ENVI1002 Lecture 8

Wastewater treatment

Solids

Chemical wastes

Organic wastes

Living microorganisms

Measuring Water Quality

Three major approaches

- total organic carbon (TOC)
- chemical oxygen demand (COD)
- biochemical oxygen demand (BOD)

Total organic carbon (TOC)

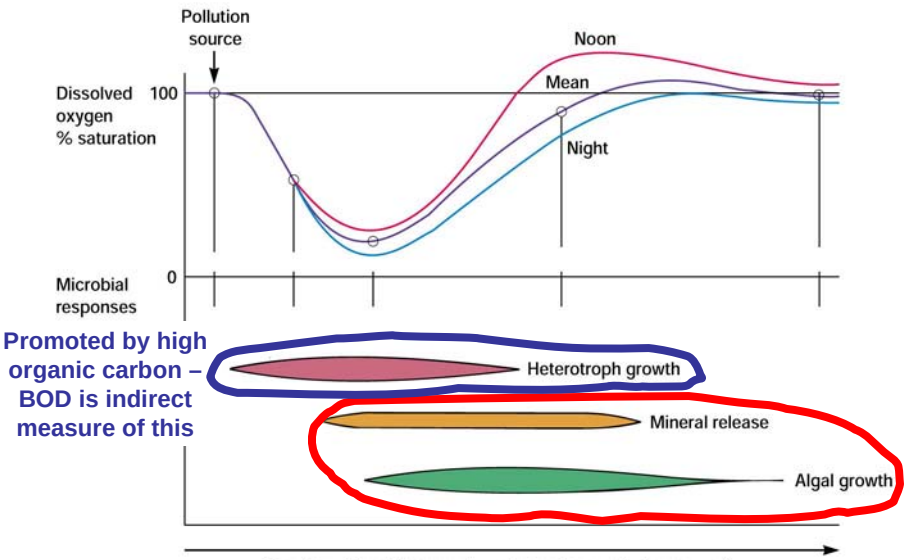
- quantifies all carbon
- organic matter oxidized at high temperature
- amount of CO_2 produced is measured
- fastest, but less informative

Chemical oxygen demand (COD)

- quantifies organic matter (except lignin)
- organic matter reacted with strong acid (permanganate)
- slower test
- high cost for chemical waste disposal

Biochemical oxygen demand (BOD)

- Indirect measure of amount of dissolved oxygen needed for microbial degradation of organic matter
  - can be affected by presence of ammonia
    - nitrogen oxygen demand (NOD)
      - use of oxygen during nitrification process
      - inhibited by addition of chemicals to sample



Promoted by high organic carbon – BOD is indirect measure of this

Secondary effect of organic carbon – or promoted directly by inorganic nutrients (especially N and P)

