Taste and Odor Control

California State University: Sacramento
Water Treatment Plant Operation

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Taste and Odor Classifications

- Objectionable Taste Classifications

Sweet | Sour | Bitter | Salty

- Objectionable Odor Classifications

Aromatic	Fishy	Grassy
Musty	Septic	Medicinal

- sMCL Odor = 3 TON (threshold odor number)
- sMCL Color = 15 color units
- sMCL pH = 6.5 - 8.5

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Taste and Odor Problems

- Consumer uses three senses to evaluate water
  - Sight (color)
  - Smell (odor)
  - Taste (objectionable)
- Leads to consumers purchasing bottled water or switching to alternative water supplies
- Loss of public confidence in water utility
- Funding restrictions
- Increased public relations problems
- Key to success is to prevent tastes and odors from every developing

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Common Causes of Tastes & Odors

- Geosmin
  - Natural byproduct of blue green algae and certain bacteria in the soil (Actinomycetes)
  - Associated with earthy odors in water
- 2-Methylisoborneol (MIB)
  - Natural byproduct of blue green algae and Actinomycetes
  - Imparts a musty odor to water
- Chlorine
  - Most common disinfectant and most common source of T&O
  - Complaints range from bleach to chlorinous and medicinal tastes and odors

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Common Causes of Tastes and Odors

- Chloramines
  - Made by combining ammonia and chlorine
  - Monochloramine – rarely causes T&O
  - Dichloramine – swimming pool or bleach odor detected at 0.9-1.3 mg/L
  - Trichloramine – geranium-like odor at 0.02 mg/L or higher
- Aldehydes
  - Caused by oxidation of amino acids and nitriles
  - Fruity odor in ozonated waters
- Phenols and Chlorophenols
  - Chlorine reacts with phenols to form chlorophenols
  - Pharmaceutical and medicinal tastes and odors most common

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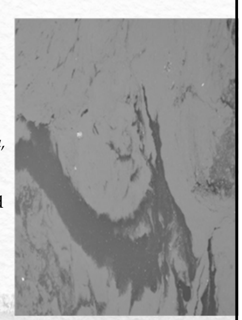
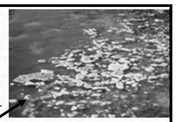
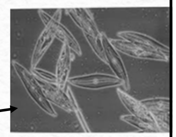
Natural Causes of Tastes and Odors – Biological Growth

- *Actinomycetes* – group of bacteria identified as sources of earthy-musty odor
  - Geosmin and MIB are byproducts
- Algae is a major cause of tastes and odors
  - Blue-green algae (*Cyanophyta*)
    - Most common odor producer
      - *Anabeana, Aphanizomenon, Oscillatoria, Microcystis*
      - Earthy-musty to septic
        - Dependent on species, density, and physiological state
    - Grow into blooms that float on top of water



Natural Causes of Tastes and Odors – Biological Growth


- Algae is a major cause of tastes and odors
  - Yellow-green algae (*Chrysophyceae*)
    - *Dinobryon, Mallomonas, Synura*
    - Large numbers not necessary to produce odors ranging from cucumbery to fishy
  - Diatoms (*Bacillariophyceae*)
    - *Asterionella, Cyclotella,* and *Tabellaria* produce fishy odors
    - *Melosira* & *Fragellaria* produce musty odors
  - Dinoflagellates (*Pyrrophyta*)
    - *Ceratium* & *Peridinium* produce rotten, septic, or fishy odors in large quantities

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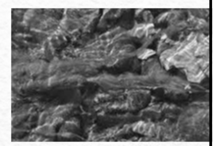
Natural Causes of Tastes and Odors – Biological Growth

- Planktonic algae and periphyton (attached algae) are significant sources of geosmin and MIB
- Sulfate-reducing bacteria are anaerobic bacteria that reduce sulfate to hydrogen sulfide
  - Results in rotten egg odor
  - Can occur in when bottom of stratified lake becomes anaerobic

Planktonic algae



Periphytonic algae

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Natural Causes of Tastes and Odors – Biological Growth

- As microbial populations grow and multiply, metabolic byproducts may deteriorate the T&O quality
  - Amount of byproduct produced is minimal (ng/L)
- As microbial population dies off, T&O issues increase due to natural decomposition

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Natural Causes of Tastes and Odors – Environmental Conditions

- Pollutants
  - Microorganisms that feed off the organic material (pollutants) cause oxygen depletion following nutrient enrichment from runoff
  - Increased nutrient concentrations allow for rapid microbial growth
    - Microbes consume dissolved oxygen in water faster than it can be replaced creating an oxygen-poor condition

