The Metropolitan

Water Reclamation District

of Greater Chicago

WELCOME

TO THE JULY EDITION

OF THE 2016

M&R SEMINAR SERIES

BEFORE WE BEGIN

- SAFETY PRECAUTIONS
  - PLEASE FOLLOW EXIT SIGN IN CASE OF EMERGENCY EVALUATION
  - AUTOMATED EXTERNAL DEFIBRILLATOR (AED) LOCATED OUTSIDE
- PLEASE SILENCE CELL PHONES OR SMART PHONES
- QUESTION AND ANSWER SESSION WILL FOLLOW PRESENTATION
- PLEASE FILL EVALUATION FORM
- SEMINAR SLIDES WILL BE POSTED ON MWRD WEBSITE (www. MWRD.org: Home Page ⇒ Reports ⇒ M&R Data and Reports ⇒ M&R Seminar Series ⇒ 2016 Seminar Series)
- STREAM VIDEO WILL BE AVAILABLE ON MWRD WEBSITE (www.MWRD.org: Home Page ⇒ MWRDGC RSS Feeds)

Richard J Pope, P.E., BCEE

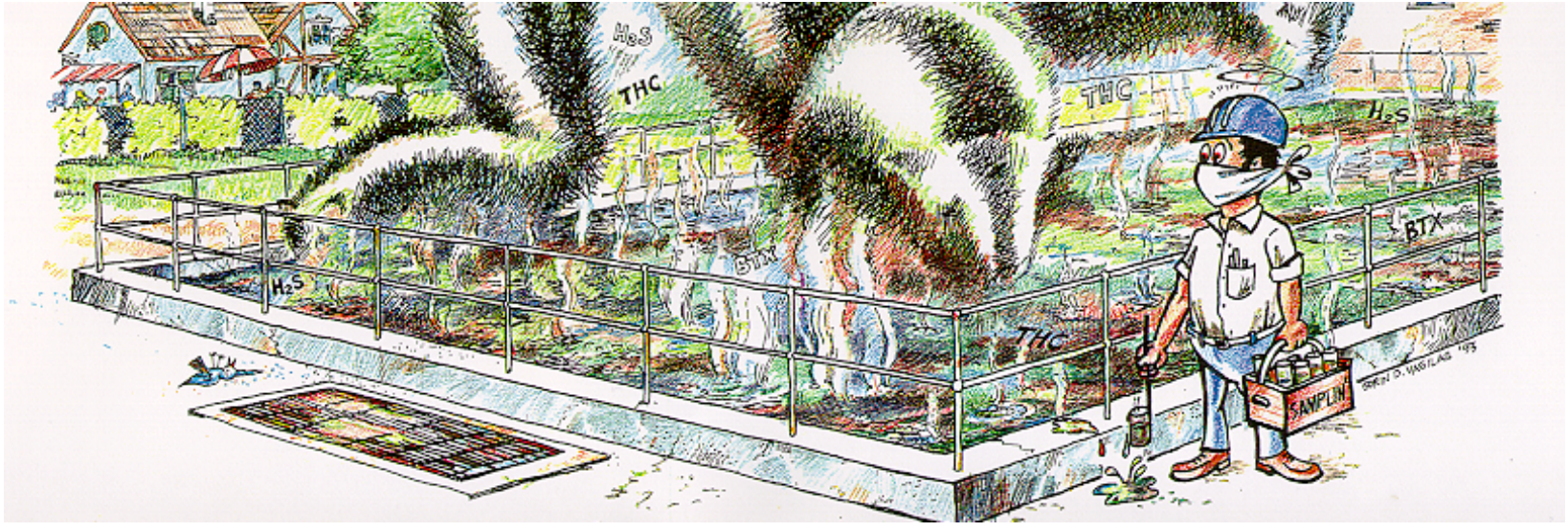
Current: Vice President and Odor Services Leader, Hazen and Sawyer, New York
Consultant to MWRD Odor Control Strategy Development

Education: Master and Bachelor degrees in Environmental and Civil Engineering,

Experience: Direct Hazen and Sawyer's corporate-wide odor services;
As a nationally and internationally recognized expert, he has conducted site odor assessment surveys at over 250 municipal and industrial facilities;
He has personally been involved in the planning and design of over 250 odor control systems during his 37 year career.

Professional: A contributing author on multiple WEF MOP in odor-related text books,
Technical expert reviewer for WE&RF odor research studies.
With well over 100 presentations at local, state, federal and international conferences/workshops and universities, he continues to put his nose where no one else wants to go!
Serves as Chair of the K-12 Committee of the AAEES where he strives to educate and influence our young students about the joys and lifelong careers in environmental engineering and science.

Hazen



Point Source Odor Control Technologies –
Design, Operation, Maintenance

Richard J.Pope, P.E., BCEE
Vice President | Odor Services Leader
Hazen and Sawyer

MWRD Professional Development Series | July 29, 2016

Agenda

- Community Issues
- Sense of Smell
- Odorous Compounds
- Dispersion Modeling Tool
- Odor Control Technologies
  - Carbon
  - Wet Scrubbing
  - Biotrickling Filter
  - Biofilter
  - Other Technologies
- Odor Control Sustainability
- Conclusions
- Q&A

Odor Control
Starts
with the
Community

Community is the Driving Force

- Without them
  - Would not need Odor Control
- Reality
  - They **exist!**
  - They **complain!**

Complaints – Ignore at Your Own Peril

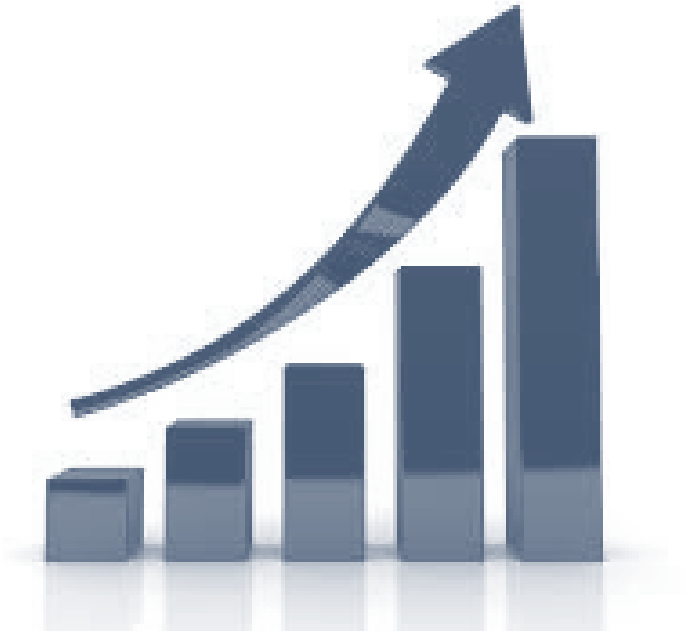
- Ignoring Community Complaints

  Generally ill advised!

- In Majority of Cases

  They don’t go away

But **Build**



Nuisance Odor Complaints Can Lead To

- Galvanizing the community
- Political representative involvement
- Media attention
- Regulatory scrutiny
- Law suits
- Forced reaction

On the Other Hand…

Formal Procedure

- Important

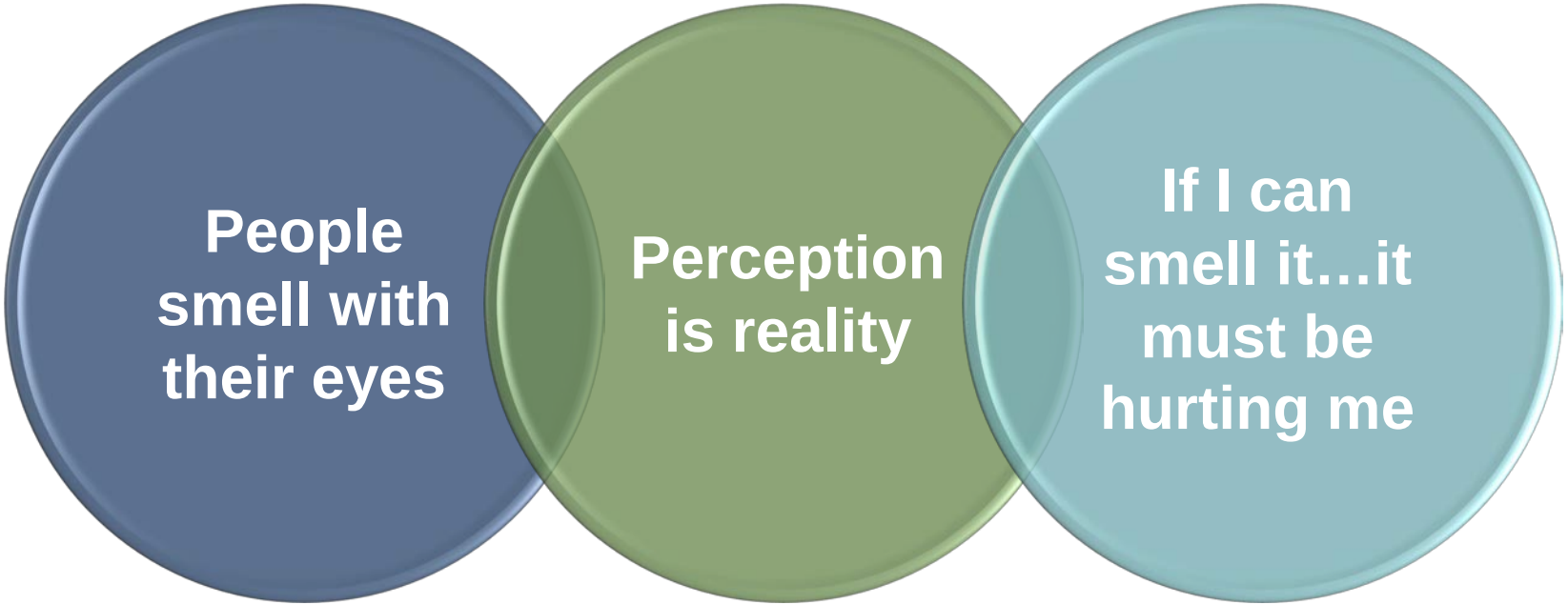
Odor Complaints

- Not a good barometer
  - Agenda
  - Real/Imagined
  - Me/Someone else
- Need to be verified
- Set trends

Odor Complaint Recordkeeping Process

- Central contact
  - Phone
  - Internet
  - APP
- Form
  - Essential questions
  - Meteorolgical conditions
- Trained Contacts
- Investigation
- Follow-up
- Trending

Three Odor Truths/Community Constants



Understanding these truths is tantamount to understanding the community!

Down to Basics

Wastewater, by its nature, is Odorous

Reminder

Can never have 100% Odor Free WWTP!

