

**The Islamic University of Gaza
Faculty of Engineering
Civil Engineering Department**

**Environmental Engineering
(ECIV 4324)**

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Water Treatment- Part A

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Introduction

Freshwater is a finite resource, and readily accessible supplies are becoming less abundant. With water scarcity a reality in many parts of the world, increases in population and income along with the impacts of climate change are expected to further exacerbate this issue. Achieving sustainable solutions is compounded by the energy demands of obtaining, storing, and producing a safe water supply.

Approximately 1.4kWh of energy are needed to collect and treat 1,000 gallons of surface water, and 1.8 kWh are needed to collect and treat a similar volume of groundwater

Introduction

The purpose of water treatment is to provide potable water that is palatable. **Potable** water refers to water that is healthy for human consumption and free of harmful microorganisms and organic and inorganic compounds that either cause adverse physiological effects or do not taste good.

Palatable describes water that is **aesthetically** acceptable to drink or free from turbidity, color, odor, and objectionable taste. Water that is palatable may not be safe.

Introduction

In developed countries, water is treated to be both potable and palatable. However, some people do not like the palatability of municipal waters, and this has given rise to the increased use of household point-of-use treatment systems and bottled water.

Introduction

Table / 8.1

Global Definitions of Improved and Unimproved Water Supplies

Improved Water Supplies	Unimproved Water Supplies
Household connections	Unprotected well
Public standpipes	Unprotected spring
Boreholes	Vendor-provided water
Protected dug wells	Bottled water
Protected springs Rainwater collection	Tanker truck-provided water

Characteristics of Untreated Water

Table / 8.2

Concentration of Major Constituents Found in Water

General Classification	Specific Constituents	Typical Concentration Range
Major inorganic constituents	Calcium (Ca^{2+}), chloride (Cl^-), fluoride (F^-), iron (Fe^{2+}), manganese (Mn^{2+}), nitrate (NO_3^-), sodium (Na^+), sulfur (SO_4^{2-} , HS^-)	1–1,000 mg/L
Minor inorganic constituents	Cadmium, chromium, copper, lead, mercury, nickel, zinc, arsenic	0.1–10 $\mu\text{g/L}$
Naturally occurring organic compounds	Naturally occurring organic matter (NOM) that is measured as total organic carbon (TOC)	0.1–20 mg/L
Anthropogenic organic constituents	Synthetic organic chemicals (SOCs) and emerging chemicals of concern used in industry, households, and agriculture (e.g., benzene, methyl tert-butyl ether, tetrachloroethylene, trichloroethylene, vinyl chloride, alachlor)	Below 1 $\mu\text{g/L}$ and up to the tens of mg/L
Living organisms	Bacteria, algae, viruses	Millions

PHYSICAL CHARACTERISTICS

Turbidity

Turbidity measures the optical clarity of water. It is caused by the scattering and absorbance of light by suspended particles in the water.

A turbidimeter is used to measure the interference of the light passage through the water. Turbidity is reported in terms of nephelometric turbidity units (NTU).

The World Health Organization reports that a turbidity of <5 NTU is usually acceptable but may vary depending upon the availability and resources for treatment. In the United States, many water utilities aim to treat the water to <0.1 NTU.

PHYSICAL CHARACTERISTICS

Particles

Particles in natural waters are solids larger than molecules but generally not distinguishable by the unaided eye. They may adsorb toxic metals or synthetic organic chemicals.

Water treatment considers particles in the size range 0.001–100 μm . Particles larger than 1 mm are called **suspended solids**, while particles between about 0.001 and 1 mm can be considered **colloidal particles** (though some researchers go as low as 0.0001 mm). Constituents smaller than 0.001 mm are called **dissolved particles**.

PHYSICAL CHARACTERISTICS

Color

Color is imparted to water by dissolved organic matter, natural metallic ions such as iron and manganese, and turbidity.

Most people can detect color at more than 15 true color units for water in a glass.

