VEXATION OVER VENTILATION

INADEQUATE VENTILATION CAN LEAD TO SERIOUS POOL AIR POLLUTION, WRITES POOL CONSULTANT ALAN LEWIS

WORDS: ALAN LEWIS, AQUAZURE POOL CONSULTANCY

A beautiful and inspiring setting has been built for the Olympic aquatic events in London. Australia has yet again witnessed some heroic achievements in these competitions. It is not without good reason that swimming and other recreational aquatic activities are favoured in our country. This popularity began after the inclusion of swimming as an Olympic sport as far back as the 1896 Olympic Games. The past century has seen the pool industry flourish here, with backyard pools springing up everywhere, and civic and privately owned aquatic centres being built in even the remotest of country towns. The prowess of our Olympic swimmers is celebrated across the nation. They are admired and feted wherever they go, particularly when it is well known that many of our stars suffer from asthma.

Take for example the story of '*l'enfant terrible*' Neil Brooks. Born in 1962 in the UK, he migrated with his parents to Western Australia at the age of four. Neil's greatest achievement was bringing home the gold for Australia in the 4 × 100m medley relay at the Moscow Olympics in 1980, overtaking the Soviet champion Sergey Kopliakov during the anchor leg of that relay event. This was even more spectacular because he had had the unpleasant experience of suffering an asthma attack that caused him to miss the 100m freestyle event altogether.

Today, it is an open secret that most of our Olympic swimming teams are dependent on Ventolin puffers, which classes them as asthmatics. This is also true of the US team. Why is there a connection between competitive swimming and asthma? Is it because swimmers are advised to take up the sport at a young age to develop stronger lungs and 'overcome' the problem? Or is it because competitive swimmers, training long hours in public FINA-standard pools, actually develop this lung disorder while swimming in chlorinated pools?

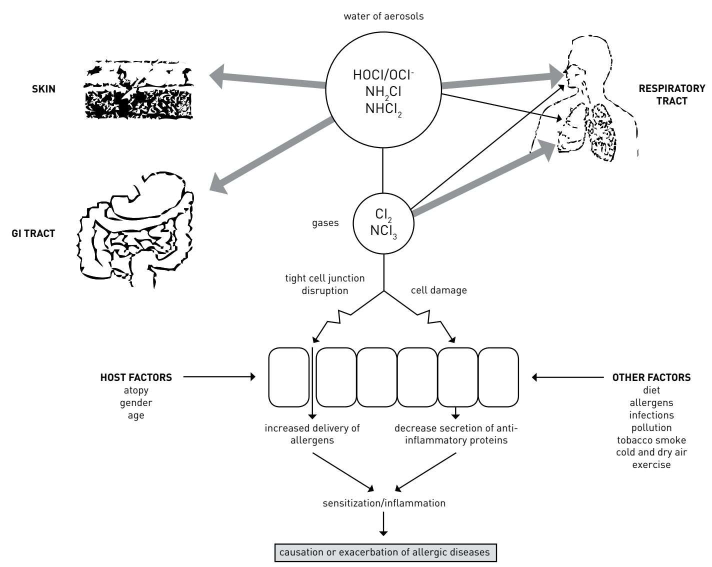
THE CHLORINE VERSUS THE HYGIENE HYPOTHESIS

Professor Alfred Bernard, toxicologist and research director of the National Fund for Scientific Research in Belgium, has been pursuing this issue for more than a decade and has produced more than 300 peer-reviewed articles and publications. Bernard's hypothesis stems from the observation that the most chronic childhood disease in most industrialised countries is asthma.

Notably, the UK, Ireland, Australia and New Zealand have asthma rates in early childhood 10 times that of southern and eastern countries. This hypothesis suggests there must be something in our lifestyle or environment that drives the marked increase of asthma among children between the ages of six and 14 years since the 1960s, compared to countries such as rural China, Gambia and Ethiopia. Despite the many opponents of this hypothesis, scientific research continues to discover, year by year, new aspects of swimming pool chlorination that expand and confirm our understanding of why disinfection by-products (DBPs) of chlorination might be the primary source of this phenomenon.

Yet more recent evidence comes from Canada: "The prevalence of respiratory symptoms and airway hyper-responsiveness (AHR) is high in elite athletes; swimmers have one of the highest prevalences."[1]

Swimmers in the western world are actually exposed to higher concentrations of chlorine in public pools than in some parts of central Europe, where there are moves towards changing standards and reducing both the pH levels and the chlorine residuals to far lower than those specified in Australian and US standards. Denmark has distinguished itself in both funding proven research into this very matter and supporting and building research-based ideas, particularly in its school pools.



