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Water pollution in Zirahuén Lake (Michoacán, Mexico): Teaching-learning Experience in a Social and Environmental Chemistry Approach

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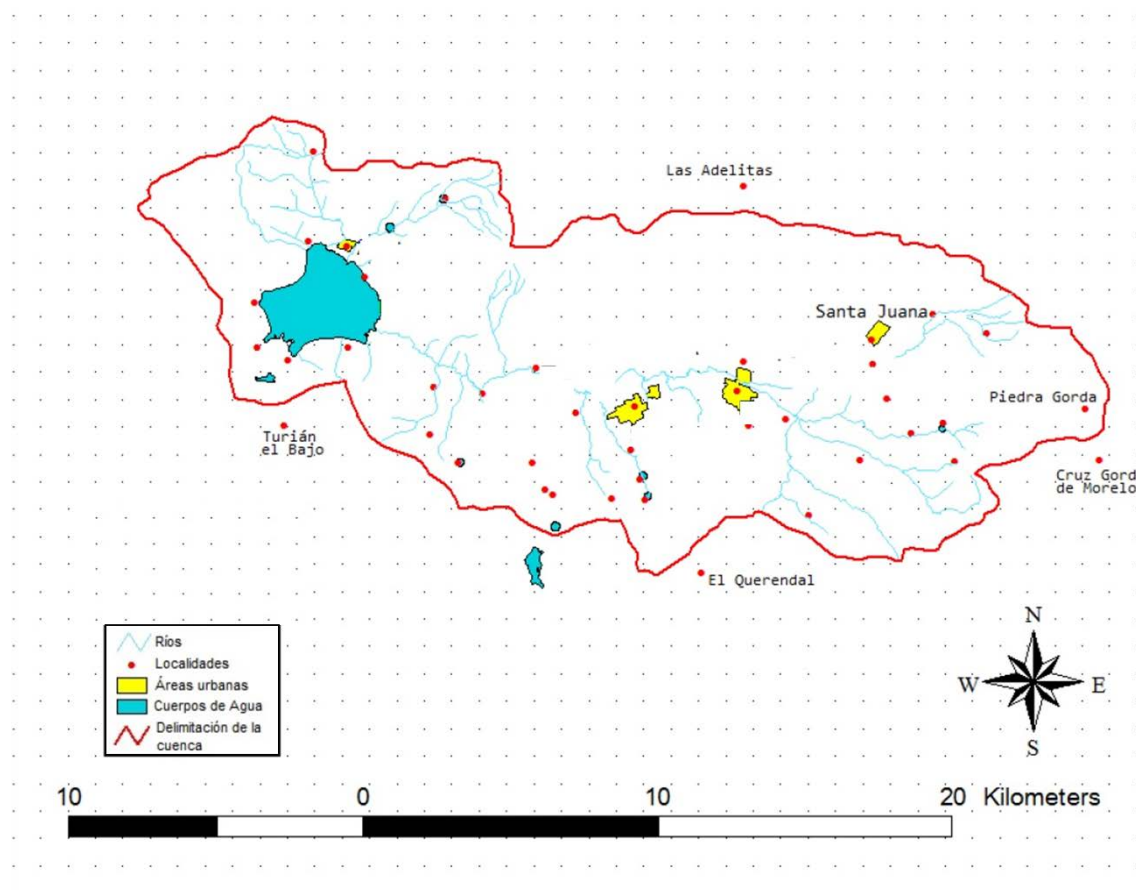
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3. With your teacher's help, locate the townships of Copandaro, Zirahuen, Agua Verde, Opoepo, Casas Blancas and Santa Clara del Cobre in the following map of the Zirahuen Lake watershed, as well as the bodies of water corresponding to the Zirahuen Lake and the Silencio River. Attempt to generate hypotheses on why the cases of Hepatitis A occur in Copandaro and not in other communities. Consider the townships' location with regards to the lake, the river and the watershed in general.



Zirahuen Lake watershed

Source: González Villareal & Flores-Díaz, 2014

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4. Homework: Read the following papers and answer these questions: Which characteristics define a complex system? What is an environmental problem?

-García, R. (2000). "Conceptos básicos para el estudio de sistemas". En E. Leff (Ed.), *Los problemas del conocimiento y la perspectiva ambiental del desarrollo* (pp. 381–409). México: Siglo XXI Editores.

- Zurlini, G., Petrosillo, I., & Cataldi, M. (2008). "Socio-ecological System". *Systems Ecology*, 4, 3264–3269.

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MODULE 1. ENVIRONMENTAL PROBLEMS AS COMPLEX SYSTEMS

General learning goal:

To identify the basic characteristic of a complex system and discuss why environmental problems can be considered complex systems.

Specific goals:

- Identify the limits, elements and structure of the case study: Contamination in Lake Zirahuen.
- Identify the characteristics of the case study's basic sub-systems: Physico-chemical and social.

ACTIVITIES

1. Carefully read the following summary of the socio-environmental situation in Lake Zirahuen.

Copandaro is a small community located on the shore of Lake Zirahuen, in the state of Michoacan, Mexico. This community has about 400 inhabitants (INEGI, 2010) and water for local consumption is extracted directly from the lake. Several other communities surround the lake, including Agua Verde and Zirahuen. The latter is more urbanized and has a population of 15,000 people (INEGI, 2010).

The Zirahuen Lake watershed is an important source of water for agriculture and human consumption in nearby populations. It is an endorreic watershed and is contained mainly within the Salvador Escalante municipality, in the North-central part of Michoacan state. The main affluent is the Silencio River, also known as Arroyo La Palma, which originates in the eastern edge of the watershed and leads into the west part of the lake.

Vegetation in this region is composed of pine, oyamel, oak and cloud forests, as well as grasslands and aquatic plants. However, the last decades have seen significant hydric erosion and lake desiccation due to deforestation, over-grazing, inadequate agricultural practices in hillsides, overexploitation of aquifers and loss of water from tectonic movements (Bravo, 2009).

The main economic activities in the region are: Agriculture, intensive farming, forestry, copper and crafts industries, fishing and tourism due to its beautiful scenery (traditional and ecotourism; Paniagua et. al., 2010). The artisanal copper industry, tourism and the fast-growing avocado industry are particularly significant.

The town of Santa Clara del Cobre, located along the Silencio River, specializes in the production of diverse copper crafts. Several different supplies are required for the elaboration of these crafts, such as water, firewood and chemicals. A number of solid, liquid and airborne waste and by-products are generated during the production process. Unfortunately, waste management is inadequate, and most substances are dumped into the river. Together with insufficient drainage in the region, this has created a contamination problem: Limnological studies have found concentrations of copper in Zirahuen Lake (Ayala Ramírez et. al., 2010).

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The shores of Lake Zirahuen are described as a secondary touristic destination, that is, most people visit the area because it is close to more important destinations such as Patzcuaro and Morelia. Within the watershed, tourism represents a major economic activity for the towns of Santa Clara del Cobre and Zirahuen, mainly through the sale of crafts, food and some recreational activities in and around the lake (Paniagua et. al., 2010). However, the infrastructure for these services is precarious, and most of the waste they generate is poured into the lake along with the town's sewage.

Historically, the main economic activity in this region has been agriculture. Avocado cultivation was adopted towards the end of the 1990s, with which the production value of this sector went from around 30% to over 90% employing only a fourth of the agricultural land. During the same period, maize cultivation generated just under 1% of production value while using more than quarter of the total cultivated area (Paniagua et. al., 2010). Avocado cultivation has since expanded throughout the region and is one of the most profitable crops as one of Mexico's main exports.

Proliferation of avocado croplands has resulted in the loss of approximately 30% of the region's forest cover (Barsimantov & Navia, 2012) and has also caused social conflict. It is one of the main drivers of land privatization, as previously community-owned lands pass into private ownership (such transactions were prohibited until a constitutional reform that occurred in 1992). Faced with economic hardships and low yields from hillside agriculture, owners of lands adjacent to Zirahuen Lake have sold them to private avocado producers, which has generated division and conflicts amongst the region's inhabitants. Additionally, high water consumption for avocado crops has also made local people angry at what they perceived as excessive water pumping.

In 2013, this situation led inhabitants from Zirahuen, Copandaro and other lake towns to approach local and state authorities, as well as the academic sector, to communicate their concerns regarding the lake's change of color and excessive algal blooms. Copandaro inhabitants were particularly concerned because this is the only population that obtains water for human consumption directly from the lake. Michoacan's government responded by calling on the *Universidad Michoacana de San Nicolás de Hidalgo* to carry out a diagnostic on the condition of the lake, and by creating the Zirahuen Lake Watershed Commission through the National Water Commission (CONAGUA).

The results of the diagnosis performed by the state university showed that the lake's change in color and algae proliferation was due to eutrophication and an accelerated deterioration that could be reversed with adequate watershed management. They also established that the lake's water is not fit for human consumption and can be potentially toxic during certain months (Gómez Tagle, 2016). The newly created Zirahuen Lake Watershed Commission met twice between 2014 and 2016.

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MODULE 2. BASIC CHARACTERIZATION OF THE SOCIAL SUB-SYSTEM

General learning goal:

Identify and classify the economic activities and interests of the main actors involved in the contamination problem of Lake Zirahuen.

Specific goals:

- Identify and classify the main economic activities developed around the study site and their relationship with the waste generated that contaminates Lake Zirahuen.
- Characterize the social actors involved in the case study according to their activities and economic interests.
- Identify the interactions between social actors and the physico-chemical environment.

ACTIVITIES

1. Using the information found in your bibliographic search, you and your team must now characterize the social actors involved in the study system. Use the following matrix:



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Social actor	Category (public or private institution, company, working class)	Main economic activity	Natural resources required for their economic activity	Environmental impact (waste) of their economic activity	Power hierarchy for decision-making (high, medium, low)

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INTERACTION MATRIX

2. In each intersection, indicate the type of relationship that exists between the identified actors, distinguishing between what the actor provides (positive or negative) and what they receive from other actors. Write what each actor provides in the direction of the columns (vertical) and what they receive in the direction of the lines (horizontal).
3. When you have finished this matrix, share your results with the rest of the teams and discuss where some relationships can lead to conflict between actors, and how this could complicate the resolution of the environmental problem. Write down some conclusions.

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Actors receive

Actors provide

	Actor 1	Actor 2	Actor 3	Actor 4	Actor 5	Actor 6	Actor 7
Interactions							
Actor 1							
Actor 2							
Actor 3							
Actor 4							



