Biological Characteristics of Water

Water quality in developed and developing countries continues to deteriorate due to increased movement of refugees in developing countries and natural disasters like flooding and droughts. Waterborne diseases bigger than wars and AIDs.

Most important biological organisms in water and wastewater are pathogens, as they transmit diseases.

- not native to aquatic systems and usually require an animal host for growth and reproduction
- unfortunately, can be transported by water, becoming a temporary member of the aquatic community
- many species of pathogens are able to survive in water and maintain their infectious capabilities for significant periods of time
- include species of bacteria, viruses, protozoa, and helminths

Background (WQI, Nov/Dec-1998 and ES&E, Sept 99)

- world wide it is estimated that 10,000 people die every day from water borne diseases
  - major cause is the lack of responsibility of water supplies at local level in developing countries
  - national governments and international aid groups say they know better than the locals and force sophisticated technologies which the locals can not afford to repair and in some cases know how to operate
  - in trial cases where the locals designed and operated the system, quality improved

- in US, between 1920 and 1992 there were 1768 waterborne disease outbreaks, with 472,228 cases of illness and 1091 deaths
- in 1993, the largest ever outbreak of illness occurred in Milwaukee, WI where 400,000 people got sick and 54 deaths due to Cryptosporidium
- diarrhea illnesses have been linked to 900,000,000 illnesses per year with approximately 2,000,000 children deaths per year
- high level of bacteria and viruses in water contaminated with untreated sewage; disinfection can reduce
  - viruses by 99.99%
  - bacteria by 99.9999%

- new pathogens adding to the problem
  - Cryptosporidium first diagnosed in 1976
    - livestock major source, typically young calves
  - Rotovirus first identified in 1973 and estimated to contribute to the death of 4 to 5 million persons per year
    - major cause of viral gastroenteritis
    - one million cases per year, with 150 deaths per year
    - all outbreaks associated with direct fecal contamination of water supply; potential source is septic tank discharge

Major Groupings

Bacteria

- comes from Greek word rod or staff, the shape characteristic of most bacteria
  - rod shape ==> bacilli
  - spherical ==> cocci
  - spiral ==> spirilla

- smallest living thing, very efficient
  - 1 bacteria could multiply and cover the earth in 36 hrs if the conditions were correct

Viruses

- smaller than bacteria
  - smallest known biological structure to contain all the genetic information necessary for reproduction

- cannot live by themselves (do not have ability to synthesize new compounds) require a host
  - obligate parasitic particles consisting of DNA

- host specific, makes enumeration difficult
  - very difficult to control medically

Plankton

- unattached microorganisms
- dispersed individually or in colonies in water
  - *Phytoplankton (Algae)*: cannot see them with the naked eye
    - size varies from 5u -500um
    - count in raw water can add up to 10^5 cells per mL
    - at this large volume they can impart colour to the water
    - most algae contain green pigment called chlorophyll and follow photosynthesis:

      Daytime

      $$nCO_2 + nH_2O \xrightarrow[\text{new cells}]{\text{sunlight + nutrients}} (CH_2O)_n + nO_2$$

      Night

      $$(CH_2O)_n + nO_2 \longrightarrow nCO_2 + nH_2O$$

    - usually nO_2 sunlight > nO_2 respiration
    - if not can cause anaerobic conditions and odours

- nuisance as high temp and sunlight increase their growth, producing:
  - taste
  - odour
  - clogging of filters
  - possible toxicity
  - change in pH, alkalinity and hardness

- four important groups are:
  - blue green algae
  - green algae
  - diatoms
  - pigmented flagellates

- *Zooplankton*: Use oxygen and release carbon dioxide; are animal types.
  - Nematodes - worms; 10,000 species
  - Water Flea
  - Cyclops
  - Rotifiers - simplest of multicellular animals, aerobic

Protozoa

- lowest form of animal life: single cell
  - aerobic or facultative anaerobic

- free-living or parasitic
- broken in four classes based on motility
  - Ciliata
  - Mastigophora
  - Sarcodina
  - Sporozoa

Fungi

- aerobic multicellular, nonphotosynthetic, heterotrophic
- most are saprophytes, obtaining food from dead organic matter
- principle micro-organism along with bacteria that decomposes carbon
- without fungi, the carbon cycle would cease and organic matter would build up
- ideal conditions are high moisture and low pH

<u>Microorganisms</u> (students review on their own)
- extract from the environment substances needed to produce new cell material
- these substances are called nutrients
- to continue growth, the micro-organisms require carbon, energy and as seen from CHONPS, nitrogen, phosphorous and sulfur
- carbon is obtained from carbon dioxide and the carbon found in organic matter
  - CO_2 --> autotrophic
  - if organic matter --> heterotrophic

