



## **PUBLICATION OF THE SUPERIOR HEALTH COUNCIL No. 8748**

### **The issue of chlorine in swimming pools: risk attendant on baby swimming and reflections on the different methods used to disinfect swimming pools**

In this scientific advisory report to policy makers, the Superior Health Council reflects on chlorine and alternative methods for swimming pool disinfection and infection control and, in doing so, focuses on the particular target group of young infants (0-12 month-old baby swimmers). It also offers specific recommendations on hygiene, quality control, Belgian and European Union legislation and on harmonising international research.

01 February 2012

## **1. INTRODUCTION**

On 14 April 2011, the Superior Health Council (SHC) received a request for advice from Minister Laurette Onkelinx. Following the publication of the advisory report on “the issue of chlorine in swimming pools” (SHC 8614, 2011), the Minister requested an additional and specific advisory report on the issue of baby swimming and the different methods used to disinfect swimming pools.

Thus, advisory report No. 8614 on the issue of chlorine in swimming pools mainly focussed on (1) the appearance of asthma in (2) children visiting (3) chlorinated pools.

Yet, this new report goes beyond the issue of asthma to include other complaints in its analysis. In doing so, it concentrates on baby swimmers in particular and looks at alternatives to chlorinated pools. This advisory report is therefore intended as an addition to the previous report.

In order to be able to respond to the Minister’s request, an *ad hoc* working group was set up which consisted of national and international experts in the following fields: microbiology, genotoxicity, swimming pool disinfection, paediatric pneumology, toxicity in children, epidemiology, etc.

## **2. CONCLUSIONS**

1. The SHC does not encourage baby swimming (age 0-12 months) in environments such as those that currently prevail in Belgian swimming pools. Although this activity offers a comprehensive form of physical exercise and provides a number of potential psychological benefits in terms of the relationship between the baby and its parents, one should consider that:
  - There are no real benefits in visiting swimming pools for infants this age, as inter-limb coordination is not acquired before the age of 3-4.
  - Babies are a particularly vulnerable population group (more prone to infections, hyperreactive mucous membranes, immature lungs, etc.).
  - The physical exercise and psychological benefits can probably also be obtained through other activities, such as taking a bath with the baby at home.

- Pools used for baby swimming exhibit relatively high water and air temperatures, which in turn results in significant humidity and increased micro-organism growth.
  - Baby swimming is often organised in privately owned pools for public use that are not systematically monitored or in which there are no systematic inspections.
2. The recommendations for older children (over the age of 1) issued by the SHC in its advisory report No. 8614 (see appendix 1) still hold: swimming remains highly advisable, even in the case of asthma. For this target group, the advantages of swimming under good hygienic conditions in monitored pools outweigh the risk of toxicity linked to chlorine and its by-products.
3. Health considerations make it imperative that swimming pools should be properly disinfected. The SHC takes the view that, at present, there is no evidence that alternatives to chlorine will provide an appropriate solution for the disinfection of swimming pools, and thus for protecting the population against the risk of infection attendant upon bathing in poorly disinfected pools. Indeed, anything that disinfects and therefore kills pathogens is potentially toxic to humans. However, it should be kept in mind that chlorine does not make the water sterile and that some organisms can resist chlorine disinfection. Chlorine is the best disinfectant currently available, provided that the following conditions are met to ensure that the level of exposure is low at all times:
- adequate hygiene measures are taken, including by the members of the public visiting the pool;
  - the pool is properly monitored;
  - the swimming pool hall is properly ventilated;
  - the water is filtered to remove chlorinated-organic compounds.

However, there is a potential risk of long-term effects and delayed appearance of serious diseases due to the genotoxic and potential endocrine disruptive properties of chlorinated organic by-products. There is no risk analysis available. It is therefore advisable for such an analysis to be carried out.

4. Both the quality of the air as well as that of the water should be monitored and inspections should be carried out. As regards the water quality, this should concern the microbiological<sup>1</sup> and physicochemical aspects of the water, as well as the presence of chlorinated organic by-products. As is the case for the water, the air needs to be renewed and/or filtered. Unfortunately, there are no regulations that govern ventilation requirements in Belgian swimming pools. Particular attention should be paid to privately owned pools for public use that are visited by small children, who inevitably produce more organic material.
5. At present, there are no standard regulations that apply to the whole of Belgium. Rather, they differ from one region to another. It therefore seems essential that these regulations should be harmonised and/or revised on the basis of norms or regulations that currently apply in other European countries, e.g. Germany and the United Kingdom (UK).
6. Organic material (sweat, urine, etc.) plays a very important part in the formation of toxic by-products that are responsible for the appearance of chlorine-related complaints. Bathers are therefore a potential source of contamination, which means that they can easily contribute towards reducing it by complying with a few basic rules, such as:
- not swimming when ill with diarrhoea;
  - avoiding swallowing pool water;
  - showering themselves and their children using soap and water before entering the pool;

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<sup>1</sup> There are no published data available on the extent of bacterial contamination in Belgian swimming pools. Yet water quality inspections are carried out for these pools.

- washing their hands with soap and water after using the toilets and changing children's nappies;
- changing nappies or taking children to the bathroom. In order to be able to do so, it is essential to provide the necessary facilities (properly equipped bathrooms).

7. For these reasons, there is a need to educate pool keepers and operators on pool maintenance and hygiene measures to be taken by swimmers to prevent both toxicity and the transmission of recreational water-borne diseases.

<b>Keywords</b>	<b>Mesh terms*</b>	<b>Sleutelwoorden</b>	<b>Mots clés</b>	<b>Stichworte</b>
Chlorine	Chlorine	Chloor	Chlore	Chlor
Swimming pool	Swimming pool	Zwembad	Piscine	Schwimmbad
Baby Baby swimming	Infant	Baby Babyzwemmen	Bébé Bébé nageur	Baby Babyschwimmen
Disinfection method infection control	disinfection method infection control method	ontsmettingsme- thode infectiebeheer- sing	méthode de désinfection maîtrise des infections	Desinfektions- methode Infektionsbe- herrschaft
Asthma	Asthma	Astma	Asthme	Asthma
Allergy	Hypersensitivity	Allergie	Allergie	Allergie
Infection	Infection	Infectie	Infection	Infektion
Cancer	Neoplasm	Kanker	Cancer	Krebs

\* MeSH (Medical Subject Headings) is the NLM controlled vocabulary thesaurus used for indexing articles for PubMed.

