Introduction

Walk into a building with a pool and you can instantly tell it's there by the smell. No matter how big the building, small the pool, or robust the heating and ventilation system, that characteristic "chlorine" smell is there. If you are like me, a few minutes of exposure to the smell will bring tightness to my chest, itching to my eyes, and after about 20 minutes a light headed feeling. Go outside and it all goes away in about an hour. Swim and it can take days to return to normal. Competitively swim or swim daily and you probably get so used to the air you become acclimated to the irritation of disinfectant by products (DBP). In the past few years, a lot of research has defined what causes this smell, what effect it has on swimmers, and what can change the creation of DBPs so the pool becomes a "you don't know there is a pool until you see it" experience.

How are DBPs Formed?

DBP's are formed when chlorine, bromine or any halide molecule used to kill bacteria in the water, combines with biologic molecules that contain nitrogen. The most prevalent molecule in the swimming environment is urea from urine and sweat. Urea undergoes chemical changes in the pool and combines with chlorine or bromine to form over 30 different DBPs. Some of these molecules stay in the water and others are volatile so they diffuse into the air above the water and eventually into the entire building. The act of swimming actually increases the concentration of DBPs by churning up the water and increasing the concentration of these molecules in the air.

What Effects do DBP's Have On People?

We know a lot about the effect of one DBP – chloroform – since it was the most commonly used anesthetic for decades. The fancy name for this class of DBP is trihalo-methane (THM). There are many different THM's with different effects on people, just like there are many different types of DBPs that have different effects on people. We will look at chloroform and tri-chloro-nitrate.

Chloroform inhaled at a concentration of 10,000 ppm puts you to sleep. Prolonged exposure at this very high level will kill your liver, depress your heart function and kill you. In human volunteers, exposure to 4,100 ppm causes serious disorientation and 1,000 ppm causes dizziness, nausea, fatigue and headaches. Prolonged exposure to as little as 10 to 200 ppm can cause liver enlargement and effects on the central nervous system. For a reference, we measures THM concentrations in two commercial indoor pools in the 3 – 4 ppm range.

Application of chloroform to the skin causes redness of the eyes and itching of the skin. One study of people exposed to low levels of chloroform in their drinking water showed a correlation between chloroform concentration and rectal and bladder cancer. In fact, an international health agency classifies chloroform as a carcinogen for humans.

Other studies, especially from Europe, document the effect of tri-chloro-nitrate (TCN) on swimmers. They conclude that this DBP is related to reactive airway disease or asthma in people who swim frequently. Another study shows that DBPs are associated with changes in DNA in urinary bladder cells that correlate with an increased risk of cancer.

To summarize, DBPs not only smell bad, they irritate your skin, eyes and lungs; cause central nervous system changes such as dizziness and headaches; cause fatigue; and with prolonged exposure are potential carcinogens

How Do DBPs Affect Swimming Performance?

Any athletic performance is determined by muscle contraction. Muscle contraction is an energy consuming activity that is related to oxygenation of the blood and blood flow to and from the contracting muscle. Oxygen is used along with blood delivered nutrients to produce energy so the muscle cells can contract and propel the swimmer through the water. Oxygen is delivered to the blood through the lungs as we breathe. Oxygen is then carried by our red blood cells to all tissues in our body including muscles, by blood flow. Blood flow depends on our heart to pump the blood and arteries to carry that blood to our exercising muscles.

At rest, our muscles require very little blood flow and oxygen. As we start to exercise and use our muscles to propel us through the water, they consume all the oxygen and nutrients in the area, then tell their arteries to dilate and send more blood. That causes our hearts to beat faster to supply more blood for the dilated arteries and that eventually causes us to breathe faster to deliver more oxygen to our lungs. A big part of athletic training, is to maximize this energy transport system from air to muscles. The more we exercise, the better the system works. The better the system works, the more we can exercise.

DBPs affect performance in a number of ways. First, the air just above the water is what a swimmer inhales during swimming. That air has the highest concentration of DBPs. The amount of oxygen in air follows the rules of physics. The higher the concentration of DBPs, the fewer oxygen atoms in the same amount of air. So the swimmer in a pool with high DBPs needs to move more air in and out of their lungs to remove the same amount of oxygen as a swimmer in a pool with lower DBPs.

DBPs like tri-chloro-nitrate cause lung irritation and narrowing of the tubes that bring air into our lungs. Because of the narrowing, less oxygen gets to the microscopic areas of our lungs where the delivery of oxygen to the blood occurs. Therefore, we need to move more air to extract enough oxygen for our exercising muscles. One result of this lung irritation is the use of drugs, called bronchodilators, that open up the airways and others, that control the inflammation caused by the irritating DBP's. This asthma is a significant problem in many competitive swimmers.

Like most diseases, some people are more sensitive to DBPs than others. Those swimmers who are sensitive to DBPs have to work harder to provide adequate energy for their contracting muscles than those who are less sensitive to DBPs irritation.

