

## The Role of Oxygen

### THE CURSE OF LAKE NYOS

It started because Nurse Christine Nkwain hadn't heard from her sister in nine weeks. "This is not usual," she said firmly to Karl Jacobs, the World Health Organization doctor at her clinic. "You always say you are here to help."

"I'm happy to give you the day if you want to go yourself," Karl offered. There were plenty of needy people right there in Bamenda; no need to go chasing after more. Nurse Nkwain was shaking her head, and there was an unfamiliar expression on her face. After a year in Cameroon he still had trouble reading people's body language, but he thought she looked afraid. "I don't go there," she said. "We only write letters. It's a bad place."

"The village?" He cast his mind back over his briefing; he couldn't recall any warnings about problems, political or medical, in the village of Cha. "The lake. Lake Nyos is a bad place." When she saw his dark eyebrows go up she added, "I'm a Christian, Dr. Jacobs, you know that. But there are evil spirits in that lake, or why would people die just from being there? When my sister married a man from Cha, I mourned for her as if she were dead. I'm always afraid until I get an answer to my letters. Nine weeks is too long; I'm sure the spirits have her."

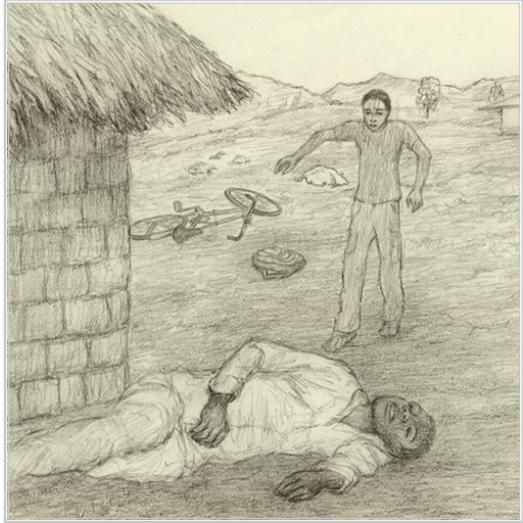
"People die just from being there? That's not possible, Nurse. There must be some sickness endemic to the area that hasn't been diagnosed. You have medical training; how can you embrace those ignorant superstitions?" He realized he'd gone too far as her face froze into a mask of contempt. "But," he added, "if there's sickness there it could spread. I'll investigate it tomorrow morning; I'm meeting with the schoolteachers today about immunizations. Please get those materials ready for me and be ready to translate into French or Pidgin if necessary." Jacobs himself spoke English well, French badly and Cameroonian Pidgin not at all.

The next day, after getting a later start than he had hoped for, Karl loaded up his bike basket with food and water, water purification tablets and quinine pills, and basic diagnostic and first-aid equipment; it would take him most of the day to reach Cha. Though August is winter-time south of the equator, it was hot, and it seemed to him that the outline of the Oku Volcanic Field barely changed as he pedaled along the mountain road. It was empty except for him—no trucks, no bikes, no one on foot in either direction—and he began to zone out as he rode, so that when his front wheel hit the dead frog he almost fell.

He stopped to make sure the tire hadn't blown out but saw, instead of a nail or a sharp rock, the tiny corpse. He frowned. Surely a frog could hop out of the way of a bike? His confusion, and his sense of unease, increased as he continued toward the valley where Cha was: every few feet, it seemed, he saw a dead rat, a dead lizard, another



dead frog. They weren't roadkill; there were no wounds or marks of crushing; strangest of all, nothing had eaten them. This was an all-you-can-eat buffet for vultures; where were they? And then he saw them, or at least two of them—lying dead by the side of the road. "Evil spirits," he said out loud, "what superstitious garbage!" His voice sounded strange to him, and the muscles in his legs didn't seem to want to pedal. He forced himself to bike onward; his shadow grew longer as the sun sank lower; he could see the roofs of Cha in the valley below, while the hill that held Lake Nyos loomed off to the left. Here on the slopes were the villagers' crop fields and grazing grounds—and the bodies of antelopes, monkeys and foxes. He forced himself forward around a bend in the road and stopped cold, swearing and cursing.



An entire herd of cows—fifty or more—lay on the grazing ground where they had fallen. They were beginning to rot, and so was the boy who had been watching them, but no scavenger had touched them. Karl leaned over to the side of the road and vomited. His bike had fallen to the ground; his mind was empty of everything but panic. "There are no evil spirits," he said out loud; his voice sounded like an insect buzzing in the bushes, but there were no insects buzzing. After what might have been a minute or an hour, he picked up the bike and walked it beside him down into the village itself. There was no sound of grindstones scraping or goats bleating; no sound of children fighting or playing; no sound of women and old men humming or chatting while they worked.

