Deactivation and Valorization of an inflammable mining residues into a highly efficient catalyst

Faiza Ferjani, Inès Esma Achouri*
Research Group on Technologies and Processes (GRTP), Sherbrooke, Québec (Canada)
Canadian Research Chair on Process Intensification
*Corresponding and presenting author: ines.esma.achouri@usherbrooke.ca

Magnesium, widely used in industries like automotive for its lightness and strength, generates substantial mining waste in its production, particularly in Quebec. These wastes, including by-products from electrolysis and foundry processes (BPEFs), are not only environmentally challenging due to their complex composition but also release hazardous gases like hydrogen (H_2) and ammonia (NH_3). Tergeo, a Quebec-based magnesium producer, generates 1,100 metric tons of such flammable and hazardous residues, currently stored in Val-des-Sources. With recycling centers unable to process these residues, developing sustainable management strategies has become crucial.

This project aims to reduce the environmental footprint of magnesium production by transforming waste into catalysts for methane-to-hydrogen conversion, enhancing sustainability and circular economy efforts.

The first step in the approach involved an exhaustive characterization of the residues. XRD, ICP-MS, ion chromatography, and elemental analysis were employed. These analyses were complemented by TGA-MS and SEM to detail the chemical composition and structure of the residues. Subsequently, experiments were carried out to decontaminate and deactivate the residues. These experiments led to the generation of hydrogen and a secondary residue enriched in magnesium hydroxide ($Mg(OH)_2$) and magnesium oxide (MgO). The project uses enriched residue to develop an innovative catalyst infused with nickel (Ni) through the wet impregnation method. On a laboratory scale, the catalyst's efficiency in methane dry reforming is being evaluated.

The characterization of the residues revealed a total mass composition of 95.09%, with specific elements being detailed. This thorough analysis was crucial to determining the composition, which was previously unknown due to the residues originating from various stages of magnesium production and their inherent complexity. A notable finding was the presence of chlorine at a concentration of 32% by weight, a factor that significantly complicates the synthesis of MgO-based catalysts. Chlorides, even in low concentrations of around 1% by weight, have been observed to cause sintering and grain growth in MgO-supported catalysts during reforming tests. Additionally, chloride anions during catalyst preparation can increase the mobility of MgO, negatively impacting the specific surface area of the resulting product. Consequently, tests have been designed to remove impurities detrimental to the catalyst's activity. The EDX analysis of the fresh-BPEFs, accompanied by a SEM image, reveals aggregates of small particles averaging approximately 444 nm. In contrast, the EDX analysis of the deactivated-BPEFs, also supported by a SEM image, shows that the chlorine content becomes virtually undetectable. The predominant presence of magnesium and oxygen promotes the formation of $Mg(OH)_2$ and MgO. Ongoing trials focus on optimizing H_2 recovery and refining the catalyst preparation process, utilizing wet impregnation techniques for effective methane dry reforming. Catalytic tests indicate a high H_2 yield and a high conversion rate for CH_4 and CO_2. The characterization of both fresh and used catalysts, along with additional tests, are scheduled to evaluate the effectiveness of this innovative catalyst in the reaction. The successful valorization of these residues advances the industry, reduces environmental impacts, and promotes sustainable waste management.