The Green Pool: Water Made Visible

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August, 2016, the world turned its attention to Rio de Janeiro and the Olympic Games. In the run up to the Games there had been concern about the quality of the water in Guanabara Bay, the site of the sailing competition. The bay was notorious for sewage and debris. Members of the German sailing team reported that during practice their boats hit objects in the bay, including a floating chair.

So it was a surprise when the big water quality story of the Games occurred inland, at the diving pool. By Tuesday of the first week, the water in the diving pool at the Maria Lenk Aquatic Center was a murky emerald green. It had turned green overnight; the water polo pool just 20 meters away in the same venue was still clear and blue. That day Ruolin Chen and Huixia Liu of China won the gold medal in the Women's Diving Synchronised 10m Platform event, diving into green water.

Then the questions and speculation began. Why had the water turned murky and green? Was the green water a safety or health problem? Divers don't like to dive into water with poor visibility—would this affect the competition? Ruolin Chen said that it hadn't affected them that Tuesday, but what if it got worse?

"We don't know exactly what happened," organizing committee spokesman Mario Andrada said. He joked that if the water had turned green and yellow, it would have been patriotic.

I remember looking at the pictures Wednesday morning and shaking my head. To me it was obvious that algae was growing in the diving pool, and that the pool's chlorine protection had been lost. Back in 2007 Dave Langhus and I had published a paper in the *Journal of Chemical Education* about the chemistry of swimming pools, so I knew there were many ways that chlorine protection could be lost, but for it to happen that quickly, at the world's most significant sporting event—it had to be a big mistake and a big embarrassment.

But I headed out the door to my office; I had my own water issue to deal with. I was preparing to teach my First Year Writing Seminar, *Water in a Thirsty World*. I had taught the course twice before, but several years had passed since I taught it last, and there were important changes to make, and new syllabus requirements to install in the writing course. Ironically, my development of the FYWS on water around the world had been a direct outgrowth of the pool chemistry paper, because in writing that paper I realized that many of the concerns related to pool chemistry also arise in drinking water. With just two weeks to go, I had plenty of preparation left to do, but that Wednesday the pool paper was going to make its presence felt.

The phone calls started just before lunch. First it was a reporter from the Canadian Broadcasting Company, then a call from the New York Times. "You've published a paper on swimming pool chemistry; can you help us understand what happened?" Oh, sure. I knew how to *maintain* good pool chemistry. But I had never actually taken care of a swimming pool. My coauthor, Dave Langhus, who is now retired from Moravian College, is certified by the state of Pennsylvania to maintain public swimming pools. He takes care of a large pool at a summer camp every year—when it comes to how things can *go wrong*, he's got the real experience.

Nothing to do but soldier on. The CBC reporter told me that Andrada had released a new statement blaming a "decrease in alkalinity". Would that make sense? Yes, that would affect the pH of the pool, and could cause the effectiveness of the chlorine to decrease. How could alkalinity decrease? Most automated pool systems can add either hydrochloric acid or sodium carbonate to the pool water to maintain pH balance. Speculation: if the system were to run out of either chemical, it might lose control of the pH.

Some of the contestants blamed the temperature and the sunlight for the algae bloom. Well yes, both environmental factors, but especially sunlight, can remove chlorine from pool water. But there was the water polo pool right next to the diving pool—its water wasn't green. That seemed to rule out an environmental cause.

The New York Times reporter asked similar questions about pH. But he also had heard speculation that algae might not be the source of the green color; could "some other chemical" color the pool green, "maybe a metal". Yes, there are other green chemicals besides algae's chlorophyll: A dye called fluorescein is used to color the Chicago River green on St. Patrick's Day. The metal nickel can color water green, but the concentration of nickel required to color a pool would be very high, and would be very difficult to achieve by accident. "What about copper?" Again, very high concentrations would be required, and usually copper causes water to turn blue.

Not the Wednesday I had hoped for.

In case the calls continued, I decided I'd better pay attention to further developments. I didn't have to wait long. By Friday the water polo pool was starting to turn green. The diving pool was so cloudy that morning practice was canceled. The explanation/blame game had shifted to "faulty filtration." Andrada announced that "Chemistry's not an exact science." My students couldn't agree more—thanks, Senhor Andrada!

Finally Saturday arrived, and with it came some clarity, both for the pools and the reason why the water had turned green. Both pools were drained and refilled with good water. And it was announced that a contractor had added hydrogen peroxide to the water in both pools on the Friday before the start of the Games. Now you might think, since hydrogen peroxide is also a disinfectant, that having both chlorine and hydrogen peroxide in the pool water would make it twice as protected. Alas, that isn't so, because hydrogen peroxide and chlorine react and destroy each other.

$$H_2O_2 + HOCl \rightarrow O_2 + HCl + H_2O$$

Hypochlorous acid, $HOCl$, the active ingredient in bleach and chlorine-protected water, reacts with hydrogen peroxide, producing oxygen gas and hydrochloric acid and water. The protection against bacteria and algae is gone; it literally bubbles out of the water. And the acid byproduct would make that pH go down, consistent with the original "decrease in alkalinity" statement.

Some questions remained. Why was anyone adding hydrogen peroxide to a pool protected by chlorine? That action was a gross error. And why did the chlorine monitors for the pool indicate that the chlorine protection was still present after the addition of hydrogen peroxide? Was the reaction slow? Or could the dissolved oxygen produced by the reaction have fooled the chlorine monitors? It seems a stretch.

On the first day of my FYWS class, I try to sell my students on the idea that we should pay attention to water. Society has come to expect that water is invisible, unproblematic, always at our beck and call. But that isn't always the case. Whether it's a drought in California, or lead in the drinking water of Flint, Michigan, or a green pool at the Rio Olympics, water often rears up and demands attention. And when water becomes visible and problematic, the truth of the old axiom is reaffirmed: "Whiskey is for drinking, water is for fighting".

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