Objectives of wastewater treatment

Solids removed – removes physical pollution

****BOD less than 5 units** – removes the risk of anoxia due to heterotrophic activity

****Pathogen removal** – lowers disease risk

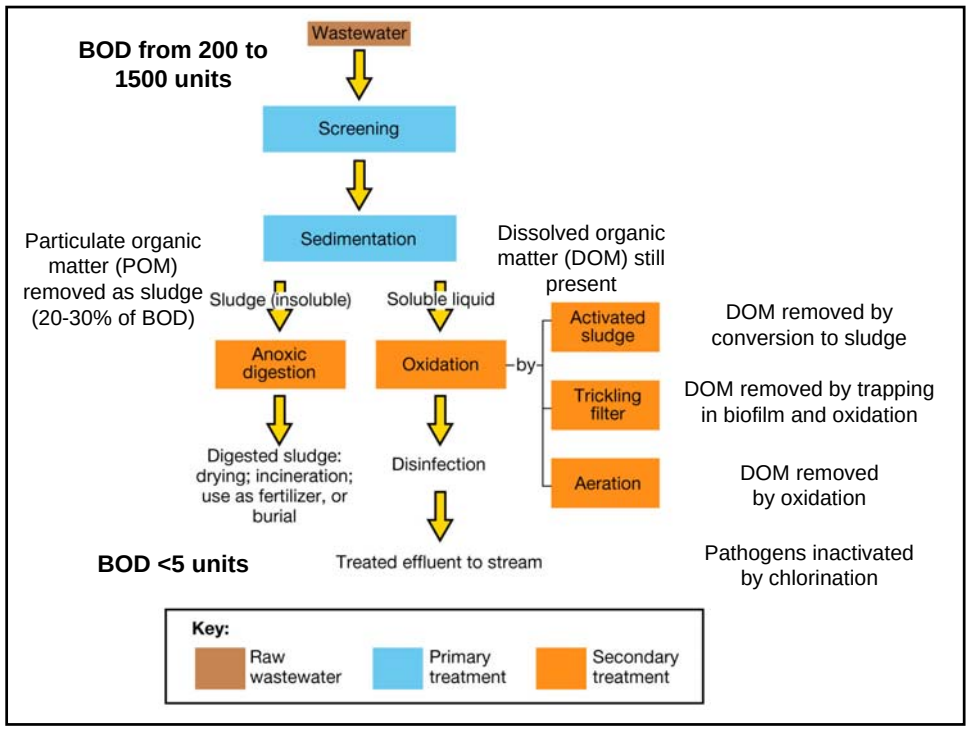
N lowered – lowers risk of algal blooms

P lowered – lowers risk of algal blooms

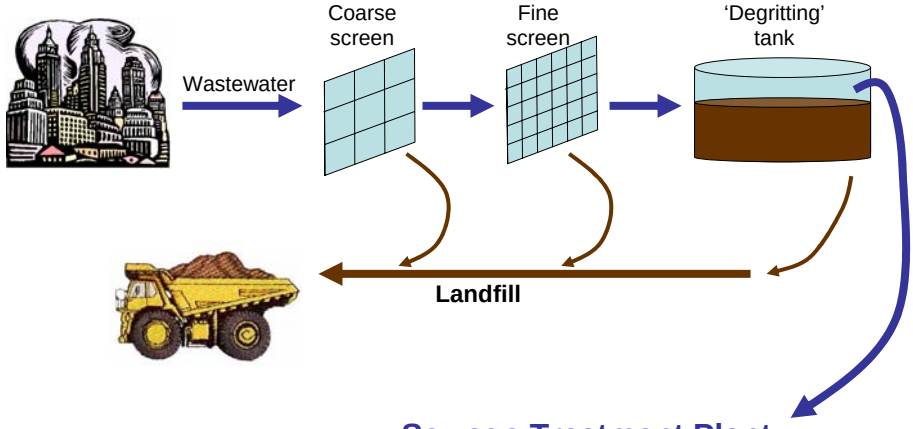
S lowered – could lead to high sulfur stream ecology

Table 29.7 Major Steps in Primary, Secondary, and Tertiary Treatment of Wastes

Treatment Step	Processes
Primary	Removal of insoluble particulate materials by settling, screening, addition of alum and other coagulation agents, and other physical procedures
Secondary	Biological removal of dissolved organic matter Trickling filters Activated sludge Lagoons Extended aeration systems Anaerobic digesters
Tertiary	Biological removal of inorganic nutrients Chemical removal of inorganic nutrients Virus removal/inactivation Trace chemical removal



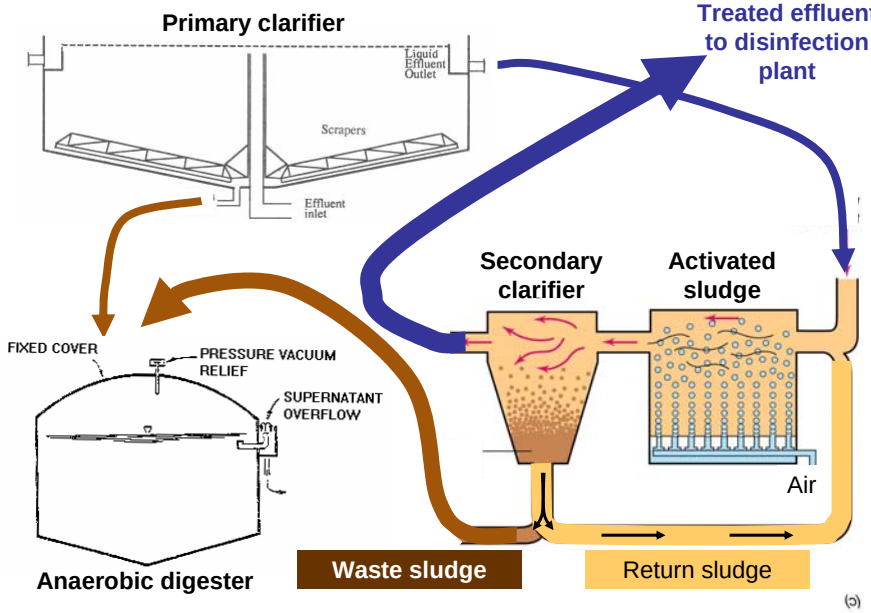
Primary Wastewater Treatment

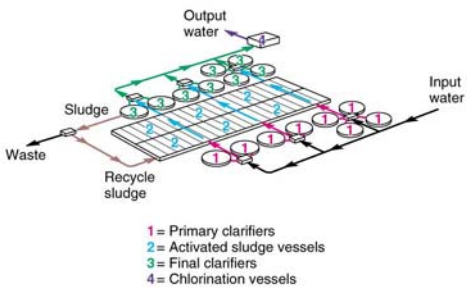


Sewage Treatment Plant

Influent has been pre-treated to remove large debris, sand, gravel etc. 'Organic solids' usually still suspended and pass through.

