Chapter 12

PCBs in the Last Frontier

Michael Tessmer

http://commons.wikimedia.org/wiki/File:Wonder_Lake,_Denali.jpg

Mount McKinley and Wonder Lake: Denali National Park, Alaska

The Case

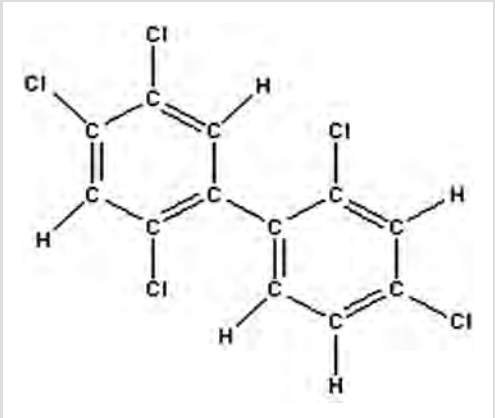
Part I: PCBs

Polychlorinated biphenyls (PCBs) are compounds that were once used as insulators in electrical transmission lines and in the production of polymers. Each PCB differs by the quantity and location of the chlorine atoms. An example of one of the many different PCBs is shown in Figure 12.1. PCB production was halted in 1977 due to the potential toxicity, but the chemicals are still found in the environment due to their stability. Studies in remote areas of Alaska have shown that PCBs can even be found in lakes untouched by humans. There is no known natural process that produces PCBs, so all of the PCBs in existence are presumed to have been produced by humans.

Questions

1. What scientific observation about PCB distribution is described above?

Figure 12.1. 2,2',4,4',5-Pentachlorobiphenyl



2. Propose a hypothesis or "explanatory story" to explain the global movement of pollutants such as PCBs. Specifically, how could they end up in the most remote Alaskan lakes?
3. Propose a method, either through observations or direct experimentation that would test your hypothesis from question 2. (Note: Your approach may be on a local scale despite examining a global phenomenon.)

Part II: Global Transport

Later studies showed that the global circulation of PCBs was due at least in part to atmospheric transport. PCBs enter the atmosphere by several mechanisms, including the burning of organic material and evaporation in warmer climates, followed by condensation at higher latitudes. This explained how chemicals made by humans could be found in areas untouched by humans.

Questions

1. Come up with a hypothesis or "explanatory story" to answer the following question: Should PCB levels differ significantly in Alaskan lakes that are near each other and at the same altitude? (Keep in mind that a hypothesis is an educated guess, so it requires a reason why you think your answer is correct.)
2. Propose a method, either through observations or direct experimentation, that would test your hypothesis from question 1.

Part III: Significant Difference?

Recent observations of PCB levels in arctic lakes have shown that the levels of PCBs are not the same in all lakes that are near each other and at the same altitude. In fact, lakes at the terminus (i.e., the start) of river systems had higher PCB levels than completely isolated lakes that were close by.

Questions

1. What possible "explanatory story" might explain the observation described above? (Hint: Think of species that leave a lake but return later in life.)
2. How would you test your hypothesis?

Part IV: Riddle Solved

Recent scientific studies have shown that sockeye salmon returning from the ocean to spawn in Alaskan lakes contain elevated levels of PCBs. After spawning, the salmon die and their contents become part of the lake sediment and/or enter the food chain. The salmon are responsible for adding approximately six times as many PCBs to

remote lakes as atmospheric circulation. The types of PCBs in the salmon also match those found in the ocean.

Question

Imagine yourself as a scientist working on this issue. What would you want to look at next?

Teaching Notes

Introduction and Background

This case study was developed after reading an article by Krummel et al. (2003) in the journal *Nature* concerning the bio-accumulation and transport of PCBs by sockeye salmon from the Pacific Ocean to Alaskan lakes. It involves students reading basic background information before proposing hypotheses to explain the information. The emphasis is on making predictions and explaining the reasoning behind the predictions.

PCBs are a good example of a persistent pollutant that has a global distribution. The example shown in the case study is one of 209 possible congeners. The precise mixture of congeners depends on the original source and is quite variable. The compounds are excellent insulators and were used mainly in heavy electrical equipment. Examples of other uses include polymer manufacturing and carbonless copy paper production. The persistence of PCBs in the environment is related to their thermal stability and general resistance to biodegradation. The acute toxicity of PCBs was first recognized on a large scale in the 1960s from an accidental contamination of cooking oil in Japan. Several thousand people suffered a variety of illnesses, ranging from skin discoloration to higher mortality for infants born to exposed mothers.

This case was designed to be used early in a course such as general or introductory chemistry, general biology, or environmental science. Since little background knowledge is needed, it can be used with majors or nonmajors. The case could also be extended for use in a course such as analytical chemistry, where it could involve reading and discussing the original paper from *Nature* and subsequent work.

Objectives

- To help students review the scientific method
- To teach students how to better state hypotheses
- To encourage students to design experiments that test a hypothesis
- To give students an introduction to the scientific literature with a relatively easy-to-read article

Common Student Misconceptions

- Areas with little direct human interaction are pollutant-free.
- All global transport of chemicals occurs via the atmosphere.
- Chemicals can "drift" up rivers from the ocean.
- Salmon cannot transport measureable amounts of chemicals long distances.

Classroom Management

I have used this case in a General Chemistry I class of 40 students working in groups of three. As written, the case can be completed in a 50-minute lecture session or in a lab setting. The case is broken up into four parts, and the instructor distributes one part at a time, with discussion after each part. (In large classes, this may be less practical, and the instructor may want to hand out the entire case and instruct students not to look ahead.) Students read each part and then spend about 5 minutes discussing the questions as a group. After each part, there is a short class discussion with a summary of the best answers.

Before beginning the case, I run a short class discussion on the steps of the scientific method. With input from the class, I draw a diagram showing the steps of the scientific method as a refresher. Most students have seen the steps to the scientific method enough times that the basics can be discussed as a class. Added discussion can also occur during the case study on the difference between conducting an experiment where a variable is manipulated and making observations to answer a question. This more subtle distinction can be emphasized while students are discussing ways to test hypotheses. The case presents several opportunities for students to propose experiments, and the discussion from the early part of the case will likely lead to improved answers later.

After completing the case, I provide copies of the article to any students who are interested in reading more. The article can be found in Krummel et al. (2003). It is also available at *www.biology.mcgill.ca/faculty/gregory_eaves/articles/KRUMME~1.pdf*.

Web Version

This case and its complete teaching notes and answer key can be found on the website of the National Center for Case Study Teaching in Science at *http://science-cases.lib.buffalo.edu/cs/collection/detail.asp?case_id=191&id=191*.

References

Krummel, E. M., R. W. Macdonald, L. E. Kimpe, I. Gregory-Eaves, M. J. Demers, J. P. Smol, B. Finney, and M. Blais. 2003. Delivery of pollutants by spawning salmon. *Nature* 425 (6955): 255–256.