Wisconsin Department of Natural Resources
Wastewater Operator Certification

Advanced General Wastewater Study Guide

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Wisconsin Department of Natural Resources
Bureau of Science Services
Operator Certification Program
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Preface

This operator's study guide represents the results of an ambitious program. Operators of wastewater facilities, regulators, educators and wastewater businesses jointly prepared the objectives and exam questions for this subclass.

How to use this study guide with references

In preparation for the exams you should:

1. Read all of the key knowledges for each objective.

2. Use the resources listed at the end of the study guide for additional information.

3. Review all key knowledges until you fully understand them and know them by memory.

It is advisable that the operator take classroom or online training in this process before attempting the certification exam.

Choosing A Test Date

Before you choose a test date, consider the training opportunities available in your area. A listing of training opportunities and exam dates is available on the DNR Operator Certification home page http://dnr.wi.gov/org/es/science/opcert/. It can also be found in the annual DNR "Certified Operator" or by contacting your DNR regional operator certification coordinator.

Acknowledgements

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Chapter 1 - Sources and Characteristics of Wastewater

Section 1.1 - Sources of Wastewater

1.1.1 Explain the effect of excessive infiltration or inflow on a wastewater treatment plant.

Excessive infiltration or inflow in a treatment plant can:

A. Cause increased pumping costs
B. Decrease detention time in the biological treatment process
C. Cause excessive hydraulic loading to the clarifiers
D. Exceed the hydraulic capacity of other processes
E. Lead to bypassing of raw wastewater in the collection system or at the plant

1.1.2 Describe the types of materials prohibited from discharge into sewer systems and the reasons they should not be discharged.

The materials with the characteristics listed below are generally prohibited from discharge to the sewer system. These prohibitions are included in local sewer use ordinances. Generally materials that can interfere with wastewater treatment, pass through the treatment system and cause a water quality violation, or accumulate in sludges making the sludges toxic or hazardous are prohibited. Many of the industrial materials can be handled with proper pretreatment or segregation of waste streams that cannot be pretreated.

A. Volatile organics such as gasoline or solvents that can cause an explosive atmosphere in the sewer system or at the treatment plant.

B. Heavy metals such as chromium, zinc, copper, nickel, and cadmium are very toxic and can cause treatment plant upset, pass through the plant or accumulate in the sludge.

C. Acidic and alkaline wastes that can damage the sewer system or upset the treatment plant; generally pH's lower than 5.0 or greater than 10.0 should be neutralized prior to discharge to the sewer system.

D. Oil and grease must be controlled at industrial and commercial sources with oil separators and grease traps to prevent maintenance problems in wet wells and at the treatment plant.

E. High strength loadings of BOD or suspended soils that could organically overload the treatment plant; this would especially be a problem with "batch" dumping that would cause large slug loads; any "batch" type operation should be handled by flow equalization to prevent plant upsets.

F. High temperature wastewaters that could inhibit biological activity.

G. Any solid or viscous materials that could cause sewer blockages.

H. Any debris such as rags or other materials that could cause sewer blockages or pump clogging.

I. Any other toxic materials that impair or interfere with the treatment process.

Section 1.2 - Characteristics of Wastewater

1.2.1 Explain when petroleum contaminated groundwater can be accepted at a treatment plant.

The clean-up operations associated with leaking underground storage tanks have led to many requests to accept groundwater containing dilute hydrocarbons. One reason is cost. Another is administrative it is easier to use an existing point source discharge than to permit a new one for a short term situation.

DNR guidelines (December, 1990) state:

"Petroleum-based wastewater can be discharged to a sewage treatment plant without causing a plant upset provided any free product gasoline has been removed beforehand and the ratio of daily plant influent flow to daily discharge of petroleum-laden wastewater is at least 100 to 1. An alternative approach to using a 100:1 dilution factor is to limit the concentration of gasoline constituents at the treatment plant headworks to 150 ug/L or less."

EPA guidance proposed using the four main constituents of gasoline as indicator parameters for monitoring dissolved hydrocarbons during clean-up of gasoline from underground storage tanks. The indicator parameters are benzene, ethyl benzene, toluene, and xylene (BETX). Discharge limits are expressed in terms of a combined BETX limiting concentration.

This means:

A. Most treatment plants can occasionally accept some gasoline without a plant upset

B. Safe concentrations of gasoline to target for at the headworks of the treatment plant should be less than 150 ug/L

C. The concentration of gasoline is measured by analyzing for BETX (benzene, ethyl benzene, toluene, and xylene)

D. The concentration of gasoline is the summation of the individual BETX concentrations

Care should be taken in how and where the waste is introduced to the plant to eliminate explosion hazards. Also care should be taken in interpreting the guidance when deciding whether or not to accept this type of waste at facilities which discharge to groundwater. More study may be needed to be sure there is adequate dilution and treatment to meet groundwater standards for gasoline constituents.

1.2.2 Discuss the wastewater characteristics and problems with the following industrial processes:

A. Dairy operations
B. Metal finishing
C. Fruit and vegetable processing

A. Dairy operations: Milk product operations include receiving stations, bottling plants, cheese and butter factories, and ice cream plants. Milk wastes are very high in BOD and suspended solids with values from 1,000 to 10,000 mg/L. Many times batch operations can cause shock loads of organic materials to the treatment plant. Milk wastes also can have high oil and grease concentrations, high salt concentrations from certain types of cheese production, and high levels of phosphorus from cleaning compounds. Normal pretreatment for dairy wastes would be flow equalization to prevent shock loads and biological treatment (activated sludge, trickling filters or RBC's) to reduce the organic loading before discharge to the treatment plant.

B. Metal finishing: Metal finishing operations include wastewater from pickling (metal acid cleaning), phosphorizing (metal hot water alkaline washing with high strength phosphorus compounds), and electroplating (surface coating with heavy metals such as copper, cadmium, nickel, zinc, and chromium). The wastewater from metal finishing is generally not a large volume but it contains many problem constituents that can impair treatment. The problem constituents include acid wastes, alkaline wastes, heavy metals, cyanide, and phosphorus. The acid and alkaline wastes need to be neutralized prior to discharge and any cyanide solutions need to be segregated and totally destroyed by chlorine oxidation at pH values greater than 12. The heavy metals are not treatable in biologic secondary systems and in high enough concentrations can completely kill all biologic organisms in the secondary system of the treatment plant. Some heavy metals such as copper can precipitate and enter the sludge stream and if the concentrations are high enough they can shut-down anaerobic digester operations. These heavy metal solutions need pretreatment using chemical precipitation to acceptable levels before discharge. The phosphorus compounds can generally be handled at the treatment plant but may require pretreatment in small communities. Special concerns with metal finishing facilities would be accidental discharges or spills of concentrated solutions that could allow toxic materials to shock load the treatment plant and shutdown secondary treatment.