### 3. FURTHER DETAILS AND ARGUMENTATION

#### List of abbreviations

AFSSET	<i>Agence française de sécurité sanitaire de l'environnement et du travail</i>
AGW	<i>Arrêté du Gouvernement Wallon</i>
AGRBC	<i>Arrêté du Gouvernement de la Région Bruxelles-Capitale</i>
DCA	Dichloramine
DBP	Disinfection by-products
HAAs	Haloacetic acids
HANs	Haloacetonitriles
IARC	International Agency for Research on Cancer
NDBA	Nitrosodibutylamine
NDMA	<i>N</i> -nitrosodimethylamine
NPIP	<i>N</i> -nitrosopiperidine
PAC	Polyaluminium chloride
SHC	Superior Health Council
TCA	Trichloramine
THM	Trihalomethane
TOVO	<i>Toezicht Volksgezondheid</i>
UK	United Kingdom
UV	Ultraviolet
VLAREM	<i>Vlaams reglement betreffende de milieuvergunning</i>
WIV-ISP	<i>Wetenschappelijk Instituut Volksgezondheid - Institut Scientifique de Santé Publique</i>
WHO	World Health Organisation

#### 3.1. Methodology

This advisory report is based on a review of the scientific literature as well as the grey literature, and on the experts' opinion.

#### 3.2. Elaboration

##### 3.2.1. Swimming pools

###### 3.2.1.1. Introduction

Swimming pools are in fact containers filled with water that can be used for both swimming and water-based recreation. A distinction should be drawn between two types of pools, viz. public pools and privately owned pools for public use. Public pools are usually large pools that are intended for a large number of visitors from the general population. They may for instance be part of a larger leisure centre or recreational complex, which often have several pools, e.g. a heated indoor pool, a heated or unheated outdoor pool, a shallower pool for children and a paddling pool for toddlers and infants. Conversely, privately owned pools for public use tend to be fairly small in size and are used by few people, usually within settings such as private homes, physiotherapy practices or wellness centres, saunas and hotels. The swimming pools are usually characterized by high humidity conditions and, in many cases, poor ventilation. Moreover, pools intended for toddlers or children exhibit relatively high water and air temperatures, viz. 35°-36°C and 32°C, respectively.

### 3.2.1.2. Regulations

**In Flanders**, the *Vlaams reglement betreffende de milieuvergunning* (Vlarem I) draws a distinction between three types of pools:

- pools under 50 m<sup>2</sup> (class 3);
- pools between 50 and 300 m<sup>2</sup> (class 2);
- pools over 300 m<sup>2</sup> (class 1).

Pools for baby swimmers are often class 3-pools, which means that it is the town councils that are responsible for carrying out the necessary inspections. In many cases, the water is not analysed frequently enough or not at all (Feyen & Appel, 2011). The same is true for certain small pools used for patient rehabilitation (e.g. in hospitals).

As regards the other pools (classes 1 and 2), inspections are carried out on a monthly basis by licensed laboratories. The results of these analyses are sent to the *Toezicht Volksgezondheid* (TOVO). Trichloramine (TCA) air level measurements are carried out upon request (VLAREM I, 1991).

**In Wallonia**, a distinction is drawn between two types of pools: (1) closed-circuit indoor pools that are over 100 m<sup>2</sup> in size and over 40 cm deep and (2) closed-circuit outdoor pools over 100 m<sup>2</sup> in size and over 40 cm deep. For indoor pools, TCA-measurements are taken once a year. Still, most small pools too are subject to inspections, despite their not being mentioned in the legislation (AGW, 2003).

**In Brussels**, all types of pools are considered by the legislation.

- large pools: pools that are over 1,5 m deep;
- small pools : pools that are up to 1,5 m deep;
- paddling pools: pools that are up to 0,4 m deep.

The water turnover time is set at 90 minutes for small pools; TCA-measurements are taken three times a year. It is mandatory for small pools to be fully emptied once a year (AGRBC, 2002).

### 3.2.1.3. Swimming pool water treatment

The main issue that needs to be taken into account when considering the treatment of swimming pool water is the microbiological health risks attendant upon swimming in contaminated water. Micro-organisms, such as bacteria, fungi and viruses, inevitably proliferate in highly frequented locations and may potentially cause disease. Also, if the water were not disinfected, there would quickly be an unpleasant odour to it that would simply spoil the pleasure of swimming. In addition, every swimmer releases substances into the water, such as sweat, dandruff, urine, hair, etc., thus further polluting the water. It follows that the water in swimming pools has to be disinfected and treated in order to prevent the appearance of water-borne complaints, such as infections.

The treatment of pool water involves, on the one hand, eliminating all dirt and micro-organisms via filtration, flocculation and water renewal (50 %), and, on the other, removing them through disinfection and oxidation (50 %) (Feyen & Appel, 2011).

Flocculation is a process in which colloids and other suspended particles that are found in the water and pass through the filtration systems are made to coagulate into larger clusters, or flocs, by adding flocculating agents (also called flocculants or flocking agents) to the water, thus making the flocs filterable. In swimming pools, flocculants are used to clarify the water by making it possible to remove particles that would make it cloudy and that cannot simply be filtered out of the water. Flocculation is no longer carried out with Al<sub>2</sub>(SO<sub>4</sub>)<sub>3</sub>. Instead, polyaluminium chloride (PAC) is used, which offers various advantages over Al<sub>2</sub>(SO<sub>4</sub>)<sub>3</sub>: stronger base, less dosed, shorter flocculation time, less aluminium released in the environment, etc..