They were all dead. The people of Cha, like their cattle, lay where they had fallen—over the grindstones where they had been making fufu, over the babies they had been nursing, near the doorway they had been mending. One woman lay across the fire where she had been cooking. Even the flies were dead. There was no sign of what had killed them—no marks, other than those of decay, on their bodies. The smells of so much death sickened him and he vomited again.

When he looked up, he looked again at the woman lying dead across her cooking fire. Her body and clothes should have been burned, but they looked like all the others. To keep from panicking, he began to look around at the other cooking fires and coal stoves. Unattended, they should have burned themselves out, and the indoor ones would probably have set fire to the roofs. Instead, they seemed to have stopped burning long before their fuel was used up. He used his radio to send out a call for help. What could have caused such devastation?

### Scientific Connection

This is a dramatization of “the Lake Nyos disaster”, one of the worst environmental catastrophes in history. Four different villages were affected and over 1,800 people and thousands of animals were killed. Whatever the lethal agent was, it acted so quickly that there was no opportunity for escape. What could kill so many, so quickly, and in such a wide area?

The legends about Lake Nyos were correct about its danger but not its lethal mechanism. The absence of burning lamps and candles in any of the four affected villages was an important clue to unraveling the mystery. Fire is visible evidence of a combustion reaction. Combustion reactions can only occur if oxygen is present to accept electrons from whatever is being burned. No oxygen means no fire. This evidence led investigators to believe that all of the oxygen in the valley had been rapidly eliminated or displaced for some period of time. It is believed that a gas cloud of tremendous size and density displaced air from the valley, but what kind of gas could do this and where would it come from?

In sufficient quantities, carbon dioxide gas is more deadly than any evil spirit. Carbon dioxide gas is extremely dense; a physical property that allows it to be poured like a liquid. Concentrated carbon dioxide gas could displace the ambient gases of air (20% oxygen, 80% nitrogen) from the valley just like poured water would displace the air that occupies the inside of a cup. An estimated 1.6 million tons of carbon dioxide gas was effectively poured out of Lake Nyos and into the village below it. The volume of carbon dioxide gas was so gigantic that it pushed the air out of the valley, resulting in the rapid death of nearly every living thing in it.

The theory behind the source of the carbon dioxide gas had to do with several factors: the great depth and stagnancy of Lake Nyos; and the activity of a nearby volcano. Lake Nyos is one of the world’s deepest lakes and it is also one of the most stagnant. Continuous, mild volcanic activity beneath the lake produced significant amounts of carbon dioxide gas that accumulated in the water until it was completely saturated.

Carbon dioxide gas seeps into every lake from the ground but the motion of the water brings it to the surface so it never accumulates to dangerous levels. The water of Lake Nyos is very stagnant so massive amounts of carbon dioxide gas were able to accumulate within it as the water lay undisturbed. It is believed that every now and then a big bubble of carbon dioxide gas would come to the surface and asphyxiate any nearby organisms, thereby leading to the legend of the soul-stealing demons. In the case of the Lake Nyos disaster, a massive cloud of carbon dioxide gas was released rather than a gigantic bubble.

The precipitating event for the release of the gas cloud is unknown, though it is thought to be related to an acute increase in volcanic activity. This could have caused a giant shock wave to pass through the water, forcing the normally stagnant water to move rapidly. This massive

shake-up of lake water could have released carbon dioxide gas in the enormous amount required to overwhelm the valley.

Oxygen deprivation is extremely dangerous. Oxygen is the most physiologically important gas in air due to its role in cellular respiration. Electrons are harvested from nutrient molecules (sugars, fats, amino acids) by the oxidation reactions of the Krebs cycle. These electrons are then passed through the electron transport chain in order to generate the energy necessary to establish a hydrogen ion (proton) gradient. The energy of the proton gradient provides ATP synthase with the necessary power to make ATP ( $\text{ADP} + \text{Phosphate} \rightarrow \text{ATP}$ ) in the same fashion that a water wheel harnesses the power of a waterfall to make electricity.

Much like a highway, the electron transport chain is all about flow. Electrons have to enter and electrons have to leave. As long as things are flowing everything is fine. Oxygen accepts electrons at the end of the chain and allows them to leave, just like an exit ramp allows you to leave a highway. Without oxygen, electrons continue to enter the transport chain but do not leave leading to saturation or an “electron jam”. The rate of ATP production grinds to a rapid halt without oxygen to accept electrons from the electron transport chain. Insufficient production of ATP prevents cells from doing work that is essential to maintaining order. Once order is lost the cells will die rapidly. Imagine a highway where cars continued to get on and none ever left. In time the whole highway would fill up with cars and all traffic would stop. Oxygen is essential to removing electrons from the transport chain so new electrons can enter and lead to a high ATP production rate.

↪ **Take Home Message** ◀

**Oxygen is an essential component of cellular respiration. A constant supply of oxygen is essential to produce enough ATP to keep you alive.**