Sewage Treatment Plant (Primary to Secondary)





Primary clarifiers: settling tanks to collect heavier organic solids, floating scum and grease. The primary sludge is usually taken to an anaerobic digester or incinerator.

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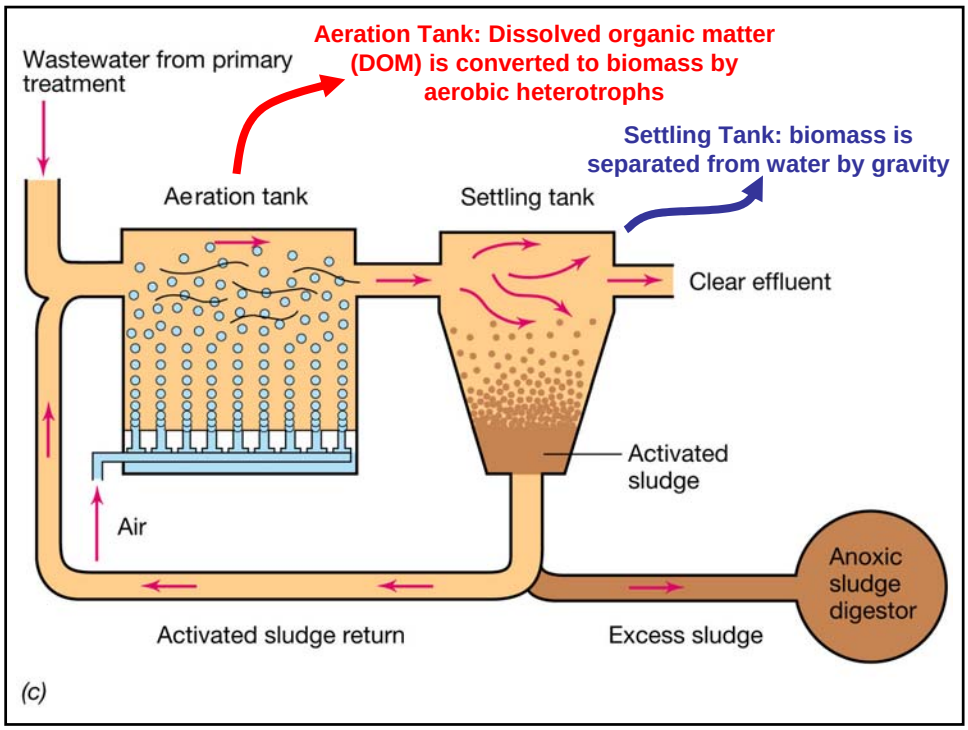
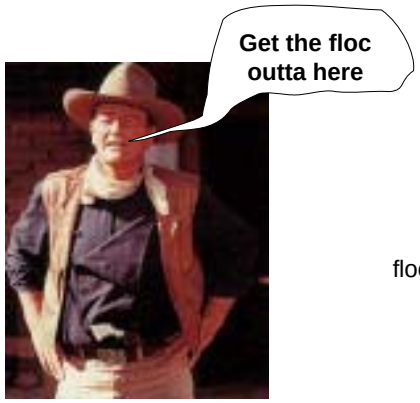
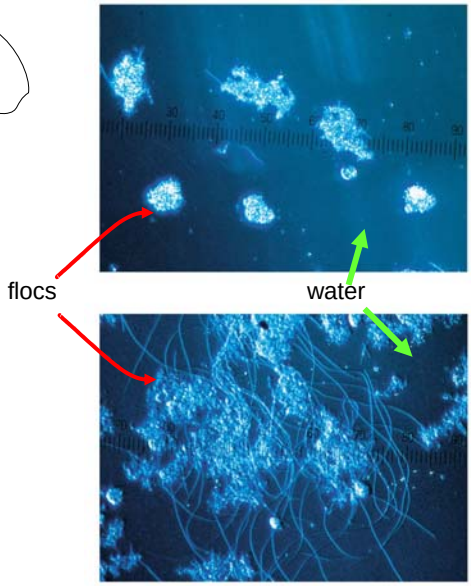


The secret to successful activated sludge treatment is separation of sludge from the water



