A Review of Chlorine in Indoor Swimming Pools and its Increased Risk of Adverse Health Effects

Sara ANGIONE* [1], Heather McClenaghan [1], Ashley LaPlante [1]

[1] Student, University of Ottawa, Canada

* *Auteur(e) correspondant* | *Corresponding author*: N/A

Résumé :

(traduction)

Contexte : Le chlore est un agent communément utilisé pour désinfecter l'eau des piscines. La ventilation inadéquate des piscines intérieures et les produits dérivés de la désinfection au chlore (DDC) provenant de la matière organique favorisent l'augmentation des risques de conséquences nuisibles pour la santé. On doit surveiller la qualité de l'eau et une ventilation adéquate pour éviter que les jeunes et les adolescents courent des risques.

Méthodes : Les auteurs ont étudié des recherches menées sur des enfants et adolescents âgés de 2 à 18 ans qui nagent dans les piscines intérieures. Toutefois, ils ont seulement étudié celles parues dans les journaux des années 2000 à 2010, et contenant des statistiques globales. Ils ont aussi passé en revue des articles scientifiques de collègues, et fait la méta-analyse de trois bases de données scientifiques différentes : PubMed, Web of Science et Google Scholar.

Résultats et Conclusions : Les enfants de moins de cinq ans, les maîtres-nageurs et les nageurs d'élite courent un risque accru de symptômes des voies respiratoires supérieures et inférieures, tels que l'asthme, parce qu'ils sont exposés fréquemment à de l'eau chlorée. Mais les nageurs récréatifs qui ne nagent que modérément ont moins de risques de contracter de l'asthme professionnel.

Conséquences : Si on réduit l'exposition au chlore des piscines intérieures, cela peut diminuer les risques de contracter des infections des voies respiratoires supérieures et inférieures.

Mots-clés : Chlore, effets nuisibles pour la sante, piscines intérieures

Abstract:

Background: Chlorine is a commonly used agent for water disinfectant in swimming pools. Inadequate ventilation in indoor swimming pools and chlorination disinfectant by-products (DBP's) caused by organic matter promote the increased risk of adverse health effects. Water quality and proper ventilation must be monitored to avoid health risks in youth and adolescents.

Methods: Studies were researched on children and adolescents from 2-18 years old who swim indoors. Articles were limited by only including journals from the year 2000 through 2010 and contain global statistics. Peer reviewed scientific articles were reviewed and a meta-analysis of three different scientific research databases, PubMed, Web of Science and Google Scholar, was conducted.

Results and Conclusions: Children under five years of age, lifeguards and elite swimmers are at an increased risk of upper and lower respiratory symptoms, such as asthma, when exposed to chlorinated swimming frequently. Recreational swimmers who swim moderately are at a lower risk for developing occupational asthma.

Implications: Reducing exposure to chlorine from indoor swimming pools may limit the risk of developing upper and lower respiratory infections.

Keywords:

Chlorine, adverse health effects, indoor swimming pools

Introduction

Physical activity, such as swimming, is highly beneficial for overall health and well being because it reduces and relieves pressure on joints, improves endurance and develops muscle strength (Bougault, Turmel, Levesque, & Boulet, 2009). However, chlorine based disinfectants, including chlorine, hypochlorite, and chloroisocyanurates are the most common water disinfectants for the prevention of water borne diseases (Bernard, Carbonnelle, de Burbure, Michel, & Nickmilder, 2006). When disinfectants react with organic amino compounds, disinfection byproducts (DBP's), commonly referred to as trihalomethanes, are formed (Nemery, Hoet, & Nowak, 2002). Organic compounds, for example chloramines and hypochlorous acid, are powerful oxidants, which destroy tight junctions in epithelial tissue and increase lung epithelium permeability (Bernard et al., 2006). Frequent exposure of these agents triggers the development of asthma and potentially allows the passage of allergens (Nemery et al., 2002).

Exposure of chlorination and organic matter and decreased ventilation from indoor swimming pools may have detrimental acute and chronic effects on the respiratory system (Bernard et al., 2006). Children, lifeguards, pool attendants and elite swimmers are at an increased risk for developing upper and lower respiratory problems (Lourencetti et al., 2008). Epithelial and mucosal damage caused by the exposure to chlorine products in children less than five years of age, pool attendants and competitive swimmers causes an early onset of asthma (Bernard et al., 2006). Children and youth are most susceptible to developing health effects because of the increasing use in youth for physical activity (Bougault et al., 2009) and they are likely to be swimming in water which is warmer and have higher levels of disinfectant (Weisel et al., 2009).

