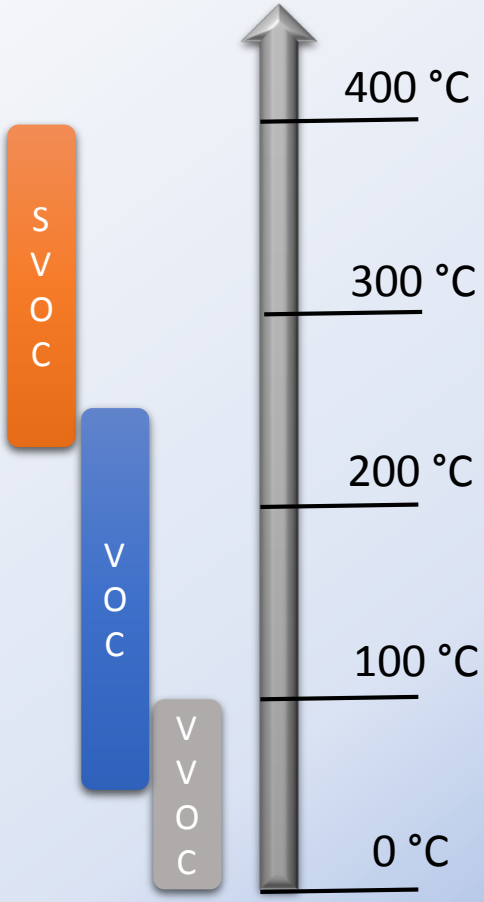
- BP 50-100 to 240-260 ºC
- Both gas and liquid/solid state

Methane (-151)
Ethane (-89)
CFCs (~ -40 to 50)

Very Volatile Organic Compounds

- BP < 50 to 100 ºC
- Permanent gases

Formaldehyde (-19°C)



World Health Organization (WHO) Definition

VVOCs

- Permanent gases

- Light hydrocarbons
- Blowing agents
- Refrigerants (e.g., Freons®)

- Dissipate quickly
- Relatively non-toxic

VOCs

- Lot of variability

- Non-toxic to extremely hazardous
- Mostly responsible for odors

SVOCs

- Most persistent
- Many toxic

- Polymers
- Pesticides, flame retardants, plasticizers

HIGHER VOCs

HIGHER VOCs

LOWER VOCs

INCREASE
Temperature
Humidity
Ventilation

DECREASE
Temperature
Humidity
Ventilation

LOWER VOCs

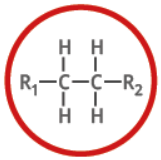
LOWER VOCs

HIGHER VOCs

FUNCTIONAL GROUPS IN ORGANIC CHEMISTRY

FUNCTIONAL GROUPS ARE GROUPS OF ATOMS IN ORGANIC MOLECULES THAT ARE RESPONSIBLE FOR THE CHARACTERISTIC CHEMICAL REACTIONS OF THOSE MOLECULES. IN THE GENERAL FORMULAE SHOWN BELOW FOR EACH FUNCTIONAL GROUP, 'R' REPRESENTS THE REST OF THE MOLECULE, AND 'X' REPRESENTS ANY HALOGEN ATOM.

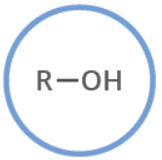
HYDROCARBONS | SIMPLE OXYGEN HETEROATOMICS | HALOGEN HETEROATOMICS | CARBONYL COMPOUNDS | NITROGEN-BASED | SULFUR-BASED | AROMATIC



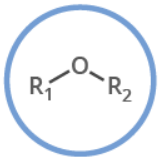
ALKANE
Naming: -ane
e.g. ethane

ALKENE
Naming: -ene
e.g. ethene

ALKYNE
Naming: -yne
e.g. ethyne



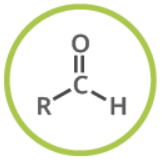
ALCOHOL
Naming: -ol
e.g. ethanol



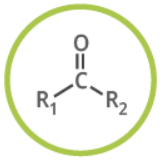
ETHER
Naming: -oxy -ane
e.g. methoxyethane

EPOXIDE
Naming: -ene oxide
e.g. ethene oxide

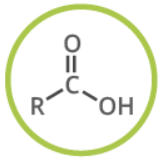
HALOALKANE
Naming: halo-
e.g. chloroethane



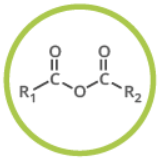
ALDEHYDE
Naming: -al
e.g. ethanal



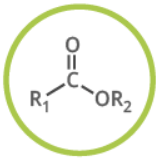
KETONE
Naming: -one
e.g. propanone



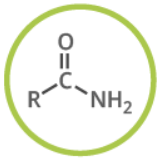
CARBOXYLIC ACID
Naming: -oic acid
e.g. ethanoic acid



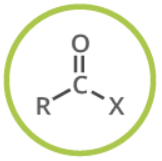
ACID ANHYDRIDE
Naming: -oic anhydride
e.g. ethanoic anhydride



ESTER
Naming: -yl -oate
e.g. ethyl ethanoate



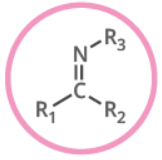
AMIDE
Naming: -amide
e.g. ethanamide



ACYL HALIDE
Naming: -oyl halide
e.g. ethanoyl chloride

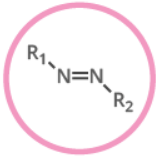
AMINE
Naming: -amine
e.g. ethanamine

NITRILE
Naming: -nitrile
e.g. ethanenitrile



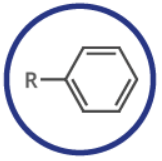
IMINE
Naming: -imine
e.g. ethanimine

ISOCYANATE
Naming: -yl isocyanate
e.g. ethyl isocyanate



AZO COMPOUND
Naming: azo-
e.g. azoethane

THIOL
Naming: -thiol
e.g. methanethiol



ARENE
Naming: -yl benzene
e.g. ethyl benzene

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Functional Groups

Hydrocarbons → Slight petroleum odor; little health concern

- Solvents, paints and coatings, gasoline & fuel oil/diesel fuel, combustion
- Methyl butane, hexane, cyclohexane

Aromatics → Petroleum odor; health concern

- Gasoline, adhesives, solvents
- Benzene, toluene, xylene, trimethylbenzene, styrene

Halogenated → Little to sweet odor; some health concern

- Solvents, refrigerants
- Tetrachoroethylene (PCE), methylene chloride; Chlorofluorocarbons (CFCs)

Amines → Fishy odor; some health concern

- Catalysts
- Dyes
- Biological processes

Functional Groups

Oxygenated Compounds

- Alcohols → Little odor or health concern
  - Personal care/cleaning and fragrance products, disinfectants, solvents, pharmaceutical, human consumable
- Ketones → Solvent to fruity odor
  - Solvents, combustion, biological processes
- Esters → Mostly pleasant odor
  - Fragrance products, synthetic fibers (i.e., polyester), plastic bottles, etc.
- Aldehydes → Strong mostly pleasant odor; health concern
  - Fragrance products, solvents, combustion, biological processes, oxidation product, intermediate
- Organic Acids → Irritating
  - Solvents, preservation (e.g., food), oxidation product
- Acrylates → Very irritating
  - Resins/adhesives, plastics (polymers)

Example

Methyl Ethyl Ketone

Names

MEK
2-Butanone
Butan-2-one
Ethyl methyl ketone

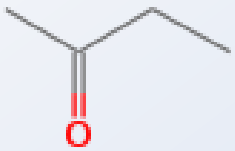
Formula

C_4H_8O

ID Number

CAS 78-93-3
RTECS EL6475000
DOT UN1193

Structure



A BRIEF GUIDE TO

• TYPES OF ORGANIC FORMULAE •

A GUIDE TO THE DIFFERENT WAYS ORGANIC COMPOUNDS CAN BE REPRESENTED IN CHEMISTRY

MOLECULAR FORMULA

The molecular formula of an organic compound simply shows the number of each type of atom present. It tells you nothing about the bonding within the compound.

$C_4H_8O_2$

EMPIRICAL FORMULA

The empirical formula of an organic compound gives the simplest possible whole number ratio of the different types of atom within the compound.

C_2H_4O

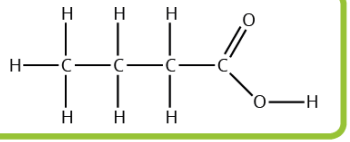
CONDENSED FORMULA

The condensed formula is also text-based; here, each carbon atom is listed separately, with atoms attached to it following. An exception is cyclic parts of molecules, e.g. benzene, where the carbons are grouped.

$CH_3CH_2CH_2COOH$

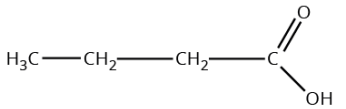
DISPLAYED FORMULA

A displayed formula shows all of the atoms and all of the bonds present in an organic compound. The bonds are represented as lines.



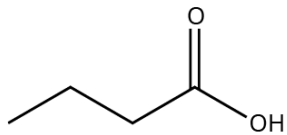
STRUCTURAL FORMULA

Similar to displayed formula - not all bonds are shown, although all atoms are still indicated using subscript numbers. Carbon hydrogen bonds are often simplified.



SKELETAL FORMULA

In a skeletal formula, most hydrogen atoms are omitted, and line ends or vertices represent carbons. Functional groups and atoms other than carbon or hydrogen are still shown. Easiest to draw & commonly used.



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Units & Conversion Factors

Concentration: normalized amount of chemical substance

ng/L	nanogram per liter
$\mu g/m^3$	microgram per cubic meter
mg/m^3	milligram per cubic meter
ppm	parts per million (~ 1 second in 11.5 days)
ppb	parts per billion (~ 1 second in 32 years)

Conversions (factor of 1000)

1 ng/L = 1 $\mu g/m^3$ = 0.001 mg/m^3

1 mg/m^3 = 1000 $\mu g/m^3$ = 1000 ng/L

1 ppm = 1000 ppb 1 ppb = 0.001 ppm

Need molecular weight to convert

$$1\frac{ng}{L} of\ Benzene * \frac{24.04}{78} = 0.3\ ppb\ of\ Benzene$$

Health

No Effect → Irritating → Highly Toxic

- Individual specific
- Environmental Conditions
- SBS, Building-Related, Sensitivity
- Most common – respiratory
- Exacerbate existing conditions (asthma, allergies)
- Chronic and short term exposure

- Half life – time required for concentration to decrease by half
- LD50 – lethal dose for 50% of population

Effects or Symptoms

Change in health resulting from exposure to a source

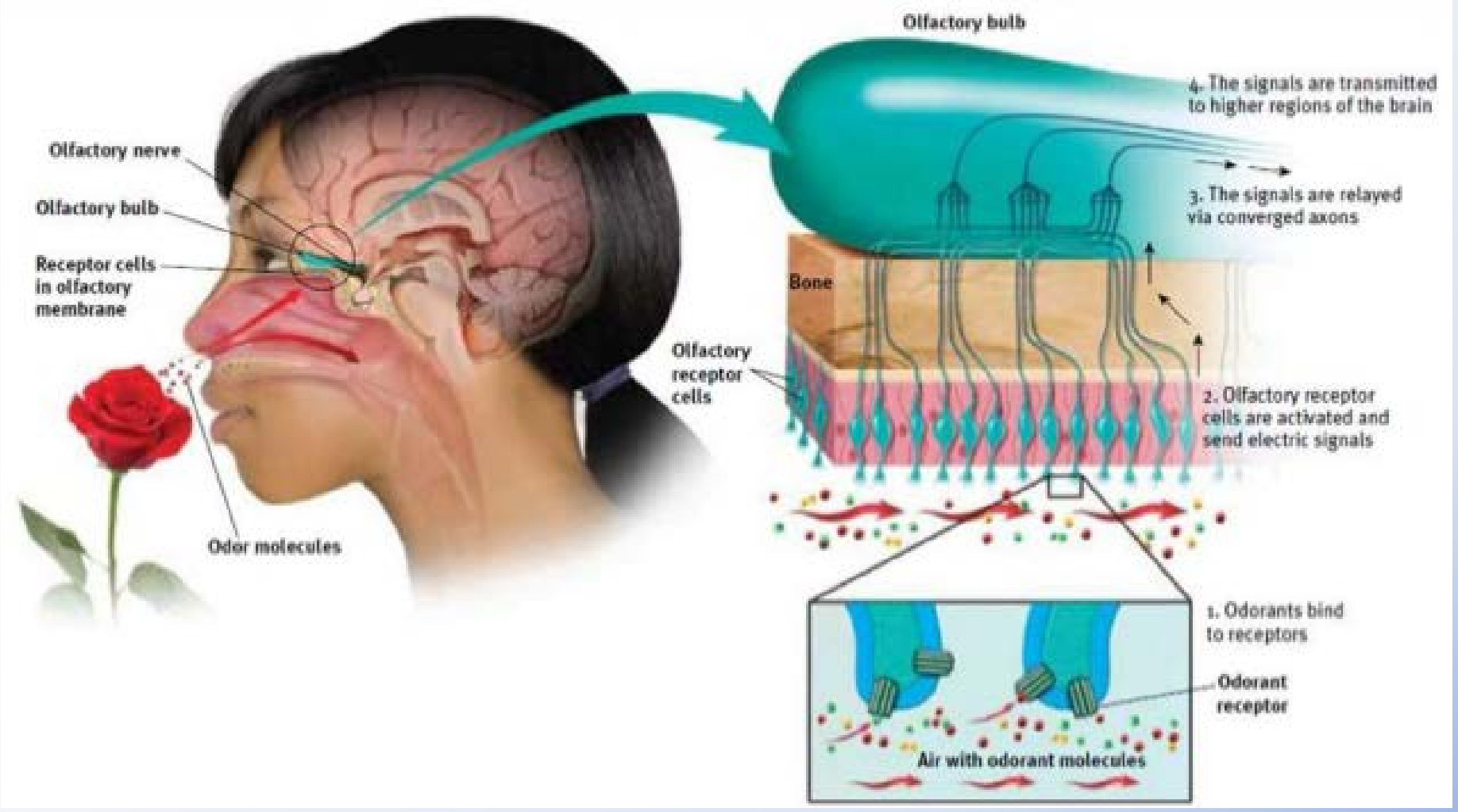
- Eye, nose, throat irritation
- Headache
- Loss of coordination
- Nausea
- Damage to liver, kidney, central nervous system (CNS)
- Cancer (applicable to certain VOCs only)

Sensitive Groups

- Infants and young children; under-developed respiratory and immune systems
- Children
- Individuals with chronic or preexisting respiratory medical conditions
- Individuals with other cardio-vascular or other vascular conditions
- Pregnant women
- The elderly
- Individuals with immunocompromised conditions
- Individuals with infections at the time of exposure
- Smokers and former smokers

https://www.aiha.org/government-affairs/PositionStatements/AIHA_IH_Disaster%20FinalJuly72017.pdf

Odors


Olfactory bulb
4. The signals are transmitted to higher regions of the brain
Olfactory nerve
Olfactory bulb
Receptor cells in olfactory membrane
3. The signals are relayed via converged axons
Bone
Olfactory receptor cells
2. Olfactory receptor cells are activated and send electric signals
Odor molecules
1. Odorants bind to receptors
Odorant receptor
Air with odorant molecules

Odors

- Odor Threshold:

