Overview

c__________________ drinking water has the greatest impact on human health for > 50% of world’s population.

worldwide d____________ due to contaminated drinking water are approximately 14,000 - 25,000 per day.

25% of h______________ b_______ occupied by people infected with waterborne illnesses.

currently the world’s population that lacks a____________ to “safe” drinking water is 18% or 1.1 billion. (Johannesburg World Summit on Sustainable Development, 2002)
World Water

- 2.5 billion are without proper sanitation.
- More than 5 million people die each year from diseases caused by unclean drinking water, lack of sanitation, and insufficient water for hygiene. In fact, over 2 million deaths occur each year from water-related diarrhea alone. At any given time, almost half of the people in developing countries suffer from water-related diseases.
- Insufficient supply of water and sanitation disproportionately affect women, children, and the poor. The majority of deaths from water-related diarrhea are among children under 15, and women.
- Agriculture accounts for more than _____ percent of global water consumption. The inefficient use of water for irrigation has led to depletion of groundwater resources in many of the world’s most important agricultural regions, and is the primary source of groundwater pollution in parts of Europe, the US, and Asia.
During the 1990s, about _______ million people in developing countries gained access to improved drinking water, demonstrating the possibility for major improvements in safe water access worldwide.

At the Millennium Summit in September 2000, world leaders agreed to the goal of h_______, by 2015, the proportion of people without access to safe drinking water and sanitation. To meet this goal, an additional 1.6 billion people will need access to adequate water, and 2 billion will need improved sanitation. The annual investment required to meet the goal is estimated to be $_____ billion, nearly twice the current level of investment.
World Water

Within 25 years, half the world's population could have trouble finding enough fresh water for d_______ and i_______ (BBC News, Wednesday, 15 December, 1999, CU study).

A third of the world's people already live in regions considered to be "water-stressed" - where there is not enough, or barely enough water to go around.

Areas at risk Waterways under most pressure included:

- China's Y_______ River basin,
- the Z_______________ River in Africa,
- and the rivers that lead into the Aral Sea in Central Asia.

(Most of the water from those sources is used for irrigation, not drinking)
to protect public health

- need for multiple barriers to contamination:
  - s________ protection, land use restrictions
  - livestock r____________
  - collection, treatment, and d___________ of wastewater
  - treatment, disinfection, and d_____________
  - prevent cross c____________________
Microbiological Quality of Source Water

- want to find best possible s___________ quality
- influence of
  - p___________ sources (wastewater treatment plant discharges)
  - non-point source discharges (agricultural runoff, stormwater runoff, street runoff, s___________ tank effluent)
  - a___________ pollution
  - bird and animal f_____________
Microbiological Quality of Source Water

- surface water systems
  - comprise approximately 6,000 systems and serve a population of approximately 155 million people
  - affected by both point and non-point sources
  - Lake D leads to an increase in turbidity and pathogens
contaminated groundwater can be a concern
- u_________________________ groundwater
- non-c____________________ groundwater
- n________________________
- a________________________
- other contaminants (inorganics, e.g., fluoride, and organics)
Overview of Water Treatment

Conventional S___________ Water Treatment
- raw water p__________
- s__________
- pretreatment (optional)
  - pre-a________
  - prec________________
- rapid m__________
- s__________ mix — coagulation/flocculation
- s__________________
- f________________
- d________________
- s_______________
- d________________
Overview of Water Treatment

Conventional Groundwater Treatment Plant

- raw water pH________
- a____________ (H₂S, Fe⁺²)
- rapid mix — l__________ addition
- slow mix — coagulation/flocculation
- Sedimentation
- filtration
- Disinfection
- storage
- distribution
Fate of Pathogens in Water Treatment Plants

- **Viruses**
  - e_________________ present at levels of 3 - 20 pfu per 1000L in finished water in Payment, 1989 study
  - normally viruses will be removed in n_________ water treatment plant operation

Virus Survival in WTP pfu/1000 L (page 328 in Bitton)

<table>
<thead>
<tr>
<th>Raw Water</th>
<th>Sedimentation</th>
<th>Filtration</th>
<th>Ozonation</th>
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<tr>
<td>10.4</td>
<td>&lt;25</td>
<td>9.1</td>
<td>&lt;1</td>
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<tr>
<td>6.1</td>
<td>132</td>
<td>&lt;1</td>
<td>&lt;1</td>
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<td>100</td>
<td>75</td>
<td>&lt;2</td>
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<tr>
<td>90</td>
<td>5</td>
<td>&lt;1</td>
<td>&lt;1</td>
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<td>10</td>
<td>20</td>
<td>3</td>
<td>&lt;1</td>
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<tr>
<td>30.7</td>
<td>10</td>
<td>5</td>
<td>&lt;1</td>
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</tbody>
</table>
Fate of Pathogens in Water Treatment Plants