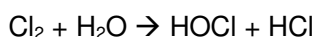
Oxidation is a process that causes substances that are dissolved in the water (viz. ammonia, urea, proteins, carbohydrates, lipids and amino acids) to break down, whereas disinfection

involves killing and inactivating micro-organisms. The product must work as a disinfectant and oxidising agent and have the following characteristics:

- effective against most micro-organisms;
- risk-free at the dose that is effective in water;
- simple and easy to monitor;
- effective oxidation properties;
- few potential adverse effects or at least controllable and limited.

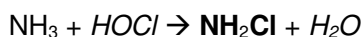
### Chlorine

In most public swimming pools, chlorine-containing reactants are used to disinfect the water. In the Walloon and Brussels Regions, chlorine gas is used, whilst this is prohibited in the Flanders Region. In the latter, a sodium hypochlorite solution is used that contains 150g/l active chlorine. Chlorinating the water leads to the formation of a complex mixture of disinfection by-products. Thus, adding chlorine to the water causes the following reaction to occur:



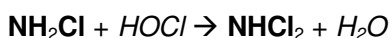
Chlorine gas + water → hypochlorous acid + hydrochloric acid

The main sanitising agent produced by this reaction is **hypochlorous acid (which releases free chlorine)**, which is a very potent bactericide. It is also highly reactive and oxidises certain inorganic or organic substances contained in the water at different rates. It readily reacts with **nitrogenous substances**, which represents about 60 % of the nitrogen pollution introduced by swimmers (De Laat et al., 2011). Urea is converted into ammonia at the filters (which contain urease-producing bacteria). This ammonia in turn reacts with the free chlorine and, through successive reactions, forms **mono-, dichloramines (DCA) and TCA**. TCA and DCA have harmful effects on health, which is why the formation of chloramines should be avoided, as pointed out in section 3.2.2. The successive reactions are as follows:



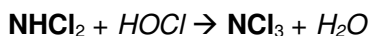
ammonia + hypochlorous acid → monochloramine + water

then:



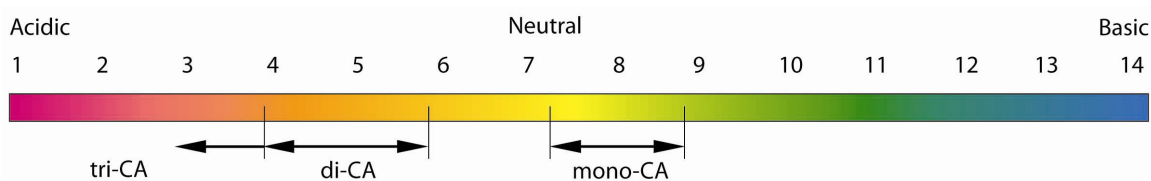
monochloramine + hypochlorous acid → dichloramine + water

then:



dichloramine + hypochlorous acid → trichloramine + water

and so on.



Chloramine formation is linked to the pH-level (formed at pH 7.5-9) and to the “free chlorine/pollution” ratio. DCA and TCA are mainly formed at low pH-levels and in the event of an altered chlorine/carbon ratio (>1:12) (NHS Scotland, 2001).

Thus, in order to reduce the build-up of DCA and TCA to a minimum, it is necessary to:

- maintain the pH and hypochlorite levels close to the lower threshold without compromising the disinfection (pH 7,2 -7,3);
- ensure regular maintenance for the filter;
- maintain a constant flow of water and air;
- treat (and filter) the water in order to remove chlorinated organic compounds such as ammonia, but also nitrates and nitrites.

Yet chloramines also react with **amines** to form **chlorinated hydrazine intermediates**. The latter can in turn react with dissolved oxygen to form N-nitrosamines, such as N-nitrosodimethylamine (**NDMA**), N-nitrosodibutylamine (**NDBA**), N-nitrosopiperidine (**NPIP**) (Kulshrestha et al., 2010).

Alternatively, nitrosamines may be formed as a result of the high concentrations of **nitrate** in urine and sweat. This nitrate may first be reduced to nitrite in the absence of strong oxidants and then chlorinated to form nitryl chloride. **Nitryl chloride** can react with nitrite to form the nitrosating agent ONONO<sub>2</sub>, which can readily react with amines to yield nitrosamines (Eiserich et al., 1996).

The two main disinfection by-products (DBPs) are **trihalomethanes** (THMs) and **haloacetic acids** (HAAs). A third important species are haloacetonitriles (HANs). THMs are the result of the complex reaction between chlorine and naturally present or imported organic matter. Chloroform is the dominant and prevailing species found in the air and water of chlorinated pools (Florentin et al., 2011; Richardson et al., 2010).

In view of these considerations, physicochemical standards have been set to ensure that the water and air in swimming pool halls are of sufficient quality. Some of these parameters can be found in tables 1 and 2 below.

Table 1: Standards for various physicochemical parameters in Belgium (AGW, 2003 ; AGRBC, 2002 ; KWR, 2011)

Parameters measured	Brussels		Wallonia		Flanders
	Large pool	Small pool	Type 1 pools (indoor)	Type 2 pools (outdoor)	
threshold values					
pH	7,0 - 7,6		7,0 -7,6		7,0-7,6
Free chlorine	0,5-1,5 mg/l		0,5-1,5 mg/l	0,8-3,0 mg/l	0,5-1,5 mg/l*
Combined chlorine	0,8 mg/l		0,8 mg /l		≤ 1,0 mg/l
Water temperature	28°C	30°C			≤ 32°C
Urea	2,0 mg /l		2,0 mg/l		2,0 mg/l
Chloroform	0,1 mg/l				
TCA in the air	0,5 mg/m <sup>3</sup> (sampling over 2 hours)		0,5 mg/m <sup>3</sup> (at 1,5m above the floor/once a year)	-	-

\* As regards outdoor pools and hot whirlpools, the threshold value is 3,0 mg/ml.