Taste and odor

Taste and odor can originate from dissolved natural organic or inorganic constituents and biological sources present in raw waters. They can also be an outcome of the water treatment process

MAJOR AND MINOR INORGANIC CONSTITUENTS

Table / 8.4

Major Dissolved Constituents Found in Water

Constituent	Source	Problem in Water Supply	Range in Natural Waters
Calcium and magnesium	Surface water and groundwater	Above 60 mg/L can be considered nuisance as hardness.	For calcium, less than 1 mg/L to more than 500 mg/L. Surface water concentrations of magnesium are less than 10 mg/L up to 20 mg/L. Groundwater concentrations are less than 30 mg/L up to 40 mg/L.
Chloride	Surface water and groundwater; saltwater intrusion	Above 250 mg/L can impart salty taste. Below 50 mg/L can be corrosive to some metals.	Typical surface water is usually less than 10 mg/L.
Fluoride	Surface water and groundwater Some water utilities add fluoride in the form of sodium fluoride or hydrofluorosilic acid at doses of about 1.0 mg/L	Toxic to humans at concentrations of 250–450 mg/L; fatal at concentrations above 4.0 g/L.	For surface water with total dissolved solids (TDS) concentrations less than 1,000 mg/L, fluoride is usually less than 1.0 mg/L.

MAJOR AND MINOR INORGANIC CONSTITUENTS

Iron and manganese	Surface water and groundwater	Taste threshold of iron for many consumers is around 0.01 mg/L. Iron can impart a brownish color to laundry and bathroom fixtures. Manganese ion can impart a dark brown color. At concentrations around 0.4 mg/L, manganese can impart an unpleasant taste to water and can stain laundry and fixtures.	In oxygenated surface waters, the concentration of total iron is usually less than 0.5 mg/L. In groundwater that has low bicarbonate and dissolved oxygen, iron concentrations can range from 1.0 to 10.0 mg/L. The concentration of manganese ion in surface water and groundwater may be less than 1.0 mg/L.
Nitrate	Surface water and groundwater can contain high concentrations of nitrate from runoff from fertilizers found in urban and agricultural watersheds.	Very high nitrate concentrations may produce infant methemoglobinemia.	
Sulfur	Surface water and groundwater	Groundwater low in dissolved oxygen can contain reduced sulfur compounds, which impart objectionable odors such as that of rotten eggs. Sulfates are also corrosive in concrete structures and pipes.	Sulfate concentrations in freshwater can approach 10 mg/L.

MAJOR ORGANIC CONSTITUENTS

Table / 8.6

Effect of Natural Organic Matter (NOM) on Water Treatment Processes

Water Treatment Process	Effect
Disinfection	NOM reacts with, and consumes, disinfectants, which increase required dose to achieve effective disinfection.
Coagulation	NOM reacts with, and consumes, coagulants, which increase required dose to achieve effective turbidity removal.
Adsorption	NOM adsorbs to activated carbon, which depletes adsorption capacity of the carbon.
Membranes	NOM adsorbs to membranes, clogging membrane pores, and fouling surfaces. This leads to decline in water passed through the membrane.
Distribution system	NOM may lead to corrosion and slime growth in distribution systems (especially when oxidants are used during treatment).

MICROBIAL CONSTITUENTS

Table / 8.7

Representative Pathogenic Organisms in Raw-Water Supplies

Pathogen(s)	Type	Health Effects in Healthy Persons	Normal Habitat
<i>Vibrio cholera</i> Shape: wormlike Size: 0.5 by 1–2 μm	Bacteria	Classic cholerae—explosive diarrhea and vomiting without fever followed by dehydration; abnormally low blood pressure and temperature; muscle cramps; shock; coma followed by death	Human stomach and intestines
<i>Salmonella</i> (several species) Shape: rod Size: 0.6 μm	Bacteria	<i>S. typhi</i> species causes enteric fever, headaches, malaise, and abdominal pain	Intestines of warm-blooded animals
<i>Shigella dysenteriae</i> Shape: round Size: 0.4 μm	Bacteria	Bacillary dysentery: abdominal pain, cramps, diarrhea, fever, vomiting, blood, and mucus in stools	Human stomach and intestines
<i>Escherichia coli</i> Shape: rod Size: 0.3–0.5 by 1–2 μm	Bacteria	Diarrhea	Intestines of warm-blooded animals

