Highly efficient styrene removal by smectites impregnated with Ni, Cu and Ag transition metals

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Styrene is one of the most important and essential industrial chemicals belonging to volatile organic compounds (VOCs). Chemically it is an aromatic hydrocarbon with vinyl group in the structure. This increases its reactivity including the ease of polymerization. In industry large quantities of styrene are used in the production of e.g.: polystyrene, polyester resins, and fiberglass. However the compound itself is considered harmful even at very low concentration. In manufacturing facilities workers are mostly exposed to styrene vapors when working with unsaturated polyester resins. Especially the gelcoat spraying technique leads to high release of styrene. The emission can be substantially reduced by using closed molding techniques but still this is not always possible. Therefore a highly-efficient ventilation system is necessary in the workplaces. Such system usually contains a set of filters filled with granulated activated carbon. Although this material is efficient it cannot be regenerated or reused after saturation.

Our earlier research showed that surfactant-intercalated smectites show a very high uptake of styrene [1]. In most cases the adsorption was higher than for activated carbons. This was connected with simultaneous hydrophobization of clay mineral surfaces and expansion of the interlayer space due to intercalation of cationic surfactants. Most importantly the smectite-based adsorbents saturated with styrene can be introduced into several products. One drawback of this approach is connected with a relatively large content of surfactant that must be used for smectite modification (~20-30% wt.). Earlier reports showed that doping the surface of mineral materials (e.g. zeolites) with transition metals improves adsorption of aromatic hydrocarbons. Therefore we decided to investigate the effect of Ni, Cu and Ag impregnation of smectites on the styrene uptake.

The montmorillonite from Texas (STx) and beidellite from Idaho (BId) were modified by wet impregnation method using Ni(II), Cu(II) and Ag(I) in varying amounts. The styrene uptake experiments were conducted in a closed system to study the adsorption at the highest possible styrene concentration in gaseous form. The research revealed that small content of introduced metals (below 2% wt.) led to a remarkable increase in styrene uptake (from ~1% wt. for the raw smectites up to ~200-350% wt. styrene content in the materials after 48 h). These values were even higher than for the surfactant-intercalated smectites (~40-80% wt.) and desorption of styrene in time was not observed. The presence of metals dispersed on clay surfaces gave rise to new active centers which were responsible for π-complexation properties of smectites. The simple ion-exchange with *d*-block metals induced high selectivity for π-electron-rich styrene molecules.

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References

[1] Matusik J., Koteja-Kunecka A., Maziarz P., Kunecka A. (2022). Styrene removal by surfactant-modified smectite group minerals: Efficiency and factors affecting adsorption/desorption. Chemical Engineering Journal 428, 130848.