Taste and Odor Control Problems

- Taste and odors in drinking water is a common problem faced by the operator
- Consumer evaluates water on three senses: sight, smell, and taste
- Effects of taste and odor problems
  - Complaints by customers
  - Consumer may switch to unsafe water
  - Loss of confidence in utility to produce a safe water

Secret to successful taste and odor control is to PREVENT TASTES AND ODORS FROM EVER DEVELOPING

Causes of Tastes and Odors

Can be the result of natural or manmade conditions that exist within the total water supply system
- Raw water sources
- Conveyance facilities
- Treatment plants
- Chlorination stations
- Finished storage facilities
- Distribution systems
- Consumer plumbing
Types of Pollutant Sources

- Municipal wastewaters
- Domestic wastes
- Industrial discharges (requires NPDES permit)
- Chemical spills (primary concern is health related effects)
- Urban runoff
- Agricultural wastes
- Irrigation runoff
- Distribution system maintenance
- Consumer plumbing

Note: If taste and odor problems and organic loadings are controlled, the need for activated carbon treatment at the plant may be reduced or eliminated.

What is the first step in determining the cause of taste and odor problems in a water system?

a. Flush the system
b. Change the coagulant dosage
c. Do a taste test
d. Locate where in the system the problem is originating

Environmental Conditions

- Organisms (bacteria, algae, diatoms, or fungi) that grow in water or in the sediments of lakes, reservoirs, and rivers are significant contributors to tastes and odors.
- If organic matter decays when there is no oxygen present (anaerobic conditions) undesirable tastes and odors are produced.
  - When sulfate is reduced to sulfide in the anaerobic bottom sediments of a lake or reservoir the result can be a strong odor of rotten eggs.
- The diurnal variation in dissolved oxygen concentrations may have significant effect on taste and odor.
**Diurnal Variation in Dissolved Oxygen Concentrations**

- Large populations of algae can produce oxygen faster than it can escape to the atmosphere.
- Oxygen depletion during the night may result in fish kills and die-off of aquatic organisms and vegetation which will produce foul tastes and odors.

**Importance of Diurnal Oxygen Fluctuations**

- Significantly different conditions can and do exist from day to night.
- Oxygen depletion at night may result in fish kills and die-off of aquatic organisms and vegetation which will produce foul tastes and odors.
- During darkness anaerobic organisms may become established and contribute to the aesthetic qualities of the water.

**Operations Impact**

- Significant dissolved oxygen fluctuations caused by algae in raw water will also be accompanied by changes in the pH:
  - During daylight hours when algae produces oxygen, carbon dioxide (CO₂) is removed and the pH will increase.
  - At night during the respiration process, algae will consume oxygen and release carbon dioxide which will lower the pH.
  - These changes will influence the chemical doses required to effectively treat the water.
- Tastes and odors caused by algae are best removed through improved coagulation and sedimentation:
  - Allows longer filter runs.
  - If chlorine is used upstream of filtration it will reduce the reaction of chlorine on algae cells that would be released cellular materials into the water.
Taste and Odor Control by Aeration

- Effective in removing gases and organic compounds which are relatively volatile, this is known as DEGASIFICATION.
- Can also destroy some compounds by OXIDATION, such as ferrous iron and manganous manganese.
- Aeration may also reduce the chemical dosage needed.

Taste and Odor Control Through Adsorption

- Adsorption is the process of removing materials from water by adding a material to the water to which taste-and-odor-producing compounds will attach themselves.
  - Addition of powdered activated carbon; usually at the influent.
  - Use of granular activated carbon as a filter medium.

