DW Module 26:
Ultraviolet Disinfection
Answer Key

Calculation

If you need to achieve 2.0- log inactivation of *Giardia* through UV disinfection and the active *Giardia* concentration before disinfection is 0.05 cysts/L, what is the maximum allowable concentration of active cysts remaining after the UV disinfection process?

Ans: Rearrange the formula in the following manner:

$N_0/N = 10^{(\log \text{ inactivation})}$

$N = N_0 / 10^{(\log \text{ inactivation})}$

Replacing 'N_0' with 0.05 cysts/L and 'log inactivation' with 2, we have:

$N = 0.05/(10^2)$

$N = 0.05/100$

$N = 0.0005 = 5 \times 10^{-4}$ active *Giardia* cysts/L.

Calculation

1. The transmittance of some water that will be disinfected using UV light has been measured at 95%. The UV intensity 1 cm away from the UV lamp must be 25 mW/cm^2 to adequately disinfect the water. What must the UV intensity be at the surface of the lamp? What must the UV intensity be at the surface of the lamp if the UV intensity needs to be 25mW/cm^2 at a distance of 2 cm from the lamp?

Ans: Transmittance is typically reported for a pathlength of 1 cm, so for the first question, the distance from the lamp is the same as the pathlength the transmittance was measured at. To solve, rearrange the equation for transmittance to solve for the initial intensity:

$T = 100 * I/I_0$

$I/I_0 = T/100$

$I_0 = (100 * I)/T = (100 * 25)/95 = 26.3$ mW/cm^2

To determine how what the initial intensity would be 2 cm away, the transmittance (or absorbance) must be determined for a pathlength of 2 cm:

$A_1 = -\log(T/100) = -\log(95/100) = 0.0223$

$A_2 = A_1 * P = 0.02228 * 2 = 0.0446$

$A = \log(I_0/I)$

$10^{A} = I_0/I$

$I_0 = I * 10^{A} = 25\ mW/cm^2 * 10^{0.0446} = 27.7\ mW/cm^2$

Note: This could also be solved by converting A back into T and then solving as was done for the first part of the question:

$T = 100*10^{-A} = 100 * 10^{-0.0446} = 90.24\%$

$I_0 = (100 * I)/T = (100 * 25)/90.24 = 27.7\ mW/cm^2$

Unit 1 Exercise

True or False:

1. Ultraviolet Disinfection is one method of treatment that destroys or reduces the growth of harmful microorganism. T F (TRUE)

2. Ultraviolet light is measured with a volt-meter. T F (FALSE)

3. Ultraviolet light disinfects DNA or RNA. T F (TRUE)

4. Bacteria and Protozoan are made up of a single strand on DNA. T F (FALSE)

5. Ultraviolet light at wavelengths of 300nm will break the existing bond between the nitrogenous base.
   T F (TRUE)

Multiple Choice:

1. Disinfection regulations target three types of microorganisms for disinfection, which one does not apply.
   a. Cryptosporidium
   b. Filamentous Bacteria
   c. Giardia
   d. Viruses

   Answer: B

2. The log removal for Giardia is:
   a. 1-log
   b. 2-log
   c. 3-log
   d. 4-log

   Answer: C

3. Cryptosporidium is found in the:
   a. Surface water
   b. Ground water not under the direct influence of surface water
   c. After disinfection
   d. In the distribution system where the resident time is high.

   Answer: A

4. One benefit to UV disinfection is that it does not cause Disinfection Byproducts. Which statement is not correct:
   a. UV does not have a residual.
   b. UV is not an oxidant.
   c. UV can be used a sole source of disinfection in a plant that treat GUDI.
   d. UV is one option for providing additional inactivation required under the LT2ESWTR.

   Answer: C

5. Two common terms used to relate water quality to UV light are:
   a. Adsorption and Deflection
   b. Absorption and Transmittance
   c. Reflection and Refraction
   d. Pathlength and Pressure

   Answer: B

6. If the light intensity of a UV lamp is 20.0 mW/cm^2. Three centimeters away from the lamp, the UV intensity is measure as 15.2 mW/cm^2. What is the absorbance of the water for the pathlength of 3 cm?

