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AUTHOR Carnegie, John W.
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ABSTRACT

This unit provides an introduction to basic concepts which are applicable to all biological treatment systems. It consists of three lessons which focus on: the microorganisms found in biological systems; the factors that affect the growth and health of biological systems; and the interrelationship between groups of microorganisms, their competition, predominance, and symbiosis. The instructor's guide for the unit includes: (1) an overview of the unit; (2) lesson plans; (3) lecture outlines (keyed to a set of slides designed for use with the lessons); (4) a student worksheet for each lesson (with answers); and (5) two copies of a final quiz (with and without answers). (JN)

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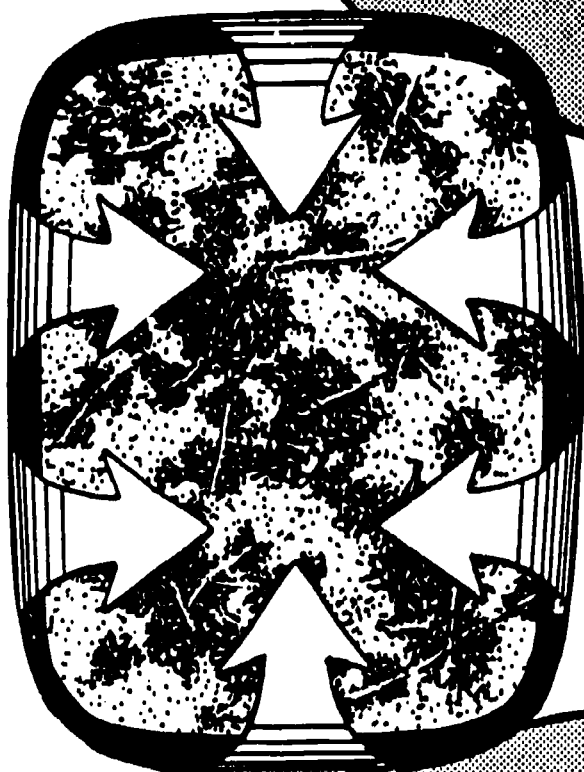
Biological Treatment Process Control

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Biological Concepts



Instructor's Guide

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BIOLOGICAL TREATMENT PROCESS CONTROL

CONCEPTS OF BIOLOGICAL TREATMENT

INSTRUCTOR'S GUIDE

Text Written By:
John W. Carnegie, Ph.D.
Linn-Benton Community College
Albany, Oregon

Edited By:
John W. Carnegie, Ph.D.
Project Director
Linn-Benton Community College
Albany, Oregon

Instructional Design By:
Priscilla Hardin, Ph.D.
Priscilla Hardin Instructional Services
Corvallis, Oregon

Developed Under:
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CONCEPTS OF BIOLOGICAL TREATMENT

Instructor's Guide

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CONCEPTS OF BIOLOGICAL TREATMENT

Overview

This section is intended to be used introductory to the more specific biological treatment processes that follow. Material in this section is basic and applies to all biological treatment systems. This section could also be used in conjunction with single lessons. The section is presented in three lessons: #1 The Microorganisms; #2 Environmental Factors; and #3 Population Dynamics. Lesson 1 is a survey of the microorganisms found in biological systems. Lesson 2 deals with the factors that affect the growth and health of biological systems. Lesson 3 covers the interrelationship between groups of microorganisms, their competition, predominance and symbiosis.

Lesson Plans

Lesson 1 - The Microorganisms

- Have students read text material ahead of time, if possible
- Lecture from outline with slide support (about 45 min)
- Assign worksheet (10 min)
- Correct and discuss worksheet (15 min)

Lesson 2 - Environmental Factors

- Have students read text material ahead of time, if possible
- Lecture from outline with slide support (about 30 min)
- Assign worksheet (10 min)
- Correct and discuss worksheet (10 min)

Lesson 3 - Population Dynamics

- Have students read text material ahead of time, if possible
- Lecture from outline with slide support (about 30 min)
- Assign worksheet (10 min)

- Correct and discuss worksheet (10 min)
- Assign final quiz (15 min)

