University Curriculum Development for Decentralized Wastewater Management

Aerobic Treatment of Wastewater and Aerobic Treatment Units

Suggested Course Materials

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Aerobic Treatment of Wastewater and Aerobic Treatment Units
Suggested Course Materials

Table of Contents

Aerobic Treatment of Wastewater and Aerobic Treatment Units
Overview

This module provides specific information about aerobic treatment units as a means of providing rapid oxidation of carbonaceous and nitrogenous compounds found in domestic wastewater. While the module is directed toward engineering students, it is fully anticipated that most science-based undergraduate students will be able to understand and apply the concepts contained within the module

Overall, the objectives of this module are to provide a review of the biochemical oxidation of soluble and colloidal organic compounds using aerobic microbial digestion, provide descriptions of various engineered systems that maintain high-rate digestion, and provide an understanding of the operation and maintenance required to keep these system functional. This module is divided into two sections: (1) the aerobic treatment process and (2) aerobic treatment units. The design of biological treatment units can be roughly divided into two categories: suspended-growth and attached-growth. The bio-processes used to convert organic carbon into inorganic carbon are the same in both categories. Citations are provided in the module to direct the reader to textbooks that can provide a more rigorous explanation about processes involved in biological wastewater treatment.

Onsite and decentralized wastewater management systems can take advantage of technologies developed for centralized municipal treatment systems. Aerobic treatment units can be an option when insufficient soil is available for the proper installation of a traditional septic tank and soil absorption area. Increasingly, homes and small commercial establishments are being constructed in rural areas with no central sewer and on sites with marginal soils. In these situations, wastewater must receive a high-level of pretreatment before being discharged into the soil environment. Depending on local regulations, the use of an aerobic treatment unit may allow for reductions in the required infiltration area and/or reduction in depth to a limiting soil layer. This ability to produce a high-quality effluent may open sites for development that were previously unsuitable because of soil.

The instructor is encouraged to tailor the material in this module to best fit the objectives of the class. This module is part of an overall curriculum developed for teaching the concepts of decentralized wastewater management and treatment. While this module is intended as a standalone source of information about aerobic treatment units, for a more complete understanding of the engineered-processes references are available to direct the students to more rigorous text.

Aerobic Treatment of Wastewater and Aerobic Treatment Units
Agenda

This module is one of several modules that can be combined to form a graduate or undergraduate level course (or courses) in the decentralized treatment of domestic wastewater. Depending on the population of students within the class, the following are recommendations on the delivery of this material.

Recommendations

- For graduate engineering students who have backgrounds in water and wastewater units processing,
  - One lecture period that focuses on the packaging of aerobic treatment units for onsite application, the certification of ATUs, and the operation and maintenance of ATUs.
  - Require the reading of the module text material before the lecture.

- For non-engineering graduate students (who do not have a background in water and wastewater unit processing) and for senior-level engineering students who have completed a water and wastewater unit processing course,
  - two lecture periods
    - the first period reviewing suspended-growth and attached-growth bioreactors, methods of oxygen transfer, and environmental conditions
    - The second period should focus on the packaging of aerobic treatment units for onsite applications, the certification of ATUs, and the operation and maintenance of ATUs.
  - Require the reading of the module text material before the lecture.

- For science-based undergraduate students,
  - four lecture periods
    - The first period reviewing biochemical oxygen demand (both carbonaceous and nitrogenous), and the stoichiometry of microbial degradation of organic compounds.
    - The second period should focus on suspended growth and attached-growth bioreactors (using background material from unit processing textbooks).
    - The third period should methods of oxygen transfer, influent and effluent characteristics, and expected daily flows.
    - The forth period would focus on ATUs as part of the overall treatment train, investigate the operational issues, and explore the packaging of ATUs for simple installation.

Aerobic Treatment of Wastewater and Aerobic Treatment Units
Outline

I. Introduction

II. Aerobic Treatment Processes
- A. Biochemical Wastewater Treatment
- B. Natural Process
- C. Microbial Metabolism
  - 1. Fermentation and Respiration
  - 2. Biosynthesis
  - 3. Endogenous Respiration
- D. Environmental Effects
  - 1. Temperature
  - 2. Food to Microorganism Ratio (F/M)
  - 3. Acid Concentration