3 Reasons why:

1. Nature of wastewater: odorous
2. Mechanical systems used to treat and odor control
3. Humans operating

At any point, one or more can go wrong

Intent of odor control:

- Keep from going wrong

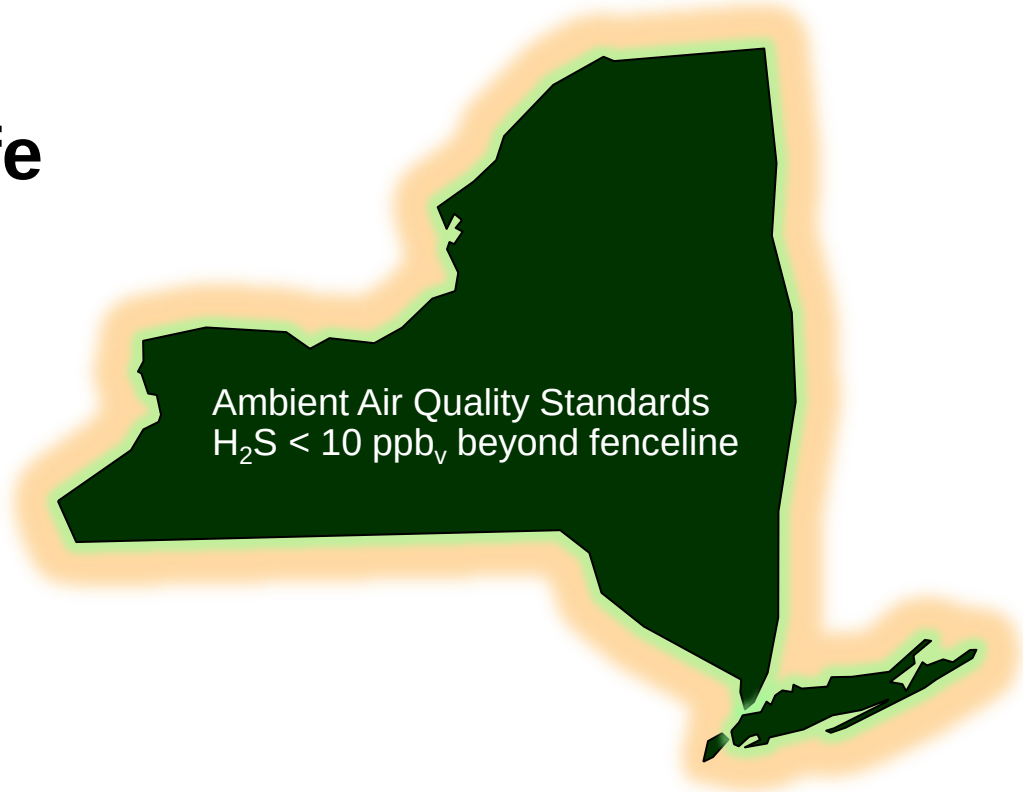
Status of Odor Regulations

No Federal Regulations for Control of Odors

EX. - New York State Odor Regulations

Quality of life

“No emission of air which interferes with enjoyment of life”



Public Outreach is Valuable

What you don’t tell them

- They don’t Know”

Take advantage of Public Outreach to

- Open dialogue with Community

Make them realize that you are

- Listening

Improve credibility/respect

Results

- Don’t expect full support

Traditional Focus -- Hydrogen Sulfide

Standard surrogate – WHY?

- Almost always present
- Caracteristic scent
  - Rotten Egg
- Very low odor threshold
  - 1 to 5 ppb (Critiqued literature value)
- Hand held monitor
- Persistent
- Good tracer indicator

But it is not the only odor present!!!

Typical Wastewater Odorous Compounds

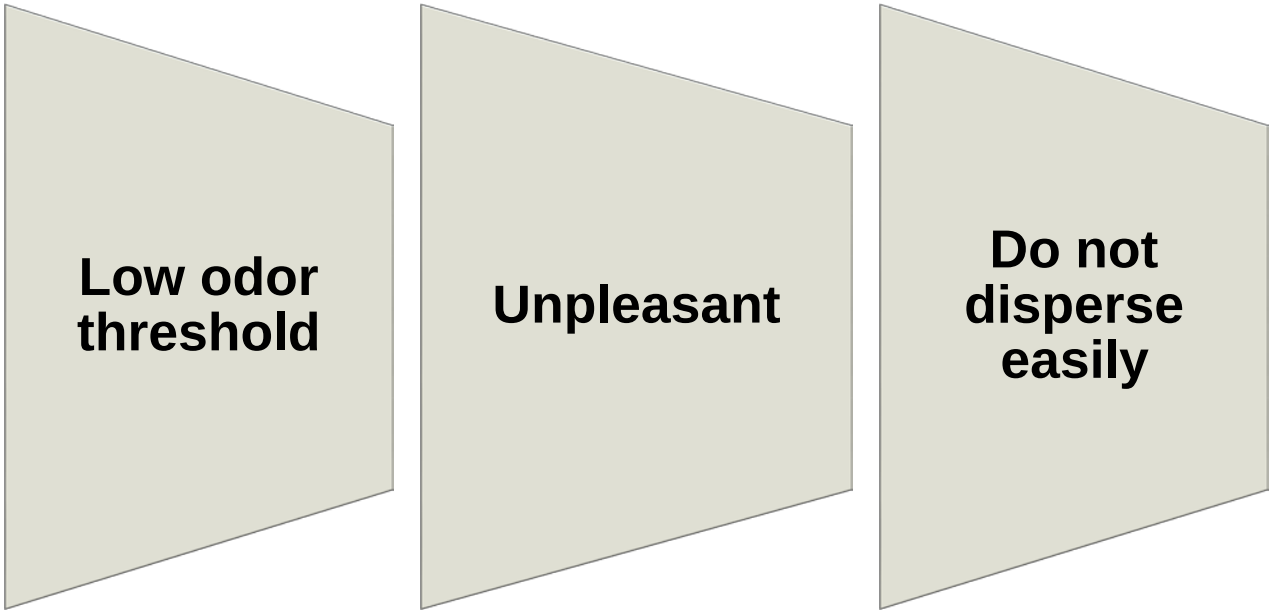
- Reduced sulfur compounds
- Nitrogen
- Carboxylic Acids
- VOCs
  - Generally higher thresholds (ppm)

Typical Wastewater Odors

SULFUR:
Hydrogen Sulfide
Mercaptans
- Methyl
- Ethyl
Dimethyl Sulfide
Dimethyl Disulfide
Carbon Disulfide
Carbonyl Sulfide

NITROGEN:
Ammonia
Indole
Skatole
Amines
- Trimethylamine
OTHER COMPOUNDS
Butyric Acid
VOCs
- Aldehydes
- Ketones - Esters

Why Are These Compounds of Concern?



Odor – Potentials of Compounds

Sulfur/Nitrogen } - Very low thresholds

- Perceive in ppb/ppt levels

VOCs } - Higher thresholds

- Perceive in ppm levels

Conclusion:
Odor focus on S/N compounds

What is odour?

Odours are often produced by a composite of many odorous compounds that are perceived by an individual

Compound Name	Formula	Human Detection Threshold (ppb)	Odor Description
Allyl Mercaptan	CH_2=CH-CH_2-SH	0.05	Disagreeable, garlic
Ammonia	NH_3	17,000	Pungent, irritating
Amyl Mercaptan	CH_3-$(CH_2)_3$-CH_2-SH	0.3	Unpleasant, putrid
Benzyl Mercaptan	$C_6H_5CH_2$-SH	0.2	Unpleasant, strong
Crotyl Mercaptan	CH_3-CH=CH-CH_2-SH	0.03	Skunk-like
Dimethyl Amine	$(CH_3)_2NH$	340	Putrid, fishy
Dimethyl Sulfide	$(CH_3)_2S$	1	Decayed Cabbage
Ethyl Mercaptan	C_2H_5SH	0.3	Decayed Cabbage
Hydrogen Sulfide	H_2S	0.5	Rotten Eggs
Indole	C_6H_4 $(CH)_2NH$	0.1	Fecal, nauseating
Methyl Amine	CH_3NH_2	4,700	Putrid, Fishy
Methyl Mercaptan	CH_3SH	0.5	Rotten Cabbage
Skatole	C_9H_9N	1	Fecal, nauseating
Thiocresol	$CH_3C_6H_4SH$	0.1	Skunky, irritating

Source: WEF MOP 25 (2004)

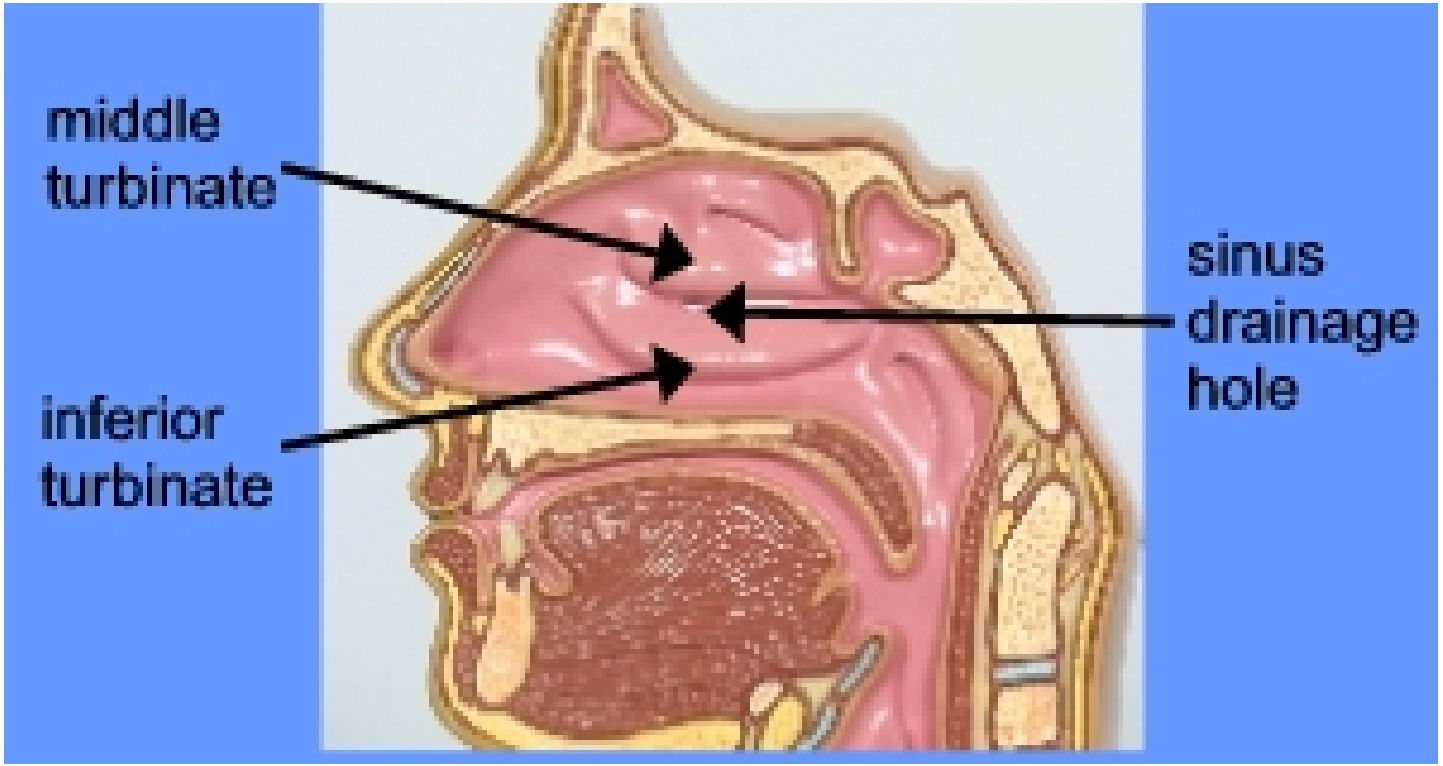
What are the Physical Attributes of the "Sense of Smell"?

- Nose
- Turbinate bones
- Olfactory bulbs
- Direct connection to the brain
- Connected to Limbic area of brain
  - Center for:
    - Memories
    - Emotions
    - Behavior

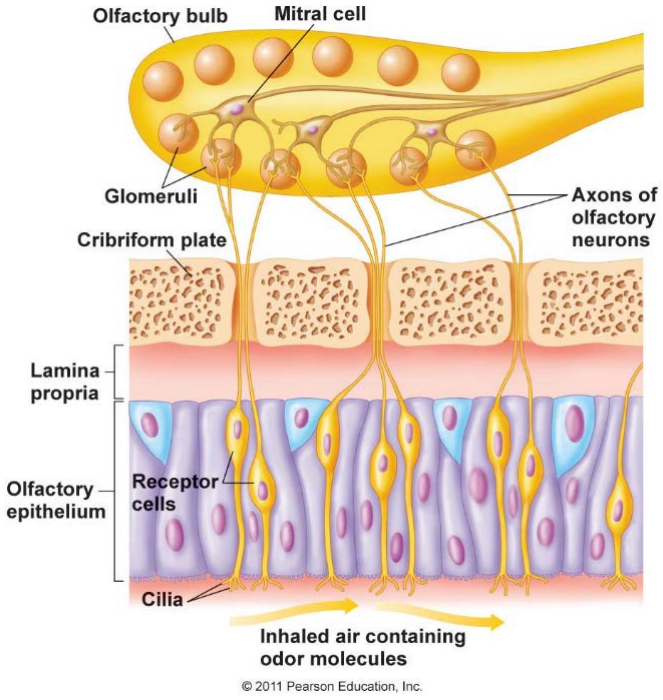
Maybe we can better understand why the community acts the way they do about nuisance odors!