1.2.3 Discuss the wastewater characteristics and problems with the following industrial processes: {Continued}

C. Fruit and vegetable processing

C. Fruit and vegetable processing: Fruit and vegetable operations include wastewater from washing, peeling, cooking, canning, bottling, and freezing the products at canneries, freezer plants, and bottling operations. Most fruit and vegetable operations are seasonal in nature producing large volumes of wastewater over short periods of time. In most operations washing is the first step and can produce significant amounts of wastewater high in suspended solids. This is especially true with root crops (potatoes, carrots, onions, radishes, and beets, etc.), because of the amount of soil on the crops. The second step may involve peeling which can include such operations as caustic peeling (beets and tomatoes) or abrasion (potatoes). Both peeling operations cause large amounts of suspended solids to be generated; with caustic peeling the wastewater is very high in sodium making the wastewater unsuitable for land application as it will bind-up the soil. The cooking, canning, and juice bottling processes produce wastewater from spillage, breakage, and container cleaning. Freezer plant operations produce wastewater that is similar to washing, peeling, and cooking but vegetable packaging does not require container cleaning. The wastewater from fruit and vegetable processing is highly variable depending on the crop being processed and will require significant pretreatment before it can be discharged to a treatment plant. In many cases food processing facilities must totally treat their wastewater especially when located in small communities that cannot handle this high strength wastewater. Pretreatment includes grit removal, screening, waste segregation, and lagooning. Where the industry has to treat its wastewater it is usually pretreated and land applied, usually by spray irrigation. Where it is discharged to a municipal treatment plant it usually involves significant pretreatment, then controlled low flow discharges to the municipal treatment plant.

Chapter 2 - Collection and Flow Monitoring of Wastewater

Section 2.1 - Collection of Wastewater

2.1.1 Discuss how submersible pumps are used in lift stations.

Submersible pumps are designed with the pump and motor completely submerged in a wetwell. They are normally used at small lift stations with flows of 600 GPM or less. The submersible centrifugal pump is watertight and normally controlled by teardrop shaped plastic floats containing mercury switches. These pumps are designed to handle raw wastewater, but provisions must be made to easily remove them for cleaning and wetwell cleaning. This is normally done with either a chain or rail system with various methods to reconnect the discharge piping. These pumps should not be run dry as this could cause seal damage and allow water to enter the motor housing.

2.1.2 Explain how a wetwell/drywell pumping station works.

In wetwell/drywell lift stations, the centrifugal pumps and other equipment are located in a separate chamber (drywell) with only the suction pipe being submersed in the wetwell. The pumps are often controlled by an air bubbler pipe which senses the depth of the water in the wetwell. Back pressure on the air supply actuates a pressure switch which controls the pumps. It is important that the drywell be well ventilated and dehumidified to protect the equipment and ensure the safety of the operator.

2.1.3 Define cross connection and the importance of cross connection control devices.

Cross connection is a physical piping connection between a potable water supply and a different piping system that could have the potential to contaminate the potable supply. The importance of cross connection control is a public health concern. If backflow allows bacterial contamination or other chemical solutions to enter the potable supply the possibility of causing illness exists.

Backflow can happen in two general ways. The first would be if a negative pressure were to occur in the potable system allowing backflow to happen by backsiphonage. The second would be if pumping equipment in the other piping system created a higher pressure than in the potable supply system. This would cause backflow by the pressure differential.

Cross connection control is especially important at treatment plants because of both the bacterial contamination and the numerous chemical solutions present. Backflow at treatment plants could come from hoses or wetwells, hoses submerged in chemical solution tanks, hoses at sinks where the end of the hose could be in a waste liquid in the sink (hoses on discharge lines are seen fairly commonly in laboratory sinks), the use of potable water for pump seals, and improper connection of the discharge of a high pressure pump to the piping system.

2.1.4 Discuss the devices (backflow preventers) used in cross connection control in wastewater treatment and their required inspection and certification intervals.

The devices (backflow preventers) for cross connection control at treatment plants are in the Wisconsin state plumbing code of the Department of Industry, Labor, and Human Relations (DILHR). The section of the code for these devices is ILHR 82.41.

There are two general ways for backflow prevention at treatment facilities: physical air gap with subsequent repumping and the reduced pressure principle backflow preventer (RP units). The air gap system that may exist in older treatment plants is the open flow of potable water to an open tank with the discharge point a fixed distance above the tank. The water in the open tank is repumped into a pressure tank for distribution to process piping lines in the treatment plant. All water after this system would be considered non-potable because the air break and open tank could make the water unsafe.

The more common device used in all newer applications is the RP unit. The RP unit would be located close to where the potable water enters the treatment plant. At larger plants there may be several RP units if there are several connections to the potable water supply or have the administrative and office areas separated from the in-plant process piping with each area having a separate RP unit. Large lift stations in the collection system that use potable water for seal water would use RP units. Smaller lift stations would probably use wastewater for seal water rather than the potable supply because of the need of a RP unit.

At treatment plants that have a private well as a water supply it is required under the well code to follow the plumbing code on backflow to prevent possible contamination of groundwater. The backflow preventers must be inspected and certified annually by a qualified person licensed by DILHR.

Section 2.2 - Flow Monitoring of Wastewater

2.2.1 Identify where the following flow measuring devices should be located in a wastewater treatment plant.

A. V-notch weir
B. Parshall flume
C. Palmer-Bowlus flume
D. Magnetic flow meter
E. Ultrasonic

A. V-notch weir (60 degrees or 90 degrees) - Located in an open channel, usually at the effluent end to avoid debris problems. It is often used to measure discharge from stabilization ponds and smaller flows including return flows, sidestream flows, and flow measurements in sewer manholes

B. Parshall flume - Located in an open channel. This is the most common type of flow measurement device for raw wastewater and is located in an influent channel after coarse screening. It may also be used for effluent measurements.

