Wastewater Modules

WW Instructor Guides 11 - 13, 15 - 20 - Answer Key

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Module 11:
Maintenance
Instructor Guide – Answer Key

What are some factors that impact the availability of equipment? (What causes "downtime"?)

Ans: Many possible answers are available. Generally, the answers will fall into these categories:

- Human Error
- Acts of God or Nature
- Product Defects
- Planned Service Work

What are some factors that help to ensure high availability of equipment (minimal "downtime")?

[After participants have had an opportunity to think of some answers (3 minutes), ask them to share responses.]

Ans: Many possible answers are available. Generally the answers will fall into these categories:

- Continuous Monitoring and Assessment of Equipment
- "Real Time" Knowledge of Equipment Condition
- Analysis of Other Information, such as Equipment History, Operational Protocols, and Manufacturer's Data

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What safety hazards can you identify in the photograph?

Ans: No shaft guard on pump; leaking oil or water on the floor; limited clearance in the area; limited lighting in the area (the flash photography brings out some details that would be missed in a low-lighting area).

UNIT REVIEW:

1. List the five goals of a wastewater treatment plant's maintenance program.

Ans: Fixed asset management; maintenance of design intent; efficiency of operation; safety and environmental protection; and system reliability

2. Explain why the banker or municipal residents are concerned about plant maintenance.

Ans: (possible answer) He/She/They want to protect their investment.

3. How does regular maintenance impact the availability of personnel?

Ans: Management knows how many people to assign to various tasks; keeping crises to a minimum, through regular maintenance, means that staffing is not "hit or miss" but is planned and organized.

4. Give three examples of the ways in which plant maintenance directly impacts the quality of the treatment process.

Ans: Possible answers include valves, meters that read quality standards, equipment that responds to the metered data, etc.

5. What could happen if a pump were allowed to operate with excessively worn wear rings?

Ans: Possible answers include lower pump efficiency; higher power consumption; need for more capacity placed online; increased burden on electrical system.

What maintenance tasks might a plant operator in a small facility complete?

Ans: Various answers are possible. The overall theme is that operators in a small facility will probably complete many types of maintenance on a routine basis.

What maintenance tasks might a plant operator in a large facility complete?

Ans: Various answers are possible. The overall theme is that operators in a large facility will probably have a maintenance staff that does most of the maintenance tasks. However, the operator will make some minor adjustments, monitor equipment, and so forth.

Why does it make sense to involve operators in the maintenance plan of any facility?

Ans: The operators, of course, are involved in the everyday functioning of equipment and systems. They know the equipment well and know how it should perform. They can quickly notice any changes in performance. Also, it makes sense to think that operators know what works in the "real world" environment, as opposed to what works on the design table. Their input is valuable to the maintenance plan.

What are some examples of PM that are performed at the facility in which you work? How often are the tasks performed?

Ans: Various answers are possible; answers vary according to the size and type of facility. Some examples include: adjusting packing gland on a pump seal; checking and recording pressure gauge readings for pumps, exercising valves as part of a semi-annual valve program.

What consequences could you imagine if the PM work was neglected for a long time?

Ans: Various answers are possible, including equipment failure, higher costs, lower available labor pool, operation-wide failures, etc.

What are some examples of corrective maintenance that are performed at the facility in which you work?

Ans: Various answers are possible. Some include: adjustment of pump/motor alignment after excessive vibration was observed; lubrication of a roller bearing on a conveyor after noise was detected; replacement of an air filter after excessive differential pressure across the filter was observed.

How do you identify the items in need of corrective maintenance?

Ans: Various answers are possible. Some include: visual inspection; noise patterns; vibration analyses.

What are some examples of breakdown maintenance that are performed at the facility in which you work?

Ans: Various answers are possible. Some answers include: replacement of a motor after it overheated and failed; rebuilding a clarifier gear case after oil leaked and gears were damaged from lack of lubrication.

Thinking about the examples you have heard in class, what other types of maintenance, if any, could have prevented the breakdown maintenance?

Ans: Various answers are possible, according to the answers given to the previous question. In most cases, regular preventive maintenance and timely corrective maintenance will prevent the need for breakdown maintenance.

List some maintenance activities that occur at your plant during these time frames:

[NOTE: Various answers are possible in all categories.]

- *Daily*

Ans: Pump operation (noise, vibrations, smell); tank levels; and aeration patterns on tank.

- *Weekly*

Ans: Meter readings; check maintenance reports to tweak equipment or order chemicals.

- *Monthly*

Ans: Check hours of operation (unit may need periodic servicing); check for animals such as groundhogs; check embankments of ponds; clean the sampler; check filters on aeration blowers.

- *Quarterly*

Ans: Change out or rotate equipment; generate extra testing as needed; perform required testing from Permit or Regulatory Agency; check, clean, or change HVAC filters; check, clean, or change process filters.

- *Annually*

Ans: Check and service all equipment on its year anniversary; check large gear cases on clarifier drives, bar screens, mixer motors, and comminutors; inspect vehicles.

- *Seasonally*

Ans: Exterior building inspection (cracks, remove wind screens, etc.); change oil viscosity for aeration mixer motors; roof inspection; check and make adjustments for changes in seasonal discharge requirements.

How does your facility plan for the unplanned? What resources are available to deal with emergencies?

Ans: Various answers are possible. Participants may state that their facility has spare parts on hand, duplicates equipment, or has redundant operations.

Looking at the picture shown below, how many types of identification systems can you find?

Ans: Various answers are possible. Be sure the participants see, at a minimum, the following tags: function (in blue duct tape); manufacturer's number (black plastic tag); facility's pump number (written on the equipment in black Magic Marker); components (blue duct tape).

What are the possible consequences of this kind of labeling?

Ans: Various answers are possible. Make sure participants note, at a minimum: safety issues; confusion when identification is required.

[In the following activity, you will create three types of tagging systems. Using the equipment listed below, create a Number Code, Alpha-numeric Code, and Smart Number Code for each of the products.]

Number Code:

Ans: Various answers possible. The earliest purchases should have the lowest number. An example:

Bar Screen (Brunning facility)	2355
Bar Screen (Main Street facility)	2356 (this was bought the same day as the other bar screen; therefore, it is probably tagged with the next available number)
Sump Pump	3888 (this was purchased two years after bar screens)
Aeration Blower	5203 (this was purchased the year after the pump)

Alpha-numeric Code:

Ans: Various answers are possible. The earliest purchases will have a lower number, according to the type of equipment. An example:

Bar Screen (Brunning facility)	BS2355 (BS stands for bar screen in this example)
Bar Screen (Main Street facility)	BS2356 (this was bought the same day as the other bar screen; therefore, it is probably tagged with the next available number)
Sump Pump	SP4200
Aeration Blower	AB5203

Smart Number Code:

Bar Screen (Brunning facility)	BS032355 (BS stands for bar screen in this example; 03 is the facility; and 2355 is the identification number)
Bar Screen (Main Street facility)	BS042356 (BS stands for bar screen; 04 is the facility; and 2356 is the identification number, indicating it was the purchase made directly after the previous bar screen purchase, therefore, it is probably tagged with the next

	available number)
Sump Pump	SP024200 (SP stands for sump pump; 02 indicates the Lee Highway facility; 4200 is the identification number for this piece of equipment)
Aeration Blower	AB045203 (AB is Aeration Blower; note that the next two digits, 04, are the same as the bar screen in the Main Street facility; the 04 indicates the location of the equipment)

Which impeller type in the centrifugal pump would you use for primary clarifier sludge? Why?

Ans: The appropriate choice would be an open type because it would tend not to clog.

Which impeller type in the centrifugal pump would you use for a utility water pump? Why?

Ans: The appropriate choice would be a closed impeller because there should be no solids in the treated water that could clog it. Using the closed impeller would yield a more efficient pump system.

What are the "first line of defense" tactics that you can use to detect trouble by using only your own senses? Think of all the systems in your plant.

Ans: Various answers are possible, including: smelling hot wires; seeing leaking valves; hearing excessive vibration noises.

What was being scanned?

Ans: The scan shows a 440 volt distribution panel secondary mixer fuse block.