Odor detection → Odor recognition

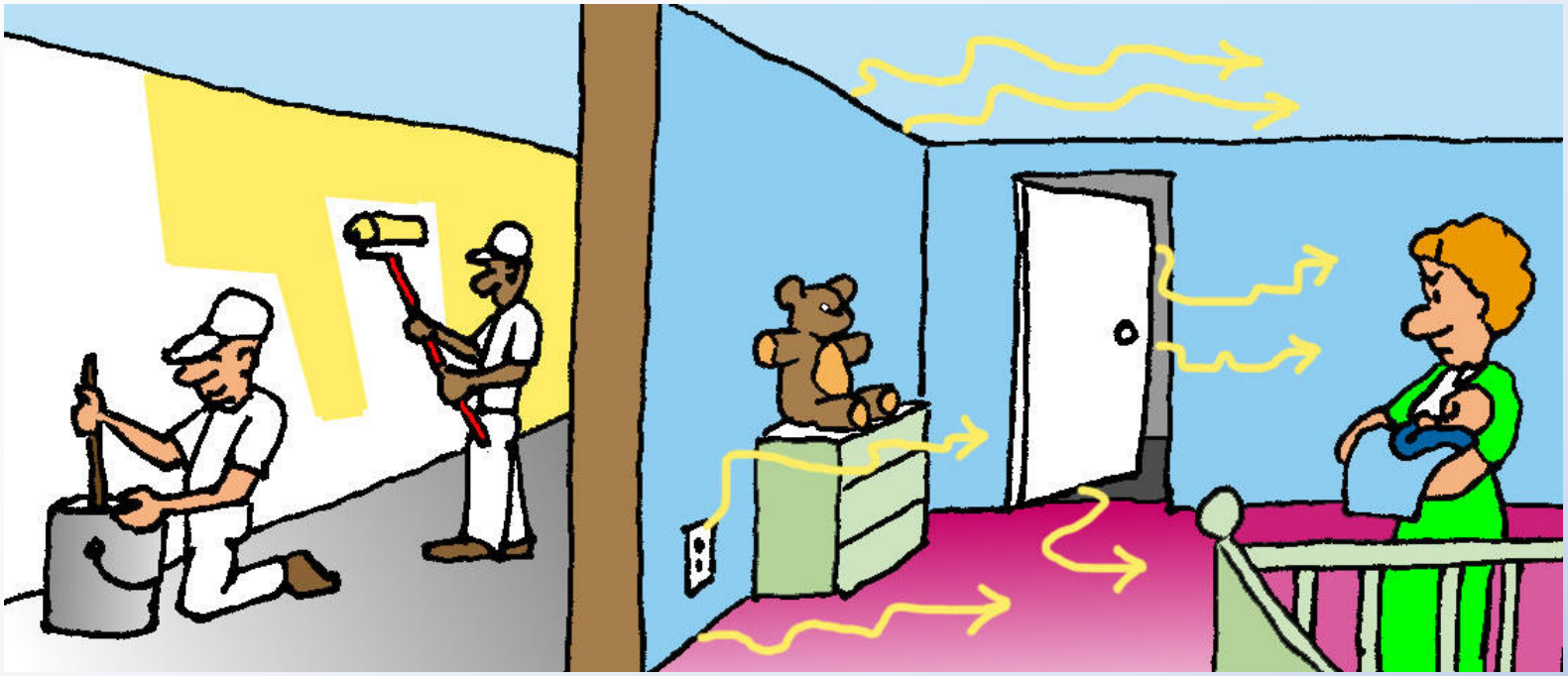
  - < 1 ppb to 1000s of ppm

- Odor Character

Sweet; Floral; Pungent; Musky; etc.

- Odor compound may or may not be responsible for physical symptoms; there is no specific relationship linking the odor to other effects
  - Odors and physical symptoms are both effects

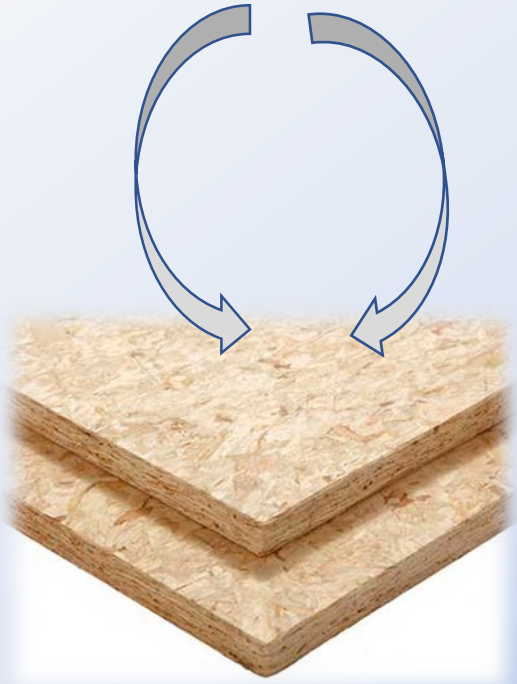
Material Off-Gassing



Ad(b)sorption

Imbalance

- Adsorption
  - Adhesion to a surface
- Absorption
  - Something takes in another substance
  - Enter bulk phase
- Sorption – includes both processes

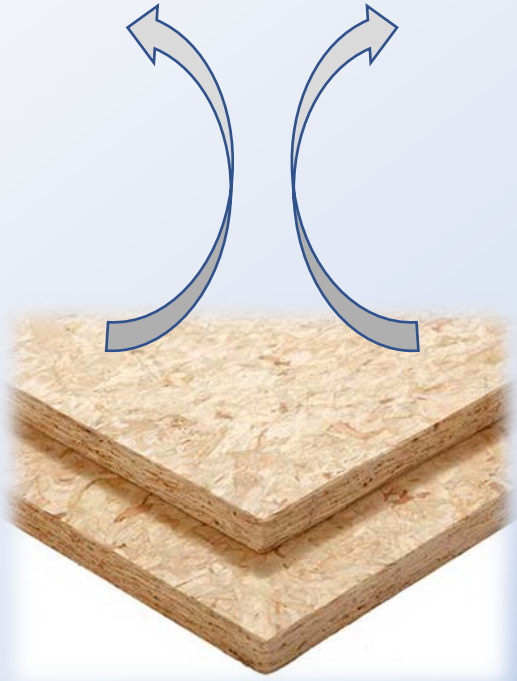


Emission

Imbalance

- Emission
  - Something leaves another substance
  - Surface and interior
  - Exits bulk phase

- Highly dependent on:
  - Temperature and humidity
  - Air flow or exchange

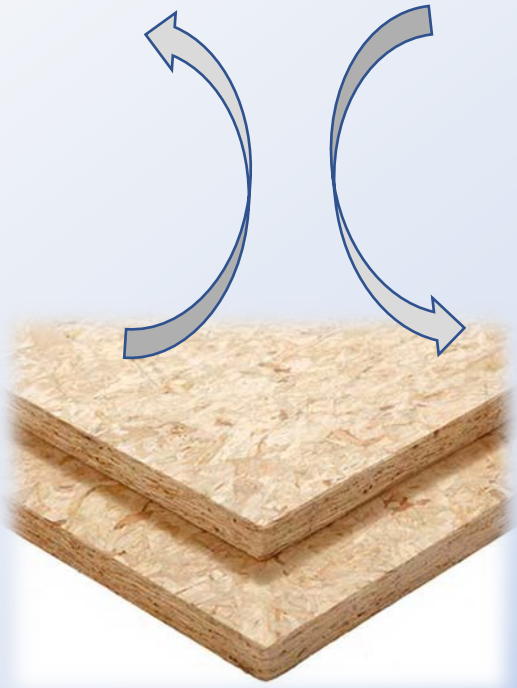


Equilibrium

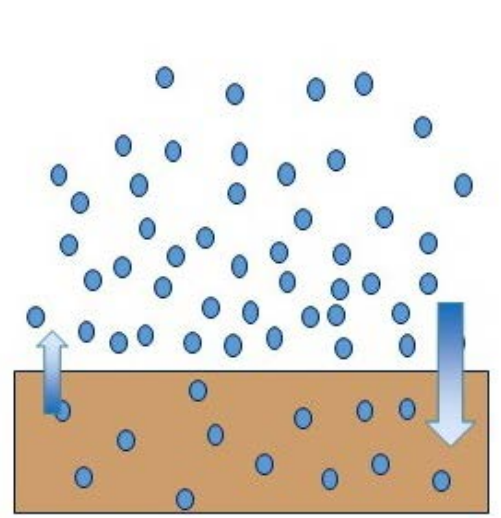
Balance

- Concentration same in air and material

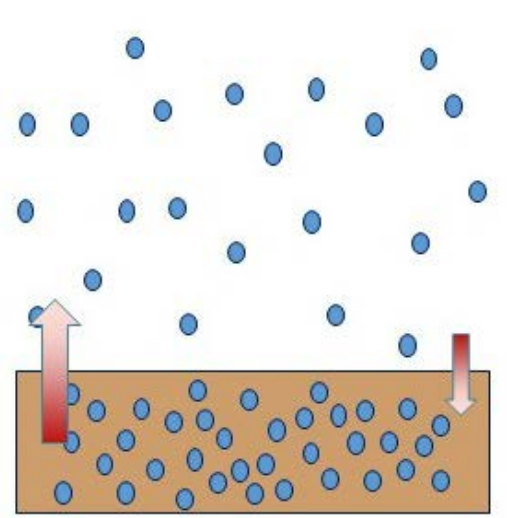
- Dynamic equilibrium
  - Equal movement in and out of material



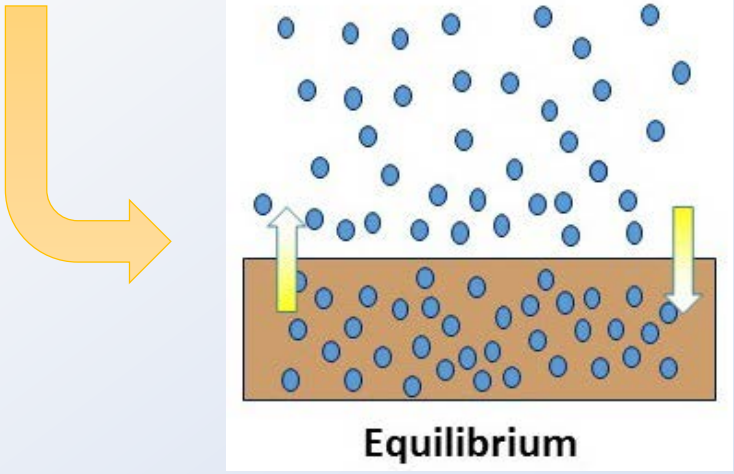
Adsorption & Emission



Adsorption by Material



Emission from Material



Equilibrium

Disasters

Hurricane Katrina

Hurricane Sandy

Hurricane Harvey

https://www.cbsnews.com/pictures/catastrophic-flooding-in-texas-from-harvey/

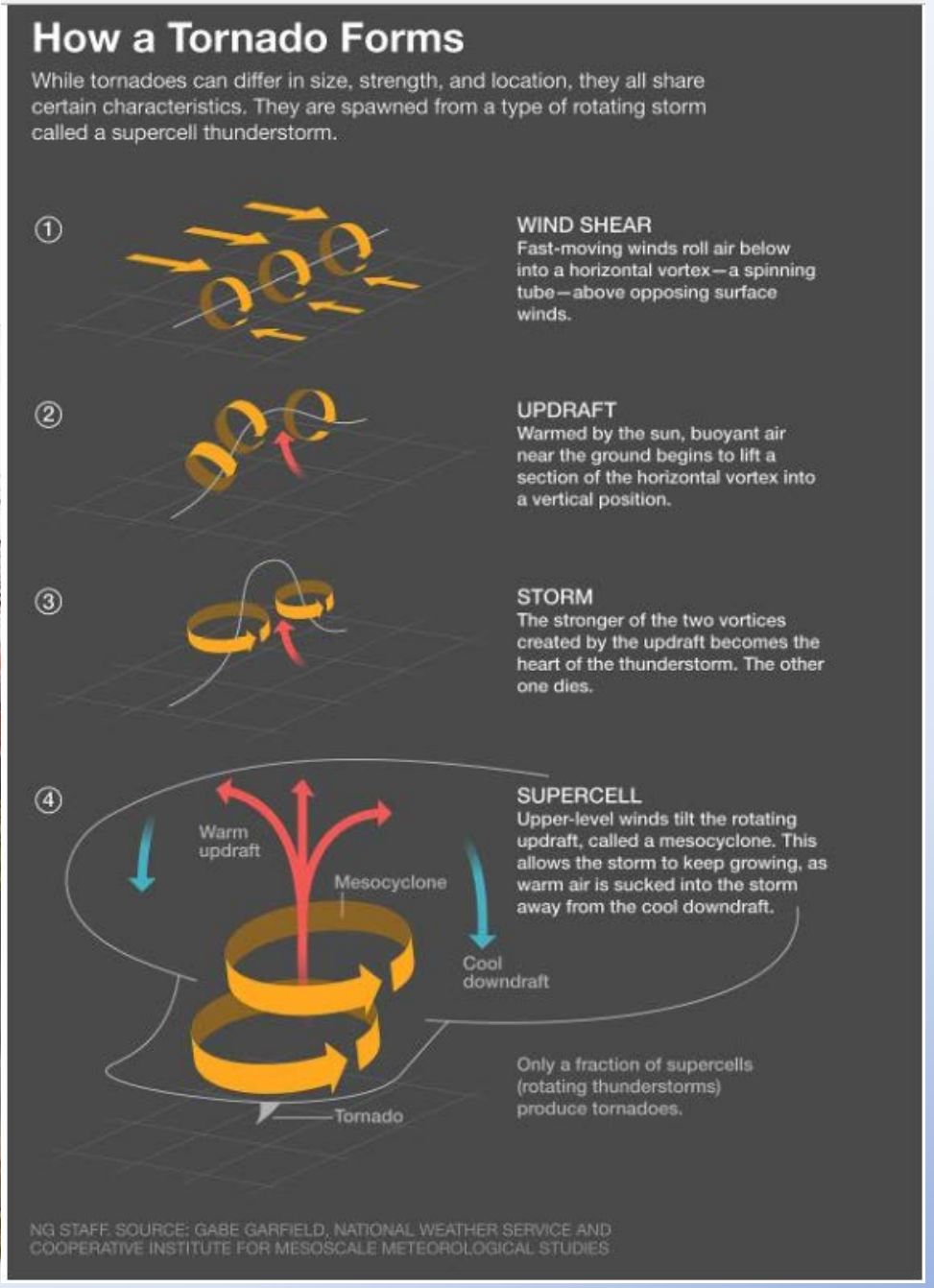
Tsunami

Earthquakes

Tornados

How a Tornado Forms

While tornadoes can differ in size, strength, and location, they all share certain characteristics. They are spawned from a type of rotating storm called a supercell thunderstorm.



https://news.nationalgeographic.com/2015/05/150511-tornadoes-storms-midwest-weather-science/

https://science.howstuffworks.com/nature/climate-weather/storms/tornado.htm

Volcano

Fire

Disasters & Damage

- Fire
- Flood
- Physical
- Hazardous materials

- Secondary
  - Mold
  - Bacteria
  - Disease
  - Other health

- Materials that are:
  - Burned
  - Smoke-damaged
  - Water-damaged
  - Decaying
  - Damaged

- Systems outages
  - Power,
  - Electrical
  - Water

Types of Damage

	Water	Fire	Debris	Hazardous
Fire	✓	✓	~	✓
Flood	✓	~	~	✓
Hurricane	✓	~	✓	✓
Severe Storm	~	~	~	✓
Tornado	~	~	✓	~
Earthquake	~	~	✓	✓
Volcano		✓	~	~
Tsunami	✓	~	✓	✓
Wind Storm		~	✓	~