C. Palmer-Bowlus flume - Located in an open channel flow, usually in an influent channel after screening. It is also often used in sewer manholes to measure flow. It looks like an open pipe with an odd u-shaped end. It is not as sensitive as the Parshall flume.

D. Magnetic flow meter - It is used only in pumped full pipe flow and may be used in many applications from effluent to sludges. A very accurate and reliable device.

E. Ultrasonic flow meter - It is used only in pumped full pipe flow. The accuracy varies with the application. It is important to follow manufacturers specifications for any given application. Any air bubbles or lack of air bubbles and the density of any solids being pumped affect the meter's performance. There are several other closed pipe flow measuring devices including differential head flow meters (venturi meter, orifice plates, and pilot tubes) and mechanical flow measurement (propeller meter). All of these devices are more commonly used to measure flows of clean liquids and would only be appropriate to measure flow of a high quality filtered effluent.

2.2.2 Explain how the following water level measurement devices are used.

A. Floats
B. Ultrasonic devices
C. Bubbler tube systems
D. Diaphragm bulb systems

Water level measurement devices:

A. Floats - Floats are used to measure water elevations for weirs and flumes. They are normally located in a stilling well a fixed distance upstream of the throat of the flume or the weir plate. The stilling well and float must be kept free of debris or grease to ensure accurate operations and to prevent sticking. Floats may have cold weather problems due to the formation of ice.

B. Ultrasonic devices - Ultrasonic devices are used to measure water elevations for weirs or flumes. They are located a fixed distance upstream of the throat of the flume or the weir plate. They measure water elevation by sending an ultrasonic pulse wave that bounces off the water surface. The time it takes for the pulse to return determines water elevation. Changes in air temperature, surface foam, and fog can adversely affect the accuracy of an ultrasonic device.

C. Bubbler tube systems - Bubbler tube systems are used to measure water elevations by applying air pressure through a tube submerged in a stilling well in the wastewater stream. The back-pressure measured determines the depth of liquid. As with the other devices, it can be used for flumes and wells. It is not used as commonly as floats or ultrasonic devices.

D. Diaphragm bulb systems - Air inside a sealed diaphragm submerged in a liquid will have pressure changes dependent on the static water level above the diaphragm. This pressure change determines the elevation of the water surface. This system can be used for flumes and weirs. Temperature changes of the wastewater or any heating and cooling of the trapped air in the diaphragm can affect the accuracy. This device is not used as commonly as floats or ultrasonic devices.

2.2.3 List the conditions to consider in the placement of open channel flow meters.

Open channel flow measurement involves a hydraulic structure, which creates certain hydraulic conditions, and a device to measure the water level. The flow meter needs to be located so it measures the desired flows. For influent wastewater flows, this means the flow meter must be located upstream from any wastewater plant sidestreams.

Placement of open channel flow meters:

1. The approach conditions: Flow to the structure should be free of turbulence; sometimes this is not the case which can significantly affect the accuracy of the measured flow. If flow enters the measuring chamber at a 90 degrees angle to the device or there is a change in channel shape (round pipe to rectangular channel) an extra long approach channel is needed so the water can become non-turbulent. The only thing that is supposed to affect the water level is the amount of water flowing through the structure, not the turbulence caused by some other obstacle or condition.

2. The structure (flume or weir) should be clean and free of any debris. A v-notch weir should be scrubbed occasionally, its edge should remain sharp and clean. If the effluent contains significant solids they must be cleaned-out of the v-notch chamber regularly. The walls of the flume should be smooth and flumes should also be scrubbed occasionally. A Parshall flume must be properly installed - level from side to side and longitudinally with no bowing in of the walls. A Parshall flume is the preferred hydraulic structure as it is less subject to clogging problems as compared to a v-notch weir.

3. If the level detector is a mechanical float it must be checked frequently to make sure that it does not have any scum, grease, algae or strings attached to it. The arm must be lubricated so it does not stick and it needs to be checked frequently in very cold weather to

ensure that ice is not a problem. If the level detector is ultrasonic, foam in the channel will be read as the water surface causing a false high flow reading. The specifications for the ultrasonic level detector must include operation at temperature variations expected in the state.

4. The level detector must be placed at the correct point for the hydraulic device. In the flumes there is a precise distance upstream from the throat at which the level measurement is supposed to occur. A level detector placed further back or closer is improperly installed. For weirs, the distance must be at least four times the maximum expected water level.

2.2.4 Explain the possible causes for operational problems with open channel flow meters.

Problems with open channel flow meters:
A. Undersized - A flume that is too small will not be operating under normal flow conditions. Submerged flow conditions require an additional head reading and calculations. An undersized weir will become submerged or the approach velocity may get too high.

B. Low flow/oversized - All flumes have a high percentage error at low flow conditions which declines to 3% as the flow approaches 100% of design. With a 3" to 12" flume percent error is high when water height is only 1"- 2".

C. Slope/faulty construction - If a Parshall flume is improperly installed with a (longitudinal) slope in the converging zone or a (transverse) side-to-side slope, the accuracy of flow measurement is severely impaired. Flows may be off by 25% or more. With a v-notch weir the most typical errors are: error in the angle of the v-notch, installing the weir plate with a slight upstream or downstream slope (not vertical), rounding of the sharp edge at the weir crest, and roughness of the upstream face of the weir plate.

D. Turbulence - Turbulence and surges in the zone of measurement affects the accuracy with all open flow devices.

E. Wrong calculations - The use of the wrong equation for the flume or v-notch weir affects the accuracy of readings.

F. Incorrect zero setting - This is one of the greatest controllable sources of error. It can result from improper instrument installation (wrong location, wrong elevation, or at an angle). An improper setting of the zero reference level can also be the result of lack of knowledge. With the Palmer-Bowlus flume the zero level is the floor of the flume throat not the invert of the pipe as might be suspected.

G. Clogging/debris/grease in the float stilling well - If the flume was installed with a float stilling well, the pipe must be kept clear and the well itself must be accessible for cleaning and float adjustment.

2.2.5 Describe how a magnetic flow meter works and is installed.

A magnetic flow meter works on the principle that a conductor passing through a magnetic field will pick-up an induced voltage. The meter measures the average liquid velocity.

