# Regeneration of iron-molybdate catalyst for methanol to formaldehyde reaction: molybdenum recovery and circular economy

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***Highlights***

- Multi-step chemical purification enables recovery of molybdenum from spent catalysts
- Regenerated catalyst achieves >91% selectivity and kinetics comparable to conventional material
- Recovery yields exceed 70%, supporting industrial circular economy and cost reduction
- Sustainable approach reduces waste generation and raw material consumption in chemical industry

## 1. Introduction

Iron-molybdate $Fe_2(MoO_4)_3$ catalysts are widely used for the selective oxidation of methanol to formaldehyde, a key intermediate for resins, polyurethanes, and other industrial products [1]. After prolonged use, these catalysts become solid waste requiring disposal, generating significant environmental concerns. The increasing price of molybdenum, a strategic metal critical for numerous industrial applications, has stimulated growing interest in catalyst recovery strategies aligned with circular economy principles [2]. The recovery of molybdenum from spent catalysts represents both an environmental purpose and an economic opportunity, addressing the challenge of strategic metal availability while reducing industrial waste. This work, carried out in collaboration with Clariant, investigates the regeneration of spent iron-molybdate catalysts through chemical purification and their successful reintroduction into the industrial production cycle, demonstrating a viable pathway toward more sustainable chemical manufacturing [3].

## 2. Methods

Spent catalysts containing $Fe_2O_3$ and various metal impurities (Ca, Mg, Zn, Na, K) were subjected to a multi-step chemical purification process specifically designed to remove contaminants while recovering the active iron-molybdate phase. The regenerated powder was mixed with fresh conventional catalyst powder at controlled ratios and processed into tablets for final catalyst preparation. Comprehensive characterization included ICP analysis for chemical composition, XRD for crystalline phase identification, $N_2$ physisorption measurements for surface area and porosity, FT-IR spectroscopy for molecular structure, and rheological testing to assess powder processability. Catalytic performance was evaluated in a pilot plant for methanol oxidation to formaldehyde, with particular focus on selectivity, conversion, and kinetic behavior compared to fresh catalyst.

## 3. Results and discussion

The multi-step purification procedure enabled catalyst recovery yields exceeding 70%, producing regenerated powders suitable for reintegration into industrial catalyst manufacturing. XRD analysis confirmed successful regeneration of the $Fe_2(MoO_4)_3$ crystalline phase and ICP analysis demonstrated effective removal of metal impurities, restoring chemical composition. Surface characterization via $N_2$ physisorption and FT-IR spectroscopy confirmed structural compatibility between regenerated and fresh materials, while rheological tests demonstrated adequate processability for tablet formation. Catalytic performance tests in the pilot plant revealed that the mixed conventional-regenerated material achieved formaldehyde selectivity exceeding 91%, comparable to conventional fresh catalysts. Kinetic analysis demonstrated reaction rates similar to the fresh catalyst, indicating successful restoration of catalytic activity.

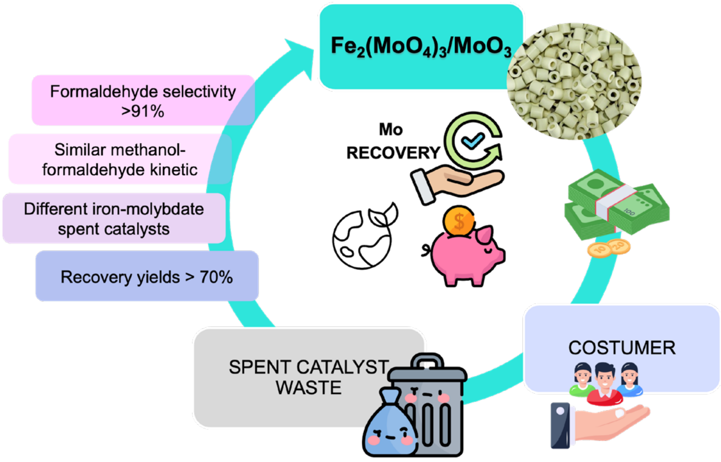


**Figure 1.** Chemical recovery of iron-molybdate spent catalyst

## 4. Conclusions

This work demonstrates a viable chemical regeneration strategy for recovering molybdenum from spent iron-molybdate catalysts, achieving recovery yields above 70% and catalytic performance (>91% selectivity) similar to fresh material. The successful reintegration of regenerated catalyst into industrial production represents a concrete application of circular economy principles in the chemical industry, addressing both the challenge of strategic metal availability and the environmental concern of catalyst waste disposal. This approach offers significant potential for cost reduction through decreased raw material consumption while supporting more sustainable chemical manufacturing.

## References


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***Keywords***
Spent catalyst regeneration; Iron-molybdate; Molybdenum recovery; Circular economy