CONCEPTS OF BIOLOGICAL TREATMENT

Lecture Outlines

Lesson 1 - The Microorganisms

Slide

#1 & #2	Title & Credit Slides
#3	The Biological System The flow The sound The "dirty, foaming water" The "Bugs"
#4, #5, #6	To "See" the "Bugs" - Consider the Objectives of Wastewater Treatment
#7	Protect receiving stream Prevent oxygen depletion
#8	Reduce food material in waste The "Bugs" use food in waste
#9	Oxygen supplied
#10	"Bugs" eat and eat Clean water discharged Drawback - "Bugs" grow - too many
#11, #12	Excess must be separated and disposed of The Operator's main job
#13, #14	Keep "bugs" comfortable and happy Must have enough to eat Correct environment Free of disease Free of poison Free of predators

What are these "bugs"?

#15

A mixed biological system

Workers

Troublemakers

Freeloaders

#16

You can find -

Bacteria

Protozoa

Viruses

Fungi

Algae

Other higher forms

#17

Bacteria

Most numerous

Most important to treatment

Single-cells

1 micron (micrometer; 10^{-6} m) long

#18

Shapes

cocci - spheres

bacilli - rods

spirals

#19

Motility

gliding

flagella

#20

Capsules

#21

Protozoa

Microscopic animals

Single-cells

Much larger than bacteria

More complex than bacteria

#22

4 types

#23

Amoeba (Sarcodina)

no definite shape

false feet

amoeboid movement

I-CB-4

- #24 Ciliates (Ciliata)
Free-swimming
cilia
ovoid to pear-shaped
- #25 Stalked
cup-shaped cell with a
stalk
cilia around "cup"
- #26 Flagellates (Mastigophora)
Flagella
Free-swimming
- #27 Suctoreans (Suctoria)
Rigid tentacles
Stalked
- #28 Viruses
Strictly parasitic
Lack metabolic systems
Extremely small
Genetic material and a protective coat
- #29 Fungi
Similar to bacteria
- #30 Algae
Microscopic plants
Photosynthetic
- #31 Higher forms
Rotifers
Snails
Worms
Insect larvae and adults
Crustaceans
- #32, #33 Review Slides

Lesson 2 - Environmental Factors

Slide

#1 & #2	Title and Credit Slides Review of Biological Process
#3	What does the operator really see? Population of mixed microorganisms
#4	Organisms consume organics, use oxygen and remove dissolved and suspended solids before they get to the receiving stream
#5	The health of the population depends on several factors: Oxygen Nutrients Flow Temperature pH Toxics
#6	Outline Slide - Food
#7	The food (nutrients) comes from many sources in the collection system
#8	The nutrients (organic food) directly affect the amount of growth; number of microorganisms More cells with more food Typical batch growth curve
#9	Increase in microorganisms vs time after a single dose of food
#10	Log growth phase - exponential growth unlimited by food supply
#11	Declining growth phase - food starts to limit the rate of cell increase

- #12 Endogenous growth phase -
food is limiting;
bacteria use stored nutrients
to survive
- #13 Food to microorganism ratio -
F/M ratio - high at first then
become small
- #14 Other nutrient requirements
How easily are the organics
used?
Inorganic minerals and trace
elements
- #15 Outline Slide - Hydraulic Load
- #16 Affects solids and nutrient concentration
Low flow - high concentration
High flow - low concentration
- #17 Affects detention time
Low flow - long DT
High flow - short DT
- #18 Outline Slide - Oxygen
- #19 Aerobic conditions - use free,
dissolved oxygen
- #20 Anaerobic conditions - use chemically
bound oxygen
- #21 Facultative - aerobic or anaerobic
conditions - bacteria can use either
form of oxygen
- #22 Under aerobic conditions aerobic
and facultative organisms present

Under anaerobic conditions,
anaerobic and facultative
organisms present
- #23 If oxygen is present the facultative
organisms will use aerobic respira-
tion and convert organics at a
faster rate