Fire

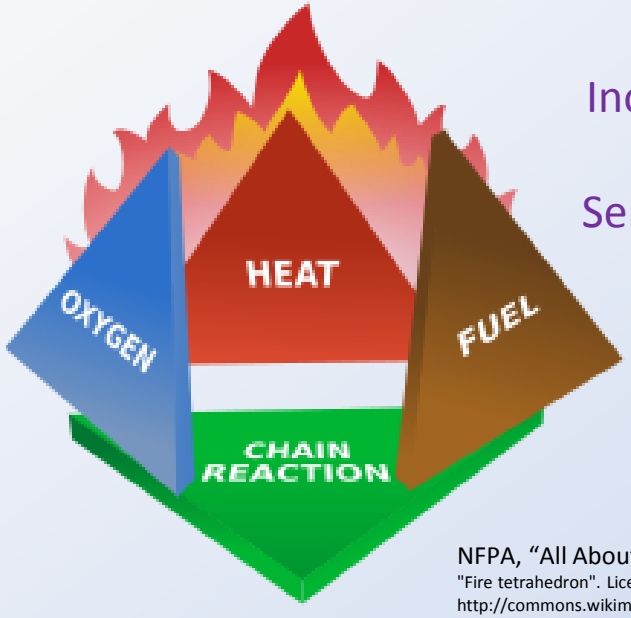
How It Works

Rapid oxidation process involving

fuel, heat, and oxygen

that releases heat, light, and various reaction products

Particulate
Soot
Char
Ash



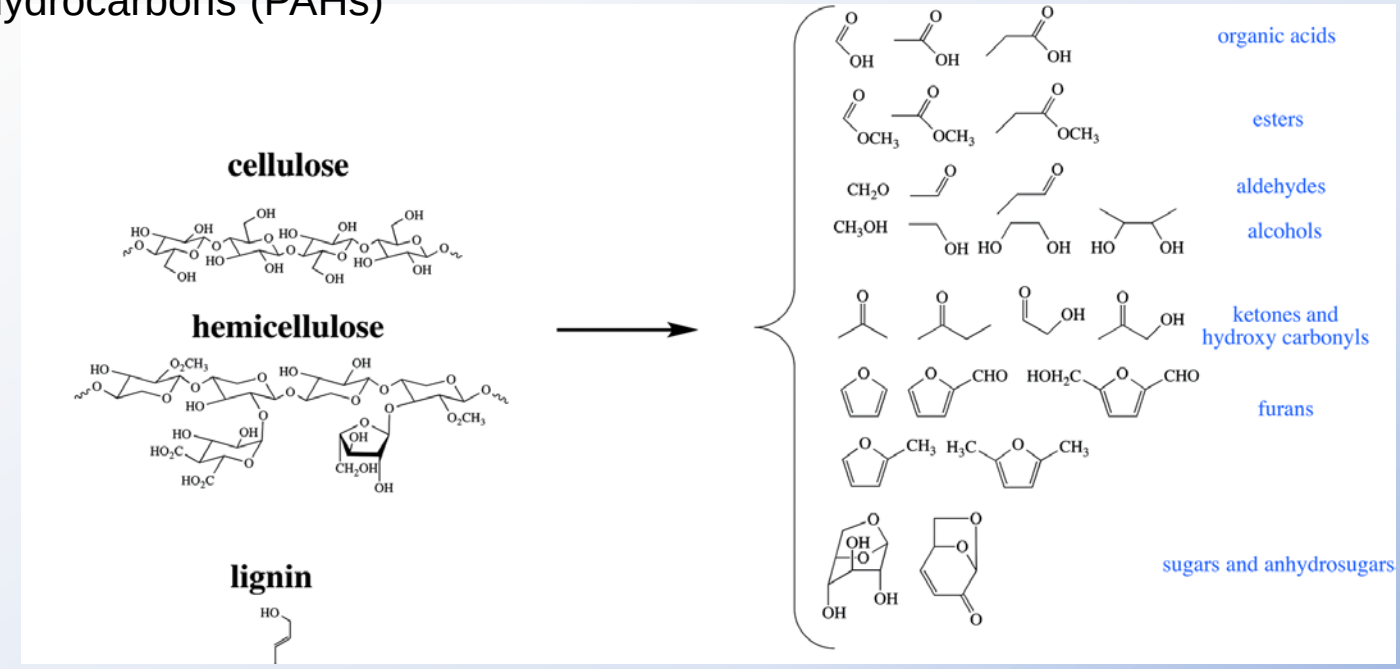
Gases
Inorganic Gases (CO, CO_2, etc.)
Volatile Organics (VOCs)
Semi-Volatile Organics (SVOCs)

NFPA, "All About Fire"
"Fire tetrahedron". Licensed under Public Domain via Wikimedia Commons - http://commons.wikimedia.org/wiki/File:Fire_tetrahedron.svg#mediaviewer/File:Fire_tetrahedron.svg

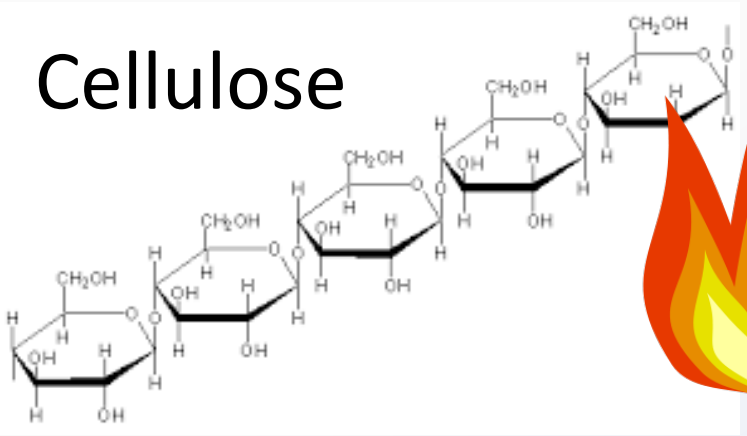
Chemical Contamination

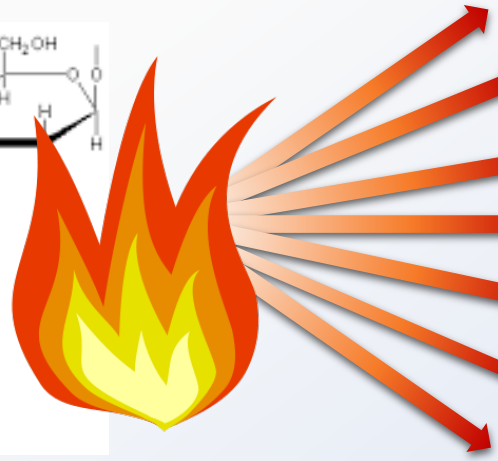
Fire is oxidative process

- Small, reactive compounds
  - acrolein, cyanide, hydrogen sulfide, hydrogen chloride, NOx, CO, CO2
- Larger, range of reactivities and volatilities
  - inorganics, hydrocarbons (alkanes, alkenes, cyclic), oxygenates (furans, esters, acids, carbonyls, phenols), aromatics, polycyclic aromatic hydrocarbons (PAHs)



Thermal Breakdown & Oxidation





CO

CO_2

C_3H_4O

(Acrolein)

H_2O

HCHO

(Formaldehyde)

C_6H_6

(Benzene)

C_7H_8

(Tolulene)

C_8H_{10}

(Xylenes)

C_7H_8O

(Cresols)

$C_8H_{10}O_2$

(Creosol)

$C_{10}H_8$

(Naphthalene)

$C_{12}H_8O$

(Dibenzofuran)

$C_{12}H_8$

(Acenaphthylene)

Variables

Type of fire

- Indoor vs Outdoor or Wildfire
- Small vs Large
- Low vs High Temperature

Length of time since fire

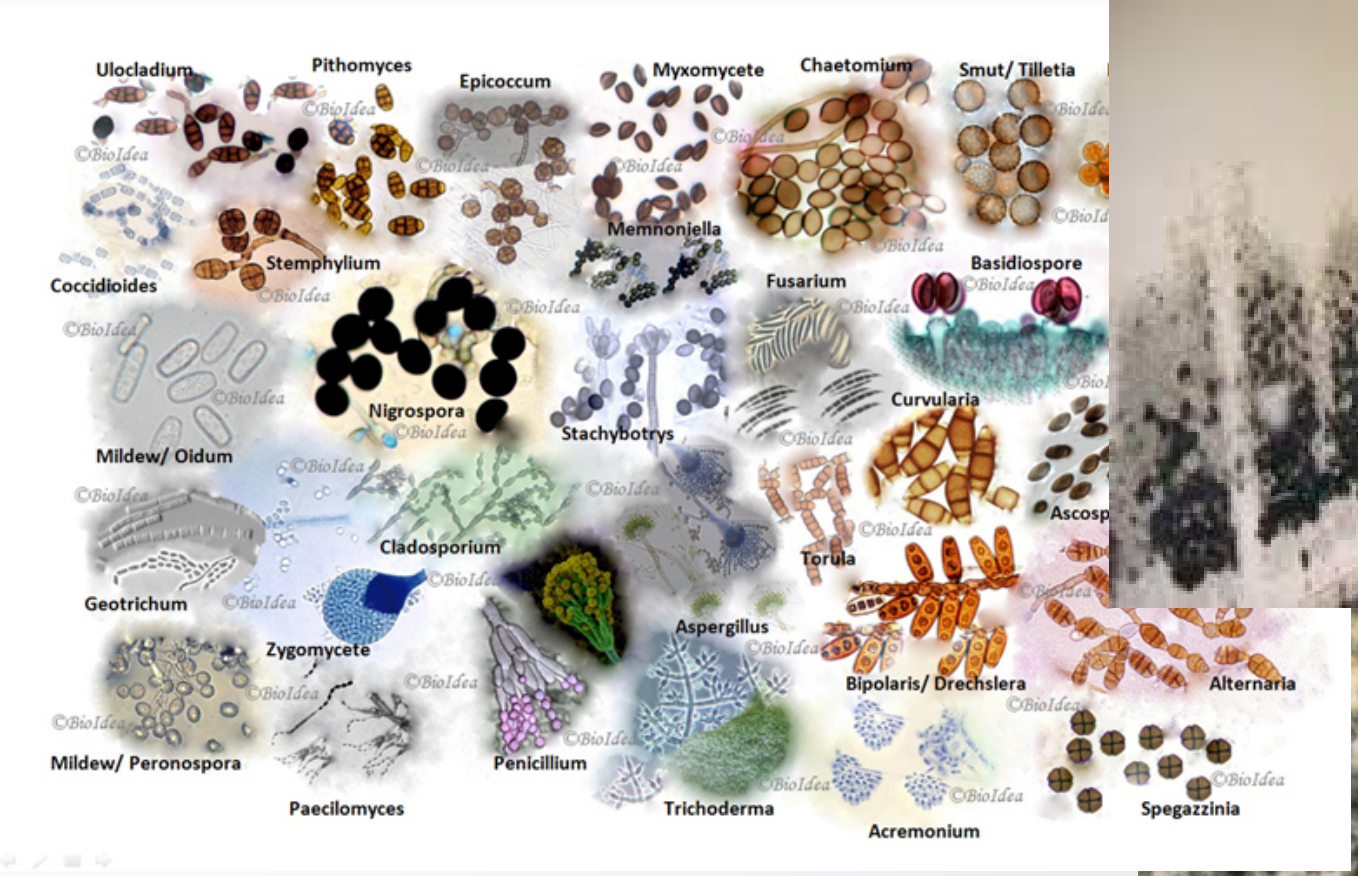
- Weeks, months, years

Level of cleanup or remediation performed

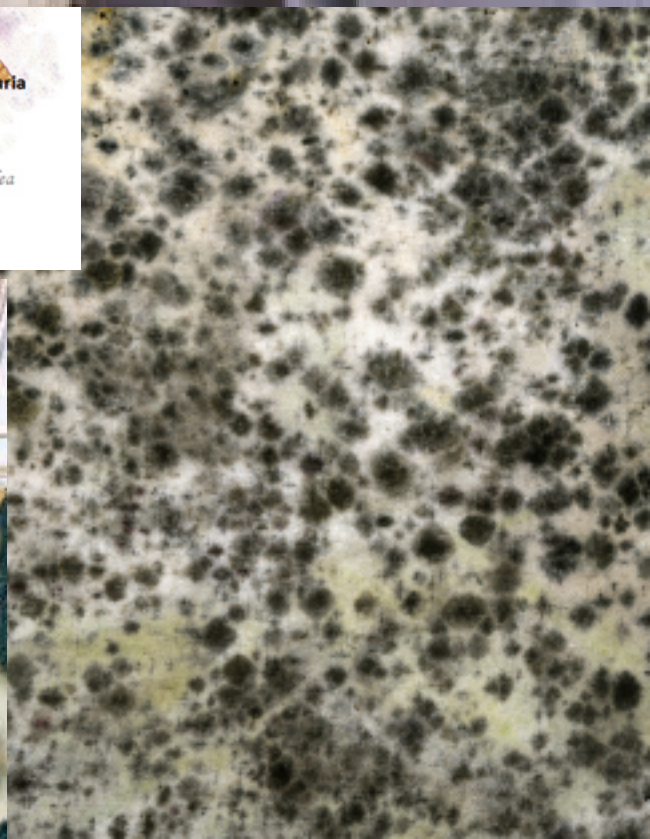
- None
- Surface
- Complete Replacement

Chemical Residues

- VVOCs
  - CO & CO2, cyanide, acids, formaldehyde
- VOCs
  - Cresols & creosol
  - Guaicols & syringols
  - Aromatics
  - Hydrocarbons
- SVOCs
  - PAHs
  - Dioxins
- Particulate
  - Carbon

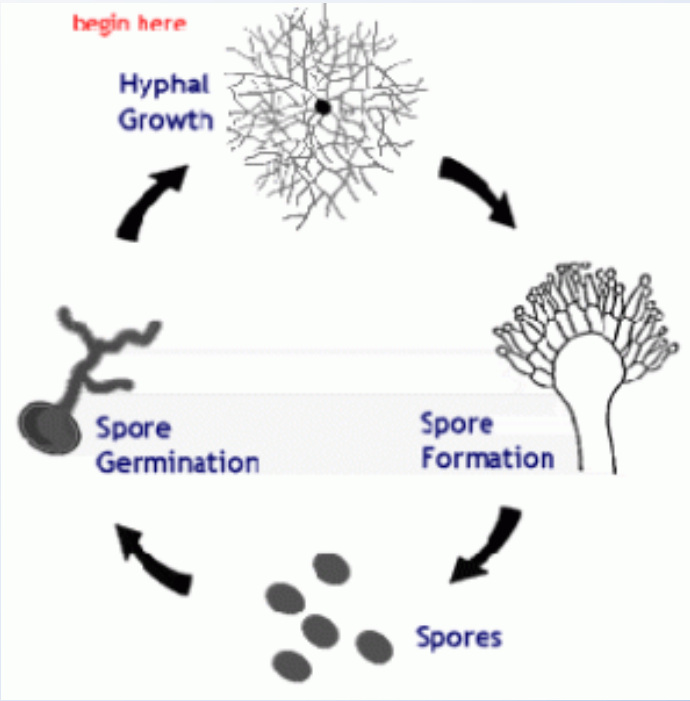

Ulocladium
Pithomyces
Epicoccum
Myxomycete
Chaetomium
Smut/ Tilletia
Memnoniella
Stemphylium
Coccidioides
Fusarium
Basidiospore
Nigrospora
Stachybotrys
Curvularia
Mildew/ Oidum
Ascosp
Cladosporium
Torula
Geotrichum
Aspergillus
Zygomycete
Bipolaris/ Drechslera
Alternaria
Mildew/ Peronospora
Penicillium
Trichoderma
Spegazzinia
Paecilomyces
Acremonium