Iron and Manganese Problems

- Dissolved ferrous iron (Fe^{2+}) gives water a disagreeable taste and will encourage the growth of iron bacteria in the water distribution system.
- Iron combined with tea, coffee and other beverages, produces an inky, black appearance and a harsh, unacceptable taste.
- Vegetables cooked in water containing excessive iron turn dark and look unappealing.
- Concentrations of iron as low as 0.3 mg/l will leave reddish brown stains on fixtures, tableware and laundry that are very hard to remove.
- Precipitates will form in the distribution system.
- When these deposits break loose from water piping, rusty water will flow through the faucet.
Forms of Iron Found in Water Treatment

- Soluble Iron or Clear Water Iron (Fe\(^{2+}\))
- Precipitant Iron or Red Water Iron (Rust, Fe\(^{3+}\), settles out)
- Organically Bound Iron Soluble Iron
- Iron Bacteria (Slime or biogrowth)

Iron and Manganese Facts

<table>
<thead>
<tr>
<th>Regulated SMCL</th>
<th>Problem Types</th>
</tr>
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<tbody>
<tr>
<td>Iron &lt; 0.30 mg/l</td>
<td>Red Water</td>
</tr>
<tr>
<td>Manganese &lt; 0.05 mg/l</td>
<td>Black Particles</td>
</tr>
</tbody>
</table>

- Weathering processes release the elements into waters.
- Iron dissolved by reaction with CO\(_2\). Reduces insoluble iron (Fe\(^{3+}\)) & Manganese (Mn\(^{3+}\)) to soluble Fe\(^{2+}\) & Mn\(^{2+}\) only under anaerobic conditions.
- Ground waters that contain Iron and Manganese are devoid of Oxygen otherwise they would settle out.
- When exposed to O\(_2\), precipitants forms insoluble hydroxides in water.
- Visible as red and brown color. Will stain fixtures and clothes. Imparts taste and odor to water.

Iron Bacteria in Water Supply System

- Iron and manganese are most frequently found in water systems supplied by wells and springs.
- Iron and manganese react with oxygen to promote the growth of iron bacteria.
- These bacteria form thick slime growths on the walls of the piping system and on well screens.
- The growth can be controlled by chlorination.
Iron and Manganese Control

- Alternate source
- Ion exchange
- Oxidation
- Phosphate treatment
- Lime softening

Soluble Iron (Fe^{+2}) and Manganese (Mn^{+2}) Can be Removed by Aeration

- Water with Fe + Mn > 0.3 PPM will have disagreeable taste and odor.
- Removal of Fe/Mn by aeration is dependent on pH, contact time, temperature and presence of organic material.
- By maintaining pH above 7, contact time can be significantly reduced.
- pH can be adjusted by adding lime (increases pH and speeds oxidation).
- It will be necessary to periodically chlorinate the aeration system to control slime growths.

What effect does pH have on the reaction? Accelerates it

Plot of pH vs. Time for Iron Removal at 90% Efficiency (min 30 minutes detention)
Treatment Methods to Remove Iron and Manganese

Comparison of Oxidants Required to Oxidize 1mg/l of Ferrous Iron or Manganous Manganese

<table>
<thead>
<tr>
<th>Oxidant</th>
<th>Iron</th>
<th>Manganese</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oxygen</td>
<td>0.14</td>
<td>0.29</td>
</tr>
<tr>
<td>Chlorine</td>
<td>0.62</td>
<td>1.30</td>
</tr>
<tr>
<td>Chlorine Dioxide</td>
<td>1.21</td>
<td>2.45</td>
</tr>
<tr>
<td>Ozone</td>
<td>0.86</td>
<td>0.87</td>
</tr>
<tr>
<td>Potassium Permanganate</td>
<td>0.93</td>
<td>1.92</td>
</tr>
</tbody>
</table>

Aeration Processes

- Aeration works in two different ways to remove the undesirable compounds from the water, oxidation and volatilization (degasification.)
- Volatilization removes undesirable gases such as Hydrogen Sulfide or Carbon Dioxide by forcing them to escape into the air.
- Removal of iron and manganese is accomplished by chemical oxidation. Once oxidized, these new compounds can be removed by sedimentation or filtration.
- Aeration also facilitates the oxidation reaction by removing CO2 which raises pH.

Schematic of Typical Fe Removal Aeration System

- Add lime to increase pH
- Aerator: Removes CO2, H2S and increase pH
- Oxidant:
- Fe and Mn removal by filtration
Results of Aeration

- Taste and odors caused by Fe, Mn, H₂S, and any volatile compounds are removed.
- Reduces corrosive constituents, i.e. CO₂ (to 5 ppm) and H₂S.
- Supersaturated water is corrosive and stability must be adjusted.
- Aeration will not remove tastes and odors caused by organic sources such as algae.

