Module 10: Exploring Tradeoffs in Water Quality Management Using Environmental Data - Student Handout

eddie
environmental data-driven inquiry & exploration

Name:

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Completed on:

Macrosystems EDDIE Module 10: Exploring Tradeoffs in Water Quality Management Using Environmental Data

Focal Question:

How can we use environmental data to inform our understanding of the tradeoffs involved in water management decision-making?

Summary:

Many water management decisions come with tradeoffs. One important example of such a decision is the use of chlorine in the drinking water treatment process. Chlorination is an important disinfection step in water treatment and is needed to protect water consumers from harmful pathogens (such as bacteria). However, when there are high amounts of organic matter in the raw water, chlorination can result in the formation of potentially cancer-causing disinfection byproducts. Environmental sensor data on water quality conditions, such as organic matter measurements from drinking water reservoirs, can help inform water management decision-making and reduce the risk of unintended consequences due to use of chlorine in water treatment.

In this module, you will explore organic matter data collected from drinking water reservoirs and learn how to interpret these data to inform your decision-making about chlorination during drinking water treatment.

Learning Objectives:

By the end of this module, you will be able to:

- Define what disinfection byproducts are.
- Describe the environmental and water treatment processes that influence the formation of disinfection byproducts.
- Understand the trade-offs between disinfection and byproduct formation that can occur when chlorinating water, and treatment techniques that can be used to manage these tradeoffs (e.g., coagulation, activated carbon filters).
- Use environmental data visualizations to identify when additional treatment techniques to avoid disinfection byproduct formation should be used to meet water quality objectives.

Module overview:

- Introductory presentation on concepts related to drinking water disinfection byproducts (DBPs) and environmental data from drinking water reservoirs
- **Activity A:** Explore how disinfection byproducts are formed during the drinking water treatment process and examine tradeoffs between disinfection and byproduct formation
- **Activity B:** View and interpret environmental data that can indicate when naturally-occurring DBP precursors are present
- **Activity C:** Make water treatment decisions using environmental data that can indicate when DBP precursors may be present

Module materials:

The lesson content is hosted on an interactive R Shiny web application at https://macrosystemseddie.shinyapps.io/module10/

This can be accessed via any internet browser and allows you to navigate through the lesson via this app. You will fill in the questions below on this handout as you complete the lesson activities. Some instructors may ask students to enter their answers to module questions using a Canvas quiz. Confirm with your instructor as to how to submit your answers.

Module workflow:

1. Watch the introductory presentation provided in Canvas and embedded in the interactive R Shiny web application if you have not already done so.
2. Watch the “Guide to Module” video embedded in the interactive R Shiny web application to learn about key features of the module that will help you complete module activities and answer questions. Optionally, you can also go through the “Quick-start” guide to the module using the button at the top right corner of the module web page.
3. Select a focal reservoir.
4. Open the Canvas quiz questions associated with the reservoir you have chosen OR if you are not using Canvas, download a copy of all the questions as a Word document by clicking the “Download student handout” button.
5. Work through the module to complete the Introduction questions and Activities A, B, and C in this web app. When you are prompted to answer questions, enter your answers in the Canvas quiz. Be sure to fill in the Canvas quiz that corresponds to the reservoir site you have chosen! If you are not completing the module using Canvas, you may type your answers into the Word document.
6. If you would like to take a break and come back later, or if you lose internet connection, all you have to do is re-load this web app, re-select your reservoir site in the Introduction, and you will be able to resume your progress. On Canvas, you can save your quiz responses using the “Save” button. In Word, you can save your answers in the document on your computer.

Module Questions:

Introduction

Think about it!

Answer the following questions:

1. Which of the following is a correct definition of disinfection byproducts?
    a. substances used to disinfect the water, such as chlorine
    b. naturally-occurring substances that can create cancer-causing compounds during water treatment, such as organic matter
    c. substances that are unintentionally created during the disinfection process and can cause cancer, such as trihalomethanes
2. How do disinfection byproducts form?
    a. when chlorine reacts with organic or inorganic compounds during the treatment process
    b. when high-nutrient fertilizers are used in a watershed
    c. when inorganic material is accidentally introduced into the treatment plant
3. How can environmental data be used to help avoid the formation of disinfection byproducts?
    a. environmental sensors can measure how much organic matter is present in a drinking water reservoir
    b. environmental sensors can measure the turbidity, or clarity, of the water, which can indicate the presence of DBP precursors
    c. both a and b
    d. neither a nor b

Activity A - Explore how disinfection byproducts can be formed during chlorination

Explore how disinfection byproducts can be formed due to chlorination during the drinking water treatment process

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Objective 1: Understand factors affecting DBP formation and drinking water thresholds for DBPs

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Be sure you have answered questions 1-3 in the previous Introduction section before you begin Activity A!