Olfactory Sense

Nasal Cavity



Why is Odor Unique



- **Science is not fully understood**
- **Subjective**
- **No standards of acceptance levels**
- **Odor sensitivity vs. analytical**
- **Perception:**
  “If I can smell it, it must be ….”

Sense of Smell Factoids

- 80 – 90% of what we taste is attributed to sense of smell
- How you smell is unique, like a fingerprint
- You can perceive ~10,000 different smells, in an area the size of a postage stamp
- Your ability to smell increases through the day
- Sense of smell feeds into the emotional area of the brain
- Women smell better than men

How do we measure odour?

Olfactometry

- Odour panels
  - odour detection to threshold
  - intensity
  - persistency

Measurement of individual compounds

- Field instruments – Jerome, Odalog, etc.
- GC, GC-MS

Associated Engineering

How do we measure odour?

Measurement of individual compounds

- Field instruments – Jerome, Odalog, etc.
- GC, GC-MS

Olfactometry

- Odour panels

Dynamic Dilution, Forced Choice, Triangular Olfactometer

Field Monitoring Equipment

Still the BEST field instrument!

How do We Gauge Off-Site Impact?

Odor Dispersion Models

They are the best methods available

to predict off-site impact

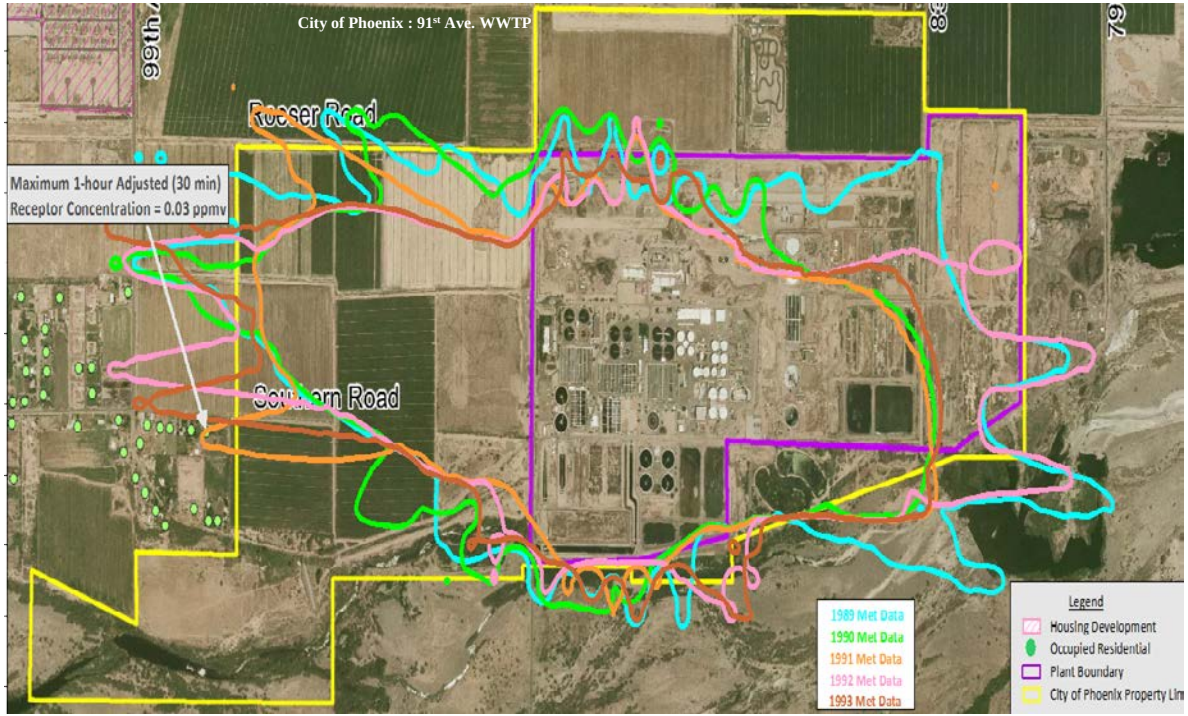
Odor Dispersion Modeling

Predictive “TOOL”

- Assess culpability
  - Assign Ranking
- Evaluate controls
- Assess Future conditions
  - What if’s?

Tool Box

Odor Model Results: Isopleth Example



Isopleth

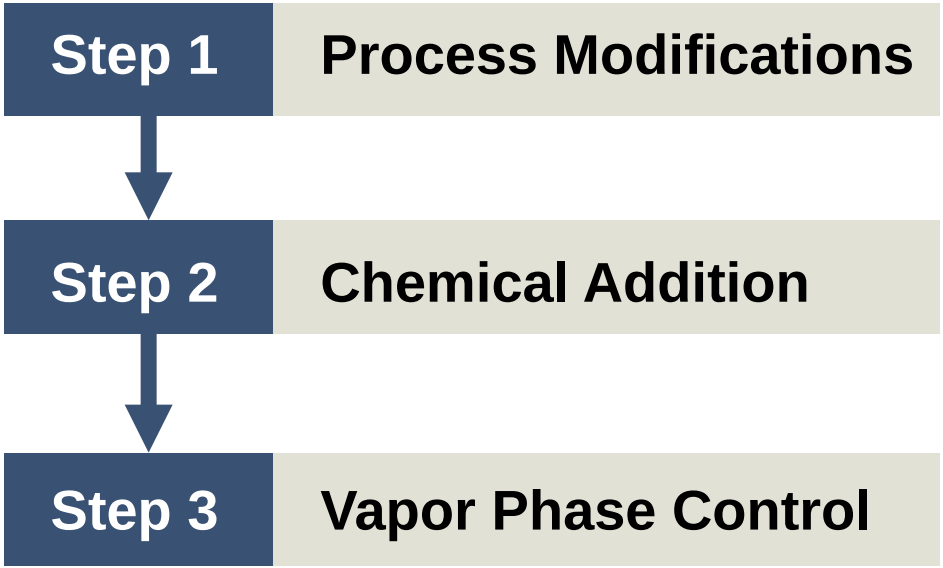
Represents lines of equal value/ concentration.

Phoenix, AZ

What Are My Odor Control Options?

- No single panacea
- Site specific

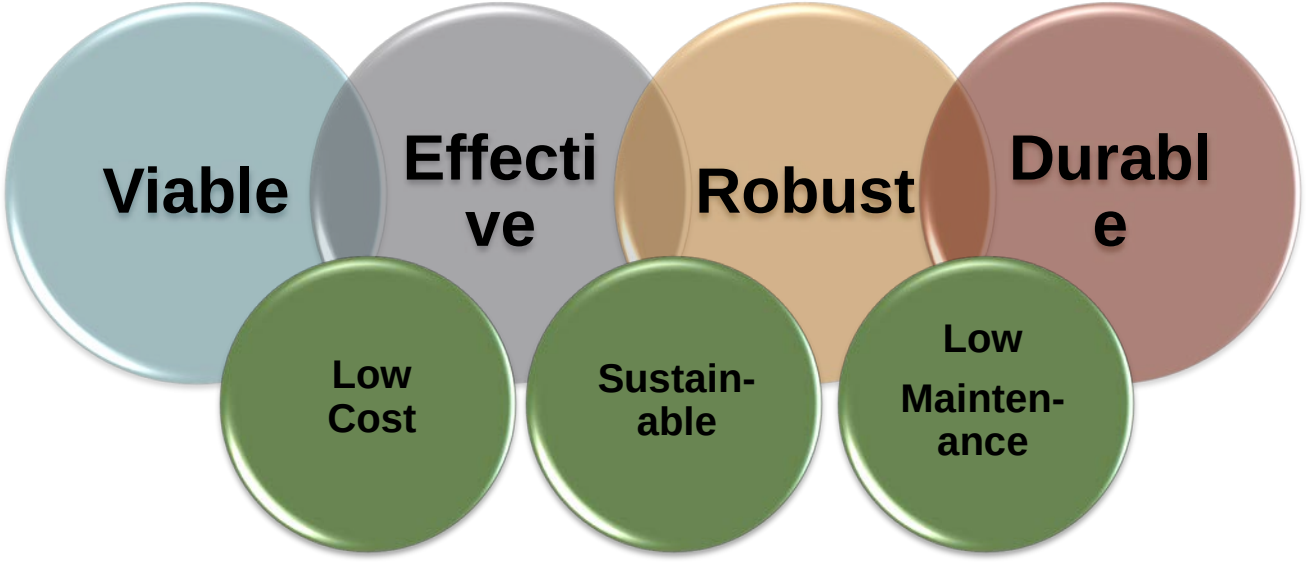
Odor Control Approaches



Our focus today

What Comes to Mind When You Think of Vapor Phase Odor Control?

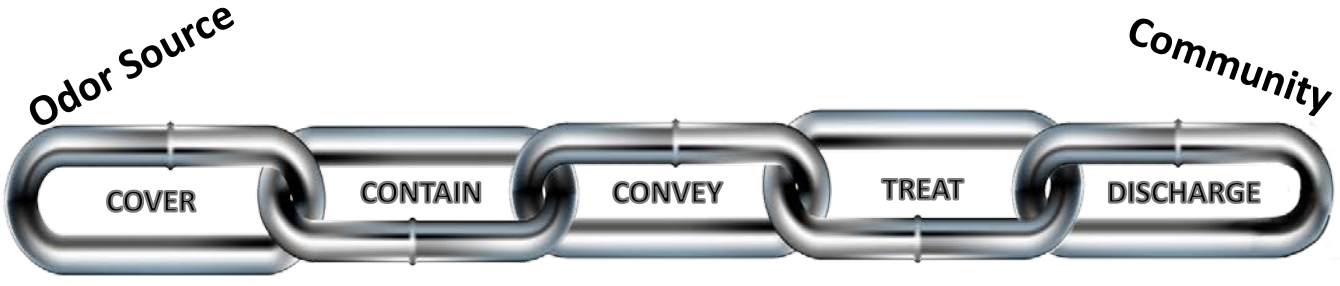
Selecting the right technology!



But Odor Control is more than just the technology!

Odor Control Approach

Consider these elements as links in a chain:



The odor control chain will only be as strong as the weakest link!

Vapor Phase Control Technologies

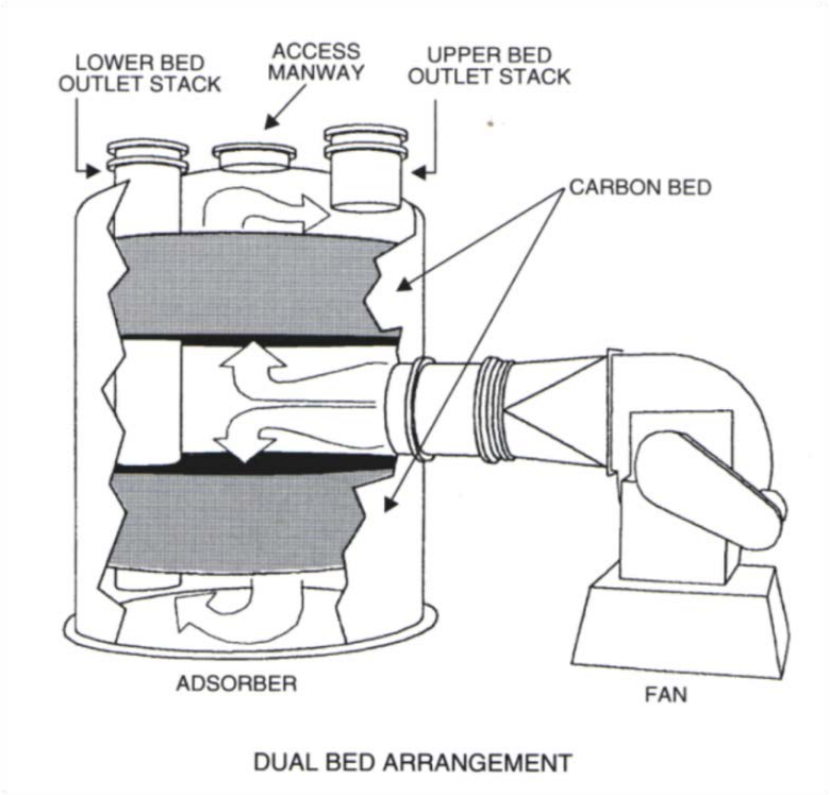
- Carbon*
- Wet scrubbing*
- Biological*
- Ionization
- Ozone
- Photocatalytic + Carbon
- Entrainment,Dilution, Dispersion
- Counteractants
- Masking agents

* Will discuss in more detail

Carbon

Adsorption Process: Carbon

- Most popular: carbon
  - Other: potassium permanganate impregnated activated alumina, resins, iron sponge
- Proven track record
- Dry process
- Simple process



What Does Carbon Come From?

