CHAPTER: 1
Quality of untreated water and wastewater

Treatment methods for water and wastewater

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Treatment Methods
For Water and Wastewater

Physical Unit Operations
Chemical Unit Operations (Processes)
Biological Unit Processes
Physical Unit Operations

Treatment operations in which the treatment is brought through the application of physical forces.

Examples:
- Screening
- Communion
- Aeration
- Mixing chemicals and gases with water
- Flocculation
- Gravity sedimentation
- Filtration
- Adsorption
- Gas Stripping
- Membrane processes (e.g. Reverse osmosis, electrodialysis, ultrafiltration)
Chemical Unit Operations (Processes)

Treatment operations (processes) in which the treatment of contaminants is brought by the addition of chemicals or by chemical reactions.

Examples:

- Chemical precipitation
- Coagulation
- Disinfection
- Ion exchange
Biological Unit Processes

Treatment processes in which the treatment of contaminants is brought by biological means.

Examples:

- Aerobic processes
- Anaerobic processes
- Anoxic processes
Water Sources

**Surface Water Sources**
- Streams
- Lakes
- Impounding
- Reservoirs

**Ground Water Sources**
- Wells
- Galleries
- Spring Water

**Saline Water**
- Sea Water

**Brackish Water**
Well water high in TDS as a result of salt water intrusion
A) Surface Water Sources
(Streams, lakes, impounding reservoirs)

Streams or rivers

→ Rapid changes in water quality

→ Changes in turbidity and other constituents during heavy rains and run off

→ Require flexible and reliable treatment processes
Lakes and impounding reservoirs

→ Seasonal changes in water quality

*Thermal stratification*
Thermal Stratification

Heat transfer in reservoirs and lakes is controlled by a phenomenon known as **THERMAL STRATIFICATION**.

Thermal stratification $\rightarrow$ Changes in the temperature profile with depth within a lake system.

Ref: http://faculty.gvsu.edu/videticp/stratification.htm
Figure 3-3  Changes in the density of (a) water and (b) ice with changes in temperature. (From Warren [3-27].)  Ref: Peavy, McGraw-Hill, 1985
As air temperature rises in late spring, *heat from the sun begins to warm the lake*

As the amount of solar radiation absorbed decreases with depth, *the lake heats from the surface down*

The warm water is less dense than the colder water below, *resulting in a layer of warm water that floats over the cold water.*
The warm water, abundant sunlight, and nutrients brought up from the lake bottom during spring overturn an ideal environment for algae growth within the epilimnion.

Algal blooms tend to give the epilimnion a greenish hue.

Wind circulates the surface water, but the warm water of the epilimnion is unable to drive through the cold, dense water of the hypolimnion. The water is only mixed in the epilimnion.
Dead algae sink to the lake bottom and are decomposed by bacteria.

*anaerobic bacteria begin to decompose organic material*

*anaerobic bacteria produce hydrogen sulfide ($H_2S$) gas*

*the odor of “rotten egg”*

Dead algae accumulation rate $>>$ organic matter decomposition rate of bacteria

*sediment deposited in the lake will be rich in organics*
As autumn approaches and temperature decreases, 

the epilimnion begins to decrease in depth

epilimnion gets so shallow, no longer be maintained as a separate layer

the lake loses its stratification

uniform temperature

wind can thoroughly mix the lake water
As winter approaches, the surface water is eventually cooled below 4°C. *water no longer sinks*

As water temperatures at the surface reach 0°C, *ice begins to cover the surface of the lake.* *ice cover prevents wind from mixing the lake water*
After the ice melts on a lake,

lake water is at the same temperature from the surface to the bottom.

wind allows circulation and mixing of the lake water.

large amounts of oxygen reaches to the bottom of the lake.
Surface Water Contaminants

- Turbidity and Suspended Matter
- Color
- Taste and Odor
- Organic Matter
- Dissolved Gases
- Hardness Ions (Ca\(^{++}\), Mg\(^{++}\))
- Iron and Manganese
- Pathogenic Organism
### Surface Water Contaminants and Treatment Techniques Used (continue)

<table>
<thead>
<tr>
<th>CONTAMINANT</th>
<th>SOURCE</th>
<th>TREATMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Turbidity and Suspended Matter</strong></td>
<td>Inorganic solids such as clay, silt and other soil constituents</td>
<td>→ Screening</td>
</tr>
<tr>
<td></td>
<td></td>
<td>→ Coag/floc/sed./filt</td>
</tr>
<tr>
<td><strong>Color</strong></td>
<td>Organic debris such as leaves, needles of conifers and wood</td>
<td>→ Coag/floc/sed/filt</td>
</tr>
<tr>
<td></td>
<td>Tannin, humic acid, humates derived from the decomposition of plant matter</td>
<td>→ Adsorption</td>
</tr>
<tr>
<td></td>
<td>Suspended matter</td>
<td></td>
</tr>
<tr>
<td><strong>Taste and Odor</strong></td>
<td>nonvolatile organic metabolic products of blue green algae</td>
<td>→ Chemical oxidation (commonly ozonation) prior to coagulation</td>
</tr>
<tr>
<td></td>
<td>dissolved gases (e.g. H₂S)</td>
<td>→ Adsorption</td>
</tr>
<tr>
<td></td>
<td>some volatile organic chemicals</td>
<td>→ Aeration</td>
</tr>
</tbody>
</table>
## Surface Water Contaminants and Treatment Techniques Used (continue)