- energy is obtained from light or chemical oxidation or reduction of organic and inorganic matter
  - microorganisms that use light ---> phototrophs
  - microorganisms that use chemical energy ---> chemotrophs

photoautotrophs ----> light ------> CO_2 -----> higher plants, algae, photosynthetic bacteria

photohetrotrophs ---> light ------> organic matter --> photosynthetic bacteria

chemautotrophs -----> inorganic matter--> CO_2 ------> bacteria

chemoheterophs ---> organic ---> organic -----> bacteria, fungi, protoza, animals
matter matter

- oxygen also plays an important role
  - aerobic or anaerobic
  - facultative anaerobes; can grow in the presence or absence of O_2

- temperature also important

Psychrophilic	10 to 30	optimum 12 to 18	°C
Mesophyllic	20 to 50	optimum 25 to 40	°C
Thermophilic	35 to 75	optimum 55 to 65	°C

BACTERIA

- gastrointestinal disorders are common symptoms of diseases transmitted by waterborne pathogenic bacteria
- *Escherichia coli*, is a common organism in human feces (fecal)
- *Vibro cholerae*
  - caused Cholera, a disease which ravaged Europe during the 18th and 19th centuaries
  - caused vomiting, diarrhea, and without treatment results in dehydration and death
  - 1854 Hamilton had an outbreak of cholera; pop. 20,000 and 1 in 40 died
    - researchers were watching the epidemic and others similar in 19th century; observed that people with clean water were not getting sick
    - determined that clear water should be provided, reason why not known
    - commissioned Thomas E. Keefer, considered a pioneer professional engineer to solve the problem
      - anticipated a future demand of 3.6 MGD
      - pumped clean water from Lake Ontario through a filtration gallery, completed in 1860 at which time the cholera outbreaks also ceased
      - cost nearly $600,000, which almost forced city into bankruptcy
      - at that time a good daily wage was $1.00
      - site remains as a museum and is recognized by the CSCE a National Engineering Monument
  - immunization and disinfection of water supplies have eliminated cholera and most parts of the world, however, poor sanitary conditions can still cause an outbreak

- *Francisella tularensis*; Tularemia
  - deer fly fever

- *Leptospira*; Weils disease
  - jaundice, fever

- *Salmonella typhosa*; Typhoid fever
  - gastrointestinal disorders, high fever, ulceration of the intestines, and possible nerve damage

- *Shigella*; Shigellosis (dysentery)
  - severe diarrhea

VIRUSES

- need a host to live
- *Enteric cytopathogenic human orphan*; aseptic meningitis, epidemic exanthem, infantile diarrhea

- hepatitis A (destroys liver)
  - second most commonly reported infection in US
    - outbreak of over 60,000 of hepatitis cases a year in USA
    - 10,000 to 100,000 infectious doses of hepatitis virus are emitted from each gram of feces from ill person

  - result of eating shellfish contaminated by waters polluted by viruses
  - easier to contract than HIV

- some viruses will live as long as 41 days in water or wastewater at 20°C and for 6 days in a normal river

- Eastern Europe (*WQI*-1994#4) has 100 million people still lacking access to sanitation or safe drinking water
  - biggest concern is hepatitis A
  - estimated cost of doing so is $216 billion
  - UN feels the best way to improve public health is via sanitation

- *Poliomyelitis*; acute anterior poliomyelitis (infantile paralysis)
  - immunization has reduced the incidence of polio to a few cases a year in developed nations

- common cold
  - standard disinfection practices kill viruses but quick conclusive tests are not available like for bacteria, makes monitoring of treatment methods expensive
  - uncertainty in viral disinfection is major obstacle in direct recycling of wastewater and a concern for land application of wastewater

PROTOZOA

- pathogenic or non-pathogenic, microscopic or macroscopic
  - are highly adaptable and distributed in natural water, but only a few are pathogenic

- protozoal infections are usually characterized by gastrointestinal disorders that are milder than bacterial infections

- *Entamoeba histolytica*; amoebiasis (amoebic dysentery, amoebic enteritis andamebic colitis)
  - include diarrhea, nausea, indigestion, flatulence, bloating, fatigue and appetite and weight loss
  - serious in 1933 where 1400 people were affected and 98 deaths occurred
  - drinking water contaminated by sewage

- *Giardia lamblia*; giardiasis
  - carried by wild animals who live near natural water systems
  - contracted by persons drinking untreated surface waters
    - can survive in cool H_2O for months
  - difficult to deactivate by disinfection
  - complete treatment and filtration required to eliminate from water