What is the problem? How does it show on the scan?

Ans: C Phase line side of the breaker is overheated. (Point out the "hot spot" indicated by color change.)

What is the ambient temperature? What is the temperature of the overheated area?

Ans: Ambient temperature is 70º F; the overheated area reads 99.2º F.

[Display Slide 8—Thermographic Scan #2. (Participants should refer to Figure I3 of the workbook.)]

What is being scanned here? What is the problem, and what solutions are suggested?

Ans: Main drive cabinet main breaker is overheated. The suggested solution is to disassemble, clean, and retighten bad connection.

Remember that these analysis companies simply report their findings and recommendations. They do not fix the problem. It is up to the customer to decide what to do with the findings they receive.

[Display Slide 9—Thermographic Scan #3. (Participants should refer to Figure I4 of the workbook.)]

What do we see here? What is the temperature difference? Can you point out the "hot spot?"

Ans: The scan shows a main buss duct. Ambient temperature is 74.2 F and hot spot shows 110.5 F.

What are some factors that impact the schedule of dewatering tanks?

Ans: Various answers are possible; make sure participants list, at a minimum, the following answers:

- During summer months, the flow into most WWTPs is lower. This may provide some flexibility in removing tanks from service.
- However, discharge limits in the NPDES permit may become more stringent in the summer. This may create some concern about when tanks can be removed from service without fear of permit violations.
- If a major storm is expected (such as a hurricane), you may need to put a tank back into service with only partially completed repairs. For example, painting may not have been finished on all submerged parts, but the storm is expected to arrive within the next 24 hours. Here it is important to document the service completed and then finish it as soon as possible after the crisis situation.

Module 12:
Laboratory Overview
Instructor Guide – Answer Key

Exercise

Ans: A pipet and volumetric flask are the most accurate ways to measure liquids when making a standard solution. Extra credit if participants said a TD (to deliver) pipet.

Exercise

1. An Imhoff cone would most likely be used for what type of analysis?

Ans: B. Sludge Volume

2. What is the purpose of a desiccator?

Ans: A desiccator is used to keep chemical reagents and samples dry. Typically, a sample is heated in an oven to dry it and then placed in the desiccator to cool prior to weighing or undergoing further preparation.

3. An analytical balance would be used to do what type of analysis?

Ans: D. Gravimetric

4. List three sample concentration techniques.

Ans: Centrifuge, Distillation and Digestion

Exercise

1. List the two general types of hazards that a Wastewater Treatment Plant Operator may find himself exposed to.

Ans: Infectious wastes and toxic chemicals.

2. List the three most common routes that infectious agents can enter your body.

Ans: Cutaneous, oral ingestion and inhalation.

3. List seven common types of laboratory accidents.

Ans: Any seven of the following: electric shock, cuts, burns, heat, chemical, toxic fumes, chemical spills, slip and fall and fire.

☑ Exercise

This is your first week of work in the lab at a large Wastewater Treatment Plant and the effluent composite sampler is broken. You need to run samples for NPDES compliance. The boss has told the operators to get grab samples, put them in the refrigerator and to read the effluent totalizer every hour. This morning he has told you to take the individual grab samples the operators collected and make the composite sample yourself. You are required to do a flow based composite and you will need about 1,000 ml of sample to conduct all of the required tests. The night shift operator threw a sheet at you as he ran out the door. It reads:

Time	Totalizer (1,000s)	Time	Totalizer (1,000s)
Midnight	002215	1 PM	010960
1 AM	002740	2 PM	010992
2 AM	003925	3 PM	011012
3 AM	005037	4 PM	011124
4 AM	006135	5 PM	011276
5 AM	007500	6 PM	011409
6 AM	008555	7 PM	011650
7 AM	009869	8 PM	011788
8 AM	010050	9 PM	011952
9 AM	010650	10 PM	012050
10 AM	010725	11 PM	012134
11 AM	010801	Midnight	012215
Noon	010859		

How much of the sample collected for the 8 AM to 9 AM time period should be used to make the 24 hour composite sample?

First, you need to calculate the flow for the day: 012215 – 002215 = 10,000 (but the totalizer reads in 1,000 gallons) So its 10,000 * 1,000 = 10,000,000 gallons. Second, you need to calculate how

much water passed through the plant between 8 AM and 9 AM: 010650 – 010050 = 600 * 1,000 = 600,000 gallons. Third, you need to calculate what percent of the total daily plant flow passed through the plant between 8 AM and 9 AM: (600,000 / 10,000,000)*100 = 6 %. From this you can see that since 6% of the total plant flow passed through the plant between 8 AM and 9 AM, 6 % of the final composite sample you need to make should be from the 8 AM to 9AM sample. It was stated in the problem above that you will need 1,000 ml of the composite to run all of your tests. So 6% of the 1,000 ml should be from the 8 AM - 9 AM sample. 1,000 * 6% = 60 ml.

Ans: You need to add 60 ml of the 8 AM - 9 AM sample to you composite sample.

Exercise

1. Explain the importance of collecting a representative sample.

Ans: If the results of a non-representative sample are used to adjust the treatment process, it could very likely upset the process and lead to less than optimal treatment.

2. What is the single biggest source of errors in laboratory results?

Ans: Sampling errors.

3. Explain how to manually prepare a flow based composite sample.

Ans: Collect grab samples at regular time intervals and store those samples in the refrigerator. At the completion of the compositing time frame, examine the flow data. Calculate the total flow for the day and the flow for each of the time frames during which samples were collected. Calculate the percent of flow that passed through the plant during each of the samples time frame. Use that percent to calculate the amount of each individual sample that will be used to create the composite sample.

Exercise

1. List the four types of solids analyses and explain the significance of each.

Ans: Dissolved solids. Solids analyses are important in the control of biological and physical wastewater treatment processes.

Settleable Solids. This analysis indicates the volume of solids removed by sedimentation.

Total Suspended Solids. This analysis indicates the quality of the influent wastewater and is used to gauge plant performance at various locations in the plant. It is also used to verify discharge compliance.

Total Solids (Volatile and Fixed). Total solids are the combined amounts of suspended and dissolved material in the sample. It is comprised of volatile and fixed solids. Volatile solids are composed of organic compounds which are either plant or animal origin (such as waste material that can be treated biologically). Fixed solids are inorganic compounds such as sand, gravel and minerals.

Exercise

1. What is the significance of conducting pH and Alkalinity analyses?

Ans: pH: The purpose of the test is to determine whether the pH at various points of the treatment process is favorable for the process.

Alkalinity: Alkalinity is a measure of the wastewater's ability to neutralize acids. It is an indirect measure of the concentration of carbonate, bicarbonate and hydroxide in the sample.

2. When conducting a pH analysis, the sample is collected from which locations?

Ans: From the influent, recirculated sludge, digester supernatant and plant effluent.

3. When conducting an alkalinity analysis, the sample is collected from which locations?

Ans: The sample is collected from the influent and effluent.

Exercise

1. Explain the principal difference between BOD and COD analyses.

Ans: BOD quantifies the depletion of oxygen due to biological activity over a 5 day period. COD uses a chemical reflux to quantify the amount of oxygen used by a sample. COD analyses can be run in a matter of hours rather than days.

Exercise

1. Explain the purpose of testing a WWTP's effluent for total coliform.

Ans: It is used as a surrogate to indicate the quantity of human or animal waste in finished water.

2. Explain the purpose of testing a WWTP's effluent for fecal coliform.

Ans: It is used as a surrogate to indicate the quantity of human or animal waste in finished water. The presence of fecal coliforms indicates that disease producing organisms may be present in the sample tested.

Exercise

1. Why are there limits placed on the amount of certain metals that can be discharged from a WWTP?

Ans: High concentrations of some metals can be toxic to some forms of aquatic life.

Exercise

1. What is the significance of conducting a chlorine analysis?

Ans: To determine the presence of chlorine in the discharge since it is toxic to aquatic life.

