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Commentary

# Keep swimming but stop peeing in the pools

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Swimming is excellent exercise and offers many health benefits. However, the "chlorine smell" in swimming pools may be a turn-off for some people. Although this smell is often thought to be of chlorine, it actually comes from volatile compounds that are produced from unintended reactions between disinfectants (*e.g.*, chlorine) and organic matter in the water (Li and Blatchley, 2007; Zwiener et al., 2007; Schmalz et al., 2011; Daiber et al., 2016). Body fluids, such as sweat and urine, are among the sources of this organic matter that contribute to the formation of disinfection byproducts (DBPs) (Richardson et al., 2007; Arnaud, 2016; Tang et al., 2016).

According to a 2012 survey of 1000 people in the United States, approximately one in five admitted to "peeing in the pool" (Wiant, 2012), a result consistent with a previous survey conducted in 2009. A recent study published in *Environmental Science & Technology Letters* (Blackstock et al., 2017) shows evidence of urine in swimming pools and hot tubs. This new evidence is obtained from the analyses of pool water for a common artificial sweetener, acesulfame potassium (ACE). This sweetener is often used in processed food and is widely consumed; it is chemically stable and passes through the body unchanged into urine (Voltz et al., 1991; von Rymon Lipinski and Hanger, 2001; Buerge et al., 2009; Liu et al., 2014; Tran et al., 2014; Wu et al., 2014). Therefore, the researchers measured this sweetener as a urinary marker and estimated the equivalent amount of urine in swimming pools and hot tubs. The results indicate the presence of approximately 75 L of urine in a swimming pool one-third the size of a standard Olympic pool.

Within one day of its online publication on March 1, 2017 (Blackstock et al., 2017), the study was covered by more than 100 news stories in multiple media and languages (Altmetric, 2017). The coverage ranged from scientific press, such as Science Daily (ACS, 2017), to popular press, such as The Guardian (Devlin, 2017), BBC News (2017), CBC News (2017), and CBS News (Gunaratna, 2017). The work even inspired a science communicator to write a poem, educating people "please do not piss into the pool" (Illingworth, 2017). At the time of submission of this commentary on March 5, 2017, there were 172 news stories from 151 news outlets around the world (Altmetric, 2017).

The initial objective of the study by Blackstock et al. (2017) was "to investigate a marker for urine in swimming pools and

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hot tubs". Monitoring human urinary input to swimming pools is important because "urine contains many nitrogenous organics, such as urea, ammonia, amino acids, and creatinine. These compounds can react with disinfectants (e.g., chlorine) in swimming pools to form disinfection byproducts (DBPs)." Most DBPs may not cause adverse health effects at concentrations they are typically found in water. However, studies conducted using higher concentrations of emerging DBPs have shown various toxic effects (Richardson et al., 2007; Fu et al., 2017).

Blackstock et al. (2017) chose acesulfame potassium (ACE) as an indicator of human urinary input on the basis of its widespread consumption and urinary excretion without metabolism. Using a liquid chromatography tandem mass spectrometry technique that they developed, they analyzed more than 250 water samples from 31 swimming pools and hot tubs from two Canadian cities. They also analyzed more than 90 samples of input tap water used to fill the pools and tubs. The concentration of ACE in the swimming pools and hot tubs ranged from 30 to 7110 ng/L, up to 570 times higher than that in the corresponding input tap water (6–15 ng/L).

The authors repeatedly collected and analyzed water samples from two different sized swimming pools, ~416,000 L (110,000 U.S. gallons) and ~832,000 L (220,000 U.S. gallons), for three weeks. These pools are about 1/6 and 1/3 the standard Olympic-size. The average concentrations of ACE in these two pools over the three weeks were 156 ng/L and 210 ng/L, respectively, with a similar relative standard deviation of 15%–18%. On the basis of the volume of each pool and the ACE concentration, the authors estimated the total mass of ACE present in the two pools as 65 mg and 176 mg, respectively. They further determined an average concentration of ACE in a pooled Canadian human urine sample (N = 20) to be 2360 ng/L. Using this average ACE concentration in Canadian urine, they estimated the equivalent volume of urine to be approximately 30 L in the smaller pool and 75 L in the larger pool. These represent less than 0.01% of the total water volume in the pools.

The crude estimation of volume of urine present in the pools was intended to demonstrate the feasibility of using ACE as a marker for urine input. Although the daily analyses of ACE in six replicate water samples from each of the two pools for three weeks provided useful measures of the concentrations of ACE in these pools, concentrations of ACE in other pools could be very different. Many parameters could influence the concentrations of ACE present in the pools. For example, differences in bather load and demographics could contribute to differences in input of ACE into the pools. The size of pools, the amount and rate of water loss from the pools, and the corresponding refill of water into the pools would affect dilution of the input ACE in the swimming pools. Furthermore, the estimation of urine volume from the measured concentrations of ACE in the pools hinges on the concentration of

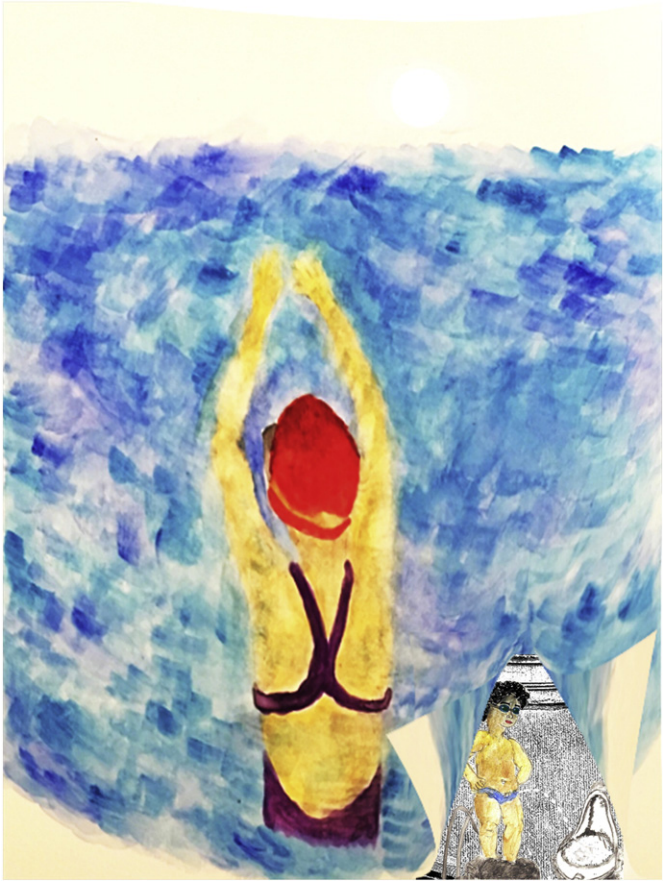

**Fig. 1 – Enjoy swimming for active and healthy living and practice good swimmer hygiene. Art design by Yi Li, Edmonton, Alberta, Canada.**