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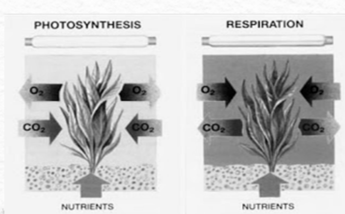
Natural Causes of Tastes and Odors – Environmental Conditions

- Blooms of photosynthetic algae can affect oxygen concentrations
    - Photosynthesis converts carbon dioxide and inorganic substances into oxygen using sunlight
    - Respiration consumes oxygen and produces carbon dioxide during the night



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Natural Causes of Tastes and Odors – Environmental Conditions

- Diurnal Dissolved Oxygen Cycle
  - Large algal blooms produce oxygen faster than it can escape during the day (photosynthesis)
    - The water then becomes supersaturated with oxygen especially during the afternoon hours
    - DO and temperature are inversely proportionate
  - At night, algae consume the oxygen faster than it can be replenished (respiration)
    - By early morning, nearly all dissolved oxygen has been consumed

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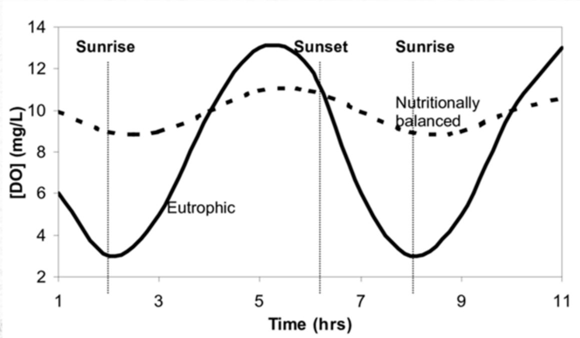
Diurnal Dissolved Oxygen Cycle



Human Causes of Tastes and Odors

- Municipal Wastewaters
  - Directly adds odoriferous compounds to water such as phenols and aromatic hydrocarbons
  - Adds nutrients that result in T&O causing algal blooms
  - Major source of nutrients that cause eutrophication
    - Phosphorus and nitrogen
- Industrial Wastes
  - NPDES – National Pollutant Discharge Elimination System permit designates pollutant discharge limits for those entities that discharge to Waters of the State
- Household Plumbing
  - Age and type of plumbing materials affect T&O

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Human Causes of Tastes and Odors

- Urban Runoff
  - Oils, grease, gasoline, and other residues are was local receiving waters from roadway storm drainage systems during first big rain after a dry period
    - If complaints slow down after storm, this may be the cause
    - Can contain nitrates
- Agricultural Wastes
  - Fertilizers, microbial contaminants (*Cryptosporidium* & *Giardia*), pesticides, and herbicides
  - High density animal feeding and dairy operations can lead to heavy nutrient loading of water
    - Discharges require NPDES permit

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Human Causes of Tastes and Odors

- Treatment Plant and Distribution System Conditions
  - Debris and sediments transported to the plant accumulate over a period of time
  - Taste and odor causing conditions can occur in a treatment plant that is not kept clean
  - Filamentous algae growth in basins can lead to geosmin and MIB production
  - If odors are detected in the finished water but not in the raw water, conduct a sensory profile of treatment plant to pinpoint location of algal growth
  - Distribution system flushing should be used to flush out accumulated debris in the mains to prevent bacterial growth leading to T&O

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Locating Taste and Odor Sources

- Raw Water Sources
  - Any part of system used to store, transport, or regulate untreated water can lead to taste and odor due to lack of chlorine residual
  - Sample locations should provide water that is representative
    - Outlet works of major reservoirs & regulating basins
    - Inlets and outlets of transmission channels & pipelines
    - Plant influent upstream from any chemical additions
  - Analyze for plankton levels and predominant type, turbidity, pH, taste threshold test, threshold odor number (TON), geosmin, and MIB
    - Different results between sampling points may be due to conditions contributing to the T&O problem

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Locating Taste and Odor Sources

- Treatment Plant
  - Visually inspect basin and filter walls, channels, and weirs for blue-green algae attaching to surfaces
    - *Oscillatoria* and *Phormidium*
    - Can produce geosmin and MIB
  - Yearly dewatering operations allow inspection and cleaning of suspected or potential problem facilities

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Locating Taste and Odor Sources

- Distribution System
  - Main causes of T&O are microbiological activity, disinfection residuals and their byproducts, organic or mineral compounds, external contaminants from cross connections
  - Dead ends, low-flow zones, and areas subject to variable flows may have higher T&O complaints
    - Flush frequently and keep records of customer complaints (5 years)
  - Cross connections must be prevented to minimize contamination due to backflows

