# Chapter 1
# Valorization of Abandoned Lakhouat Mine Waste in Metakaolin-Based Geopolymers:
## Mechanical Properties and Immobilization of Toxic Elements

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## ABSTRACT

*This study investigates the valorization of abandoned Lakhouat mine waste (LKH) through its incorporation into metakaolin-based geopolymers. The waste material, mainly composed of carbonates with minor amounts of metal-bearing minerals such as sphalerite (ZnS), galena (PbS), and marcasite ($FeS_2$), was blended with calcined kaolinitic clay and activated using sodium hydroxide (NaOH) solutions. The resulting geopolymers were characterized by XRD, XRF, compressive strength measurements, FTIR spectroscopy, and leaching tests to assess their chemical composition, structural development, and capacity for heavy metal immobilization. The influence of NaOH concentration (8, 10, and 12 M), mine waste content (0, 10, 20, 50, 80, and 100 wt.%), and curing duration (7, 14, 21, and 28 days) was systematically evaluated. The optimal formulation was achieved using 10 M NaOH and curing for 28 days, resulting in materials with high compressive strength, a dense and cohesive matrix, and efficient immobilization of potentially toxic elements (Pb, Zn, As, and Cd). These results highlight the potential of Lakhouat mine waste as a raw material for sustainable geopolymer production, offering an environmentally responsible approach to mine waste management and the development of eco-friendly construction materials.*

## 1. INTRODUCTION

Tunisia possesses a rich geological and mining heritage, with mineral exploitation dating back to Antiquity and continuing into the present day (Mobbs, 2005). Mining activities have primarily targeted various ores, notably iron, lead, zinc, and barite, which are mainly concentrated in the northwestern region of the country (Jemmali et al. 2014; Ayari et al. 2025). While these activities provide valuable resources, they also generate substantial amounts of waste, posing significant environmental and socio-economic challenges. Former mining operations often leave large volumes of

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