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Functionalized fluorescent nanomaterials for sensing pollutants in the environment: A critical review

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A B S T R A C T

Quantitation of environmental pollutants has gained momentum due to its widespread requirement in the fields of clinical research, occupational hygiene, public health, and societal welfare. The use of functionalized fluorescent nanomaterials (FFNMs: e.g., metal nanoparticles, semiconductor quantum dots, carbon dots, nanotubes, and nanocrystals) has opened a new avenue for creating simple, selective, and non-invasive real-time analysis, as they can satisfy the growing demand for rapid and cost-effective quantitation. Here, we discuss novel strategies for the qualitative and quantitative analysis of a variety of organic and inorganic environmental pollutants by detecting changes in photo-physical or optical properties (e.g., fluorescence, absorbance, and color) of FFNMs used as probes. Particularly, we emphasize potential approaches for the synthesis and characterization of FFNMs and their underlying interactions with environmental pollutants. The simplification of design and enhancement of specificity towards target analytes should be pursued further to upgrade their real-world applicability in diverse fields.

1. Introduction

In recent years, nanomaterials (NMs) have attracted much attention due to their unique electronic, optical, catalytic, and magnetic properties [1,2]. As nanomaterials also offer great stability, sensitivity, and size-dependent optical properties, they have been employed in diverse applications including sensing, drug delivery systems, catalysis, gas/energy storage, adsorption, etc. [3–8]. Due to such vast applicability, the scientific awareness of NM-based sensing applications has been expanding rapidly, as evidenced by more than several thousands of research articles (>5000) published over the past decade.

Functionalization of NMs enhances their binding affinity towards specifically desired target analytes. Such development is ideal for sensing harmful substances during various environmental remediation processes. Additionally, functionalized fluorescent nanomaterials are advantageous for a number of sensing applications due to their porous structure, large surface area, high loading capacity, and specific interaction with analytes (such as lead, cadmium, copper, mercury, etc.). Moreover, functionalization of NMs can considerably improve their stability in aqueous solution by capping their surfaces with stabilizing agents, such as biomolecules, surfactants (cationic/anionic), or organic molecules. In addition to protecting their luminescence properties, the controlled surface capping of nanoparticles further endows them with target-specific sensing capabilities.

Among the different NMs, silver (AgNPs) and gold nanoparticles (AuNPs) have been extensively investigated for a variety of sensing applications. A broad absorption band in the visible region of the

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