- Activated carbon sources:
  - Coal
  - Lignite
  - Peat
  - Wood
  - Coconut shell

Carbon Forms

- Carbon types
  - Virgin activated carbon
  - Impregnated (caustic for H2S)
  - Catalytic
- Regenerate, Reactivate or replace carbon
  - Before breaking through

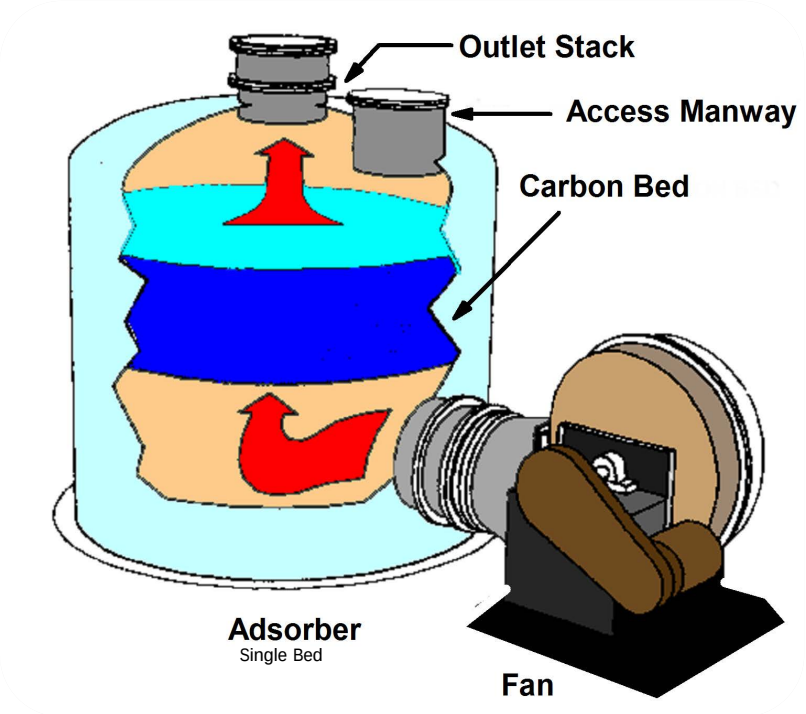
What Does Carbon Look Like?

Granular

Extruded

Adsorption Design Considerations

- Limited capacity
  - Monitor exhaust
- Use carbon when average H2S is 10 ppmv or less



Adsorption Design Considerations

- Air flow drives tower diameter
- Target velocity 50-60 fpm
  - Higher velocities increase pressure drop
- Standard bed depth: 3 feet
- Single or dual bed units
- H2S removal efficiency: 99 - 99.9%

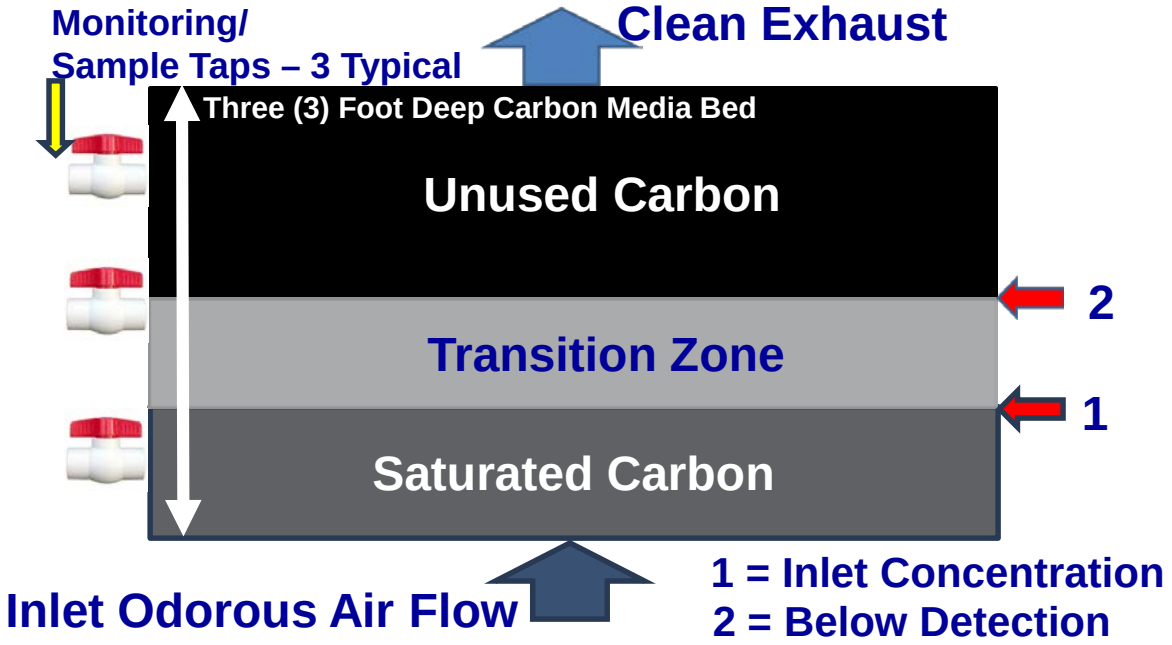
New design – radial flow

Carbon Operating Considerations

- Carbon works like a sponge
  - Sponge soaks up water
  - Prevents pass-through
  - When saturated
  - Water drips through

Carbon has limited removal capacity!

Activated Carbon Bed Operating Schematic



Common Carbon Capacity Examples

Manufacturer/Type	H_2S Capacity (g H_2S/cc Carbon)
Calgon	
BPL	0.03
Centaur	0.09
Impregnated	0.14
Norit	
Virgin	0.20
Catalytic	0.30
Siemens	
Midas	0.30
UOCH-KP	0.14
Carbon Activated Corp	
Virgin	0.04-0.06

Carbon Operating Considerations

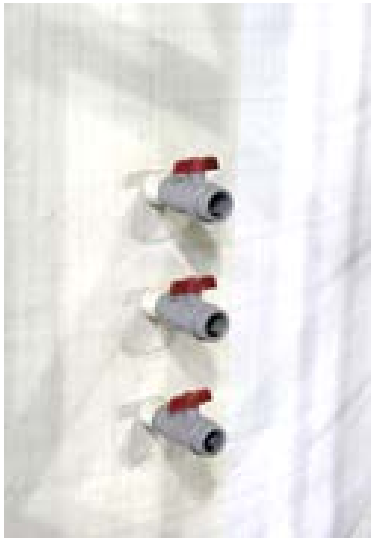
- Remove influent particulates
- Drain water in sump
- Monitor ΔP across beds
- Monitor taps for bed life
- Monitor exhaust

Carbon Operating Considerations

Prefilter

ΔP Gauges

Sump Drain



Sample Taps

Carbon Concerns

- Carbon will burn
- Unlikely auto ignition
- Impregnates can increase potential
  - Caustic material
    - Significantly lowers ignition temperature
- Virgin and catalytic carbons
  - Very low potential

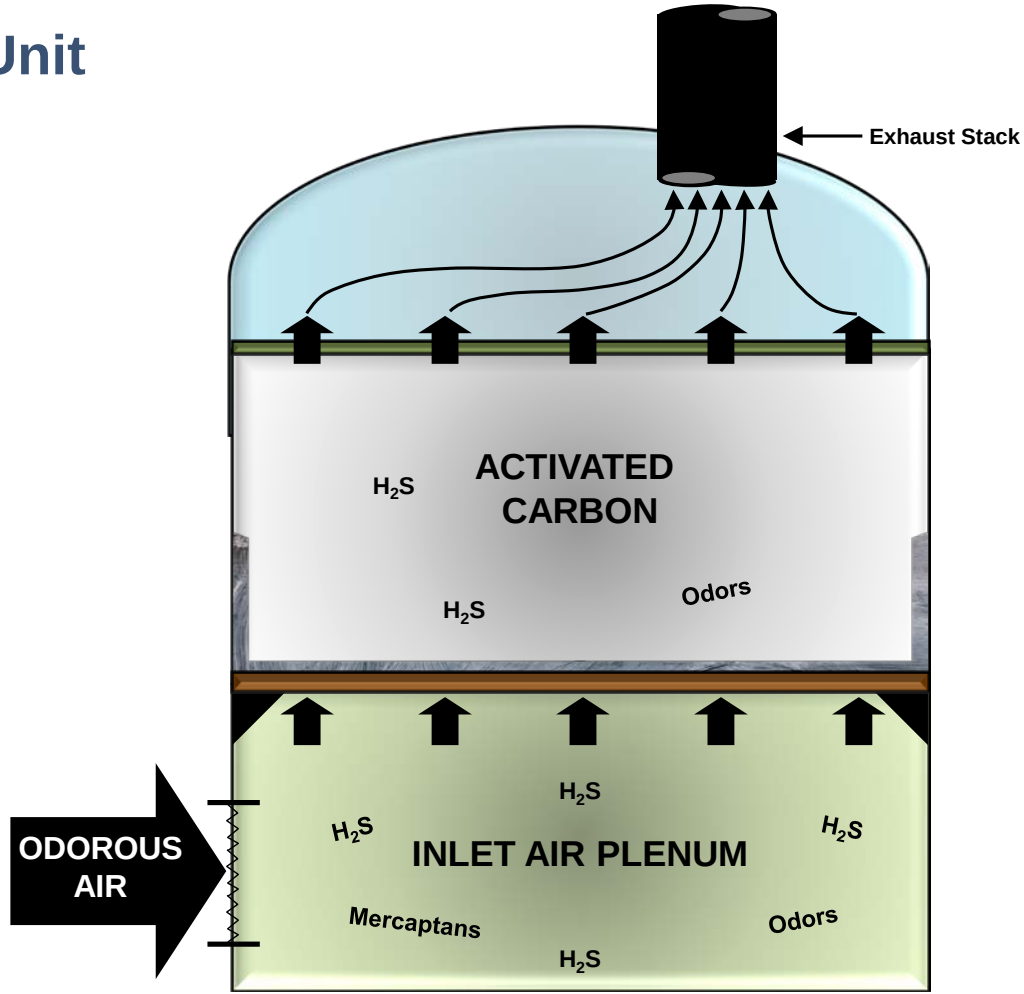
Summary - Unitized Capital Cost Comparison

Carbon Type	Auto Ignition Temperature (ºF)
Virgin	450
Catalytic	350–450
Impregnated	150–250

