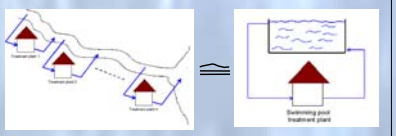
Water disinfection by means of ozone in the olympic swimming pool of the Autonomous University of Barcelona

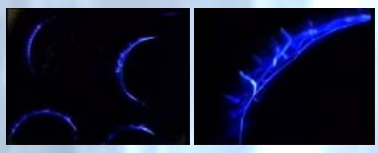
BARTROLÍ, J.[a]; GOMÀ, A.[b]
[a]Grup de Sensors I Biosensors. Departament de Química. Jordi.Bartroli@uab.es - [b]Servei d'Activitat Física (SAF). Anton.Goma@uab.es

The fact and the problem

Chlorine is the most used halogen to disinfect tap water and sewage and it has played an historical role preventing many human diseases. 5% of total chlorine produced in the world is used to those applications.
Volume of recreational-water is growing throughout the world, and it is estimated to be about 870 Hm^3 in 2001*(Arbonés X.2002)*. that means, per year, about 5.540.000 Tn equivalent of commercial NaClO, 740.000 Tn equivalent of commercial HCl used as pH regulator and 1.206 Hm^3 of water used to renovate the total volume of swimming pools and similar.
Since seventies it is being studied toxic effects of even low level exposure to some chlorine by-products, mainly those which appear as reaction with organic material contained in water and what are assimilated by drinking. Nowadays it is known that such toxic effects can be enhanced when these contaminants are assimilated by inhalation or, even more, across skin (*Zwick H. 1990, Freixa A. 1994, Jo, Wan K. 1994*). Besides, in a swimming pool part of chlorine compounds forms also chlorine gas which is evaporated through water surface and which will be inhaled by the users and/or just released to atmosphere. Waste water coming from a leisure pool and poured out back to river will contain too much organochlorine by-products and chlorides to be efficaciously purified again.
Therefore, these chlorine and water consumptions, in spite of meaning just small sectorial ones, involve outstanding enough health and environmental impacts to consider their reduction.

One of the interests of the project bases on the fact that treating water in a swimming pool, which is mostly always the same, means a kind of scale-pilot of the consecutive treatments suffered by water in a river. Some by-products of the process, like bromates, can show worrying amplifications.





Ozone is produced locally at plant by means of high voltage corona discharges across ultra-dried air, that flows around glass tubes which lay distributed along a reactor.

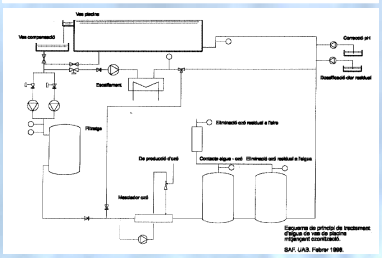
What is ozone

Ozone is a strong non-residual disinfectant, superior to chlorine, chlorine dioxide, chloramines or Ultraviolet light (UV), which is able to destroy bacteria and to inactivate virus and water-borne pathogens, such as *Cryptosporidium* oocysts or *Giardia*.
Samoilovich, V. G. in 2000 proved swimming pool water disinfection effectiveness of 99.999% at 25°C at ozone 0.3-0.4 mg/l and contact time of 2 minutes.

An alternative: the ozonation. State of art

How does it work

Water is continuously withdrawn from swimming pool and pumped to filtration. Afterwards ozone is added through a Venturi allowing a contact in tanks of 4 min. Once disinfected, activated charcoal eliminates possible ozone remains from water before being slightly chlorinated, as residual disinfectant, and driven back into the basin.



Main features

- Ozone is normally used together with a residual disinfectant, such as a combination of hypochlorous acid and hypochlorite, bromine, chlorocyanurates or chlorine dioxide.
- Ozone remains after disinfection in the contact vessel need to be destroyed with activated charcoal, UV or thermal methods.
- Disinfection by-products (DBP) such as those halogenated are known to be less hazardous in an ozone treatment than in a chlorine one (*Richardson, S. D. 2000, Hu, J. Y 2002*). Anyway formation of bromate, aldehydes, ketones, ketoacids, carboxylic acids or bromoform must be controlled.
- Monitoring of free ozone in water involves in-line or on-line sensors to control the reactor ozone production. Availability and reliability of such sensors are still far away from being optimal.
- Ozone production and addition efficiency depends on many parameters. That leads to find so many solutions as ozone systems manufacturers exist.
- 25 KWh produce about 1 Kg ozone. 85% of that electrical energy becomes heat, what is recoverable in a swimming pool.