Important components of the meter include the magnetic coil, the grounding rings, the grounding straps, the nonconductive liner, and the electrodes. The meter can be used in many applications from clear liquids to sludges. The electrodes must be in contact with the liquid which is sometimes prevented by a grease coating. Ultrasonic cleaners are often used. However to prevent grease build-up, the ultrasonic cleaner must be on all the time (each meter would need its own unit). Alternately use a rag to clean the electrodes. If the electrodes are removable, the tube liner must be nonconductive and must remain unbroken. Too much torque in tightening the flanges can damage the liner. If there is leakage around the electrodes or a broken liner, the magnetic meter is ineffective. There are various liner materials and the proper one would be selected at design. The purpose of grounding rings is to give a fixed background reading. The grounding strap must go to earthground (e.g. moist earth). Corrosion impairs the electrical contacts (grounding straps need to be checked for corrosion).
The magnetic meter should be installed with shut-off valves and bypass piping so it can be serviced easily. It should be installed where it can be reached. Other location requirements would be as specified by the meter manufacturer.

Chapter 3 - Treatment and Equipment of Wastewater

Section 3.1 - Treatment of Wastewater

3.1.1 Describe the following preliminary treatment processes.

A. Bar screen
B. Grit removal
C. Comminution/barminutor

A. Bar screen - Removes large objects such as rags and debris to protect pumping equipment, prevent clogging, and the need for manual removal of this material from downstream channels and tanks.

B. Grit removal - Takes inorganic solids (sand, grit, etc.) out of the waste flow to protect pumps and to prevent this material from settling out in downstream tanks especially the primary clarifier where the grit can be pumped to the anaerobic digester. Plants without grit removal will eventually have major operational problems requiring plant shut-down.

C. Comminutor or barminutor - Reduces the size of the remaining suspended solids so that they can be more easily processed by downstream units without causing clogging.

3.1.2 Explain how to clean bar screens and dispose of the debris.

Bar screens are either mechanically or manually cleaned. At large plants bar screens are mechanically cleaned using various devices and conveyor systems to take the debris to storage containers or directly to incinerators. Manually cleaned bar screens require the physical removal of debris using a rake, fork, or other similar hand tools. Bar screen debris should be disposed of by incineration, burial on site, or hauled to a sanitary landfill.

3.1.3 Describe the following ways wastewater treatment plants use to control odors:

A. Aeration
B. Chlorination
C. Other chemicals
D. Odor management

A. Aeration - Preaeration is used at the plant headworks to freshen the raw wastewater and to remove hydrogen sulfide if the raw wastewater is septicl. Often preaeration is done in conjunction with grit removal. Aeration is also used in other parts of the plant to control odors such as in wastewater feed channels, return activated sludge channels, sludge holding tanks, and other tankage where anaerobic conditions might occur.

B. Chlorination - Chlorination for odor control is normally done at the plant headworks to oxidize odor causing agents. Chlorine forms would include free chlorine, sodium and calcium hypochlorite, and chlorine dioxide.

C. Other chemicals - Other chemicals that are used in odor control include ozone, hydrogen peroxide, activated carbon, potassium permanganate, nitrate, and calcium and sodium hydroxide. Sometimes iron or aluminum salts are used to precipitate odor causing agents. Chemicals can also be used to change airborne odors such as masking agents (odor modification) and counteraction chemicals (odor neutralization).

D. Odor management:
1. Source control - Many odor problems may be caused by specific industries and commercial facilities. These sources should be controlled with an effective sewer use ordinance and pretreatment of problem discharges.

2. Collection system management - Many odor problems are directly caused by the collection system. A good maintenance program should include sewer and wetwell cleaning. In addition, flow management and chemical odor control should be done in such cases as very flat sewer lines, oversized sewer lines, oversized lift stations, and discharge points of force mains.

3. Ventilation - The use of properly designed and operated ventilation systems should help minimize odor problems. In addition the use of domes, covers, or buildings with proper ventilation over certain processes should reduce odors.

4. Treatment plant operations - Where possible, the scheduling of some of the routine operation and maintenance activities can minimize odor problems. Selecting the time of day, day of the week, and time of the year should be used to minimize potential odor problems. Special consideration should be given to the more odorous operations like grit removal and storage, screenings storage area, primary sludge pumping, acceptance of septage, and sludge dewatering and hauling. Wherever possible an operator should try to prevent organic overloads by placing more units in operation so odors will not occur. Weather conditions are an important consideration and high odor operations should be delayed (if possible) to when the weather is very hot with high relative humidity and very low

wind velocity.

3.1.4 State the overall BOD and suspended solids removal efficiencies expected from the primary treatment process.

Well designed and operated primary facilities can expect removal efficiencies of 60-75% for suspended solids and 20-35% for BOD.

3.1.5 Discuss what photosynthesis is and how it aids the biological treatment of wastewater in stabilization ponds.

Photosynthesis in a stabilization pond is a process in which green plants (algae in ponds) containing chlorophyll will use carbon dioxide and other inorganic salts in the presence of sunlight to produce oxygen and new cell growth. The importance in treatment is the production of the oxygen which is used by aerobic microorganisms (mainly bacteria) to stabilize the dissolved and suspended organic material in the pond wastewater.

3.1.6 State the overall BOD and suspended solids removal efficiencies expected from a biological secondary treatment system.

A secondary treatment system can achieve overall BOD and suspended solids removal in the 85-95% range.

3.1.7 Explain the function of a secondary clarifier.

The secondary clarifier is a large basin or tank designed to allow organic solids to settle from effluents discharged from trickling filters, rotating biological contactors (RBC's), and/or the activated sludge process. Hydraulic overloads or operational problems in the secondary system can cause major problems in the efficiency of the secondary clarifier because the biologic solids to be removed have a density very close to that of water.

3.1.8 State the overall BOD and suspended solids removal efficiencies expected from the tertiary treatment process.

The overall efficiency of treatment plants with tertiary filtration could exceed 95%.

3.1.9 List waterborne diseases that can be expected in wastewater flows caused by bacteria, viruses or parsites, and describe their importance to public health.