Scheme illustrating how chlorine-based oxidants in water or air can disrupt the epithelial barriers of exposed organs and thereby facilitate the penetration of allergens and the allergic sensitisation[2].

Snatching a breath. Photo: iStock.

SOURCES OF IRRITANTS

Research over the past decade has shown that swimmers are affected in several ways.

First, nitrogen trichloride, otherwise known as trichloramine, which can easily be recognised as the "chlorine smell" in a pool hall, develops from mono-chloramine, which forms immediately a swimmer jumps in to make contact with the free chlorine in the water:

- Free chlorine plus body amines produces monochloramines.
- Free chlorine plus monochloramines produces dichloramines.
- Free chlorine plus dichloramines produces trichloramines.

All three forms of chloramines are continually evolving in a busy public pool.

Second, they absorb chlorine through the pores of the skin into the bloodstream in the form of nitrogen trichloride and chloroform, which over years can lead to cancer of the bladder.[3]

Third, the direct contact between the skin and free chlorine creates chloroform. Skin cells continue to react with free chlorine when they are trapped in a pool filter and/or have fallen to the floor of the pool and are simply lying in "dead" areas of a poorly designed pool circulation system.

- Free chlorine plus human skin produces tri-chloromethane or chloroform plus some other less prevalent trihalomethanes.

It has been proved conclusively that UV photolysis neither destroys nor creates chloroform.[4]

Fourth, both chloroform and nitrogen trichloride are volatile and can easily transform to gases at the surface of the pool. This is helped along by swimmers splashing down the lanes, by air jets in spas and by water sprays or mushroom showers in water parks. These noxious gases are heavier than air and will simply gravitate to the lowest areas of the pool hall or lower areas adjacent to an outdoor pool. In many cases, pools have been designed with an overflow gutter positioned lower than the pool deck, and these gases are simply trapped in this recess immediately above the pool surface.

Finally, other disinfection by-products that have been found in the pool water and air are haloacetic acids, haloketones, trichloroaldehydes, trichloronitr, methane and cyanogen chloride. These are usually found in quantities too small to influence one way or the other the impact of trichloramines in the air.[5]

Testing methods over this period of research differed markedly but currently standard methods of testing are progressing and will lead to more accurate and consistent results.

In pool halls with poor air quality these noxious gases further gravitate to the lowest point in the building or, in the case of outdoor pools, the lowest point in the surroundings of the pool. Thus, for example, the chloramines can be smelt even in a pool car park that is positioned below the surface of the pool. If the pool is in a building several storeys high, the chloramines often find their way to the lift shaft and gravitate to lower floors with surprising ease. It is ignorance of this phenomenon that leads directly to the exacerbation of asthma, bronchiolitis, and eye, nose and throat irritations in swimmers, pool staff, lifeguards, swim teachers, children learning to swim, and in patrons caring for children or watching competitions.

Beyond that, poor ventilation in indoor chlorinated pool halls can lead to corrosion, even collapse, of exposed metal structural elements in the hall and/or equipment in the plant room.

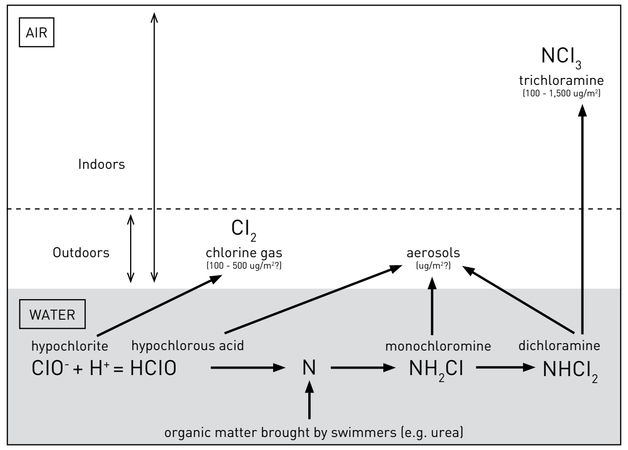
We now know that when a swimmer is immersed in a chlorinated pool, access to oxygen is complicated by the fact that the air immediately above the surface is often so contaminated with volatile disinfectant by-products that it hampers healthy functioning of the lungs' epithelium, leading to frequent respiratory illnesses — see figure opposite.