- Cryptosporidium and Giardia lamblia
d_____________ to detect routinely

- Opportunistic Pathogens
  - waterborne, can cause s______________ infections
  - Psudomonas putida
  - Alcaligenes
  - Acinetobacter
  - Flavobacterium
  - Legionella
    - can be i_______ from air conditioning or shower heads
Fate of Pathogens in Water Treatment Plants

- Storage of Raw Water — can result in reductions of pathogens (approximately ______ log)
  - t__________________
  - s__________________
  - s__________________
  - p__________________
Prechlorination — can lead to increased
d________________ byproducts

Coagulation — Flocculation (alum, ferric chloride, polyaluminum chloride)
will achieve significant reductions in t__________
(and consequently pathogens)
- b_______ : 90% removal
- v_______ : 90-99% removal
- protozoan c____ : 90% or greater removal
Fate of Pathogens in Water Treatment Plants

- **Softening**
  - will achieve significant reductions in t__________: 60-70%
  - viruses: 96-99% removal

- **Filtration**
  - requires adequate c__________ to be effective:
  - p__________ removal with f__________ but without coagulation: 1-50%
  - poliovirus removal with filtration and with coagulation: 90-99%
  - *Cryptosporidium* o__________ removal with filtration without coagulation: 90%
Surface Water Treatment Plant
Surface Water Treatment for Turbidity and Color Removal

Intake and Pump Station → Bacteria, Color, Turbidity → add Cl₂ or O₃ for taste and odor

Stream

Rapid Mix: G: 700-1000 s⁻¹, t: 30-60s

Slow Mix: alum or iron salts for coagulation

Sedimentation basin: overflow rate:
- 143-179 m³/d/m light floc
- 179-268 m³/d/m heavy floc

Filtration

Clear-well

add Cl₂ and Ca²⁺ for pH

to distribution

<table>
<thead>
<tr>
<th>Gt₀ values for Flocculation</th>
<th>Type</th>
<th>G(s⁻¹)</th>
<th>Gt₀</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Low turbidity</td>
<td>20-70</td>
<td>60,000-200,000</td>
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<tr>
<td></td>
<td>High turbidity</td>
<td>30-80</td>
<td>36,000-96,000</td>
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</tbody>
</table>
**Groundwater Treatment Plant**

**Treatment of Groundwater for Hardness Removal**

- **Bore Hole Well**
- **Hard Water Ca^{+2} + Mg^{+2}**
- **Aeration**
  - add D. O.
  - to remove CO₂ and H₂S
- **Rapid Mix**
  - add lime (for CH)
  - and soda ash (for NCH)
  - raise pH to 10 - 11.5
- **Slow Mix**
- **Recarbonation**
  - add CO₂ to decrease pH
  - Sedimentation overflow rate: 268-322 m³/d.m
- **Filtration**
- **Clear-well**
  - add Cl₂ and F⁻

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**Gt₀ values for Flocculation**

<table>
<thead>
<tr>
<th>Type</th>
<th>G(s⁻¹)</th>
<th>Gt₀</th>
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<tbody>
<tr>
<td>Softening (10%)</td>
<td>130-200</td>
<td>200,000-250,000</td>
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<tr>
<td>Softening (39%)</td>
<td>150-300</td>
<td>390,000-400,000</td>
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</table>
Membrane Processes

R_________________ o________________________ (RO)
primarily used to remove s_______ from brackish water or seawater desalination.
Has a high rejection of synthetic organic chemicals (SOCs)

N_______filtration (NF)
often used for water softening and to remove precursors to d________ byproducts.

E__________________ (ED)
demineralize b______________ water and seawater, also water softening.

U___________filtration (UF)
t___________ and p___________ removal

M___________filtration (MF)
turbidity and pathogen removal

Cost of treatment increases as s_______ of solute decreases
## Membrane Processes

<table>
<thead>
<tr>
<th>SIZE, MICRONS</th>
<th>IONIC RANGE</th>
<th>MOLECULAR RANGE</th>
<th>MACRO RANGE</th>
<th>MICRO PARTICLE RANGE</th>
<th>MACRO PARTICLE RANGE</th>
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<td>RELATIVE SIZE OF VARIOUS MATERIALS IN WATER</td>
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<td>AQUEOUS SALTS</td>
<td>VIRUSES</td>
<td>HUMIC ACIDS</td>
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Water Treatment Plants