Mold



Mold Life Cycle

1. Hyphal Growth
   - thread-like filamentous cells
   - degrade and absorb nutrients from substrate
   - grow into mycelium (visible portion)
2. Spore Formation
   - form on ends of hyphael cells
   - dependent on variety of environmental factors
     - light, oxygen, temperature, nutrient availability
3. Spore Dispersal
   - released into air and carried elsewhere
   - begin process of germination and growth
   - highly resistant and durable; can remain dormant for years
4. Spore Germination
   - spore will begin to germinate into new hyphael cell



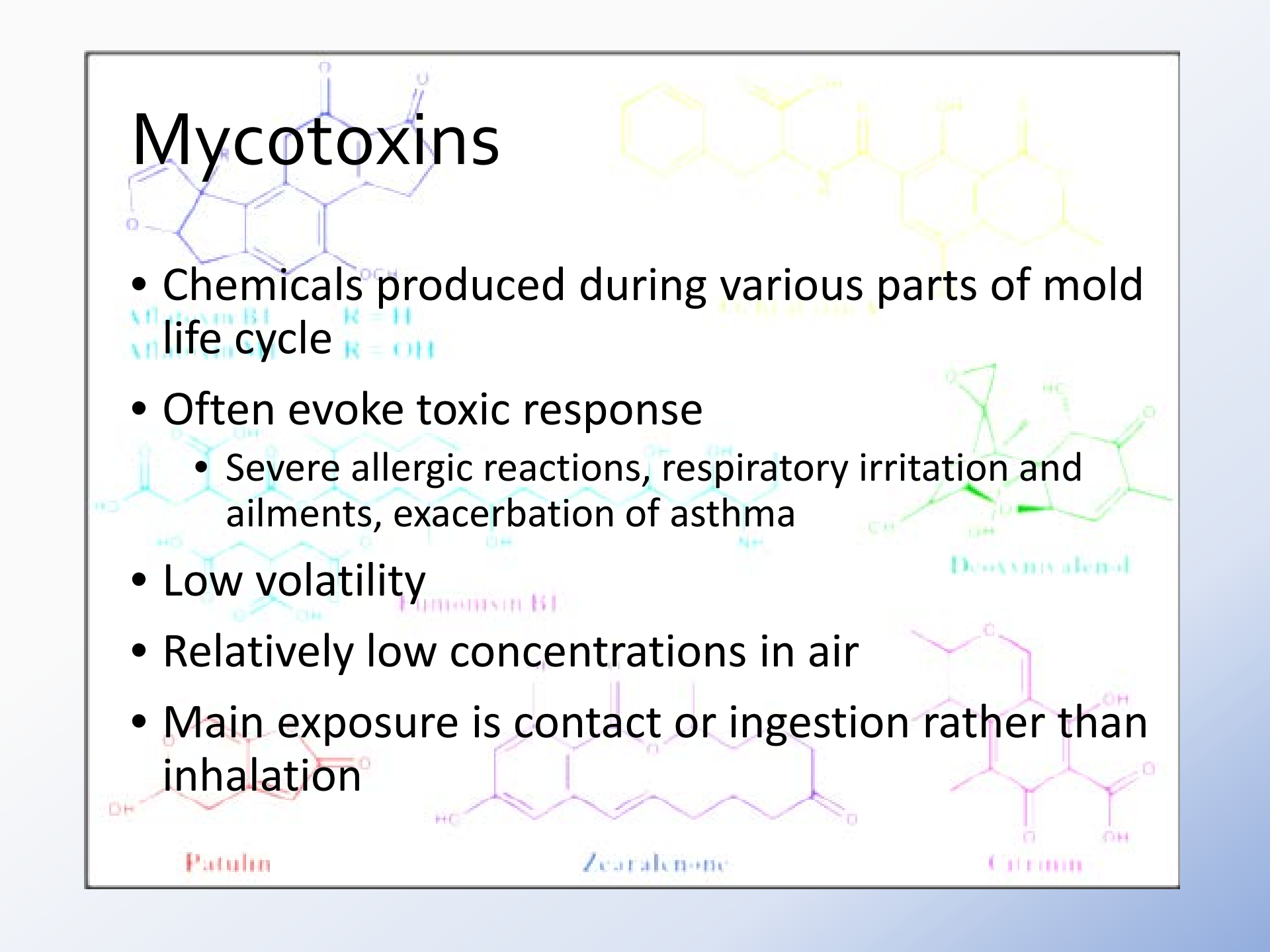
Moisture, Nutrients, Temperature

Mold VOCs

- VOCs produced by digestive process
  - Indicator of active mold growth
  - Hundreds of compounds; use select indicators as representatives
- Affected by …
  - Genus/species
  - Ventilation
  - Temperature & humidity
  - Growth surface
  - Competition from other molds

Mycotoxins

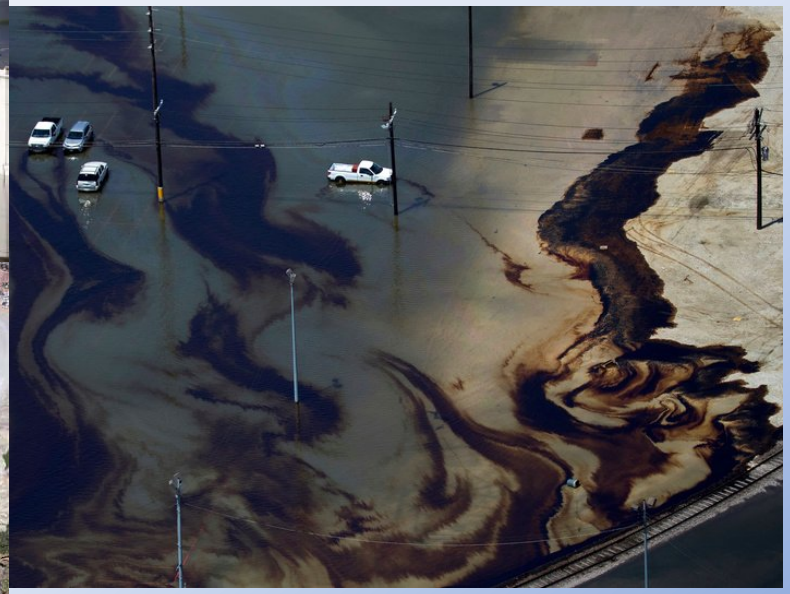
- Chemicals produced during various parts of mold life cycle
- Often evoke toxic response
  - Severe allergic reactions, respiratory irritation and ailments, exacerbation of asthma
- Low volatility
- Relatively low concentrations in air
- Main exposure is contact or ingestion rather than inhalation



Mold VOCs	Mycotoxins
Volatile	Semi-volatile or nonvolatile
Travel freely through the air	Travel mostly on surfaces or attached to spores or dust
Primary metabolite	Secondary metabolite
Produced only during active mold growth	Produced at different growth stages; typically as response to a threat
Hundreds of compounds from many chemical classes (e.g., furans, ketones, alcohols, aldehydes, terpenes, hydrocarbons, etc.)	Hundreds of compounds divided into several general families/categories that have many members (e.g., trichothycenes, aflatoxins, etc.)
Cannot determine mold species; specific compounds depend on mold species, growth substrate, and environmental conditions	Specific mycotoxin families/categories often associated with specific mold genus/species; however, one mold species may produce multiple mycotoxins and one mycotoxin may be produced by multiple mold species
Usually responsible for 'moldy' odor	Not typically associated with odor
Typically irritants; can cause more significant symptoms or conditions in certain situations or individuals	Typically causes more severe symptoms or conditions

Hazardous Materials

- Spills
  - Petroleum
  - Industrial chemicals



Organic Pollutants

What are "POPs"?

Persistent organic pollutants (POPs) are organic compounds that are resistant to environmental degradation through chemical, biological, and photolytic processes.

POPs **persist** in the environment for long periods, are capable of **long-range transport**, **bioaccumulate** in human and animal tissue and **biomagnify** in food chains, and have **potentially significant impacts** on human health and the environment.

Exposure to POPs can cause serious health problems including certain cancers, birth defects, dysfunctional immune and reproductive systems, greater susceptibility to disease and even diminished intelligence.

Persistent Organic Pollutants (POPs)

- Highly toxic
- Persistent in the environment (i.e., last forever)
- Bioaccumulate

- "Dirty Dozen"
  - aldrin, chlordane, DDT, dieldrin, dioxins, endrin, furans, heptachlor, hexachlorobenzene, mirex, PCBs, and toxaphene

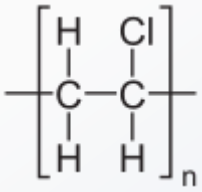
ToxTown https://toxtown.nlm.nih.gov/text_version/chemicals.php?id=86

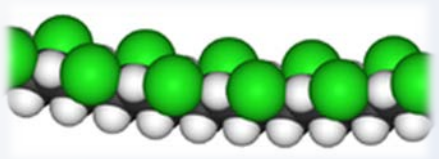
The 16 new POPs

Since its fourth meeting in 2009, The COP has decided to amend Annexes A, B and C to the Convention by adding the following chemicals:

Chemical	Annex	Specific exemptions/ acceptable purposes
Alpha hexachlorocyclohexane ●	A	**Production**: None **Use**: None
Beta hexachlorocyclohexane ●	A	**Production**: None **Use**: None
Chlordecone ●	A	**Production**: None **Use**: None
Hexabromobiphenyl ▲	A	**Production**: None **Use**: None
Hexabromocyclododecane ▲	A	**Production**: As allowed by the parties listed in the Register of specific exemptions **Use**: Expanded polystyrene and extruded polystyrene in buildings in accordance with the provisions of the Part VII of Annex A
Hexabromodiphenyl ether and heptabromodiphenyl ether (commercial octabromodiphenyl ether) ▲	A	**Production**: None **Use**: Articles in accordance with the provisions of Part IV of Annex A
Hexachlorobutadiene ▲■	A and C	**Production**: None **Use**: None
Lindane ●	A	**Production**: None **Use**: Human health pharmaceutical for control of head lice and scabies as second line treatment
Pentachlorobenzene ●▲■	A and C	**Production**: None **Use**: None
Pentachlorophenol and its salts and esters ●	A	**Production**: As allowed for the parties listed in the Register in accordance with the provisions of Part VIII of Annex A **Use**: Pentachlorophenol for utility poles and cross-arms in accordance with the provisions of Part VIII of Annex A
Perfluorooctane sulfonic acid (PFOS), its salts and perfluorooctane sulfonyl fluoride (PFOSF) ▲	B	**Production:** For the use below **Use:** Acceptable purposes and specific exemptions in accordance with Part III of Annex B
Polychlorinated naphthalenes ▲■	A and C	**Production**: For the use below **Use**: Production of polyfluorinated naphthalenes, including octafluoronaphthalene
Technical endosulfan and its related isomers ●	A	**Production**: As allowed for the parties listed in the Register **Use**: Crop-pest complexes as listed in accordance with the provisions of Part VI of Annex A
Tetrabromodiphenyl ether and pentabromodiphenyl ether (commercial pentabromodiphenyl ether) ▲	A	**Production:** None **Use:** Articles in accordance with the provisions of Part V of Annex A
Decabromodiphenyl ether (Commercial mixture, c-DecaBDE) ▲	A	**Production**: As allowed for the parties listed in the Register **Use**: Vehicles, aircraft, textile, additives in plastic housings etc., polyurethane foam for building insulation, in accordance with Part IX of Annex A
Short-chain chlorinated paraffins (SCCPs) ▲	A	**Production**: As allowed for the parties listed in the Register **Use**: Additives in transmission belts, rubber conveyor belts, leather, lubricant additives, tubes for outdoor decoration bulbs, paints, adhesives, metal processing, plasticizers

PVC

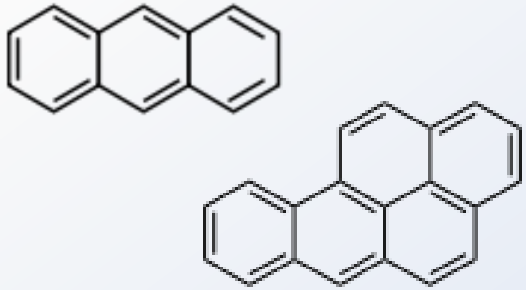




Polyvinylchloride

- Synthetic plastic polymer
  - Similar to polyethylene and polypropylene
- Rigid and flexible
- Plasticizers like phthalates
- Plumbing, electrical cable insulation, imitation leather, signage, phonograph records, inflatable products (rubber replacement)

PAHs

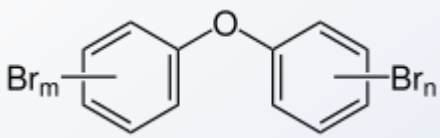


Polycyclic Aromatic Hydrocarbons

- Coal and tar deposits, creosote
- Incomplete combustion

- Carcinogen
- Cardiovascular disease
- Effects on development

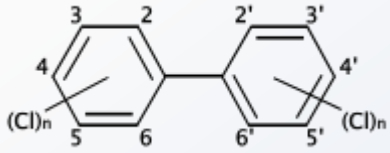
PBDEs



Polybrominated diphenyl ethers

- 209 substances
- Persistent Organic Pollutants (POPs)
- Similar to PCBs
- Flame retardant
- Toxicity
- Carcinogenicity uncertain

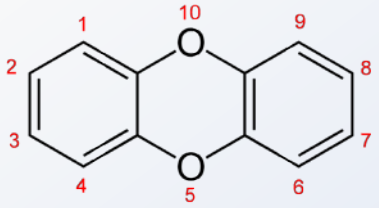
PCBs

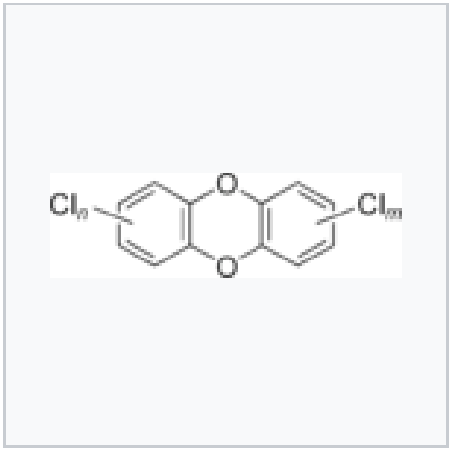


Polychlorinated biphenyls

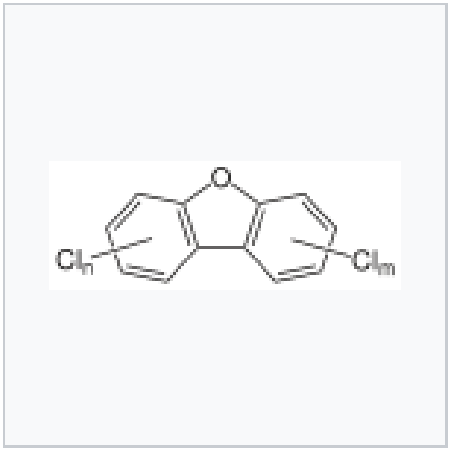
- Dielectric and coolant fluids, heat transfer fluids
- POPs
- PBC production banned in US in 1978
- Carcinogenic
- Aroclor
- Some are “dioxin-like”
  - More toxic
- Can convert to dioxins under 1000 °C