WHAT ARE THEY **BREATHING?**

Pure air is mainly nitrogen, about one-fifth oxygen and small amounts of water vapour, argon, carbon dioxide, neon, helium and hydrogen. We take it for granted because it is everywhere. It is free and invisible. No wonder then that champion competitive swimmers can suffer serious difficulties if, when they gasp for the six or seven breaths they take as they power down the lane, they are clearly not inhaling "fresh" air but rather air heavily dosed with noxious gases.

In a 2007 study "Trichloramine concentrations were found to be greater in leisure pools ... than in public pools ..."[6]

The diagram to the right illustrates the development of the gas phase nitrogen trichloride and chloroform. Because chloroform is hard to measure — being of relatively low concentration — it is usually masked by the trichloramine gases, which are more pervasive. The wide range of the residuals shown in this diagram is an indication of how bad the air can get.



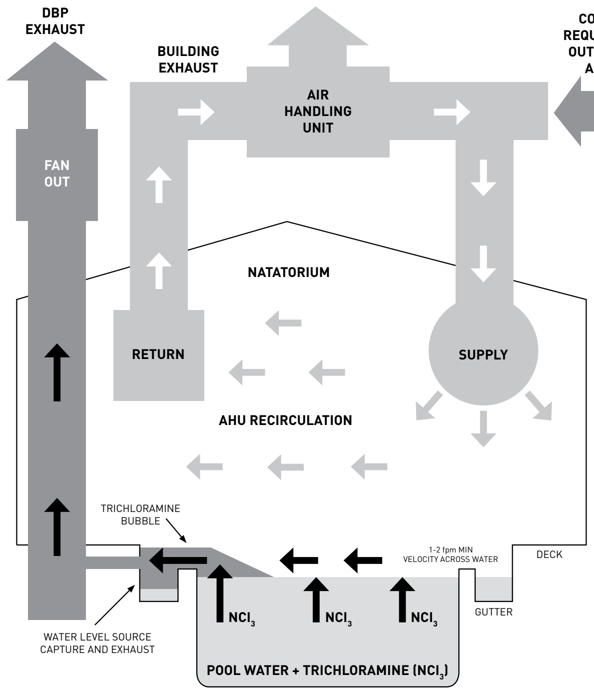
Major chlorine-based oxidants present in the water and the air of indoor or outdoor chlorinated swimming pools.[6]

WHY DO THESE GASES STILL IRRITATE US IN MOST AQUATIC CENTRES?

Air circulation in a public pool hall may well have been designed to Australian Standards,[7] but this will give the pool manager little cause for complacency, when the malodorous pollution from the pool hall permeates the air throughout the building. Why is this so?

Ventilation engineers have, until recently, all followed the minimum dictates of the relevant national standards and guidelines for the required air changes in buildings. Since these unwanted gases are in the lowest areas, the conventional methods of ventilation have overlooked the need to extract the air from the lowest areas in the pool complex.

It can be assumed that the vast majority of indoor pools actually continue to this day to cause severe discomfort to teachers and staff, competitive swimmers and tots and young children learning to swim. The existing Australian Standards do not treat pool halls as spaces that contain noxious gases, but rather as any other normal hall frequented by people who are breathing out carbon dioxide normally, as in, say, a picture theatre.



Schematic diagram of source capture and exhaust over an existing air handling system (provided by Paddock Evacuator South Carolina).

In such circumstances all that needs to be done is to introduce fresh air at the same rate as the carbon dioxide is created.

Since most indoor commercial pools have not been designed to extract the toxic gases satisfactorily, it is important that we examine the various ways in which we can retrofit air ducts that actually focus primarily on this objective.