Exercise

1. List the three types of nitrogen/ammonia analyses and explain the significance of each.

Ans: Nitrate/Nitrite: The presence of nitrate in the effluent of a WWTP is significant because it is an essential nutrient for algae growth. Excessive amounts of nitrate can cause algae blooms. When the algae die and decays it can exhibit a large oxygen demand on the stream which in turn can cause the fish and other aquatic life to be killed.

Ammonia: Ammonia in the effluent of a wastewater treatment plant can create a significant oxygen demand in the receiving stream. This demand will lower the amount of DO available for aquatic life and lead to fish and aquatic life kills.

TKN: TKN is the sum of organic nitrogen and the ammonia nitrogen in a sample.

Exercise

1. What is the significance of conducting a phosphate analysis?

Ans: Wastewater is usually quite rich in phosphorus compounds and its removal is extremely important because their presence can stimulate the growth of algae. These growths can be a great nuisance and the die-off of algae will create a large DO demand in the receiving stream.

Exercise

1. List 5 elements of a good QA plan.

Ans: Any five of the following should be included in a QA plan: a cover sheet with plan approval signatures, a laboratory organization chart, sample control and documentation procedures, Standard Operating Procedures (SOPs) for each analytical method, analyst training procedures, equipment preventative maintenance procedures, calibration procedures, quality control procedures, and data reduction, validation, and reporting procedures.

2. Duplicates are used to demonstrate the _____ of a laboratory method.

Ans: precision

3. Spikes are used to demonstrate the _____ of a laboratory method.

Ans: accuracy

4. A well written QA manual can be used for what other purpose?

Ans: B.

A is not the correct answer because even a poorly written QA plan makes a fine door stop. C is not true because a lab QA manual only deals with the laboratory issues not plant operations. D is not true because even if the QA manual is perfect, the QA Officer must verify that the procedures contained in the manual are being adhered to.

Exercise

1. What are the two general types of laboratory records?

Ans: Analytical results and QC results.

2. Which of the following information does not need to be reported on a DMR?

Ans: c. Routine chemical deliveries are not reportable. However, if a spill of a treatment chemical occurred while receiving the chemical it would, most likely, be reportable.

3. DMRs must be received at the appropriate office within _____ days of the end of the monitoring period.

Ans: 28.

4. Completed DMRs and the data used to complete them must be maintained for at least _____ years after the date of submission, sample measurement, report or application.

Ans: 3.

Module 13:
General Administration of Wastewater Treatment Plants
Instructor Guide – Answer Key

Would charting effluent trends be advantageous? Why or why not?

Ans: Yes, it can show deviation in plant product which should correlate with unit process performance.

Would charting unit process trends be advantageous? Why or why not?

Ans: Yes, it provides direct feedback on the health of the plant.

Which would be more helpful—effluent trends or process trends?

Ans: Process trends would be more helpful because it provides more direct feedback on the health of the individual parts of plant.

In the space provided to the right of each meeting, ask the participants to indicate whether the meeting is formal or informal.

Ans:

Internal meetings include:	External meetings include:
❖ Staff meetings <u>usually formal, could be informal</u>	❖ City, town or council meetings <u>formal (be prepared to deal with issues that are not on the agenda)</u>
❖ Training sessions <u>formal</u>	❖ Civic group meetings <u>formal and informal (there will usually be a structured portion, but the question and answer session can wander)</u>
❖ Safety meetings <u>formal</u>	❖ Regulatory personnel meetings <u>formal</u>
❖ Change of operator information meetings (should be conducted at the beginning of each shift). <u>informal</u>	❖ Contractor meetings <u>informal</u> ❖ Supplier meetings <u>informal</u>

Module 15:

The Activated Sludge Process - Part 1

Instructor Guide – Answer Key

Unit 1 - General Description of the Activated Sludge Process

What purpose does the activated sludge process serve within wastewater treatment?

Ans: To oxidize and remove soluble or finely divided suspended materials that were not removed by previous treatment (preliminary and primary).

When the biochemical oxygen demand (BOD) of incoming wastewater increases, what happens to the air requirement in the aeration tank?

Ans: Air requirements increase—more food (BOD) encourages biological activity, which in turn requires more air (oxygen).

Let's calculate the sludge age for an activated sludge process if the aeration volume is 0.5 million gallons (MG) and the mixed liquor suspended solids concentration is 2,100 mg/L. The influent flow is 4.0 MG per day and the primary effluent suspended solids concentration is 70 mg/L.

1. Determine the pounds of solids under aeration:

   2,100 mg/L x 0.5 MG x 8.34 = 8,757 pounds

2. Determine the pounds of solids in the primary effluent:

   70 mg/L x 4.0 MGD x 8.34 = 2,335 pounds per day

3. Divide the solids under aeration by the solids in the primary effluent to get sludge age:

   8,757 pounds/2,335 pounds per day = 3.75 days

<u>Exercise for Unit 1 – General Description of the Activated Sludge Process</u>

1. Why is air added to the aeration tank in the activated sludge process?

Ans: Air is added to the aeration tank in the activated sludge process to provide oxygen to sustain the living organisms as they oxidize the wastes to obtain energy for growth. The application of air also provides mixing to ensure that the oxygen and food (BOD) are distributed to all the organisms.

2. What does the volatile content of the mixed liquor suspended solids represent?

Ans: The volatile content of the mixed liquor suspended solids represents the amount of microorganisms in the activated sludge process.

3. What influences the amount of air required in an aeration tank?

Ans: The amount of food (BOD) in the wastewater and type of treatment are the principal influences on the amount of air required in the aeration tank.

4. Aerobic organisms grow relatively quickly, efficiently oxidize waste, produce little or no odor, but require a proper amount of dissolved oxygen to function properly.

a. True b. False

5. The conventional activated sludge process produces a high quality of effluent and the process has some ability to absorb shock loads.

6. As the water temperature drops, water will be able to dissolve:

a. more oxygen b. less oxygen

Unit 2 - Aeration

Diffused aeration systems are the most common. Can anyone tell me why this might be true?

Ans: More versatile, mobility, cost effective—can make repairs which do not require shutting down the whole tank, can adjust airflow to be more efficient, etc.

Safety Case Study

You are an operator at a wastewater facility where you will be changing the diffusers in an aeration tank. The aeration lines are equipped with swivel joints, so you can keep the tank in service during the change out. There was a rain shower an hour before the scheduled change

out. Please identify safety concerns associated with this operation and how you would address the concerns to make the operation safer.

Ans:

Concern	Possible Solution
Slips, trips, and falls	▪ Make sure the walking surface is clean and dry (remove slime and brush away standing water). ▪ Keep handrails in place, if possible. ▪ Wear fall arrest device.
Drowning	▪ Wear flotation device. ▪ Shut off aeration to the header being serviced.
Overhead falling hazards	▪ Wear hard hats. ▪ Ensure lifting devices are securely attached. ▪ Ensure lifting devices are functioning properly.
Pressurized line	▪ Relieve the line pressure prior to any work. ▪ Wear protective eyewear.

Exercise for Unit 2 - Aeration

1. What are the purposes of aeration?

Ans: To dissolve oxygen into the wastewater and, to mix the mixed liquor suspended solids with the incoming wastewater. Both of these functions are necessary to ensure the survival of the microorganisms that actually remove the contaminants from the wastewater.

2. What is the difference between mechanical and diffused aeration?

Ans: Mechanical is done by contacting atmospheric oxygen with the wastewater, either by drawing air into the water or by splashing water into the air. Diffused aeration is done by oxygen or air being "blown" under pressure into the depths of the wastewater through a diffuser.

3. What are the precautions that must be taken before one attempts to maintain or repair a surface aerator?

Ans: Wear the proper clothing floatation – fall arrest... Turn off machinery. Turn off electricity (tag out/lock out) Wait for motion to STOP.

4. What are some of the hazards that could be found when working on air headers?

Ans: Because of the location of air headers, slips, trips, and falls are potential hazards. Also, if the work involves lifting, such as with a hoist, care must be taken to ensure that the hoist cable is properly connected; that personnel do not work beneath the hoist or the load; that the hoist is in good working order; and that the load if lifted properly. Finally, if the air line is to be opened, pressurized air, carrying dust or small particles, could be released at a high rate of speed unless the pressure is released first under controlled conditions.