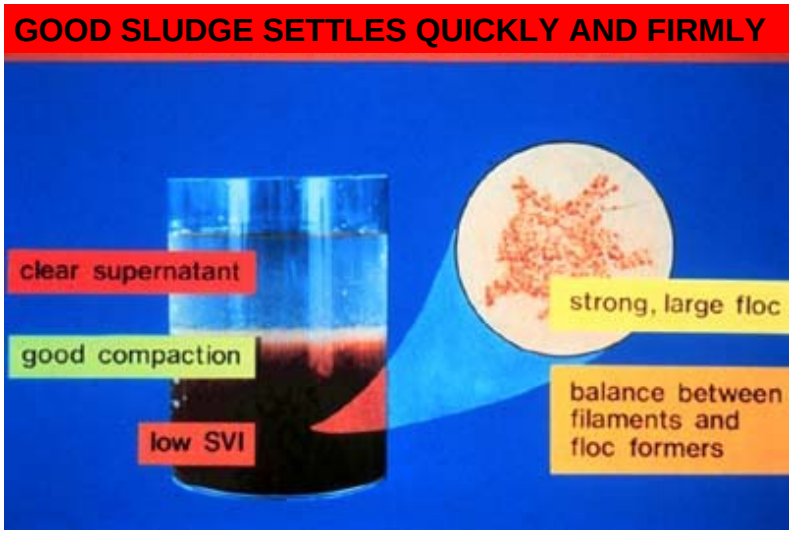


Sludges ain't sludges

Aeration is critical for growth and sludge quality.

The retention time is critical for the amount of growth.

The type of organism is critical for the 'floc form' of the sludge.



A ‘young’ sludge

Lots of white foam, pale brown or grey colour.

Poor settling qualities, most sludge is returned to the aeration tank.

Young sludge in settleometer

Inefficient separation of solids from water.

Effluent of poor quality.

Mature sludge: chocolate brown, minor amounts of foam. Usually good settling properties.

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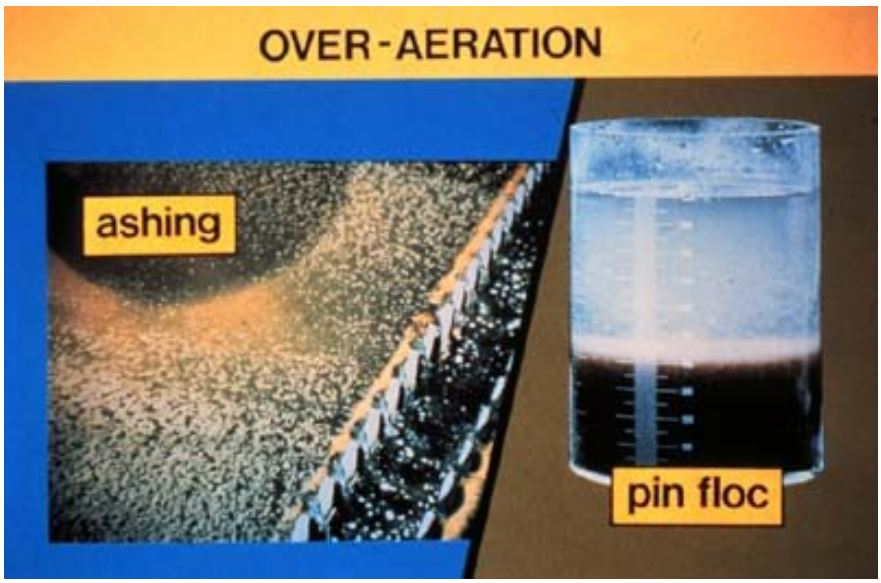
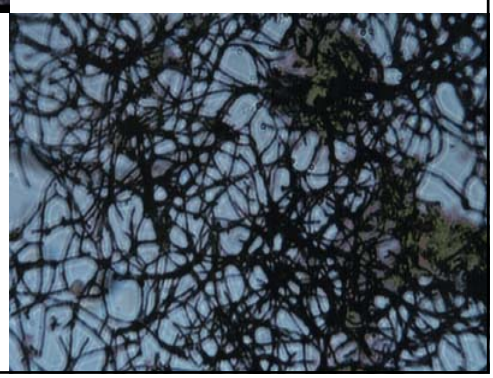
When sludges go bad

