CHARACTERIZING AIR EMISSIONS FROM WASTEWATER FACILITIES

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Odors and Air Pollutants

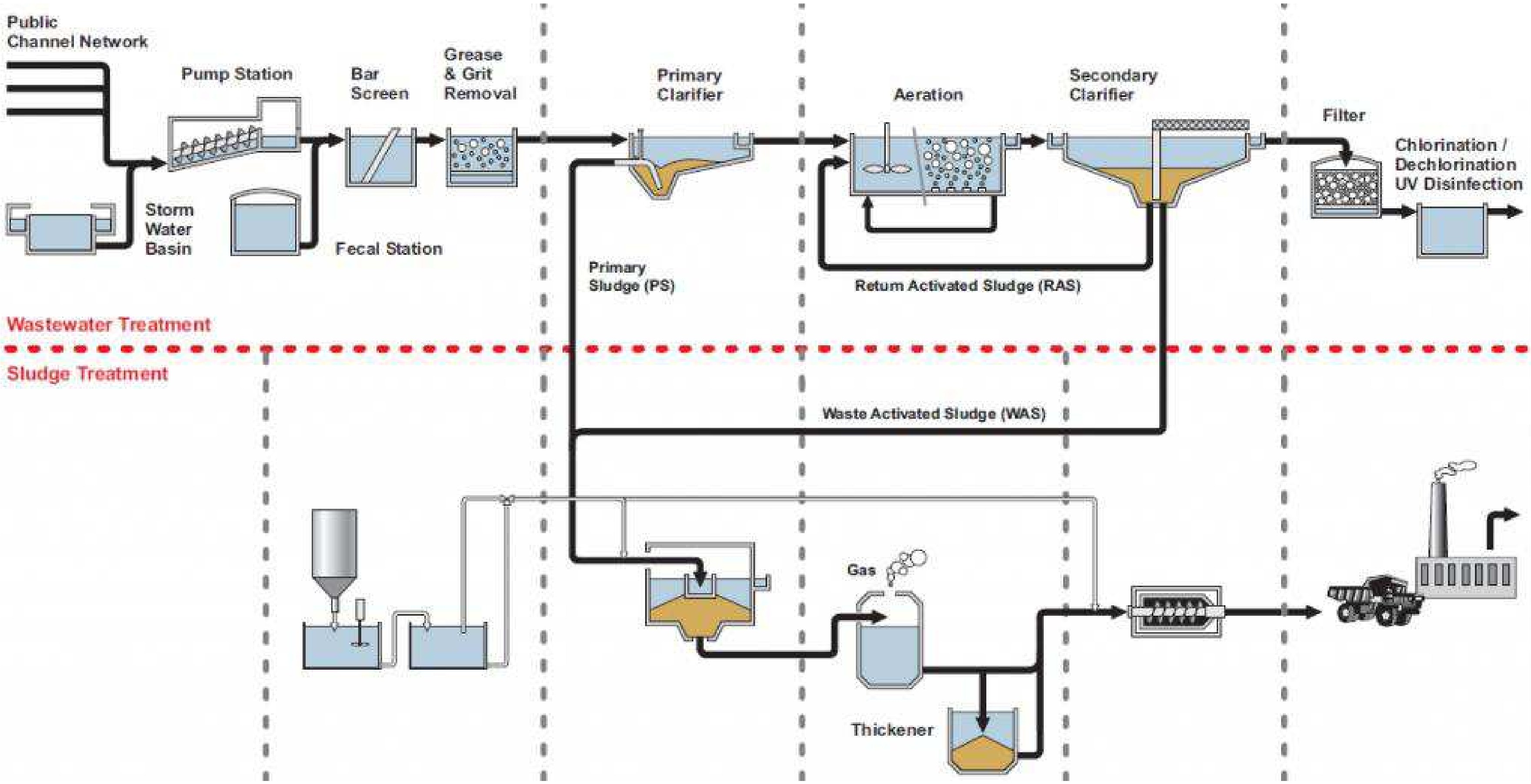
2016

Agenda

- Overview – air emissions in wastewater treatment
- Sources of emissions
- Measurement & Reporting of emissions
- Role of Fate & Transport models in characterizing Air Emissions
- Conclusion

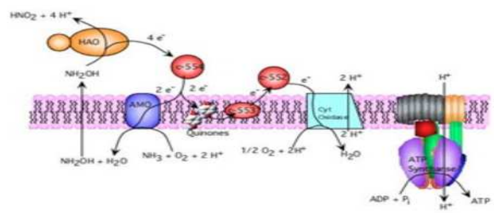
Wastewater Treatment

The Activated Sludge Process



Air Pollutants & Odors

Sources in wastewater treatment



Generated In-situ →

- THMs from Cl_2 disinfection
- Reduced Sulfur Compounds

  O_2 – Aerobic → CO_2
  NO_3 – Anoxic → N_2
  SO_4 – Anaerobic → H_2S

In Wastewater influent →

Odors – Mercaptans, H_2S
VOCs – Benzene, Toluene, etc.
HAPs

Air Pollution Regulations Through the Years

The Air Pollution Control Act of 1955

- First federal air pollution legislation
- Funded research on scope and sources of air pollution

Clean Air Act of 1963

- Authorized a national program to address air pollution
- Authorized research into techniques to minimize air pollution

Air Quality Act of 1967

- Enforcement procedures involving interstate transport of pollutants
- Expanded research activities

Clean Air Act of 1970

- Established National Ambient Air Quality Standards (NAAQS)
- Established requirements for State Implementation Plans
- Establishment of New Source Performance Standards for stationary sources
- **Establishment of National Emission Standards for Hazardous Air Pollutants**
- Authorized control of motor vehicle emissions

1977 Amendments to the Clean Air Act of 1970

- Authorized provisions related to prevention of significant deterioration
- Authorized provisions relating to non-attainment areas