4. Which of the following correctly describes DBP precursors (compounds in the water that can lead to DBP formation during treatment)?

    a. DBP precusors can be naturally-occurring
    b. DBP precursors can be organic compounds
    c. DBP precursors can come from sources related to human activities (e.g., agriculture)
    d. DBP precursors can be inorganic compounds
    e. all of the above

5. Exposure to DBPs has been associated with which of the following health concerns?

    a. eczema
    b. diabetes
    c. cancer

6. Which of the following is NOT a type of DBP?

    a. trihalomethanes
    b. chloramines
    c. haloacetic acids

Objective 2: Explore tradeoffs in chlorination vs. DBP formation

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7. Which best describes the "breakpoint" in the chlorination process?

    a. the point at which adding more chlorine to the treatment system will lead to an exceedance of the MRDL
    b. the point at which complete disinfection is achieved and free residual begins to build up

c. the point at which formation of DBPs is most likely
d. the point at which chlorine begins to break down organic matter DBP precursors

8. Breakpoint chlorination has been achieved when:

   a. the expected residual is less than or equal to the actual residual
   b. the actual residual is less than the expected residual
   c. neither of the above

9. What chlorine dosage should be applied to raw water with a demand of 0.6 mg/L and an intended residual of 1.2 mg/L? Round your answer to the nearest tenth (e.g., 1.2).

   Answer:

10. What should the chlorine feed rate setting be in lb/day if the plant flow is 1.1 MGD and the required chlorine dose is 1.5 mg/L? Report your answer to the nearest tenth (e.g., 12.4).

    Answer:

11. Use the following information to answer Q11-Q13. A chlorinator setting of 20 lbs chlorine per day results in a chlorine residual of 0.3 mg/L. The chlorinator setting is increased to 23 lb/day. The chlorine residual increases to 0.54 mg/L at this new dosage rate. The average flow being treated is 1.5 MGD. On the basis of these data, what is the expected increase in residual? Round your answer to the nearest hundredth (e.g., 0.12).

    Answer:

12. Using the information provided in Q11, what is the actual increase in residual? Round your answer to the nearest hundredth (e.g., 0.12).

    Answer:

13. Using the information in Q11 and your answers to Q11 and Q12, is breakpoint chlorination being reached?

    a. yes
    b. no
    c. the answer cannot be determined from the information given

14. Which of the following is NOT a method for removing DBP precursors prior to disinfection?

    a. increase coagulation time or add more coagulant
    b. use activated carbon filters to remove organic matter
    c. increase the frequency of TOC testing
    d. pass water through a membrane that filters out DBP precursors

Activity B - Explore environmental data that can indicate the presence of DBP precursors

Use high-frequency water quality data to explore how water quality changes over the course of a year and make decisions about water withdrawal depth

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Objective 3: Select and learn about a focal drinking water reservoir

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15. What is the name of your selected reservoir?

    Answer:

16. What is the four-letter site identifier of your selected reservoir? Use lower case (e.g., 'fcre').

    Answer:

17. What is the use of your selected reservoir?

    a. recreation
    b. irrigation
    c. hydropower
    d. drinking water supply

18. What is the reservoir area in square feet of your selected reservoir? Provide your answer as a whole number (without decimal points) and with no spaces or commas (e.g., 123456).

    Answer:

19. What is the maximum depth of your reservoir in feet? Round your answer to the nearest whole number.

    Answer:

Objective 4: View and interpret organic matter data from your reservoir

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20. Which of the following is NOT a characteristic of fDOM?

    a. it is composed of particles
    b. it is dissolved in the water
    c. it is derived from living things and contains carbon
    d. it fluoresces when exposed to light at particular wavelengths

21. fDOM is measured in quinine sulfate units, or QSU. Which of the following is true regarding QSU?
    a. QSU is an indirect measure of fDOM
    b. calibrating sensors using QSU enables consistent fDOM measurements across sensors and reservoirs
    c. QSU compares organic matter fluorescence to the fluorescence of known concentrations of quinine sulfate
    d. all of the above
22. How is fDOM related to DBPs?
    a. fDOM molecules are DBPs
    b. the presence of fDOM molecules is correlated with other molecules in the raw water that are DBPs
    c. high fDOM levels in raw water may indicate the presence of DBP precursors which will form DBPs during treatment
    d. high fDOM levels in raw water may indicate that treated water will exceed the MRDL
23. On what day of the year did the highest observed fDOM occur in your reservoir? Write out the full month name and day (e.g., September 20).