Unit 3 – New Plant Start-up Procedures

If your waste treatment plant were missing a particular manufacturer's manual, how would you go about obtaining one?

Ans. Usually the contract specifications require that several copies of manufacturers' manuals be provided. If they are lost, call or write to the manufacturer or contact the manufacturer's representative and request another copy of the manual. If the manufacturer's representative does not have the necessary equipment information, you will need to provide it. Be prepared to provide the equipment serial number, which should have all the necessary information. As additional verification, provide the equipment model number and size, and a purchase contract number if available.

Why should an effluent weir be level?

Ans. An effluent weir should be level to prevent short-circuiting of effluent, to maintain the intended overflow rate, and to minimize solids carry-over, which could occur if high velocity flow patterns are created by the uneven weir setting.

As a review, how is air cleaned before it is compressed and sent to the aeration tank?

Ans. Air filters are used to clean the air.

Blowers should be started prior to admitting primary effluent to the aeration tank. Why?

Ans. Blowers should be started and air should be flowing to the diffusers before primary effluent is admitted to the aeration tank to prevent the diffusers from clogging. Without the air discharging through the diffusers, solids would settle on and stick to the diffusers, but with the air discharging that is less likely.

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1. Why must the horizontal pipes containing the air diffusers all be at the same elevation (level)?

Ans: If the diffusers are not all at the same elevation, the higher diffusers will receive too much air and the lower diffusers will not receive enough (or any) air. This is because the higher diffusers would have less water pressure on them so there would be less resistance to flow. Uneven air distribution would make oxygen transfer less efficient and disrupt the normal mixing pattern in the aeration tank.

2. Why should an operator completely check the equipment and structures before startup?

Ans: The main reasons to check equipment and structures prior to startup are to: a) become familiar with the equipment, b) learn how it works, c) learn where all the controls are located, d) make sure it is installed properly, and e) have confidence that it should function properly when started up.

3. The Operations and Maintenance (O&M) manual, if available, should contain a wealth of information concerning how to run the plant.

4. Record plans will summarize the as-constructed information about the plant.

5. Out of level weirs can cause an imbalance of flows in the plant and potentially cause problems with the plant effluent.

   a. True b.False

Module 16:

The Activated Sludge Process - Part II

Instructor Guide – Answer Key

Exercise

1. What are the six key monitoring points within the activated sludge process?

Ans: Plant influent, primary clarifier effluent, aeration tank, secondary clarifier, internal plant recycles and plant effluent.

2. For each of the monitoring points listed above, explain what key characteristics a TPO should look for.

Ans: Plant influent – check for flow increase and influent solids increase

primary clarifier effluent – check BOD/COD, TSS and nutrients

aeration tank – check MLSS/MLVSS, residual DO, pH and total alkalinity, SOUR, color and the biomass

secondary clarifier – check sludge blanket level, sludge return rate and floating solids on clarifier surface

internal plant recycles – check digester or sludge holding tank supernatant and sludge dewatering or thickening process recycle

plant effluent – check turbidity and NPDES permit requirements

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Calculation

Step 1: Calculate the total aeration tank volume

Total volume (Vr) = 250,000 x 4 = 1 Mgal

Step 2: Calculate total wastewater flow

Total flow (Qe) = 1.25 x 4 = 5 Mgd

Step 3: Calculate MCRT

$$\theta c = \frac{1 \text{ Mgal} \times 2{,}000 \text{ mg/l}}{(0.1 \text{ Mgd} \times 8{,}000 \text{ mg/l}) + (5 \text{ Mgd} \times 0 \text{ mg/l})}$$

= 2.5 days

Calculation

Ans: % settleable solids = (200/1000) x 100 = 20

$$SVI = \frac{20 \times 10{,}000}{2{,}000} = 100 \text{ mL/g}$$

Calculation

In this calculation, the MCRT is used to control the activated sludge process, so that tells us what formula to use. By using the formula on page 1-24 of your workbook and plugging in the numbers, we get the following:

$$Q_w = \frac{\left[\frac{1.7 \times 1{,}600}{5}\right] - (10 \times 10)}{8{,}000}$$

$Q_w = 0.06$ mgd

Exercise for Unit 1 – Process Control Strategies

1. List the nine process parameters that require record keeping and briefly explain why:

Ans: TSS and VSS; BOD, COD or TOC; DO; Settleable Solids/SVI; Temperature; pH; Chlorine Demand; Coliform Group Bacteria.

Exercise

1. List six process operational problems.

Ans: plant changes, sludge bulking, septic sludge, rising sludge, foaming/frothing or toxic substances.

2. What is sludge bulking?

Ans: A condition in which activated sludge has poor settling characteristics and poor compactability. This causes the sludge blanket in the secondary clarifiers to rise until solids eventually escape the clarifiers and are discharged from the plant.

3. What is septic sludge?

Ans: It is sludge that has become anaerobic and has a foul odor. The anaerobic conditions generate gases, which causes the sludge to rise to the surface of vessels.

4. List five classifications of toxic substances.

Ans: heavy metals, inorganic compounds, organic compounds, halogenated compounds, and pesticides, herbicides and insecticides.

☑ Exercise

1. You notice that the MLSS concentrations differ significantly from one aeration basin to another. What is the potential cause(s) of this and how would you solve it?

Ans: One cause could be unequal flow distribution to the aeration tanks. The solution to this is to adjust the valves and/or inlet gates to equally distribute the flow.

Another cause could be the return sludge distribution is unequal to the aeration basins. In this case, you would check the return sludge flows and discharge points.

2. The sludge concentration in the return sludge is low. What are the four possible causes of this? For each cause, identify what you should check or monitor.

Ans:

Probable Causes	Check/Monitor
Sludge return rate too high	Return sludge concentration, solids level around final clarifier and settleability test.
Filamentous growth	Microscopic examination, DO, pH, nitrogen concentration.
Actinomycetes predominate	Microscopic examination, dissolved iron content
Collector mechanism speed Inadequate	Collector mechanism

3. There are thick billows of white, sudsy foam on the aeration tank. It has been determined that the reason for this is because the MLSS is too low. What should you do to resolve this problem?

Ans: Decrease sludge wasting to increase MLSS and MCRT.

☑ Exercise for Unit 2 – Typical Operational Problems

1. If the shaft coupling on the surface aerator makes an unusual noise and vibration, what are the possible causes and how would you fix the problem?

Ans: The possible cause is a lack of proper location. Solutions include repair or replacement of oil pump and an oil change or removing an obstruction from the oil line.

2. Explain the monthly maintenance requirements for air headers/diffusers.

Ans: Exercise all regulating/isolation valves to prevent seizing for coarse bubble diffusers but not for porous media filters.

Apply grease to the upper pivot swing joint O-ring cavity.

Check for loose fittings, nuts and bolts and tighten them if necessary.

Increase air flow to the diffusers to 2-3 times the normal flow to blow out biological growths.

3. Describe the typical operational problems associated with air filters.

Ans: Cleanliness of the filter and pressure drops across the air filter.

4. If sludge is present in the pipe of the air distribution system, what is the possible cause and how would you resolve the issue?

Ans: A possible cause is vacuum action caused by the blower operating in reverse. Solutions include flushing the pipe, installing a check valve on the blower and/or repairing the check valve.

Exercise for Unit 3 – Microbiology of the Activated Sludge Process

1. Name four typical microorganisms found in activated sludge.

   a. bacteria

   b. protozoa

   c. rotifers

   d. worms

2. List three observations that are recorded in your activated sludge process.

   a. size and nature of floc particles

b. microorganism counts

c. filament index

3. List three possible process changes in an activated sludge process. Briefly explain the purpose of each change. Answers may vary. Here are some possible responses:

a. Reducing the waste activated sludge (WAS) flow rate may remedy a decreasing MLSS problem.

b. Increase the WAS rate if you see an increasing trend in rotifers.

c. Increase air flow rate if the problem is rising sludge and the plant is not required to denitrify.

Module 17:

The Activated Sludge Process - Part III

Instructor Guide – Answer Key

What other differences can you see between Complete Mix and Step Aeration?