1990 Amendments to the Clean Air Act of 1970

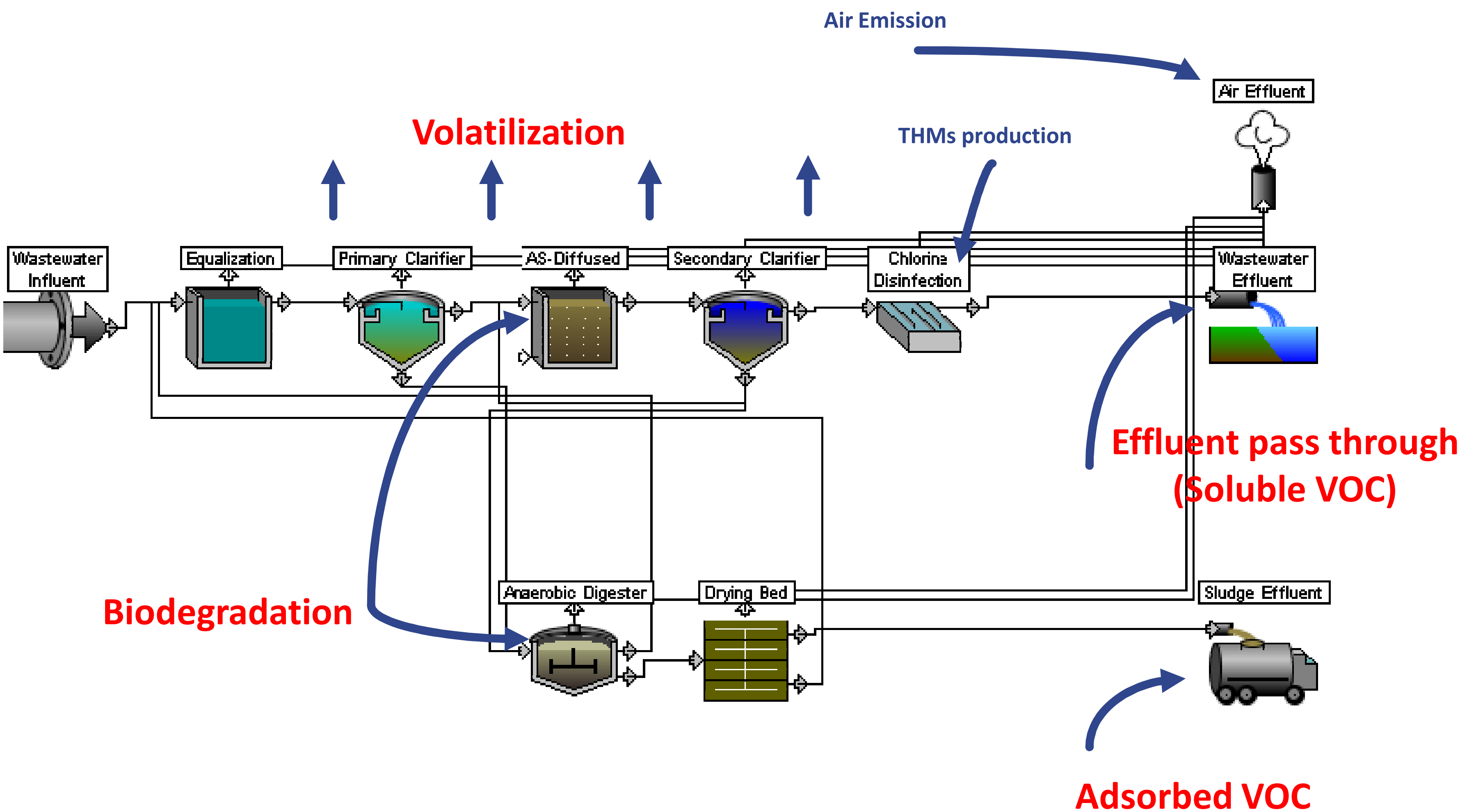
- Authorized programs for acid deposition control
- **Authorized controls for 189 toxic pollutants, including those previously regulated by the national emission standards for hazardous air pollutants (HAPs)**
- **Established permit program requirements**
- Expanded provisions concerning NAAQS

- What happens to odors & HAPs in conveyance & WWTP (Fate & Transport)
- What happens to HAPs that are emitted into the air at the treatment plant (Dispersion)?

Fate & Transport models developed in response to 1990 CAA Amendments

Contaminant Fate & Transport in Wastewater Treatment

How are they removed?



What are Emission Sources?

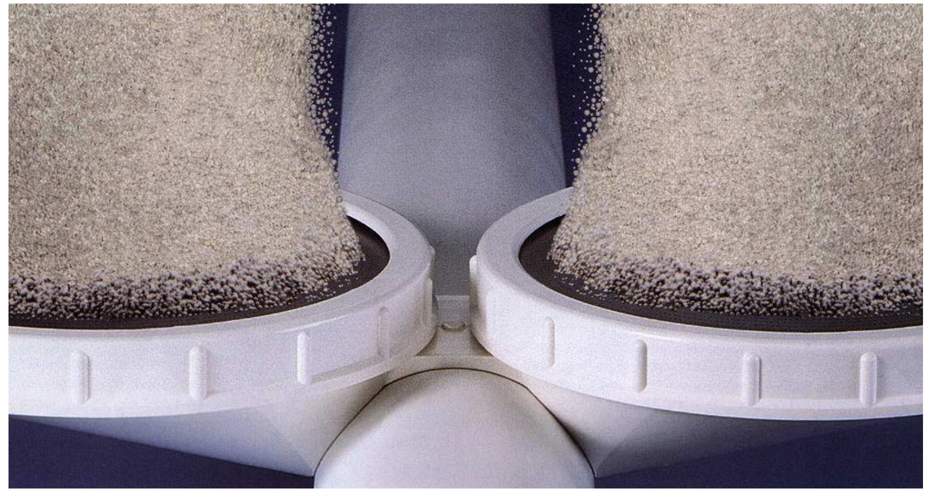
- Wherever energy is transferred to wastewater (wherever turbulence is created)
  - Gravity (waterfalls, weirs)
  - Mixers
  - Surface Aerators
  - Diffusers
- Wherever air streams with low concentrations of VOCs are in contact with VOC laden liquids

Activated Sludge Aeration

Mechanical Aeration

- Extreme turbulence causes VOC stripping and surface renewal

Diffused Aeration



- Only about 10-20% of O_2 is dissolved
- i.e., only 2-4% of influent gas @ 21% O_2 is dissolved
- ~96%-98% vent gas strips VOCs and odors!

Clarifiers

Surface

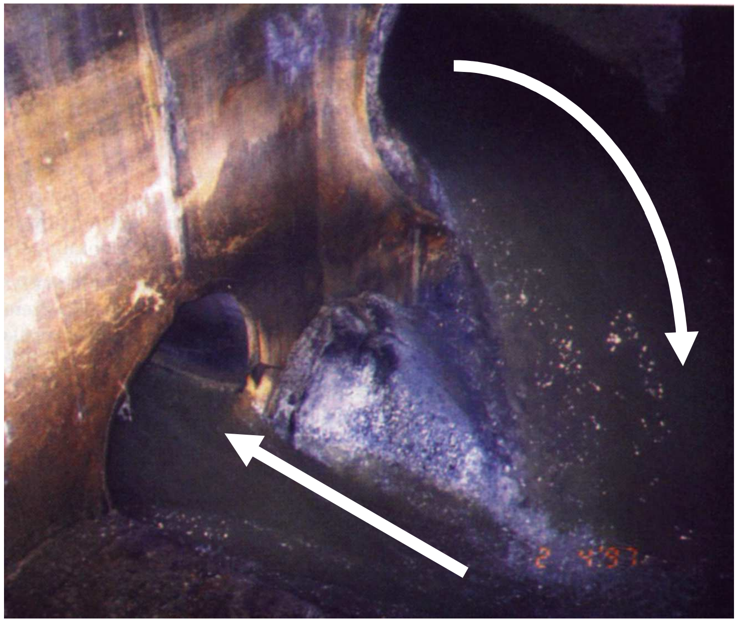
- Large surface area enhances VOC release

Weirs

- Note foam in the trough due to air entrainment

Emissions from Drop Structures & Ponds

Drop Structure



- A drop structure with process flow flowing into an existing process stream

Equalization Ponds

- Wind passing over large wastewater surface areas results in high surface volatilization rates

Emissions Estimation Methods

Direct Methods

Direct Measurement of Off-gas

- For enclosed headspaces, pipe flows, etc.
- Analyze concentration in off-gas flow (C_g)
- Measure off-gas flow rate (Q_g)
- Emission rate = $C_g * Q_g$

Measurement from Open Surfaces

- For open, non-confined surfaces (e.g. aeration tanks)
- Use floating flux chambers
- Trap and analyze emissions from surface area enclosed by chamber
- Measure gas flow through chamber
- Emission rate = $C_g * Q_g$

Indirect Methods

Emission Factors (EFs)

- Often based on some unit of production (e.g. lb of product per day) or WWTP operation (e.g. flow)
- Mass emitted = EF * mass production rate
- Accuracy is not that great; requires much historical evidence

Mathematical Modeling

- Main EPA approved models are BASTE, TOXCHEM™ and WATER9 (EPA)
- Based on mass balances, kinetic rate expressions and empirically-derived relationships