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Taste and Odor Treatment

- Two Categories of T&O Treatment
  - Removed by coagulation/flocculation/sedimentation, degasification, and adsorption
  - Destruction by oxidation
- Coagulation/Flocculation/Sedimentation
  - Use jar tests to determine if coagulation dosage is effective
  - Chlorination of raw water may lead to increased odor levels
    - May produce chlororganics
  - Chlorination of settled water upstream of the filters may improve T&O

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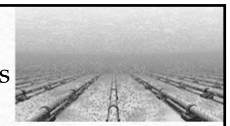
Aeration Processes and Systems

- Effective in removing volatile gases and compounds
  - Volatile – capable of being evaporated or changed to a vapor at low temperatures
  - Volatile compounds = objectionable odor
  - Non-volatile compounds = objectionable tastes
- Degasification removes volatile dissolved gases from water
- Oxidation (through aeration) is effective in removing inorganic compounds
  - Not effective in removing nonvolatile organic compounds

Aeration Processes & Systems



- Aeration Treatment Designs
  - Air into water – air is pumped into water flow
  - Water into air – water is distributed through the air
  - Air stripping – combines both methods
- Air Blowers
  - Compressors that supply air to water
  - Degasification accomplishes best gas transfer with very small bubbles
  - Compressor must be able supply very high pressures
  - Overall not very effective for T&O control

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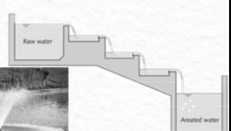
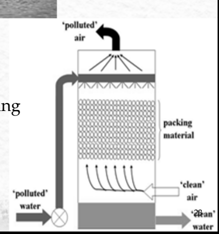
Aeration Processes and Systems

- Cascades
  - Termed waterfall devices
  - Series of concrete steps over which the water flows
- Spray Aerators
  - Spray water through air
  - Efficiency depends on air-to-water ratio
- Air Stripping
  - Water flows over a support medium (aka packing) contained in a tower while pumping air through the packing in the opposite direction





Oxidative Processes

- Chlorine
- Potassium Permanganate
- Ozone
- Chlorine Dioxide

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Oxidative Processes

- Chlorine
  - Treats many raw water issues
    - Fishy, grassy, or flowery odors
    - Iron and sulfide
  - Effectiveness depends on type of odor, problem severity, applied dosage, contact time
  - Superchlorination at the intake followed by dechlorination
    - Powdered or granular activated carbon
  - Chlorinating phenolic compounds will increase odors
    - Produces chlorophenolic compounds

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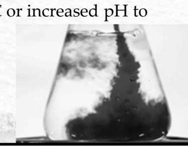
Oxidative Processes

- Potassium Permanganate
  - Strong chemical oxidizer able to destroy many organic compounds as well as oxidize iron, manganese, and sulfide
  - Permanganate ion is reduced changing colors from purple to yellow or brown forming manganese dioxide (MnO_2)
    - MnO_2 can then be settled or filtered out
    - Pink water should be absent on top of filter
  - Feed permanganate at intake to allow longer contact time and to allow operator to monitor feed rate
    - Overdose can be counteracted by PAC or increased pH to precipitate manganese



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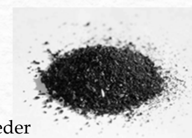
Oxidative Processes



- Potassium Permanganate
  - Dosage ranges from 0.1 to 5 mg/L
    - Typical dosage is 0.3 to 0.5 mg/L
  - Dry, crystalline product feed with dry feeder
  - Store in dry and well ventilated area to prevent caking and clogging of the feeder
  - Ventilation and PPE are a must to protect operators from dust and equipment from corrosion
  - Never store permanganate in same room as activated carbon
    - Both are highly flammable

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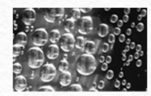
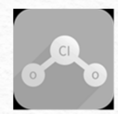
Oxidative Processes



- Ozone (O_3)
  - Must be generated onsite by passing dry air or oxygen through a high energy ozonator
  - Advantages over chlorine:
    - Stronger oxidant
    - Less objectionable byproducts produced (DBPs)



- Chlorine Dioxide (ClO_2)
  - Strongly oxidizing, unstable compound
  - Generated onsite using sodium chlorite and chlorine
  - Good for controlling phenolic tastes and odors and those caused by industrial pollution