Table 2: Standards for certain physicochemical parameters in neighbouring countries  
(KWR, 2011)

Parameters measured (threshold values)	Germany (norms)	France (norms)	UK (regulation)	Italy (norms)	Netherlands (norms)
pH	6,5-7,6	6,9-8,2	7,2-7,4	6,5-7,5	6,8-7,8
Free chlorine	0,30-0,60 mg/l	0,4-1,4 mg/l	< 2 mg/l	0,7-1,5 mg/l	0,5-1,5 mg/ml
Combined chlorine	0,20 mg/l	0,6 mg/l	< 1 mg/l	0,4 mg/l	< 1,0 mg/
Water temperature			27-30°C	24-30°C	
TCA in the air		0,3 mg/m <sup>3</sup>			

### Alternatives

Disinfection must have a residual effect to maintain the microbiocidal activity in the pool, which is particularly important when there are many bathers in the water. Yet ozone and UV are oxidising treatments which have no such residual effect. As a result, chlorine disinfection is usually used as an additional treatment, but in this case the chlorine concentration may be lower than when it is used on its own, which reduces the negative effects of the product (AFSSETS, 2010 ; WHO, 2006).

Disinfectants used most frequently in large, heavily used pools	Disinfectants used in smaller pools and hot tubs	Disinfectants used for small-scale and domestic pools
Chlorine <ul style="list-style-type: none"> <li>• Gas</li> <li>• Calcium/sodium hypochlorite</li> <li>• Electrolytic generation of sodium hypochlorite</li> <li>• Chlorinated isocyanurates (generally outdoor pools)</li> </ul> Bromochlorodimethylhydantoin (BCDMH)                     Chlorine dioxide <sup>a</sup> Ozone <sup>a</sup> UV <sup>a</sup>	Bromine <ul style="list-style-type: none"> <li>• Liquid bromine</li> <li>• Sodium bromide + hypochlorite</li> </ul> Lithium hypochlorite	Bromide/hypochlorite                     UV <sup>a</sup> UV-ozone <sup>a</sup> Iodine                     Hydrogen peroxide/silver/copper                     Biguanide

<sup>a</sup> Usually used in combination with residual disinfectants (i.e. chlorine- or bromine-based)

(WHO, 2006).

The following list and short descriptions of alternatives should not be looked upon as a scientific assessment. Indeed, such an undertaking would require a special commission of independent experts in the field of swimming pool infectiology and engineering that focuses on assessing the efficacy of disinfection and on its potential toxic effects on human health.

- **Ozone** is a powerful, broad spectrum antimicrobial agent that is rapidly very effective against bacteria, including spores, viruses, fungi and protozoa. It is a more potent oxidising agent than chlorine and chlorine dioxide and is more effective than chlorine on sporulated microorganisms. It is more toxic and is also a potential hazard for the staff. In addition, there is a risk of ozone entering the pool in case of overdosing or if inappropriate equipment and/or deoxygenation systems are used and/or in the event of poor maintenance.

**Ozone** always has to be used in combination **with chlorine** (formation of deposits in the pool), which means that it cannot be claimed to be an alternative to chlorine.



All the disadvantages of chlorine therefore remain, though at somewhat lesser concentrations. Ozone needs to be used with free chlorine to ensure a remanent disinfecting effect in the water

- **Copper-silver ionisation.** Though quite expensive, copper-silver ionisation is effective against most types of *Legionella*, which can, however, easily develop resistance or a tolerance to it. It is not effective against protozoa such as e.g. *Naegleria fowleri*. Its effectiveness as a disinfectant depends on the free ion concentrations, with both copper and silver forming precipitates under certain chemico-physical conditions; the ion concentrations should be carefully monitored. Copper and silver are both heavy metals that can leave deposits in the water systems and are potentially toxic for living organisms, including humans. These deposits can be removed through simple means before the water is evacuated. Thus, adding chlorine causes silver to precipitate in the rinsing buffer. This method is applied in two pools in Belgium: the university pool in Louvain-la-Neuve and the St-Vith pool.
- The use of **UV light** alone does not constitute an alternative. It is not effective enough as a disinfectant on its own (no residual effect). Also, it does not generate any deposits, but forms THMs.  
**UV light in combination with chlorine** is an attractive complementary alternative, especially since UV light radiation is more effective against *Cryptosporidium* and *Giardia* ssp, both of which are parasites causing diarrhoeal outbreaks. Unlike chlorine or ozone, UV does not entail any danger of overdosing or by-product formation. This method involves the filtered water going through a reactor fitted with a UV lamp into which a small amount of hydrogen peroxide is continuously dosed. The combination of these two factors causes the chloramines to dissolve. By reducing the level of chloramines in the water, UV use increases swimmer comfort. The efficacy of UV light depends on water turbidity and light system maintenance. Indeed anything that affects the penetration of UV light into the water reduces its efficacy. This alternative is being implemented in the Longchamps pool in Uccle and the Triton pool in Evere.
- **Silver stabilised hydrogen peroxide** is used in the Grimbergen thermal baths with good results but still has to be shown to be innocuous.
- **Quaternary-ammonium compounds** do not constitute an attractive alternative, as they increase the pH-level of the water, which in turn makes them less effective against viruses. They are also more toxic, which poses an additional problem with small children, who tend to swallow the water.
- **Bromine** is not a valid alternative either, because it is more toxic and less stable than chlorine (Wagner et al., 2012; Zhang et al., 2012).

There are limited data available in the literature regarding the in vitro efficacy of alternatives to chlorine in preventing recreational water associated infections, and even less regarding their effectiveness in actual practice. Some *Cryptosporidium* outbreaks have been described in pools using ozone. Many systems have only been used for a short time, and to a very limited extent.

Importantly, in most countries (but not in the USA and the UK), the majority of pool related individual infections or outbreaks are not reported. This makes it difficult to establish the incidence of pool related infections. There are no studies available that compare the effectiveness of disinfection products in swimming pools. In actual fact, some products have not been studied as swimming pool disinfectants. This is the case with, copper-silver ionisation, which has been almost exclusively studied as a means for preventing *Legionella* sp. in water systems. One study has compared the in vitro efficiency of a range of disinfectants (including chlorine, ozone and

copper-silver). The authors looked at their efficacy in controlling *Legionella*, protozoa (*Hartmannella*, *Acanthamoeba* and *Vahlkampfia*) and biofilm formation in an in vitro waterpipe system. Chlorine dioxide and chlorine were the most efficient treatments, especially against *Legionella*; ozone was more active against protozoa and copper silver showed a poor effect on all studied endpoints. Moreover, copper-silver appeared to cause more corrosion than the other methods (Loret et al., 2005).