Dioxins

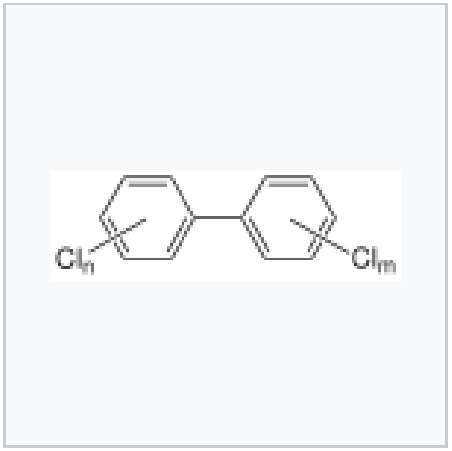




Polychlorinated dibenzo-*p*-dioxins



Polychlorinated dibenzofurans



Polychlorinated biphenyls

- Dioxins – Polychlorinated dibenzo-p-dioxins (PCDDs)-75
- Furans – Polychlorinated dibenzofurans (PCDFs)-135
- Dioxin-Like Substances – some PCBs
  - Polychlorinated biphenyls (PCBs)

Dioxins – Toxicity

- Probably carcinogen
- Reproduction and sexual development, immune system
- Chloracne

- Toxic Equivalence Factor (TEF)
  - 0 – 1 (2,3,7,8-Tetrachlorodibenzodioxin (TCDD) = 1)
  - Consensus values for mammals, birds, fish
- Toxic Equivalence (TEQ)
  - expresses the toxicity as if the mixture were pure TCDD

Polychlorinated dioxins	
2,3,7,8-TCDD	1
1,2,3,7,8-PeCDD	1
1,2,3,4,7,8-HxCDD	0.1
1,2,3,6,7,8-HxCDD	0.1
1,2,3,7,8,9-HxCDD	0.1
1,2,3,4,6,7,8-HpCDD	0.01
OCDD	0.0003
Polychlorinated dibenzofurans	
2,3,7,8-TCDF	0.1
1,2,3,7,8-PeCDF	0.03
2,3,4,7,8-PeCDF	0.3
1,2,3,4,7,8-HxCDF	0.1
1,2,3,6,7,8-HxCDF	0.1
1,2,3,7,8,9-HxCDF	0.1
2,3,4,6,7,8-HxCDF	0.1
1,2,3,4,6,7,8-HpCDF	0.01
1,2,3,4,7,8,9-HpCDF	0.01
OCDF	0.0003

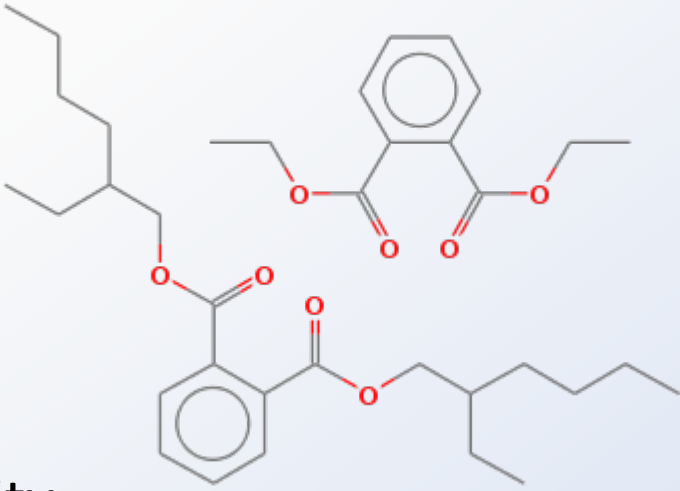
TEF

Non-ortho-substituted PCBs	
3,3',4,4'-TCB (PCB77)	0.0001
3,4,4',5-TCB (PCB81)	0.0003
3,3',4,4',5-PeCB (PCB126)	0.1
3,3',4,4',5,5'-HxCB (PCB169)	0.03
Mono-ortho-substituted PCBs	
2,3,3',4,4'-PeCB (PCB105)	0.00003
2,3,4,4',5-PeCB (PCB114)	0.00003
2,3',4,4',5-PeCB (PCB118)	0.00003
2',3,4,4',5-PeCB (PCB123)	0.00003
2,3,3',4,4',5-HxCB (PCB156)	0.00003
2,3,3',4,4',5'-HxCB (PCB157)	0.00003
2,3',4,4',5,5'-HxCB (PCB167)	0.00003
2,3,3',4,4',5,5'-HpCB (PCB189)	0.00003

Industrial or Man-Made Dioxin Releases

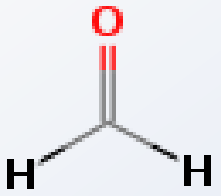
1949	Monsanto herbicide plant (WV)
1961-1971	Agent Orange (Vietnam)
1963	Philips-Duphar plant (Amsterdam)
1965-1968	Spolana-Naritovice (Czechoslovakia)
1976	Industrial accident (Seveso, Italy)
1978	Love Canal (Niagara Falls, NY)
1982-1985	Soil contamination (Times Beach, MO)
1991	Electrical fire (SUNY New Paltz, NY)
1999	Animal contamination (Belgium)
2001	9/11 (New York)
2002	Production ceased 1987 (New Zealand)
2007	Refuse contamination (Naples, Italy)
2008	Pork contamination (Ireland)
2011	Animal feed contamination (Germany)

Phthalates



- Plasticizers – increase flexibility
  - Also transparency, durability, longevity
  - Soften PVC
  - Adhesives and glues, agricultural adjuvants, building materials, personal-care products, medical devices, detergents and surfactants, packaging, children's toys, modelling clay, waxes, paints, printing inks and coatings, pharmaceuticals, food products, textiles, paints, caulk
- di(2-ethylhexyl) phthalate (DEHP), diisodecyl phthalate (DIDP), and diisononyl phthalate (DINP)
- Rapidly degraded (do not accumulate)
- Endocrine disruptors

Formaldehyde

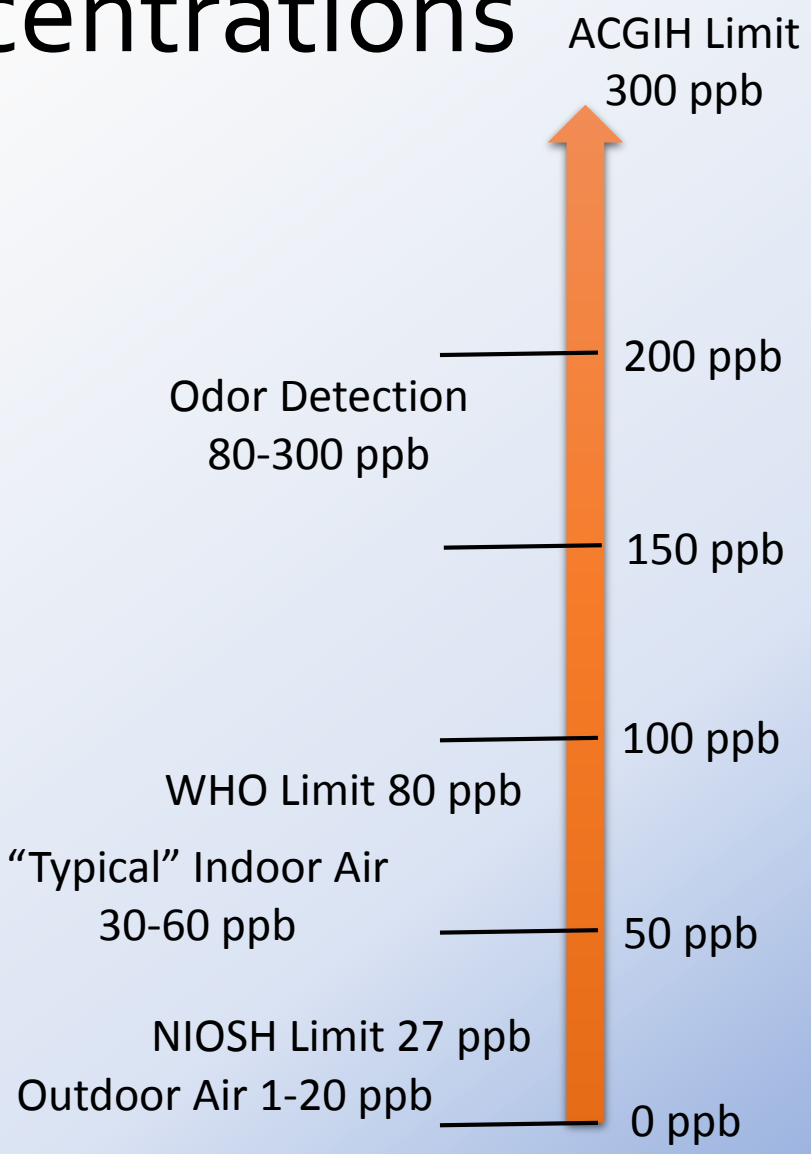


- Wood products, resins (urea, phenol, melamine) textiles, automotive parts, disinfectant, biocide, embalming, stabilizer
- Living systems
- Byproduct of combustion or thermal degradation

- Carcinogen

Formaldehyde Concentrations

- Outdoors
  - 1 ppb
  - 10-20 ppb
- Indoors
  - 20 ppb – “clean” or “baseline”
  - ~50 ppb – “typical”
  - ~100 ppb – “high”
- Odor
  - Strong, pungent odor
  - Detection at 30-800 ppb



Hydrocarbons

- C and H
- Thousands
- Solvents, surface coatings, gasoline and other fuels, wood products
- Rarely included in target testing

Flame Retardants

Organohalogens

- Chlorines
- Bromines
  - decabromodiphenyl ether (decaBDE)

Organophosphorus

- triphenyl phosphate (TPP)
- TDCPP, TDCP, Tris
  - Tris(1,3-dichloro-2-propyl) phosphate CAS 13674-87-8
- TCPP
  - Tris(1-chloro-2-propyl) phosphate CAS 13674-84-5
- TCEP
  - Tris(2-chloroethyl) phosphate CAS 115-96-8
- Firemaster® 550

VOCs of Remediation

- Building products
  - Structural
  - Insulation
  - Flooring
  - Paints and coatings
- Treatment products
  - Cleaners
  - Sealers
  - Odor

Building Products

- Sub-structure
  - MDF, OSB, particleboard (resins and glues)
- Flooring
  - Hardwood, engineered wood (e.g., laminate)
  - Carpet
    - Backing ; fibers & additives
  - Vinyl
    - Adhesives
  - Tile
- Paints and other coatings
  - “Regular”
  - “Low-” or “No-VOC”

New Materials

- High initial VOCs → High offgassing
- Packaged
- Interact with existing contaminants

Solvents & Coatings

- Paints, varnishes, stains
- Adhesives and glues
- Light solvents (e.g., mineral spirits)
- Halogenated solvents (e.g., PCE)

Low & No VOC Paints

- Definition of “VOC”
  - Photochemical reactivity
- What replaces “VOCs”
- What about –
  - Additives
  - Sheen
  - Color
  - Viscosity

Adhesives & Sealers

- Active
  - Toluene
  - Xylenes
  - Polymers
    - Vinyl acetate, Urethane, Alcohols, Acrylics
- Fillers
  - Mechanical properties
- Pigments
- Additives
  - Accelerators, corrosion inhibitors, fire retardants, fungicides

Spray Foam Insulation (SPF)

Heat, pressure, spray configuration, mixture

Problems

- Incorrect temperature
- Incorrect humidity
- Moisture on substrate
- Incorrect mixture
- Chemical defect in component
- Incorrect thickness
- Exposure to light
- Poor application expertise

Solvents

Oxygenated solvents

- Alcohol, esters, glycol ethers, ketones (e.g., MEK)

Hydrocarbon solvents – derived from petroleum

- Acetone, acetonitrile, benzene, dioxane, gasoline, hexane, kerosene, methanol, phenol, styrene, toluene, turpentine, xylene, aliphatic and aromatic hydrocarbons

Halogenated solvents – mostly chlorine

- Carbon tetrachloride, CFCs, chlorobenzene, chloroform, ethylene dichloride, methylene chloride, tetrachloroethylene (PCE), 1,1,1-trichloroethane, trichloroethylene (TCE)

Petroleum Distillate

- Hydrocarbon solvents from crude oil
- mineral spirits, kerosene, white spirits, naphtha, and Stoddard solvent
- removal of heavy oil and grease, tar, and waxes

Ink
Upholstery
CDs
Vitamin Capsule
Denture Adhesive
Putty
Guitar Strings
Heart Valves
Anesthetics
Cortisone
Toilet Seats
Crayons
Pillows
Artificial Turf
Deodorant
Lipstick
Hair Coloring
Aspirin

Treatment Products

Cleaners

- Surface
- In-depth

Sealers

- Resistant coating
- “back” side of surface

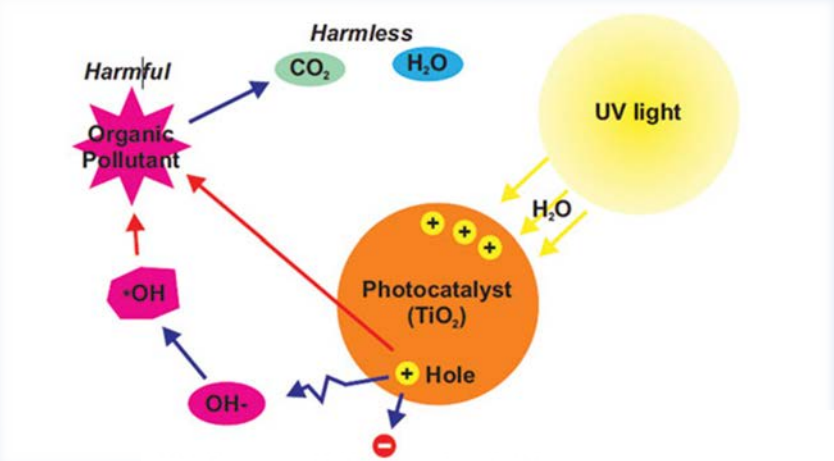
- Deodorizers
  - “Capture”
  - Convert (e.g., Oxidize)
  - Mask

Air Purifiers

Filter (Carbon-based)

Oxidation

- Types
  - OH (hydroxyl)
  - H_2O_2 (peroxide)
  - Cl (chlorine)
  - O_3 (ozone)
- Chemical reaction – converts to different form
- Not selective – affects all chemical
- Intermediate chemical forms