Carbon Vessel Fire Aftermath

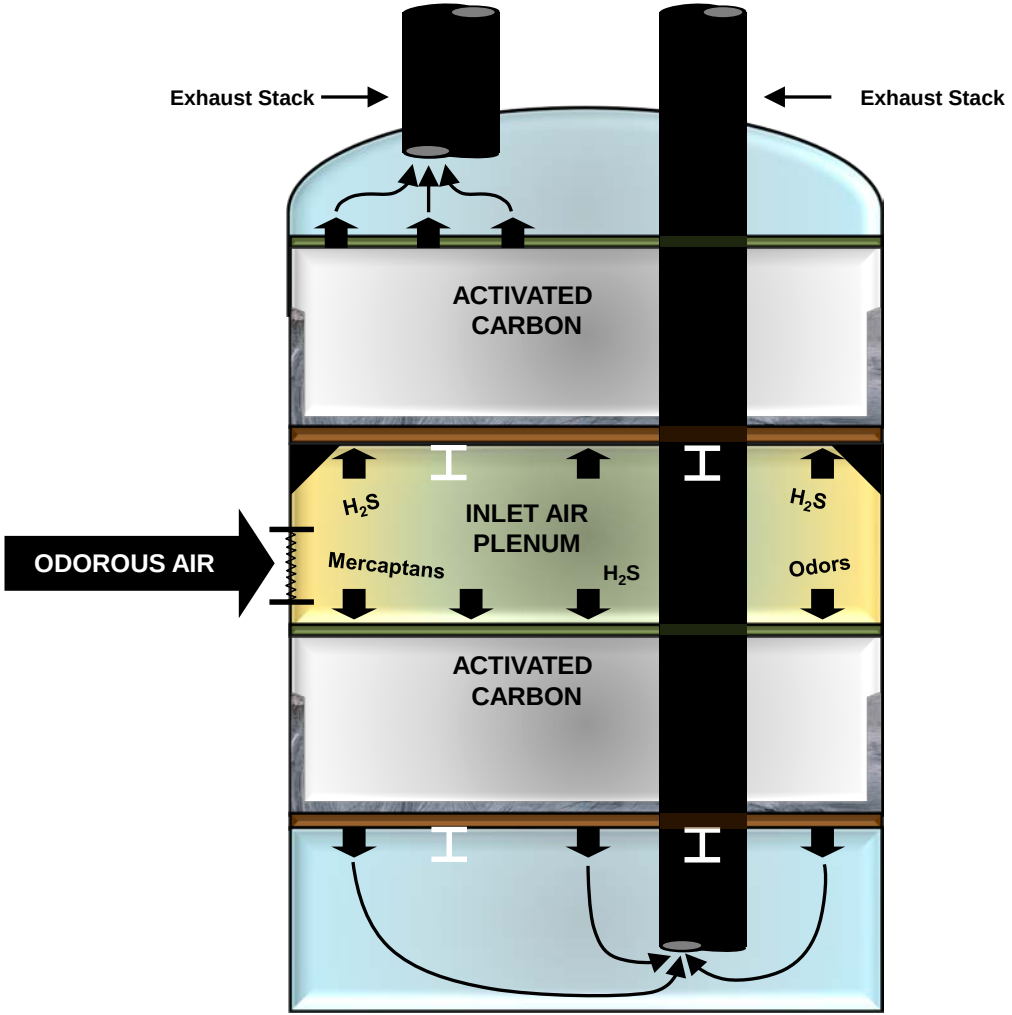
Activated Carbon Systems

Single Deep Bed Unit



Activated Carbon Vessel – Large Single Bed

Dual Deep Bed Unit



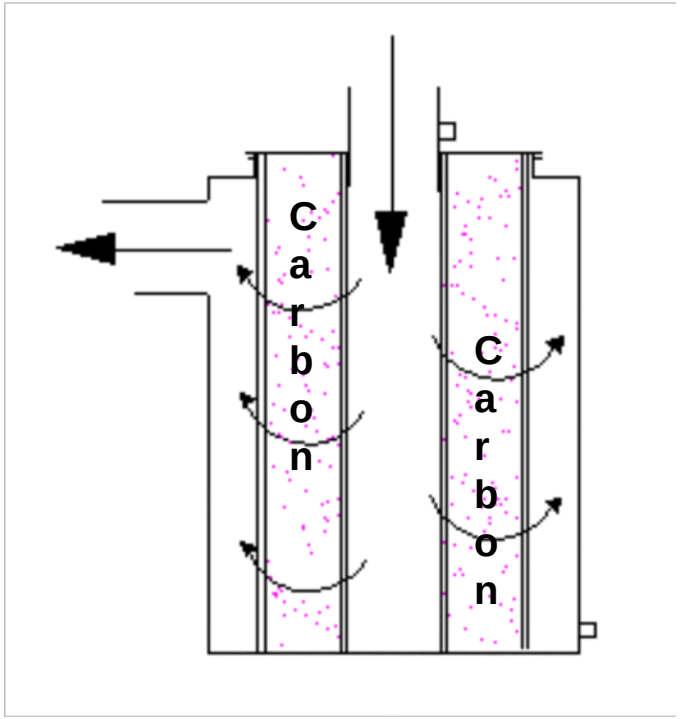
Activated Carbon Vessel - Dual Bed

City of Mesa WWTP

Activated Carbon Vessel - Dual Bed

Carbon – Radial Flow Design

Carbon – Radial Flow Design



Carbon Advantages/Disadvantages

Advantages

- Low maintenance
- Moderate foot print
- No acclimation required
- Long track record
- Reliable performance
- Preferred final polishing technology

Disadvantages

- Nasty byproducts of regeneration
- Replacing carbon
- No reserve capacity
- Two exhaust stacks per dual bed unit
- Unequal dual bed utilization
- Always removes everything

Carbon Advantages/Disadvantages

Advantages

- Simple system
- Minimal mechanical pieces
- Proven technology
- Effective H2S/odor removal
- Dry system
- Simple monitoring
- Good polishing unit

Disadvantages

- Carbon disposal
- Limited capacity
- Comparatively high pressure drop
- Moisture concerns
- No operating flexibility
- Potential bed fires
- One fan per vessel
- Must monitor for bed capacity

Wet Scrubbing

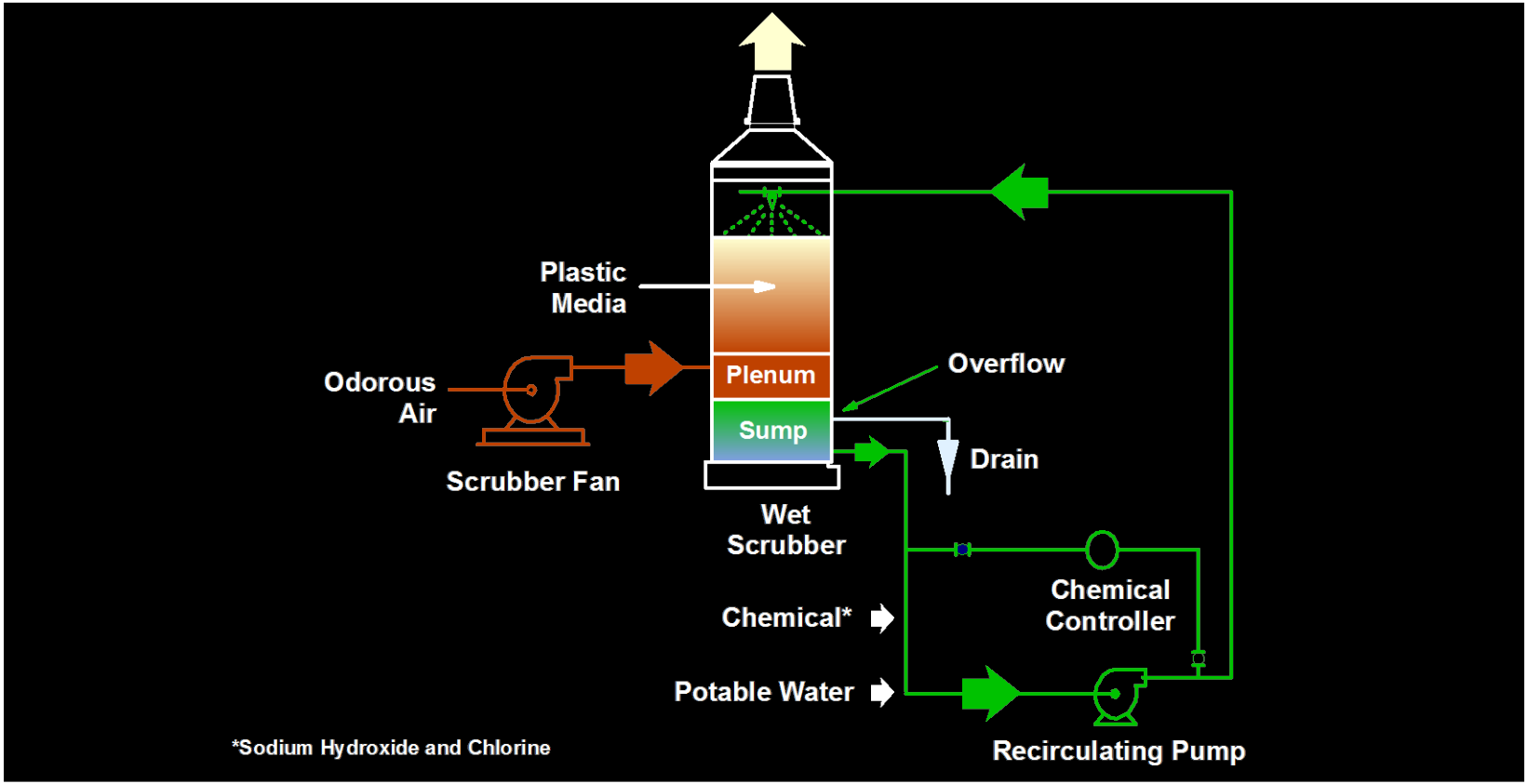
Biotrickling Filter

- Traditional technology
- Proven track record
- Small footprint
- Adjusts to variable odor loads

Wet Scrubbing Process

- Random plastic packing
- Scrubbant distributed over packing
- Odors passed through packing
- Odors absorbed into liquid film on packing
- Odors are treated in liquid film
- Limited gas-gas removal

Odor Control Wet Chemical Scrubber



Wet Chemical Scrubbers

Modular Unit

Small Scale

Cross Flow

Vertical Packed Tower Wet Chemical Scrubbers

Single Stage

Two Stage

Wet Scrubbing Chemistry

- **H_2S: solubilized by sodium hydroxide**

  $H_2S + 2\ NaOH \rightarrow Na_2S + 2\ H_2O$

- **Organics and H_2S oxidized by sodium hypochlorite**

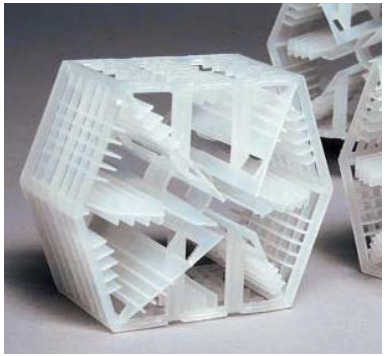
  $Na_2S + 4\ NaOCl \rightarrow Na_2SO_4 + 4\ NaCl$

- **Ammonia: solubilized by sulfuric acid**

  $2NH_3 + H_2SO_4 = (NH_4)_2SO_4$

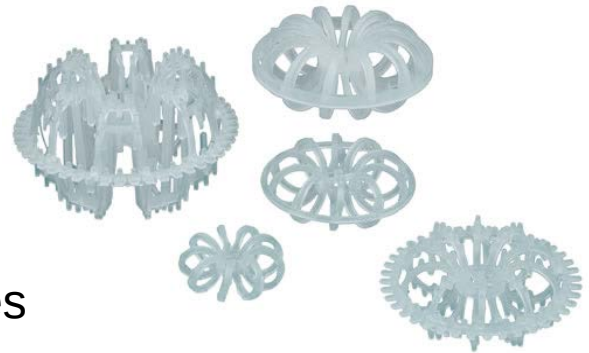
Wet Scrubber Design Features

- Bed Velocity
  - ROT: 250 - 350 feet per minute
- Media
  - Various plastic shapes
  - High surface to volume ratio
  - Low pressure drop



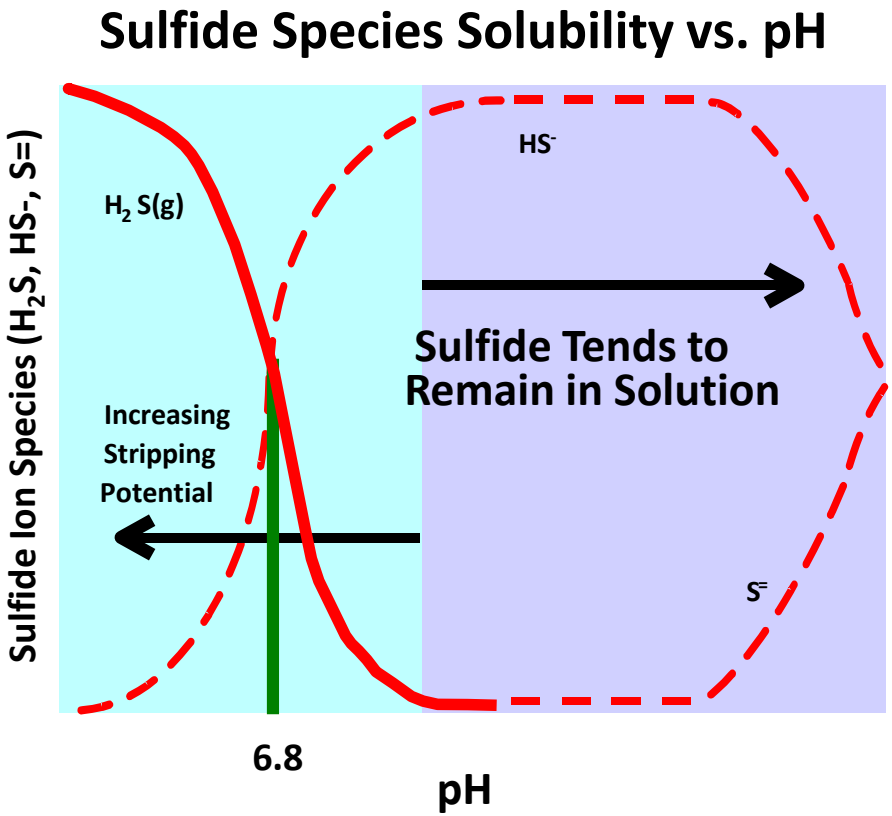
LANPAC

Tri-pack



Tellerettes

What Keeps H2S IN/OUT of Solution?



Wet Chemical Scrubbers – Performance

- Typical two chemical system -- caustic & bleach
  - 99% removal of H2S
  - 20 to 70% removal of organic sulfur compounds
- Separate vessel or stage for ammonia removal:
  - 99% removal of NH3

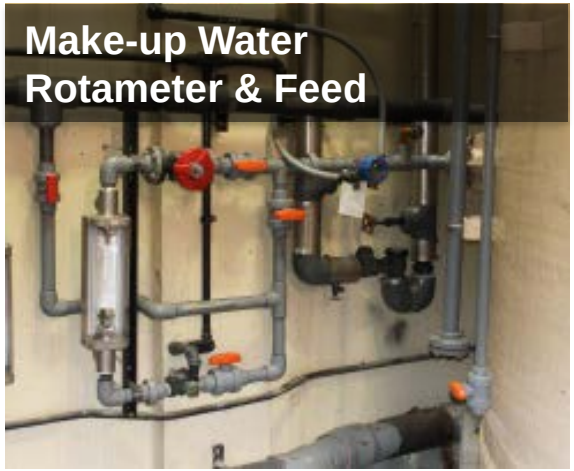
Wet Scrubbing Operating Considerations

- ORP & pH at set points
- Even distribution of scrubbant solution
- Monitor ΔP across bed
  - Across mist eliminator
- Make-up water/Blowdown active
- Monitor exhaust
- Sophisticated controls and instrumentation
- Complex and Maintenance intensive

Wet Scrubbing Operating Considerations

pH & ORP Probes and Readout

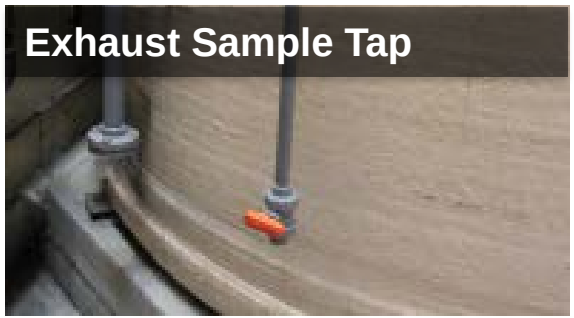
Make-up Water Rotameter & Feed



Bed ΔP Readout

Nozzle Distribution

Exhaust Sample Tap



Chemical scrubbers – H & S

- Hazardous chemicals
  - Caustic
  - Sodium hypochlorite
  - Sulfuric acid

Wet Scrubber – Advantages/Disadvantages

Advantages

- Physical-Chemical process
- Small foot print
- Automatic chemical feed
- Recirculates scrubbant solution
- Proven track record
- Thousands of installations
- Familiarity of mechanical systems

Disadvantages

- Uses hazardous chemical
- Safety is an issue
- Mechanically intensive
- Poor VOC removals
- Continuous blowdown
- Scale build up
- Removes CO2 (sink for caustic)

Wet Scrubber – Advantages/Disadvantages

Advantages

- Effective H_2S/Odor Removal
- Adjusts to seasonal loads
- Can eliminate chemical in off odor season
- Single stack discharge
- No acclimation time required

Disadvantages

- More labor intensive
- Greater degree of O&M
- Calibration needs on probes
- More systems to monitor
- Take system O/S to acid wash

Wet Scrubber – Advantages/Disadvantages

Advantages

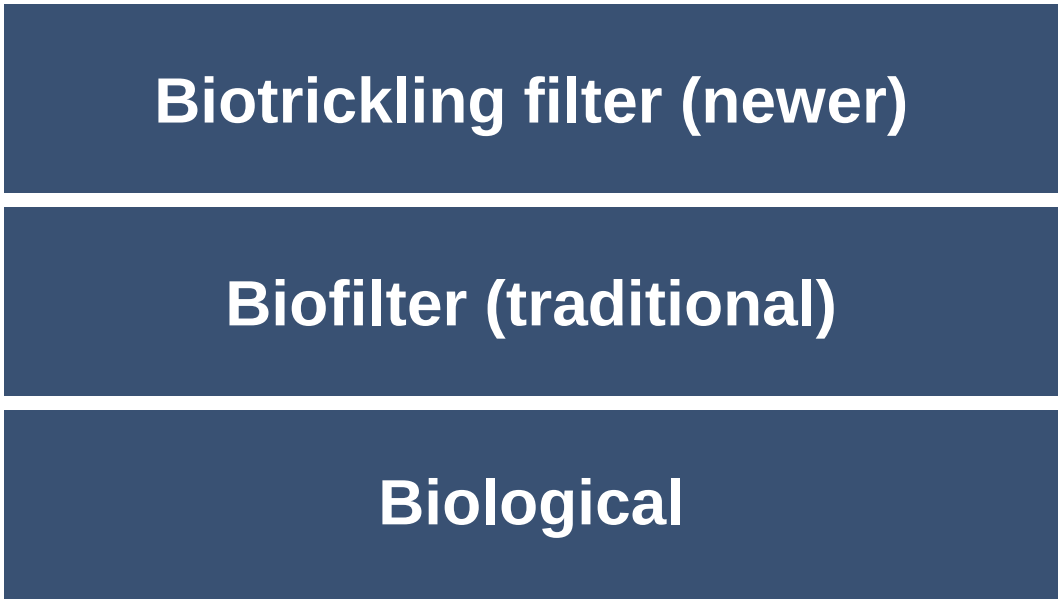
- Visible odor control device
- Less subject to upsets
- Easy to monitor exhaust

Disadvantages

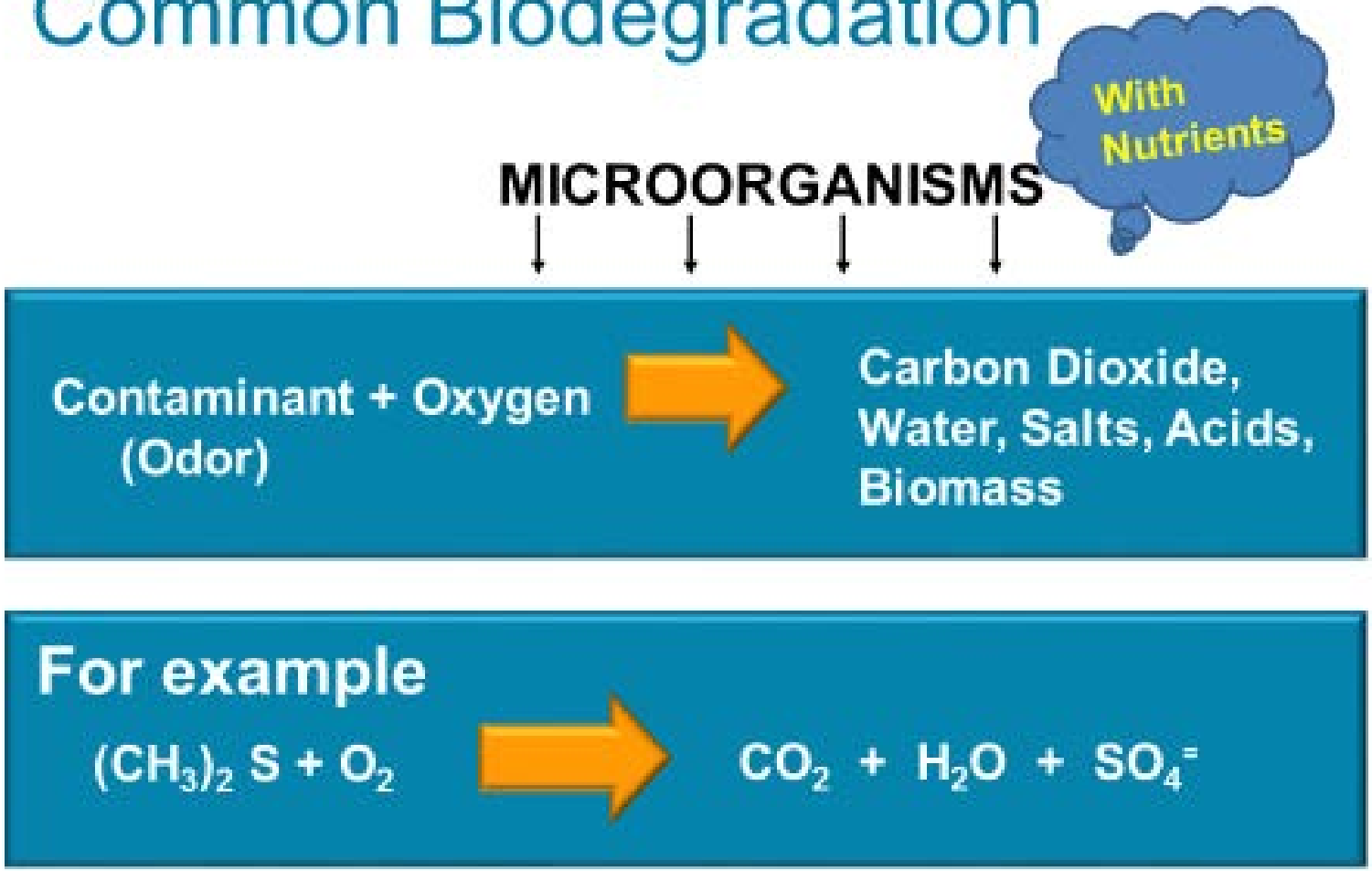
- Chlorine odor in exhaust
- Waste chemical in blowdown
- Hard waster causes scale
- Stores hazardous chemical
- Hazardous chemical truck deliveries through streets and plant

