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Adsorption of Chromium (III) on Fired Brick Particles

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Introduction

Chromium is present in the environment in both trivalent and hexavalent oxidation states. Cr(III) occurs naturally and is an essential micronutrient that is involved in metabolizing sugar, protein and fat (Park and Jung, 2001). Heavy metals such as chromium are not decomposed through biological means, and they are toxic to aquatic organisms as well as humans if exposure levels are sufficiently high. Chromium compounds are present in many types of industrial effluents, including electroplating, metal finishing, leather tanning, pigments and photography. In order to comply with the tolerance limits, it is essential that industries treat their effluents to reduce the chromium to acceptable levels before discharge in order to maintain environmental quality and human health. Ion exchange, electrochemical precipitation, chemical precipitation and adsorption are some acceptable treatment methods practiced worldwide (Kocaoba and Akein, 2004). Most of these methods suffer from drawbacks such as high capital and operational cost and/or problems associated with the disposal of sludge. The objective of this research is to investigate the removal of Cr(III) species from aqueous solution, through adsorption, by brick particles fired at different temperatures, and to optimize the firing temperature for the most efficient removal.

Materials and methodology

Materials

Standard solutions of Cr(III) were prepared using $Cr_2(SO_4)_3$ (98% assay). Unfired, dry brick clay samples obtained from Gelioya, Kandy, were first sieved to obtain particles of diameter < 1.0 mm, and fired in the laboratory at 100 °C, 200 °C, 300 °C, 400 °C, 500 °C, 600 °C, 700 °C, 800 °C and 900 °C.

Instrumentation

The Carbolite CTF 12/100/900 furnace was used to fire brick clay samples. GBC 933AA model Atomic Absorption Spectrometer was used to measure Cr(III) concentration, while DRT-model ISCE turbidity meter was used for turbidity measurements.

Research design

The amount of Cr(III) adsorbed by brick was determined by treatment of standard Cr(III) solutions of concentration varying from 1.00 mg dm^{-3} to 50.0 mg dm^{-3} with brick samples fired at each temperature. These measurements were then used for adsorption isotherm analysis. Comparison between the percent Cr removal from aqueous solutions and the turbidity of aqueous brick suspensions was also investigated.

Results and discussion

The amount of Cr(III) ions (in μg) adsorbed on a unit mass (1.000 g) of laboratory fired brick clay samples (d < 1.0 mm) varies linearly with the initial concentration of Cr(III) in solution for samples fired up to 400 °C. Samples fired at higher temperatures show less extent of adsorption at all concentrations investigated, and further they obey Type I adsorption isotherm (amount adsorbed vs. concentration), reaching saturation at higher concentrations. This observation supports monolayer coverage, suggesting the formation of inner sphere complexes between Cr(III) and surfaces of minerals containing Fe, Al and Si present in brick matrix. Change in the extent of adsorption with temperature is probably due to phase changes and chemical processes that would occur at high temperatures.

An interesting feature observed thorough these measurements is that the percent removal of Cr(III) by brick generally increases up to a certain intermediate temperature followed by a decrease at high temperatures. However, turning points of percent removal – temperature curves, and the shape of the curves depend on the initial Cr(III) concentration (Figure 1).

Aqueous suspensions prepared using brick particles fired at temperatures between 200 °C and 600 °C are very clear while those at lower and higher temperatures are not.

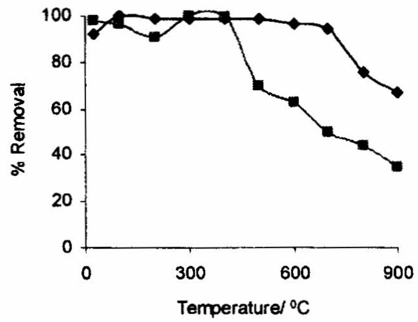

Figure 1. Percent removal – temperature relationship for (♦) 10 ppm Cr(III) and (■) 50 ppm Cr(III)

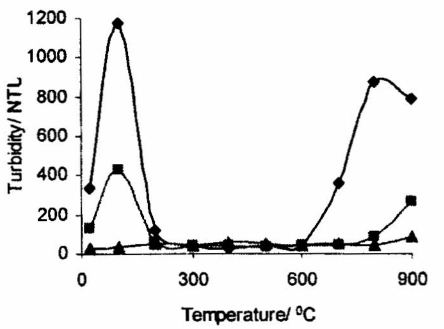

Figure 2. Turbidity of aqueous suspensions of brick particles fired at different temperatures. (♦) no Cr(III) (■) 10 ppm Cr(III) (▲) 50 ppm Cr(III)

This is evident through turbidity measurements shown in Figure 2, where the turbidity is initially decreased from 1200 NTU, then leveled off at a value less than 50 NTU, and finally increased up to 800 NTU. When Cr(III) is introduced to brick particle suspensions, turbidity is decreased for all concentrations higher than 10 mg dm^{-3} Cr(III). Nevertheless, the general shape of turbidity – temperature relationship is not changed significantly.

When both turbidity and percent removal are considered, brick fired at intermediate temperatures range results in low turbidity and high Cr(III) removal. This behavior although depends on the initial concentration of Cr(III), a firing temperature of 400 °C is selected as the optimal temperature for the most efficient removal and the lowest turbidity.

Conclusions

The adsorption behavior of Cr(III) on brick particles highly depends on the initial Cr(III) concentration and the firing temperature of brick. Although the Cr(III) /brick system obeys both the Langmuir and Freundlich adsorption isotherms, brick treated at higher temperatures tend to follow monolayer adsorption. Comparison of turbidity of brick particle suspensions to which Cr(III) are added and the percent Cr(III) removal clearly indicates that the optimum temperatures for the highest removal and lowest turbidity is 400 °C. Such finding would be extremely important in designing effluent treatment methodologies using fired brick particles, a low-cost and a readily available material.

References

Kocaoba, S. and Akein, G. (2004) *Adsorption Science and Technology*, 22, 401-410.

Park, S. and Jung, W. (2001) *Carbon Science*, 2, 15-21.