Chlorine levels are usually between 1.0 – 3.0 ppm in public swimming pools, both indoors and outdoors, and are increased upon water and surface contamination. The recommended chlorine levels are mandated by government agencies to avoid recreational water illnesses (Centers for Disease Control and Prevention, 2010). To ensure water facilities minimize contamination and are safe for public use, safety standards and guidelines for public pools must be implemented by officials and pool operators (Canadian Center for Occupational Health and Safety, 2003). These standards for indoor swimming pools include, but are not limited to, water disinfectant and temperature levels, and proper ventilation (Health Canada, 2009; see also Bernard et al., 2006). Consumers should continually review current information about safety standards and proper sanitation practices to minimize health hazards from chlorine and related agents from indoor swimming pools (Health Canada, 2009).

Methods

Search Strategies

Pubmed, Web of Science, and Google Scholar were three scientific databases used to search for related articles using the keywords: child, adolescent, swimming pool, chlorine, and asthma.

Inclusion and Exclusion Criteria

This systemic review only included human studies conducted on children and adolescents from the ages of 2 to 18. Studies included all geographical locations, which allowed for diversity among subjects and regulations. Data was collected from both indoor and outdoor public swimming pools. Articles included: Belgium, Italy, Spain, England, the US, Japan, Germany and Canada. Original research articles published after 2000 were included in this review. Some articles not included within the defined scope include articles found for "Protection and Action" section that dealt with policy and recommendations. Many of the studies included in our review were quasi-experimental research and association studies.

Data Extraction

Information that was extracted included statistics as well as quotations and conclusions. The purpose of the data extraction table was to illustrate the various methodologies researchers used to collect their data.

Data Synthesis

The data was reviewed and general trends emerging from the scientific literature were identified. These trends and relationships from the systemic review are presented in the results section.

Results

Environmental Hazard

Indoor swimming pools contain numerous chlorine-based

oxidants, which can be found in the water. These oxidants are located in not only the swimming pool, but in hot tubs, as well as whirl pools. The concentration of these oxidants in the air vary based on several factors such as the chlorine dosage in the water, bathing load, mode of swimming, the temperature of the air and the quality of ventilation (Bernard, Carbonnelle, Dumont, & Nickmilder, 2007). Within the environment, the most concentrated oxidants include trichloramine in the gaseous phase and the hypochlorous acid, as well as mono-and dichloramine, which can be found in aerosols (Bernard et al., 2007).

Human Exposure and Internal Dose

The main route of exposure for swimmers is through inhalation of aerosols that are actively floating in the air on the surface of the water. There is a shift from nose breathing to combined nasal and mouth breathing when the pulmonary ventilation exceeds a level of 30 L per minute (Bernard, 2007). This change in breathing allows the aerosols to bypass the nasopharynx filter and penetrate deeper within the lungs. Asthma is more prevalent in indoor swimming pools due to the decreased ventilation and concentrated inhalation of chemicals (Bernard et al., 2006).

Within children, aged 6 and 7, who have to attend the smaller pools and swim primarily in the shallow end, they are being exposed to the most polluted area of the pool. When looking at the concentration of trichloramine (refer to Figure 1) in the air around the small pool, the level of trichloramine is about 50% higher than levels in the large pool (Bernard, 2007). When children are first learning to swim, they inhale and swallow aerosols containing chloramines, which are soluble and can be carried to deep levels of the respiratory tract (Weaver et al., 2009). Due to the fact that children have a greater surface area, they absorb higher levels of chlorine products across the surface of their skin, in proportion to their body weight.

