

# CHAPTER I

## INTRODUCTION

### I.1 Background

Mesoporous silica (MS) is a recent advancement in nanotechnology, featuring a honeycomb-like silica structure with numerous empty channels capable of holding bioactive compounds. Its unique structure, consisting of nanometer-sized pores with uniform size distribution, provides a high surface area, offering excellent adsorption potential (Yadav *et al.*, 2016). Furthermore, functional groups can be added to the surface of mesoporous silica to enhance its selectivity in capturing specific ions or molecules from solutions. These properties make adsorbent materials highly effective in various applications, such as treating heavy metal contamination in water (Filha *et al.*, 2006).

Sulfonic acids, which are salts or esters of sulfonic acids, contain the functional group  $RS(=O)_2O^-$ , where R represents an organic group. This functional group is commonly used to modify protein crosslinkers like N-hydroxysulfosuccinimide (Sulfo-NHS) and sulfosuccinimidyl 4-(N-maleimidomethyl)cyclohexane-1-carboxylate (Sulfo-SMCC) (Tabuchi and Sakai, 2021). Sulfonate functional groups can be deposited on the surface of mesoporous silica, and these strongly acidic groups are particularly efficient in capturing heavy metal ions, such as hexavalent chromium (Cr(VI)). The presence of sulfonate groups enhances the interaction between the adsorbent material and the contaminant, improving adsorption capacity. As a result, mesoporous silica modified with sulfonate groups is a promising solution for addressing Cr(VI) pollution in water sources (Furtmair *et al.*, 2021).

To produce mesoporous silica with an ordered structure and controllable pore size, the use of surfactant templates like Cetyltrimethylammonium Bromide (CTAB) has gained popularity (Khoeini *et al.*, 2019). CTAB is a cationic surfactant consisting of a hydrophilic head (trimethylamine) and a hydrophobic tail (cetyl). As a quaternary ammonium surfactant, it can form micelles in aqueous solutions, making it an effective emulsifying agent. Utilizing CTAB as a template in mesoporous silica synthesis results in materials with uniform, nanometer-sized pores (Kumar *et al.*, 2021). The CTAB template has been extensively used in research focused on mesoporous silica synthesis, and its application is considered a key factor in developing effective adsorbent materials for the removal of Cr(VI) from industrial chrome waste solutions. This study has the potential to combine the advantages of mesoporous silica, sulfonate groups, and the CTAB template to significantly enhance the sorption efficiency of Cr(VI) from waste solutions (Khoeini *et al.*, 2019).

While mesoporous silica (MS) with functional group modifications and the use of surfactant templates like Cetyltrimethylammonium Bromide (CTAB) have been extensively studied for various applications, including the removal of heavy metals from contaminated water, there is limited research on the combined effect of sulfonate functionalization and CTAB templating in enhancing the adsorption efficiency of Cr(VI) ions from industrial waste solutions (Khoeini *et al.*, 2019). A large surface area is provided by the mesoporous structure, and the CTAB template regulates the pore size, which is necessary for efficient adsorption. The adsorption efficiency is raised by the sulfonate groups because they greatly improve the

interaction with Cr (VI). This novel method of removing heavy metals from wastewater, which hasn't been thoroughly investigated, combines structural and chemical alterations. The synergistic potential of these components to significantly improve Cr(VI) removal remains underexplored, leaving a gap in understanding the optimal conditions for maximizing adsorption performance (Huang *et al.*, 2016).

This study aims to investigate the synthesis of sulfonate-modified mesoporous silica using a CTAB template and evaluate its effectiveness in removing Cr(VI) ions from industrial waste solutions. By exploring the combined effects of mesoporous structure, sulfonate functionalization, and CTAB templating, this research seeks to develop an efficient adsorbent material for Cr(VI) remediation.

## **I.2 Research Purpose**

1. Synthesize sulfonate group-modified mesoporous silica using a CTAB template.
2. Characterize the properties of the sulfonated mesoporous silica with the CTAB template.
3. Compare the adsorption efficiency of sulfonated mesoporous silica with a CTAB template to that of non-sulfonated mesoporous silica with the same template.