Ventilation

- Air coming from …
- Air going to …

- Positive pressure
- Negative pressure
- Adjacent spaces

- Filtration or purification

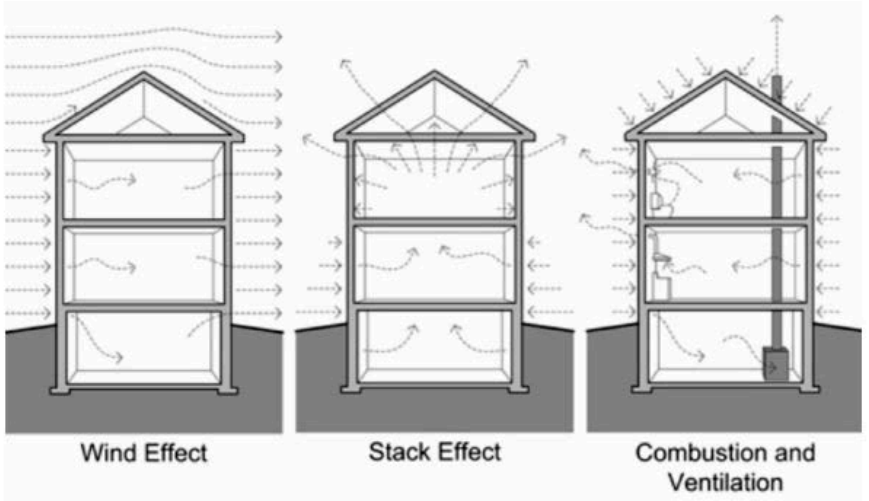
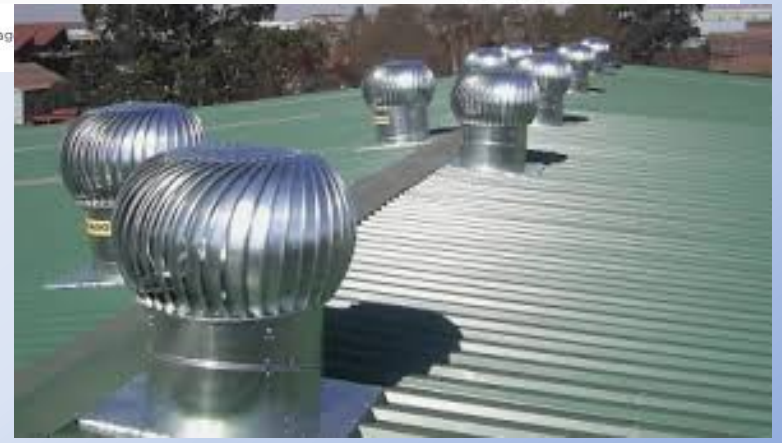


Figure 1: Examples of infiltration. Imag



Testing …

- Disaster-specific VOCs
- New contaminants
- Separate VOCs of remediation from “normal” VOCs

- Cleanup completion
- Remediation completion

Testing …

Before

- Initial conditions
- Extent of damage and/or problems
- Amount of work to get to “acceptable” conditions

Testing …

<u>After</u>

- Final conditions
- Comparison to “acceptable” conditions
- “Clearance” testing
- Remediation materials

Testing …

Before & After

- Amount or % difference
- When no acceptance criteria exist
- “100%” completed

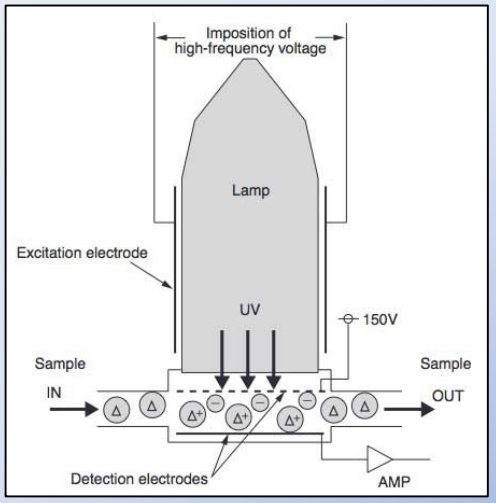
On-Site Inspection

- History
- Occupant experience

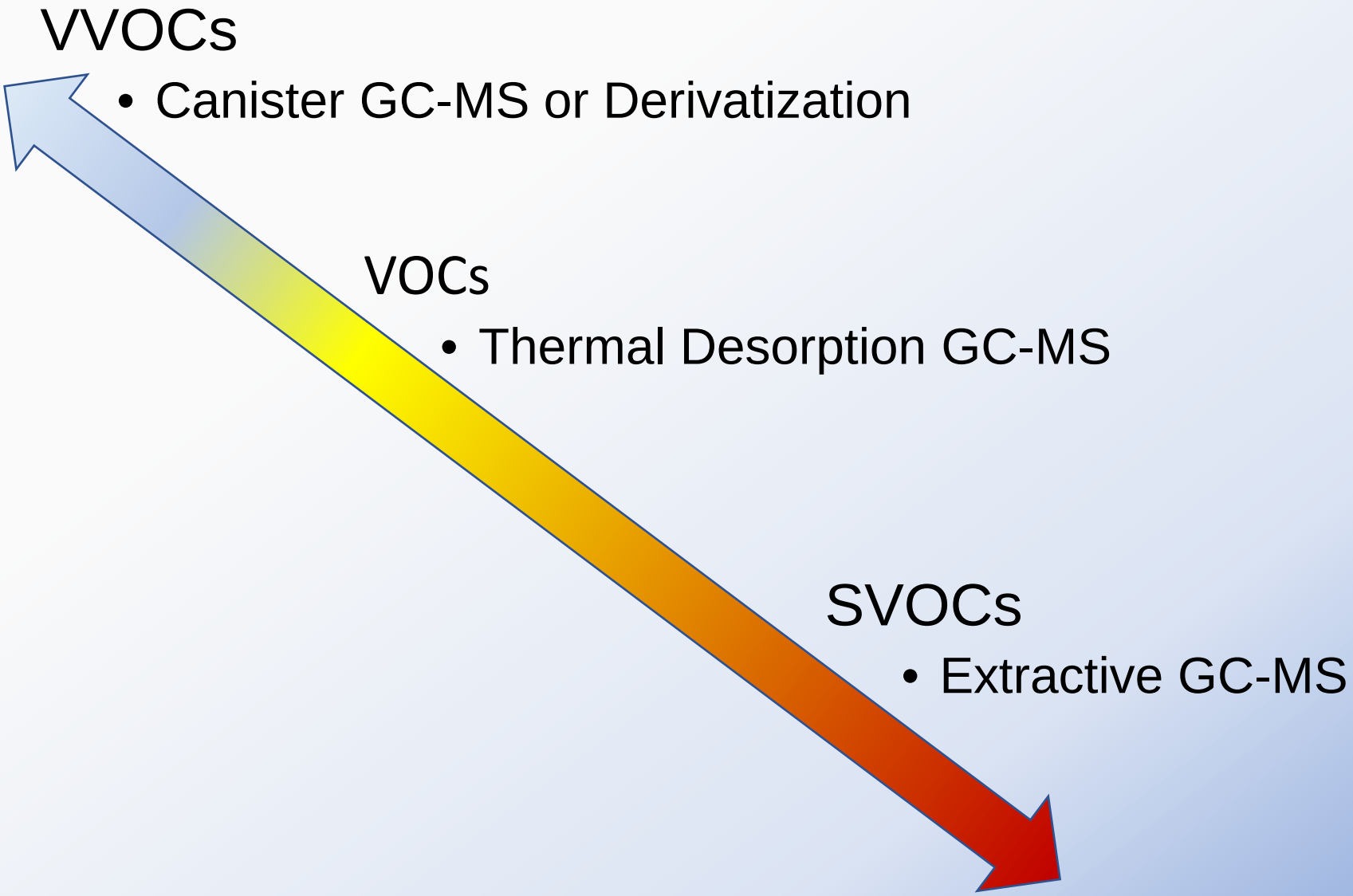
- Visible damage
- Odors
- Health effects

Photoionization Detector

- How it works
  - Lamp generates ultraviolet (UV), which breaks up (ionizes) molecules into positive and negative ions
  - Measure electric current produced by ions
  - Current converted to concentration by single compound calibration, typically isobutylene
  - Ionization potential (IP) determines which compounds detected
- Features
  - Broad detection (not selective)
  - Wide range (ppb to ppm)
  - Instantaneous and continuous
  - Non destructive



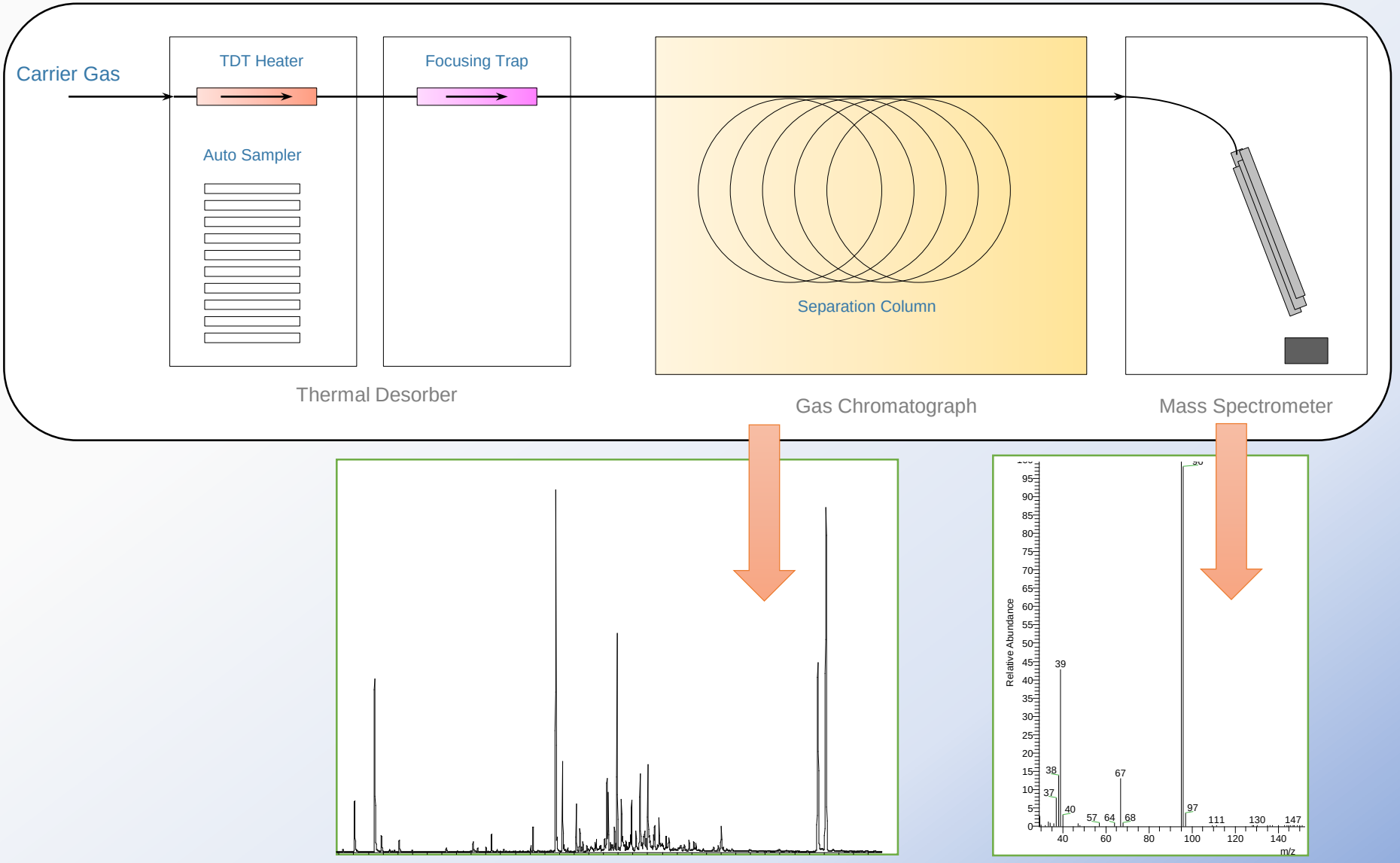
Technology


VVOCs
• Canister GC-MS or Derivatization
VOCs
• Thermal Desorption GC-MS
SVOCs
• Extractive GC-MS

Laboratory-Based Media

Air	• Thermal desorption tubes • Solvent extraction tubes
Surface	• Canisters • Bags
Bulk	• Diffusive samplers

Gas Chromatograph-Mass Spectrometer



Gotcha's!

Detection-Instrument
LOD, LOQ, PQL
Reporting-Normalized

From Where …
Based on What …

Units

ppm
ppb
µg/m^3
ng/L

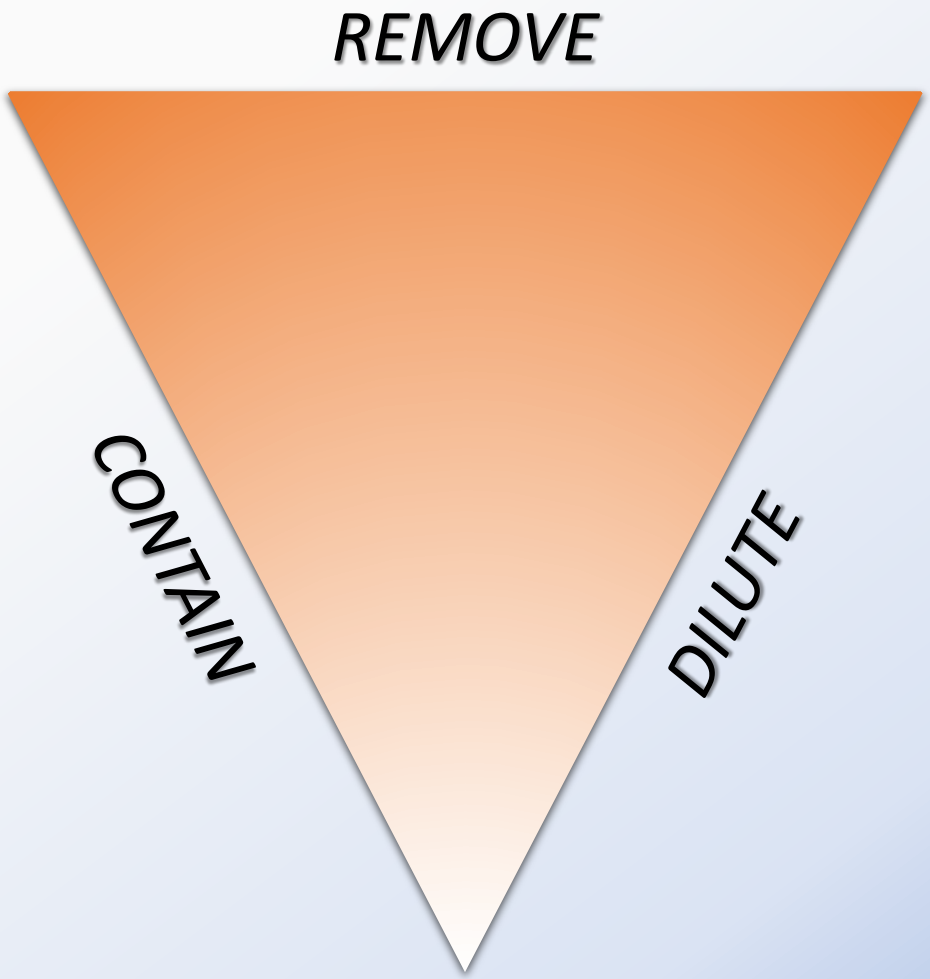
Detection & Reporting Limits

What's *not* included

Results are not the whole picture …

Reference Values

The “Big 3”



