Environmental Water Quality
BAE 452/552

Session 3

Physical, chemical and biological properties of water

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Impact on Receiving Waters

- National Water Quality Inventory Report submitted to Congress bi-annually as required by Section 305(b) of Federal Water Pollution Control Act
- For details on standards visit: http://www.epa.gov/305b

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National Water Quality Inventory

- Siltation, nutrients, bacteria, metals (Hg), and oxygen depleting substances top causes of impairment.
- Pollution from urban and agricultural land transported by precipitation and runoff (NPS) is leading source of impairment
- Identifying causes and sources of pollution is difficult in impaired waters

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National Water Quality Inventory

Water pollution threatens public health:

- Consumption of contaminated food or drinking water
- Skin exposure in recreational and bathing water
- Toxic chemicals, waterborne disease-causing pathogens such as viruses, bacteria, and protozoa

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National Water Quality Inventory

Designated uses:

- Aquatic life support (cold/warm water biota)
- Fish consumption
- Primary contact – swimming
- Secondary contact – boating, fishing
- Water supply (drinking water supply, agriculture, industrial)

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National Water Quality Inventory

- 40% of streams, 45% of lakes, and 50% of estuaries assessed were not clean enough to support uses such as swimming and fishing
- Assessed were 700,000 river miles (19%), 17.34 million acres of lakes (43%), 31,000 square miles of estuaries (36%)

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National Water Quality Inventory

Rivers and streams:

- Pathogens most common pollutant followed by siltation
- Agriculture leading source of pollution

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National Water Quality Inventory

Lakes and Reservoirs:

- Nutrients most common pollutant followed by metals and siltation
- Agriculture is leading source of pollution

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Physical Characteristics

- Most of our impressions of water quality are based on physical properties rather than chemical or biological properties

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Physical Characteristics

Common analyses:

- Turbidity
- Solids
- Color
- Odor
- Temperature

Other:

- Substrate
- Flow velocity
- Flow depth
- Channel/habitat
- Stream order

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Physical Characteristics

Turbidity:

- Measure of the insoluble solids (soil, organics, and micro-organisms) in water which impede light passage
- Unit is NTU (nephelometer turbidity units)
- Practical limit for drinking water is 5 NTU
- Muddy water exceeds 100 NTU
- 1 TU = 1 mg/L of silica in suspension

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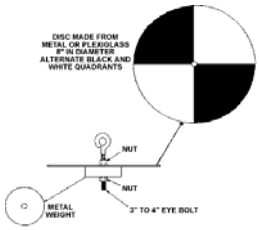
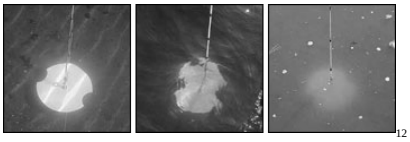
Secchi Disk





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Physical Characteristics

Solids:

- Suspended solids: same as filterable solids, are measured by filtering a sample of water and weighing the residue
- Total solids: measured by drying a sample of water and weighing the residue
- Dissolved solids: same as non-filterable solids, are measured as the difference between total solids and suspended solids

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Physical Characteristics

Solids (cont'd):

- Volatile solids: measured as the decrease in weight of total solids which have been ignited in an electric furnace
- Fixed solids: difference between total solids and volatile solids

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Physical Characteristics

Solids (cont'd):

- Settleable solids: measured in mL/L by allowing a sample to stand for one hour in a graduated conical container (*Imhoff cone*)

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Physical Characteristics

Solids based on origin:

- Allochthonous: from the drainage basin ('brown' solids)
- Autochthonous: from photosynthesis process ('green' solids)

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Physical Characteristics

Allochthonous	Autochthonous
• Low organic carbon	• High organic carbon
• High density	• Low density
• Size in wide range (10^{-8} – 10^{-2} m)	• Size in low range (10^{-10} – 10^{-5} m)
• Aggregation may increase size (flocs, colonies)	• Aggregation may increase size (flocs, colonies)

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Physical Characteristics

Typical values for solids:

- 3 – 60 mg/L in surface waters
- 60 – 300 mg/L in waste water (untreated)
- Upper limit of 500 mg/L of total solids is recommended