Bacterial diseases -
1. Bacillary dysentery
2. Cholera
3. Diarrhea
4. Leptospirosis
5. Salmonellosis
6. Typhoid fever
7. Tularemia

Viral diseases -
1. Gastroenteritis
2. Hepatitis A

3. Polio

Parasitic diseases -
1. Amebic dysentery
2. Ascarariosis
3. Cyrptosporidiosis
4. Giardiasis

Most waterborne diseases are enteric (intestinal) or are transmitted from enteric sources. It is important that wastewater treatment plants control these pathogenic (disease-causing) organisms to protect the health of people that may use downstream waters for recreation or for drinking water purposes. Typical secondary treatment can remove up to 99% of waterborne pathogenic organisms but usually disinfection is required as a further safeguard to ensure public health protection. As an example, the 1993 outbreak of cyrptosporidiosis in Milwaukee was traced to the drinking water supply which uses surface water from Lake Michigan as the raw water source.

Section 3.2 - Equipment in Wastewater

3.2.1 Explain what "cavitation" is, what causes it, what it sounds like, and what to do.

Cavitation occurs in wastewater systems when the pressure at any point in the system is lowered to the vapor pressure of the liquid. Under such conditions vapor bubbles form and then collapse producing effects ranging from decreased efficiencies to equipment failure. Places where cavitation usually occur are in pumps on impellors or at restrictions in a flowing liquid. Cavitation in pumps may occur as suction cavitation or discharge cavitation.

Cavitation can make a pump very noisy. This noise has been described as a popping sound, clattering, or like marbles rattling around in the pump. Operating the pump continuously under this condition can cause pitting of the impeller and corrosion. If cavitaion is occurring contact your consultant or pump service representative to determine the cause and corrective actions.

3.2.2 Discuss the purposes and methods of priming a centrifugal pump.

Before a centrifugal pump can actually pump water it is necessary to remove air and fill the pump casing with water or wastewater (priming). This can be done by physically filling the pump with water or by removing the air with a vacuum pump which will draw in water from the wetwell. If the pumping unit is located below the static water level priming will occur by allowing the air to escape from the pump.

3.2.3 Describe why a centrifugal pump might lose prime.

There are several things which can cause a pump to lose its prime. If the wetwell low-level shut-off is set below the pump level the water in the pump and suction line can drain back into the wetwell. This can be corrected by resetting the low-level pump shut-off, installing a check valve in the suction line, or relocating the pump at an elevation below the low-level shut-off.

Other causes of pumps losing their prime include:

A. In a situation where there is more than one primary sludge pump, they are rotated, and where sludge is infrequently pumped - the sludge which is sitting in the pumpline can become anaerobic and start to produce gas which can lead to a loss of prime.

B. A bad packing or seal can allow air to enter and water to escape causing a loss of prime.

C. A cracked line can cause loss of prime.

3.2.4 Describe the common electrical, mechanical, and physical, operational problems with lift stations and suggest corrective actions.

A. Electrical:

1. Power failure - Utilize stand-by power. Reset the circuit breakers.
2. Motor overheats and hums while running or fails to start - Check to make sure all leads under load are well connected and there are no loose wires. If unsure of the problem an electrician should be called in.
3. Tripped breaker - Reset the circuit breaker. If the breaker again trips check the pump for clogging.

B. Mechanical:

1. Pump shaft packing leaks excessively - Tighten the packing nut. If this does not correct the problem replace the packing. Inspect the shaft sleeve for wear, it may need replacement.
2. Pump is cavitating - Determine how air is entering the pump and correct.
3. Loss of pump prime - Check the shut-off float switch. Check if wetwell shut-off level is below the pump.
4. Leakage around the pump - Mechanical seals may be in need of possible replacement. Check O&M manual and with service company if necessary.

C. Physical:

1. Pumps fail to start or shut-off - Use manual control to check operations, check float switches, and return to auto control (check through a complete pumping cycle).
2. Septic wetwell - Pump more often, flush the tributary sewers, install mixing, and ventilate. If severe, add chemicals to oxidize septic wastewater.
3. Grease build-up - Clean more often. Check the collection system sources. Make sure grease traps are being serviced
4. Solvent or other volatile organic compound odor - Check explosivity with tri-gas meter. Ventilate from upstream manhole. Check for likely sources to try to eliminate.

3.2.5 Describe the use of an amp-probe to troubleshoot possible pump problems.

In order to use an amp-probe to troubleshoot possible pump problems it is necessary to have good base line data on current readings from the pump motor. The data needed would be on the motor driving the pump under full load conditions. If the actual amps increase from the historical data the operator could expect the possibility of impeller binding due to rags/debris or a partially blocked discharge line. If the readings are lower than normal it is possible that the impeller is loosened or sheared or the motor is running under low or no load conditions.

Chapter 4 - Maintenance and Sampling

Section 4.1 - Maintenance

4.1.1 Develop a planned (preventive) maintenance outline for a standard wetwell/drywell lift station with an emergency generator.

The following list of preventive maintenance tasks was prepared to evaluate the number of hours needed per year to properly run a small treatment plant with several lift stations. This plant had two lift stations in addition to a main raw pump station at the plant.

Three times per week - inspect the lift station:

A. Check the generator building
   1. Check the heater in cold weather
   2. Check the battery charger
   3. Check the time clock on the generator
   4. Check the generator oil and water

B. Check the dry well
   1. Test the pumps
   2. Test the sump pump
   3. Check the valves and pump couplings
   4. Test the alarm
   5. Blow-off the air compressor
   6. Check the dehumidifier
   7. Blow-out the air lines/bubbler tubes in the wetwell (1x/wk)
   8. Check the filters on the pumps

C. Inspect the wetwell without entering

Monthly preventive maintenance:

A. Lift station
   1. Replace the seal water filters
   2. Exercise the shut-off valves (2 per pump, 4 total)
   3. Blow-out the bubbler tubes in the wetwell
   4. Check the check/valves and clean (if needed)

B. Generators
   1. Run the generator for 1-3 hours: Note any problems with power switching and

automatic window vent openers. The generator should be run up to full temperature and full load. Frequent short runs (0.5 hours only) can cause generator maintenance problems

2. Check the batteries and clean (if needed)
3. Test the batteries
4. Check the oil
5. Check the antifreeze in winter months
6. Log the running time
7. Check the fuel level

Quarterly preventive maintenance:

A. Grease the bearings on all sewage pumps permanufacturers specifications
B. Clean/replace filters on the air compressors
C. Drain the moisture traps on the compressors
D. Oil the window louvers (associated with generator use)
E. Clean the filters on the dehumidifiers in the drywell
F. Pull and clean the sump pumps in the drywell

Semi-annually:

A. Generators
   1. Change the oil
   2. Change the plugs
   3. Change the antifreeze (if needed)

B. Check valves
   1. Disassemble half of the check valves at the facility
   2. Clean

Annually:

A. Grease the pump motors per manufacturers specifications
B. Arrange for flow meter calibration
C. Order supplies (grease, oil, and filters for pump seals) check when received and store
D. Arrange for a septic tank service to remove grease and sludge from the wetwell

Section 4.2 - Sampling

4.2.1 Describe the common causes of the following sampling errors and explain how they might alter laboratory results:

A. Poor sampling location
B. Improper use of grab or composite sampling
C. Sampling equipment not properly cleaned
D. Composite sampler not cold enough for storage
E. Improper chemical preservation
F. Selective sampling
G. Feed line problems

A. Poor sampling location - The sample no longer represents the flow stream. This can occur with manual sampling or with automatic sampling. Samples should be taken from a spot where the entire flow stream is present and where there is good mixing.