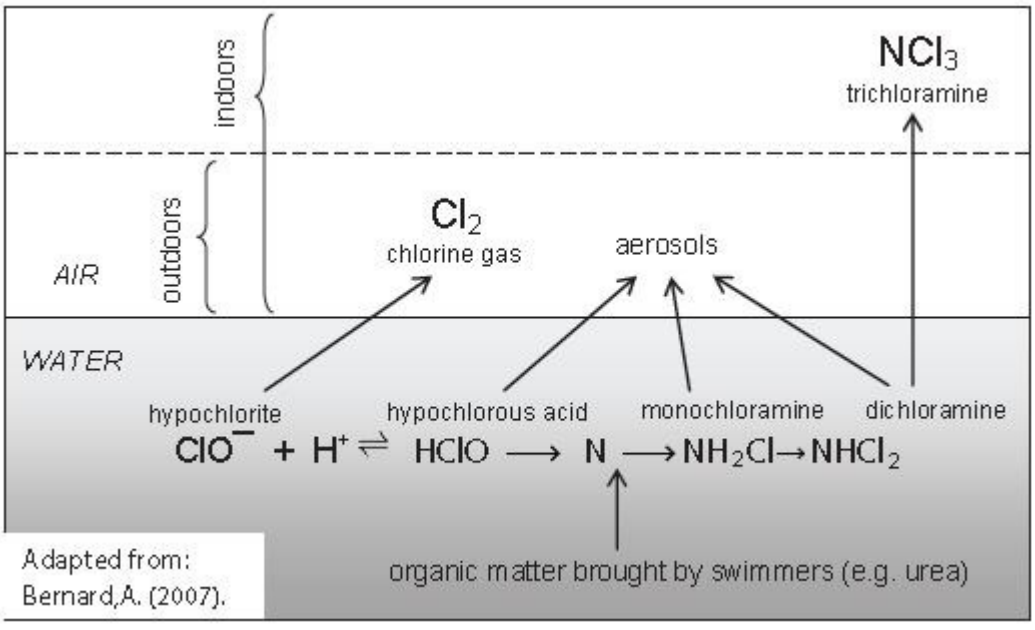
Health Effects

A common problem from the use of chlorinated swimming pools is the pungent smelling 'chlorine' water This smell, which is irritating for the eyes and upper respiratory system, is due to the presence of chloroamines (Weaver et al., 2009). Chloroamines, such as monochloroamine (NH2Cl), and dichloroamine (NHCl2) are synthesized from hypochlorite and ammonia compounds, which originate from the sweat and urine of swimmers (Weaver et al., 2009). The risks of exposure from chloroamines are determinant among the level of chlorine used, contamination of water from swimmers and their personal hygiene and air circulation (Lourencetti et al., 2008).

Risks

Figure 1

The diagram below illustrates potent chemicals which are found in the air of indoor swimming pools. Children in industrialized countries are exposed to trichloramine frequently, which has been shown to be one of the most concentrated air pollutants. Swimmers and competitive swimmers are most frequently exposed to chlorination products.