    Answer:

24. On what day of the year did the lowest observed fDOM occur in your reservoir? Write out the full month name and day (e.g., September 20).

    Answer:

25. Based on the data in the figure and your understanding of how fDOM levels relate to DBPs, on what day of the year is the risk of DBP formation during treatment highest in your reservoir according to the fDOM data? Write out the full month name and day (e.g., September 20).

    Answer:

26. In your focal reservoir, what is the corresponding TOC in mg/L for the highest observed fDOM in your reservoir? Round your answer to the nearest tenth (e.g., 3.1).

    Answer:

27. The U.S. Environmental Protection Agency (US EPA) has a rule regarding removal of TOC from drinking water during treatment (see table below). The percentage of TOC that must be removed during treatment depends on the amount of TOC in the raw water (see the first column of the table), as well as the raw water alkalinity (second, third, and fourth columns of the table). Use the fDOM-to-TOC converter to determine how much TOC should be removed from a reservoir with an fDOM concentration of 40 QSU and a raw water alkalinity of 50 mg/L. Report your answer in mg/L of TOC (e.g., 2 mg/L TOC).

Answer:

Table 2
Required Removal of Total Organic Carbon by Enhanced Coagulation and Enhanced Softening for Subpart H Systems Using Conventional Treatment[1]

Source Water TOC (mg/L)	Source Water Alkalinity (mg/L as $CaCO_3$)		
	0-60	>60-120	>120[2]
>2.0-4.0	35.0%	25.0%	15.0%
>4.0-8.0	45.0%	35.0%	25.0%
>8.0	50.0%	40.0%	30.0%

1-Systems meeting at least one of the alternative compliance criteria in the rule are not required to meet the removals in this table.

2-Systems practicing softening must meet the TOC removal requirements in the last column to the right.

Table reproduced from US EPA 816-F-01-014: Stage 1 Disinfectants and Disinfection Byproducts Rule https://www.vdh.virginia.gov/content/uploads/sites/14/2024/08/Stage-1-Disinfection-By-products-fact-sheet.pdf

Activity C - Use environmental data to inform water treatment decisions

Make water treatment decisions using high-frequency water quality data

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Objective 6: Use fluorescent dissolved organic matter data to make coagulation decisions

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Management decision #1: Winter data

28. For Feb. 20, what is the corresponding TOC in mg/L of the fDOM observation for today? Use the fDOM to TOC converter to help answer the question. Round your answer to the nearest tenth (e.g., 3.1).

    Answer:

29. Which best describes the pattern in fDOM data over the previous month?

    a. increasing
    b. decreasing
    c. steady (very little change)
    d. highly variable, but neither increasing nor decreasing overall

30. Do you decide to increase the coagulation time to reduce the risk of high TOC and potential DBP formation in the filtered water? There is no right or wrong answer to this question. Type 'yes' or 'no'.

    Answer:

Optional exercise: Reflect on why you made this decision. What information did you use to arrive at your final choice?

Management decision #2: Spring data

31. For Apr. 15, what is the corresponding TOC in mg/L of the fDOM observation for today? Use the fDOM to TOC converter to help answer the question. Round your answer to the nearest tenth (e.g., 3.1).

    Answer:

32. Which best describes the pattern in fDOM data over the previous month?

    a. increasing
    b. decreasing

    c. steady (very little change)
    d. highly variable, but neither increasing nor decreasing overall

33. Do you decide to increase the coagulation time to reduce the risk of high TOC and potential DBP formation in the filtered water? There is no right or wrong answer to this question. Type 'yes' or 'no'.

    Answer:

Optional exercise: Reflect on why you made this decision. What information did you use to arrive at your final choice?

Management decision #3: Summer data

34. For Aug. 20, what is the corresponding TOC in mg/L of the fDOM observation for today? Use the fDOM to TOC converter to help answer the question. Round your answer to the nearest tenth (e.g., 3.1).

    Answer:

35. Which best describes the pattern in fDOM data over the previous month?

    a. increasing
    b. decreasing
    c. steady (very little change)
    d. highly variable, but neither increasing nor decreasing overall

36. Do you decide to increase the coagulation time to reduce the risk of high TOC and potential DBP formation in the filtered water? There is no right or wrong answer to this question. Type 'yes' or 'no'.

    Answer:

Optional exercise: Reflect on your decision. How did accessing high-frequency data (vs. the normal monthly samples) affect your decision-making?

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