Development of an Optical Nanosensor for Detection of Quaternary Ammonium Compound Disinfectants

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Abstract

Single-walled carbon nanotubes (SWCNTs) display unique thermal, electrical, and optical properties. Due to their non-photo bleaching fluorescence in the near-infrared region, high optical sensitivity, and stability, these materials are ideal for developing minimally invasive, real-time, optical nanosensors. SWCNTs can be functionalized to detect various molecules and species such as viruses, proteins, mRNAs, neurotransmitters, COVID-19 viruses, etc. Use of disinfectants has increased in public places and households during the COVID-19 pandemic to mitigate virus burden. Overuse and improper handling of disinfectants may cause adverse impact to human health and the environment. Among many disinfectant chemicals, quaternary ammonium compounds (QACs) are key ingredients in a large number of commercial disinfectants due to their antimicrobial efficacy. The increase in use of QACs to disinfect various surfaces and materials has resulted in an increase in human and environmental exposure to these chemicals. Recent studies showed that QACs could enter blood circulation, and can increase in inflammatory cytokines, decrease mitochondrial function, and disrupt cholesterol homeostasis. Thus, real-time detection of QACs is crucial. In this project, we investigate an optical nanosensor comprised of single-walled carbon nanotubes (SWCNTs), tiny tools that are 50,000–100,000 times thinner than a human hair, functionalized with anionic surfactants for detection of QAC disinfectants.

Background and Objective

Structure of SWCNT

Graphene Sheet Carbon Nanotube

SWCNT-based sensors
- Exhibit stable fluorescence in the near-infrared region (900 nm – 1600 nm)
- Change their fluorescence precisely upon interaction with target molecules
- Can be encapsulated in a variety of materials to tailor functional sensors
- Can be integrated into portable, implantable, and wearable sensors

Use of Disinfectants during the COVID-19 Pandemic

Increased Exposure to QACs

Effects on Human Health and the Environment

Materials and Methods

Preparation of SWCNT-based sensors
- Prepared aqueous suspension of surfactant-coated SWCNTs complexes
- Prepared aqueous suspension of surfactant-coated SWCNTs complexes
- Treated with increasing concentrations of selected QACs to potential nanosensors in solution
- Measured the nanotube’s optical responses via near-infrared fluorescence measurements from 950 nm – 1250 nm

Sensor Response to QACs

Results

Sensor Response to QACs

QACs quenched SWCNT fluorescence compared to the control
As concentration of QACs increases, fluorescence response increase
Different QACs quenched the fluorescence of nanosensor at differing rates.

Conclusions & Future Work

Conclusions:
- Prepared aqueous suspension of surfactant-coated SWCNTs complexes
- Nanosensor detected QACs in solution.
- Response was facilitated by electrostatic interactions.

Future Work:
- Optimize sensor for specificity and sensitivity
- Expand QACs library for detection
- Investigate sensor function in native environment

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