MICROBIAL CONSTITUENTS

Poliovirus types 1, 2, 3 Shape: round Size: 28–30 nm	Virus	Fever, severe headache, stiff neck and back, deep muscle pain, and skin sensitivity	Human intestinal tract
Human adenovirus type 2 Shape: 12 vertices Size: 70–90 nm	Virus	Severe infections in lungs, eyes, urinary tract, genitals; some strains affect intestines	Human intestinal tract
Rotavirus A Shape: round Size: 80 nm	Virus	Severe diarrhea and dehydration	Human intestinal tract
<i>Cryptosporidium parvum</i> Type 1 oocyst Shape: ellipsoidal Size: 3–5 μm Sporozoite and merozoites Shape: wormlike Size: 10 by 1.5 μm	Protozoa	Severe diarrhea, abdominal pain, nausea or vomiting, and fever	Human intestinal tract

MICROBIAL CONSTITUENTS

<i>Giardia lamblia</i> Shape: single-celled flagellated protozoa Size: 9–15 μm long, 5–15 μm wide, 2–4 μm thick	Protozoa	Sudden diarrhea, abdominal cramps, bloating, cramps, and weight loss	Human intestinal tract
<i>Schistosoma haematobium</i> A wormlike organism	Helminthic	Squamous cell carcinoma of the bladder; urolithiasis; ascending urinary tract infection; urethral and ureteral stricture with subsequent hydronephrosis; renal failure	Blood vessels of the human bladder and in mammals

Water Quality Standards

Table / 8.8

Representative Chemicals Found in Water and Their Maximum Contaminant Level Goals (MCLGs) and Maximum Contaminant Levels (MCLs) MCLGs are based solely on health and risk assessment information. MCLs are based not only on health and risk assessment information, but also on costs and the availability of technology.

Chemical	Maximum Contaminant Level Goal (mg/L)	Maximum Contaminant Level (mg/L)
Synthetic Organic Chemicals (SOCs)		
2,4-D (2,4-dichlorophenoxyacetic acid)	0.07	0.07
Alachor	0	0.002
Atrazine	0.003	0.003
Benzo(a)pyrene	0	0.0002
Chlordane	0	0.002
Lindane	0.0002	0.0002
Polychlorinated biphenyl (PCB)	0	0.0005
Volatile Organic Chemicals (VOCs)		
1,1-Dichloroethylene	0.007	0.007
1,1,1-Trichloroethane	0.2	0.2

(continued)

Water Quality Standards

Table / 8.8

(continued)

1,2-Dichloroethane	0	0.005
Benzene	0	0.005
Carbon tetrachloride	0	0.005
cis-1,2-Dichloroethylene	0.07	0.07
Dichloromethane	0	0.005
Ethyl benzene	0.7	0.7
Toluene	1	1
Tetrachloroethylene	0	0.005
Trichloroethylene	0	0.005
Vinyl chloride	0	0.002
Xylenes (total)	10	10
Inorganics		
Arsenic	0	0.01
Cadmium	0.005	0.005
Chromium (total)	0.1	0.1
Cyanide	0.2	0.2
Fluoride	4	4
Lead (at tap)	0	0.015 (action level)*
Mercury	0.002	0.002
Nitrate (as N)	10	10
Nitrite (as N)	1	1