Types of Aeration Systems

- Water into Air. This method produces small drops of water that fall through the air.
- Air into Water. This method creates small bubbles of air that rise through the water being aerated. (less common in small systems).

Cascade Tray Aerator

- Termined to be a waterfall device; passes water through the air.
- Even distribution of water over top tray.
- Loading Rates of 1 to 5 GPM for each sqft. of tray area.
- Trays 1/8” openings perforated bottoms.
- Protect from insects with 24 mesh screen.
- May encourage biological growths which may cause taste and odor problems.
- Evaporation losses are a disadvantage.
Forced Draft Aeration System (Air Stripping)
- Combines elements of both air blowers and waterfall devices
- Includes weatherproof blower in housing
- Counter air through aerator column
- Includes 24 mesh screened downturned inlet/outlet
- Discharges over 5 or more trays

Packed Tower Odor Removal System
- Uses Henry’s Law constants for mass transfer
- Usually requires pilot testing
- Used to Remove VOCs below MCL
- Col to Packing > 7:1 ratio
- Air to water at pk > 25:1 with max 80:1
- Susceptible to Fouling from CaCO₃ > 40 PPM

Protection of Aerations Systems from Insect, Vermin and Slime
- Growth of Insects
- Contamination from Bird Droppings
- Contamination from Animals
- Growth of Slime
Chemical Oxidation of Fe and Mn Using Chlorine

- The main advantage of chlorine over aeration is the requirement for much shorter reaction times.
- Chlorine is frequently used instead of aeration when iron concentrations exceed 5 PPM.
- When levels of iron and manganese exceed 5 PPM, sedimentation may also be necessary prior to filtration.
- The higher the amount of chlorine fed, the more rapid the reaction.
- After filtration, water may need to be dechlorinated by addition of sodium bisulfide or sulfur dioxide to prevent TTHMs.
- Chlorine residual concentration after a contact tank should never be allowed to drop below 0.5 PPM.
- The Chlorine concentration that is most effective is determined by the use of a jar test.

Clarification Requirements for Iron and Manganese

- Oxidized particles must be removed.
- Anthracite filters are frequently employed.
- With high Fe/Mn concentrations in source water (> 6 PPM) a clarifier may be necessary.

Use of Potassium Permanganate

- Oxidizes iron and manganese to insoluble oxides.
- Sulfides and color are also removed.
- Potassium permanganate is added upstream of filters.
- Permanganate is a reactive, fast-acting oxidizer.
- Dose must be exact.
- Too little will not oxidize the manganese in the water.
- Too large a dose will allow permanganate to enter the system and may produce a pink color in the water.
- Bench scale tests required to determine the proper dosage.
- It is a poor disinfectant.
Filter Considerations Using Permanganate

- Filtration is used as the final step in Fe and Mn treatment.
- Gravity and pressure filters are typically used.
- The normally-used filter media will work if the combined concentration is below 1 ppm.
- Higher concentrations require different type of filter materials and different methods of operation.
  - Use of manganese greensand filter.
  - Charged with potassium permanganate after the backwashing process.
  - This method allows the oxidation process to be completed in the filter.

Stabilization of Iron and Manganese using Phosphates

- Phosphates are used to keep Fe and Mn in a dissolved state. The effect is called sequestration.
- Reduces the layer of scale that forms on the pipe.
- Very small quantity are required to inhibit precipitation in water distribution lines.
- Sequestering agents bind with the mineral (Fe, Mn, Ca, Mg) to keep them in suspension. This prohibits (delays) them from falling out and causing buildup, stains, discoloration, etc.
- At high mineral levels, the agents are not very effective. With long detention times in your storage, they are also not very effective.
- Testing should be performed to determine if they work.