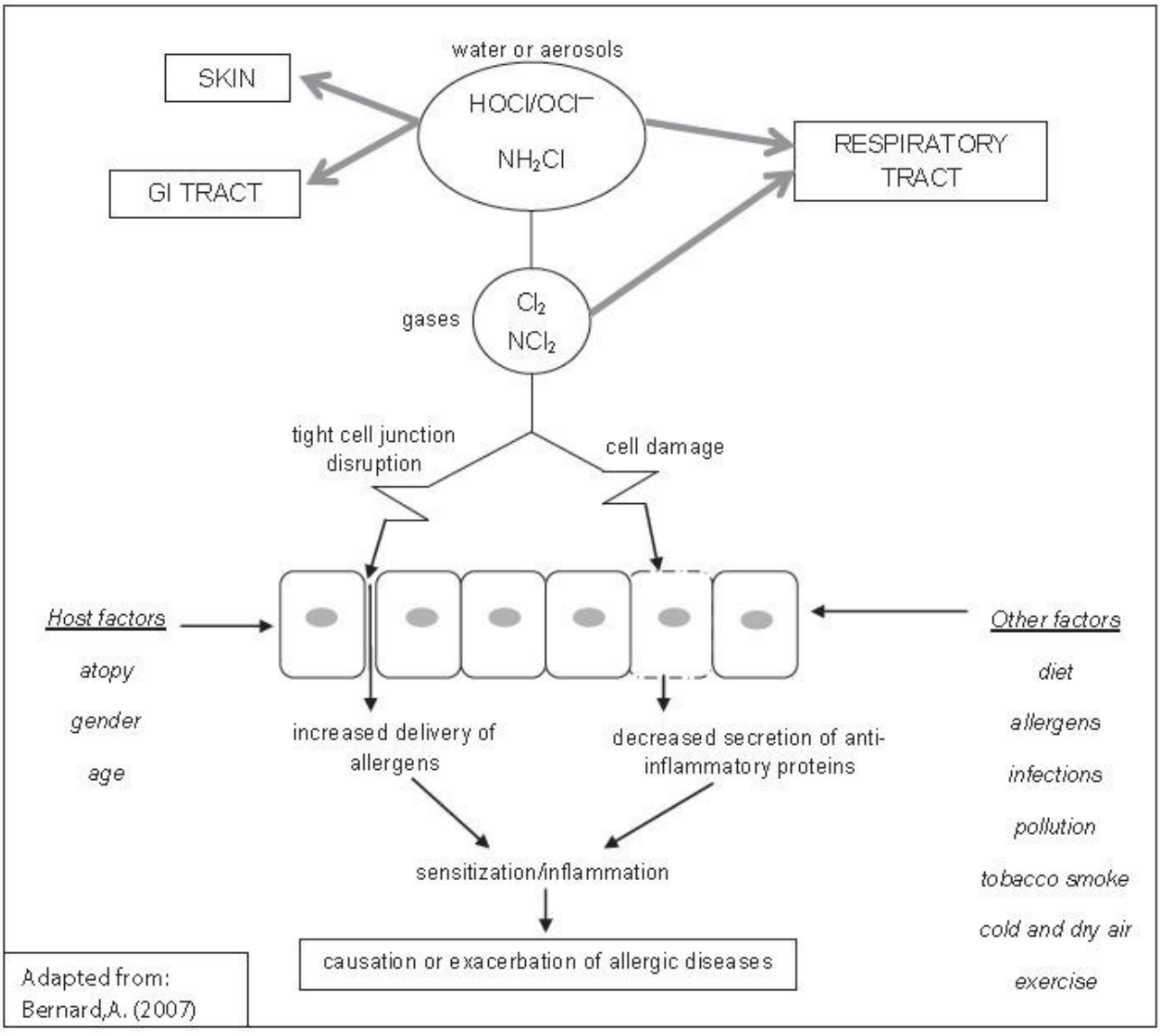
Malfunctioning of chlorine disinfection installations is a potential problem, which may cause serious side effects from acute exposure (Bernard et al., 2006). Asthma attacks, laryngeal oedema (swelling of the larynx) and upper and lower airway mucosa damage may result (Nemery et al., 2002). Reactive Airways Dysfunction Syndrome (RADS) and hyperventilation are linked to serious effects from prolonged chlorine exposure (Nemery et al., 2002). Individuals who routinely swim are at risk of chlorine exposure, especially competitive swimmers who are typically swimming up to two times a day (Bernard et al., 2006). The greater number of years individuals swim in an indoor chlorinated pool, the greater risk for developing wheezing and early onset of asthma (Bernard, Nickmilder, Voisin, & Sardella, 2009). Lifeguards, swim instructors and other personnel exposed to DBP's have an increased risk for developing occupational asthma, which is activated by inadequate ventilated facilities (Bernard et al., 2009). Drowning and chemical hazards are factors, which contribute to creating an unsafe aquatic environment. Air and chemical quality in indoor swimming facilities affect exposure levels in individuals (World Health Organization, 2006).

Protection and Action

The exposure of environmental toxins can be reduced by preventative measures, which are reinforced through education programs. Adults and children alike will continue to swim for leisure and physical activity, however, a reduction

Figure 2

The illustration above shows how chlorine based oxidants, which can be found in the air or water can enter the body through the respiratory tract or penetrate through the skin to cause either acute or chronic effects.