Ans: One of the features that make Complete Mix Aeration different from Step Aeration is that mixed liquor is also removed from the tank at several locations. This, together with the orientation of the aerators, creates a series of backmixing zones within the aeration tank that produce a uniform environment throughout the aeration tank.

What were the three reasons for modification?

Ans: Operational Benefits; Site Characteristics; Energy and Labor Requirements

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Exercise for Unit 1 - Modifications of the Conventional Activated Sludge Process

1. BOD measurements are used as a measure of the _organic_ strength of wastes in water.

2. The conventional activated sludge process uses a _plug_ - _flow_ reactor that is generally long and relatively narrow.

3. Potential benefits of modifying the conventional activated sludge system include:
   a. Increasing organic loading.

   b. Providing additional nutrients required for proper treatment.

   c. Accommodating flow rate or organic loading that varies seasonally.

   d. Achieving nutrient removal.

   e. All of the above

4. The contact stabilization process assumes that BOD is first _absorbed_ by the microorganisms and then BOD is _metabolized_ by the microorganisms for energy and growth.

5. In a contact stabilization activated sludge process the maximum organic loading should be no more than _60 # BOD_ per 1,000 cubic feet/day.

6. The Kraus Process is applicable to treatment facilities receiving waste water that is low in carbohydrates.

   a. True b. False

7. The _step_ - _feed_ Aeration Process can be used to provide a more uniform distribution of oxygen demand throughout the aeration tank.

8. In general, the _extended aeration (or oxidation ditch)_ process requires the longest minimum aeration time.

9. Oxidation ditches are configured in a ring with _continuous_ flow around the ring that is induced by aerators.

Inflow/Outflow Characteristics

How do influent and effluent flows occur in the conventional activated sludge process?

Ans: Both influent and effluent flows occur continuously in the conventional process.

Aeration Schedule

 When does aeration occur in the conventional activated sludge process?

Ans: Aeration occurs continuously in the conventional process.

Organic Loading Schedule

 When does organic loading occur in the conventional activated sludge process?

Ans: Organic loading is continuous in the conventional process.

Mixed Liquor Management

 What happens to the return sludge in the conventional activated sludge process?

Ans: Conventional activated sludge systems receive return sludge from the secondary clarifier to make up for the sludge that was lost during the discharge of mixed liquor.

Clarification Efficiency

 What makes clarification efficiency less than ideal in the conventional activated sludge process?

Ans: The clarifier is always receiving influent, which creates opportunities for short-circuiting and currents that disrupt the clarification process.

 Why do you think it is important for SBR tanks to have such depth?

Ans: Sufficient depth is required to accommodate the variable depth requirements associated with a fill and draw operation.

Aeration and Mixing Equipment

 Why are mechanical mixers favored in SBRs?

Ans: When doing nutrient removal, they can provide mixing energy without aerating.

Why would an air diffuser prohibit anoxic, or anaerobic, treatment cycles that are required for nutrient removal?

Ans: When operating, the diffuser's bubbles provide oxygen to the environment; anoxic and anaerobic treatment cycles require no free oxygen.

Why is the settling time longer when removing phosphorus (P)?

Ans: The extra settling time is needed to create the anaerobic conditions for the biological phosphorus removal process.

Exercise for Unit 2 – The Sequencing Batch Reactor

1. The maximum operating depth of a typical SBR system ranges from 12 to 20 feet.

2. SBR systems can in general use the same aeration and mixing equipment that is used for conventional activated sludge systems.
   a. True b. False

3. PLC means Programmable Logic Controller. A PLC controls the mechanical equipment and the timing of the different stages.

4. List the five stages of operation in a SBR and briefly explain what happens in each stage.
   a. fill- (biological treatment) Influent raw wastewater entering the reactor during this mode, there may also be periods of mixing without aeration (anoxic) and mixing with aeration (aerobic). cBOD removal, nitrification and denitrification may be taking place during this mode. Typically, you would want raw wastewater (carbon source) for anoxic denitrification periods. No wastewater is being discharged in this mode. The amount of time spent in this mode could be dependent on flow. Storm flow could significantly limit the amount of time.

   b. react - During this mode, there is typically no raw wastewater entering the SBR (this could be different in storm mode). Periods of aerobic and anoxic treatment may occur to provide for cBOD removal, nitrification and denitrification. No wastewater is being discharged in this mode. This is a time for reaction, providing time for the microorganisms contained in the SBR to consume and convert the pollutants in the wastewater

c. settle - (physical treatment) During this mode there is typically no wastewater entering or exiting the SBR. There is no mixing or aeration, it is a quiescent period that provides for settling of the mixed liquor. In this mode the SBR is essentially a clarifier.

d. decant - (physical treatment) In the decanting mode, the treated wastewater is decanted from the reactor and sent on for disinfection. It is typically in this mode that sludge is also wasted from the system

e. idle - (endogenous phase) As the name suggests, this is a mode where the process is at an idle. There is no wastewater entering or exiting the system. There may be some mixing and aeration. The biomass is at endogenous respiration. Some reactors may not have an idle mode or the idle mode may not be used during wet weather.

Module 18:

The Activated Sludge Process - Part IV

Instructor Guide – Answer Key

Review Exercise

1. List the five types of nitrogen.

Ans: Ammonium, Ammonia, Nitrite, Nitrate and Organic-N.

2. List seven nitrogen removal mechanisms.

Ans: Biological nitrification, biological denitrification, living systems, land application, ammonia stripping, breakpoint chlorination and ion exchange.

Climates with large temperature variations can have a significant impact on denitrification. For example, the denitrification reactor volume at 10 °C would be about four times the volume required at 20 °C to achieve the same degree of nitrification. Why do you think this is the case?

Ans: T1 = 20 degrees C
T2 = 10 degrees C

$P = 0.25T^2$

$$\frac{P2}{P1} = \frac{0.25(T2)^2}{0.25(T1)^2} = \frac{0.25(10)^2}{0.25(20)^2} = \frac{25}{100} = 1/4$$

The denitrification rate at 10 degrees C is only 1/4 the rate at 20 degrees C and would, therefore, require 4 times the reactor volume to achieve the same degree of treatment.

Exercise for Unit 1 – Nitrification and Denitrification

1. MCRT is the abbreviation for Mean Cell Residence Time .

2. The two types of aeration systems used in nitrification processes are surface aerators and diffusers.

3. The optimal pH range for biological nitrification is 7.2 to 9.0 .

4. Nitrification in the winter months may require up to five times the detention time used during the summer.

   a. True b. False

5. Single stage biological nitrification typically requires a MCRT of 8 to 20 days.

6. For biological nitrification to proceed efficiently, there must be an adequate supply of carbon, nitrogen, and phosphorous in the wastewater. If the phosphorus level is too low, it may be remedied by adding a phosphate fertilizer to the aeration tank.

   a. True b. False

7. In a denitrification process, it may be necessary to add a carbon source such as methanol if the total effluent nitrogen limit is less than 7.5 mg/L.

8. List the four types of suspended growth biological nitrification reactors that are commonly used.

   a. conventional or plug flow .

b. complete mix .

c. extended aeration .

d. SBR .

Exercise for Unit 2 – Biological Phosphorus Removal

1. List the three forms of phosphorus considered important for wastewater.
   a. Orthophosphates
   b. Polyphosphate (P_2O_7)
   c. Organically Bound Phosphorus

2. List four metal salts that can be used in treating water for phosphorus removal.
   a. Aluminum sulfate (or alum)
   b. Ferric chloride
   c. Ferric sulfate
   d. Ferrous sulfate

3. Using lime to remove phosphorus requires that the wastewater has a pH of about 11. After pH removal, carbon dioxide gas can be injected into the water to lower the pH.

4. How do the three phosphorus removal mechanisms differ?

Potential responses:

The A/O process is a "mainstream" process where phosphorus is removed along the main plant flow stream (i.e., the secondary clarifier). The PhoStrip process removes phosphorus in a "sidestream" process (i.e., in the sidestream anaerobic stripper tank).