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<tr>
<th>CONTAMINANT</th>
<th>SOURCE</th>
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</thead>
<tbody>
<tr>
<td>Organic Matter</td>
<td><em>from natural sources;</em> decay products of organic solids, decaying weeds, leaves, especially humic acid derived from the decomposition of plant matter&lt;br&gt;<em>from human activities;</em> wastewater discharges agricultural activities (e.g. pesticides)</td>
<td>→ Chemical oxidation&lt;br&gt;(e.g. ozonation; alter and polymerize metastable organics) followed by coag/floc/sed/filt&lt;br&gt;→ Adsorption</td>
</tr>
<tr>
<td>Dissolved Gases</td>
<td>from atmosphere (CO₂)&lt;br&gt;from decomposition of organic matter</td>
<td>→ Aeration</td>
</tr>
<tr>
<td>Hardness Ions (Ca⁺⁺, Mg⁺⁺)</td>
<td>contact of water with mineral deposits</td>
<td>→ Chemical precipitation&lt;br&gt;(water softening)&lt;br&gt;&lt;br&gt;<em>for low flowrates;</em>&lt;br&gt;→ Ion exchange</td>
</tr>
</tbody>
</table>
## Surface Water Contaminants and Treatment Techniques Used (continue)

<table>
<thead>
<tr>
<th>Contaminants</th>
<th>Treatment Techniques</th>
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<tbody>
<tr>
<td><strong>Iron and Manganese</strong>&lt;br&gt;Fe²⁺, Fe³⁺&lt;br&gt;Mn²⁺, Mn⁴⁺</td>
<td>Soluble iron( Fe²⁺ ) and manganese( Mn²⁺ ) released from the bottom mads in the waters of the hypolimnion (reservoirs that stratify) until the fall turnover occurs&lt;br&gt;→ Aeration will not provide oxidation and precip. within a reasonable time, especially for manganese&lt;br&gt;Mn²⁺ Fe²⁺&lt;br&gt;Oxidation &lt;&lt; Oxidation rate&lt;br&gt;→ Chemical oxid.(eg. ozonation)/precip/filt.&lt;br&gt;→ Ion exchange</td>
</tr>
<tr>
<td><strong>Heavy Metals</strong></td>
<td>industrial discharge&lt;br&gt;→ Chemical precipitation&lt;br&gt;→ Ion exchange</td>
</tr>
<tr>
<td><strong>Pathogenic Organisms</strong></td>
<td>sewage discharge&lt;br&gt;→ Disinfection</td>
</tr>
</tbody>
</table>
FLOW DIAGRAM THE TREATMENT OF TURBID SURFACE WATER WITH ORGANICS

RAW WATER

SCREENS

AERATION

PRE-OZONATION

COAGULATION & FLOCCULATION

(OR)

removes dissolved organics (e.g. pesticides)

Adsorption (optional)

SENSITIZATION

FILTRATION

(OR)

Adsorption (optional)

DISINFECTION (chlorination)
B) Ground Water Sources (wells, galleries, spring water)

→ Relatively constant in quality from season to season

→ may be highly variable in quality from one well location to another due to changes in hydrogeological conditions

→ superior in quality with respect to surface water

- **bacteriological content**
  - LOW

- **turbidity**
  - DUE TO NATURAL FILTRATION

- **total organic concentration**

→ mineral content (hardness ions (Ca++, Mg++), iron, manganese) may be inferior

→ trace concentrations of organic chemicals (e.g. pesticides, herbicides, solvents)

→ location of landfills, buried underground storage tanks etc. should be a part of groundwater quality evaluation
Ground Water Contaminants

→ Fe⁺⁺, Mn⁺⁺
→ Dissolved Gases
→ Hardness Ions (Ca⁺⁺, Mg⁺⁺)
→ Volatile Organics
→ Non-volatile Organics
**Groundwater Contaminants and Treatment Techniques Used**