In sum, though there are few studies available on the different alternatives to chlorine/treatments that may be used in combination with chlorine, they appear to be either more toxic, more expensive, or less effective than chlorine. An additional problem is that it is very difficult to get unbiased information on these alternatives, as it is always provided by the companies that produce them. However, this is also true for studies that are conducted on chlorine. In the future, it would be interesting to carry out a properly designed study in the Belgian pools using different disinfection options (currently chlorine, UV+chlorine and copper-silver) to compare the microbial contamination of the water, especially as regards the more resistant viruses and protozoa. System costs and maintenance should also be evaluated, as well as toxicity of these different alternatives.

### **Conclusions**

For the moment, chlorine remains the most effective option, provided that a number of conditions are met. Thus, the air and the water have to be of sufficient quality. They also have to be well monitored and subject to enough inspections .

The SHC takes the view that, at present, there is no evidence that alternatives to chlorine will provide an appropriate solution for the disinfection of swimming pools, and thus for protecting the population against the risk of infection attendant upon bathing in poorly disinfected pools. Anything that disinfects and therefore kills pathogens is potentially toxic.

Chlorine is the best disinfectant currently available, provided that all of the following conditions are met:

- the exposure of the swimmer remains low;
- the swimmers take adequate hygiene measures, including showering with soap and water before entering the pool;
- the pool is properly monitored for water and air quality;
- the swimming pool hall is properly ventilated;
- the water is treated to remove chlorinated organic compounds.

Both the quality of the air as well as that of the water should be monitored and inspections should be carried out. As regards the water quality, this should concern the microbiological<sup>2</sup> and physicochemical aspects of the water, as well as the presence of chlorinated organic by-products. As is the case for the water, the air needs to be renewed. Particular attention should be paid to privately owned pools for public use that are visited by small children (more organic material).

At present, there are no standard regulations that apply to the whole of Belgium. Rather, they differ from one region to another. It therefore seems essential that these regulations should be harmonised and/or revised on the basis of the norms/regulations that currently apply in Germany and the UK. Also, there should be a greater emphasis on educating the general public and pool operators on hygiene issues.

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<sup>2</sup> There are no published data available on the extent of bacterial contamination in Belgian swimming pools. Yet water quality inspections are carried out for these pools.

## **3.2.2. Risks attendant on swimming in chlorinated water**

### **3.2.2.1. General considerations**

Swimming and related sports activities are very popular. They are relatively inexpensive and easy to perform at any age. The risk of sustaining a sports injury in water is extremely low, whereas many health benefits can be attributed to this activity: reduced risk of cardiovascular complaints, obesity, etc.

As a result, the time spent in swimming pools is on the rise. Therefore, much attention is devoted to swimmers' well-being. The complaints reported usually concern irritation to the eyes, respiratory tract and skin and their occurrence should be reduced to a minimum. They are suspected to be caused by high concentrations of chloramines, which are compounds with little bactericidal activity. They are highly lachrymatory and are responsible for the distinct chlorine smell in indoor swimming pools. TCA is a very volatile and toxic gas that is also highly irritant for the eyes and respiratory tract (Feyen & Appel, 2011).

An overview of the different publications available on swimming in chlorinated water can be found in appendix 2. These publications are listed in chronological order and include the papers that were used to write SHC advisory report No. 8614 (SHC, 2011), which assessed the strengths and the weaknesses of the published reports (see appendix 1). This overview also contains the references of other publications, which are highlighted in green in the summary table (Nystad et al., 2003; Villanueva et al., 2007; Kogevinas et al., 2010; Cantor et al., 2010; Nickmilder & Bernard, 2011). The papers that deal with babies in particular are marked with an asterisk. In addition, it provides a list of the different complaints reported on in these papers. They are ranked on a scale from the most disease-specific symptoms on the left to the least disease-specific symptoms on the right.

In Belgium, there are many retrospective studies available (Bernard et al., 2006; Bernard et al., 2007; Bernard et al., 2008; Bernard et al., 2009; Bernard et al., 2011; Nickmilder & Bernard, 2007; 2008; Voisin et al., 2010) that were carried out with older children, but from which it is very difficult to draw conclusions. The reasons are the following:

1. Retrospective studies can raise questions regarding a possible association between exposure and disease, but do not provide any evidence for a causal relationship that accounts for the observed association. This needs to be confirmed by prospective controlled studies.
2. There are many confounding factors that affect these studies (such as parental smoking).
3. In these studies, the exposure to chlorine and by-products is not known;
4. Pneumologists advise children with asthma to practice swimming. This means that the children in these studies may have been suffering from asthma prior to visiting swimming pools.

There is only one prospective study available (Font Ribera, 2011). This methodologically sound study suggested that swimming did not increase the risk of asthma. By contrast, it associated swimming with an increased lung function and reduced risk of asthma symptoms at age 7 (Font Ribera, 2011).

The potential risk factors that have been associated with swimming in chlorinated water are: cancer, asthma, respiratory disorders (such as upper respiratory tract infections and allergies), eye irritation and, more recently, endocrine disruption, although no causal relationship has been proved to exist for any of these factors. Also, there have been no diarrhoeal episodes notified following pool attendance.