III. Aerobic Treatment Units
- A. Process Description
- B. Typical ATU Configurations
  - 1. Extended Aeration
  - 2. Suspended Growth Bioreactors
  - 3. Attached-Growth Bioreactors
  - 4. Rotating Biological Contactor (RBC)
  - 5. Sequencing Batch Reactor Systems or Periodic Processes
    - a. Process Description
    - b. Nitrogen Removal in SBR
    - c. Typical Applications
  - 6. Proprietary Systems
  - 7. Oxygen Transfer
  - 8. ATU Influent
  - 9. Hydraulic and Organic Loading
  - 10. Flow Equalization
  - 11. Nitrogen and Phosphorus in Wastewater
- B. Operational Issues
  - 1. Start Up
  - 2. Typical Problems
  - 3. Biomass (Sludge) Wastage

C. Performance Certification
   1. Mechanical Evaluation
   2. Performance Evaluation

IV. Summary

Aerobic Treatment of Wastewater and Aerobic Treatment Units

Goals

The primary goal of this module is for the student to understand how aerobic treatment technologies (which are well established in large, centralized systems) can be scaled-down for use in decentralized wastewater management systems. Before a student can appreciate aerobic wastewater treatment, that student must understand the consequences to the environment if high oxygen-demand wastewater enters a natural water body. The primary purpose of aerobic treatment systems is to remove the oxygen demand from the wastewater.

The students of this module should be pre-professionals who are interested in water resources engineering, environmental and public health, or water quality. Each of these groups has different needs within this topic. This module is not rigorous enough to provide the engineering student a complete background in the design of biological unit processes. Therefore, it is expected that engineering students will have had an introductory course in biological treatment theory, including first-order kinetics, reactor hydraulics, and wastewater characteristics. For the engineers, this module is intended to introduce them to the design parameters that allow aerobic processes to be scaled for onsite or small-scale applications.

Science-based students need to understand the concepts of aerobic treatment so that they can know the proper application of these technologies. These students must understand that aerobic treatment systems are biological processes, and as such, care must be taken to prevent systems upsets. Upsets occur when toxic substances are passed through the reactor, when heavy-water use flushes microbes out faster than they can reproduce, and when the microbial food supply is reduced and the population is reduced.

Aerobic Treatment of Wastewater and Aerobic Treatment Units
Learning Objectives

1. Upon completing this module, students will have a fundamental understanding of concepts pertinent to wastewater treatment that will enable them to more fully understand processes used for wastewater treatment, disposal, and reuse.

2. After completion of this module students should be prepared for more in-depth study available in other curriculum modules.

Aerobic Treatment of Wastewater and Aerobic Treatment Units
Prerequisites

The construction of this module presumes some background in math, chemistry and biology. For senior-level water-resources engineering students, a junior-level water and wastewater biological unit processing course should be a prerequisite.

For science-based undergraduate, suggested prerequisites should include freshman chemistry, freshman biology (which should include microbial metabolism), and college algebra.

Aerobic Treatment of Wastewater and Aerobic Treatment Units
Evaluation Form

Reviewer: _____

We are requesting your assistance in reviewing the modules developed through the On-Site Consortium curriculum project. Please complete the following form while reviewing the materials

With a rating scale of 1 (Disagree) to 5 (Agree), please respond to the following questions

Review of printed materials:

	Disagree Agree
The text completely covers the topic area.	1 2 3 4 5
The visuals completely cover the topic area.	1 2 3 4 5
The discussion notes completely cover the topic area.	1 2 3 4 5

Review of learning objectives:

I gained a better understanding of how ATU's function.	1 2 3 4 5
I gained a better understanding of aerobic wastewater treatment theory.	1 2 3 4 5
I gained a better understanding of how maintenance and operation of ATU's.	1 2 3 4 5

What specific recommendations would you provide for the text? _____
_____
_____
_____

What specific recommendations would you provide for the visuals._____?
_____
_____
_____

What specific recommendations would you provide for the notes? _____
_____
_____
_____

Please give specific positive comments on the topic/module. _____
_____
_____

Aerobic Treatment of Wastewater and Aerobic Treatment Units
Problem Sets

1. Name and explain two problems that severely complicate the proper functioning of an aerobic treatment unit.

2. The national Sanitation Foundation (NSF) Standard 40 has some significant omissions when used to properly define the water quality of ATU effluents. Explain.

3. Although there are two different operational schemes used in small aerobic treatment units, there is one fundamental principle that remains the same for each scheme. Explain the fundamental process.

4. Explain a good way to judge the quality of activated sludge in an aerobic treatment unit.

5. Explain the phenomenon know as sludge bulking in an aerobic treatment unit.

6. An excessive growth of the bacterium *nocardia* in the aerobic treatment unit liquid contents may cause a problem. Name and explain it.