- #24 Outline Slide - Temperature
- #25 Three temperature growth ranges
- thermophilic
 - mesophilic
 - psychrophilic
- #26 Temperature vs growth rate
- Organisms have an optimum growth temperature
- #27 Efficiency increases as temperature increases
- Growth rate doubles for each 10 degrees increase
- #28 Outline Slide - pH
- #29 Most organisms prefer pH near neutral
- Fungi grow well at lower pH
- #30 pH vs growth rate
- Organisms have an optimum growth pH
- #31 Outline Slide - Toxics
- #32 Toxics can inhibit growth or completely stop growth
- #33 Review Slide of growth factors
- #34 All of these factors affect the bio-system
- #35 The operator must control these growth factors in order to keep the bio-system going down the path of optimum treatment
- #36 It is only with a knowledge of these growth factors that the operator can truly "see" what is going on in the treatment plant

Lesson 3 - Population Dynamics

Slide

#1 & #2

Title and Credit Slides

#3

Population Dynamics - The changes that occur within the microorganism population as a result of environmental factors

#4

Predominance - The organisms that get the most to eat and do it the fastest and most efficiently will predominate

Efficiency

#5

Aerobic metabolism is more efficient; aerobic organisms will predominate when free oxygen is present

#6, #7, #8

Anaerobic metabolism uses bound oxygen; less efficient

Competition

#9

If there is one group of organisms alone they will use food at a certain efficiency

#10

If a second group is present the one that is the most efficient at converting the same food will predominate

#11

If two organisms are present the one that converts food the fastest will predominate

#12

If two groups use the same food but one is much more efficient the second may get left out all together

#13

unless they can switch to a second choice of food. Then they will survive also.

Growth Pressures

#14

Temperature

A shift in temperature may favor the increase in one type of organism

Secondary Predominance -
After the primary organisms have
partially metabolized the material
the less specialized organisms
can deal with the material

#23

Dynamic Equilibrium

Keeping a changing system in balance

#24

Energy in must equal the energy
going out of the system

#25

Review of Population Dynamics

CONCEPTS OF BIOLOGICAL TREATMENT

Answers to Worksheet 1 - The Microorganisms

1. We use the term "bugs" to mean all of the microorganisms in the biological treatment system.
2. The primary objective of wastewater treatment is to:
prevent the degradation of the receiving stream by reducing the amount of organic material discharged to it.
3. When organic material is allowed to enter a stream the natural biological activity in the stream depletes the oxygen.
4. In biological treatment processes, with the exception of anaerobic digestion, the bugs or microorganisms are supplied with air (oxygen) so they can consume the food in a controlled environment.
5. The only drawback to the bugs eating and eating is that they create excess solids (cells).
6. Name the five major groups of bugs typically found in biological treatment systems:
bacteria
protozoa
viruses
algae
fungi
7. The microorganism which is responsible for the majority of the stabilization activity is the bacteria.
8. On the average bacteria are about 1 micron wide.
9. The three structural shapes of bacteria are:
rod (bacillus)
spheres (cocci)
spirals

10. The slimy, gummy coat around some bacteria is called the capsule.
11. The protozoa are a group of microscopic animals.
12. The four major groups of protozoa found in biological treatment systems are:
- amoeba
 - ciliates
 - flagellates
 - suctoria
13. Amoeba move about with the use of pseudopods or false feet.
14. The two types of ciliates are the free-swimming and the stalked.
15. The Mastigophora move about with the use of flagella.
16. The suctoria resemble the ciliates except they have tentacles instead of cilia.
17. The viruses are strictly parasitic because they have no enzyme systems.
18. The algae are true photosynthetic plants.
19. Four types of "higher" animal forms are frequently found in and around biological systems. These include:
- insect larvae
 - rotifers
 - worms
 - snails