- *Cryptosporidium*
  - protozoan parasite found in waste of most mammals
  - oocysts (parasitic "eggs") are ingested and invade intestinal tract
  - nausea, diarrhea, cramps
  - similar to "giardia" but half as big
    - thus more difficult to physically remove or kill than "giardia"

  - reported incidences
    - April 1993 - 195 people became sick k-w
    - 400,000 people in Milwaukee, WI
    - Whitehorse, 17% of water infected
    - 1996 Sydney, AUS; repeated boil orders given
      - built a new plant for the 2000 Olympics
      - private operation - City owned
      - management ultimately charged with not taking public health into consideration
      - oocysts @ 10/L

  - water impact
    - surface waters that are unfiltered at highest risk (animal discharges)
      - raw sewage ☞ 28 oocysts/l
      - river source ☞ 0.94 oocysts/l
      - filtered h_20 ☞ 0.001 oocysts/l

        - groundwater relatively safe
            - natural filtration

    - WATER21, pg 6, 1999
        - UK introduced regulations requiring the monitoring of Cyrptosporidium
        - if more than 10 oocysts/L, continuous monitoring required
        - becomes part of criminal offence

    - disinfection alone cannot do the job
    - need to filter with the elimination of backwash and supernatant recycling
    - installed enhanced membranes with can filter out items larger than 0.1 µm
        - Town of Sioux Lookout has two membranes units from Zennon

    - recommend
        - source protection
        - turbidity monitoring
        - media inspection
        - proper disinfection **practices**

HELMINTHS (Worms)

- life cycle involves two or more animal hosts, of which one may be human
- water contamination may result from human or animal waste that contains helminths
- modern water-treatment methods are very effective in destroying these organisms
- greatest risk is from untreated sewage, i.e. sewage plant operators, swimmers in recreational lakes polluted by sewage or stormwater runoff from feedlots

- *Dracunculus medinensis*; dracontiasis (dragon or guinea-worm infection)
  - arthritis of joints

- *Echinococcus*; echinococcosis (dog tapeworm)

- *Schistosoma*; schistosomiasis (blood fluke disease)
  - tissue damage
  - blood loss in bladder
  - full cycle
    - eggs passed in feces
    - hatch in fresh water (Miracidia) and enter snail which is first host
    - leave snail (Cercaria) and become free swimming
    - penetrate skin of human leaving behind tail
    - travel through veins, in which it also develops
    - reside in intestinal tract until discharged

2.6.2 Pathogen Indicators

- analysis of water for all known pathogens would be very time consuming and expensive
- usually specific pathogens are not tested for unless they are suspected, instead indicator organisms are used
- indicator organisms suggest that contamination had occurred and the level of contamination
- ideal one
  - applicable to all types of water
  - always present when pathogens present
  - always absent when pathogens absent
  - routine analysis with no confusion
  - safe for laboratory personnel and not be a pathogen

- selected *Escherichia Coli*
  - belong to fecal coliform group
  - most waterborne pathogens are introduce through fecal contamination
  - since *E. Coli* are found exclusively in the intestinal tract of warm blooded animals and are excreted in large numbers in feces
  - are non-pathogenic and are believed to have a longer survival rate outside the body than most pathogens
  - die off is logarithmic, allowing comparison of number of surviving organisms to time lapse since contamination

- other coliform groups exist outside the intestinal tract of animals
  - present in soil and decaying vegetation
  - used to indicate presence of helminths

- usual practise is to use the total coliform group (fecal and non-fecal origin)
  - simple tests have been developed (membrane-filtration technique, plate count, multiple tube fermentation)
  - tests go faster and require lower temperatures than fecal coliform
  - if total present than fecal test is done

NOTE: **Pathogens are not identified by coliform test, rather that the water has recently contacted soil, decaying vegetation or discharge from warm-blooded animal**

  - if coliform are present, pathogenic organisms may also be present
  - all pathogens are destroyed by the time coliform organism are destroyed
  - these assumptions are being questions for infectious hepatitis
  - enumeration does not apply for other biological contaminant; algae, cyclops, etc

- if fecal coliform present, can also determine fecal streptococci
  - based on the ratio can evaluate which animal was source of pollution
  - human FC/FS = 4.4
    cow FC/FS = 0.2
    sheep FC/FS = 0.4
    turkey FC/FS = 0.1

NOTE: safe water does not necessarily mean absolutely no risk in drinking it, but rather that the danger, if any, it is so small that it cannot be discovered by available means of observation

In Summary:

<u>If coliforms are present:</u>

(1) Water was contaminated by discharge from human sources
(2) Pathogens <u>may</u> be present
(3) Water should be treated prior to consumption

<u>If no coliforms are present</u>:

(1) pathogens were destroyed by the methods used to kill the coliform, provided they were present in the first place.