Safe vs Risk

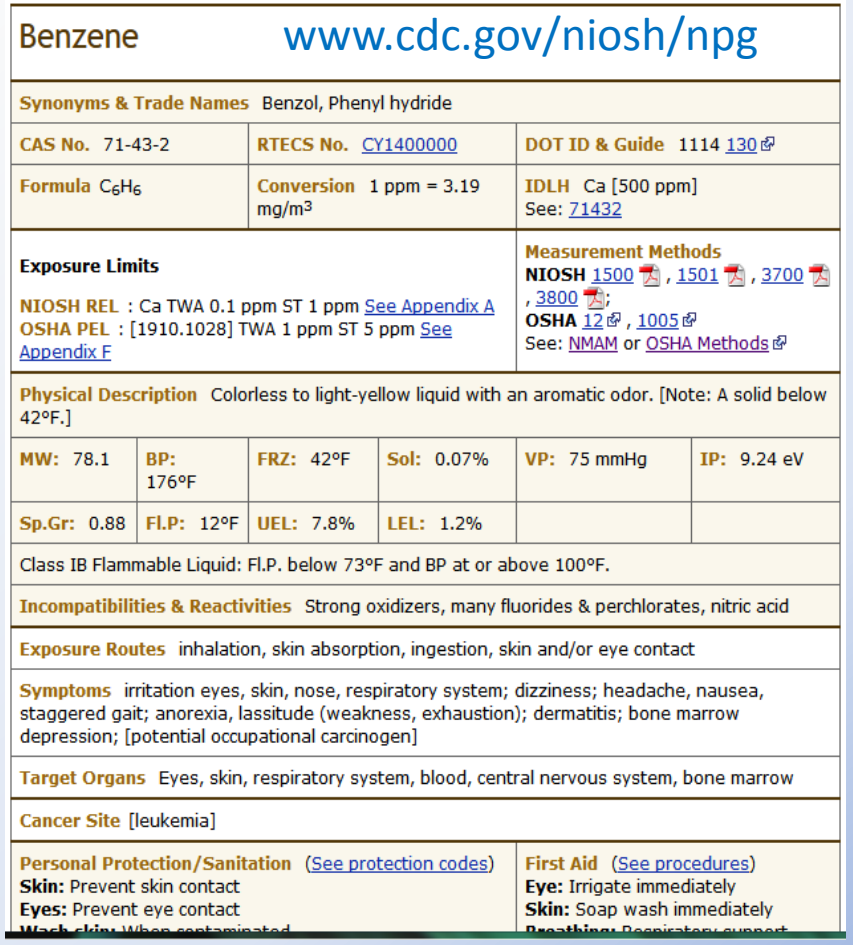
- Safe: protected from or not exposed to danger
- Risk: exposure to danger

- “Minimal” risk
  - 1 in 10,000
  - 1 in 100,000
  - 1 in 1,000,000

Exposure Limits

Don’t really apply in disaster recovery

- OSHA PEL
- NIOSH REL
- ACGIH TLV



Benzene	www.cdc.gov/niosh/npg	
Synonyms & Trade Names Benzol, Phenyl hydride		
CAS No. 71-43-2	**RTECS No.** CY1400000	**DOT ID & Guide** 1114 130
Formula C_6H_6	**Conversion** 1 ppm = 3.19 mg/m³	**IDLH** Ca [500 ppm] See: 71432
Exposure Limits **NIOSH REL** : Ca TWA 0.1 ppm ST 1 ppm See Appendix A **OSHA PEL** : [1910.1028] TWA 1 ppm ST 5 ppm See Appendix F		**Measurement Methods** **NIOSH** 1500 , 1501 , 3700 , 3800 ; **OSHA** 12 , 1005 See: NMAM or OSHA Methods
Physical Description Colorless to light-yellow liquid with an aromatic odor. [Note: A solid below 42°F.]		
MW: 78.1	**BP:** 176°F	**FRZ:** 42°F	**Sol:** 0.07%	**VP:** 75 mmHg	**IP:** 9.24 eV
Sp.Gr: 0.88	**Fl.P:** 12°F	**UEL:** 7.8%	**LEL:** 1.2%		
Class IB Flammable Liquid: Fl.P. below 73°F and BP at or above 100°F.					
Incompatibilities & Reactivities Strong oxidizers, many fluorides & perchlorates, nitric acid					
Exposure Routes inhalation, skin absorption, ingestion, skin and/or eye contact					
Symptoms irritation eyes, skin, nose, respiratory system; dizziness; headache, nausea, staggered gait; anorexia, lassitude (weakness, exhaustion); dermatitis; bone marrow depression; [potential occupational carcinogen]					
Target Organs Eyes, skin, respiratory system, blood, central nervous system, bone marrow					
Cancer Site [leukemia]					
Personal Protection/Sanitation (See protection codes) **Skin:** Prevent skin contact **Eyes:** Prevent eye contact				**First Aid** (See procedures) **Eye:** Irrigate immediately **Skin:** Soap wash immediately	

Exposure Guidelines

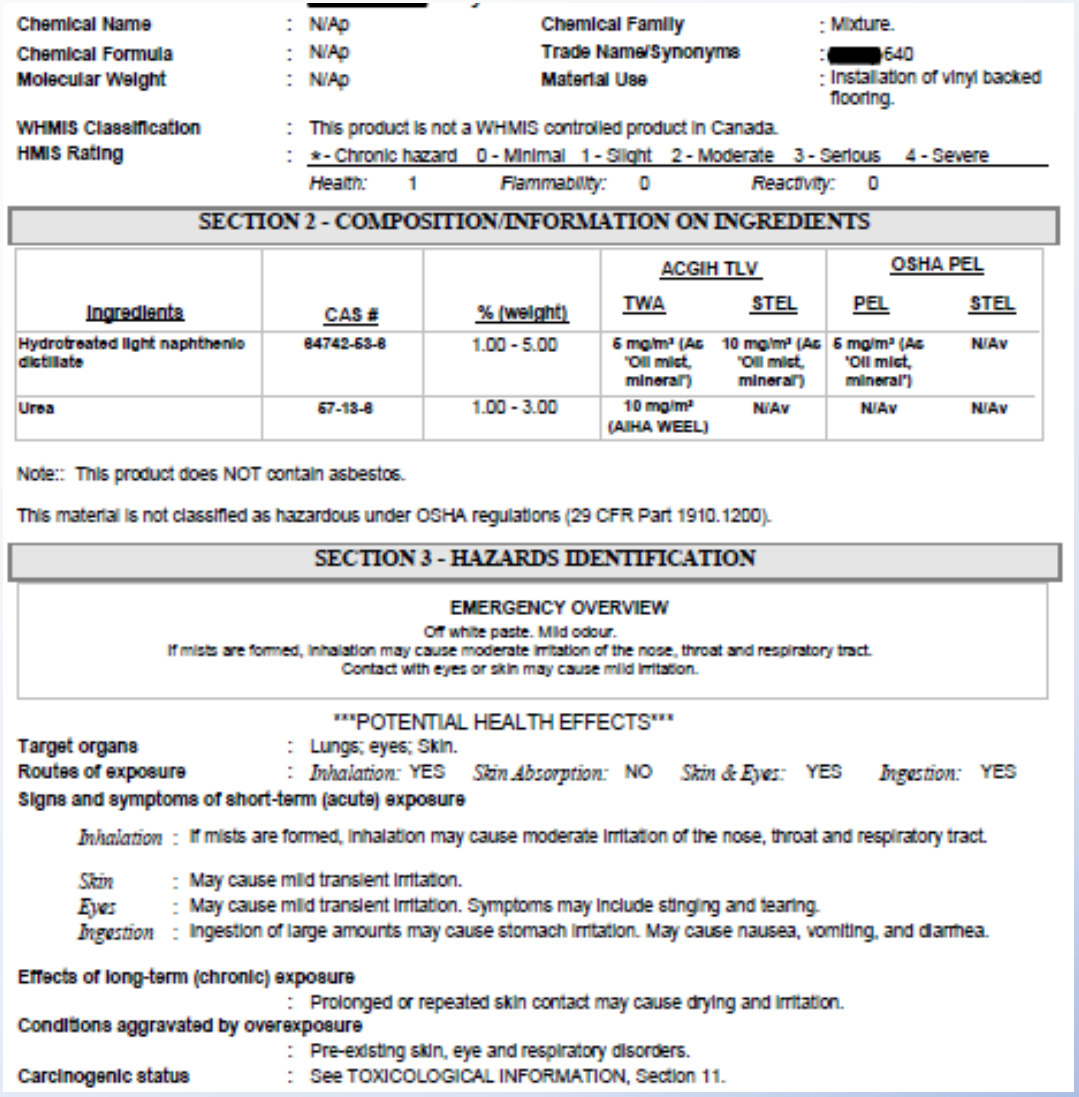
Recommendations available for select compounds

- CA CREL Chronic Reference Exposure Levels – CRELs, RELs
  www.oehha.ca.gov/air/Allrels.html
- ATSDR Minimal Risk Levels – MRLs
  www.atsdr.cdc.gov/mrls
- EPA Regional Screening Levels – RSL
  - EPA Reference Concentration – RfC

  https://www.epa.gov/risk/regional-screening-levels-rsls-generic-tables-may-2016
- EPA Vapor intrusion guidelines
  https://www.epa.gov/vaporintrusion/vapor-intrusion-screening-levels-visls

Product Ingredients

Safety Data Sheets



Chemical Name	: N/Ap	**Chemical Family**	: Mixture.
Chemical Formula	: N/Ap	**Trade Name/Synonyms**	: [redacted]640
Molecular Weight	: N/Ap	**Material Use**	: Installation of vinyl backed flooring.

WHMIS Classification : This product is not a WHMIS controlled product in Canada.

HMIS Rating : * - Chronic hazard 0 - Minimal 1 - Slight 2 - Moderate 3 - Serious 4 - Severe

Health: 1 *Flammability:* 0 *Reactivity:* 0

SECTION 2 - COMPOSITION/INFORMATION ON INGREDIENTS

Ingredients	CAS #	% (weight)	ACGIH TLV TWA	ACGIH TLV STEL	OSHA PEL PEL	OSHA PEL STEL
Hydrotreated light naphthenic distillate	64742-53-6	1.00 - 5.00	5 mg/m³ (As 'Oil mist, mineral')	10 mg/m³ (As 'Oil mist, mineral')	5 mg/m³ (As 'Oil mist, mineral')	N/Av
Urea	57-13-6	1.00 - 3.00	10 mg/m³ (AIHA WEEL)	N/Av	N/Av	N/Av

Note:: This product does NOT contain asbestos.

This material is not classified as hazardous under OSHA regulations (29 CFR Part 1910.1200).

SECTION 3 - HAZARDS IDENTIFICATION

EMERGENCY OVERVIEW

Off white paste. Mild odour.
If mists are formed, inhalation may cause moderate irritation of the nose, throat and respiratory tract.
Contact with eyes or skin may cause mild irritation.

POTENTIAL HEALTH EFFECTS

Target organs : Lungs; eyes; Skin.

Routes of exposure : *Inhalation:* YES *Skin Absorption:* NO *Skin & Eyes:* YES *Ingestion:* YES

Signs and symptoms of short-term (acute) exposure

Inhalation : If mists are formed, inhalation may cause moderate irritation of the nose, throat and respiratory tract.

Skin : May cause mild transient irritation.
Eyes : May cause mild transient irritation. Symptoms may include stinging and tearing.
Ingestion : Ingestion of large amounts may cause stomach irritation. May cause nausea, vomiting, and diarrhea.

Effects of long-term (chronic) exposure
: Prolonged or repeated skin contact may cause drying and irritation.

Conditions aggravated by overexposure
: Pre-existing skin, eye and respiratory disorders.

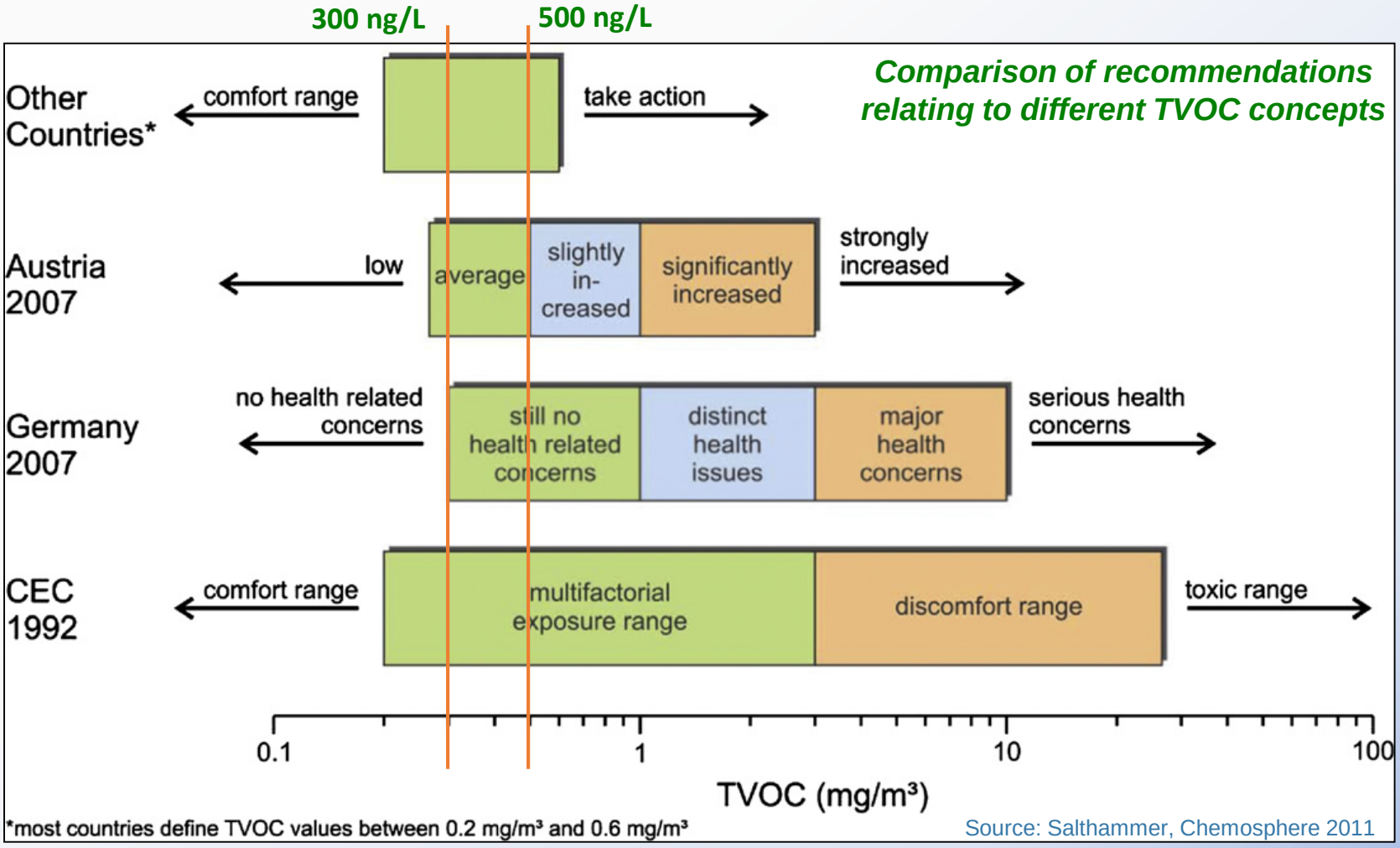
Carcinogenic status : See TOXICOLOGICAL INFORMATION, Section 11.