CONCEPTS OF BIOLOGICAL TREATMENT

Answers to Worksheet 2 - Environmental Factors

1. The main "objective" of the microorganisms in the treatment system is to obtain food and energy for maintenance and reproduction.
2. The environmental factors that cause the microorganisms to react in some way are often called environmental pressures.
3. The food materials available to the microorganisms are mostly organic materials.
4. The phase of a bacterial growth curve in which the bacteria are increasing at a maximum rate is called the log growth phase.
5. The phase of the growth curve in which food is no longer available and the bacteria are utilizing energy stored within their own cells is called the endogenous phase.
6. The amount of liquid entering the system is called the hydraulic load.
7. Most organisms in the biological treatment processes use free dissolved oxygen. These are called aerobic organisms.
8. At times bacteria carry out anaerobic respiration in which they use chemically bound oxygen.
9. Many bacteria in biological systems are capable of using either aerobic or anaerobic respiration. These organisms are said to be facultative.
10. Microorganisms that thrive at about 35 degrees Celsius are called mesophilic organisms.
11. Microorganisms that prefer relatively high temperatures are called thermophilic organisms.
12. Most microorganisms in the biological treatment systems do well at a pH in the range of 6.5 to 8.5.
13. One group of microorganisms tend to prefer lower pH and high carbohydrate conditions. These are the fungi.
14. Large amounts of toxic or poisonous materials could actually kill (destroy) all the microorganisms in the system.

CONCEPTS OF BIOLOGICAL TREATMENT

Answers to Worksheet 3 - Population Dynamics

1. The term population dynamics is used to describe the continuous fluctuations that occur with the many types of microorganisms in the system.
2. Predominance is established by the microorganisms that derive energy from the available food most efficiently.
3. The process of converting energy in the organic food to usable energy is called respiration.
4. As a result of the energy derived aerobically from the organics, new cells are produced along with two by-products: carbon dioxide and water.
5. Anaerobic respiration produces different by-products depending on the source of bound oxygen used. These are:
for nitrate bound oxygen = nitrogen gas (N₂)
for sulfate bound oxygen = hydrogen sulfide (H₂S)
for carbon dioxide oxygen = methane (CH₄)
6. Anaerobic respiration will derive only about 15 percent as much energy from the same organics as from aerobic respiration.
7. The food (organics) provides energy and also raw (building) material needed to produce new cells.
8. Efficiency of converting food to usable energy can be accomplished either by converting organics rapidly or completely.
9. Name three growth pressures other than oxygen and food that can affect population predominance.

temperature, pH, sunlight, salinity, toxic materials
10. At times one organism will prey upon a certain type of organism and at the same time be preyed upon by a third type. This is an example of the food chain.
11. Organisms at the bottom of the food chain are typically smaller, but in total have a larger mass.

12. Protozoa can be used to observe the conditions of the bacterial population because the protozoa feed on the bacteria.
13. During photosynthesis the algae utilize sunlight, inorganics, and carbon dioxide to produce new algae cells and oxygen.
14. The algae are provided with the inorganics and carbon dioxide by the bacteria in the system.
15. A healthy population of bacteria can be developed to act as primary predominance on almost any type of waste material.

CONCEPTS OF BIOLOGICAL TREATMENT

Final Quiz

MATCHING: Choose the best answer(s) for each of the following questions and place an "X" in the appropriate space.

1. When microorganisms in a treatment plant come into contact with food (organic material), they:
 a. eat and reproduce
 b. become aerobic
 c. become anaerobic
 d. die
 e. settle

2. Which of the following characteristics does NOT describe logarithmic growth:
 a. microorganisms grow and multiply at their maximum rate
 b. food is in excess
 c. continues until food begins to be used up
 d. common when there is a high F/M ratio (food:microorganism)
 e. slow growth rate

3. Declining growth occurs when:
 a. food is almost used up and growth rate slows down
 b. food is in excess
 c. microorganisms grow and multiply at their maximum rate
 d. microorganisms are in endogenous respiration
 e. there is a high F/M ratio (food:microorganism)

4. Endogenous growth phase occurs when:
 a. there is a low F/M ratio
 b. food is in excess
 c. microorganisms grow and multiply at their maximum rate
 d. there is a high F/M ratio
 e. microorganisms use up food reserves that is stored inside their cells

5. "Hydraulic load" refers to:

- a. the amount of food entering a system
- b. the amount of water entering a system
- c. the weight of water in a system
- d. the weight of organic material in a system
- e. the length of pipe in the collection system

6. Some bacteria obtain the oxygen they need from chemically bound compounds, and in fact, can't grow when free oxygen is present. These organisms are called:

- a. anaerobes
- b. aerobes
- c. microbes
- d. facultative
- e. filaments

7. Temperature is a growth pressure. As a general rule, as temperature goes up:

- a. growth rate slows down
- b. growth rate speeds up
- c. growth rate stays the same
- d. pH goes up
- e. pH goes down

8. Microorganisms that grow best at high temperatures are called:

- a. thermophillic
- b. mesophillic
- c. psychrophillic
- d. anaerobic
- e. aerobic

9. pH is a term which describes how acidic or basic a solution is. pH 7 is considered:

- a. acidic
- b. basic
- c. neutral

10. As waste materials break down in a stream:

- a. temperature goes down
- b. fish reproduce
- c. dissolved oxygen is consumed
- d. temperature goes up
- e. dissolved oxygen goes up

11. What group of microorganisms do the most work in a secondary treatment plant?

- a. viruses
- b. fungi
- c. worms
- d. bacteria
- e. protozoa

12. Bacteria are:

- a. single-celled
- b. multi-celled
- c. always aerobic
- d. visible to the naked eye
- e. always the same shape

13. Rod-shaped bacteria are also called:

- a. coccus
- b. spirillum
- c. bacillus
- d. vibrio
- e. sarcina

14. Protozoa are:

- a. usually about a hundred times bigger than bacteria
- b. about the same size as bacteria
- c. photosynthetic
- d. always non-motile
- e. responsible for doing the most work in secondary treatment

15. Which of the following does NOT apply to free-swimming ciliates:

- a. move with flagella
- b. usually ovoid to pear-shaped
- c. single-celled
- d. have fine "hair-like" appendages for locomotion
- e. are larger than bacteria

16. Which of the following does NOT apply to stalked ciliates:

- a. usually attached to something in the water (substrate)
- b. are single-celled
- c. may be colonial
- d. are common in biological treatment systems
- e. use flagella for locomotion

17. Which of the following does not apply to flagellates:

- a. also called Mastigophora
- b. are usually ovoid to pear-shaped
- c. single-celled
- d. use flagella for locomotion
- e. are covered with fine "hair-like" appendages for feeding

18. Which of the following characteristics does NOT apply to a virus:

- a. are strictly parasitic and lack the metabolic systems necessary to obtain energy on their own, or even reproduce by themselves.
- b. they steal energy and raw materials of their host.
- c. are about the same size as bacteria.
- d. are a hundred to a thousand times smaller than bacteria.
- e. they do very little work in secondary treatment

19. When one type of organism derives energy more efficiently than another type

- a. anaerobic respiration is occurring
- b. aerobic respiration is occurring
- c. the pH is too high
- d. predominance will occur
- e. one will die completely

20. By-products of anaerobic respiration include

- a. nitrogen gas
- b. nitrate
- c. hydrogen sulfide
- d. methane gas
- e. all of the above

21. Anaerobic respiration will derive about _____% as much energy from the same organic material as aerobic respiration.

- a. 5
- b. 10
- c. 15
- d. 25
- e. 50

22. Which of the following are environmental pressures that can cause predominance to shift?

- a. temperature
- b. pH
- c. sunlight
- d. salinity
- e. toxic materials

23. In the prey-predator relationship known as the food chain:

- a. those at the top of the chain are the ultimate prey.
- b. protozoa are lower than bacteria and algae.
- c. organisms at the bottom are typically smaller.
- d. those at the top are dependent upon those at the bottom.
- e. the mass of those at the bottom is greater than that of those at the top.

24. Which of the following is NOT true about the protozoa population dynamics in activated sludge?

- a. protozoa feed on bacteria
- b. amoeba and flagellates are found under high food availability
- c. rotifers are found at the same time that the bacterial population is maximum.
- d. stalked-ciliates begin to predominate as the food supply begins to diminish.
- e. free-swimming ciliates predominate at the same time as the bacteria are at maximum.

25. In the algae-bacteria inter-relationship

- a. algae use sunlight for energy
- b. algae produce oxygen
- c. bacteria use organics
- d. bacteria provide dissolved inorganics, and carbon dioxide
- e. bacteria use carbon dioxide

CONCEPTS OF BIOLOGICAL TREATMENT

Answers to Final Quiz

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