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Rapid detection of residual antibiotics in wastewater treatment plants by surface enhanced Raman scattering (SERS) analysis

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Abstract

Wastewater reuse has become an important part of the water resource portfolio in California. However, residual pharmaceuticals and personal care products in wastewater are important human health concerns in water reuse. Real time and sensitive sensors are needed to monitor the safety of recycled water. Here, we report the development of a label-free sensor utilizing surface enhanced Raman scattering (SERS) for detection of quinoline, a residual antibiotic commonly found in wastewater. SERS relies on the enhancement of light scattered from molecular vibrations near metal surfaces to provide a molecular fingerprint. Using gold nanoparticles chemically assembled onto polymer substrate as a SERS substrate, we tested the sensitivity, specificity and background interference for detection of quinoline in wastewater. Primary and secondary sewage effluents from a local wastewater treatment plant were collected for testing. Pure quinoline was seeded into wastewater in a range of concentration from 1 ppb to 10 ppm. Quinoline seeded as the same concentration range in DI water was used as a control sample. Water samples were spotted directly onto SERS substrate; and SERS spectra were collected by a Renishaw InVia Raman Microscope immediately following sample spotting to avoid sample evaporation. 625 reproducible spectra were collected for each sample. Spectral data were processed using non-negative matrix factorization (NMF) before splitting data into test/train (20/80) data sets for linear regression analysis. The results of seeded quinoline concentration showed a linear relationship between quinoline concentrations and spectral data. No significant background noise from the residuals in wastewater was observed based on the comparison of spectral profile of quinoline in DI water and that in sewage effluent. Detection for quinoline was possible at the lowest concentration, 1 ppb, in all samples. The uniform nano-gaps between gold nanoparticles assembled on the polymer substrate are attributed as the key factor to provide robust data sets to differentiate background interference from quinoline in wastewater effluents. Small nano-gaps exclude larger molecules, which selectively enhances signal from smaller molecules such as quinoline. This proof of concept study indicates that SERS substrates are able to distinguish and quantify specific target molecules even in a complex sample have strong potential for applications in detecting antibiotic contamination in water.