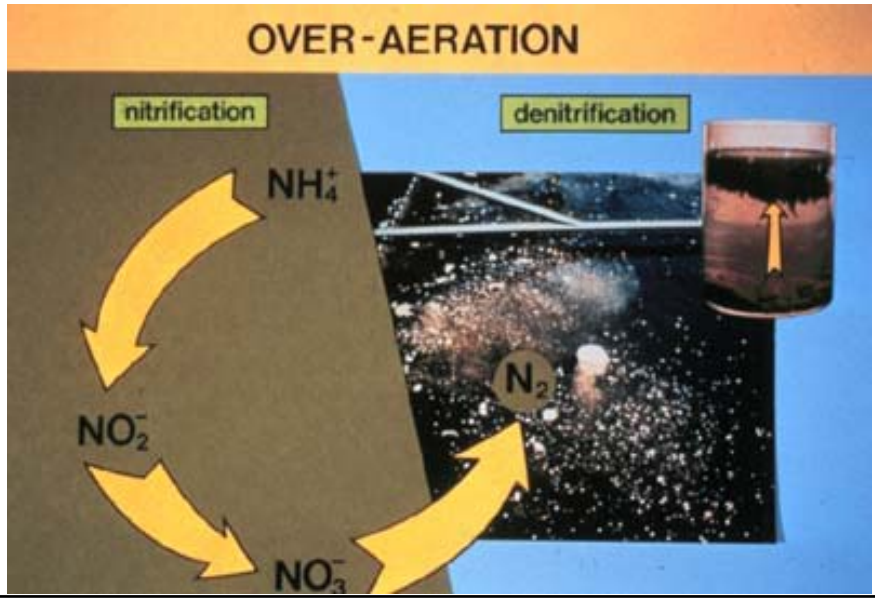


Bulking sludges can be dramatic resulting in overflow of foam from the tank.

Various filamentous actinomycetes (e.g. *Nocardia*) are the principal cause of bulking



Nitrification/denitrification may result from over-aeration. Leads to entrapment of gas bubbles in flocs and flotation.



Sludge may be further processed in an anaerobic digester

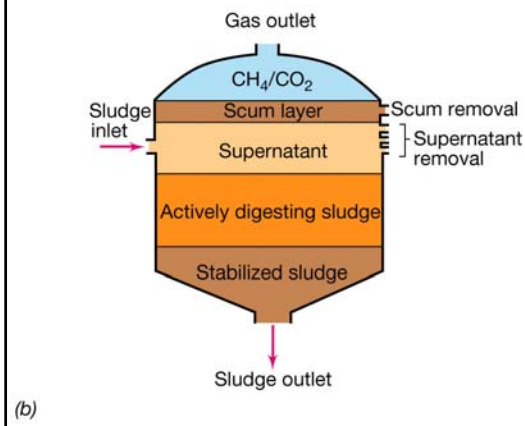
Biomass further consumed by microbial activity to CO2 and CH4.

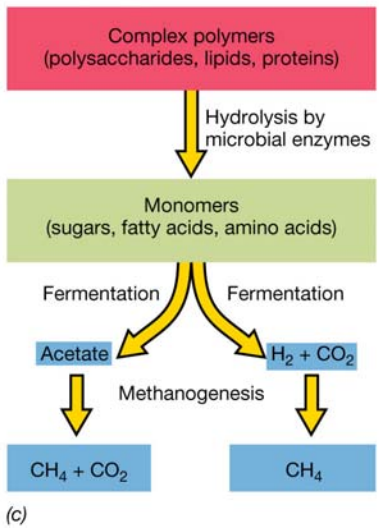
Reduces sludge volume.

CH4 can be harvested as energy source.

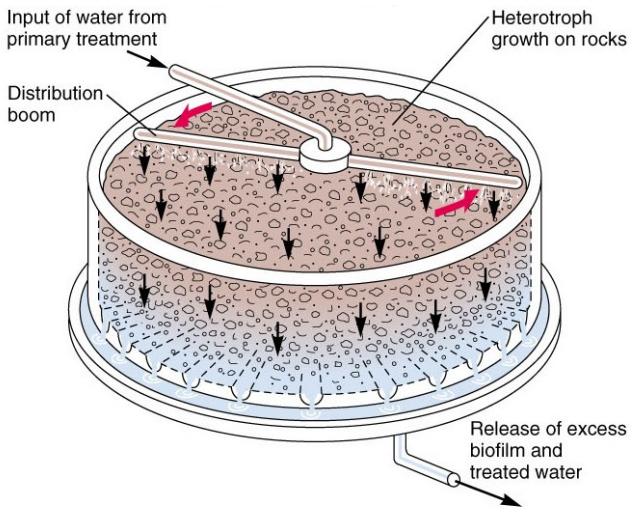
Sludge disposed of at sea or landfill.

May give long-term problems by concentration of parasite cysts or heavy metals.