The A/O and PhoStrip processes are biological, whereas the flocculation and precipitation process is chemical.

The anaerobic and aerobic hydraulic retention times (HRT) for the PhoStrip process is longer than the corresponding HRTs for the A/O process.

Explain the difference between the A^2O process and the Bardenpho process.

Ans: The A2O process is a three stage process consisting of an anaerobic stage, an anoxic stage and an aerobic stage. The Bardenpho process is a five stage process consisting of an anaerobic stage, then an anoxic stage, followed by an aerobic stage and then another anoxic and aerobic stage.

Exercise for Unit 3 - Combined Nitrogen and Phosphorus Removal or Biological Nutrient Removal (BNR)

1. In the spaces below, write in the typical range of values for the indicated process control parameters:

   a. MCRT A^2O 4 – 27 days Bardenpho 10 – 40 days

   b. RAS recycle rate A^2O 20 – 50 % Bardenpho 50 – 100 %

   c. MLSS concentration A^2O 3000 – 5000 mg/L Bardenpho 2000 – 4000 mg/L

   d. F/M ratio A^2O 0.15-0.25 lb BOD / lbMLSSday

   Bardenpho 0.1-0.2 lb BOD / lbMLSSday

2. From the chart in Figure 3.3, determine the optimum pH range for the following processes:

   a. Aerobic treatment 6.5 – 8.3

   b. optimum for nitrifiers 7.5 – 8.2

   c. phosphorus removal by Al^{3+} addition 5.0 – 6.5

   d. phosphorus removal by Fe^{3+} addition 4.0 – 6.0

Module 19:
Treatment Ponds and Lagoons
Instructor Guide – Answer Key

What are some undesired effects of discharging wastewater directly into clean water sources?

[Ans: Some possible answers include odor, disease, and destruction of habitat.]

An aerobic pond with no mechanical agitation should be shallow. Why is this important?

[Ans: An aerobic pond, by definition, has DO throughout its entire depth. Shallow depth allows for distribution of DO throughout; a deeper pond would not have an adequate DO supply using natural methodology, such as algae or wind.]

Ask students to apply their critical thinking skills to the following questions about facultative ponds:

- What supplies the dissolved oxygen (DO) for the supernatant layer of the facultative pond?

  [Ans: Algae; wind; mechanical aeration devices; and diffused aeration can supply DO.]

- What stabilizes organic waste in the supernatant layer of the facultative pond?

  [Ans: Aerobic bacteria and algae stabilize organic waste.]

- What ferments the organic waste in the anaerobic layer of the facultative pond?

  [Ans: Anaerobic bacteria ferment organic waste in the anaerobic layer.]

- Why is the facultative pond the most common type of treatment pond?

  [Ans: It is nearly impossible to maintain completely aerobic or anaerobic conditions in a pond.]

Percent Removal Calculation

To determine the percent removal, you should perform this calculation:

$$\text{Percent Removal (\%)} = \frac{\text{(Influent Concentration, mg/l)} - \text{(Effluent Concentration, mg/l)}}{\text{(Influent Concentration, mg/l)}} \times 100$$

Percent Removal Calculation Exercise

Now we will perform the calculation using some real numbers. Insert the numbers on the screen into the appropriate spot in the calculation. Figure the answer; remember that the answer you want will be represented as a percentage.

Influent Ammonia Nitrogen = 25 mg/l
Effluent Ammonia Nitrogen = 20 mg/l
What is the percent removal?

[Ans: [(25 – 20) / 25] x 100 = 20
The answer is 20%.]

Surface Area Calculation

$$\text{Surface area (in acres)} = \frac{\text{(Surface width, in feet)} \times \text{(Surface length, in feet)}}{43{,}560}$$

Surface Area Calculation Exercise

[When students have had the opportunity to perform the calculation, click the mouse to show the calculation on the same slide. Finally, after explaining the calculation, click the mouse again to show the answer on the same slide.

Surface Length = 700 feet
Surface Width = 400 feet
Depth = 5 feet
What is the surface area of the pond?

Ans: Surface area (in acres) = $\frac{700 \text{ feet} \times 400 \text{ feet}}{43{,}560} = 6.4$ acres]

Volume Calculation

[Volume (in gallons) = (Average Length) x (Average Width) x (Average Depth) x 7.48 (in gallons)]

Volume Calculation Exercise

[When students have had the opportunity to perform the calculation, click the mouse to show the calculation on the same slide. Finally, after explaining the calculation, click the mouse again to show the answer on the same slide.

Average Length = 700 feet
Average Width = 400 feet
Average Depth = 5 feet
What is the volume of the pond?

Ans: Volume (in gallons) = 700 feet x 400 feet x 5 feet x 7.48 = 10,472,000 gallons]

There is an easy calculation that tells us how much time a drop of wastewater will remain in a pond or lagoon.

$$\text{Detention time (in days)} = \frac{\text{Pond Volume (in gallons)}}{\text{Influent Flow (in gallons/day)}}$$

Pond Volume = 5 million gallons
Influent Flow Rate = 0.125 million gallons per day (mgd)
What is the detention time of this pond?

$$\text{Detention time (in days)} = \frac{5{,}000{,}000 \text{ gallons}}{125{,}000 \text{ gallons/day}} = 40 \text{ days}$$

Ans: Detention time (in days) = 5,000,000 gallons / 125,000 gallons/day = 40 days]

Exercise for Unit 1 – General Overview

1. List the three basic types of ponds used in wastewater treatment processes.
   a. aerobic
   b. anaerobic
   c. facultative

2. Aerobic ponds contain dissolved oxygen (DO) throughout the entire depth of the pond all of the time.

   a. True b. False

3. Anaerobic ponds function without dissolved oxygen (DO) and rely on anaerobic bacteria at the bottom of the pond to ferment the sludge.

4. Water can flow through ponds connected together in either parallel or series configurations.

5. The influent to a facultative pond contains 30 mg/l of total nitrogen. What is the percent removal if the effluent contains 6 mg/l of total nitrogen?

$$\text{Percent Removal (\%)} = \frac{\text{(Influent, mg/l)} - \text{(Effluent, mg/l)}}{\text{(Influent, mg/l)}} \times 100\% = \frac{30 - 6}{30} \times 100\%$$

$$= \frac{24}{30} \times 100\% = 80\%$$

6. A thermocline can act as a physical barrier between surface water and bottom water.

7. A pond is 500 feet long by 200 feet wide and the water is 5 feet deep.
   a. What is the surface area of this pond in acres? (1 acre = 43,560 square feet)

$$\text{Area} = 500 \text{ ft} \times 200 \text{ ft} = 100{,}000 \text{ ft}^2$$

$$100{,}000 \text{ ft}^2 \times \frac{1 \text{ acre}}{43{,}560 \text{ ft}^2} = 2.3 \text{ acres}$$

   b. What is the volume of the pond in gallons? (1 ft^3 = 7.48 gallons)

$$\text{Volume} = 500 \text{ ft} \times 200 \text{ ft} \times 5 \text{ ft} = 500{,}000 \text{ ft}^3$$

$$500{,}000 \text{ ft}^3 \times \frac{7.48 \text{ gal}}{1 \text{ ft}^3} = 3{,}740{,}000 \text{ gal}$$

   c. What is the detention time if the influent flow rate is 125,000 gallons per day?

$$\text{Detention Time} = \frac{\text{Pond Volume}}{\text{Influent Flow}} = \frac{3{,}740{,}000 \text{ gallons}}{125{,}000 \text{ gal / day}} = 30 \text{ days}$$

Hydraulic Load Calculation.

The hydraulic load is a means of describing the volume of flow into a pond as it relates to the depth of the pond; the result is the "height" of influent wastewater into the pond on a daily basis. To determine the hydraulic load, you should perform this calculation:

$$\text{Hydraulic Load (inches per day)} = \frac{\text{Depth of Pond, inches}}{\text{Detention Time, days}}$$

Hydraulic Load Calculation Exercise.