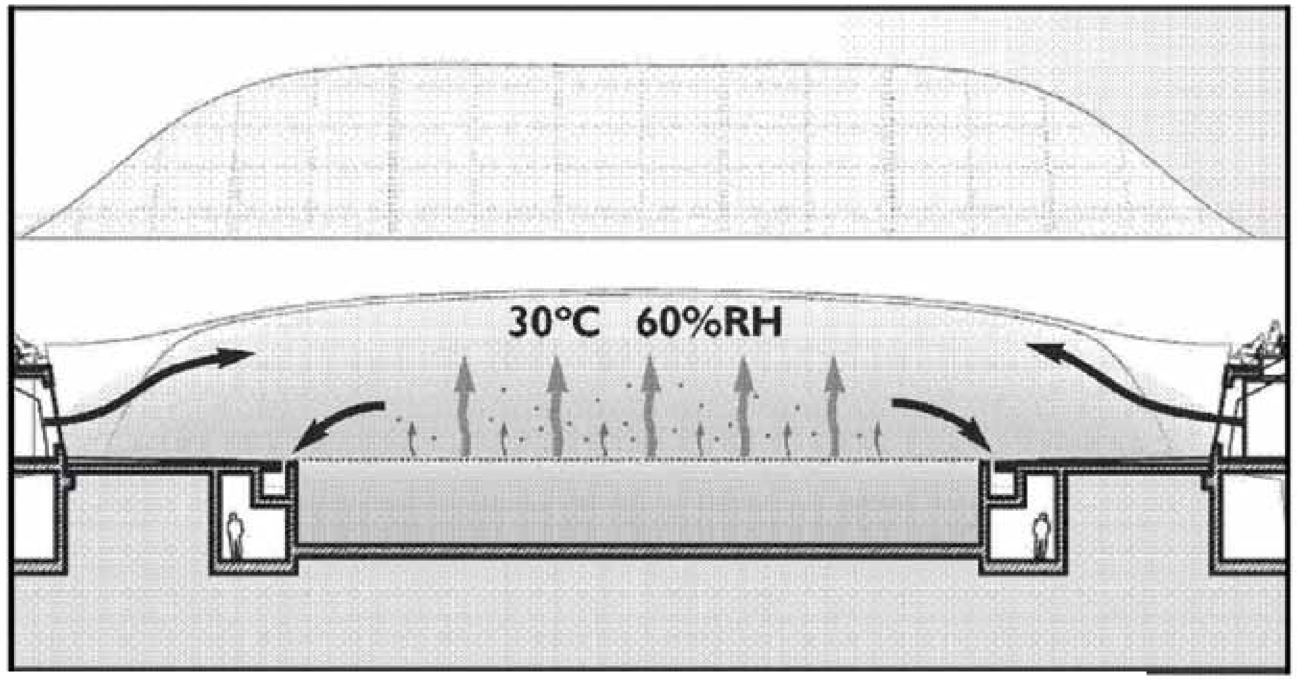
SOURCE CAPTURE AND EXTRACTION OF BAD AIR

There are three basic options.

