

Identifying the Problem

To many people the image of a flamingo may bring to mind thoughts of paradise. A flamingo spends much of its time wading and dipping its bill in an inverted motion into the algae-rich water. Its bill serves as a filter to capture its primary food source, a blue-green algae. A flamingo prefers to spend its time in this manner and can be stressed by other activities such as flying and swimming (Vick, 2000). About 80 percent of the world's flamingos reside in the Great Rift Valley of eastern Africa (Vick, 2000). Roughly 1 million of these rift valley flamingos reside at Lake Nakuru located in Nakuru National Park in Kenya.



Figure 1. A lone flamingo at Lake Nakuru (left)¹; a large group of flamingos at Lake Nakuru (middle)¹; and a map of Lake Nakuru National Park and surrounding area (right)².

Lake Nakuru can appear ensconced in pink when occupied by lesser flamingos (*phoeniconiaia minor*) stopping to feed during their annual migrations through Kenya. Hundreds of thousands of tourists come every year from throughout the world to see the spectacular views as shown above.

Lake Nakuru is an alkaline (pH = 10.5) salt lake that provides an ideal environment for the growth of *arthospira fusiformis* and *spirulina platensis*, the types of cyanobacteria consumed by the flamingos. Volcanic activity in the area supports Nakuru and other “soda lakes”, named for their high levels of carbonate and bicarbonate. The Lake Nakuru catchment basin is a “closed system”. Five seasonal rivers flow into it, but there is no exit stream and the water loss is only due to evaporation. These factors, along with the shallow depth (averaging around 2.5 m, Odada, 2006) of the lake create a fragile ecosystem, susceptible to climatic



Figure 2. The Town of Nakuru, Kenya.

¹ Photo courtesy of Dr. Terry Master, Professor of Biology at East Stroudsburg University

² http://www.shoortravel.com/image/LakeNakuru_Map1.gif

and human activities. The area around the catchment basin includes not only the national park, but also agricultural land and the growing city of Nakuru (pop. 400,000; Odada, 2006).

Facts, Observations and Evidence

The typical lifespan of a flamingo is 50 years (Mukhebe, 2005). Flamingos do not breed at Lake Nakuru, but at Lake Natron in Tanzania. In recent years the flamingo has been classified as “near threatened” due to its susceptibility to small changes in its fragile habitat (Bloomfield, 2008).

During only 3 months of 1993, tens of thousands of flamingos died during a drought period. In 1997, El Nino diluted the salinity of the lake, adversely affecting food sources and driving flamingos to nearby Lake Bogoria (Odada 2006). During the year 2000 40,000 flamingos were reported dead at Nakuru National Park (Vick, 2000; Astill, 2001). Peculiar behavior, such as disorientation and a lack of mobility, were also observed (Astill, 2001). Flamingos have been observed not only to be dying at Lake Nakuru, but to be changing their migratory habits. Many have left Lake Nakuru, never to return (Mukhebe, 2005). Some of these birds were found dead along ponds around the city’s sewage treatment plant.

Heavy metal pollutants, such as lead, mercury and arsenic have been found in the tissue of flamingos from both Lake Nakuru and Bogoria which are 60 km apart (Astill, 2001; Wanjiru, 2001). These were attributed to effluents from local industries. Other pollutants, such as organochlorine pesticides were also found in flamingo body tissues (Kairu, 1994; Wanjiru, 2001). Heavy metals and pesticide residues have been found to be present in both the waters and sediments of Lake Nakuru, particularly during the rainy season (Mavura, 2003).

The waste treatment and disposal in the city cannot keep up with the population growth and development in the area. Some of the excess waste that accumulates is deposited in the lake via stormwater and wind (Odada, 2006).

The question to be answered is: What is causing the changes in behavior and death of the Lake Nakuru flamingos?

Some hypotheses as to possible (and perhaps intertwined) causes include:

Pollution. Toxins get into the lake via runoff from various sources, including fertilizers, organochlorine pesticides, and effluents from industrial plants. Some scientists suspect that organochlorine pesticides first accumulate in the cyanobacteria that the flamingos feed on (Mukhebe, 2005) and then are transferred to the tissue of the flamingos (Kairu, 1994; Wanjiru, 2001). Fertilizers could be enhancing the growth of cyanobacteria, which are hypothesized to accumulate organochlorine pesticides (Mukhebe, 2005). When the flamingos eat the cyanobacteria, the organochlorine compounds bioaccumulate into their tissues (Kairu, 1994).