Biological

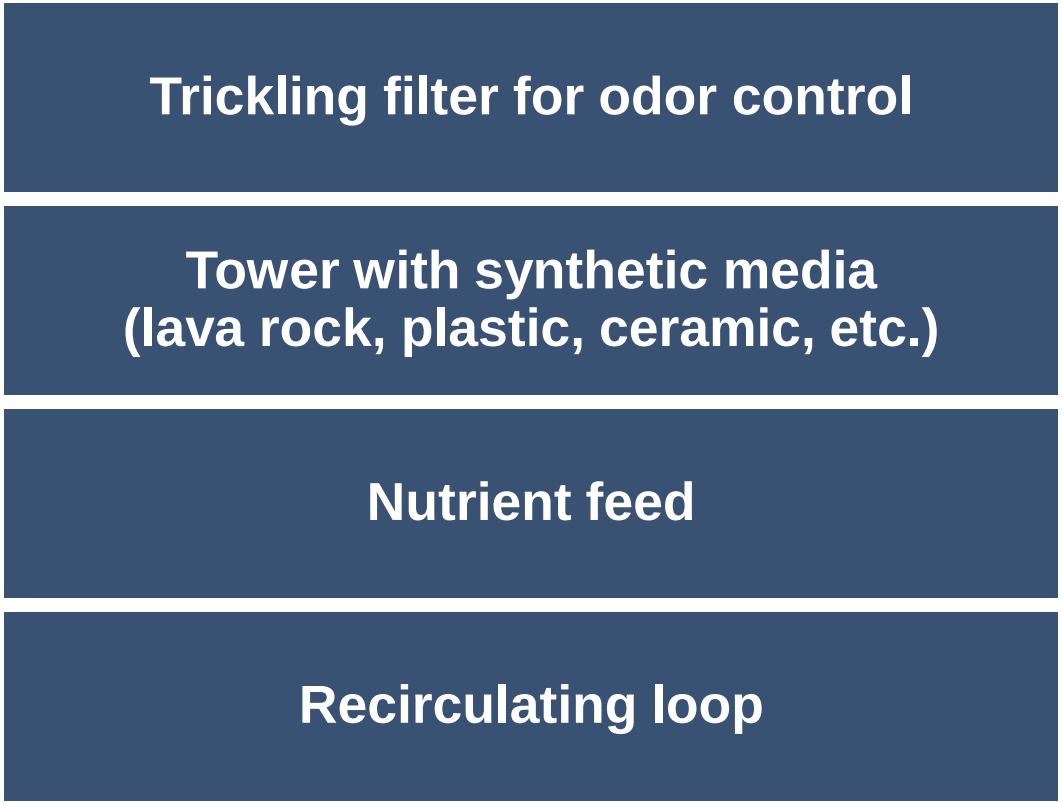
Biological Vapor Phase Control Technologies



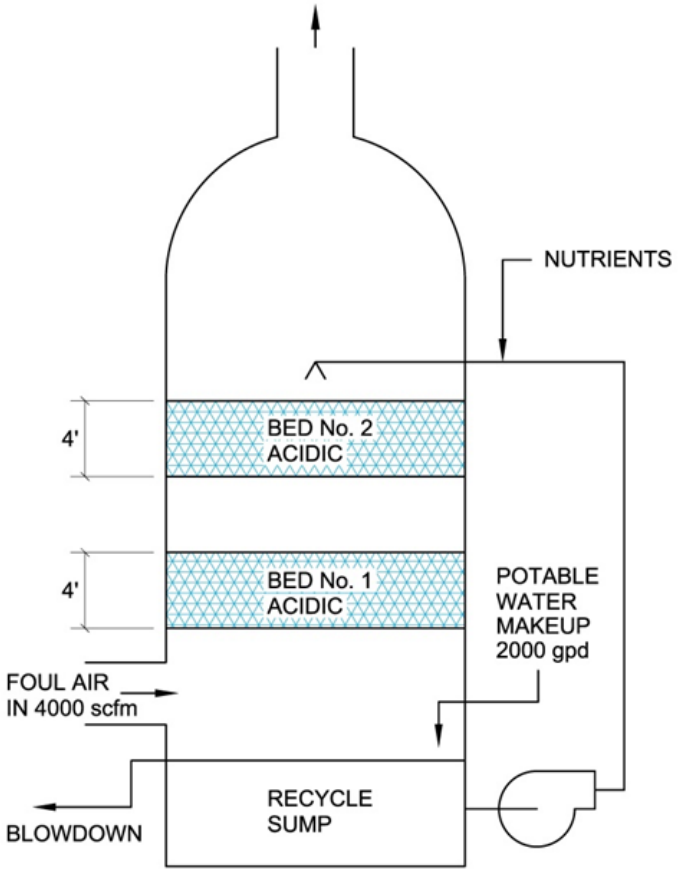
Common Biodegradation



Biotrickling Filter



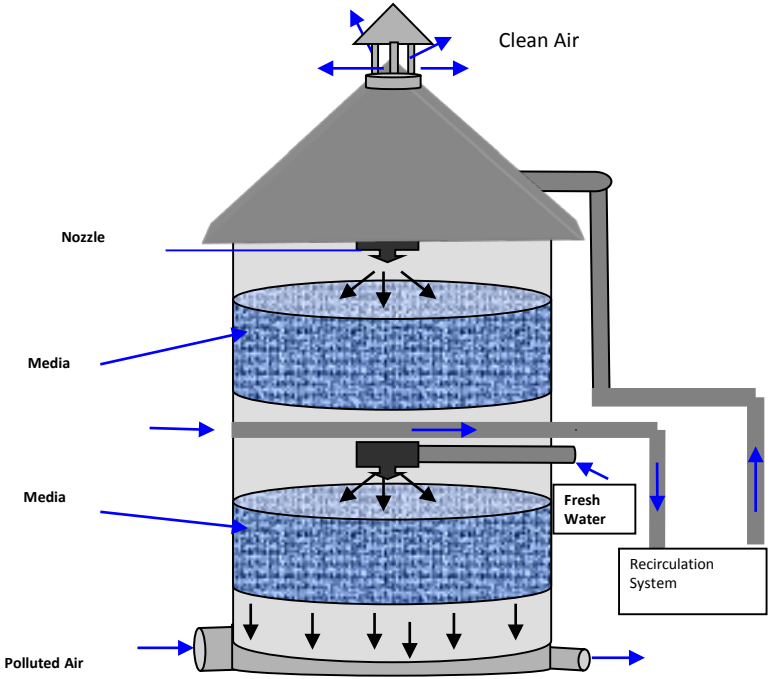
Bio-trickling Filter (BTF)



Multiple Stages and Different pHConditions

- Flexibility to operate upper stage and lower stage independently with different pH and recirculation or fresh once through water flow

- Lower stage can be pH 3 and upper stage can be pH 6-7



Bioway Unit

Biotrickling Filter

- Key application
  - High H2S removal
  - Great roughing filter

- H_2S removal - Acidic
- Autotrophic organisms
  - Get carbon (cell growth) from
    - Carbon dioxide

- Will not treat organic odors
  - May require 2nd stage

Multiple Biotrickling Towers

BTF – Design Considerations

EBRT (Empty Bed Residence Time)

- Dictates size
- H_2S removal
- 7 -20+ seconds

Operating pH

- Control it
- Let it go

Media

- Wet
- Nutrients

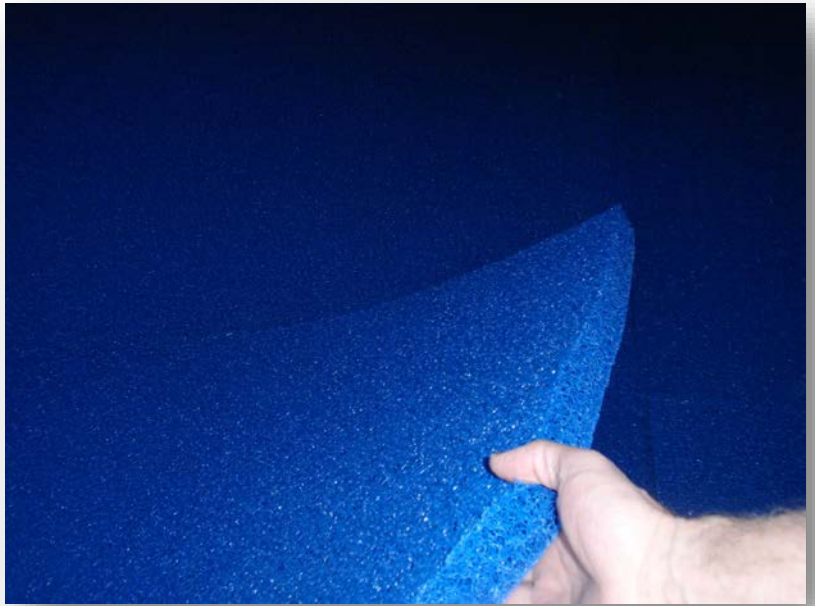
Biotrickling Filter Design Features

Bed Velocity: 50-200 fpm

Odor Load Limits

- H_2S concentrations
  - Effective up to 1,000+ ppmv

Less effective non-H_2S remover



Example of plastic foam media

BTF Media Alternatives

Inorganic

- Proprietary blends
- Polyurethane (PU) Foam Cubes
- Porous Lava rock
- Ceramic
- Structured foam
- “Popcorn”

Biotrickling Filter Operating Principles

Maintain wet environment
- •Liquid film on media surface

Odors absorbed into film
- •Microorganisms reduce H_2S

Microorganisms
- Autotrophic (use CO_2 as carbon source)
- Convert H_2S to H_2SO_4
  - Low pH
- Extremely efficient

Prefilter

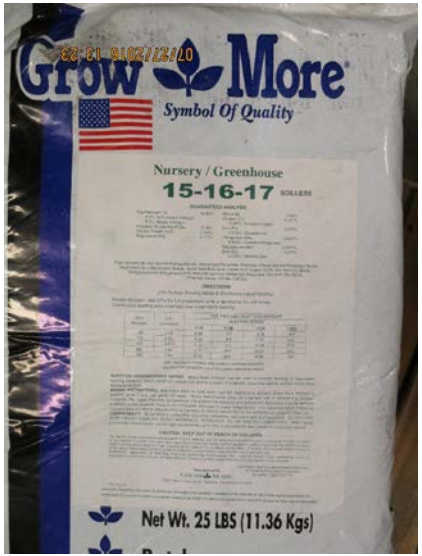
Monitoring

Plastic Foam Media Cassettes

Biotrickling Filters

Biotrickling Filter Operating Considerations

Pre-Filter



Nutrients

Nutrient Feed Tank

Monitoring

Biotrickling Filter – Advantages/Disadvantages

Advantages

- No chemical
- Plant effluent for nutrients
- Low O&M required
- Biological process
- Efficient at removing H2S
- Can operate at low pH
- Autotrophs operate with minimal biofilm thickness

Disadvantages

- Biological process
- Subject to upsets
- Very poor non H2S removals
- Drainage is low pH
- Corrosive operating pH
- Not start/stop system
- Need second stage for other odors

Biotrickling Filter – Advantages/Disadvantages

Advantages

- Can remove very high H_2S
- Small to modest foot print
- EBRT from 2 – 20 seconds
- Low pressure drop
- Once through water/nutrients

Disadvantages

- Need CO_2 in odorous air flow
- Where to put low pH drainage
- Media breakdown can plug media and impact pressure drop
- Not economical for low H_2S

Biotrickling Filter – Advantages/Disadvantages

Advantages

- Long lasting media available
- Manageable by-products
- Relatively quick acclimation
- Environmentally friendly system