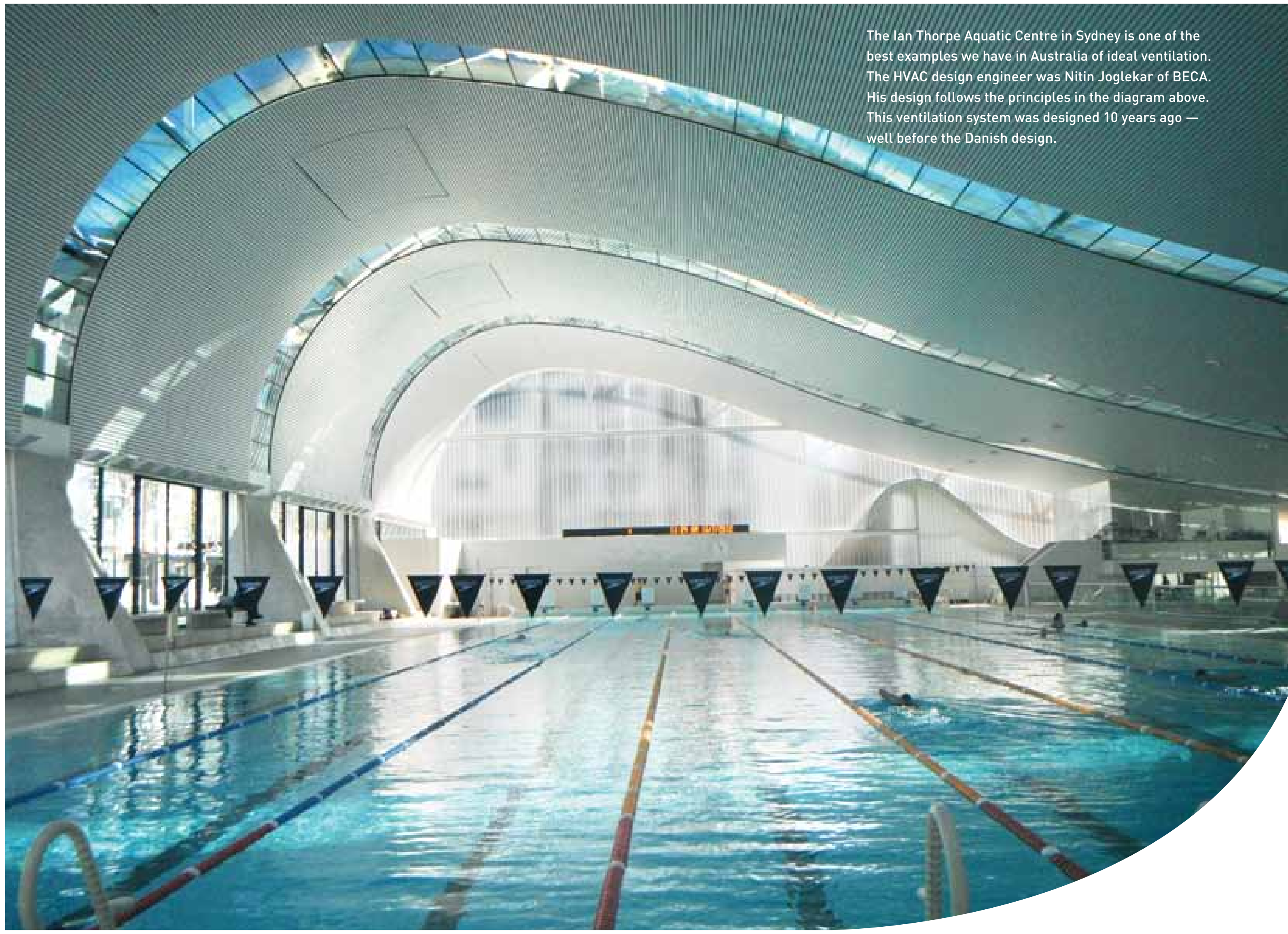
First, capture the air above the water in the gutter where more gases are formed as the water splashes through the grille. This extraction should be combined with the collection of the air that is displaced in the balance tank. From there it is exhausted to the outer atmosphere.

Second, at the building perimeter a duct can be run along the base of the walls where they are built close to the pool edge. In this case the duct is slightly above the lowest point (the surface of the pool) but nevertheless gets dragged over the deck between the gutter and the pool edge.

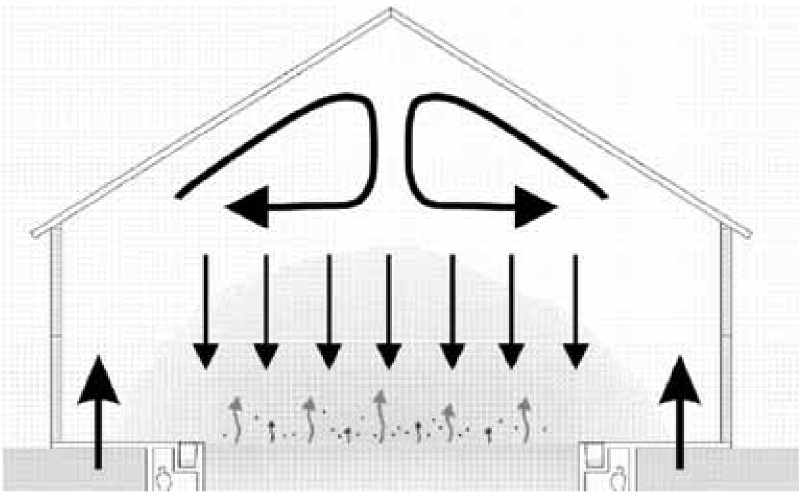
Finally, the air can be vented under the deck. This usually entails the raising of the deck high enough to accommodate a duct beneath it so that the intake is again immediately above the surface of the pool.



