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Ozone-assisted catalytic oxidation of toluene, ethanol, and their mixture over copper-manganese oxide catalyst

Keywords

VOC; ozone-assisted catalytic oxidation; $CuMnO_x$ catalyst; mixture

Aim

Assessment of interaction effects during simultaneous ozone-assisted catalytic oxidation of toluene and ethanol over a $CuMnO_x$ catalyst.

Justification

In recent years, the emission of volatile organic compounds (VOCs) from industries and transportation has increased significantly, which is harmful to all ecosystems. The presence of VOCs, which are defined as carbon-based chemicals with boiling points below 250°C, can lead to a decrease in air quality and contribute to a variety of health issues. Among all the VOC removal techniques, catalytic oxidation stands out as an economically viable technology for the abatement of VOCs pollutants. However, the conventional catalytic oxidation technique, utilizing oxygen (O_2) as the oxidation, requires high reaction temperatures (200–500°C), making it energy-intensive. In contrast, ozone-assisted catalytic oxidation (OzCO), using ozone (O_3) as the oxidant, lowers the reaction temperature to 50–150°C [1], offering a more energy-efficient alternative.

While VOC OzCO has been extensively studied for individual compounds, VOCs typically occur as mixtures in both indoor and outdoor environments. Previous studies have noted mutual effects in binary VOC mixtures during OzCO. For instance, in VOC OzCO of a toluene-acetone mixture, acetone conversion was inhibited, whereas toluene conversion was enhanced [2]. This underlines the necessity of investigating the mutual effect between different VOC components in OzCO.

Program

Given that aromatic hydrocarbons and alcohols significantly contribute to overall VOC emissions, the activities in the framework of this thesis focus on toluene and ethanol as model compounds representing these two groups. Both pure model component experiments as well as their mixtures will be investigated, seeking to understand the effectiveness and limitations of VOC mixture OzCO:

- Acquiring intrinsic kinetic data for toluene and ethanol OzCO, individually (T=50 – 150 °C, C_{VOC} = 100 – 1000 ppm, O_3/VOC= 2 – 15, P_{tot}=100 kPa, spacetime = 100 – 1000 kg_{cat} s/$mol_{VOC,0}$)
- Acquiring intrinsic kinetic data for OzCO of binary mixture of toluene and ethanol (T=100 °C, C_{tol} = 100 – 1000 ppm, C_{eth}=100 – 1000 ppm, C_{tot}= 1000 ppm, P_{tot}=100 kPa, O_3/(eth+tol)= 10 , spacetime = 500 kg_{cat} s/$mol_{VOC,0}$)
- Exploring the effect of operating conditions on OzCO of the binary mixture (T=50 – 150 °C, C_{tol} = 500 ppm, C_{eth}=500 ppm O_3/VOC= 2 – 15, P_{tot}=100 kPa, spacetime = 100 – 1000 kg_{cat} s/$mol_{VOC,0}$)

Reference

[1] B. Liu, J. Ji, B. Zhang, W. Huang, Y. Gan, D.Y.C. Leung, H. Huang, Catalytic ozonation of VOCs at low temperature: A comprehensive review, J Hazard Mater. 422 (2022). https://doi.org/10.1016/j.jhazmat.2021.126847.

[2] M. Aghbolaghy, J. Soltan, N. Chen, Low Temperature Catalytic Oxidation of Binary Mixture of Toluene and Acetone in the Presence of Ozone, Catal Letters. 148 (2018) 3431–3444. https://doi.org/10.1007/s10562-018-2536-8.