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Adsorption Processes

- Adsorption – gathering of a gas, liquid, or dissolved substance on the surface of another material
  - Adsorbate: material being removed
  - Adsorbent: material responsible for removal
- Powdered activated carbon (PAC) and granular activated carbon (GAC) are primary adsorbents
  - Wood, coal, coconut shells, or bones activated using high temperature and high-pressure steam treatment
  - Activation significantly increases surface area by forming holes and crevices resulting in particles with a very porous structure
  - Phenol number or Iodine number indicates the adsorption capacity of the carbon
    - Higher number = greater adsorption capacity

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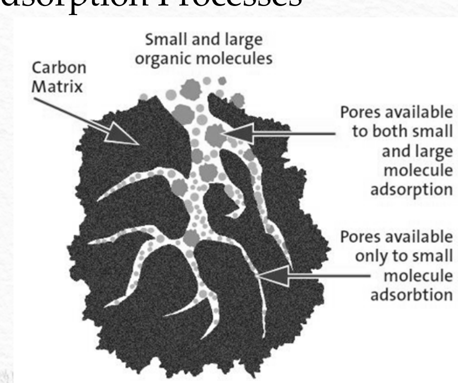
Adsorption Processes



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Adsorption Processes

- Powdered Activated Carbon
  - May be applied any point before filtration
  - Less effective after chlorination
    - Reaction neutralizes affect of carbon and chlorine
  - Thorough mixing and long contact time improves effectiveness
  - Feed Systems
    - Dry-type feeder – small scale applications if used only for short-term, occasional incidents
    - Slurry feeder – more common with larger facilities or those that use PAC regularly

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Adsorption Processes

- Powdered Activated Carbon
  - Feeder Systems
    - Carbon slurry tanks require constant mixing
    - Do not allow suction side of carbon intake to extend into drain sump in slurry tank
    - PAC is hydrophobic (dislikes water) so does not mix well with water
    - Fill PAC storage tank ¼ to 1/3 full of water before adding PAC
    - Operate tank mixers during loading
    - Load into hopper slowly enough to allow complete mixing and wetting of the carbon
      - Improper mixing can lead to cake formation on water surface

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Adsorption Processes

- Powdered Activated Carbon
  - Dose Determination
    - Use jar tests to determine necessary doses
      - Jar test trials should mimic plant conditions
    - Use TON test to determine dosage
      - Can indicate PAC alone is insufficient or if results don't change above a certain dosage
    - Olfactory fatigue – condition in which a person can no longer detect an odor after prolonged exposure
    - Feed equipment requires more maintenance, cleaning and inspections to ensure proper dosage
      - Valves and lines can easily become clogged with carbon leading to a decreased feed rate

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Adsorption Processes

- Powdered Activated Carbon
  - Filtration Considerations
    - Overfeeding can lead to caking on top of filters
      - Remedied by optimizing the settling process
        - This will increase physical removal of T&O components PAC can pass through filters
      - Determine carbon penetration by filtering 1 liter of filter effluent through membrane filter

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Adsorption Processes

- Powdered Activated Carbon
  - Handling
    - Dust collectors must be clean and functional at the start of any loading operations
    - Operators must wear PPE during loading: goggles, dust masks, and gloves at the very minimum
    - PAC tanks are confined spaces
      - Powdered carbon will active remove oxygen from the air
    - Store bags of PAC off the floor
      - Carbon is combustible but will smoke be produced
      - Do not stack bags more than 3 or 4 high
      - Do not store near potassium permanganate or HTH

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Granular Activated Carbon

- Made up of larger particles than PAC
- Placed in a stationary bed instead of fed as a slurry
- 2 considerations that make carbon contactors different than conventional filters
  - Empty Bed Contact Time (EBCT)
    - Time that the water is actually in media bed
    - EBCT must be long enough to provide adequate contact time as the water is filtered
  - Regeneration interval of the carbon
    - Varies with type of material being removed and volume of water treated
    - Accomplished same way as initial activation