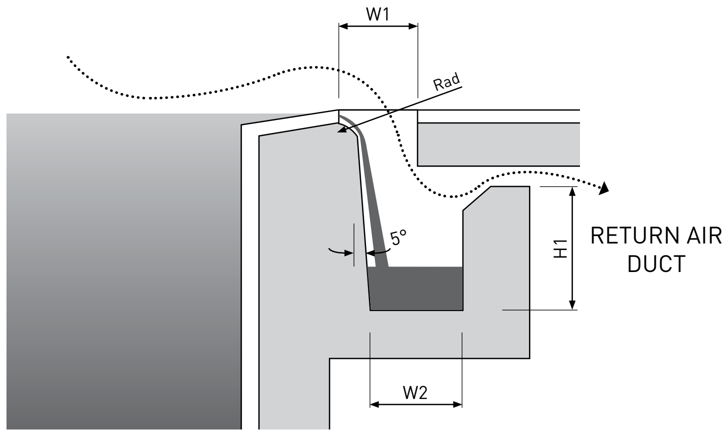
Schematic integration of heat, comfort (relative humidity), and toxic gas removal. Ole Gronborg, Ultraaqua design.



The Ian Thorpe Aquatic Centre in Sydney is one of the best examples we have in Australia of ideal ventilation. The HVAC design engineer was Nitin Joglekar of BECA. His design follows the principles in the diagram above. This ventilation system was designed 10 years ago — well before the Danish design.



Pool hall air needs to be forced down (not up) from the ceiling so that noxious gases can be extracted at the lowest level — Ultraaqua schematic.



Schematic detail of wet-edge gutter provided by Ole Gronborg of Ultraaqua.

DILUTION OF POOL HALL AIR

Another solution is the conventional introduction of outside air to replace extracted air, but combined with source capture and exhaust as a retrofit that utilises or extends an existing system, as demonstrated in the diagram on the previous page. The fresh supply forces the air from one side to the other, taking with it the trichloramine or trihalomethane (THM) "bubble" on the surface of the pool.

Ian Thorpe Aquatic Centre pool filtration room.

STRATEGIES FOR IMPROVING INDOOR AIR QUALITY

How can we remove or reduce the precursor contaminants from the circulation of the pool? Here are several solutions.

- We can insist on a compulsory pre-immersion shower by all bathers. This removes 80–90 per cent of urea, sweat, and body amines, which contribute to the immediate build up of monochloramines when bathers first dive into the pool.
- Secondary disinfection sytems including UV, ozone and electrolysis all help remove chloramines. UV is effective in reducing chloramines but not chloroform. Much of the chemistry in this application is as yet undefined and controversy still exists regarding the specifications and sizing of any such unit.
- Ozone applications need to be carefully thought out and detailed to avoid breakdowns. The materials selected in ozonated systems must all be of the highest quality and totally ozone-resistant. Ozone sizing should not be excessive since it is dealing with relatively small residuals that need to be broken down. Ozone does oxidise skin cells captured in the filter media or residing in poorly circulated parts of the pool, and so it has a slight advantage over UV. Modern ozone applications use cold plasma fields for the creation of low levels of ozone, that breaks down the monochloramines.

Chloramine stripper.

The Ecoline electrolytic system, developed by Australian Innovative Systems, not only does away with the need for chlorine feed, but creates free oxidants from tap water with a low total dissolved solids (TDS) rating of 500mg per litre. No added salt is needed. This process also breaks down the monochloramines as well, in a single process. As yet we have not been able to quantify this part of the system. Clearly the application of an Ecoline system to a public pool — indoor or outdoor — will reduce the chloramines by virtue of the very low levels of hypochlorous acid created. We do know that the need for UV or ozone will be markedly reduced when the Ecoline unit is working well.

Another option is reducing the chlorine feed. European countries already accept that good disinfection is not dependent on high levels of free chlorine in the pool but also on very low pH levels. Many countries already allow pH in the range 6.8–7.4 and free chlorine levels at 04–0.8mg/l. Nearly always, they advocate the use of disinfection systems, and in Australia several states are now accepting that oxygen-reduction potential (ORP or Redox) levels of no

Section of typical natatorium

less than 740mV are sufficient. This allows lower free chlorine residuals.

Pool circulation should be designed so that skin cells are rapidly swept from the floor out of the pool via the wet-edge gutters. The Danes have now shown that by placing the return spigots near the bottom of the walls of the pool, the water jet will sweep the skin cells on the floor towards the centre of the pool and up to the surface at the centre and back along the surface to the wet-edge gutters.

Replace media (sand or DE) filters, which retain the skin cells for many days at a time until backwashed, with drum filters with automatic back rinsing at regular intervals every few hours. The Hytech filter is designed with a fine membrane that filters out all suspended solids up to 10 microns. The membrane is automatically cleaned as soon and as often as it is clogged with the suspended matter.