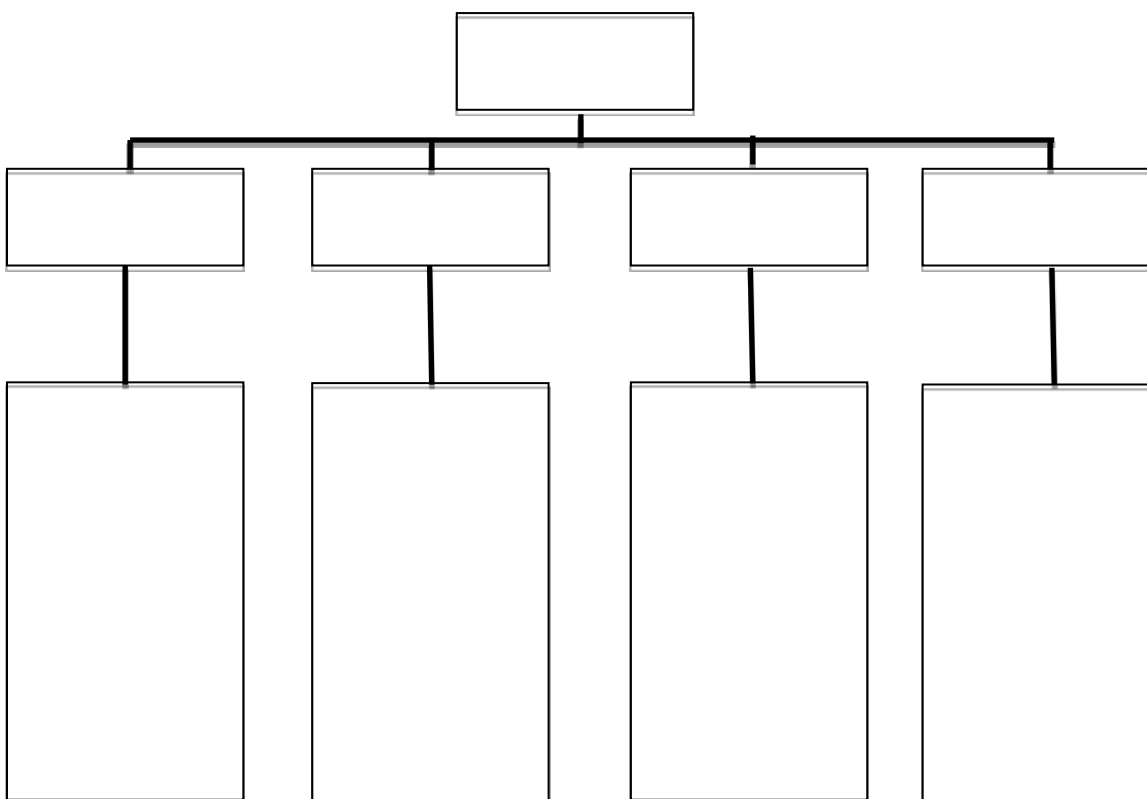
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Actor 5							
Actor 6							
Actor 7							

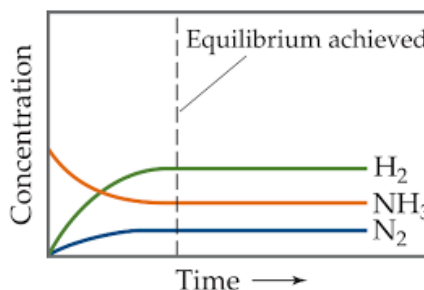
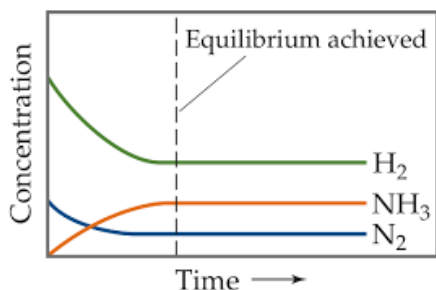
Observations:

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4. Using the following figure, explain:
 - a) What are the sources of contamination in Zirahuen Lake?
 - b) How are these pollutants transported and how are they shared between environmental spheres?
 - c) What are the routes (air, water, ground, food) and what are the exposure pathways (inhalation, dermal, ingestion) through which contaminants can reach local populations at risk of suffering from the presence of toxic substances in Lake Zirahuen?
 - d) Which chemical reactions could occur between different pollutants found in Lake Zirahuen, and how could this affect their effect on human health?



5. Observe the following figures and describe, for each of them, the changes in concentrations of the reacting elements. What conclusion can you draw from this?



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6. From all the information gathered so far, your team must now generate a conceptual map that explains “The socio-environmental problem in Lake Zirahuen”. Consider the following:
 - a) Represent two subsystems: social (characterization of the actor’s economic activities and the waste these generate) and physico-chemical (characterization of the pollutants present in Lake Zirahuen, chemical reactions and transport pathways).
 - b) Write a maximum of three words per box.
 - c) All boxes must be linked using short phrases.
 - d) Write a 1-page explanation of your map (be aware that the map should be self-explanatory).

You may use <https://cmapcloud.ihmc.us/> to elaborate your map.