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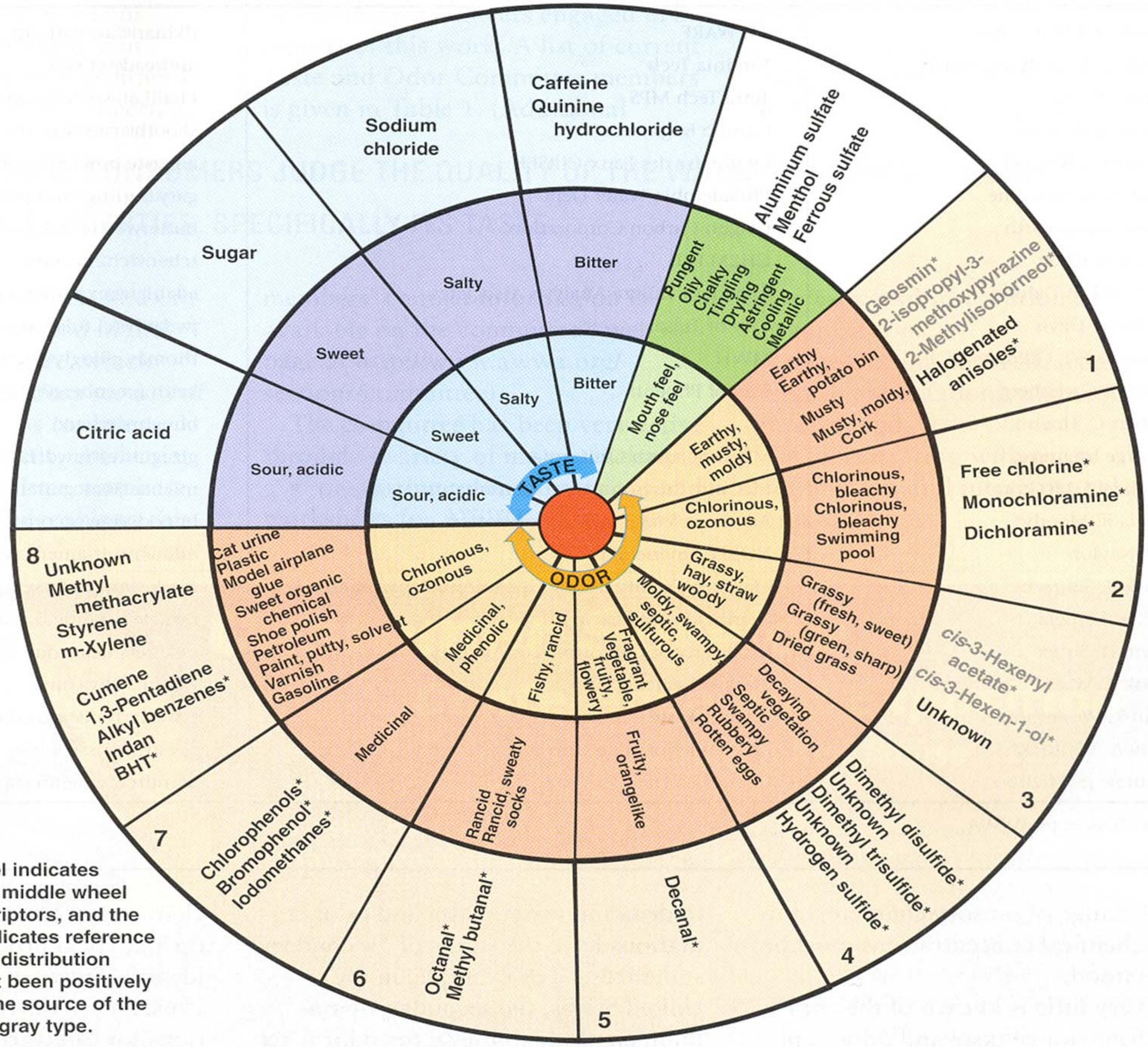
Examples of Customer Complaints

Customer Complaint	Possible Cause
Red water or reddish-brown staining of fixtures and laundry	Corrosion of iron pipes or presence of natural iron in raw water
Bluish stains on fixtures	Corrosion of copper lines
Black water	Sulfide corrosion of copper or iron lines or precipitations of natural manganese
Foul tastes and/or odors	Byproducts from microbial activity
Loss of Pressure	Excessive scaling, tubercule (buildup from pitting corrosion), leak in system from pitting or other type of corrosion
Lack of hot water	Buildup of mineral deposits in hot water system (can be reduced by setting thermostats to under 140°F [60°C])
Short service life of household plumbing	Rapid deterioration of pipes from pitting or other types of corrosion

FIGURE 1 Wheel identifying distribution system–generated tastes and odors

TDEC - Fleming Training Center



The inner wheel indicates categories, the middle wheel indicates descriptors, and the outer wheel indicates reference standards. The distribution system has not been positively confirmed as the source of the compounds in gray type.

***Presence confirmed in water**

Source: D. Khiari et al, 2002. *Distribution Generated Taste-and-Odor Phenomena.* AwwaRF Report, AWWA Bookstore catalog no. 90897. AWWA, Denver.