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Stokes' Law

- Settling velocity v_s (cm/s) of a particle:

$$v_s = \alpha\ (g/18)\ [(\rho_s - \rho_w)/\mu]\ d^2$$

where

- α = dimensionless form factor reflecting effect of particle's shape (sphere: 1.0)
- g = acceleration of gravity (981 cm/s)
- ρ_s , ρ_w = densities of particle and water (g/cm^3)
- μ = dynamic viscosity (g/cm s)
- d = an effective particle diameter (cm)

Note: assumes flow is laminar

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Stokes' Law

- Settling velocity v_s (m/d) of a particle:

$$v_s = 0.033634\alpha\ (\rho_s - \rho_w)\ d^2$$

where

- α = dimensionless form factor reflecting effect of particle's shape (sphere: 1.0)
- ρ_s , ρ_w = densities of particle and water (g/cm^3)
- μ = assumed to be constant at 0.014 (g/cm s)
- d = an effective particle diameter (μm)

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Stokes' Law

- Generally, particles in natural waters are not spherical (α<1):

	diameter (μm)	v_s (m/d)
• Phytoplankton:	2 – 84	0.08-1.1
• Particulate org C:	1 – 10	0.2
	10 – 64	1.5
• Clay	2 – 4	0.3 – 1
• Silt	10 – 20	3 - 30

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Physical Characteristics

Color:

- In domestic water undesirable aesthetically
- Colloidal suspensions and dissolved materials
- Measured with colorimeter or comparatively with tubes containing standard platinum/cobalt solutions
- Range: 0 (clear) to 70 color units

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Physical Characteristics

Odor:

- Result from decaying organic matter, or in mineral springs from the reduction of sulfates by bacteria to H_2S
- Offensive odors: Amines (fishy), Ammonia (ammoniacal), Diamines (decayed flesh), Hydrogen Sulfide (rotten egg), Mercaptans (skunk secretion), Organic Sulfides (rotten cabbage), Skatole (fecal)

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Physical Characteristics

Temperature:

- Chemical and biochemical reaction rates, mineral solubility, growth rates of aquatic organisms increase
- Gas solubility, respiration rates of aquatic organisms decrease
- Reproduction and survival for organisms has different temperature ranges

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Physical Characteristics

Substrate:

- Solid structures in contact with the bottom or sides of the stream, that modify surface and interstitial flow patterns and influence the accumulation of organic matter while providing a place for production, decomposition, and other biological processes

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Physical Characteristics

Substrate (cont'd):

- range from very fine clays, silts, sands, and gravels to large cobbles, boulders and snags (usually woody debris)
- high gradient (low order) streams dominated by large substrate types; low gradient (high order) streams will be mainly comprised fine substrates (silt and sand)
- Most streams have heterogeneous substrates

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Physical Characteristics

Channel/Habitat:

- Channel morphology depends on:
  - ➢ Stream discharge
  - ➢ Stream particle size
  - ➢ Stream slope

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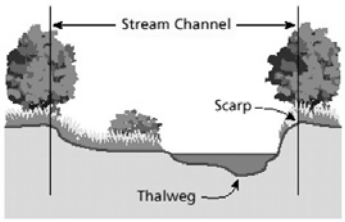
Cross section of a stream

The scarp is the sloped bank and the thalweg is the lowest part of the channel.



Physical Characteristics

Channel/Habitat (cont'd):

- Pools: regions of deeper, slow-moving water with fine substrates (silts and sands)
- Riffle: region of shallow, fast-moving water, with coarse substrates (gravels and cobbles)
- Run: regions where the flow is less turbulent than in riffles but moves faster than in pools

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Physical Characteristics

- Pools and riffles alternate with a riffle occurring appr. every 5-7 channel-widths
- Pool-riffle sequences are important component to stream ecosystems.
- Riffles are nesting areas for fish, support abundant macroinvertebrate and juvenile fish populations, and re-aeration of the water.
- Pools support larger adult fish and function as a depositional area for the decomposition of organic silts and detritus.