Drought. The Kenyan Wildlife Service cited dramatic decreases in lake water volume since the last El Nino cycle. Corresponding changes in the lake salinity in the mid to late 1990’s were noted to have adversely affected the flamingo’s food supply (Odada, 2006). Specifically, the type of phytoplankton residing in the lake changed to a smaller size that could not be captured by the flamingo, thus reducing the amount of algae that the flamingos are able to capture. This

phenomenon could be happening again as a result of increased settlement and farming in the area which consumes water from the rivers that run into Lake Nakuru

Multiple factors may be contributing to the increased death rate. For example, in addition to decreasing flamingo food supplies, as the lake dries up pollutants and toxins that are already present become more concentrated. It is possible that the upswing in flamingo deaths is due to a factor that is as yet unrecognized and altogether different from those hypothesized above.

Identifying Possible Analysis Methods

There are three hypotheses that have been put forward that could be responsible for the death of flamingos at Lake Nakuru. The purpose of this exercise is to identify analysis methods that could be used to test the chemical species that contribute to each of the three hypotheses. Among the various analytical methods you find that may be applicable to this measurement, identify their strengths and weaknesses (e.g., sensitivity, expense, ease of use, reproducibility).

Hypothesis 1. High levels of pesticides found in flamingo tissues interfere with their endocrine systems leading to the high levels of disease and death that have recently been observed.

Q1. Using available literature and other sources of information, identify possible analytical methods that could be used to detect pesticides and measure their levels in components of the lake (e.g., water, sediment).

Hypothesis 2. Heavy metals such as lead, mercury and arsenic from industrial effluents, which have also been found in the tissue of flamingos at Lake Nakuru, are the main cause of the high flamingo death rate.

Q2. Using available literature and other sources of information, identify possible analytical methods that could be used to detect heavy metals and measure their levels in components of the lake (e.g., water, sediment).

Hypothesis 3. Increasing salinity due to decreases in lake water levels has decreased the food supply of flamingos and hunger and starvation are key reasons for the recently observed increase in the flamingo death rate.

Q3. Using available literature and other sources of information, identify possible analytical methods that could be used to measure the salinity of the water and the chemical constituents that account for the salinity.

Experimental Design for this Project

The other sections of this website are designed to support the investigation of the hypothesis that organochlorine pesticides in Lake Nakuru are responsible for the deaths of the flamingos. The next step is to design how the experiment will be conducted.

All analyses face certain real world limitations, such as cost, availability and compound stability. It is also important that the experiments be performed in such a way that the results are of sufficient quality to allow a scientifically sound conclusion to be drawn from the data. Standard methods such as those published by the Environmental Protection Agency (EPA) or Association of Analytical Communities (AOAC) can be useful in designing the experimental plan. You often may have to adapt a method based on available equipment or other limitations. Therefore, it is

important to understand all aspects of a given method and be able to show that your method is valid.

Analysis of Samples from Lake Nakuru

In our case study we will develop a sampling plan for water samples to be collected by local scientists in Kenya and shipped back to the United States for analysis. Therefore, there are limitations on the cost of sample preparation and shipping, as well as sample stability. As a result, the analysis will be limited to 200 samples (the maximum capacity of the GC-MS autosampler). Taking this in to consideration:

- How do you decide where to collect samples to ensure they are representative?
- What sample preparation method will you utilize (considering cost, effectiveness, and availability)?

A series of assignments are presented within this website to help you understand how to design a GC-MS experiment utilizing EPA method 525.2, and address questions such as those posed above. Through this process, you will also be introduced to important analytical chemistry concepts that underlie the analytical methods discussed.

References

- Astill, James. 2001. "Toxins Suspected of Killing Flamingos", *The Guardian (London)*, June 11, 2001.
- Kairu, J. K. 1994. "Pesticide residues in birds at Lake Nakuru, Kenya", *International Journal of Salt Lake Research* **3**, 31-48.
- Mavura, W. J.; Wangila, P. T. 2003. "The pollution status of Lake Nakuru, Kenya: heavy metals and pesticide residues, 1999/2000", *African Journal of Aquatic Science*, **28**, 13 – 18.
- Mukhebe, M.O. 2005. "Flamingos flee Lake Nakuru"
<http://www.safariweb.com/safarimate/flamingo.htm>.
- Odada, E. O., Raini, J., and Ndeti, R. 2006. "Lake Nakuru. Experiences and Lessons Learned Brief" [www.ilec.or.jp/eg/lbmi/pdf/18 Lake Nakuru 27February2006.pdf](http://www.ilec.or.jp/eg/lbmi/pdf/18_Lake_Nakuru_27February2006.pdf).
- Vick, K. 2000. "Kenya's Pink Death: Heavy Metals Found in Flamingo Carcasses Lead Directly to Effluent of Lakeside Factories", *The Gazette (Montreal, Quebec)*, March 9, 2000.