Performance and conditioning is all about maximising oxygen extraction from the air, blood flow to the muscles, and removal of waste products from the exercising muscle. DBPs play a significant role in oxygen concentration in the air; delivery of air to the blood, and pumping of blood to the muscles. Along with the other health effects of chronic exposure to DBPs and the uncomfortable irritation they cause, swimmers should do everything possible to minimise the concentration of DBPs in their pools.

CWS CLEAR WATER SUPPLIES

What Can Swimmers Do?

Since urea is one source of nitrogen containing bio-molecules that form DBP's, swimmers can reduce their formation by not urinating in the pool. Sweat is another source of urea that cannot be easily controlled since training causes increased sweating. I've talked to many competitive swimmers who tell me they don't want to stop their training to go to the bathroom to urinate or that their coaches won't let them take a break. Changing this would help create a more healthful environment for every swimmer, coach, lifeguard, and spectator.

What Can Facilities Do?

Ventilation

To understand the role of ventilation in this problem, we need to remember that DBP's are at their highest concentration on the surface of the water. This is the boundary layer where there is little air movement. Traditional ventilation brings outside air inside, warms it up or cools it off depending on the temperature, and then moves it through the building, eventually pushing the air back outside. This is a very expensive process. Moving more air from the outside and through the entire space of the natatorium doesn't address the area of the pool where DBP's are in their highest concentration. Increasing the air movement at the surface of the pool does result in a decrease in the concentration of DBP's. Paddock Pools' Evacuator System achieves this by a system that sucks the air across the boundary layer and moves it outside.

Water Treatment

Water disinfection and formation of DBPs is a classic "rock and a hard place" situation. Chlorine and bromine are very effective and efficient killers of swimming (planktonic) bacteria and algae. They accomplish this through their chemistry. They are very reactive with other atoms and molecules. This reactivity punches holes in the cell wall of bacteria and algae but also reacts with nitrogen containing compounds to form DBPs in the water and air. It is the main way we control bacterial growth in most water systems. Even treatment systems, such as salt pools, control bacterial growth with chlorine. You don't have to add the chemical, a reactor in the pool creates bio-reactive chlorine from the chloride ion in common salt.

When we started treating commercial pool water with the PoolNaturally® Plus system we found that the air quality in the pool area improved in a couple of days and the air in the entire facility was significantly improved after a week of treatment. Over time our customers starting saying that the only way you know there is a pool in the building is to see the water. Swimmers, coaches, lifeguards, and pool patrons all reported less eye, skin, hair, and lung irritation. After a swim meet in one of our pools, many swimming teams demanded that their facility add the PoolNaturally® Plus system.

To measure the effect of the PoolNaturally® Plus system on DBP concentration, we did a study with a fitness club to measure the THM in the air above the pool surface and the water in their two 400,000 gallon indoor pools. We measured levels weekly, for two weeks before the PoolNaturally® Plus system was introduced and then every week for 24 weeks. They have a high bather load and use chlorine for disinfectant. We measured a steep decline of THM in the water resulting in an 85% reduction in 24 weeks. In the air above the pool the THM concentration was decreased by 55%. The air quality improved just like in our other indoor facilities.

How Does The PoolNaturally® Plus System Affect DBP Production?

The quick answer is we don't know. We do have a hypothesis. The PoolNaturally® Plus system is made from Sphagnum Moss leaves. In our laboratory, over the past 8 years, we have shown that the PoolNaturally® Plus system inhibits organic contamination formation. Organic contamination is a slime like substance that adheres to the pool or filter surface. We think, the unique environment inside the organic contamination helps convert urea from urine and sweat into DBPs. We postulate that inhibiting organic contamination reduces the production of DBP. The product could also have a direct effect on the DBP produced in the pool. We know the concentration is significantly decreased. We don't quite yet know how.

The PoolNaturally® Plus System and Swimming Performance

We know competitive swimmers like training in water conditioned with the PoolNaturally® Plus system. We know that swimmers with asthma report that they don't use their inhalers when they swim in outdoor or indoor pools where water is treated with the PoolNaturally® Plus system. We also know that lifeguards and aquatic professionals report fewer respiratory problems working around pools with the PoolNaturally® Plus system. We don't know if their training and eventual performance is improved, and it will take time and study to know if the reactive airway disease, DNA changes and other health effects of DBP's are improved.

Summary

Use of chlorine and bromine as disinfectants in pools produces Degradation By Products that have significant health and performance effects.

DBP's, such as chloroform (tri-halo-nitrate) irritate people's eyes, skin, lungs, and central nervous system.

Pool water conditioned with the PoolNaturally® Plus system reduces the "chlorine smell" in treated pools and resulted in an 85% decrease in THM in commercial pool water and 55% reduction in natatorium air.

Patrons of pools treated with the PoolNaturally® Plus system report significantly less eye, skin and lung irritation.

For technical support please contact **Clear Water Supplies International Limited** or visit **www.CWSNaturally.co.uk**