   Where $A= \log (I_0/I)$
   $I_0 = 20\ mW/cm^2$
   $I= 15.2\ mW/cm^2$

   a. 0.76 for the measured pathlength of 3 cm
   b. 0.76 for the measure pathlength of 1 cm
   c. 0.1192 for the measure pathlength of 1 cm
   d. 0.1192 for the measured pathlength of 3 cm

   Answer: D

7. What is the absorbance for a pathlength of 1 cm above?

   Where $A_2=A_1*P$

   a. 0.0397
   b. 0.2533
   c. 0.3576
   d. 2.28

   Answer: A

8. If a lamp UV intensity out put is 35 mW/cm^2, what UV intensity will be measured for 1 cm from the lamp surface if the lamp is submerged in water with a UVT of 93%?
   Where T(%) = 100* I/I_0
   a. 37.6 mW/cm^2
   b. 0.0266 mW/cm^2
   c. 32.55 mW/cm^2
   d. 0.0307 mW/cm^2

   Answer: C

Unit 2 Exercise

Fill in the blank:

1. Reactors are found in two basic configurations _____channel and _____channel.

   Answer: Open and Closed

2. UV lamps fall into three categories; low pressure, low pressure-high output and _____ pressure.

   Answer: Medium

3. All three use _____ vapor to produce UV light.

   Answer: Mercury

4. Position the lamp in the _____ _____ can affect the UV does reaching the pathogens.

   Answer: Lamp Sleeves

5. UV lamps require power at specific _____, _____ and frequency to maximum the efficiency of UV light.

   Answer: Current, Voltage

6. Ballasts are used to limit the current flow through the lamp. The two classification of ballasts are: _____ and _____.

   Answer: Magnetic, Electronic

7. A UV _____sensor measures the _____ of the UV light at some distance away form the UV lamp.

   Answer: Intensity

8. A UVT monitor measures the _____ of the water flowing through the reactor.

   Answer: Transmittance

9. The major components of a UV disinfection systems are: controls and _____, the _____system and the _____ components and the UV _____.

   Answer: Instrumentation, Electrical, Piping and Reactors.

Unit 3 Exercise

Multiple Choice:

1. UV _____ increases the dose will increase, as _____ increase, the dose will decrease. As UV _____decreases, dose will decrease.

   a. flowrate, transmittance, intensity,
   b. intensity, flowrate, transmittance
   c. transmittance, flowrate, intensity

   Answer: B

2. When a reactor is tested at various UV intensities and flowrates is called a _____ _____.

   a. reactor validation
   b. reactor calibration
   c. reactor standardization

   Answer: A

3. _____ will scatter the UV light, decreasing the intensity of the UV light reaching the pathogen.

   a. Algae
   b. Coagulates
   c. Particles

Answer: C

4. When particles and substances dissolve in the water deposit onto the surface of the lamp sleeve is called _____.

   a. fouling
   b. deposition
   c. lamp coating

   Answer: A

5. Improving operations of the UV system by increasing the UVT of the water can be accomplished by _____ _____.

   a. upstream treatment
   b. water treatment
   c. taking off-line

   Answer: A

6. Water _____ has little effect on the disinfection effectiveness of the UV light but can affect the fouling rates.

   a. pH
   b. temperature
   c. color

   Answer: B

7. Algae growth can be _____; it can cause taste and odors problems in the finished water.

   a. beneficial
   b. overlooked
   c. a nuisance

   Answer: C

8. The intensity of the UV light and UVT _____ as a lamp and lamp sleeve age.

   a. decrease
   b. increase
   c. remain the same

   Answer: A

Unit 4 Exercise

1. The following data is collected during validation testing of a reactor using UV Intensity Setpoint control. What would the UV intensity setpoint be for a flowrate of 7 mgd and 2.5-log inactivation using:

Flowrate (mgd)	UV Intensity (mW/cm^2)	Log Inactivation Credit
6	3.6	2.0
6	5.3	2.5
6	6.7	3.0
8	4.9	2.0
8	7.3	2.5
8	9.7	3.0
10	6.1	2.0
10	9.3	2.5
10	13.0	3.0

a) A Single Setpoint operational strategy. _____

b) A Variable Setpoint operational strategy _____

Answer: a) 9.3 (max dose for 2.5 log inactivation for all flow rates)
b) 7.3 (max dose for flowrate range 6 to 8 mgd and 2.5 log inactivation)

2. Assuming a linear interpolation, the Setpoint Interpolation Operational Strategy would be:

Where: $y_2 = (y_1 + \text{slope})(x_2 - x_1)$
Slope= 1 mW/cm2 per mgd
The liner interpolation = 6.3
The Flowrate (x_2) = 7 mgd

Answer: Rearrange to solve for y_1, which is the required UV intensity:

$y_2 = (y_1 + \text{slope})(x_2 - x_1)$
$y_2 = (5.3 + 1)(7-6)$
$y_2 = (6.3)(1)$
$y_2 = 6.3$ mW/cm^2

3. Match the UV control/operational strategies with their definitions.

___E_ 1. A UV intensity or dose setpoint is used for all flowrates and UVTs within the validated ranges. A. UV Intensity Set point

___F_ 2. UV intensities would be set at a different intensity for each flowrate. B. Setpoint Interpolation

___F_ 2. UV intensities would be set at a different intensity for each flowrate.

___B_ 3. An equation would be developed that describes the relationships between flowrate and UV intensity.

___A_ 4. Control method to make sure the UV intensity sensors control the reactors.

___C_5. Water quality parameter that has the greatest impact on the operated of the UV system. It is monitored to control the reactor.

___D_ 6. UV intensity, UVT and flowrate are used to calculate this.

B. Setpoint Interpolation

C. UV Transmittance (UVT)

D. UV Dose

E. Single Setpoint

F. Variable Setpoint

Multiply choice:

4. Potential problems in the UV disinfection process are: (may be more than one correct answer)
   a. Low UV intensity
   b. Low UVT
   c. Split flow
   d. Validated limits
   e. Unreliable sensor readings
   f. Power Interruptions

Answer: A, B, E, F

5. UV intensity, flow rate and _____ must be monitored and recorded every four hours as proposed by the LT2ESWT.
   a. UV Dose
   b. Lamp outage
   c. UV Residual
   d. Lamp Breakage

Answer: B

6. Working with UV disinfection has it share of safety related issued to be concerned with. Which of the below <u>does not</u> apply to UV disinfection:
   a. UV exposure
   b. Chlorine Feed line leakage
   c. High temperatures
   d. Lamp Breakage

Answer: B

Unit 5 Exercise

True of False:

1. Calibrating of the UVT monitors should be increased if performance records indicate consistent weekly results. T F (False)

2. Intensity sensors do not have to be calibrated monthly but can wait for the annual manufactures calibration. T F (False)

3. Pressure gauges may confirm spilt flow when individual flow meter to the reactors are not installed.
   T F (True)

4. Discoloration of the sleeves is one indicator of fouling. T F (True)

5. The cleaning system includes the wiper blades, drive mechanism, cleaning fluid reservoir and flow meter. T F (False)

6. A GFI circuit breaker will trip when there is a problem with the ballast cooling system.
   T F (False)

7. Flow meters should be taken off-line if the uncertainty of the flow meter is less than the uncertainty of the validation testing of the UV reactor. T F (False)

8. UVT monitors should be check against a laboratory spectrophotometer. T F (True)

9. When manually cleaning the sleeves, you should not use latex gloves because the latex will melt on the sleeve. T F (False)

10. After replacing the lamp, you will be able discard the old lamp in the regular municipal trash it you roll it in bubble wrap or heavy paper so it does not break in handling. T F (False)