B. Improper use of grab or composite sampling - This can have a major effect since grab samples are not as representative as composite samples and the use of composite samples for shockload that would require a grab sample.

C. Sampling equipment not properly cleaned - The sample can be contaminated giving erroneous results.

D. Composite sampler not cold enough for storage - Biological or chemical activity may change the properties of the sample.

E. Improper chemical preservation - Biological or chemical activity may change the characteristics of the sample.

F. Selective sampling - This occurs if an operator waits until the effluent "clears-up" before taking a sample. It means the sample is no longer representative (the sample result has less solids than the actual flow stream it was supposed to represent). This is a form of data falsification.

G. Feed line problems - An automatic sampler is fed by a line or tubing. Solids can build-up in the tubing or line. The line should not have a lot of 90 degrees bends. Tubing should not be allowed to sag. If bacteria begin to live in the tubing or line they can alter the sample characteristics. Feed lines with these problems can cause elevated values for BOD and suspended solids.

4.2.2 Explain the relationship between a flow meter totalizer reading and sample collection. Be able to identify what day each represents.

A 24-hour composite sample and totalized flow should cover the same hour/daily period. The results are often multiplied to obtain a mass loading which is invalid if they cover different time periods. If the totalizer reading and 24-hour sample collection occur today in the morning (which is very common) the results for both the flow and sample represent yesterday. Grab samples taken today represent today. In the case of 3-hour composite samples and totalizer reading an early morning totalizer reading shows yesterdays flow.

The 3-hour sample collected mid-day (from 10 a.m. to 1:00 p.m.) represents today's data. If totalizer and 24 hour sample composite are collected in the late evening both represent the results of today.

4.2.3 Explain what to do with laboratory analysis if:

A. There are problems with the sampler
B. A sample is lost
C. An emergency exists at the plant
D. Poor quality effluent is sampled

A. Sampler problems - If there is a problem with the sampler or the flow signal to the sampler it must be repaired as soon as possible. Send a note with the discharge monitoring report (DMR) stating why you are not sampling according to your permit conditions and how long you expect the repair to take. With flow signal problems take time composite samples and note the change to time composite on all daily sampling forms and on the monthly DMR for each day affected. If not enough sample is being taken you should take a sample more often by lowering the flow pulse setting or you should raise the sample volume per aliquot. If the sample bottle is too full you should decrease sample volume by raising the flow pulse setting or by lowering the sample volume. In general it is better to have small aliquots taken more often than to have large aliquots taken less often, as it would be more representative.

B. Loss of a sample - If you sample 1-5 times weekly you can makeup for a lost sample by sampling on another day, note on the DMR that your ordinary sample was lost.

C. Emergency at the plant - If it is possible collect the sample and refrigerate it. Obviously an emergency at the plant requires immediate action. Many analyses can be held over for another 24 hours. If possible make a reciprocal arrangement with a neighboring plant so you can help each other with testing in emergencies. Contract laboratories can also take samples on short notice.

D. Poor quality effluent at sampling time - Take your samples as scheduled and note any unusual circumstances on the DMR. If the plant has a sudden upset after the usual sampling time it would be good to take a grab sample of influent and effluent so you can check for anything unusual (pH, organic slug load, and some other batch discharge).

Chapter 5 - Management and Calculation

Section 5.1 - Management of Wastewater Treatment Plants

5.1.1 Define the following common types of plans used in the management of a wastewater treatment plant:

A. A Strategic Plan
B. A Contingency Plan
C. A Program Plan
D. A Capital Facility Plan
E. A Financial Plan

A. Strategic plan: describes the objectives of the organization and how to reach the objectives

B. Contingency plan: describes a course of action to deal with a particular situation if it occurs unexpectedly

C. Program plan: describes a course of action for a specific functional activity such as plant maintenance, plant operation, personnel administration, or a single project capital improvement

D. Capital facility plan: describes the capital facilities and equipment required in the future and the estimated costs, the time schedule, and the financing mechanism used to support the plan

E. Financial plan: describes the projected capital and operational resources required for a specific period of time a.k.a. the budget

5.1.2 Create a list of steps an efficient wastewater treatment plant manager uses to develop sound problem solving and decision making solutions.

1. Define the problem - the most difficult as the symptom of the problem usually is identified first rather than the problem

2. Analyze the problem - collect the relevant facts and consider all aspects of the problem carefully

3. Develop the alternatives - consider all angles and identify possible solutions; seek ideas from others

4. Evaluate the alternatives - consider the risk of failure or the creation of other problems for each alternative

5. Make a decision - select the best alternative or a combination of alternatives

6. Implement the decision - communicate the decision, the reasons for the decision, assign responsibilities, and listen to feedback

7. Monitor or measure results - an ongoing process that may even alter the original decision to an even better solution

5.1.3 Develop a list of obstacles to good in-plant communications a plant manager must be aware of.

Communication failures in a wastewater treatment plant can have severe consequences such as equipment breakdowns, process upsets, and even dangerous conditions that threaten the safety or health of personnel. Principal obstacles to interpersonal communications could be:

1. Poorly expressed messages or assignments
2. Inappropriate time or place for the message
3. Failure to discuss the instructions and issues
4. Noise or distractions when giving the message
5. Attitude of the speaker or listener
6. Talking instead of listening

5.1.4 Explain the importance of budgets and distinguish between the following types of budgets:

A. Operations and maintenance budget
B. Capital improvements budget

The budget process helps the manager determine the effectiveness of a wastewater treatment facility. A well-prepared budget defines the long-term objectives of the organization and also establishes short-term goals and operational strategies to meet the stated objectives. Budgets are an absolute necessity for the manager of any community utility to communicate operational needs to elected officials who ultimately provide the resources.

