Synthesis and Application of Silica and Calcium Carbonate Nanoparticles in the Reduction of Organics from Refinery Wastewater

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Abstract
The fast-growing interest in technological innovations in the remediation of contaminants from the oil industry effluent discharge results in global environmental concern. With the rapid expansion of global oil refineries, the management of refinery wastewater has emerged as a pressing issue. The industrial sector experiences stringent environmental restrictions along with the discharge of mounting amounts of refinery wastewater, imposing the search for innovative treatment techniques to achieve an effective wastewater management system. The release of refinery wastewater into natural ecosystems leads to environmental hazards, thereby demanding fresh strategies for proficient wastewater treatment.

Nanotechnology oriented treatment processes are revolutionizing the development of cleaner environment. This research aims to apply nanoparticle-mediated treatment of refinery wastewater by synthesizing two distinct nanoparticles, silica (SiO$_2$) and calcium carbonate (CaCO$_3$), in the reduction of chemical oxygen demand (COD). SiO$_2$ and CaCO$_3$ nanoparticles were selected for their unique properties, including biocompatibility, thermal stability, and low toxicity. The study aimed to evaluate their efficacy under varying processing conditions and to assess their potential in addressing the pressing issue of organics removal in refinery wastewater.

The research employs facile methods to synthesize these nanoparticles. Stober's method was employed for synthesizing SiO$_2$, while a combination of precipitation and homogenization processes was used for CaCO$_3$. To examine their structure and performance, various characterization techniques were employed including Scanning Electron Microscope (SEM), Fourier-Transform Infrared Spectroscopy (FTIR), and X-Ray Diffractometer (XRD) to check the surface morphology, uniformity, and surface structure of the synthesized nanoparticles.

The SEM analysis of silica nanoparticles reveals well-distributed, non-aggregated, and spherical particles of size around 100 nm. Similarly, in the case of CaCO$_3$, SEM shows cubic crystal calcite structure with nano-scale particles also sized at 100 nm. FTIR analysis provided insights into the functional groups on their surfaces, offering a foundation for understanding their chemical attributes. XRD helped identify their crystal phases and grain sizes, contributing to the understanding of their structural characteristics.

The adsorption studies were conducted by performing a series of batch experiments by changing the effluent solution pH, stirring time, stirring speed, and dosage of nanoparticles in the reduction of chemical oxygen demand (COD) from petroleum refinery effluent. The percentage reduction in chemical oxygen demand was measured using the COD test. After wastewater treatment, the nanoparticles are separated, washed, and reused for cost savings and reduced environmental pollution.
The experimental results show that CaCO$_3$ nanoparticles exhibited the highest reduction in COD (69%), highlighting their potential for effective organic pollutant removal. Furthermore, the recovered nanoparticles after treatment can be reused in the construction industry, aligning with zero emissions goals, and promoting sustainable environmental practice.

This research holds importance beyond the confines of the laboratory, with direct implications for the oil and gas sector, especially in the context of effluent treatment. The environment-friendly synthesis techniques, combined with the nanoparticles’ effectiveness in lowering COD levels, provide promising and sustainable solutions for addressing the industry’s environmental challenges. Ongoing studies are exploring the feasibility of scaling up these methods and the potential for reusing nanoparticles across multiple treatment cycles.