Measurement from Covered Tanks

- Measure off-gas flow rate (Q_g)
- Emission rate = $C_g * Q_g$

Measurement from Open Surfaces

Floating Flux Chamber

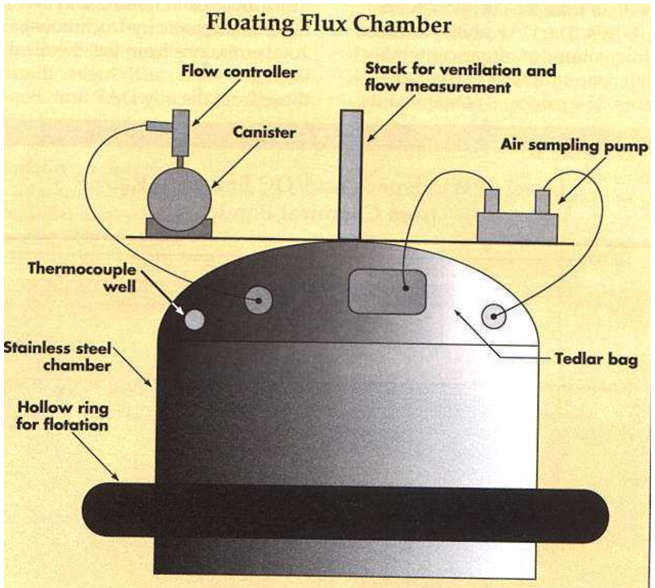


Fig D. Measuring Emissions from a Refinery Aerated Lagoon

Fig G. Municipal Wastewater Treatment

Direct Measurement of Air Emissions is Very Challenging

Indirect Estimation Methods

Emission Factors (EFs)

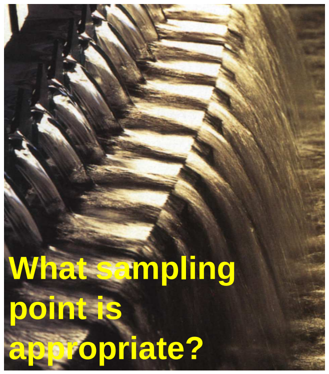
- Often based on some unit of production (e.g. lb of product per day) or WWTP operation (e.g. flow)
- Mass emitted = EF * mass production rate
- Accuracy is not that great; requires much historical evidence

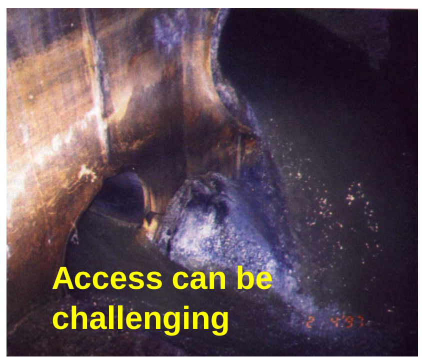
Mathematical Modeling

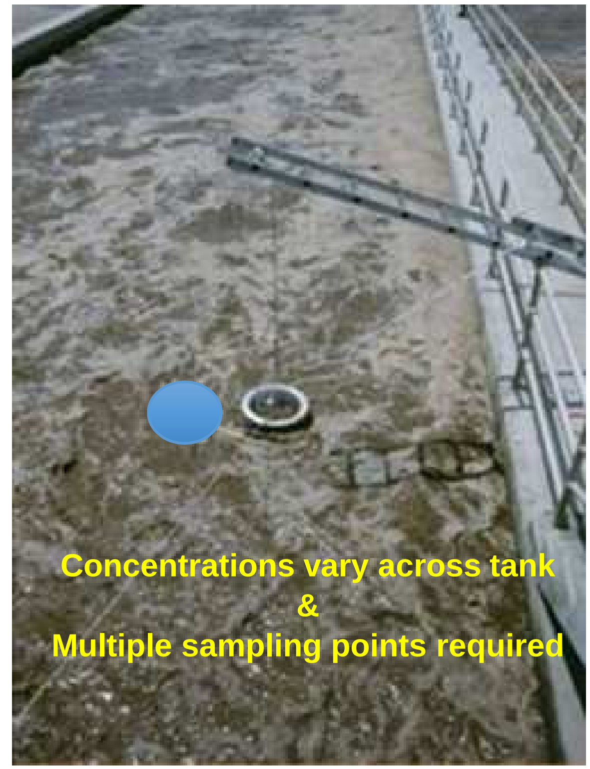
- EPA specifies applicable modeling methods in 40 CFR Part 63
- Two main models are TOXCHEM™ and WATER 9 (EPA)
- Based on mass balances, kinetic rate expressions and empirically-derived relationships

Reasons for Modeling

- Representative samples may be hard to collect
- Field staff may lack knowledge or resources for optimum sampling
- Measurements impacted by lots of variables – wind speed, throughput (Hi/Low flow), etc.
- Applicable to facilities in upgrade or design



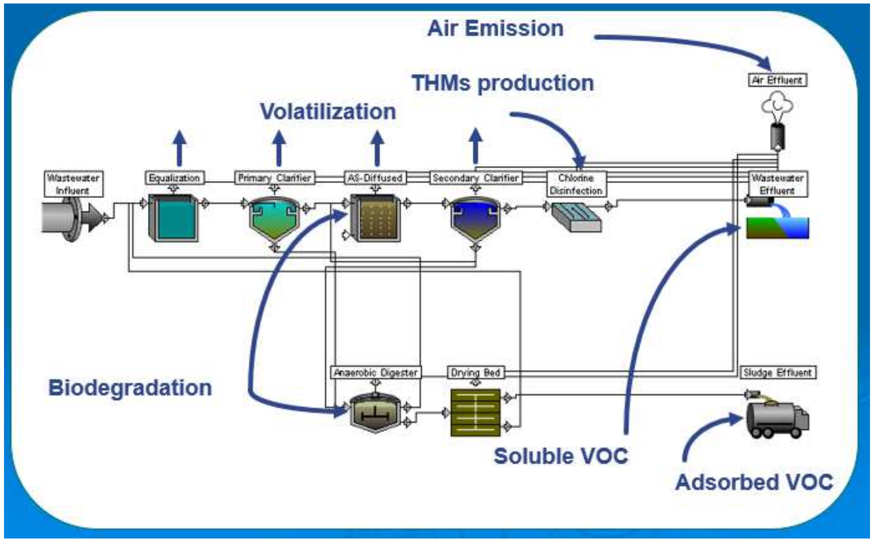




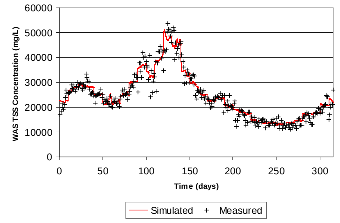
Modeling offers a robust, regulatory approved means of determining pollutant fate

TOXCHEM™ Contaminant Fate & Transport Model

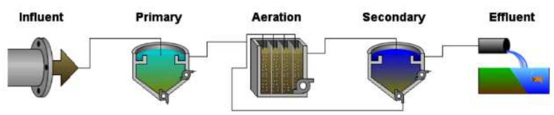
- Estimates fate and emission rates of organic compounds and metals from collection and treatment system components
- Used since 1991, +840 compounds & metals
- Specified in regulations (CAAA, SARA – 40 CFR, Part 63)
- Customizable (processes, compounds, parameters)
- Applications
    - Contaminant fate
    - Technology evaluation
    - Parameter estimation / validation



How Models are Used



Calibrate to Known Performance



$$\frac{\mathrm{d}x_\ell}{\mathrm{d}t} = \frac{\mu_\mathrm{m} S_\mathrm{e}}{K_\mathrm{s} + S_\mathrm{e}} x_\ell - k_\mathrm{d} x_\mathrm{l}$$