and/or avoidance of going to indoor swimming facilities that are disinfected using chlorine will decrease the inhalation of contaminants (Voisin & Bernard, 2008). Many studies have reported of the risk of exposure of young children (under 7 years of age) to the effects of chlorination, when young children use chlorinated pools, especially pools that emit a potent odor of chlorine (Bernard et al., 2006; Bernard et al., 2007). There are many ways in which a swimming facility can take action to reduce the harmful effects of chlorine and its by-products. Firstly, pools can maintain strict procedures regarding the control and supervision of free chlorine levels in water. Pool operators should receive training on how to measure the chemical content of water with periodic review trainings (Weisel et al., 2009). The World Health Organization (WHO) has published guidelines stating that levels of free chlorine in public pools should not exceed 3 mg/L or 3ppm (Voisin & Bernard, 2008). Health Canada advises a free residual of 1.0 to 3.0 ppm of chlorine (Health Canada, 2009). Secondly, encouraging improved swimmer hygiene in pools can reduce the production of DBP's, which are produced when chlorine combines with organic compounds (natural organic matter and bather load input) (Zwiener et al., 2007). Persuading pool patrons to shower before entering the pool, using toilet facilities, and applying watertight diapers will reduce bather load input in pools (World Health Organization, 2006; Zwiener et al., 2007). Thirdly, pools should maintain adequate ventilation around the pool's surface to reduce the inhalation of volatile by-products. The creation of volatile disinfection by-products, such as chloroform and nitrogen trichloride, is inevitable and will escape into the air, which become hazardous toxins in contained airtight facilities (World Health Organization, 2006). The WHO (2006) recommends appropriate ventilation rates of at least 10 litres of fresh air/s/m2 of water surface area. Proper ventilation will not only reduce the toxic by-product load on swimmers but also on lifeguards and other pool workers (Voison & Bernard, 2008). The management of pools has a responsibility to its patrons to balance the preservation of "the positive health effects of swimming through exercise while reducing other potential adverse health risks." (Zwiener et al., 2007).

Discussion

It is evident that the most vulnerable populations effected by chlorine exposure include children, lifeguards and elite swimmers. The exposure to chlorination by-products affects their upper and lower respiratory systems leading to either acute or chronic conditions such as asthma. In a 2006 study, research suggested that regular indoor pool attendance beginning at an early age in life could promote the development of asthma (Spivey, 2006). The main route of exposure to chemicals inducing a respiratory reaction occurs from the inhalation of aerosols that are actively floating in the air on the surface of the water. In order to reduce the burden placed on the body, the best way to reduce exposure is through avoidance and prevention.

The most recent studies conducted on adverse health effects of chlorine use in indoor swimming pools obtained a collection of accurate findings. The use of the data collected from association studies illustrated the relationship between the rate of exposure to chlorine and the prevalence of upper and lower respiratory symptoms. A positive correlation was shown between exposure to chlorine and the prevalence of childhood asthma in a 2007 study, in which more than 180,000 individuals participated (Nickmilder & Bernard, 2007). However, the unknown strength of the correlation cannot allow a conclusion on childhood asthma and other subsequent respiratory conditions to directly link to an increased exposure to chlorine. Studies suggest that further research is required to assess the relationship of exposure to chlorine and its adverse health effects.

Government agencies, such as Health Canada, set regulations for the mechanical and chemical maintenance of public swimming pools (Health Canada, 2009). These guidelines are needed in order to ensure the safety of both pool users and staff (Voisin & Bernard, 2008). Regulations set forth in public pools, include maintaining safe water quality, such as disinfectant and pH level, and filtration systems. Additionally, the proper use of handling chemicals, testing equipment following pool log documentation and routine inspection are critical for safety (Health Canada, 2009; Voisin & Bernard, 2008). Violations to swimming pools from routine inspection, which threaten public health, should be temporarily closed until proper guidelines are adhered to.

Conclusion

Children, elite swimmers, lifeguards and employees of indoor swimming pools are at the highest risk for developing respiratory conditions, such as asthma, due to their increased exposure to chlorine. The use of chlorine continues to be the main source for water disinfection, but the formation of disinfectant by-products such as chloramines from chlorine and organic substances proves to be hazard-

ous to health. Poor ventilation in swimming pools, the production of chloramines and mouth breathing from swimmers are all contributing factors to the development of upper and lower respiratory conditions.

Scientific research indicates that the early onset of asthma is associated with exposure to chlorinated swimming pools; however, more research needs to be conducted on the link between exposure and other health risks. Allergies and bronchitis are two health conditions that have yet to be linked to exposure from chlorinated swimming pools. In order to reduce the strain on the health care system and health professionals, funding for additional research needs to be provided. With further research, individuals will be able to determine at what level of exposure a specific health condition occurs. Furthermore, it will allow the ability to link a condition with the individual's involvement in swimming.