7. Actually, the term 'trickling filter' is a misnomer. Explain why.

8. With regard to a trickling filter treatment facility, what is the significance of the organisms going into a phase know as endogenous respiration?

9. Using only rotating biological contactor units, how would you arrange the units to obtain a higher degree of organic removal and nitrification of the effluent?

10. Since there seems to be high homeowner satisfaction with their ATU's performance, it is an indication the units are doing a good job. Explain.

11. Why is it likely that data from laboratory testing of aerobic treatment units should be viewed with caution?

12. Unless modifications are made to the aerobic treatment unit, no significant nitrogen removal can be expected. Explain why.

13. In the ATU a very small insignificant amount of phosphorous may be removed by sedimentation. If more removal is desired, what would have to be done?

Aerobic Treatment of Wastewater and Aerobic Treatment Units
Problem Sets With Solutions

1. Name and explain two problems that severely complicate the proper functioning of an aerobic treatment unit.

The extreme daily fluctuations in wastewater organic strength and flow are particularly troublesome. The two to three hour period without nutrients stress the organisms and the two peak flows increase the surface overflow rate.

2. The national Sanitation Foundation (NSF) Standard 40 has some significant omissions when used to properly define the water quality of ATU effluents. Explain.

There should be standards for nitrogen, phosphorous, fecal coliform and possibly viruses.

3. Although there are two different operational schemes used in small aerobic treatment units, there is one fundamental principle that remains the same for each scheme. Explain the fundamental process.

The fundamental process is to provide oxygen transfer to the wastewater with intimate contact between the microbes and water.

4. Explain a good way to judge the quality of activated sludge in an aerobic treatment unit.

A good-quality activated sludge will have a golden brown color and an earthy smell if kept aerated.

5. Explain the phenomenon know as sludge bulking in an aerobic treatment unit.

When there is a large variation in organic loading, a prolific growth of filamentous bacteria (primarily *spaerotilus*) attaches to floc particles and impedes settling.

6. An excessive growth of the bacterium *nocardia* in the aerobic treatment unit liquid contents may cause a problem. Name and explain it.

The successive growth of the bacterium *nocardia* will cause foaming and frothing on the liquid surface in the aeration chamber and secondary clarifier. The secondary settling chamber surface baffles, which are intended to retain floatables, tends to trap the foam and foster more growth of the *nocardia*.

7. Actually, the term ‘trickling filter’ is a misnomer. Explain why.

Because the primary mechanism for organic solids removal is not by a physical filtering action in the fine pores, but rather by diffusion and microbial assimilation.

8. With regard to a trickling filter treatment facility, what is the significance of the organisms going into a phase know as endogenous respiration?

As the layer of slime growth continues to thick, the adsorbed organic matter is metabolized before it can reach the inner layer of organisms near the media surface. These inner organisms are forced to metabolize their own protoplasm without replacement and hence lose their ability to cling to the media surface and are washed off by the downward flowing water. The loss of the slime layer is called "sloughing".

9. Using only rotating biological contactor units, how would you arrange the units to obtain a higher degree of organic removal and nitrification of the effluent?

By arranging the sets of RBC's in series so that each subsequent stage receives the effluent of the previous stage. Thus, each subsequent stage receives an influent with a lower organic concentration.

10. Since there seems to be high homeowner satisfaction with their ATU's performance, it is an indication the units are doing a good job. Explain.

Not so. Studies have shown that even under normal operating conditions and with high homeowner satisfaction, a large percentage of the ATU discharges have been unacceptable.

11. Why is it likely that data from laboratory testing of aerobic treatment units should be viewed with caution?

Usually, typical residential wastewater is not used, conditions in the laboratory are ideal and the unit is not likely to be subjected to unattended operational problems.

12. Unless modifications are made to the aerobic treatment unit, no significant nitrogen removal can be expected. Explain why.

While the organic nitrogen in the influent to the aeration chamber will be in the ammonium form, it will be quickly oxidized to nitrate. Any biological conversion of nitrate to nitrogen gas will be limited by the lack of sufficient carbonaceous matter and an anaerobic environment.

13. In the ATU a very small insignificant amount of phosphorous may be removed by sedimentation. If more removal is desired, what would have to be done?

Most likely, addition of a chemical coagulant.

Aerobic Treatment of Wastewater and Aerobic Treatment Units
Additional Materials: