Socio-Environmental Synthesis for Water Quality Study: Toxic Contaminants in Our Tap Water and Water Use Policy

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1. **Title.** Socio-Environmental Synthesis for Water Quality Study: Toxic Contaminants in Our Tap Water and Water Use Policy

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3. **Abstract:**
This case study is designed to invite students to apply socio-environmental synthesis to explore socio-environmental challenges of drinking water contamination and possible solutions. Lead and other toxic contaminants in drinking water become a major concern in the US. According to EPA, 41 states of US have reported higher than acceptable level of lead in drinking water. Many schools and daycare centers were alerted to test their water or install filters. In 2003-2004, over 65% of 6,118 residences tested for lead in Washington, DC exceeded the lead limit set as safe for drinking. Most recently, elevated level of lead in tap water in Flint, Michigan affected hundreds of thousand people in 2016-2017. Thousands people were threatened to lose their houses for over six month water bill dispute for the contaminated water. Even if the exposure was over a longer period of time, the literature shows that the number of people affected by high lead in drinking water in the nation's capital, DC, was estimated to be 20 to 30 times larger than in Flint, Michigan. Biologically, there is no safe level of lead in drinking water, and lead is harmful to young children at all levels. Infant's, and fetus exposure to lower than the recommended level has been linked to damage to the central and peripheral nervous system, learning disabilities, shorter stature, impaired hearing, and impaired formation and function of blood cells. Research shows that one in four Americans drinks water that doesn't meet safe drinking water act standards, including other contaminants. Other toxic contaminants in drinking water include pharmaceutical and personal products. This three-part case is designed for a wide range of courses in the class of 3 to 4 hrs. In the first part (SLO#1 - 3), students will explore sources of drinking water contamination and its effect using associated socio-environmental synthesis. In the second part (SLO#4-5), students will explore water-food-energy-health nexus, and technological solutions for water use efficiency. In the third part (SLO#6-7), students explore the policy solutions, including challenges of water as a commodity or free access for human rights.

4. **Intended courses:**
This course can be taught as part of discovery sciences, environmental sciences, environmental studies, environmental management, hydrology, water quality, water chemistry, sustainability sciences, or environmental and occupational health.

5. **Intended level:**
Upper division undergraduate (300 or 400) or lower division graduate level courses (500)

6. **SES Learning Goals:**
   - **System thinking:** ability to create a conceptual model for a socio-environmental system related to drinking water contamination and its impacts, and
   - **Project based:** ability to analyze and synthesize existing data in order to create data driven conclusions in interdisciplinary teams.

7. **Student Learning Goals:**
   1. Be able to describe the effect of toxic contaminants in drinking water on human health and society
   2. Be able to describe the type and sources of toxic contaminants in our drinking water, including regulated and unregulated
   3. Be able to describe the relationship of treatment technology and quality of drinking water, and socioeconomic implication
   4. Be able to describe the social-environmental impacts of increasing water use efficiency
   5. Be able to describe the interconnection of water, food, health and wellness
   6. Be able to discuss different water right policy and equity
   7. Describe water quality regulations (water quality standard and water quality criteria)

8. **Introduction/Background:**

Water is essential to all forms of life, and despite the large amount of water present on Earth, only 2.5 percent of that water is fresh and only 1 percent of that is accessible and can be utilized as drinking water (6). Continued population growth and increasing demands for Earth's resources have intensified climate changes and anomalies place upon on water needs and supplies. Policy measures that encourage adoption of well-managed water-conservation nationwide will make more water available for cities and the environment.

All people need clean drinking water to survive, but many human activities have caused both freshwater and saltwater to become polluted with disease-causing bacteria and chemicals. This water contamination has become a major concern and it is now required that all water be properly treated in order to be considered safe to drink, but this is not always the case (4). Many citizens across the United Sates are currently burdened with the misfortune of unsafe drinking water. According to USA Today, up to 63 million citizens in the United States are exposed to potentially unsafe drinking water (9). This has caused many people to fall susceptible to illnesses (4). The government now has the responsibility of ensuring that what little water we have to access, can be utilized. They do this by creating water quality standards and enforcing regulations.

8.1. The Importance of Water Quality Standards:

After the industrial revolution, the United States began to face multiple environmental issues, including the contamination of drinking water. In the 1970's the increase in industry coupled with the lack of environmental regulation motivated the government to set water quality standards as they began to realize that public health and ecosystems were being compromised. The most popular Federal law regarding water quality is the Clean Water Act of 1972 which established basic standards for regulating the discharge

of pollution (3). Water quality refers to the condition or the characteristics of water and whether or not they meet the requirement for sufficient human use (2). According to the Environmental Protection Agency (EPA), setting water quality standards is so important because it ensures the protection of human health and aquatic life (2). Water quality standards regulate the possible pollutants that can enter into a body of water within the United States and forces states to set water quality goals of each body of water to repair any previous damage that was done to that water (2). The federal government also implemented the Safe Drinking Water Act in 1974 that protects public drinking water supplies, sets standards for drinking water quality and implements technical and financial programs to ensure drinking water safety (3). All water sources are subject to contamination and in order for water to be considered safe for drinking, the water must be treated. There are various methods of water treatment to provide safe drinking water, including filtration and disinfection (4). Water can be contaminated with a range of constituents including lead, iron, arsenic, other heavy metals, fertilizers, pesticides, industrial waste and wastewater (4). If left untreated the use of this contaminated water can cause a variety of health problems to arise, including the spread of diseases, reproductive illnesses and neurological disorders (4). One of the most common contaminants seen today is lead. The Environmental Protection Agency and The Centers for Disease Control and Prevention have stated that any level of lead in the system is harmful, especially to children (4). The Safe Drinking Water Act requires The Environmental Protection Agency to determine the level of contaminants in drinking water "at which no adverse health effects are likely to occur with an adequate margin of safety" (1). These are called maximum contaminant level goals. The EPA has set the maximum contaminant level goal for lead in drinking water at zero because lead is a toxic metal that can be harmful to human health even at low levels (1). Lead has the ability to accumulate in the body over time and can cause damage to the central and peripheral nervous system, learning disabilities, shorter stature, impaired hearing, and impaired formation and function of blood cells in children (4). Lead poising from drinking water can also lead to cardiovascular effects, increased blood pressure, hypertension, decreased kidney function and reproductive problems in both men and women (4).

Setting water quality standards and ensuring the treatment of water protect human health and is supposed to ensure that people always have safe drinking water, however, these laws and regulations do fail. Unfortunately, Flint, Michigan is not the only place experiencing water quality issues. The EPA has reported that at least 41 states are experiencing high levels of led (12). One of those places is a Washington, D.C. Research shows that lead contamination in D.C. in 2003 was 20 to 30 times the amount of lead that Flint experienced during the peak time of its crisis. In addition to water quality standard, establishment of an effective corrosion control procedure is crucial.

8.2. The Flint, Michigan Water Crisis:

In 2014, the state of Michigan was impacted from a financial crisis and in an attempt to save money, officials decided to switch Flints' water supply from Lake Huron to The Flint River (5). The Flint River had been turned down as a source of drinking water on numerous occasions due to its high level contaminants from industrial waste, chemical waste, pesticides and run-off from the surrounding city (10). Despite the knowledge of the poor condition of the river, officials still chose to use the water as drinking water. Drinking water needs to be properly treated, however, the officials did not take the proper steps and failed to treat the water with an anti-corrosive agent and as a result, the water accumulated extremely high levels of lead, iron, bacteria and other heavy metal from the pipes that the water travels through (5). The government insisted that the water was safe to drink, but further studies found that the water had the potential to endanger the health of the

residents. This contamination caused the water to turn brown (Figure 1) and many residents filed lawsuits against the state government, where

Figure 1. Flint, Michigan Water Crisis. National Education Association (8).

they complained of a peculiar odor and taste coming from the water (8). The presence of lead and metals in the water made way for various health problems, including lead poisoning, Legionnaires' disease, elevated blood lead levels in children, and an increased spread of sickness and disease (4). The government soon issued a state of emergency, stating that the water contained toxic levels of lead. From then on, the residents could only cook, bathe and drink bottled water. As of date, the water is getting the proper treatment but it will still take multiple years to ensure that each Flint resident will receive quality drinking water (10). A water crisis like in Flint, Michigan are not uncommon and although the water may one day be restored, the health problems that the residents are facing will stay with them for a lifetime. Situations such as the Flint Crisis emphasize the importance setting water quality standards and enforcing them.

***8.3. Drinking Water Quality Issues in Washington, D.C.*:**

Since the beginning of the 21st century, Washington D.C has experienced high levels of lead in its water. Some researchers argue that lead level in DC water was far worse than the Flint Water Crisis as it affected a much larger population (7). The lead contamination in Washington DC's water was first found in 2001 after the city decided to stop treating water with chlorine and switch to chloramine (7). This change caused an increase in lead levels found in the water. According to *Cohn (7)* on the contamination of D.C.'s water, states that after the D.C. Water and Sewer Authority downplayed the lead amounts in 2002, the EPA required another new test in 2003. The new test tested drinking water in 6,118 city homes, and showed that two-thirds of the home had lead levels "high enough to trigger public disclosure and lead-pipe removal" (7). Cohn (7) states that in 157 homes, the water tested above 300 ppb, or 20 times the action level (7). During this time, residents were unaware of the toxic water and thousands of residents utilized the water as drinking water. The increase in lead led to the development of illnesses in many children and families are still suing the government for reparations.

Having lead in water is harmful to children and situations such as the ones in D.C. and Flint will continue to happen until solutions are made to prevent lead contamination in drinking water. It has been argued that clean drinking water is a basic human right and in the past the government has failed to do all it can to ensure that the proper procedures are followed. In order to protect human health and the environment, it is imperative that the government invests in the necessary infrastructure needed to properly filter water, create the proper regulations and aggressively enforce the safe drinking water standards.

Introductory video https://www.youtube.com/watch?v=CzKFuVLN0ns.

9. Classroom Management:

The case is intended to take a minimum of 30 minutes/week in a 3-credit (three contact hours per week) course over 7 weeks during the semester. Weekly course schedule is designed according to the student learning goals and presented as follows:

- Week 1. Case study introduction
- Week 2. Describe the type and sources of toxic contaminants in our drinking water
- Week 3. Describe the relationship of treatment technology and quality of drinking water, and socioeconomic implication
- Week 4. Describe the socio-environmental impacts of increasing water use efficiency
- Week 5. Describe the interconnection of water, food, energy, and health and wellness
- Week 6. Discuss different water right policy, equity, e.g. Water is a human right
- Week 7. Describe water quality regulations (water quality standard and water quality criteria)

Week 1. Case Study Introduction:

Student learning goal: *Understand drinking water contamination as a socio-environmental system.*

Activity 1. *Identify component of tap water system and main sources of lead contamination*

The instructor will introduce the case of lead contamination in our drinking water, beginning by showing the video of DC water crisis in 2003- 2004 and the Flint Water Crises in 2016 (e.g. DC Water Crisis: https://www.youtube.com/watch?v=dEgZpM6j6cc; Flint Water Crisis: https://www.youtube.com/watch?v=p4Fcs4tprKQ). It is also important to introduce the service pipeline (Figure 2). The class will then read more further reading materials, including news story about DC Water Crisis in 2003.

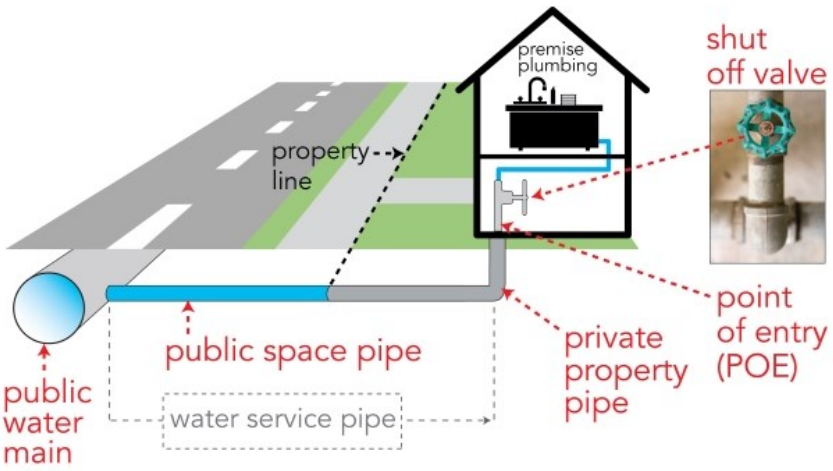

Figure 2. Understanding our water service line (14).

Individual Activity:

5 minutes: Let students try to create a mind map for possible sources of lead in tap water. Evaluate the effect of sources of drinking water on lead contamination.

Group Activity:

15 Minutes: Let students complete the mind map of in groups.

Discussion:

10 Minutes: What are the causes of drinking water contamination (Figure 3)? What is the role of the water utility and home owner in addressing this problem? What are the socio-environmental impacts of drinking water contamination with lead or others? If there is no safe level of lead in drinking water, how can we meet the goal of zero lead level? Where is corrosive water found?

According to EPA, Even low levels of lead in the blood of children can result in:

- Behavior and learning problems
- Lower IQ and hyperactivity
- Slowed growth
- Hearing problems
- Anemia

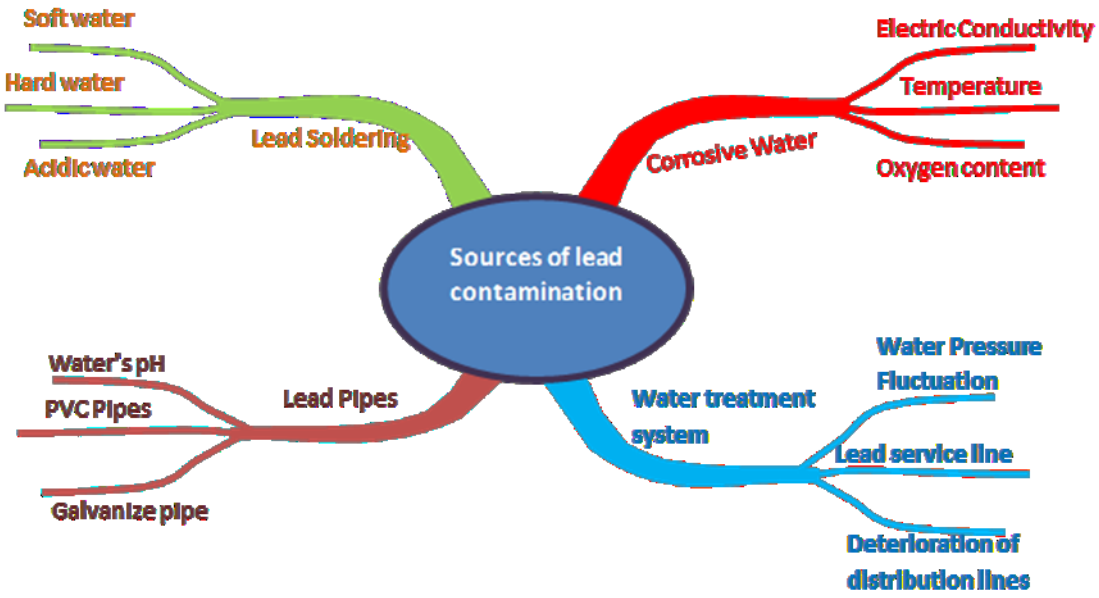

Figure 3. Mind Map on How Lead Gets into our Drinking Water.

Further media/readings:

- *Lead in tap water*: http://twon.tamu.edu/media/385808/drinking%20water%20problems-corrosion.pdf https://www.washingtonpost.com/local/dcs-decade-old-problem-of-lead-in-water-gets-new-attention-during-flint-crisis/2016/03/17/79f8d476-ec64-11e5-b0fd-073d5930a7b7_story.html?utm_term=.0c3d16f3211e

- *Flint water crises*: http://www.cnn.com/2016/03/04/us/flint-water-crisis-fast-facts/index.html
- *Before Flint: D.C.'s water crisis was even worse:* http://wtop.com/dc/2016/04/flint-d-c-s-drinking-water-crisis-even-worse/
- *Water in D.C. Exceeds EPA Lead Limit*: https://www.washingtonpost.com/archive/politics/2004/01/31/water-in-dc-exceeds-epa-lead-limit/1e54ff9b-a393-4f0a-a2dd-7e8ceedd1e91/?utm_term=.332750917b5e
- *The Flint Water Crisis: What's Really Going On?* https://www.acs.org/content/acs/en/education/resources/highschool/chemmatters/past-issues/2016-2017/december-2016/flint-water-crisis.html
- *D.C.'s decade – old problem of lead in water gets new attention during Flint crisis:* https://www.washingtonpost.com/local/dcs-decade-old-problem-of-lead-in-water-gets-new-attention-during-flint-crisis/2016/03/17/79f8d476-ec64-11e5-b0fd-073d5930a7b7_story.html?utm_term=.f789543aacf1#comments
- Lead service line: https://www.dcwater.com/servicemap

Week 2: Describe Type and Sources of Toxic Contaminants in our Drinking Water

Student learning goal: *Articulate sources of water pollution in our source water for drinking water (ground or surface water) and types of toxic contaminants of concern in our drinking water.*

Activity 2*. Identify water contaminants of concern to their possible sources of water pollution and related socio economic sectors.*

The instructor will introduce the case by showing the PowerPoint presentation of point and non-point sources of water pollutions, including industrial wastewater discharge, household sewage and wastewater, agriculture runoff, stormwater runoff, and oil and gold mining activities. Each student is assigned to one task from (a) through (e). It is also important to introduce different categories of water contaminants, including metals, organics, pathogens, disinfection byproducts, and endocrine disrupters. The introduction can be via a YouTube video, pictures or news story, e.g. pharmaceuticals in our drinking water (https://www.youtube.com/watch?v=ocQL9Mk2WJE or https://www.youtube.com/watch?v=5T7yIbZRFmU).

Group activities:

15 minutes: Students discuss one of these four tasks in four groups:

1. **Explore possible water contaminants from** (a) household sewage and wastewater, (b) pharmaceutical industry, (c) agricultural runoff, (d) urban stormwater runoff, and (e) gold mining activities.
2. **Identify type of contaminants related to these different sources of water pollution (Figure 4):**
   - Industrial waste - pharmaceutical industry waste, metals… etc..
   - Sewage and wastewater - Nutrients - nitrogen and phosphorous, pathogens
   - Agriculture - Nutrients, pharmaceuticals, hormones
   - Stormwater – Nutrients, salts, oil, gas, anti-freeze, pesticides from the field or people's yards
   - Oil spills and mining activities - oil, metals

3. **Identify lists of regulated toxic contaminants in drinking water; identify their sources based on Figure 4:**

- Metals - Mercury, Copper, Lead, Chromium, Cadmium
- Metalloids - Arsenic
- Organics - Polychlorinated biphenyls, polyaromatic hydrocarbons, pesticides… etc..
- Pathogens - *Escherichia Coli*, fecal Coliforms, parasites
- Disinfection byproducts

4. **Identify lists of unregulated contaminants and toxicity; identify their sources based on Figure 4 and 5:**

- Pharmaceuticals - endocrine disrupters
- Hormones - endocrine disrupters
- Personal Care Products - endocrine disrupters
- Cyanotoxins -toxins produced by bacteria called cyanobacteria (also known as blue-green algae) – liver inflammation and kidney damage

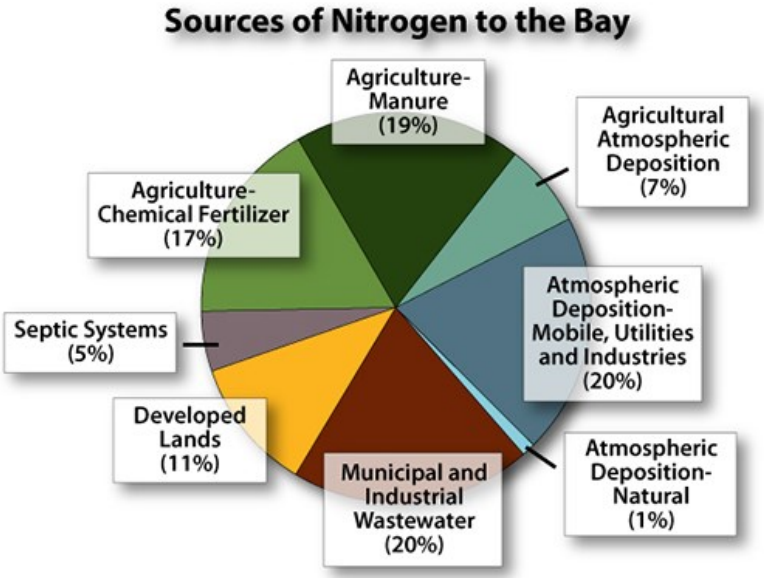

Figure 4. Sources of Nitrogen to the Chesapeake Bay (15).

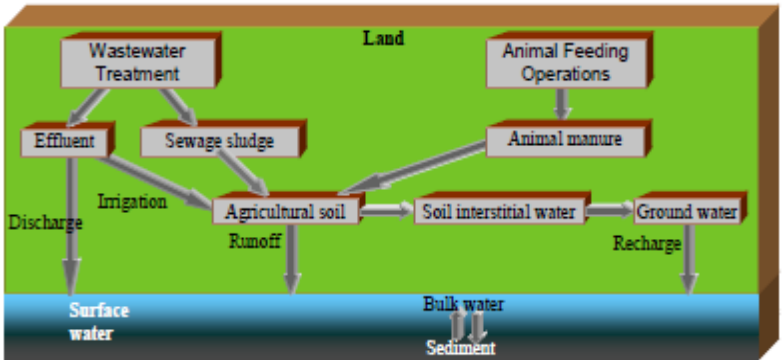

Figure 5. Sources of **s**urface and groundwater contamination with hormones (16).

Debate:

15 minutes: The instructor will form two groups. Group 1 represents a citizen rights activist, and Group 2 represents environmentalist. First, the environmentalist group proposes a federal law that would make it a crime to use fertilizer on crops or lawns because it could run off into the ground or surface water. Students must prepare justifications for the law and penalties for breaking it. Second, the citizen rights group prepares arguments against the law, contending that the law restricts their private property rights. Have the two groups debate the issue.

Home work:

- Create a mind map for:
  - Sources of nitrogen and phosphorus pollution (Figure 4), or
  - Sources of hormones (Figure 5)

Additional reading materials:

- Pharmaceutical in drinking water:
  "Vast arrays of pharmaceuticals including antibiotics, anti-Convulsants, mood stabilizers and sex hormones have been found in the drinking water supplies of at least 41 million Americans, an Associated Press investigation shows."
- http://hosted.ap.org/specials/interactives/pharmawater_site/day1_01.html
- Elk River Chemical Spill (West Virginia) 2014:
  https://www.nytimes.com/2014/01/11/us/west-virginia-chemical-spill.html
  http://wvpublic.org/term/elk-river-chemical-spill#stream/0
- West Virginia Chemical Spill https://ntp.niehs.nih.gov/results/areas/wvspill/index.html
- EPA Website for Superfund Sites https://www.epa.gov/superfund/search-superfund-sites-where-you-live
- Groundwater contamination activity – build an aquifer
  https://www.sciencelearn.org.nz/resources/1255-groundwater-contamination

Week 3: Describe Relationship of Treatment Technology and Quality of Drinking Water, and Socio-economic Implication

Student learning goal: Water treatment technologies and socio-economic implication. *Students will be able to describe different treatment technologies and their cost-effectiveness, identify challenges and opportunities using those different water treatment options and socio-economic barriers and gaps in policies. Students will also articulate the relationship between availability and necessity of those technologies driven by the socio-economic* status of different users.

Activity 3. *Water Treatment technologies and related socio-economic implication*

The instructor will introduce the case by showing different water treatment technologies and their effectiveness in removing contaminants of concern and associated costs. Use of videos on water treatment options or invited expert speakers would be useful, e.g. comparison of filters(https://www.home-water-purifiers-and-filters.com/water-purification.php).

There are seven main known treatment technologies:

1. Sand filtration
2. Activated Carbon Filtration
3. Mechanical Filters
4. Water softeners
5. Ion- Exchange
6. Ultraviolet (UV) Radiation
7. Reverse Osmosis

Individual activities:

5 minutes: Let students write the sources of tap water and what treatment technologies were involved in purifying their drinking water.

Group discussion:

15 minutes: Explore if the selection of a treatment technology depends on the type of contaminants of concern. Provide examples. If DC water switches to Reverse Osmosis in order to remove most contaminants of concern, including pharmaceuticals, must the price of tap water change? What is the socio-economic impact of this change on the low income families in DC? Who will pay more, the rich or the poor? Why? Please note that when the rate of tap water increases, the rich may purchase more advanced technology to conserve water.

Debate:

10 minutes: Divide class into two groups: group1 represents high socio-economic status and another group represents low socio-economic status. If a city decides to install a reverse osmosis treatment system for safe drinking water supply, have the group discuss if this treatment option is 1) essential, 2) sustaining, 3) requires less maintenance, 4) affordable, and 5) effective. Each group provide if they support this treatment option, why they support it or why they do not support it and if they have an alternative treatment option.

The graph below shows the drinking water treatment flow diagram of surface water (Canadians Opposed to Fluoridation, February 8, 2018, http://cof-cof.ca/surface-water-treatment-plant-flow-diagram/)

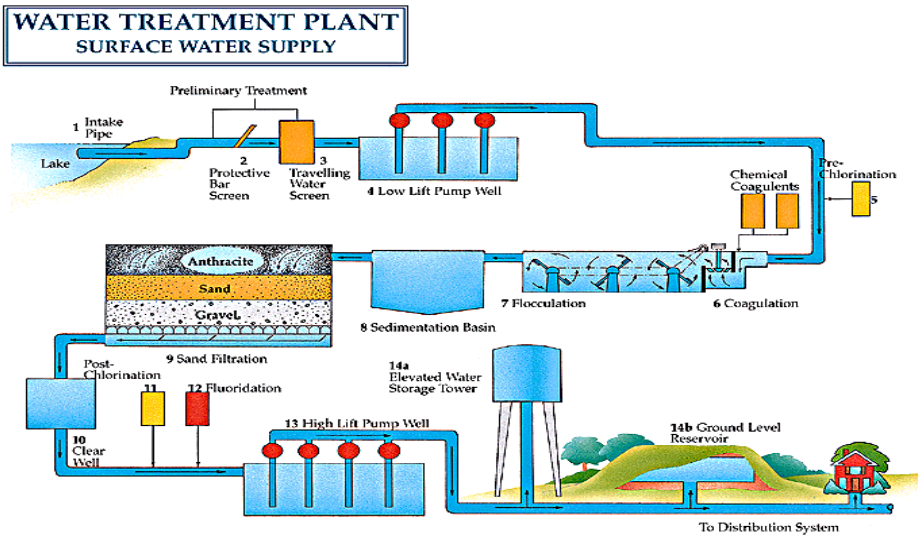

Figure 6. Drinking water treatment flow from surface water (17).

Additional media/reading materials:

- DC water treatment process: http://www.nab.usace.army.mil/Missions/Washington-Aqueduct/Treatment-Process/
- Drinking water treatment https://www.wateronline.com/solution/drinking-water-treatment
- The Water Rich versus The Water Poor. Water is Life! https://www.youtube.com/watch?v=sXKnMZwxYA8
- Drinking water treatment plant: https://www.youtube.com/watch?v=20VvpASC2sU
- Treating groundwater for drinking | Virtual tours: https://www.youtube.com/watch?v=BSYA-1Ctb9g
- Intro to drinking water treatment https://www.youtube.com/watch?v=0xPZXLHtRJw

Week 4: Describe the Socio-environmental Impacts of Increasing Water use Efficiency

Student learning goal: *in addition to water contamination, water availability depends on water use efficiency. Water use efficiency is crucial for resilient economies and societies. Agriculture commonly uses 70-90% of freshwater resources in most countries. Students will be able to reason and draw conclusion on various water uses and how household facilities and irrigation can be optimized to reduce water uses and increase water use efficiencies (i.e. toilet with water conserving flushing system, drip irrigation instead of spray irrigation in lawns, best option for lawn to plant local, seasonal plants and/or plants with less water needs).*

Activity 4. *Socio environmental impact of water use efficiency*

Lecture/information provision:

- The instructor will introduce the case, beginning by showing the video of inefficient old water system and efficient advance water use system, including household water use in US, e.g. efficient toilet: https://www.youtube.com/watch?v=9rkeqUr9DKQ; efficient irrigation system:

Individual activity:

5 minutes*:* Based on Figure 7, the Instructor may ask each student to explore the role of water efficient technologies in conserving clean water, e.g. comparing between old-fashioned toilet and new toilet, and traditional shower head and shower head with a water conserving flushing system. How does this affect once water bill? How does this affect the water utility that needs to sell more water to keep the treatment plant running?

Group activity:

10 Minutes: The instructor lets students make up to five groups and discuss the following five points:

- Compare the water uses between the lawns with seasonal, local plants and a single grass.
- Compare the lawn with sprinkler irrigation system with drip irrigation system.
- Compare the water uses for showering with continuous water flow with intermittent flow.
- Compare the water uses for brushing teeth with continuous water flow with intermittent flow.
- Compare the water uses/benefits of collecting rainwater for garden or house plants and tap water.

Discussion:

15 Minutes: The Instruct let the representative of each group share the result of their group discussion.

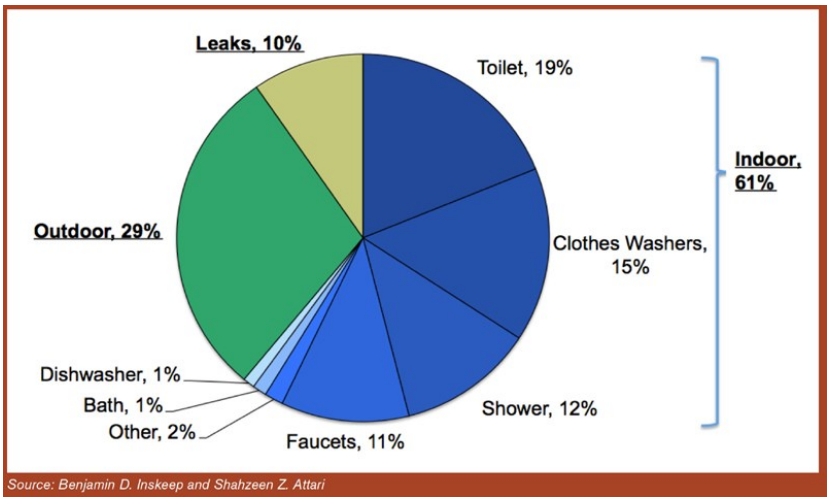

Figure 7. "End uses of water for the average U.S. household (total = 255 gallons per household per day). Indoor and leak end use values are based on data from the REUWS, and the outdoor end use is calculated by subtracting total indoor end use from total daily water use given by the USGS" (18).

Homework:

Visit wetlands with local, seasonal plants, university farms with drip irrigation and spray irrigation to calculate water uses, visit the state program at DNREC with rain barrels for using rainwater for garden and house plants. Write 100 words of the reflection paper. The reflection paper will be graded based on adequate description of the system pertaining to water use efficiency, connection of the observation with class discussion, outside experience and farsighted personal suggestion to improve water use efficiency.

Further reading/media:

- Water consumption and conservation: https://www.youtube.com/watch?v=CzKFuVLN0ns
- Grey water used to flush toilets: https://www.youtube.com/watch?v=y8kipgTJDUw
- Online water consumption calculator: http://www.csgnetwork.com/waterusagecalc.html
- EPA Water sense websites with lots of resources about increasing water use efficiency: https://www.epa.gov/watersense
- Saving Water Through Behavior Changing Technologies: https://aceee.org/files/proceedings/2016/data/papers/8_500.pdf
- Is it worth it to switch to a high efficiency toilet? https://www.youtube.com/watch?v=9rkeqUr9DKQ
- Publication of a student research project on "Outdoor Water Use Conservation through Native Plants": http://watermanagement.ucdavis.edu/files/1413/8255/4517/02_Group_Shapiro_Chan_Carson_Tayag.pdf
- Landscape irrigation for water conservation: http://articles.extension.org/pages/70453/landscape-irrigation-for-water-conservation-table-of-contents
- Your shower is wasting huge amounts of energy and water: Here's what you can do: about it. https://www.washingtonpost.com/news/energy-environment/wp/2015/03/04/your-shower-is-wasting-huge-amounts-of-energy-and-water-heres-what-to-do-about-it/?noredirect=on&utm_term=.3932c6ec192f

Week 5: Describe the Interconnection of Water, Food, Energy, and Health and Wellness

Student learning goal: Water, food, health and wellness: *Students will be able to describe the interconnection of water, food, health and wellness.*

Activity 5*. Understand the interconnection of water, food, energy, and health and wellness*

Lecture/information provision:

The instructor will introduce the case, beginning by showing the video or Figure 8 that demonstrate the interconnection of water, energy and food. The class will then read the Water-Energy-Food Nexus A new approach in support of food security and sustainable agriculture (http://www.fao.org/3/a-bl496e.pdf), and exploring the role of food and drinking water in human health and wellness.

Individual activity

5 Minutes: The Instructor lets each student choose a task "a" through "e" and work individually on each task:

a. Explain the interconnection of water supply and food production
b. Describe how water quality and quantity related to health and wellness
c. *Describe how water is related to energy*
d. Describe how food production is related to health and wellness
e. Describe how biofuel energy relates to food production

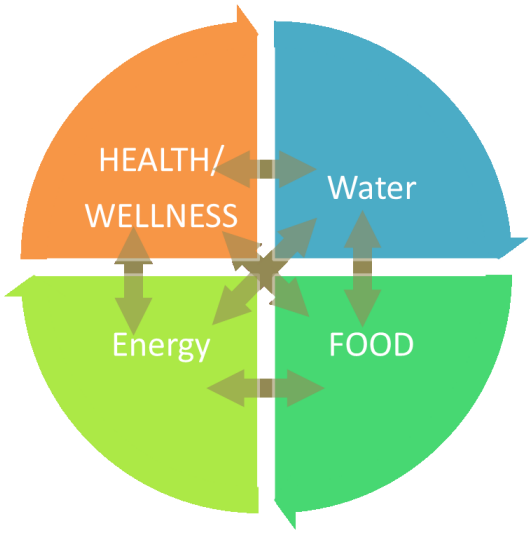

Figure 8. Interconnection of water, food, energy and health and wellness.

Group activity:
15 minutes: Student will make five different groups and each group will work on one of the task "a" through "e":

a. Explain the interconnection of water supply and food production
b. Describe how water quality and quantity related to health and wellness
c. Describe how water is related to energy
d. Describe how food production is related to health and wellness
e. Describe how biofuel energy relates to food production

Discussion:
15 Minutes: Evaluate water saving and energy saving practice in households to reduce CO2 and build sustainable cities. Compare water insecurity with energy insecurity. Which one has much more severe impact on the life quality?

Homework:

- Discuss water and energy sustainability synergies and trade-offs: http://www.diva-portal.org/smash/get/diva2:747151/FULLTEXT01.pdf

Additional reading assignments:

1) Food and Agriculture Organization of the United Nations. 2014. The Water-Energy-Food Nexus A new approach in support of food security and sustainable agriculture https://www.fao.org/3/a-bl496e.pdf
2) Exploring the role of food and drink in the future of health and wellness: https://pdfs.semanticscholar.org/presentation/3c22/42cdb6b0503550cc7b96a7bdb305c280d61f.pdf

Week 6. Discuss Different Water use Right, Policy and Equity

Student learning goal: Water equity: *Students will be able to describe the impact of water equity and sustaining ageing water infrastructure in the US.*

Activity 6: *Water equity or water human right.*

Lecture/information provision:
The instructor will introduce the case by sharing the Flint water crisis using YouTube video (e.g. https://www.youtube.com/watch?time_continue=25&v=uka4mWtDHzY) where thousands people were threatened to lose their houses for over six month water bill dispute for the contaminated water. The Instructor will also introduce fundamental questions about water rights and market reallocation (19).

Individual activity:
5 Minutes: Imagine you are part of the low-income family living in a city with poor water infrastructure. Suppose the city invested significant amount money to provide clean and reliable water to all households, including yours with the assumption that the water bill will increase and get paid by the households. The proposed bill is not affordable for the low-income families. What is your recommendation for these families to address this issue?

Group activity A:
10 Minutes: Jigsaw activity - This activity helps students learn about the different water rights and water issues stem from these rights. Students will be arranged in groups, with each group member is assigned to respond to one of these five questions:

1) What is your recommendation for these families to address this issue?
2) Who has rights and what are the competing rights? Government, privates?
3) What Are the Operational Rules for Using Water?
4) What Are the Rules for Establishing and Transferring a Right?
5) What Are the Operational Rules for Using Water?

Group members will then join with members of other groups assigned the same piece of information, and research and/or share ideas about the information – in a sense, become "experts" on this information. Eventually, students will return to their original groups and teach their group members what they have learned about their topic – their group will then piece together the information shared by each member in order to "piece together' the big picture of the topic at hand.

Group activity B:
15 Minutes: Debate – As an extension to the Pass The Jug activity, divide the class into five groups: one who represent personal/home use of the water, one who represents the agricultural use of the water, one who represents an industrial use/business use of the water, one who represents the recreational use of water, and one who represents the species of animals who have a critical need for the water.

Part I - Each group will debate amongst themselves (with the rest of the class as the audience) as to the most critical need for the water among the group members (example – recreational needs include availability of a golf course for an avid golfer, a whitewater rafting business, water recreation on the lake for a tourist to enjoy, and a golf course manager) the reason why their group "deserves" the water. The audience will then rank the need of water use in that group.

Part II -Each group will then debate why their group's water needs are more important than those of other groups (ex-agricultural vs. Industrial). These debates will allow students to consider and decide the equitable distribution of the available water.

Additional reading materials:

- Riparian water rights in Colorado: http://www.watercolorado.com/riparian-water-rights-understanding-eastern-us-water-law/
- Who owns the river water? https://www.npr.org/2013/06/15/192034094/rivers-run-through-controversies-over-who-owns-the-water
- Sustainable water use and water rights:http://sustainability.colostate.edu/sites/sustainability.colostate.edu/files/pdfs/SustainabilityPosters/WaterRights.pdf
- Effects of climate change on water:https://cleanet.org/clean/educational_resources/collection/index.html?search_text=water%20

Week 7. Describe Water Quality Regulations (Clean Water Act, Safe Drinking Water Act, Water Quality Standard, and Water Quality Criteria)

Student learning goal: Water quality regulation *– Student will be able to describe the impact of environmental regulation for source water protection: clean water act, safe drinking water act, water quality standard, and water quality criteria.*

Activity 7*: Understanding water quality standard*

Lecture/information provision:
The instructor will introduce the case by describing the Clean Water Act and Safe Drinking Water Act uses YouTube video: https://lawshelf.com/videos/entry/the-clean-water-act and https://www.youtube.com/watch?reload=9&v=inLZwGZSvSc.

The instructor will also introduce the concept of water quality criteria in detail (e.g. maximum contaminant level and maximum contaminant goal) using YouTube video: https://www.youtube.com/watch?v=_e9MZv_9Kn8.

Required water quality standards for different water uses:

Individual activity:
5 Minutes: Review Water quality standards, which include:

- Designated Uses of the water body
- Criteria to protect designated uses
- Anti-degradation Requirements to protect existing uses and high quality waters
- General Policies to address implementation issues.

Group activity: A
10 Minutes: On the basis of previous learning activities, the Instructor provides brief reading materials for five content areas. The class will work in group on five different topic areas:

- Group 1: Review and discuss the importance of shared responsibility of water utility and homeowner involvement in reinforcement of the water quality standards, e.g. lead in in DC or Flint, Michigan tap water.
- Group 2: Review the relationship of treatment technology and quality of drinking water.
- Group 3. Review the socio-environmental impacts of increasing water use efficiency.
- Group 4. Review the interconnection of water, food, energy, and health and wellness.
- Group 5. Review different water right policy and equity.

Group activity: B
15 Minutes: ***Jigsaw Activity*** - This activity will help students review all seven student learning goals. The instructor will make up to 5 groups. Students will be arranged in groups, each group member assigned to a different piece of information listed under Group activity A. Group members will then join with members of other groups assigned the same piece of information, and research and/or share ideas about the information – in a sense, become "experts" on this information. Eventually, students will return to their original groups and teach their group members what they have learned about their topic – their group will then piece together the information shared by each member in order to "piece together' the big picture of the topic at hand.

Additional reading material:

- Community Focused Exposure and Risk Screening Tool (C-FREST) Community Focused Exposure and Risk Screening Tool (C-FREST) https://www.epa.gov/healthresearch/introduction-community-focused-exposure-and-risk-screening-tool-c-ferst
- Maryland water equity legislation: https://www.foodandwaterwatch.org/news/maryland-poised-pass-groundbreaking-water-equity-legislation
- What are Water Quality Standards? https://www.epa.gov/standards-water-body-health/what-are-water-quality-standards
- Washington DC Water Quality Data: https://www.dcwater.com/sites/default/files/2017_dcwater_water_quality_report.pdf
- Enviro-Atlas https://www.epa.gov/enviroatlas

10. Assessment

Table 1. Assessment Matrix.

