The use of a nanoscale copper catalyst in the catalytic decomposition of water polluted with organic dyes

Samia A. Kosa
Chemistry Department, Faculty of Science, King Abdulaziz University, Jeddah, KSA
kousah@kau.edu.sa

Introduction

The removal of organic and inorganic pollutants is an aim shared by many researchers throughout the world [1]. Heavy metals are commonly removed by adsorbents and ion exchangers to ensure total removal [2-3]. The situation is somewhat different for organic pollutants because it is nearly impossible to remove 100% of organic pollutants from an aqueous stream through adsorption processes. In this case, the catalytic decomposition of organic pollutants may be the best choice to remove these pollutants [4-5]. Environmentally safe oxidants such as hydrogen peroxide are used either as catalysts or to promote thermal decomposition [6]. The use of hydrogen peroxide is limited by the fact that it is considered to be a mild oxidant, meaning that even in catalytic decomposition it will not totally decompose the organic pollutants into CO_2 and H_2O, potentially resulting in more organic pollution fragments. The use of excited molecular oxygen may be the solution to this problem. For example, singlet oxygen has distinct properties that enable it to be highly reactive, achieving total decompositionof the organic pollutant. The fact that the reaction of singlet oxygen is considered to occur via a free radical mechanism means that the decomposition will occur in only few minutes.

This study reports the removal of organic dye (pollutants)with a system consisting of a 5% solution of sodium hypochlorite (commercial grade), oxygen gas, and a supported copper oxide catalyst to generate singlet oxygen.

Materials and Methods

First, aluminum hydroxide was calcined at 550ºC for 3 hours to convert it into Al_2O_3. Copper was loaded as copper nitrate (20%) on the resulting gamma alumina by impregnation with stirring for 2h and then dried and calcined at 450ºC for 3 hours.

Oxygen was introduced to a 0.5 mL solution of 5% sodium hypochlorite at 100 ppm from methyl orange by passing oxygen at 20 mL/min in an open system. Copper oxide catalyst was added (0.5 g) and samples from methyl orange were collected and separated by centrifuge at several time points for analysis. For comparison, the same reaction was performed with and without catalyst and with and without oxygen.

Results and Discussion

The XRD patterns of the supported CuO catalyst over alumina are shown in Figure 1. This figure clearly shows that a pure phase of CuO was formed over an amorphous phase of gamma alumina.

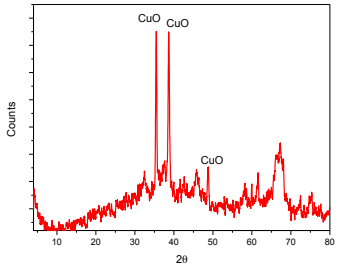

Figure 1 shows the XRD of CuO catalyst deposited on alumina.

Figure 2 shows the SEM image of the 20wt% CuO/Al_2O_3 catalyst. This image clearly shows that the CuO crystals appear as separated aggregates at different intervals over the alumina surface. The EDX analysis of these aggregates (Fig.3) showed that these aggregates are mainly composed of CuO.

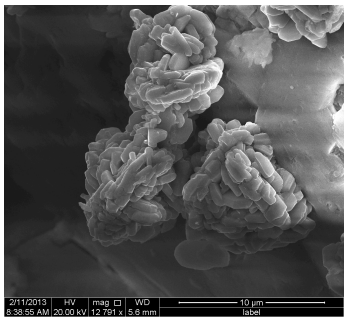

Fig.2. SEM of CuO on alumina.

Significance

The system of acopper catalyst, a solution of commercial chlorate, and any organic dye pollutant could be effective in the decomposition of organic pollutants.

The above system can be easily scaled up at low cost to achieve effective pollutant removal.

The decomposition followed a free radical reaction mechanism and produced singlet oxygen.

References

1- D. Zadaka, Y.G. Mishael, T. Polubesova, C. Serban, S. Nir, Modified silicates and porous glass as adsorbents for removal of organic pollutants from water and comparison with activated carbons, Applied Clay Science, 36, 1–3, 2007, 174-181.

2- Yong Sik Ok, Jae E. Yang, Yong-Seon Zhang, Su-Jung Kim, Doug-Young Chung, Heavy metal adsorption by a formulated zeolite-Portland cement mixture, Journal of Hazardous Materials, 147, 1–2, 2007, 91-96.
3- S.K. Pitcher, R.C.T. Slade, N.I. Ward, Heavy metal removal from motorway storm water using zeolites, Science of The Total Environment, 334–335, 2004, 161-166.
4- Michael E. Jenkin, Kevin C. Clemitshaw, Ozone and other secondary photochemical pollutants: chemical processes governing their formation in the planetary boundary layer, Atmospheric Environment, 34, 16, 2000, 2499-2527.
5- Toshiyuki Mori, Motoi Takahashi, Hiromitsu Nakajima, Tetsuya Fujimoto, Mamoru Watanabe, Synthesis and photo-catalytic property of a hollandite-type compound (K2Ga2Sn6O16), Journal of the European Ceramic Society, 26, 4–5, 2006, 583-587.
6- P. Ratnasamy, D. Srinivas, H. Knözinger, Active Sites and Reactive Intermediates in Titanium Silicate Molecular Sieves, Advances in Catalysis, Academic Press, 2004, 8, 1-169.