Trickling filter systems: less sludge produced



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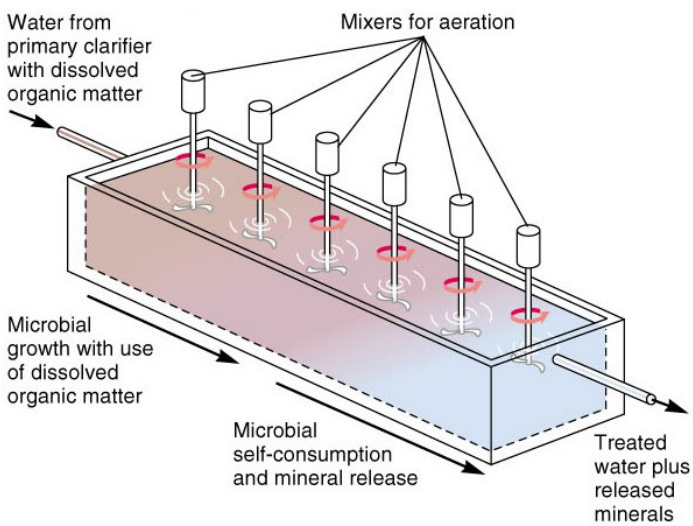
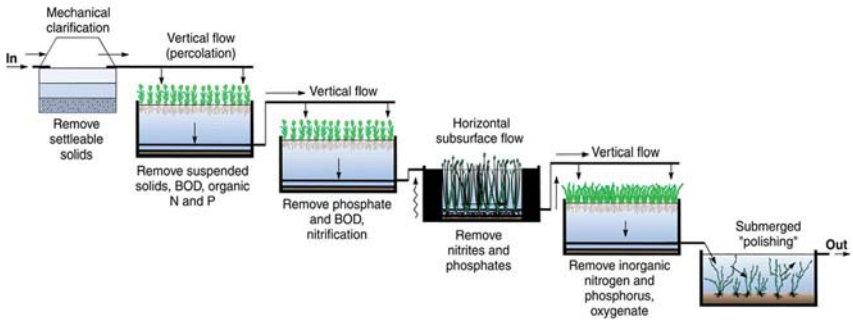
(a)

Extended aeration process – less sludge produced



Constructed wetlands



In various forms used to remove organic matter, phosphates, and metals.

Also used to treat mine drainage.

The most immediate and obvious effect of sewage pollution is anoxia due to stimulation of microbial growth.

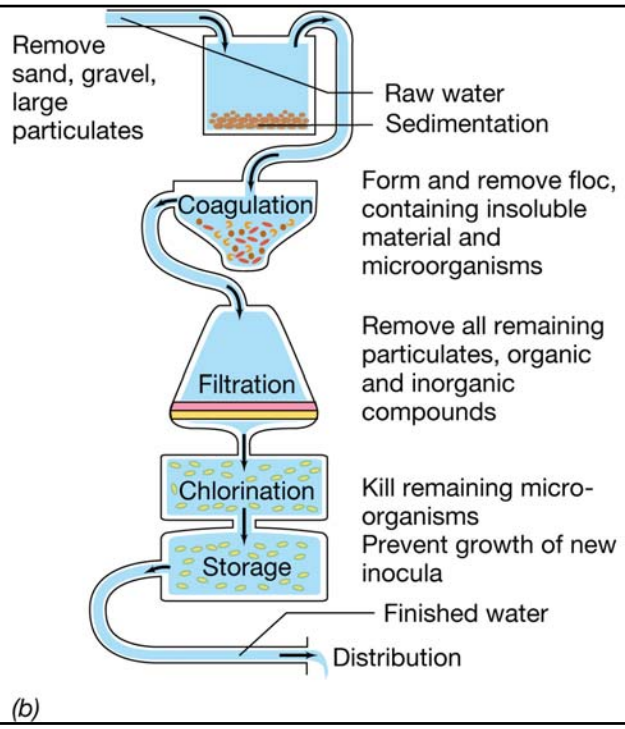
Consequently the focus of secondary sewage treatment is lowering of BOD.

NOTE: this does not remove N, P, or S and does not kill pathogens.

Much modern research is aimed at modifications of the activated sludge process to improve N, P and S removal.