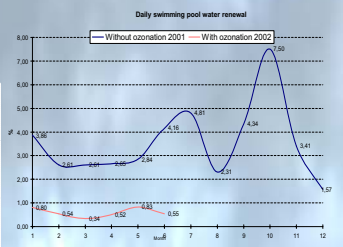
The experience in the Autonomous University of Barcelona, UAB

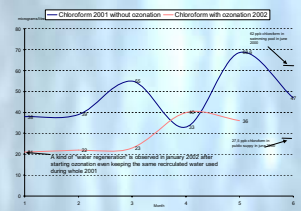
Main goals

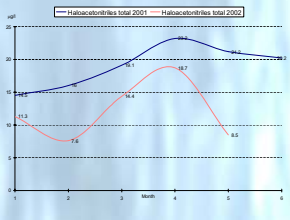
1) Comparison of presence of main chlorine DBP in water without ozonation (first semester 2001) and with ozonation (first semester 2002).
2) To set up a lower volume of daily renovated water keeping swimming pool quality conditions (microbiology and chemical).

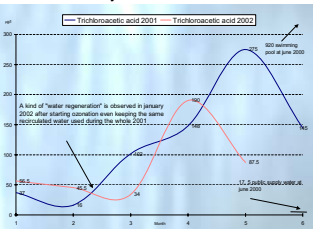
Study conditions

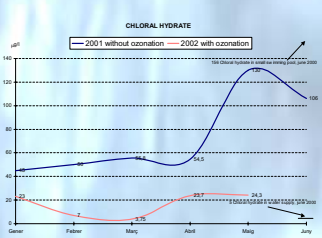
- Two indoor swimming pools, one of 850 m^3 at 27ºC, water recirculated every 4 hours, and another one of 150 m^3 at 30ºC, water recirculated every 2 hours. Most of analysis were done in the most unfavourable, the smallest one.
- Swimming pool water was changed at December 30th, 2000 and kept since that moment to June 2002 (daily renovation aside).
- Both analysis series where made in same months, January to June 2001 and 2002, in order to have similar seasonal conditions.
- 100% flowing water is ozonated to a concentration of 0,4 ppm during a contact time of 4 minutes.
- THM and Haloacetonitriles were analysed by means of Head-Space and Gas chromatography (ECD) (MA/QO-07), HAA by EPA 552.2 (MA/QO-10) method, Chloral hydrate by EPA 551.1 and bromates (only during 2002) by MA/Q-103.
- At the end of march, April and beginning of may 2002 results were affected by facility commissioning shortcomings which broke normal ozone production and reduced time of water treatment by that mean. Results of June 2002 are not available yet.







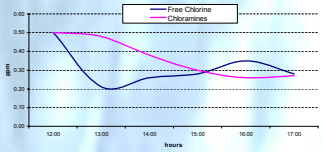




Results

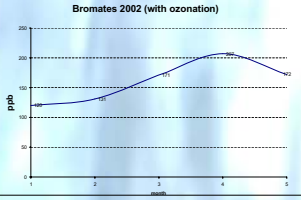
- ✓ Till the present moment they must be considered just as preliminary results, since plant operation has not been steady enough and mean operation time can be considered of 2 hours working per day. Anyway an important reduction of organic chlorine compounds has been observed already as shown in graphics above. Increase of studied DBPs during operation breaks show, in fact, how sensitive are their concentrations to ozone treatment. Chloramines compounds reduction of 50% is already observed even after just few hours ozonating.
- ✓ Even when treatment time was lower to desired, a kind of regeneration of water was observed in January, after starting ozonating without having changed water.
- ✓ Before ozonating Cl_2 gas in ambient air (2 m from water surface) was found in a mean value of 0.44 ppm. When ozonating concentrations were of 0.32 ppm. At that distance, chloroform was found to be in both cases < 0.9 ppm.
- ✓ Daily swimming pool water renewal could be cut down to less than a 25% keeping, in fact improving, sanitary conditions.

Swimming pool chloramines (NH^2Cl, $NHCl^2$) and free chlorine (ClO^-, HClO) contents trend. Period: first 6 hours ozonating after 15 days stopped.



Recommendations and outlook

- ➢ Bromates graphic shows a kind of amplification of this by-product, which is formed even when original water contains low bromide index. WHO drinking-water guideline (2000) advises to ingest less than 1 microgram/Kg.day. Therefore, even when it would be difficult to assimilate that amount in a swimming pool, generation of this ozone DBP must be limited. Although some studies (T. Gillogly, 2001) propose ammonia addition or pH depression, these options are not possible in a swimming pool and current efforts in UAB aim to find an ozone contact concentration able to disinfect and to destroy THMs and other chlorine DBPs but, at the same time, small enough to not generate bromates.
- ➢ Powdered carbon activated not only destroys ozone remainders in water after contact but also free chlorine that was added as residual disinfectant. That means an extra consumption of chlorine that was not at all desired at the beginning of the project. An engineering solution is going to be tested by-passing carbon filters when no residual ozone is left after contact, what happens most of time.
- ➢ Global amounts of water and chlorinated disinfectant products given at the beginning of this poster can be used as a basis when calculating the environmental impact of recreational water, what would give an idea of how sustainable a swimming pool is.



Background picture: Ozonated air-bubbles flowing up throughout recirculating water

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