Another solution is "stripping" trichloramines and THM in the plant room — see photo on previous page.

Finally, recycled heated pool hall air can be ozonated to destroy gaseous trichloramines and chloroform being carried in the ducts. This may need a side loop so that the products of the ozonation can be extracted from the pool hall circulation safely. In this operation the amount of fresh air introduced into the hall can be reduced because the treated air will no longer aggravate people in the hall. This method is still in the development stage and has not actually been applied yet. The concept is aimed at conserving the considerable expense of reheating the fresh air stream when the dilution is replacing all or most of the captured gases entirely.

MODEL AQUATIC HEALTH CODE

This Code is being prepared jointly by the Centre for Disease Control and Prevention (CDC) together with the National Swimming Pool Foundation (NSPF) in the USA. The first publication of this code module appeared for review on April 13, 2011.

The ventilation module contains requirements for new or modified construction that include:

- Increased make-up in addition to that required by the ASHRAE standard.[8]
- Determination of the extra make-up air needed, based on indoor venue water use type (such as flat water, agitated water or hot water) and venue or deck patron density.
- Inclusion in calculations of additional make-up air from surge tanks or gutters that source capture chloramines and exhaust them to the external air.
- Development and implementation of plans to reduce combined chlorine compounds in indoor aquatic facilities and inform facility patrons of their impact on building air quality.

The Standard then defines these four principles in great detail and provides factors for both different types of water and different types of occupancy on the deck or stadium seating. If a facility has more than one venue the additional air is calculated individually for each venue. Additional consideration must be given to ventilation in mechanical rooms, locker rooms, showers and toilets and other ancillary rooms used by staff or patrons.[9]

THE VEXATION MUST COME TO AN END

We can only hope that FINA and other relevant bodies are taking steps to prevent recurrences of the respiratory illnesses that our swimmers will inevitably experience if nothing is done to improve the indoor air quality of the competition venues.

The question is, what is your aquatic centre/venue doing about improving the removal of toxic gases from your venue in general and the pool hall in particular?

It is hoped, too, that Standards Australia will soon introduce a new standard for the improvement of air quality in public pool halls.

The time has come to efficiently and enthusiastically take up the challenge of ensuring that aquatic venues across Australia right the inappropriate systems that have been installed in the past. This is an occupational health and safety issue in need of urgent attention.

FOR MORE INFORMATION

Alan Lewis
AQUAZURE POOL CONSULTANCY
Email: aquazure34@gmail.com

NOTES

1. Bougalt, Loubaki, Joubert et al. 2012, Research Institute of Cardiology and Pneumology in Quebec, Canada.
2. Bernard 2007 (*Current Medicinal Chemistry*) issue 14; 1689–1699.
3. Vilanueva et al. 2006; Costet et al 2011.
4. Blatchley et al. 2011 proved conclusively that UV photolysis neither destroys nor creates chloroform; after Cassan et al 2005 in Montpellier showed a coincidental correlation between an increase in chloroform and a decrease in chloramines in a four-week study in the university pool, which Blatchley (in Purdue) repeated using different testing methods.
5. Hery et al. 1995 found concentrations of 0.05–1.94mg/m^3 in 13 swimming pools tested; Massin 1998 found 0.24–0.67mg/m^3 in 46 swimming pools and 17 leisure pools. Jacobs 2007 studied 38 indoor pools and found an average of 0.56mg/m^3 with a maximum of 1.34mg/m^3.
6. Bernard 2007 study found that "Trichloramine concentrations were found to be greater in leisure pools (mean 670µg/m^3, SD, 170µg/m^3) than in public pools (mean 240µg/m^3; SD, 370µg/m^3). (SD= Standard Deviation — a statistical indication of the consistency of the result)" Denmark wants to set a limit of 20µg/m^3. AS1668.2–2002. The use of mechanical ventilation and airconditioning in buildings: ventilation design for indoor air contaminant control.
7. ASHRAE (American Society of Heating, Refrigeration and Air-Conditioning Engineers) Standard 62, Ventilation for Acceptable Indoor Air Quality and/or applicable local codes with additional requirements as stated in section 4.6.2.1.7.
8. More details of this code module can be found at cdc.gov/healthywater/pdf/swimming/pools/mahc/structure-content/mahc-module-4.6.2-5.6.2-ventilation-code.pdf