Manufacturer fact sheet describing chemical properties of product

Total VOCs (TVOC)

- General VOC air quality indicator
  - Lower the better
- Composition matters
- No TVOC requirements
- Calculation Methods
  - Sum of individual compounds
    - Typically under-represents VOCs
  - Chromatographic area
    - More representative
    - Ranges: C3-C12; C3-C16; C6-C16

TVOC “Guidelines”



Disaster Preparedness

- Know background or baseline levels
- Know possible nearby sources
- Know history of area
  - Common disaster types
  - Industrial either in use or closed
- Know sensitive populations
  - Schools
  - Elder care facilities
  - Food production and processing

Agenda

- VOCs and IAQ
- Types of disaster
- Types of damage
- Critical concerns
- Before and After Assessments
- What is “Safe”?

Learning Outcomes (4)

- Be able to describe the basic attributes of VOCs and their effect on indoor air quality.
- Evaluate different disaster scenarios for the relevant hazards and concerns.
- Address each hazard or concern in terms of the impact or influence VOCs may have on the situation.
- Recommend various strategies to remove or reduce the effects of contaminant sources.

Concerns –

questions you can answer for your clients

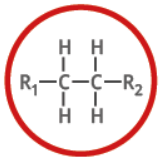
- How you can help your clients
- Is the problem fixed?
- Health
- Odor
- Long term effects
- Insurance?
- Larger scale problems
  - e.g., chemical releases due to widespread damage-Harvey

Summary

FUNCTIONAL GROUPS IN ORGANIC CHEMISTRY

FUNCTIONAL GROUPS ARE GROUPS OF ATOMS IN ORGANIC MOLECULES THAT ARE RESPONSIBLE FOR THE CHARACTERISTIC CHEMICAL REACTIONS OF THOSE MOLECULES. IN THE GENERAL FORMULAE SHOWN BELOW FOR EACH FUNCTIONAL GROUP, 'R' REPRESENTS THE REST OF THE MOLECULE, AND 'X' REPRESENTS ANY HALOGEN ATOM.

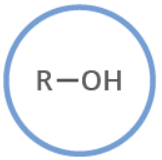
HYDROCARBONS | SIMPLE OXYGEN HETEROATOMICS | HALOGEN HETEROATOMICS | CARBONYL COMPOUNDS | NITROGEN-BASED | SULFUR-BASED | AROMATIC



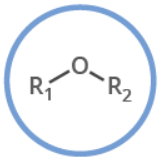
ALKANE
Naming: -ane
e.g. ethane

ALKENE
Naming: -ene
e.g. ethene

ALKYNE
Naming: -yne
e.g. ethyne



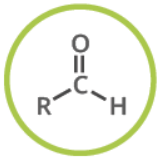
ALCOHOL
Naming: -ol
e.g. ethanol



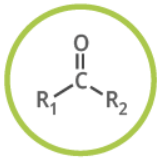
ETHER
Naming: -oxy -ane
e.g. methoxyethane

EPOXIDE
Naming: -ene oxide
e.g. ethene oxide

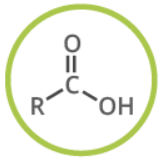
HALOALKANE
Naming: halo-
e.g. chloroethane



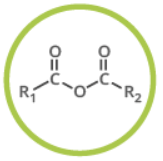
ALDEHYDE
Naming: -al
e.g. ethanal



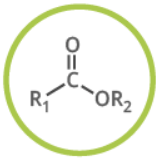
KETONE
Naming: -one
e.g. propanone



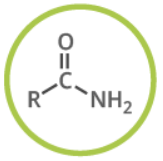
CARBOXYLIC ACID
Naming: -oic acid
e.g. ethanoic acid



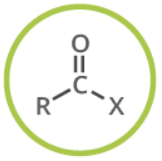
ACID ANHYDRIDE
Naming: -oic anhydride
e.g. ethanoic anhydride



ESTER
Naming: -yl -oate
e.g. ethyl ethanoate



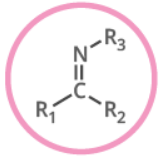
AMIDE
Naming: -amide
e.g. ethanamide



ACYL HALIDE
Naming: -oyl halide
e.g. ethanoyl chloride

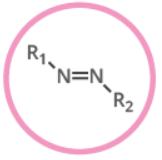
AMINE
Naming: -amine
e.g. ethanamine

NITRILE
Naming: -nitrile
e.g. ethanenitrile



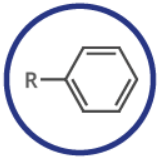
IMINE
Naming: -imine
e.g. ethanimine

ISOCYANATE
Naming: -yl isocyanate
e.g. ethyl isocyanate



AZO COMPOUND
Naming: azo-
e.g. azoethane

THIOL
Naming: -thiol
e.g. methanethiol



ARENE
Naming: -yl benzene
e.g. ethyl benzene

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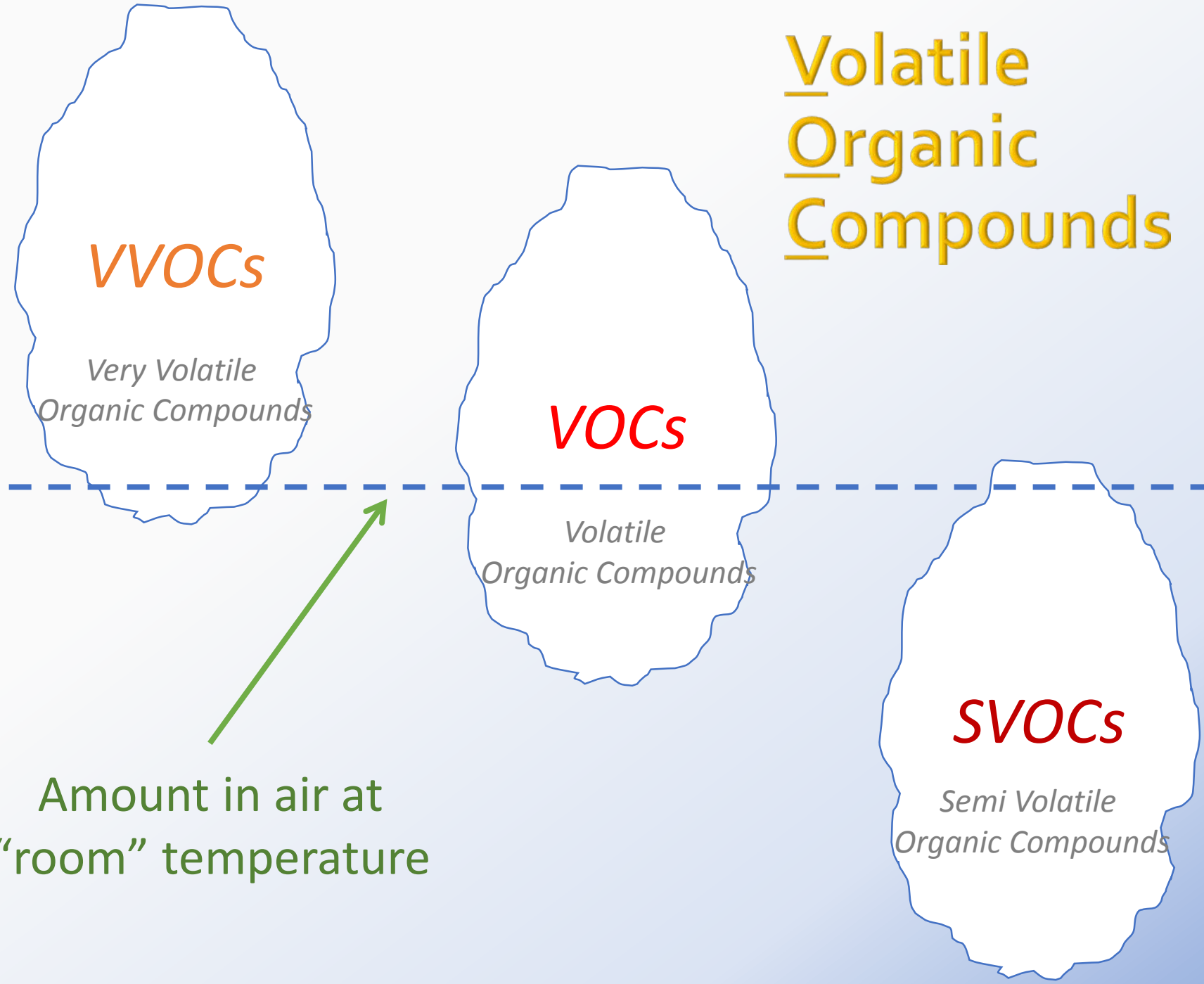
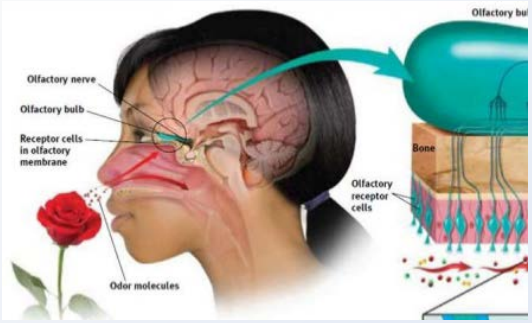
Volatile Organic Compounds



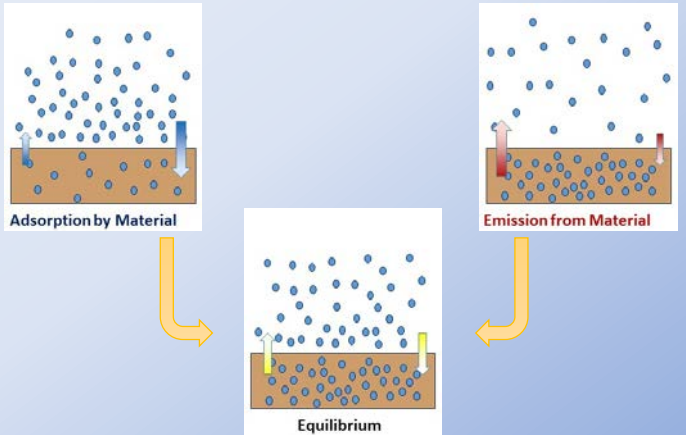
VOC Concerns

- Health

- Odors



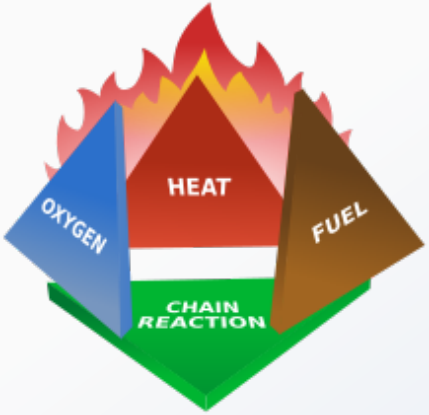
- Material off gassing



Disasters

Disaster VOCs

- Fire



- Mold

- Hazardous Materials

VOCs of Remediation

- Building products
  - Structural
  - Insulation
  - Flooring
  - Paints and coatings
- Treatment products
  - Cleaners
  - Sealers
  - Odor

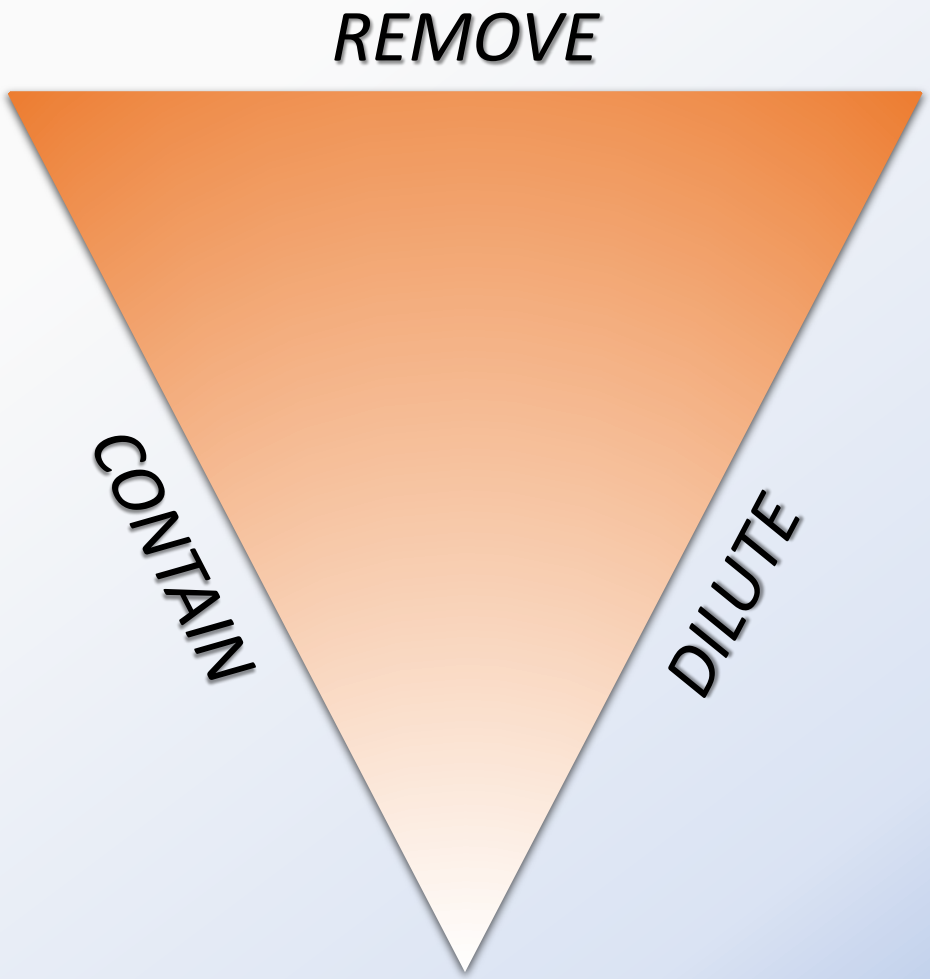
Testing …

- Disaster-specific VOCs
- New contaminants
- Separate VOCs of remediation from “normal” VOCs

- Cleanup completion
- Remediation completion

- On-Site
- Laboratory

The “Big 3”



Safe

Alice Delia

Prism Analytical Technologies
a.delia@pati-air.com
989-944-3164

Resources

- ATSDR: Agency for Toxic Substances and Disease Registry
  - www.atsdr.cdc.gov/
- IRIS: Integrated Risk Information System
  - www.epa.gov/iris/index.html
- TOXNET: Toxicology Data Network
  - toxnet.nlm.nih.gov/
  - Can search multiple databases
- NIOSH: National Institute for Occupational Safety and Health
  - www.cdc.gov/niosh/
- CARB: California Air Resources Board
  - www.arb.ca.gov
- US EPA Indoor Air Quality (IAQ)
  - www.epa.gov/iaq/
- Household Products Database
  - householdproducts.nlm.nih.gov/index.htm

More Resources

- US Green Building Council, “LEED v4 for New Construction and Major Renovations”, 2014
- BRE Global Ltd, “BREEAM New Construction: Non Domestic Buildings (Technical Manual SD5073-3.0:2012)”, 2011.
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- US EPA. Indoor Air Pollution: An Introduction for Health Professionals. www.epa.gov/iaq/pubs/hpguide.html#faq1 (accessed February 2015).
- US EPA. An Introduction to Indoor Air Quality (IAQ). www.epa.gov/iaq/voc.html (accessed June 2014).
- US EPA, The Inside Story: A Guide to Indoor Air Quality , http://www.epa.gov/iaq/pubs/insidestory.html#Suspect
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- World Health Organization, Regional Office for Europe. “Indoor air quality: organic pollutants”, 1987.
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- L. Molhave et al., Total Volatile Organic Compoiund (TVOC) in Indoor Air Quality Investigation, Indoor Air 1997; 225-240.