Some Benefits Attributed to Phosphate Addition

- Control of Iron and Manganese Color and Staining
- Scale Reduction
- Corrosion Inhibition
- Hydrogen Sulfide Oxidation
- Chlorine Demand Reduction
- Bacterial (MPN) Reduction
- Disinfectant By-Product Reduction
- Increased Life of Iron Pipelines
- Increased Life of Water Heating Elements
- Improved Taste of Water
- Water Color Enhancement
Considerations in the Use of Polyphosphates for Sequestering

- Polyphosphates are effective for low concentrations of iron and manganese
- Polyphosphate sequestering agents can start to degrade to orthophosphate after about 2 days
- Polyphosphate sequestering does not work under stagnant conditions (slow moving water or dead end conditions)
- Over feeding Polyphosphate can contribute phosphorus as a nutrient that favors the growth of slime bacteria

Considerations in the Use of Polyphosphates for Sequestering (cont.)

- The Polyphosphate, Hexametaphosphate is commonly used for Sequestering Soluble Iron and Manganese
- Large doses (>5 mg/l) will soften rust deposits in pipelines which are transported into homes
- Proper dose is to keep soluble iron and/or manganese tied up for 4 days so deposits won’t build up on the pipe walls
- Chlorine usually must be fed along with the polyphosphate to prevent the growth of iron bacteria

Use of Orthophosphates for Sequestering

- Orthophosphate is used to sequester iron ions at pipe surfaces
- The sequestering forms a protective coating that prevents further iron migration
- Ortho/Poly Blends provide both sequestering of soluble iron and manganese movement from pipelines under corrosive conditions
DEP Limitations in Sequestering Iron and Manganese

- Sequestering with polyphosphates may be used when the combination of (Fe + Mn) < 1 mg/l.
- Polyphosphate may not exceed 10 mg/l.
- Sequestering with sodium silicates may be used when the combination of (Fe + Mn) < 2 mg/l.
- Sodium Silicate can not exceed 20 mg/l.
- Sodium Silicate is applicable prior to air contact only!

Taste and Odor from Hydrogen Sulfide

- Not uncommon in Florida well waters.
- Typical concentrations not a health risk but do affect the taste of water; Detected in concentrations as low as 0.05 mg/l.
- Presence of sulfate-reducing bacteria causes rotten egg odor of hydrogen sulfide.
- Free hydrogen sulfide (H₂S) can react with water forming sulfuric acid (H₂SO₄) which is extremely corrosive to metals.
- Removed by aeration, greensand, potassium permanganate, and chlorination.

Hydrogen Sulfide Solubility

- Concentration vs pH graph showing solubility of H₂S, HS⁻, and S²⁻ at various pH levels.
**Hydrogen Sulfide Removal Techniques (DEP)**

<table>
<thead>
<tr>
<th>Sulfide (mg/l)</th>
<th>Recommended Treatment Process</th>
<th>Achievable Range of Removal</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;0.3</td>
<td>Direct Chlorination</td>
<td>100%</td>
</tr>
<tr>
<td>&gt;0.3</td>
<td>Direct Chlorination (requires filtration)</td>
<td>100%</td>
</tr>
<tr>
<td>0.3 to 0.6</td>
<td>Conventional Aeration</td>
<td>50%</td>
</tr>
<tr>
<td>0.6 to 3.0</td>
<td>Forced Draft Aeration</td>
<td>90%</td>
</tr>
<tr>
<td>&gt;3.0</td>
<td>Packed Tower Aeration</td>
<td>&gt;90%</td>
</tr>
</tbody>
</table>

**Distribution System Maintenance**

- Flushing alone does not provide an adequate level of protection against tastes and odors in a distribution system.
- Routine collection of samples for tastes and odor tests can provide an early warning of quality deterioration.
- The location of flushing stations and the frequency at which they are flushed is determined from records of complaints and water quality tests. Records can be used to:
  - evaluate the effectiveness of these spot flushing's
  - the frequency of flushing
  - the need to add or rotate stations during the year.

**Determining if Dissolved Iron is Present**

- Draw a sample from the well and allow it to stand for 30 minutes.
- Water should be clear and colorless turning to a slight yellow haze color after contact with air.
- If allowed to stand it will finally form a yellowish brown color.
- If aerated and allowed to stand it will form reddish brown deposits in bottom of container.