In order to reduce health hazards related to exposure from indoor swimming pools, actions by individuals, communities, governments and industries need to occur. At the individual level, there needs to be increased education and awareness about the effects of chlorine from indoor swimming pools on the body. Communities need to work with one another to advocate for policies and preventative strategies that the government would implement in the future. At the industrial level, substitution of water disinfectants that would decrease heath risks for the vulnerable populations need to be further researched. Bromination, which has several similar properties to chlorine, is an alternative method for water disinfectants.

References

Bernard, A. (2007). Chlorination products: Emerging links with allergic diseases. *Current Medicinal Chemistry, 14* (16), 1771-1782. doi: 10.2174/092986707781058940

Bernard, A., Carbonnelle, S., de Burbure, C., Michel, O., & Nickmilder, M. (2006). Chlorinated pool attendance, atopy, and the risk of asthma during childhood. *Environmental Health Perspectives, 114*(10),1567-1573. Retrieved from http://ehp.niehs.nih.gov/

Bernard, A., Carbonnelle, S., Dumont, X., & Nickmilder, M. (2007). Infant swimming practice, pulmonary epithelium integrity, and the risk of allergic and respiratory diseases later in childhood. *Pediatrics, 119*(6). 1095-1103. doi: 10.1542/peds.2006-3333

Bernard, A., Nickmilder, M., & Voisin, C. (2008). Outdoor swimming pools and the risks of asthma and allergies during adolescence. *The European Respiratory Journal, 32* (4), 979-988. doi: 10.1183/09031936.00114807

Bernard, A., Nickmilder, M., Voisin, C., & Sardella, A. (2009). Impact of chlorinated swimming pool attendance on the respiratory health of adolescents. *Pediatrics, 124* (4), 1110-1118. doi: 10.1542/peds.2009-0032

Bougault, V., Turmel, J., Levesque, B., & Boulet, L. P. (2009). The respiratory health of swimmers. *Sports Medicine, 39*(4), 295-312. doi: 10.2165/00007256-200939040-00003

Canadian Center for Occupational Health and Safety. (2003). Working safely with chlorine. Retrieved from http://www.ccohs.ca/oshanswers/chemicals/chem_profiles/chlorine.html

Carbonnelle, S., Francaux, M., Doyle, I., Dumont, X., de Burbure, C., Morel, G., ... & Bernard, A. (2002). Changes in serum pneumoproteins caused by short-term exposures to nitrogen trichloride in indoor chlorinated swimming pools. *Biomarkers, 7*(6),464-478. doi: 10.1080/13547500210166612

Carraro, S., Pasquale, M. F., Da Fre, M., Rusconi, F., Bonetto, G., Zanconato, S., & Baraldi, E. (2006). Swimming pool attendance and exhaled nitric oxide in children. The *Journal of Allergy and Clinical Immunology, 118*(4), 958-960. doi: 10.1016/j.jaci.2006.07.016

Centers for Disease Control and Prevention. (2010a). Violations identified from routine swimming pool inspections—selected states and counties, United States, 2008. *Morbidity and Mortality Weekly Report, 59* (19), 582-587. Retrieved from http://www.cdc.gov/mmwr/

Centers for Disease Control and Prevention. (2010b). Your disinfection team: Chlorine & pH. Retrieved from http://www.cdc.gov/healthywater/pdf/swimming/resources/disinfection-team-chlorine-phfactsheet.pdf

Eggleston, P. A. (2007). Chlorinated pools and the risk of asthma. *Environmental Health Perspectives, 115*(5), A240-A241; author reply.

Font-Ribera, L., Kogevinas, M., Zock, J. P., Nieuwenhuijsen, M. J., Heederik, D., & Villanueva, C. M. (2009). Swimming pool attendance and risk of asthma and allergic symptoms in children. *The European Respira-*

tory Journal, 34(6), 1304-1310. doi: 10.1183/09031936.00180608

Health Canada. (2009). Swimming pool and spa sanitation. Retrieved from http://publications. gc.ca/collections/Collection/H113-1-24-1999E.pdf

Ishioka, M., Kato, N., Kobayashi, A., Dogru, M., & Tsubota, K. (2008). Deleterious effects of swimming pool chlorine on the corneal epithelium. *Cornea, 27*(1), 40-43. doi: 10.1097/ICO.0b013e318156d20