Width of Pond = 700 feet
Length of Pond = 400 feet
Depth of Pond = 5 feet

Influent Flow = 275,000 gpd
Detention Time = 38 days

[Ans: Hydraulic Load = (5 feet) (12 inches/feet) = 1.58 inches/day]
38 days

Obviously, the hydraulic load will impact a pond's operation. The type of aeration in the pond also affects its operations. Interestingly enough, the aeration method is determined by the previous factors we have discussed, namely, organic loading, surface area, and depth, as well as the type of pond.

After reviewing that portion of the Design Parameter chart from Unit 1, what effect does the type of pond (and its major mode of aeration) have on the amount of organic loading which can be adequately treated by the pond?

[ANS: Of the three types of ponds with aerobic zones, aerated ponds are typically able to treat higher minimum organic loading rates. This is because they employ mechanical aeration or diffused aeration equipment, which provide a higher dissolved oxygen transfer rate than the natural methods of algae or wind.]

Organic Loading Calculation.

To determine the organic load of a pond, you should perform this calculation:

$$\text{Organic Load (lb. BOD/day/acre)} = \frac{\text{(BOD, mg/L) x (flow, mgd) x (8.34 lb./gallon)}}{\text{(Area, acres)}}$$

Organic Loading Calculation Exercise

Now we will perform the calculation using some real numbers. Insert the numbers on the screen into the appropriate spot in the calculation. Figure the answer. Remember that the answer you want will be represented as pounds of BOD per day, per acre; therefore, you will need to calculate the number of acres of the pond before calculating the organic load.

Width of Pond = 700 feet
Length of Pond = 400 feet
Depth of Pond = 5 feet
Influent Flow = 275,000 gpd
Influent BOD = 240 mg/L

[Ans: Surface Area (acres) = (700 feet) x (400 feet) = 6.4 acres
43,560 square ft./acre]

Next Step

After we determined the acreage, we can use that figure to finish the calculation.

[Ans: Organic Load = $\frac{(240\ mg/L) \times (0.275\ mgd) \times (8.34\ lb/gallon)}{(6.4\ acres)}$ = 86 lb. BOD/day/acre

The answer is 86 lb. BOD, per day, per acre.]

Why is algae found near the surface of a pond?

[Ans: Algae require oxygen; in typical facultative ponds, oxygen is most plentiful near the surface. Algae also use sunlight in the photosynthesis process.]

Exercise for Unit 2 – General Operation and Maintenance

1. Factors that can affect the operation and treatment efficiency of a pond or lagoon include:
   a. physical
   b. biochemical
   c. microbiological
   d. all of the above

2. Hydraulic load is the height in inches of the average volume of wastewater introduced into a pond in one:
   a. hour
   b. day
   c. week
   d. month

3. Water in the winter months can hold nearly twice as much dissolved oxygen (DO) as in the summer.
   a. True b. False

4. List four biochemical factors that can significantly affect pond operation.

   Answers could include: surface organic load rate, pH, DO, alkalinity, nutrient levels, and influent toxicity.

5. Aerobic bacteria require oxygen for respiration, but anaerobic bacteria do not require oxygen for respiration.

6. Protozoa are classified into two broad groups called flagellates and ciliates.

7. The three basic types of vegetation in a pond environment are: emergent weeds, suspended vegetation, and dike vegetation.

8. List five items that should be recorded in your maintenance operation logs.
   a. water temperature and pH
   b. DO
   c. Influent and effluent DOD and TSS
   d. water depth
   e. number of aerators in operation

9. Using the skills you have learned in the preceding units, calculate the surface area, volume, detention time, hydraulic load, and organic load of a pond with the following dimensions, influent BOD, and flow rate:

Surface Length = 200 feet	Average Length = 190 feet	Influent Flow = 15,000 gallons per day
Surface Width = 50 feet	Average Width = 40 feet	Influent BOD = 110 mg/L
	Depth = 5 feet	

SURFACE AREA: Note: in this step, we calculate the entire surface area of the water. The volume calculation in the next step will use the average length and width to account the sloped sides of the pond.

surface area = 200 ft x 50 ft = 10,000 sq ft

$$10{,}000 \text{ sq ft} \times \frac{1 \text{ acre}}{43{,}560 \text{ sq ft}} = 0.23 \text{ acres}$$

VOLUME: Note: to calculate volume, use the average length and average width.

volume = 190 feet x 40 feet x 5 feet = 38,000 cubic feet

convert to gallons: $38{,}000 \text{ ft}^3 \times 7.48 \text{ gallons / ft}^3 = 284{,}240 \text{ gallons}$

DETENTION TIME:

$$\text{Detention time (days)} = \frac{\text{Pond volume (gallons)}}{\text{Influent flow (gal / day)}} = \frac{248{,}240 \text{ gallons}}{15{,}000 \text{ gal / day}} = 19 \text{ days}$$

HYDRAULIC LOAD:

$$\text{Hydraulic Load} = \frac{\text{Depth of pond (inches)}}{\text{Detention time (days)}} = \frac{60 \text{ inches}}{19 \text{ days}} = 3.16 \text{ inches / day}$$

ORGANIC LOAD: note: a BOD of 110 mg/L is the same as a BOD of 110 lb / million lb of water.

$$\text{Organic Load} = \frac{\text{BOD (mg/L) x Flow (mgd) x 8.34 (lb/gal)}}{\text{Area (Acres)}}$$

$$\text{Organic Load} = \frac{110 \text{ lb} \times 0.015 \text{ mgd} \times 8.34 \text{ lb/gal}}{1 \text{ million lb} \times 0.23 \text{ acre}} = \frac{60 \text{ lb}}{\text{day x acre}}$$

What do you think will be accomplished when we suggest that running ponds in parallel mode rather than series mode may be a solution to the organic overload problem?

[Ans: As an example, imagine two identical ponds that can be run either in parallel or series. By running the two ponds in parallel as opposed to series operation, several operating parameters change:

- *The volume is doubled because the flow is split into two ponds instead of one, which is twice as large of a volume.*
- *The detention time is cut in half because the flow, however, only travels through one pond instead of two, which takes half of the time.]*

Whether you know it or not, you are probably familiar with one of the problems associated with Hydrogen Sulfide. Does anyone know what it smells like?

[Ans: It emits that classic "rotten egg" smell.]

 Exercise for Unit 3 – Typical Operating Problems

1. Malfunctioning or inadequate aeration equipment can result in low levels of dissolved oxygen (DO) and poor effluent quality.
   a. True
   b. False

2. The addition of the chemical copper sulfate can help to settle algae out of the effluent.

3. It is suspected that a toxic substance has been discharged into the collection system. List three things to monitor in the influent water.

   a. Influent pH
   b. Influent DO
   c. Influent Temperature

4. The build-up of a sludge blanket on the bottom of a pond will lessen the capacity of the pond. It may be necessary to dredge the pond after a period of several years of operation.

5. A possible solution mentioned for many of the problems in the table is to recirculate part of the effluent flow back into the influent flow.

6. Explain in an example how the recirculation solution mentioned above can help solve a pond problem. One example would be to increase DO, since effluent usually has a higher DO than influent.

7. Running ponds in _parallel_ mode may be a solution if _organic_ overload is the suspected problem.

8. List three examples of problems that may produce odors.
   a. anaerobic conditions
   b. presence of hydrogen sulfide
   c. Spring/Fall turnover, algae die-off, organic overloading, poor pond circulation, scum accumulation on pond surface, insufficient sludge.

9. List three problems or hazards that may be caused by burrowing animals.
   a. structural stability
   b. tripping hazard
   c. equipment damage

10. Explain how the choice of ground cover on a dike can make the maintenance of the dike easier. Can eliminate other undesirable growth, make mowing easier, a low-growing ground cover may improve general appearance.