A. Operations and maintenance budget - An annual categorical listing of line items that detail the plant operations and maintenance requirements in dollars of anticipated cost. Items included would be labor costs (direct and indirect), energy costs, chemicals, contractual services, and supplies. Several sub-categories may be listed in order to make the budget as meaningful as required by those who make the financial decisions. Usually each line item is further divided into the major functions of a treatment plant (i.e. collection system, pumping stations, treatment plant, maintenance and repairs, laboratory, and administrative). The manager would monitor the operations and maintenance budget on a monthly basis and be flexible in budget management to adjust for unexpected changes throughout the year.

B. Capital improvements budget - Since large expenditures may be required to replace worn or antiquated equipment, a replacement fund or budget must be established. Money reserved each year represents good financial practice and shows that the plant management is practicing good management principals. This budget usually lists items of equipment that has a projected lifespan with an estimated replacement cost projected over a period of years leading up to the retirement year. In this manner funds are available when replacement is necessary or projected. These funds are probably the hardest for the manager of a treatment plant to justify but with sound planning and a well devised budget those persons making financial decisions will see the need more clearly.

5.1.5 Discuss the importance of each of the following key managerial plans or systems:

A. Safety and health plan
B. Emergency operating plan
C. Financial management plan
D. Process control plan
E. Energy conservation plan
F. Maintenance management plan
G. Laboratory management plan

A. Safety and health plan - The purpose of this plan is to provide a safe and healthy environment for the employees. It is essential in maintaining productivity, morale, and to comply with legal requirements and avoid financial liabilities.

B. Emergency operating plan - The purpose of this plan is to define procedures to be followed in case of any natural or manmade event that would cause the plant to cease functioning in a normal manner.

C. Financial management plan - The purpose of this plan is similar to budgeting in that the manager must plan ahead to meet the cost of operating and maintaining the treatment plant.

D. Process control plan - The purpose of this plan is to provide a structure by which the manager can monitor the efficiency of the treatment plant. Treatment goals are set and through an organized process control system the planned goals are attainable.

E. Energy conservation plan - The purpose of this plan is to identify where the energy usages in the plant are and control the efficient use of that energy. Energy usage accounts for 25-50% of a wastewater treatment plant's budget and careful planning is necessary for its most efficient operation.

F. Maintenance management plan - The purpose of this plan is to develop systematic maintenance procedures for all equipment at treatment plants. Each piece of equipment should have a plan of its own in order to ensure efficient operations and to ensure maximum life of the equipment.

G. Laboratory management plan - The purpose of this plan is to detail the quality assurance and quality control aspects of plant operations. Proper recordkeeping, records retention, and analysis scheduling detail needs to be documented. Even if the plant utilizes a commercial laboratory contractual information should be well planned.

Section 5.2 - Calculations

5.2.1 Given data calculate the best setting for the "flow pulse" interval on an automatic sampler.

Given:
Minimum daily flow = 0.50 MGD
Maximum daily flow = 2.8 MGD
1 gallon = 3,785 mL

Chosen sample aliquot size = 25 mL
Sample container size = 5 gallons

Step 1 - Determine maximum number of allowable sample aliquots.

Formula:

aliquots = sample container size (gal) x (3,785 (mL) ÷ gal) x (1 aliquot ÷ chosen aliquot size (mL))
aliquots = 5 gal x 3,785 (mL) ÷ gal x 1 aliquot ÷ 25 = 757 aliquots maximum

Note: 750 for safety to prevent overflowing sample container.

Step 2 - To obtain flow pulse interval divide maximum expected flow by number of aliquots rounding partial numbers up to the nearest 100 gallons.

Formula:

flow pulse intervals (gal/aliquot) = max. treatment plan flow (gal) ÷ max. # of aliquots

flow pulse intervals (gal/aliquot) = 2,800,000 (gal) ÷ 750 aliquots

flow pulse interval (gal/aliquot) = 3,733 gal/aliquot = rounding up to 3,800 gal/aliquot

Step 3 - Check the results against the low and high flows.

Formula:

maximum flow = plant flow (gal) x aliquot size (mL) x 1 gal (sample volume)

maximum flow = 2,800,000 (gal) x 25 (mL) ÷ 3,800 gal x 1 gal ÷ 3,785 mL = 4.87 gallons

minimum flow = plant flow (gal) x aliquot size (mL) x 1 gal (sample volume)

minimum flow = 500,000 (gal) x 25 (mL) ÷ 3,800 gal x 1 gal ÷ 3,785 (mL) = 0.87 gallons

5.2.2 Given data calculate plant loadings from plant influent and plant sidestreams.

Given:
Influent flow = 2.0 MGD
Influent BOD = 180 mg/L
Supernatant flow = 6,000 GPD
Supernatant BOD = 600 mg/L
Thickener return flow = 10,000 GPD
Thickener return BOD = 120 mg/L

Formula:

pounds per day = concentration (mg/L) x flow (MGD) x 8.34

total loading = influent BOD + supernatant BOD + thickener BOD

influent BOD = 180 x 2 x 8.34
influent BOD = 3,002 pounds per day

supernatant BOD = 600 x .006 x 8.34
supernatant BOD = 30 pounds per day

thickener BOD = 120 x .010 x 8.34
thickener BOD = 10 pounds per day

total loading = 3,002 + 30 + 10
total loading = 3,042 pounds per day

5.2.3 Given data calculate detention time for multiple clarifiers operating in parallel.

Given:
Primary clarifiers = 3
Clarifier diameter = 80 feet
Clarifier depth = 12 feet
Average daily flow = 10 MGD
Sidestream flow = 500,000 gal/day
Prior to primary clarifier
All clarifiers receive equal flows

Formula:

volume (gallons) = 3.14 x r^2 x 7.48 x height

detention time = tank volume (gal) ÷ flow rate (gal/hour)

Note: 1 cubic foot = 7.48 gallons

detention time = 3 clarifiers x 3.14 x 40^2 x 12 x 7.48 ÷ [(10,000,000 + 500,000) ÷ 24 hours/day

detention time = 1,352,863 gallons ÷ 437,500 gallons/hour = 3.09 hours

This can also be calculated by using one clarifier and dividing the flow rate by 3.