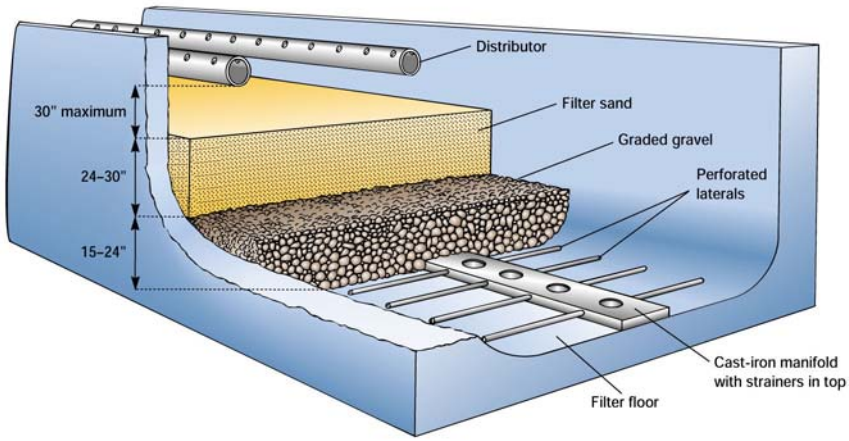
Waterborne Pathogens and Water Purification

- water purification
  - critical link in controlling waterborne disease



Rapid sand filter

Physical trapping of fine particles – removes up to 99% of bacteria



Problem microbes

- not consistently removed by coagulation, rapid sand filtration, and disinfection processes
  - *Giardia lamblia*
    - "backpackers disease"
    - slow sand filters effectively remove *Giardia* cysts
  - *Cryptosporidium*
    - small protozoan, with oocysts that escape usual purification schemes
  - *Cyclosporan*
    - protozoan that causes diarrhea
  - viruses
    - up to 99.9% are removed by usual purification schemes, but this not considered sufficient protection

Sanitary Analysis of Waters

Based on detecting organisms that indicate possible fecal contamination

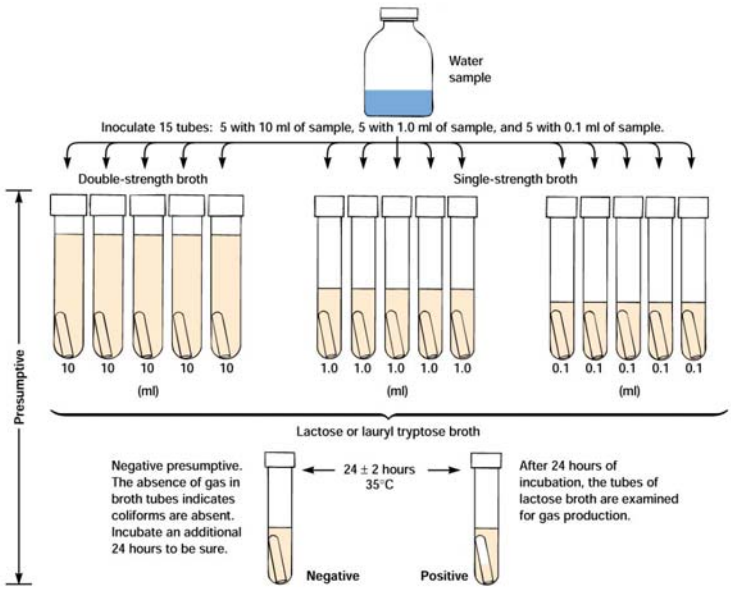
Properties of an indicator organism

- Suitable for analysis of all types of water
- Present whenever enteric pathogens are present
- Survives longer than hardiest enteric pathogen
- Does not reproduce in contaminated water
- Detected by highly specific and easy to perform test
- Harmless to humans
- Its level in water proportional to degree of fecal pollution

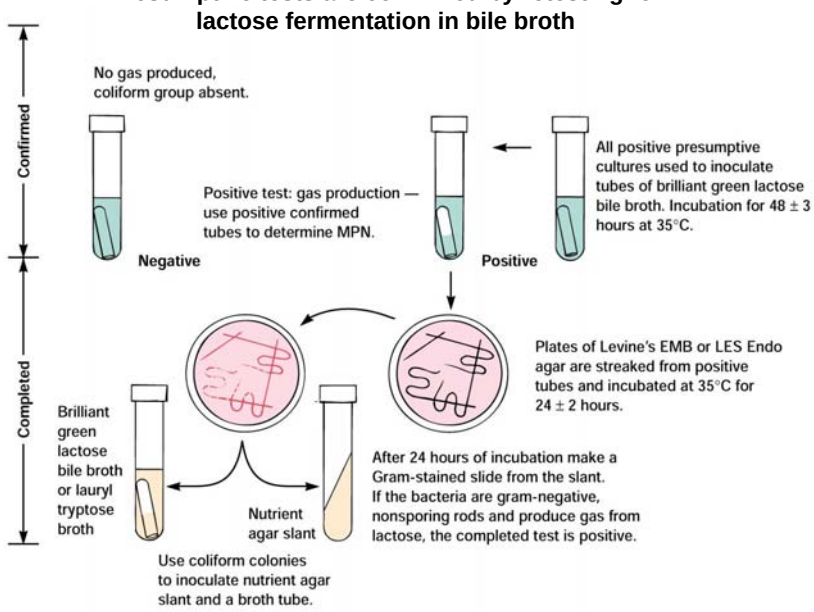
Coliforms and fecal streptococci

Coliforms ferment lactose (a mammalian sugar) to produce gas.