#### *a) Genotoxicity and carcinogenicity*

There is no International Agency for Research on Cancer (IARC) classification available on the carcinogenic risk of swimming in chlorinated pools. The IARC has placed **chloramines** (2004) and chlorinated drinking water (IARC, 1991) in group 3, i.e. substances that are non classifiable as to their carcinogenicity in humans. There are no data available in the literature on the carcinogenicity, genotoxicity, mutagenicity, teratogenicity and reproductive toxicity of chlorine (Florentin et al., 2011). The mutagenicity of pool water is probably similar to that of drinking water (Richardson et al.). Some **THMs and other DBPs** are classified as possibly carcinogenic in humans (for instance, chloroform is possibly carcinogenic - IARC, 1991). A few other **N-DBPs**, including nitrosamines (Walse & Mitch, 2008), have been reported to be carcinogenic. However, numerous publications highlight a toxic risk, especially the risk of allergy and respiratory symptoms for babies and elite swimmers. The few publications dedicated to risk assessment do not suggest that there is an increased risk, except for elite swimmers. These publications are likely to underestimate the risk associated with DBPs because the lack of data in the literature makes it impossible to calculate the risk associated with certain compounds or certain pathways. Thus, it is important that regulations take into account the risks associated with disinfection by-products, without neglecting the need to control microbiological hazards in swimming pools (Florentin et al., 2011).

Several studies have shown that there is a link between drinking chlorinated water and bladder cancer as well as colorectal cancers (Cantor et al., 2010; Florentin et al., 2011). The reported risk depends primarily on the level of exposure to THMs. Very few epidemiological studies focus on the relation between the incidence of cancer and swimming pool attendance. A Spanish research team suggests that there is an increased risk of bladder cancer due to the ingestion and, additionally, the inhalation and dermal absorption of THMs and reports that there is an increased risk for adults attending swimming pools (Villanueva et al., 2006; Villanueva et al., 2007). The most recent study (Kogevinas et al., 2010) shows that chlorine has a weak genotoxic effect, but the shortcomings of the protocol cast doubt on these results. On the one hand, the timing for the blood tests was not appropriate for carrying out a genotoxicity assessment. On the other, practicing this sport induces oxidative stress in itself. This means that the control group too has to visit a swimming pool, e.g. one that is disinfected through an alternative method. Still, the genotoxic effect seems to be of greater concern than the appearance of asthma.

#### *b) Asthma*

There are many data available on asthma and allergies, also for Belgium. Unfortunately, in most of the publications, these data were obtained from (small) retrospective studies, which are affected by many confounding factors, such as parental smoking and reverse causation. In fact, there are either no chlorine and by-product exposure assessments carried out, or they are not carried out properly (enough). This in turn means there is little certainty over potential threshold values. Also, asthma is a very difficult condition to diagnose. The only prospective study available indicates that swimming in chlorinated pools has no negative effects as regards asthma or allergies (Font Ribera, 2011). After reading the most recent literature on asthma, the SHC confirms the opinion expressed in the previous advisory report (SHC, 2011).

#### *c) Endocrine disruption*

A first epidemiological study on potential endocrine disruptions in children (aged 14-18) who regularly attended indoor and/or outdoor chlorinated pools was conducted by Nickmilder & Bernard 2011 (discussed in Weinhood 2012). There are several limitations to this study, such as the fact that it fails to include many types of water quality measurements and disinfection by-products and does not provide any data on testis size or any other indications of the examined boys' pubertal status (Weinhood 2012). The clinical significance of the hormonal changes identified is therefore unclear and should be interpreted with caution until they have been confirmed by new studies.

### 3.2.2.2. Babies

This report focuses on baby swimmers. Following the international definition of this term, “babies” are defined as infants up to the age of 12 months.

The potential risk of swimming in chlorinated water might be age-related. However, no data are available on the possibility that babies may be more prone to pulmonary infections due to hyper reactivity of the respiratory mucous membranes. As regards older children, the maturation of the lungs is not complete until the age of 6. Moreover, it is difficult to define asthma in a three-year-old. In fact, this is a particularly problematic condition to diagnose before the age of 7. It is important to take into account the oral absorption of swimming-pool water, which varies according to age, experience and type of activity. The volumes of water ingested by baby swimmers and children are believed to be twice as high as those ingested by adults (AFSSET, 2010; Dufour et al., 2006; Schets et al., 2011).

Only one retrospective study, which used questionnaires and involved children aged 6 to 16, reported that baby swimming was associated with an increased risk of recurrent respiratory tract infections in infants. The risk was only present in children born to atopic parents. No statistically significant association could be shown with otitis media (Nystad et al., 2003). These findings have not been confirmed in the only prospective study available (Font –Ribera, 2011).

Another factor that needs to be taken into account is the fact that there is a gender effect in the appearance of asthma. Thus, more boys tend to be affected by this condition than girls. The opposite is found to occur in adults, with more women affected than men.

A further parameter that needs to be kept in mind is the “potential osmotic shock” in chlorinated salted water. This effect is all the more significant in small children as regards the mucous membranes in their upper respiratory tract (ear, nose and throat) and should definitely receive more attention than any potential oxidative effect.

It is not known how many infants practice baby swimming in Belgium. Indeed, there are no centralised data available, as this activity is mainly organised in privately owned pools for public use. In these pools, there is no systematic monitoring of the water and air quality, nor are there enough inspections. This in turn means that there can be no certainty over the level of exposure in these privately owned pools for public use. Moreover, the water in pools used for baby swimming contains more organic material (urin, faeces, etc.) than pools used by adults. Also, these pools are usually heated to higher temperatures. Another factor that needs to be considered is that conditions may differ between outdoor and indoor swimming pools.

Based on the only retrospective study available and the fact that the intake of chlorinated by-products may be relatively high (compared to older children), the experts do not encourage baby swimming, in particular for babies born to atopic parents or with a family history of asthma (at-risk babies). This is also the view taken by the German health authorities (UBA, 2011), which have decided to implement the precautionary principle for predisposed children under the age of 2 (atopic parents).

This warning could be extended to other subpopulations that may be at risk due to such factors as genetic background and family history (atopic parents). Maybe some caution should be recommended for children with “spontaneous” eardrum perforations caused by otitis media (as swimming pools are not sterile), but there is no literature available on this subject (Carbonell & Ruiz-Garcia, 2002).

### **3.2.3. Benefits of swimming**

Though there are potential risks involved in swimming in chlorinated water, it should be stressed that this practice offers many benefits to the children concerned: it offers them a comprehensive form of physical exercise.