SLO	SE-Learning Goal	Learning Activities	Assessment (Formative or Summative)
1. Be able to describe the sources and the effect of lead and other toxic contaminants in drinking water on human health and society	1. Project based	1. Reading 2. View videos 3. Mind Map 4. Group Discussion	Formative - Jigsaw Activity Summative - Create a children's informational book
2. Be able to describe the type and sources of toxic contaminants in our drinking water, regulated and unregulated	System thinking: Analyzing system dynamics and driving forces; identify boundaries	1. Reading assignments 2. Concept map	Formative –Jeopardy Summative -Create an informational pamphlet for the general public
3. Be able to describe the relationship of treatment technology and quality of drinking water, and socioeconomic implication	System thinking: system tool use	1. View videos 2. Scenario analysis	Formative -Jigsaw Activity Summative -Create a Concept/Mind Map
4. Be able to describe the social-environmental impacts of increasing water use efficiency	System thinking	1. Reading assignments 2. Concept map	Formative - Google forms, survey Summative - extended response questions and writing piece
5. Be able to describe the interconnection of water, food, energy and health and wellness	System thinking	1. Reading assignment of food preparation and waterborne diseases	Formative - Google forms, survey Summative - extended response questions and writing piece
6. Be able to discuss different water right policy, equity, water is a human right	System thinking	1. Class debate	Formative - Jigsaw Activity Summative - Comprehensively compare and contrast water right issues as Summative

7. Describe water quality regulations (water quality standard and water quality criteria)	Socio-environmental	1. Jigsaw 2. C-FREST 3. Enviro-Atlas 4. Reading assignment	Write an extended essay as a Summative

Table 2. Assessment: Rubrics.

SLO	4 Excellent	3 Good	2 Fair	1 Poor
1. Be able to describe the effect of toxic contaminants in drinking water on human health and society	Several (more than 3) cases or examples are provided to illustrate the sources and effects of tap water contamination.	At least three cases are provided in adequately describing water contamination and its effect on human health.	Provide only one case or example in fairly describing water contamination and its effect on human health.	The description is vague and examples are not clear explained.
2. Be able to describe the type and sources of toxic contaminants in our drinking water, regulated and unregulated	Adequately describe sources of lead and other regulated and unregulated toxic contaminants in drinking water as a system using examples.	Describe at least lead service line and sources of lead contamination in drinking water as a system.	Fairly describe a very few regulated and unregulated contaminants in drinking water.	Unable to describe the system for lead or other contamination in our tap water.
3. Be able to describe the relationship of treatment technology and quality of drinking water, and socioeconomic implication	Adequately describe the relationship of treatment technology and quality of drinking water, and socio-economic implication using examples.	Describe the relationship of treatment technology and quality of drinking water, and socio-economic implication.	Describe the relationship of treatment technology and quality of drinking water, but does not provide socio-economic implication.	Unable to clearly describe relationship of water quality treatment technology and water quality
4. Be able to describe the social-environmental impacts of increasing water use efficiency	Adequately describes the social, economic and environmental impacts of inefficient water uses using more three or more examples.	Describes social, economic and environmental impacts of inefficient water uses using at least one example.	Describes the economic impacts of inefficient water use, but vague or no clear understanding of social and environmental impacts.	Unable to describe the social, economic, and-environmental impacts of inefficient water use.

5. Be able to describe the interconnection of water, food, energy, health and wellness	Adequately describe the interconnection of water, food, energy, health and wellness using examples.	Describe the interconnection of at least four items or water, food, health and energy nexus using examples.	Describe the interconnection of three or less items, e.g. Food and water, or food, water and energy, but has a vague understanding of the interconnection of five components: water, food, energy, health and wellness.	Unable to describe the interconnection of water, food, energy, health and wellness.
6. Be able to discuss different water right policy, equity, water is a human right	Adequately discuss different water use right, policy and equity using examples.	Discuss some water use right and policy using examples.	Describes limited water right policy, equity, water is a human right.	Unable to discuss different water right policy, equity, water is a human right
7. Describe water quality regulations (water quality standard and water quality criteria)	Describe the difference of water quality standards and water quality criteria using several examples.	Describe water quality standard and water quality criteria using a few examples.	Described water quality standard or water quality criteria with a vague understanding of the difference.	Unable to describe the terms. Vague understanding of the difference between the two terms

Student learning of the materials will be assessed using pre- and post-assessment survey for each week. The survey questions mainly focus on assessing the student's satisfaction in each learning goal. This will allow us to monitor students' learning and the gaps in their learning.

Table 3. Example of pre- and post- survey questions. Instruct students to put a check mark at the appropriate level of their satisfaction about the student learning goal of the case study.

SLG	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1. I am now able to describe the effect of toxic contaminants in drinking water on human health and society.					
2. I am now able to describe the type and sources of toxic contaminants in our drinking water, including regulated and unregulated					
3. I am now able to describe the relationship of treatment technology and quality of drinking water, and socioeconomic implication					
4. I am now able to describe the social-environmental impacts of increasing water use efficiency					
5. I am now able to describe the interconnection of water, food, health and wellness					
6. I am now able to discuss different water					

right policy and equity					
7. I am now able to describe water quality regulations (water quality standard and water quality criteria)					

11. Take Home Messages or Big Picture

Nearly 20 percent of U.S. water systems tested above the EPA's lead "action level" of 15 parts per billion (ppb). Over a period of three years the concentration of lead in the city's water was above 15 ppb blood lead level (BLL), twice the permitted level, while the average lead in city water was 59 ppb for the 90th percentile of homes sampled in 2004 and the number of people affected was 200,000 but few knew about it. The name of this city is not Flint, Michigan but our nation's capital city, Washington DC. How did this contamination happen in this modern, sophisticated city? Ironically, the same factors that caused the tragedy in Flint were responsible for the contamination of the water in Washington DC. As if no good deed goes unpunished the cause of this lead contamination was caused by the desire to reduce the byproducts in the disinfection process. However, the planners did not consider the effect this change would have on the old pipes in the city. The change in the disinfection process caused these older pipes to leach lead into the water that was used in the homes of more than 42,000 children under the age of 2.

Washington D.C.'s decade-old water quality issues are evidence of poor management and planning of drinking water supply to the communities living in D.C. For the students using the information in this case study, there are five overarching ideas in this case study:

- To understand drinking water supply as a system
- To construct socio-environmental synthesis of water resources management
- To be able to discuss issues as system dynamics
- To determine what is real versus fake information
- To synthesize what is applicable, affordable, and durable

We would like to ask the following questions to the students: Why water matters? Why it is important to you? How it matters? What can you do? How can you do it? Finally, how you can communicate the information most effective way?

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