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Physical Characteristics

Stream order:

- Stream-order can be used as a correlate to other parameters of a stream
- 1st order streams: numerous, short in length, high gradients, large substrates, and low discharges
- Higher order streams: few, greater in length, lower gradients, small substrates, and high discharges

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Stream ordering in a drainage network.

Stream ordering is a method of classifying the hierarchy of natural channels in a watershed.

Chemical Characteristics

- Inorganics
- Organics
- Gases (not in this class)

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Chemical Characteristics
(Inorganics)

Qualities of supply water:

- Acidity
- Alkalinity
- Conductivity
- Hardness
- pH
- Dissolved cations & anions
- Iron
- Manganese
- Fluoride
- Chloride
- Phosphorus
- Nitrogen

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Chemical Characteristics
(Inorganics)

Acidity:

- A measure of acids in solution or capacity to neutralize bases
- Caused by formation of carbonic acid from carbon dioxide in the air:

$$CO_2 + H_2O \rightarrow H_2CO_3$$

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Chemical Characteristics
(Inorganics)

Alkalinity:

- A measure of amount of negative ions in solution or capacity to neutralize acids
- $A = [HCO_3^-] + [CO_3^{-2}] + [OH^-]$
- Convert from mg/L to meq/L by multiplying [mg/L] by meq/mg, or z (meq)/atomic (molecular) mass (mg), where z is the valence

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Chemical Characteristics
(Inorganics)

Conductivity:

- A measure of the ability of a solution to conduct an electrical current
- Increases as ion concentration increases
- Unit: μS/cm (= μmho/cm), S = Siemens
- EC = $\Sigma(C_i \times f_i)$, where C_i is concentration of ionic species i in solution, mg/L or meq/L, and f_i is conductivity factor for ionic species i

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Chemical Characteristics
(Inorganics)

Conductivity factors f_i:

Ion	Per meq/L	Per mg/L
Ca	52.0	2.60
Mg	46.6	3.82
K	72.0	1.84
Na	48.9	2.13

Ion	Per meq/L	Per mg/L
HCO_3^-	43.6	0.715
CO_3^{-2}	84.6	2.82
Cl^-	75.9	2.14
NO_3^-	71.0	1.15
SO_4^{-2}	73.9	1.54

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Chemical Characteristics
(Inorganics)

Conductivity:

- Ionic strength (activity of ions) calculated from EC:

$$\mu \cong 1.6 \times 10^{-5} \times EC$$

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Chemical Characteristics
(Inorganics)

Hardness:

- Caused by multivalent positive metallic ions such as calcium, magnesium, iron, and manganese
- Hardness reacts with soap to reduce its cleansing effectiveness, and to form scum on the water surface and ring around the bathtub
- Also causes scaling in hot water pipes, etc.

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Chemical Characteristics
(Inorganics)

Total hardness:

- $[Ca^{+2}] + [Mg^{+2}]$, meq/L

Description	meq/L
Soft	< 1
Moderately hard	1 – 3
Hard	3 – 6
Very hard	> 6

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Chemical Characteristics
(Inorganics)

Carbonate hardness:

- Due to precipitation of carbonate molecule (HCO_3^- and CO_3^{-2}), also called temporary hardness

Non-carbonate hardness:

- Due to sulfates, chlorides, and nitrates, also called permanent hardness

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Chemical Characteristics
(Inorganics)

- pH is a measure of acidity (acid vs alkaline)
- $pH = - \log_{10} [H^+]$, $pOH = - \log_{10} [OH^-]$, and $pOH + pH = 14$
- pH determines solubility of nutrients and pollutants
- Low pH: acid rain, mine discharge, industry
- Stream organisms cannot deal with deviations from neutral pH

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Chemical Characteristics
(Inorganics)

Cation-anion balance (on major species):

- Ideally, in water analyses, Σcations = Σanions, both expressed in meq/L
- Convert from mg/L to meq/L by multiplying by meq/mg, or z (meq)/atomic (molecular) mass (mg)
- Apply:

$|\Sigma\text{anions} - \Sigma\text{cations}| \leq 0.1065 + 0.0155\ \Sigma\text{anions}$

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