5.2.4 Given data calculate pump capacity in gallons per minute using the time-volume method.

This calculation requires knowing the area of the wetwell, an accurate method to measure water levels, and a stop watch to record time.

Formula:

pump capacity (GPM) = volume of drawdown (gal) ÷ time (minutes) + volume refill (gal) ÷ time (minutes)

Note: The volume of the drawdown and refill must be calculated in gallons. 1 cubic foot = 7.48 gallons and the time in minutes (and fraction of minutes) to get pump capacity in gallons per minute.

Pump capacity (GPM) = [area (ft^2) x drawdown (ft) x 7.48 ÷ time of drawdown (min)] + [area (ft^2) x refill (ft) x 7.48 ÷ time of refill (min)]

Given:
Wetwell size = 12 feet x 15 feet
Drawdown/refill = 1.5 feet
Time of drawdown = 6 minutes 30 seconds
Time of refill = 15 minutes 45 seconds

pump capacity (GPM) = [12 x 15 x 1.5 x 7.48 ÷ 6.50] + [12 x 15 x 1.5 x 7.48 ÷ 15.75]

pump capacity (GPM) = 311 + 128 = 439 GPM

Chapter 6 - Sludge Treatment and Disposal

Section 6.1 - Sludge Treatment

6.1.1 Compare the sources and characteristics of primary and secondary sludges.

Primary sludges are the solids that settle out of the raw wastewater in the primary clarifiers. The primary sludges are usually fairly coarse with a specific gravity (density) significantly greater than water, allowing for rapid settling. Primary sludges are 60 to 80 percent volatile (organic) matter varying depending on the raw wastewater characteristics. Primary sludge is odorous, does not dewater well, and requires additional treatment prior to ultimate disposal.

Secondary sludges are those solids generated as a part of the secondary treatment process and settle out in the secondary clarifiers. These sludges are mainly composed of the microorganisms generated in the secondary process (activated sludge or fixed film systems). Excess sludge amounts must be removed to keep the secondary system in balance. Secondary sludges are more flocculent with a specific gravity (density) very close to that of water making them more difficult to settle than primary sludges. Secondary sludges are 75 to 80 percent volatile (organic) matter and contain bound water in the cells of the microorganism making them difficult to dewater or thicken. Chemical additions can be used to enhance dewatering.

Both primary and secondary sludges should be as concentrated as possible by proper operation of clarifiers. At times additional thickening is used to reduce the amount of water and volume loading on subsequent sludge treatment processes.

6.1.2 Explain the reasons for sludge treatment.

Federal, state, and local regulations require (in most cases) that treatment plant sludges be stabilized prior to disposal. This is done by several methods (aerobic and anaerobic digestion and chemical treatment) that address health related concerns, provide nuisance reduction, and yield practical operational benefits. These items would include reduction in pathogenic (disease causing) organisms, reduction of insect breeding, prevent nuisance odor problems, and conversion of organic material to gases, water, and relatively inert substances. Digestion improves dewaterability and reduces sludge solids volume which reduces hauling costs. Sludges that are land applied to agricultural lands provide a soil additive of organic material and nutrients (reduces need of additional fertilizer).

6.1.3 Compare anaerobic and aerobic sludge digestion.

Anaerobic sludge digestion -

A. Operates in a closed vessel with no air or free oxygen present
B. Uses anaerobic organisms to reduce organic solids
C. Works best using fresh primary type sludges
D. Converts organic material to methane, carbon dioxide, water, ammonia, and other stable by-products
E. The methane gas produced provides an energy source
F. Requires a heating system (using the methane gas) to heat the contents of the digester
G. Requires various types of systems to ensure that the digesters' sludge is well mixed
H. Has complex expensive equipment (gas piping system, sludge mixing, heat exchanger, complex valving, and safety related items)
I. Operations are complicated and need careful attention and testing by the operator
J. Chemical additions may be required to correct operational problems
K. Can be a source of odor problems
L. Has significant safety concerns in operating, repairing, and cleaning (methane explosions, confined space, and hydrogen sulfide gas)
M. Produces a liquid (supernatant) that may be difficult to treat when returned to the treatment plant

Aerobic sludge digestion -

A. Operates in an open vessel with aeration providing free oxygen
B. Uses aerobic organisms to reduce organic solids
C. Works best using secondary type sludges
D. Converts organic material to carbon dioxide, water, sulfate, nitrate compounds, and other stable by-products
E. Has a higher operating cost due to the high energy cost to provide the aeration
F. Does not require heating
G. Mixing is generally provided by the aeration equipment
H. Has relatively simple inexpensive equipment (air compressor, air piping, and diffusers or mechanical aerators)
I. Operations are simple with minimal attention and testing by the operator
J. Chemical additions are not required

K. Not a significant source of odor problems (unless it is being used for denitrification)
L. Has minimal safety concerns in operating, repairing, and cleaning
M. Produces a liquid (decant) that is easier to treat when returned to the treatment plant

Section 6.2 - Sludge Disposal

6.2.1 Describe the requirements for land applications of sludge.

In Wisconsin the land application of municipal wastewater treatment plant sludge is regulated through the WPDES permit and NR 204. Industrial wastewater treatment plant sludges are regulated through NR 214 and the sludge must be beneficial for the soil. Sludge fields must have specific characteristics.

Slope: the flatter the surface the better; up to 6% for summer surface spreading and up to 12% if incorporated immediately

In order to run a good sludge management program the operator needs to -

A. Obtain the county soil survey report
B. Convince a number of landowners that the sludge will be a benefit
C. Screen the landowners fields for good quality soils for sludge
D. Get the landowners permission to apply sludge to appropriate fields
E. Purchase the aerial photographs for the areas desired for approval (from the county office)
F. Take soil tests (using UW-extension sampling guidance) and submit for analysis to a soils laboratory
G. Get the site application forms from the DNR and submit them to the DNR district office for approval with the soil test results
H. Once sites are approved monitor the actual application to be sure that only the allowable areas are being used
I. Keep accurate spending records of amounts and area spread. Do not spread when a rainstorm is forecast, do not drive on wet soils because it can cause permanent soil damage, etc. Use common sense.
J. Even if sludge hauling and application are contracted the permittee is jointly responsible for the behavior of the hauler.

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