Create Model

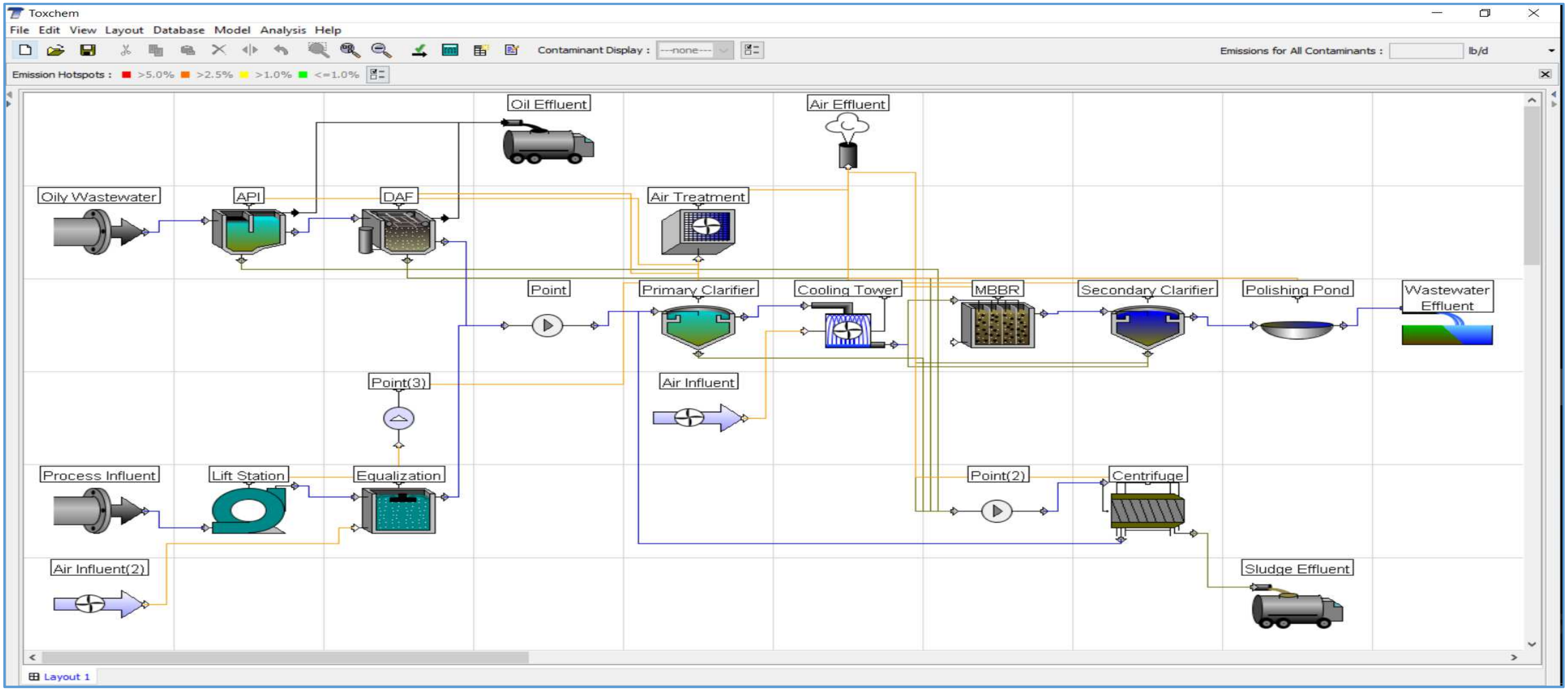
Generate Compliance Reports

- Hydraulic model
- Biological model
- Aeration model
- Equilibrium chemistry
- Transport
- Mechanical & Thermal effects