- a) They learn to swim, which can be life-saving (as soon as the infants can move around on their own). Yet it should be noted that baby swimmers don't actually learn to swim, as they are far too young to acquire the inter-limb coordination this activity requires.
- b) It provides a number of potential psychological benefits in terms of the relationship between the baby and its parents. Yet these psychological benefits can probably also be obtained through other activities, such as taking a bath with the baby at home.

The many benefits of swimming also account for the fact that, from the age of 6 (primary school), swimming lessons form an integral part of the educational curriculum and are therefore mandatory. It can therefore be concluded that, for older children, the many proven benefits of practicing a sport such as swimming (as regards its effect on the risk of cardio-vascular complaints and obesity, as well as diabetes prevention, mental health, etc.) largely outweigh the potential risks linked to chlorine disinfection.

### **3.2.4. Practical recommendations**

In swimming pools, the hazard related to microorganisms can be faecally or non faecally-derived (see appendix 3).

Among the faecally derived organisms, bacteria are easily eliminated by properly disinfecting the pool with chlorine. Viruses such as rotaviruses or noroviruses are much more resistant to disinfection and may be transmitted through pools that are accidentally heavily contaminated despite adequate chlorine levels.

Most non-faecally derived bacteria too are imported into the pool area by bathers, even ubiquitous environmental bacteria such as *P. aeruginosa*. *S. aureus*, which is used as an indicator for pool water quality, is easily removed through adequate chlorine disinfection. By contrast, mycobacteria such as *M. marinum* or *avium* have been associated with pool-related skin and pulmonary hypersensitivity, respectively. They are relatively resistant to disinfection.

Organic material (sweat, urine, etc.) also plays a very important part in the formation of toxic by-products that are responsible for the appearance of chlorine-related complaints.

Therefore bathers are a potential source of contamination, which means that they can easily contribute towards reducing it by complying with a few basic rules, such as:

- not swimming when ill with diarrhoea;
- avoiding swallowing pool water;
- showering themselves and their children using soap and water before entering the pool;
- washing their hands with soap and water after using the toilets and changing children's nappies;
- changing nappies or taking children to the bathroom on a regular basis. In order to be able to do so, it is essential to provide the necessary facilities (properly equipped bathrooms).

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## 5. APPENDIX

Appendix 1. Overview of the different publications available on swimming in chlorinated water.

Appendix 2. Microbiological aspects

## 6. RECOMMENDATIONS FOR FURTHER RESEARCH

An awareness raising campaign should be organised in schools and swimming pools in order to encourage bathers to contribute towards reducing the contamination of the pools by implementing the practical rules mentioned above.

Ideally, the Council would advise that trials be conducted at the European level which would take into account relevant confounding factors to define biomarkers for the early effects (including genotoxicity, lung epithelium permeability, endocrine-disrupting activities) as well as the complaints. This would make it possible to account for the mechanisms involved and identify a causal relationship. Alternatively, Belgium could co-ordinate an international longitudinal prospective randomised-cluster trial (which includes other biomarkers, other types of disinfection, etc.). In order to do so, it is essential to define a good prospective protocol study and to determine how the trial will be conducted.

The Council would also advise to promote epidemiological research on at-risk populations, such as babies, workers, professional swimmers, swimming teachers and asthma patients.

## 7. COMPOSITION OF THE WORKING GROUP

All experts joined the working group *in a private capacity*. The names of the members and experts of the Superior Health Council are indicated with an asterisk\*.

The following experts were involved in drawing up the advisory report:

BARTSCH Pierre	Pneumology	ULG
BOTTARI Serge	Paediatric pneumology	CHU de Grenoble - France
CASIMIR Georges	Paediatric pneumology	HUDERF
DE BAETS Frans	Paediatric pneumology	UGent
KIRSCH-VOLDERS Micheline*	Cellular and environmental genetics	VUB
KNUDSEN Lisbeth	Public Health, epidemiology	Københavns Universitet - Denmark
LEGIEST Barbara	Community health care, pulmonary toxicity , occupational medicine	KUL
NEMERY de Bellevaux Benoit*	Toxicology, occupational medicine	KUL
VANDAMME Peter	Microbiology	UGent
VERGISON Anne	Hygienist doctor, infectiology	HUDERF

The following individuals were heard:

FEYEN Ludo	General director	LaboDerva
LAZARON Philippe	General director	AquaPro

The working group was chaired by Micheline KIRSCH-VOLDERS, the scientific secretaries were Muriel BALTES and Evelyn HANTSON.

Alfred Bernard (UCL) declined to join this working group.

**Appendix 1**  
**Overview of the different publications on swimming in chlorinated pools.**

Publication Countries	n / study / year	Symptoms compared to control group: ↑ ↓ ≠								
		Respiratory tract infection	Otitis	Diarrhoea	Bronchitis	Asthma	Allergic rhinitis	Eczema	Hay fever	Wheezing
*Nystad 2003 <i>Norway</i>	2862 / R / (6-16y)  Cross-sect/ (0-11 month)	↑ atopy ↑ smoking mother  ♀ < ♂ atopy	↑ atopy ↑ smoking mother							
Kohlhammer 2006 <i>Germany</i>	R (35 – 74 y) school age							↑		
Nickmilder 2006 <i>EU</i>	European cohorts R (13-14y)					↑ number outdoor pools			↑ number outdoor pools	
* Bernard 2006 <i>Belgium</i>	341 / (10 – 13y) Incl swimming before 2y					↑↑ attendance outdoor pools ↑ atopy ↑ family hist ast				
* Bernard 2007 <i>Belgium</i>	341 / (10 – 13y) Incl swimming before 2y				↓ clara cell +perm changes	↓ clara cell +perm changes				
Villaneuva 2007 <i>Spain</i>	Increase of bladder cancer after long term exposure to DBP (disinfection by products)									
* Schoefer 2008 <i>Germany</i>	2192 / P / (6 m – 6y)	↑	↑	↑		↓				
Godman 2008 <i>International</i>	Meta-analysis					No ≠				
Bernard 2008 <i>Belgium</i>	847 adolescents (13-18y)					↑				

\* n = number of infants, study: retrospective (R) / prospective (P) / cross sectional study (cross sec) / longitudinal (L) ages of the infants involved in the trial.