Life Saving Society. (2004). Public wading pool safety standards. Retrieved from http://www.lifesaving.org/download/PublicWadingPoolSafetyStandards.pdf

Lourencetti, C., Fernández, P., Marco, E., Ballesté, C., Grimalt, J. O., Font, L., ... & Kogevinas, M. (2008). Trihalomethane levels in exhaled breath as indicators of exposure to disinfection by-products in indoor swimming pools using chlorine and bromine as disinfectants. *Epidemiology, 19* (6), 191-192. doi: 10.1097/01.ede.0000340079.17087.fc

McGrath, P. (Ed.). (2004). Guidelines for swimming pools: Province of Nova Scotia. Department of Labour and Environment. **Editor's note: this reference (1987 Department of Health Public Swimming Pool Guidelines) was retired by the Department in late 2011 because there were sections that were scientifically out of date.

Nemery, B., Hoet, P. H., & Nowak, D. (2002). Indoor swimming pools, water chlorination and respiratory health. *European Respiratory Journal, 19*(5), 790-793. doi: 10.1183/09031936.02.00308602

Nickmilder, M., & Bernard, A. (2007). Ecological association between childhood asthma and availability of indoor chlorinated swimming pools in Europe. *Occupational and Environmental Medicine, 64*(1), 37-46. doi: 10.1136/oem.2005.025452

Nieuwenhuijsen, M. J. (2007). The chorine hypothesis: Fact or fiction? *Occupational and Environmental Medicine, 64*(1), 6-7. doi: 10.1136/oem.2006.029850

Spivey, A. (2006). Swimming in allergens: Pool use and asthma. *Environmental Health Perspectives, 114* (10), A600. Retrieved from http://ehp.niehs.nih.gov/

Thomas, L., & Murray, V. (2008). Review of acute chemical incidents involving exposure to chlorine associated with swimming pools in England and Wales, June-October 2007. *Journal of Public Health, 30*(4), 391-397. doi: 10.1093/pubmed/fdn073

Uyan, Z. S., Carraro, S., Piacentini, G., & Baraldi, E. (2009). Swimming pool, respiratory health, and childhood asthma: Should we change our beliefs? *Pediatric Pulmonology, 44*(1), 31-37. doi: 10.1002/ppul.20947

Villanueva, C. M., Font-Ribera, L., Gómez, F. P., Barreiro, E., Zock, J., Nieuwenhuijsen, M. J.,...Kogevinas, M. (2008). Acute exposure to disinfection by-products in swimming pools and short term changes in respiratory biomarkers [Abstract]. *Epidemiology, 19*(6), S107 doi: 10.1097/01.ede.0000339853.71572.70

Voisin, C., & Bernard, A. (2008). Risks of allergic reactions to chlorination byproducts in swimming pools. *Environnement Risques & Santé, 7*(6), 417-423. doi: 10.1684/ers.2008.0181

Wattigney, W. A., Kaye, W. E., & Orr, M. F. (2007). Acute hazardous substance releases resulting in adverse health consequences in children: Hazardous substances emergency events surveillance system, 1996-2003. *Journal of Environmental Health, 70*(4), 17-24. Retrieved from http://www.neha.org/JEH/

Weaver, W. A., Li, J., Wen, Y., Johnston, J., Blatchley, M. R., & Blatchley, E. R., III. (2009). Volatile disinfection byproduct analysis from chlorinated indoor swimming pools. *Water Research, 43*(13),3308-3318. doi: 10.1016/j.watres.2009.04.035

Weisel, C. P., Richardson, S. D., Nemery, B., Aggazzotti, G., Baraldi, E., Blatchley, E. R., III, ... & Sattar, S. (2009). Childhood asthma and environmental exposures at swimming pools: State of the science and research recommendations. *Environmental Health Perspectives, 117*(4), 500-507. doi: 10.1289/ehp.11513

World Health Organization. (2006). Guidelines for safe recreational water environments. Volume 2: Swimming pools and similar environments. Retrieved from http://apps.who.int/iris/bitstream/10665/43336/1/9241546808_eng.pdf?ua=1

Zwiener, C., Richardson, S. D., DeMarini, D. M., Grummt, T., Glauner, T., & Frimmel, F. H. (2007). Drowning in disinfection by products? Assessing swimming pool water. *Environmental Science & Technology, 41*(2), 363-372. doi: 10.1021/es062367v