Scalable Environmental Proxy Sensing Framework for Real-Time Detection and Risk Characterization of Chloramine Accumulation in Indoor Aquatic Systems

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Indoor pools pose an under-monitored public health risk, as chloramines, formed from chlorine reacting with swimmer-derived compounds, accumulate in air and are linked to asthma and respiratory irritation. Most facilities monitor only water chemistry, leaving airborne exposures unmeasured. To address this, we developed a low-cost, portable proxy system to assess air quality conditions associated with chloramine formation. The system integrates a digital SGP30 metal-oxide gas sensor, a DHT22/SHT31 temperature-humidity sensor, and a Raspberry Pi to continuously track environmental variables. By establishing baseline conditions, the device detects relative increases in gas levels, temperature, and humidity using simplified status categories. Data is displayed in real time on an OLED screen, logged for analysis, and abnormal conditions are immediately flagged. Testing across multiple indoor pool sessions showed consistent detection of deviations during periods of increased swimmer activity. Statistical analysis demonstrated strong significance, with a p-value of less than 0.001, confirming that observed changes were not due to random variation. Additionally, total volatile organic compounds (TVOC) were found to be strongly correlated with the calculated risk index ($R^2 = 0.991$), and relative humidity showed a similarly strong linear relationship with TVOC levels ($R^2 = 0.992$), supporting the system's effectiveness as a proxy for chloramine-associated conditions. This system provides an accessible, scalable approach to improving air quality monitoring in indoor aquatic facilities. By enabling real-time detection of elevated exposure conditions, it supports data-driven ventilation strategies and contributes to reducing respiratory health risks for exposed populations.

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