Publication Countries	n / study / year*	Symptoms compared to control group: ↑ ↓ ≠								
		Respiratory tract infection	Otitis	Diarrhoea	Bronchitis	Asthma	Allergic rhinitis	Eczema	Hay fever	Wheezing
Bernard 2009 <i>Belgium</i>	847 adolescents (13 – 18y)					↑ atopy (not Cu-Ag pool)	↑ atopy		↑ atopy	
*Font-Ribella 2009 <i>Spain</i>	3.233 / R (9-12y) Cross-sec swimming before 2y					↓	↓	↑		
Kogevinas 2010 <i>Spain</i>	49 adults	Increase of MN blood, no induction of Comet blood, or MN bladder								
Font-Ribera 2010 <i>Spain</i>	48 adults	Increased biomarkers for lung permeability								
Cantor 2010 <i>Spain</i>		Influence of GSTT1, GSTZ1 and CYP2E1 gen. polym. on DBP association bladder cancer								
* Voisin 2010 <i>Belgium</i>	430 Swimming before 2y				↑ atopy No day-care	↑				
* Font-Ribera 2011 <i>UK</i>	5.738 / P (7 – 10y) L (6 – 81 months)					no ≠ (↓ asthma in patients)	no ≠	no ≠		no ≠
Nickmilder 2011 <i>Belgium</i>	361 ♂ adolescents	Hormonal modifications								

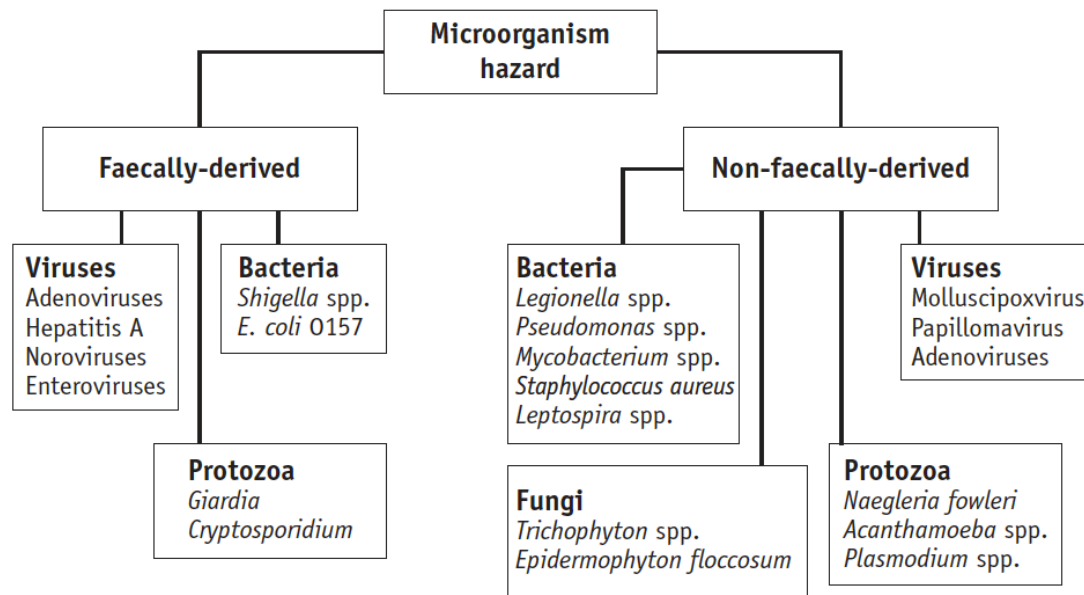
\* n = number of infants, study: retrospective (R) / prospective (P) / cross sectional study (cross sec) / longitudinal (L) ages of the infants involved in the trial.

## Appendix 2. Microbiological aspects

Among the faecally derived organisms, bacteria are easily eliminated by properly disinfecting the pool with chlorine. Viruses such as rotaviruses or noroviruses are much more resistant to disinfection and may be transmitted through pools that are accidentally heavily contaminated despite adequate chlorine levels.

*Giardia* and *Cryptosporidium* form cysts which are quite resistant to chlorine disinfection. Some alternatives to chlorine, such as ozone and UV treatment, are more effective against these protozoa cysts. Yet for this efficacy to remain sufficiently high, the oxydation system has to be very carefully maintained. Also vomit or faeces in the pool may cause contamination that persists for a prolonged period, leading to outbreaks. Many gastroenteritis outbreaks have been linked to these two pathogens, particularly *Cryptosporidium*. More than two-thirds have been associated with insufficient pool disinfection (either with chlorine or with ozone). Prevention plays a key role in avoiding these faecal contaminations: people with diarrhoea should not use swimming pool facilities, non-toilet trained children should be closely watched and preferably swim in small-capacity pools, which can be cleaned more easily. Showering before entering the pool is an important means of reducing faecal contamination of the perineal skin. In case of accidental vomiting or faecal loss, the swimmers should be evacuated from the pool and the water ideally changed.

Most non-faecally derived bacteria too are imported into the pool area by bathers, even ubiquitous environmental bacteria such as *P. aeruginosa*. *S. aureus*, which is used as an indicator for pool water quality and is easily removed through adequate chlorine disinfection. By contrast, mycobacteria such as *M. marinum* or *avium* have been associated with pool-related skin and pulmonary hypersensitivity, respectively. They are relatively resistant to disinfection and are also able to survive within amoebae in swimming pool water (Loret JF, Water Sci Technol 2008 and Int J Hyg Environ Health 2010). Molluscipoxviruses, papillomaviruses and the fungi mentioned above are traditionally associated with the transmission of skin infections through swimming pool water. Preventing these infections crucially relies on raising public awareness and on regular surface cleaning. As is the case for *Acanthamoeba sp.*, they are extremely resistant to disinfection and cause keratitis, particularly in contact lens wearers. *Naegleria meningitidis* has been linked to contaminated water sources and *Plasmodium* may be a problem in outdoor swimming pools in endemic countries.



Microorganisms that potentially cause disease in swimming pools and recreational water areas (WHO, 2006)