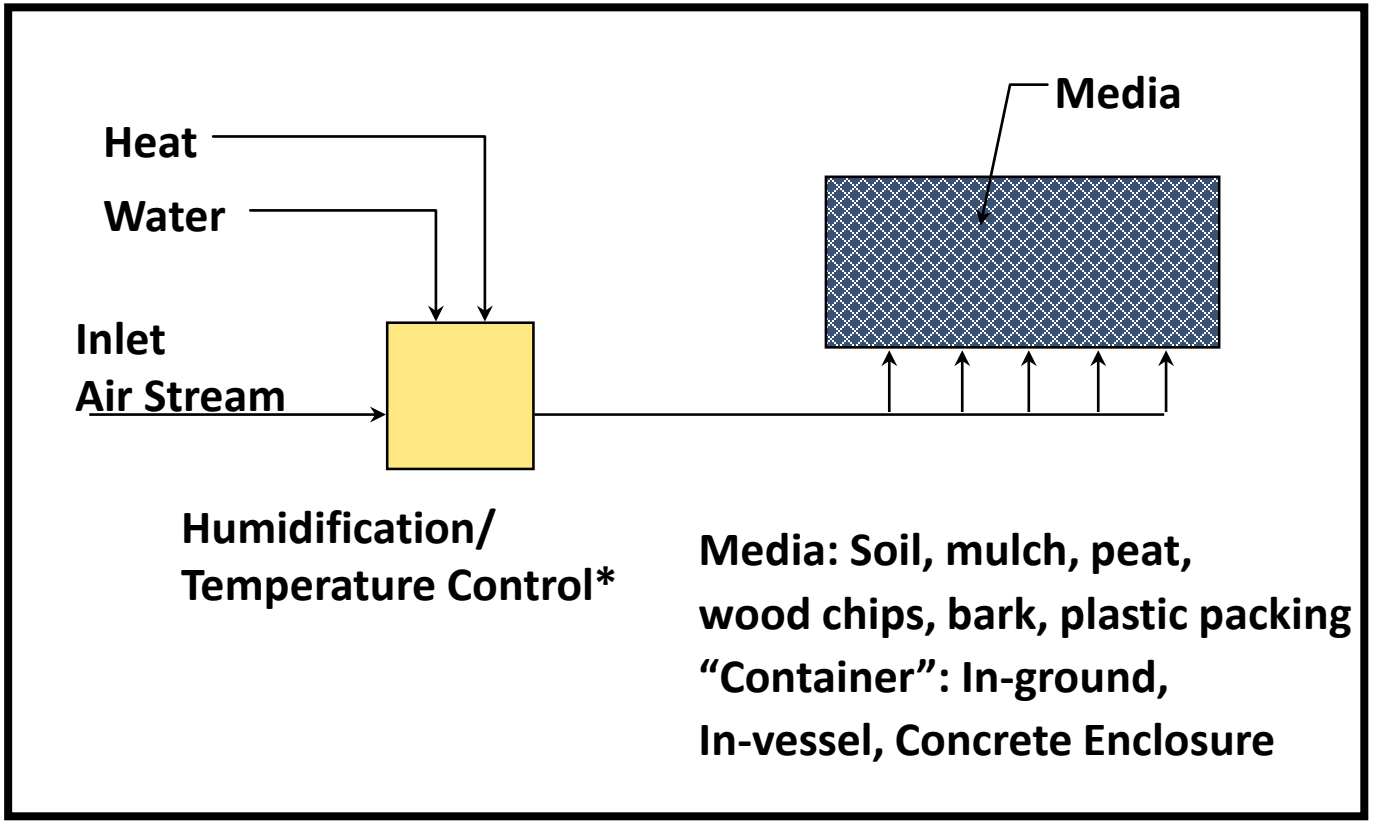
Disadvantages

- Unproven longer US track record
- Most effective systems are proprietary
- Design conditions still being developed
- Requires acclimation period

Biofiltration

- Sustainable Treatment Technology
  - Utilizes natural biological processes
  - Utilizes natural media materials
    - Compost
    - Soil
    - Wood chips
  - No environmentally harmful by-products
  - Green technology

Biofilter


Media
Heat
Water
Inlet
Air Stream
Humidification/
Temperature Control*
Media: Soil, mulch, peat,
wood chips, bark, plastic packing
“Container”: In-ground,
In-vessel, Concrete Enclosure

In-ground Biofilter

Modular Biofilters

Above Ground Biofilter

Biofilter Design Considerations

Two key parameters:

- Moisture
  - Typical range: 50% to 65%
  - Prehumidification
  - Bed irrigation
- Air Distribution

Biofilter Design Considerations

- EBRT
  - Function of inlet odors
  - 30 to 60+ seconds
- Media
  - Wood*
  - Compost
  - Bark nuggets
  - Proprietary*
- Media degradation
- Media life span

*** - Most popular today**

Biological processes – removal efficiencies

- Bio-trickling filters can remove 85 to 99% of H_2S
- Biofilters have lower efficiencies than other odour control technologies
  - Removal ranges from 50 to 95% of all incoming contaminants
- Best used to treat mixture of contaminants in the ppm range (up to 10 ppm of H_2S)
- Less efficient on the removal of NH_3

Biofilter Operating Considerations

- Remove particulate and aerosol O&G
- Media degradation
  - ΔP Build-up/monitoring
  - Replacement
  - Smoke testing
- Key operating elements
  - Moisture
  - Air distribution
- Temperature
- Drain low pH

Biofilter Operating Considerations

Pre-Filter

Pre-Humidification Chamber

Replacing Media

Smoke Candles

Biofilter – Advantages/Disadvantages

Advantages

- Environmentally friendly
- Green technology
- No chemicals
- Few mechanical pieces
- Low maintenance
- Minimal monitoring
- Removes H2S and organic odors
- Biological treatment

Disadvantages

- Media replacement
- Maintaining moisture levels
- Short circuiting
- Short bed life
- Media decomposition
- Large foot print
- Influent humidification
- Subject to upsets

Biofilter – Advantages/Disadvantages

Advantages

- Low annual operating cost
- Non-hazardous media
- Minor adjustments needed
- Capable of treating variable odor loads
- Robust microorganisms
- Proven media effectiveness: natural and propriety
- Long dilution time in media

Disadvantages

- Bed compaction
- Pressure drop increases over time
- Air distribution
- Media pressure drop
- Short track record
- Media imparts own odor to exhaust

How Sustainable Do Technologies Look?

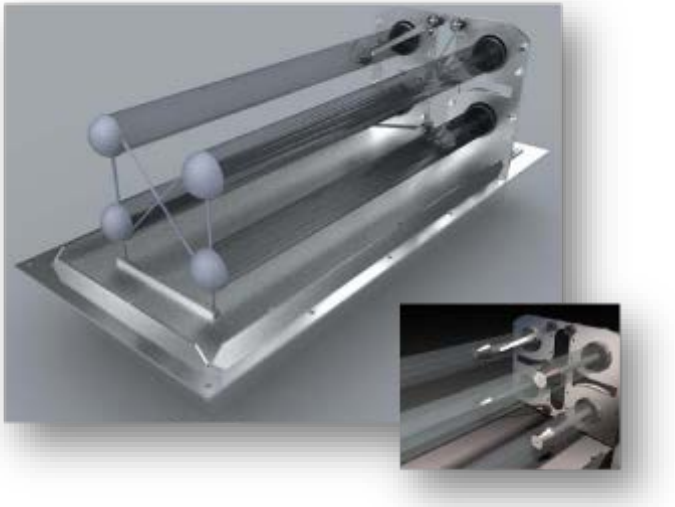
Technology	Water	Chemical	Energy	Residuals	H&S
Carbon	N	N	M	Y	N
Wet Scrubbing	Y	Y	Y	Y	Y
BTF	M	N	M	N	N
Biofilter	M	N	M	Y	N

Yes – Y
No – N
Moderate -- M

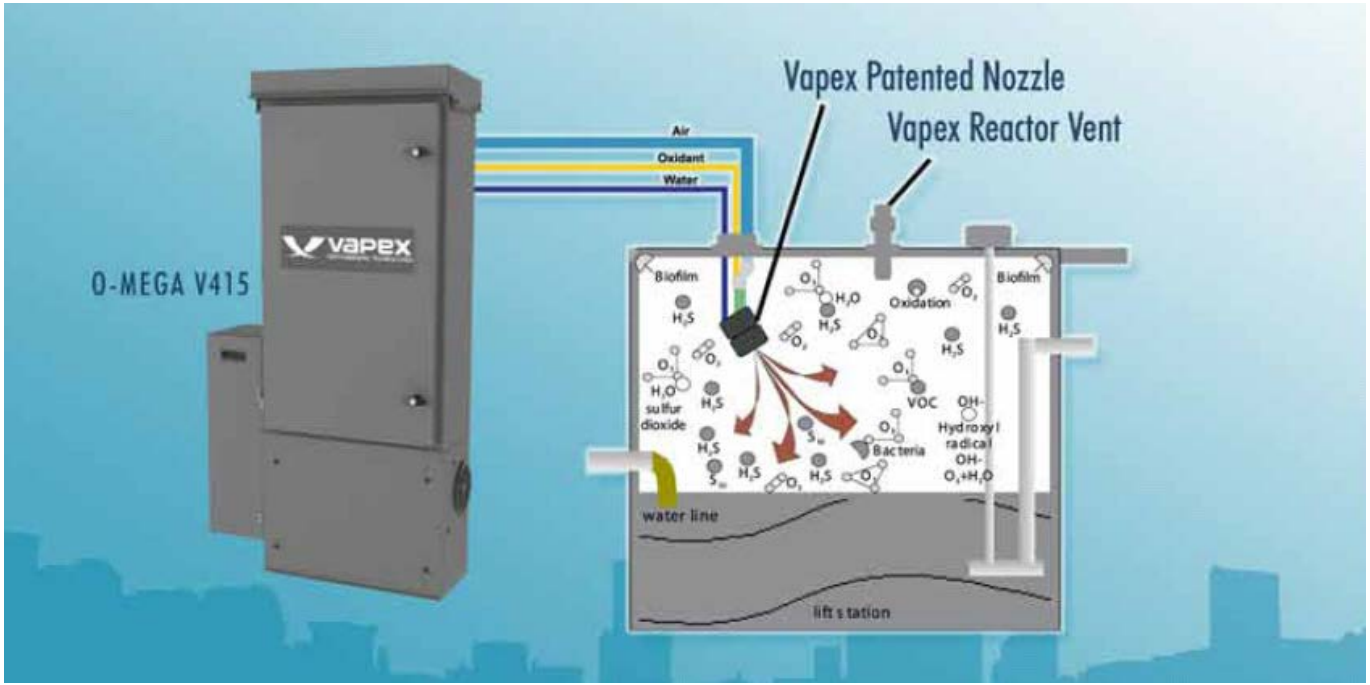
Newer Technologies

Ionization

- Use Ionized Air To Control Odors
  - Simple system
  - No chemicals
  - Low cost - Capital Operating
- Effective In Closed Areas
- Negative
  - Lack of data to support claims/effectiveness
- Applications:
  - Enclosed wet wells, buildings
- Cost - minimal



Hydroxyl Ion Fog



Hydroxyl Ion Fog

- Fog applied
  - In duct
  - Wet well
  - Holding tank
  - Vessel
- No removal of air required
- Installation simple
- Requires no chemical
- Effective on FOG

Hopeful Technologies

Odor Block Technology

Caffeine Adsorbent Canister

Vidalia Vapor Reactor 2

Monterrey, Mexico

Vidalia Vapor Reactor 1

Monterrey, Mexico

Conclusions

Odor control is not cheap!

Site specific application

- No silver bullets

Community is driving force

Helps to plan Public Outreach

Technologies available

Sustainability consideration

"Good Neighbor"

We need to recognize odors as the 3rd Plant Effluent and take them seriously!...
The Community already does!!!

Questions and Answers

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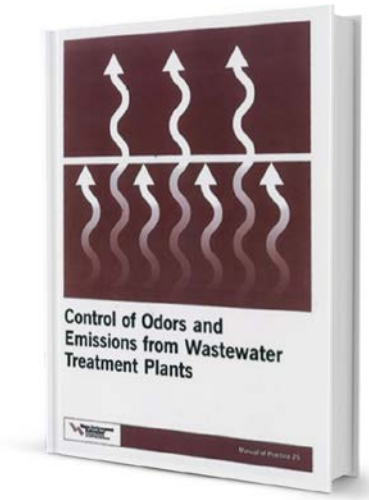
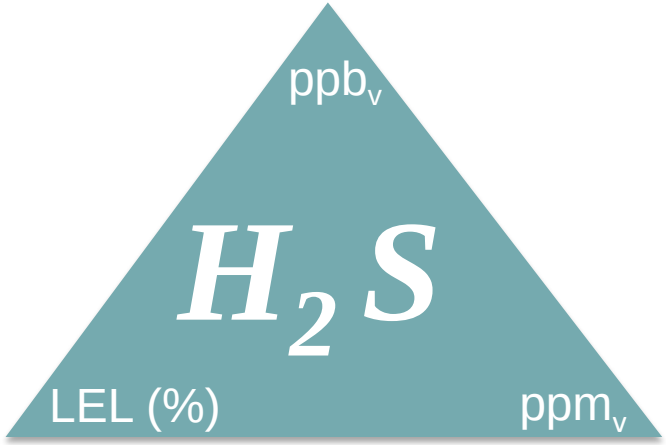
- Over 250 odor related projects
  - In 30 states & international
- Contributing author to WEF's MOPs (22,25,8)
- Frequent presenter at local/state/national/international
- Expert witness, Special Master & Court Compliance Officer



H_2S Properties

Nuisance Recognition 5 – 10 ppbv



Explosive (4%)

Toxic:

OSHA – 20 ppm$_v$

IDLH – 100 ppm$_v$

Death – 700+ ppm$_v$