Chloroform from swimming pools, a significant source of atmospheric chloroform in Phoenix?

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Introduction
Chloroform (CHCl₃) is a well-documented disinfectant by-product (DBP) of water chlorination. Chloroform is an important atmospheric pollutant by its direct health effects as well as by its contribution to photochemical smog formation.¹ Chloroform outgassing from swimming pools is not typically considered a source of atmospheric chloroform because swimming pools are scarce compared to other sources. However, urban areas in hot climates such as Phoenix generally contain a substantial amount of swimming pools per capita,² potentially resulting in significant atmospheric fluxes. In this study, swimming pools as a source of atmospheric chloroform is investigated. Measurements of chloroform concentrations are used to estimate fluxes and determine impacts on Phoenix air pollution.

What causes the CHCl₃?

![Figure 1: Illustration of chemistry occurring within swimming pools](image)

Example: chlorination of ethanol
C₂H₅OH + 4Cl₂ + H₂O → CHCl₃ + 5Cl⁻ + H₂O(HCl)₃

Other DBPs are simultaneously produced, such as dichloroacetic acid, bromoform, bromochloromethane, dibromochloromethane... more than 100 DBPs have been identified.¹ These additional DBP can contribute to halogenated VOCs in the atmosphere.

*note: brominated pools show same behavior, producing bromoform instead of chloroform.

Chloroform Sources in Phoenix

No emissions sources in Arizona were reported to EPA since 1999, but that doesn’t mean zero emissions! Average ambient CHCl₃ concentrations in Phoenix are 60 ppt, or 60 molecules CHCl₃ in 10¹² molecules “air”. So CHCl₃ is coming from somewhere.

Possible sources of CHCl₃ include natural (vegetation, soil, ocean) and anthropogenic (industry, drinking water chlorination, landfill processing) sources. Natural processes generally account for 90% of all CHCl₃ emissions.²

Arizona ranks second in swimming pools per capita behind Florida.³ However, pools in FL are distributed across the entire state whereas pools in Arizona are largely concentrated within Maricopa county. It’s possible that the high number of CHCl₃-emitting pools within a valley such as Phoenix are as a sum responsible for a substantial portion of the emissions of CHCl₃ into the urban air. This can become a potential public health issue, and can also contribute to photochemical smog.

Chloroform Flux From Swimming Pools

Flux was estimated based on previously collected swimming pool data⁴

\[ F = k_L \left( \frac{c_w - c_a}{c_a} \right) \frac{k_w}{k_H} \]

where \( k_L \) is the liquid mass transfer of CHCl₃, \( c_w \) is the concentration of CHCl₃ in water, \( c_a \) is the concentration of CHCl₃ in the air above the water, and \( k_H \) is Henry's constant. Using literature data, the estimated flux is 90 µg CHCl₃/m²·hr⁴ for the residential pool (41 m²),⁵ that correlates to 32 g CHCl₃/yr which doesn’t seem significant. Furthermore, Maricopa county has an average swimming CHCl₃ emissions is estimated to 286,000 metric tons; this means that swimming pools in Maricopa county emit an estimated 9.23 metric tons CHCl₃/yr! In comparison, the global annual anthropogenic CHCl₃ emissions are estimated to be 70,000 metric tons. Swimming pools in Phoenix result in an estimated 0.01% of the global anthropogenic emissions. Future work will refine this estimate.

Chloroform at the National Level

Ambient CHCl₃ concentrations are higher in Phoenix than most other cities of comparable size and industrial composition.

Implications

Chlorination of swimming pools might be a significant source of chlorinated VOCs in an area of high pool density such as Phoenix. Some cities have considered limiting the number of new swimming pool permits approved per year in hopes of reducing the community’s water and electricity needs; a reduction in CHCl₃-producing swimming pools as a secondary consequence might be beneficial for air quality in Phoenix. Additionally, alternate disinfection schemes might be recommended or required in efforts to reduce air pollution.

Future work

Laboratory experiments investigating how much CHCl₃ is produced by chlorination of various compounds have already begun. By examining the impacts of chlorination of cosmetics such as lotions and sunscreen, CHCl₃ fluxes can be estimated to better constrain emission fluxes and the resulting public health risks. Additionally, emission estimates for Phoenix will be refined as more data becomes available.

References