<table>
<thead>
<tr>
<th>CONTAMINANT</th>
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</tr>
</thead>
<tbody>
<tr>
<td>Fe&lt;sup&gt;++&lt;/sup&gt;, Mn&lt;sup&gt;++&lt;/sup&gt;</td>
<td>→ Aeration for Fe&lt;sup&gt;++&lt;/sup&gt; oxidation</td>
</tr>
<tr>
<td></td>
<td>→ To Fe&lt;sup&gt;+++&lt;/sup&gt; in some extent</td>
</tr>
<tr>
<td></td>
<td>→ Chemical oxidation for complete oxidation of Fe&lt;sup&gt;2+&lt;/sup&gt; to Fe&lt;sup&gt;3+&lt;/sup&gt; Mn&lt;sup&gt;2+&lt;/sup&gt; to Mn&lt;sup&gt;4+&lt;/sup&gt;</td>
</tr>
<tr>
<td>Dissolved Gases</td>
<td>→ Aeration</td>
</tr>
<tr>
<td>Hardness Ions (Ca&lt;sup&gt;++&lt;/sup&gt;, Mg&lt;sup&gt;++&lt;/sup&gt;)</td>
<td>→ Chemical Precipitation (water softening for high flowrates)</td>
</tr>
<tr>
<td></td>
<td>→ Ion exchange</td>
</tr>
<tr>
<td></td>
<td>→ Nanofiltration</td>
</tr>
<tr>
<td>Volatile Organics</td>
<td>→ Air stripping</td>
</tr>
<tr>
<td>Non-volatile Organics</td>
<td>→ Adsorption</td>
</tr>
</tbody>
</table>
Flow Diagram For The Treatment Of Hard Ground Water

Raw water

AERATION → SOFTENING → FILTRATION → DISINFECTION

Chemical oxidant of oxidize remaining Mn$^{+2}$

Sludge (Dewatering) → Sludge
Flow Diagram For The Treatment Of Groundwater Contaminated With Volatile & Nonvolatile Organic Compounds

Raw water → AIR STRIPPING → CARBON ADSORPTION → FILTER → Gas ↑ → Discharge
C) Brackish And Saline Waters

Considerable interest in conversion of saline and brackish water as a result of;

- increasing water consumption
- depletion of existing water resources

Cost of potable water production from brackish and saline water >> treating fresh water.
C) Brackish And Saline Waters (Continue)

→ May be economical where adequate fresh water is not available

→ Treatment techniques used;

   Evaporators

   Ion exchange

   Electrodialysis

   Reverse osmosis
Wastewater

Domestic Wastewater

Industrial Wastewater
Untreated Wastewater Contaminants

- Suspended Solids
- Biodegradable Organics
- Pathogens
- Nutrients (nitrogen, phosphorus)
- Refractory Organics
- Heavy Metals
- Dissolved Inorganic Solids
- Volatile Organics
# Quality Of Untreated Wastewater & Treatment Techniques Used

<table>
<thead>
<tr>
<th>CONTAMINANT</th>
<th>TREATMENT</th>
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</thead>
</table>
| Suspended Solids       | → Screening, comminution  
                         | → Sedimentation  
                         | → Floatation  
                         | → Filtration  
                         | → Coagulation/sedimentation |
| Biodegradable Organics | → Suspended growth aerobic biological systems *(e.g., activated sludge)*  
                         | → Attached growth aerobic biological systems *(e.g., RBC, trickling filter)*  
                         | → Anaerobic biological systems |
| Pathogens              | → Disinfection                                                            |
## Quality Of Untreated Wastewater & Treatment Techniques Used (Continue)

<table>
<thead>
<tr>
<th>CONTAMINANT</th>
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</tr>
</thead>
<tbody>
<tr>
<td>Nutrients</td>
<td>Biological nitrification and denitrification</td>
</tr>
<tr>
<td>a) Nitrogen in the form of NH$_3$</td>
<td>Ammonia stripping</td>
</tr>
<tr>
<td>b) Phosphorus</td>
<td>Ion exchange</td>
</tr>
<tr>
<td></td>
<td>Breakpoint chlorination</td>
</tr>
<tr>
<td></td>
<td>Chemical precipitation</td>
</tr>
<tr>
<td></td>
<td>Biological phosphorus removal</td>
</tr>
<tr>
<td>Refractory Organics</td>
<td>Carbon adsorption</td>
</tr>
<tr>
<td></td>
<td>Ozonation</td>
</tr>
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<td>Heavy Metals</td>
<td>Chemical precipitation</td>
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<td></td>
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</tr>
<tr>
<td>Dissolved Inorganic Solids</td>
<td>Ion exchange</td>
</tr>
<tr>
<td></td>
<td>Reverse osmosis</td>
</tr>
<tr>
<td></td>
<td>Electrodialysis</td>
</tr>
<tr>
<td>Volatile Organics</td>
<td>Air stripping</td>
</tr>
</tbody>
</table>
Typical Flow Diagram For The Treatment Of Domestic (Municipal) Wastewater

Raw water → Screens → Grit chambers → Primary sedimentation → Biological C,N,P removal → Secondary clarifiers → Filtration → Disinfection → Discharge

- Grit
- Primary Sludge
- Waste Activated Sludge (WAS)
- Thickening (Stabilization)
- Dewatering

(Optional)

Omitted in case of extended aeration