Module 20:
Trickling Filters
Instructor Guide – Answer Key

☑ Exercise: Calculate the hydraulic loading of a Trickling Filter with the following data:

Diameter of TF = 40 ft
Influent Flow = 2.0 mgd

Ans: Surface Area = ( ) x (radius)^2 = (3.14) x (20)^2 = 1,256 ft^2

$$\text{Hydraulic Loading} = \frac{(2{,}000{,}000 \text{ gpd})}{(1{,}256 \text{ ft}^2)} = 1{,}592 \text{ gpd/ft}^2$$

☑ Exercise: Calculate the organic loading of a Trickling Filter with the following data:

Diameter of TF = 60 feet

Depth of Media = 6 feet
Influent Flow = 100,000 gpd
Influent BOD = 200 mg/L

Ans: Media Volume (ft^3) = (π) x (radius)^2 x (depth) = (3.14) x (30 feet)^2 x (6 feet) = 16,956 ft^3

Organic Load = $\frac{(200\ mg/L) \times (.1\ mgd) \times (8.34\ lb/gallon) \times (1{,}000\ ft^3)}{(16{,}956\ ft^3)}$ = 10 lb BOD/day/1,000 ft^3

UNIT 1 EXERCISE:

1. Name the three components of a trickling filter.

Ans: Distribution System
Filter Media
Underdrain System

2. Name the two general types of trickling filters based on method of distribution.

Ans: Circular trickling filter with rotary arms
Stationary trickling filter with spray heads

3. Describe the process and operation of a trickling filter.

Ans: Wastewater is distributed over the top of a filter media. Bacteria and micro-organisms attached to the filter media metabolize the organic substances in the wastewater, producing waste products such as carbon dioxide, ammonia, and phosphates. The treated wastewater is discharged, or pumped, to sedimentation tanks. A portion of the filter effluent may be re-circulated back to the trickling filter to improve removal efficiencies.

4. Identify the three classifications of trickling filters based on hydraulic and organic loading rates.

Ans: Standard Rate Trickling Filter
High Rate Trickling Filter

Roughing Trickling Filter

5. Calculate the hydraulic loading rate of a trickling filter, given a diameter of 55 feet and an influent flow of 1.25 mgd.

Ans: Surface Area = (π) x (radius)^2 = (3.14) x (27.5 feet)^2 = 2,375 ft^2

Hydraulic Loading (gpd/day/ft^2) = $\frac{\text{Influent Flow, gpd}}{\text{(Surface Area, ft}^2\text{)}}$

= $\frac{1{,}250{,}000 \text{ gpd}}{2{,}375 \text{ft}^2}$ = 526 gpd/day/ft^2

6. Calculate the organic loading rate of the trickling filter in the above question, given a media depth of 20 feet and an influent BOD of 235 mg/L.

Ans: Media Volume = (π) x (radius)^2 x (depth) = (3.14) x (27.5 feet)^2 x (20 feet) = 47,493 ft^3

Organic Load (lb BOD/day/1,000 ft^3) = $\frac{\text{(BOD, mg/L) x (Flow, mgd) x (8.34 lbs/gallon) x (1,000 ft}^3\text{)}}{\text{(Volume, ft}^3\text{)}}$

= $\frac{\text{(235 mg/l) x (1.250 mgd) x (8.34 lbs/gallon) x (1,000 ft}^3\text{)}}{\text{47,493 ft3}}$

= 51.6 lb BOD/day/1,000 ft^3

☑ Exercise: Calculate the Ammonia Nitrogen removal efficiency of a Trickling Filter with the following data:

Influent NH_3-N = 10 mg/L
Effluent NH_3-N = 2.5 mg/L

Ans: [(10-2.5)/10] x 100 = 75%

☑ UNIT 2 EXERCISE:

1. Identify five daily operations inspections appropriate for trickling filters.

Ans: Trickling filters should be inspected on a daily basis for signs of:

• Ponding • Uneven distribution of flow • Clogging	• Roughness or vibration • Leakage	• Filter flies • Unusual odors

2. List three abnormal operating conditions typically encountered in a trickling filter facility and explain what steps can be taken to correct each problem.

Ans: Ponding—Increase the recirculation rate to flush out solids. Slow the rotary distribution arm to flush out solids. As a last resort, chlorinate the filter media to kill excess biomass.

Odors—Pre-aerate the wastewater if the influent wastewater is the cause of odor. Increase the recirculation rate to flush out excessive solids from the filter media. Verify that the nozzles are allowing for equal distribution across the media surface.

Filter flies—Increase the recirculation rate to flush out the filter media. Temporarily and periodically flood the filter media. As a last resort, chlorinate the filter media to kill the filter flies.

Sloughing—Either increase or decrease the recirculation rate depending on the suspected cause of excessive sloughing: increase the rate if low organic loading or decrease the rate if high hydraulic loading. Divert a portion of the flow to additional treatment units to control the high hydraulic loading effect, if possible.

Weather conditions—Decrease the recirculation rate to maintain a warmer temperature. Remove orifices and end plates from the distributor arms to reduce the icing caused by spraying. Breakup any ice that forms on the filter media.

Shock loads—Increase the recirculation rate to dilute high organic loading. Operate multiple filters in series to limit the damage caused by high organic loading (organic loading should only affect the first filter and be harmless to the preceding ones). Operate multiple filters in parallel to reduce the high hydraulic loading.

3. Give one example of an operation modification that may be required due to sampling results.

Ans: High Total Suspended Solids—Adjust the hydraulic loading rates as necessary. Excessive flow through the filter can flush out solids and cause high TSS.

High Biochemical Oxygen Demand—Develop and implement sewer-use ordinances to establish limitations on organic loading discharges.

High Settleable Solids—Adjust the hydraulic loading rate as necessary. Calculate the organic loading rate to determine if the rate is acceptable: increase recirculation to dilute the organic loading, place additional trickling filters units in service to distribute the excessive organic loading.

Low Dissolved Oxygen—Check for filter media clogging. Calculate the organic loading rate to determine if the rate is acceptable: increase recirculation to dilute organic loading, place additional trickling filters units in service to distribute excessive organic loads.

High Chlorine Demand—Survey sewer system customers to determine the source, it is most likely a non-domestic type wastewater discharge.

Poor Clarity—Adjust the hydraulic loading rate as necessary to control high settleable solids.

Low or High pH—Survey sewer system customers to determine the source, it is most likely a non-domestic type wastewater discharge. Adjust the pH with sodium hydroxide (to increase pH).

High Fecal Coliform—Increase solids and/or sludge disposal operations to remove the excessive solids.

Nutrient Imbalance—Adjust the number of upstream treatment units (i.e. primary clarifiers) to better control the treatment efficiency and nutrient loadings. Add necessary nutrients, if deficiency is the cause.

Unit 3 Exercise:

1. List five items that should be inspected after new construction of a trickling filter and before start-up of the operation.

Ans:	• Packing grease • Nozzles • Media • Distributor Arm	• Underdrain System • Painted Surfaces • Valves • Manuals

2. Describe the process of putting a filter into operation with no growth on the media.

Ans: After checking all components, begin operation of the unit. Allow several weeks for the bio-growth to develop. High rate recirculation will help to establish growth. Attempt to equalize flow in upstream processes so that high hydraulic peak loadings are minimized. Maintain a low sludge blanket level in the upstream primary clarifier so that organic loading to the trickling filter is minimized as much as possible. Notify regulatory agencies that effluent quality may not be in compliance with the NPDES Permit until the bio-growth is established.

3. List and describe five normal maintenance tasks required for trickling filters.

Ans: Bearings and Seals—Both distributor bearings should be lubricated as per the manufacturer's recommendations. Check the manufacturer's recommendations and change the oil accordingly. Replace the mercury seals as needed.

Distributor Arms—Use a carpenter level to check the vertical alignment of the center column and the distributor arms. Check for the proper tension of the horizontal and vertical guy supports between the column and arms. Clean the nozzles when they become clogged. Flush out each distributor arm at least once a month. Major variations in vertical alignment should be corrected.

Fixed Nozzles—Conduct a pan test annually to determine if all nozzles are providing equal flow. Flush out internal piping to prevent solids accumulation, especially at the end of the manifold nozzles.

Underdrains—Check annually for any accumulation of solids or debris. Visually inspect underdrains using a flashlight, mirror, or robotic sewer TV camera on an annual basis.

Pumps and Level/Recirculation Control System—Verify level control system set points on a quarterly basis. Test all low level and high level alarms on a quarterly basis. Follow any additional manufacturer's recommendations.