Sensitivity analyses

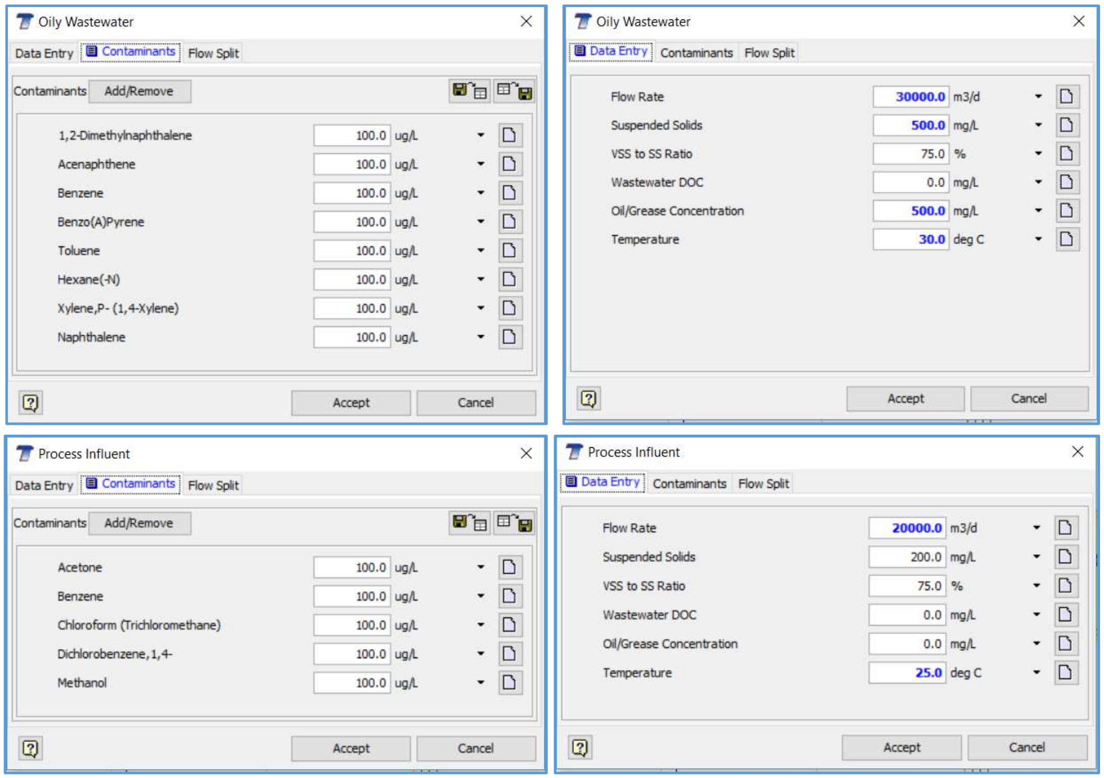
Compare, Evaluate & Troubleshoot

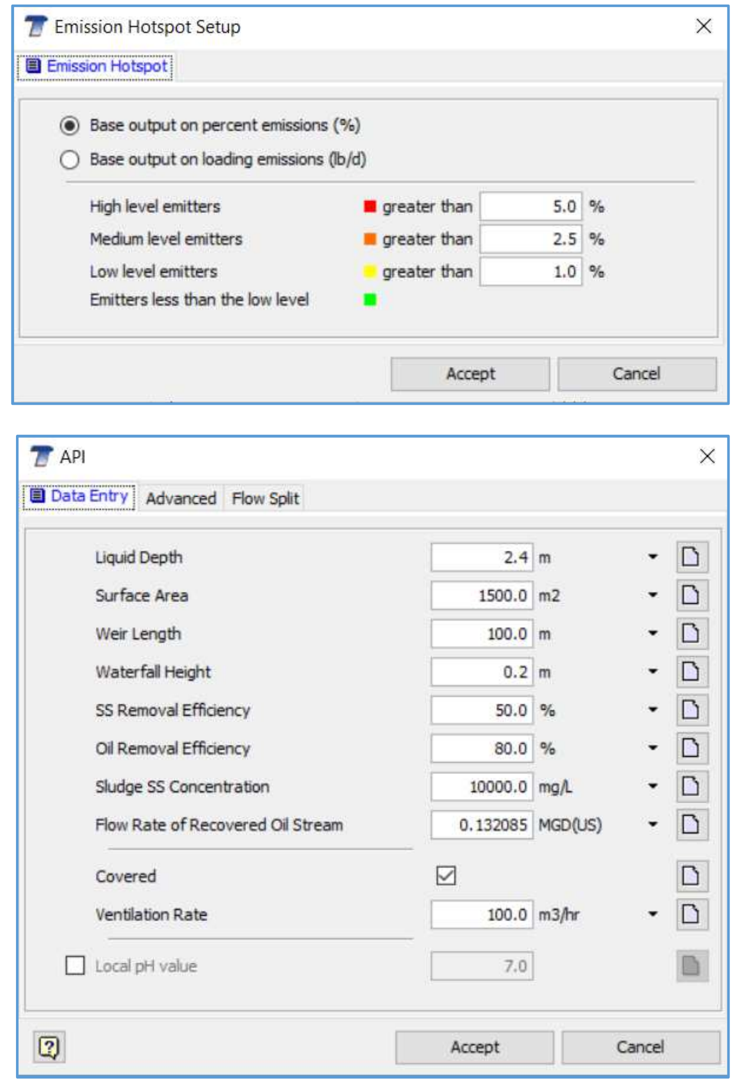
Characterizing Emissions With Toxchem



- Multiple influent streams
- 13 contaminants across both streams
- Several unique process treatment steps

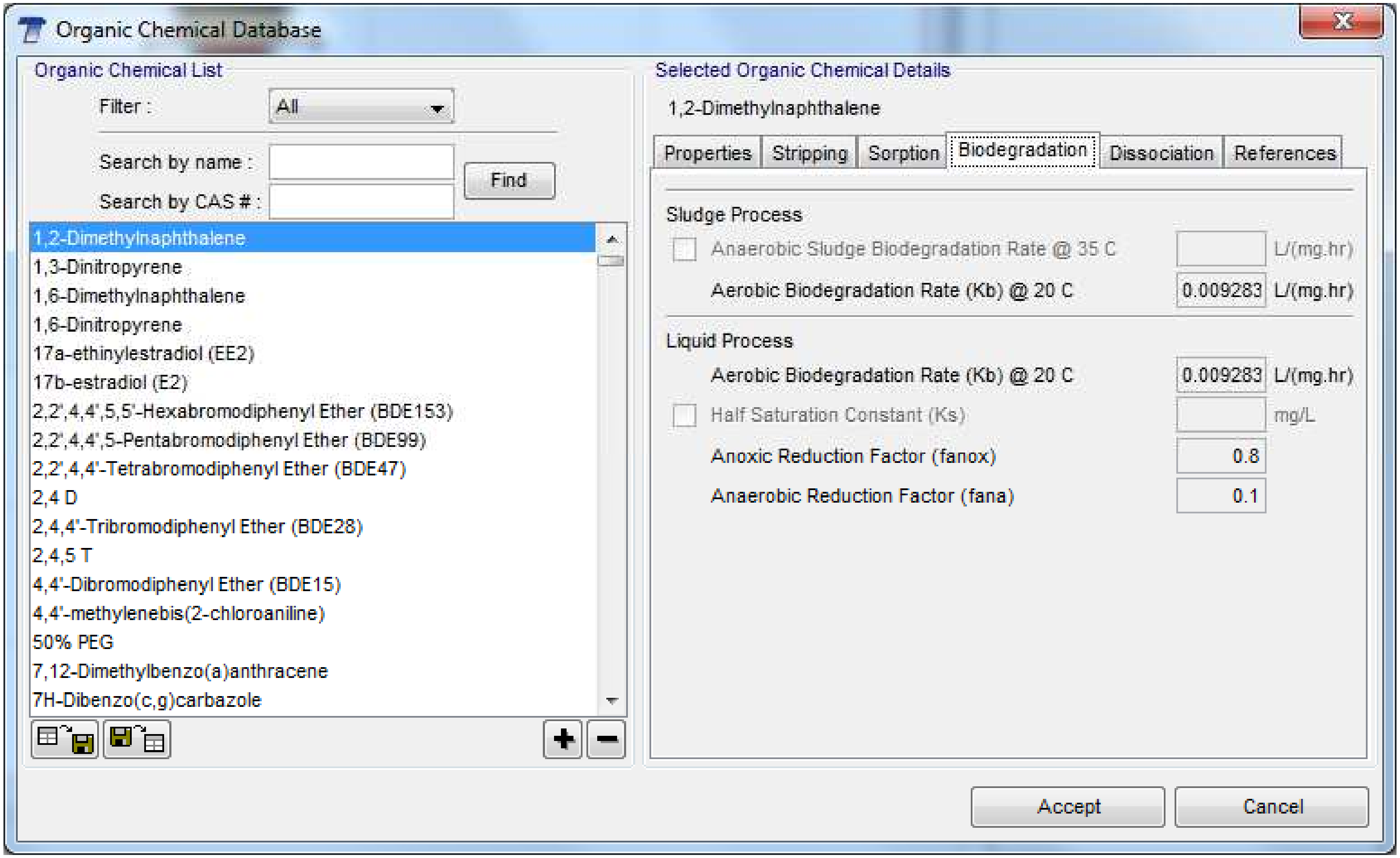
Characterizing Emissions With Toxchem

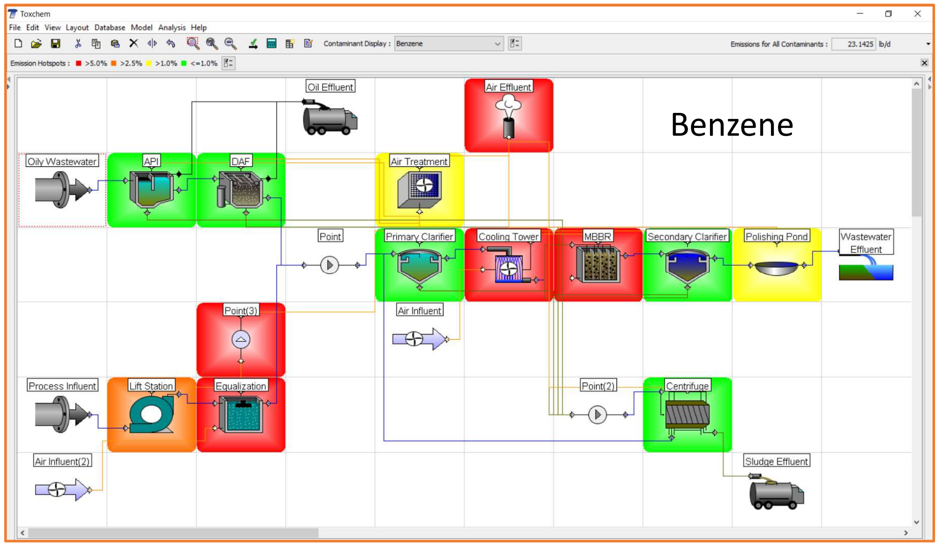


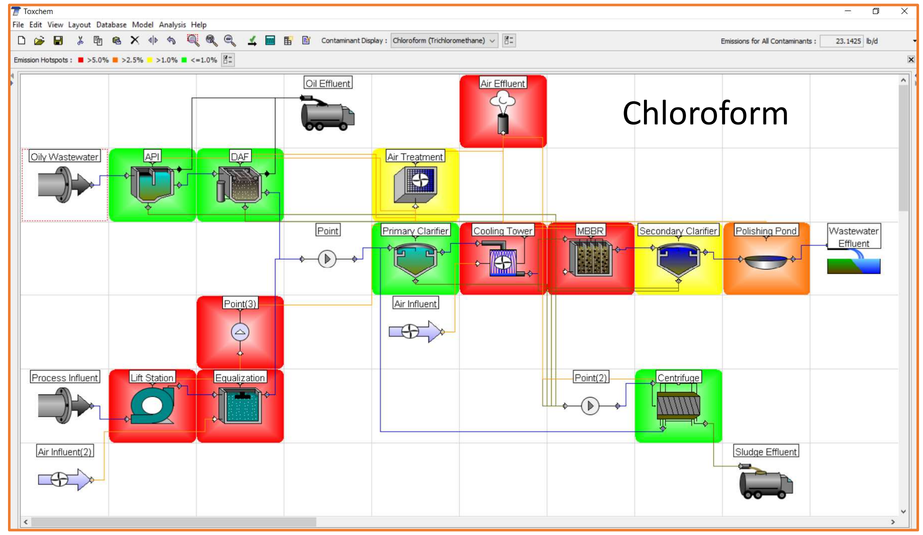


- Each unit process can be specified
- +840 chemicals and metals are available
- Custom data can be input as well

Database Details




Toxchem
Benzene
Oil Effluent
Air Effluent
Oily Wastewater
API
DAF
Air Treatment
Point
Primary Clarifier
Cooling Tower
MBBR
Secondary Clarifier
Polishing Pond
Wastewater Effluent
Point(3)
Air Influent
Process Influent
Lift Station
Equalization
Point(2)
Centrifuge
Air Influent(2)
Sludge Effluent


Toxchem
Chloroform
Oil Effluent
Air Effluent
Oily Wastewater
API
DAF
Air Treatment
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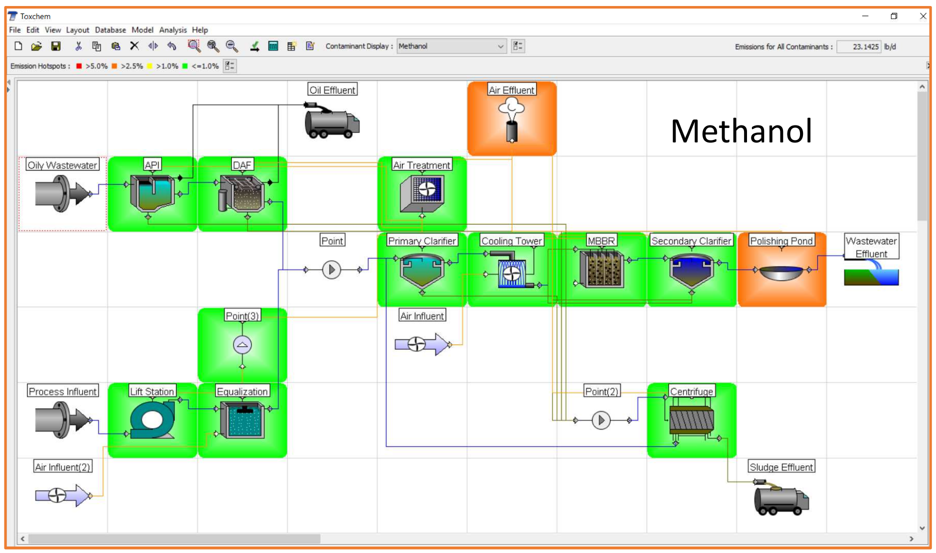
Toxchem
Methanol
Oil Effluent
Air Effluent
Oily Wastewater
API
DAF
Air Treatment
Point
Primary Clarifier
Cooling Tower
MBBR
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Polishing Pond
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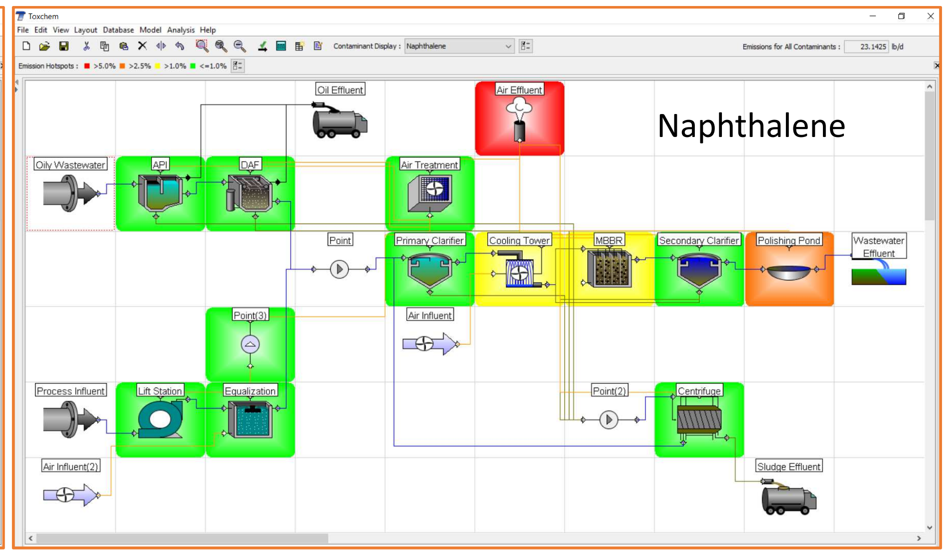
Toxchem
Naphthalene
Oil Effluent
Air Effluent
Oily Wastewater
API
DAF
Air Treatment
Point
Primary Clarifier
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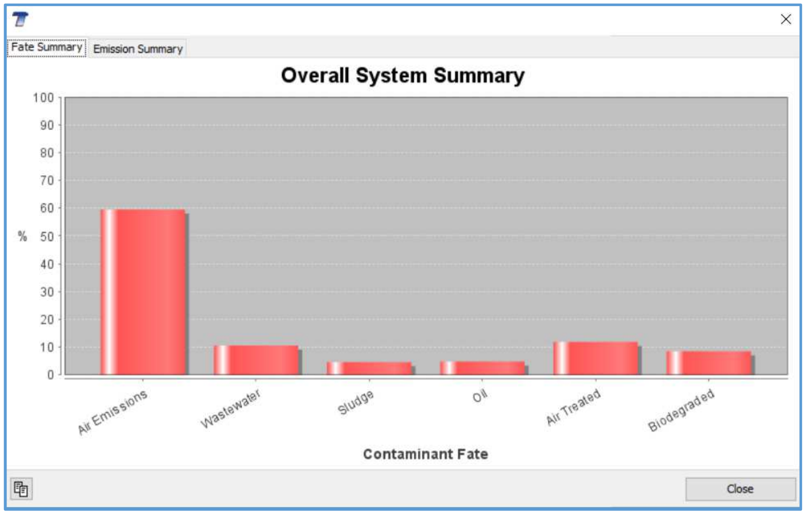
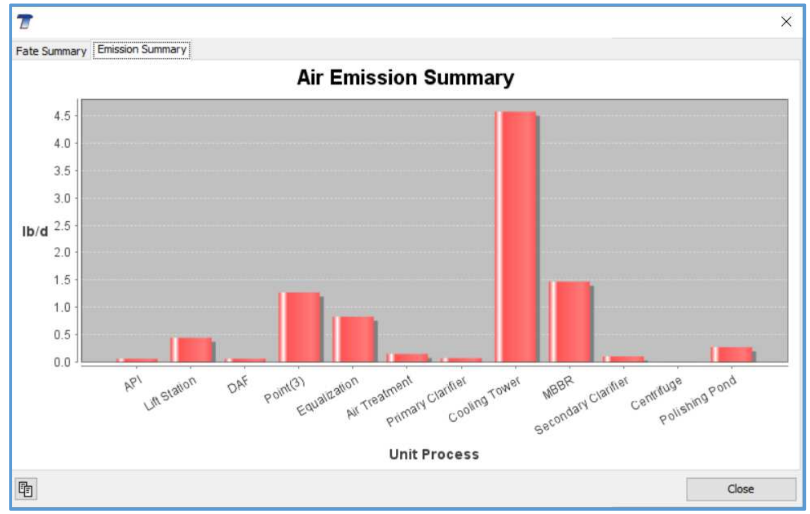
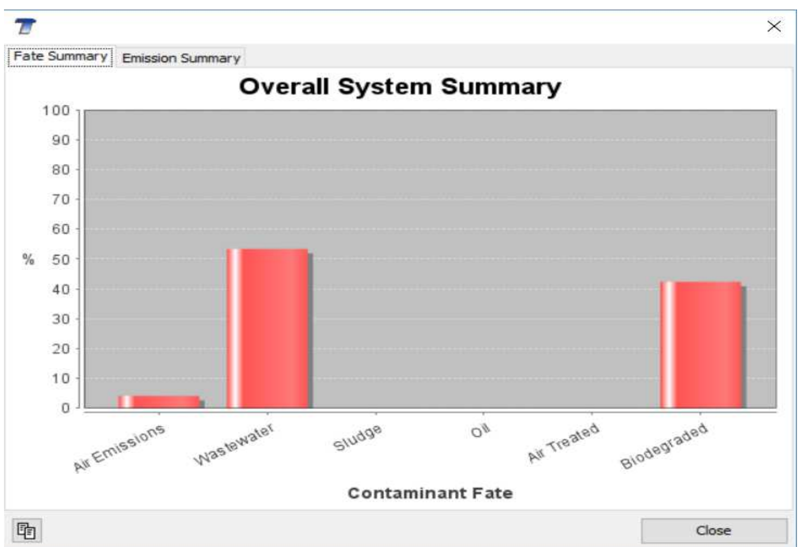
Characterizing contaminant Fate

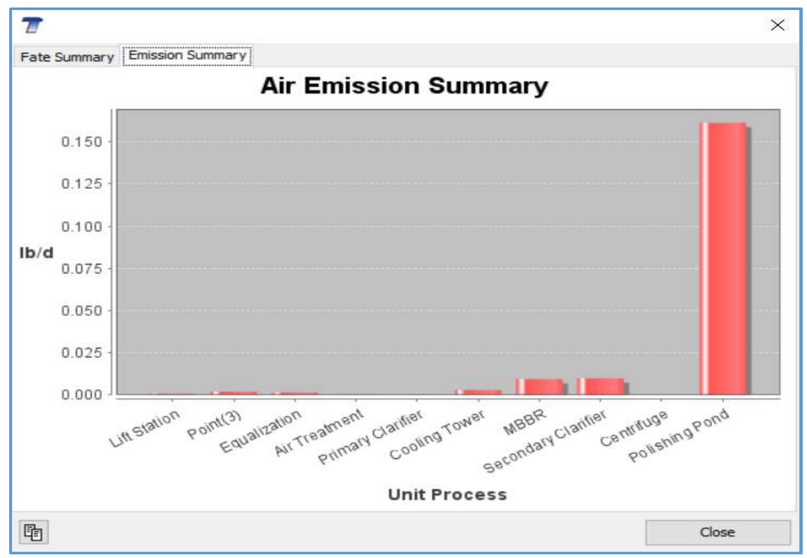
Benzene



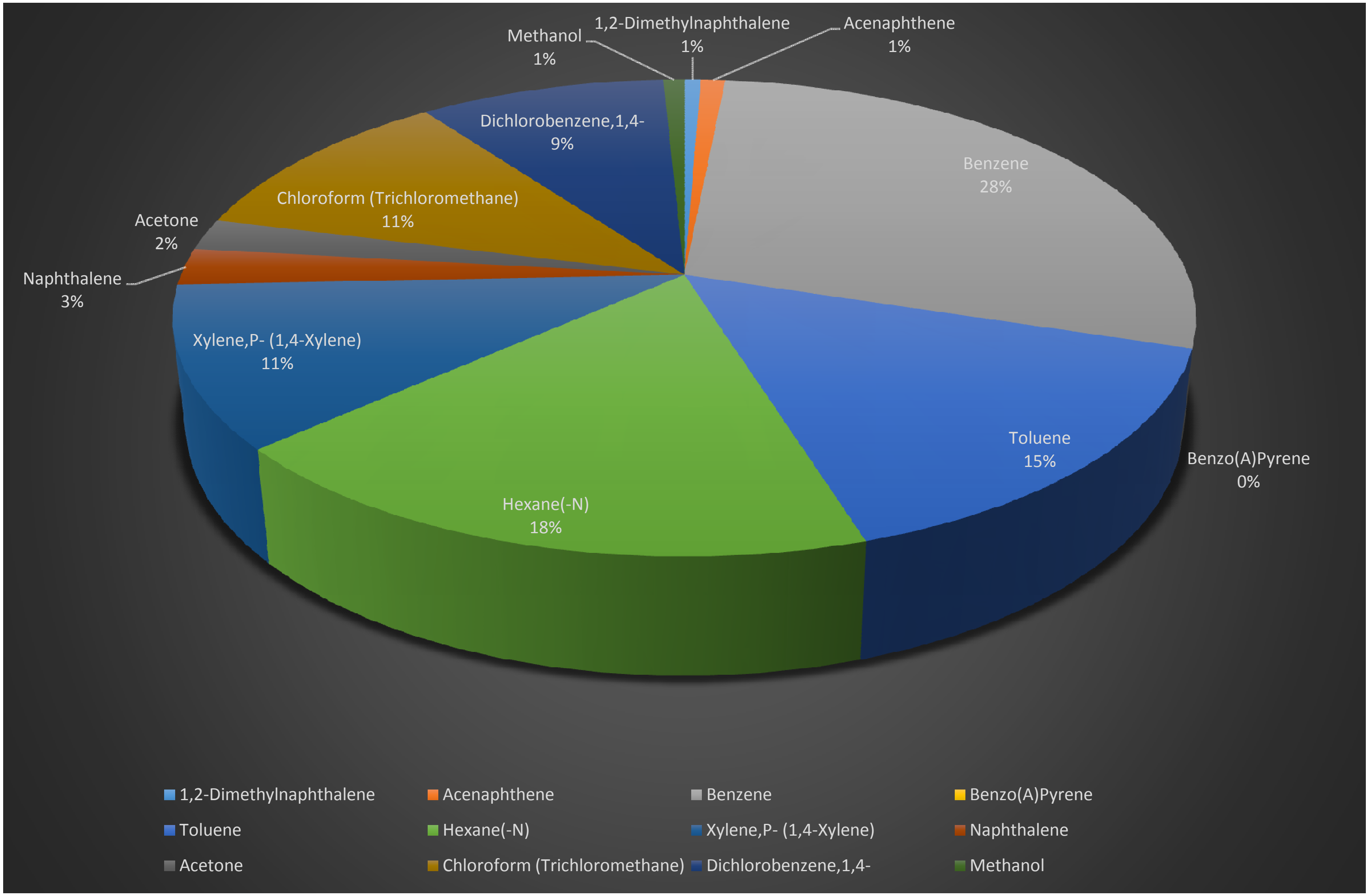


Methanol





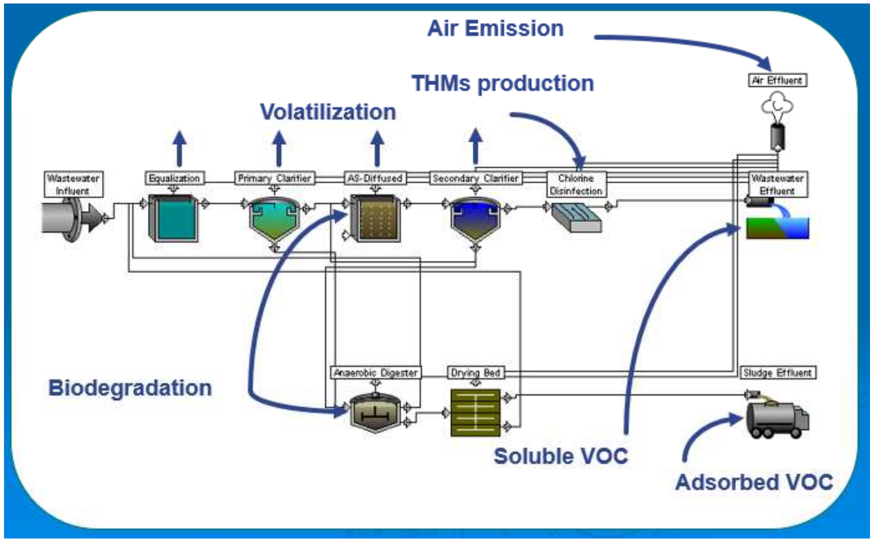
Total Air Emissions Summary



Relationship between Fate & Transport Models and Dispersion Models

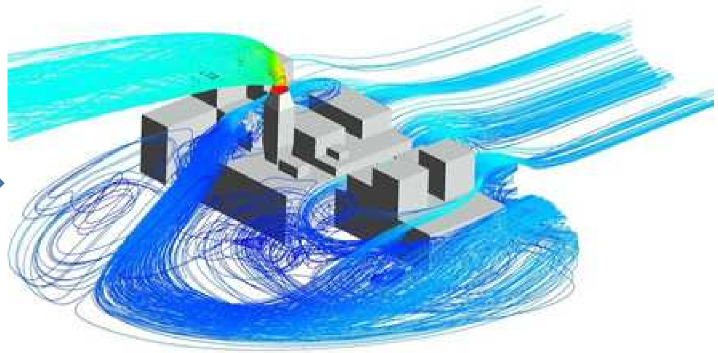
Fate & Transport models: What happens to Odor & air emissions in Conveyance systems and treatment Plant

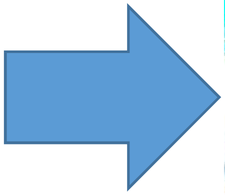
(Water 9, Toxchem™)



Dispersion Model: How far do the emissions carry?

(AERMOD, CALPUFF)





Most accurate Fate & Transport model

Conclusion

- Odors and VOCs are generated / released in the wastewater treatment process
- Process models offer a robust approach for characterizing emissions
  - Have regulatory approval (40 CFR Part 63)
  - Comprehensively cover all aspects of wastewater treatment
  - Can be calibrated to site specifics
- Additional benefits of modeling
  - Incorporate emission mitigation into process design
  - Enable sensitivity analyses
  - Troubleshooting – e.g., odor & emission sources & concentrations
  - Can be readily integrated with dispersion models

Questions

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Factors Affecting Air Emissions

- **Waste characteristics –** flow rate, temperature, chemical composition, others (suspended solids, oils)
- **Chemical compound properties –** Henry's coefficient (volatility), molecular weight, density, partition parameters. Biodegradation rates
- **Process unit parameters –** physical dimensions, process parameters, covered or open processes, air flow rates, aerator power input, sludge characteristics
- **Site & ambient conditions –** temperature, wind speed, elevation

Clean Air Act – 11 Titles

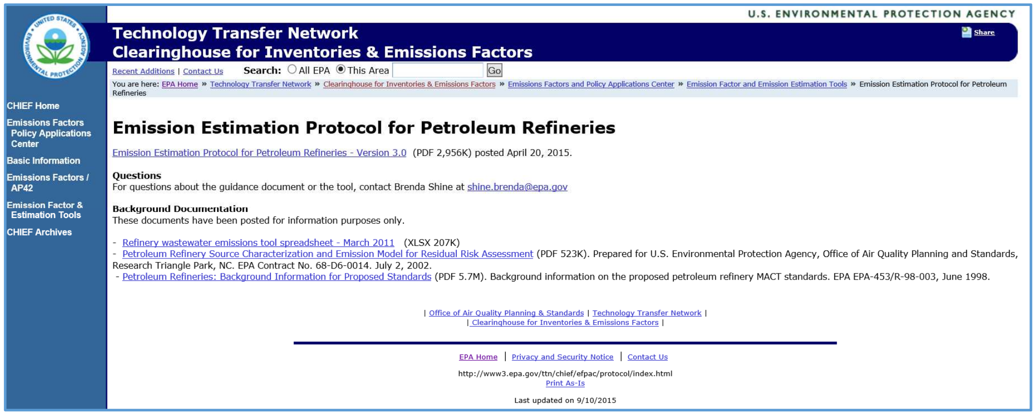
- Title I – attainment & maintenance of NAAQS*
- Title III – Air Toxics Control
- Title IV – Acid Rain Control
- Title V – Permits & Reporting
- Title VI – Stratospheric Ozone Protection
- Tile VII - Enforcement

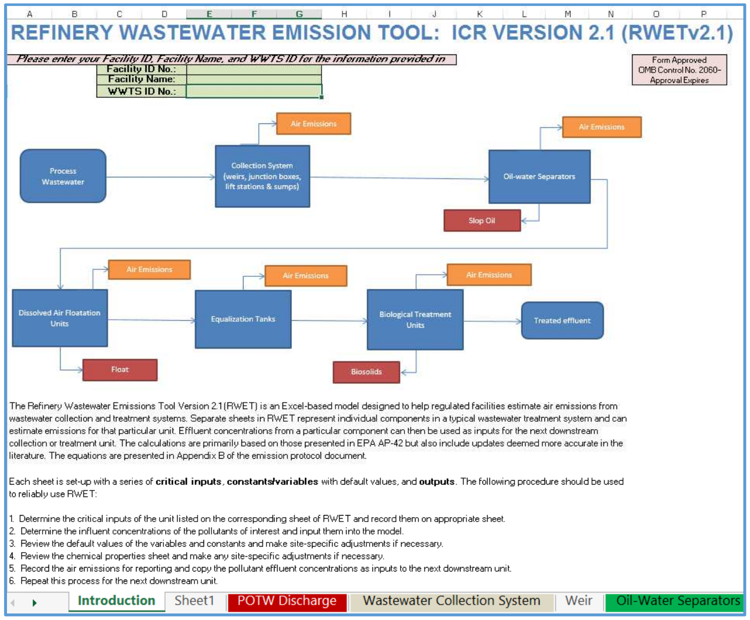
Regulated Air Pollutants

- Six criteria pollutants from 1963 CAA (SO, NOx, CO, Pb, O_3, Pm)
- VOCs
- NSPS – H_2S, Reduced Sulfur Compounds, total reduced sulfur, sulfuric acid mist, dioxin/furan, fluorides and HCl
- 188 Hazardous Air Pollutants (HAPs)

* NAAQS - National Ambient Air Quality Standards

Emission Factors





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http://www3.epa.gov/ttn/chief/efpac/protocol/index.html