MPN uses different inoculum sizes to predict numbers.



Presumptive tests are confirmed by retesting for lactose fermentation in bile broth

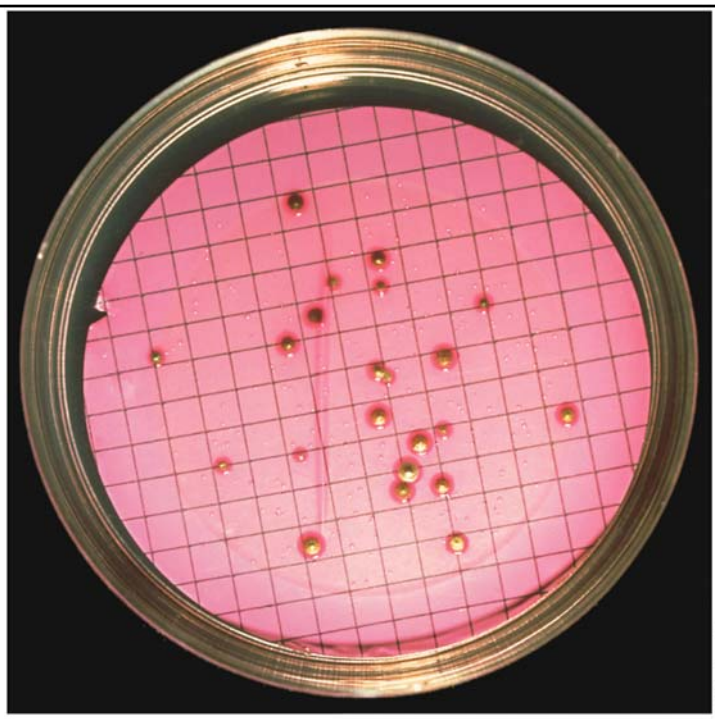


Other tests for indicator organisms

Membrane filtration technique

water passed through filter
↓
filter placed on surface of growth medium
↓
incubate
↓
count colonies

- used to detect total coliforms, fecal streptococci and fecal coliforms
  - from intestines of warm-blooded animals
  - detected by incubation at 44.5°C



T. D. Brock

Table 29.4 Advantages and Disadvantages of the Membrane Filter Technique for Evaluation of the Microbial Quality of Water

Advantages
Good reproducibility
Single-step results often possible
Filters can be transferred between different media
Large volumes can be processed to increase assay sensitivity
Time savings are considerable
Ability to complete filtrations on site
Lower total cost in comparison with MPN procedure
Disadvantages
High-turbidity waters limit volumes sampled
High populations of background bacteria cause overgrowth
Metals and phenols can adsorb to filters and inhibit growth

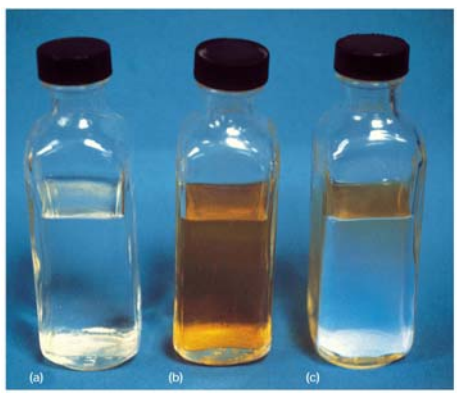
Source: Data from A. E. Greenberg, et al., *Standard Methods for the Examination of Water and Wastewater,* 16th edition, page 886, 1985. American Public Health Association, Washington, D.C.

Presence-absence test

- modification of MPN
- uses larger water sample (100 ml)
- sample added to lactose containing medium
  - contains pH indicator to detect acid production
- based on assumption that no indicator organisms should be present in 100 ml of water
- detects total coliforms and fecal coliforms

Defined substrate tests

- e.g., Colilert
- 100 ml sample added to medium containing ONPG and MUG
- detects total coliforms and fecal coliforms



Key points

Wastewater treatment has three stages: primary, secondary and tertiary.

Primary – removes solid matter

Secondary – removes dissolved organic matter

Tertiary – disinfects (sometimes also removes inorganic nutrients).

Activated sludge and anaerobic digesters are the major methods. Both are microbial processes.

Three products: ‘clean’ water – to river

gases (CO_2, CH_4) to atmosphere or harvested

Sludge – to landfill