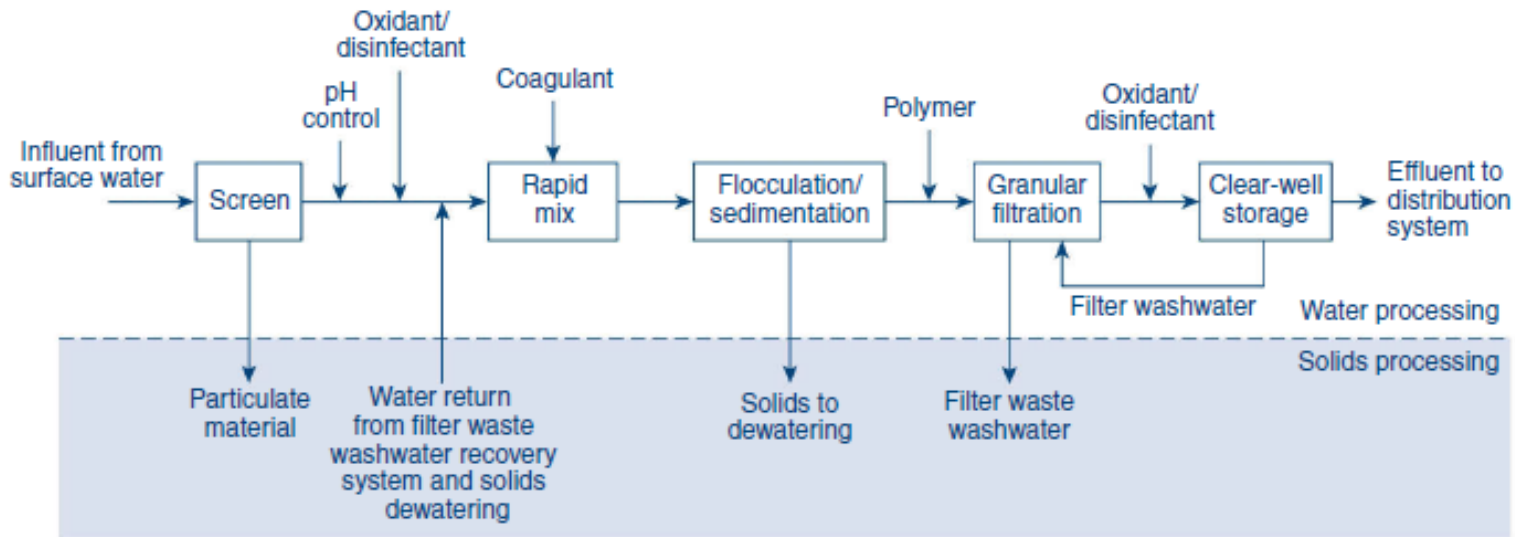
Overview of Water Treatment Processes

Table / 8.9

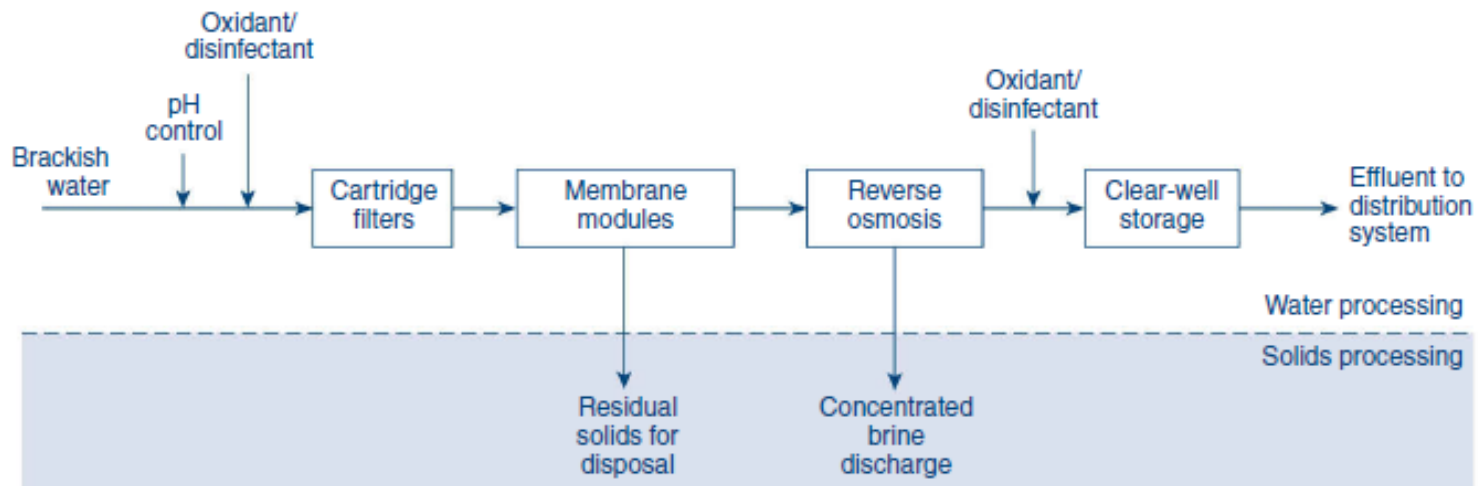
Unit Processes That Remove a Significant Amount of Raw-Water Constituents

Constituent	Unit Process(es)
Turbidity and particles	Coagulation / flocculation, sedimentation, granular filtration
Major dissolved inorganics	Softening, aeration, membranes
Minor dissolved inorganics	Membranes
Pathogens	Sedimentation, filtration, disinfection
Major dissolved organics	Membranes, adsorption

Overview of Water Treatment Processes



(a)



(b)