Center for Physical Sciences and Technology

APPLICATION OF WASTE MATERIAL FOR CATALYTIC DEGRADATION OF METAL COMPLEX DYE

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Introduction

The amount of dyes used in various industries is increasing, posing a risk to the environment and human health. Colored metal surfaces are used in decorative applications as well as for technical purposes. Organic dyes into wastewater are generally obtained from the coloring and rinsing procedures. Catalytic degradation of the dyes could be as an alternative method for adsorption processes. Various iron-based materials (oxides, hydroxides, oxyhydroxides) are classified as promising heterogeneous Fenton catalysts (Thomas et al., 2021; Garrido-Ramírez et al., 2010). Recently, the catalytic activity of iron-rich wastes of various composition generated during industrial processes were tested for activating hydrogen peroxide. The purpose of this study was to evaluate the efficiency of groundwater treatment waste (GWTW) in catalytic oxidative degradation of organic dye Sanodure Green LWN (SG dye).

Experimental

The catalytic degradation of the chromium complex azo dye used for anodized aluminum coloring was studied. The sunlight as a cheap and sustainable source of energy was explored. GWTW (Fig. 1a) was collected from a drinking water treatment plant in Vilnius (Lithuania) where it is produced as a result of cascade aeration of groundwater. The elemental sediment composition was determined by EDS and WDXRF methods. It was found that the basic chemical elements are Fe, O, Ca, P, and Si (Table 1). X-ray diffraction analysis showed that this material, dried at room temperature, was amorphous. The morphology of the adsorbent was investigated by SEM (Fig. 1b) and TEM (Fig. 1c).

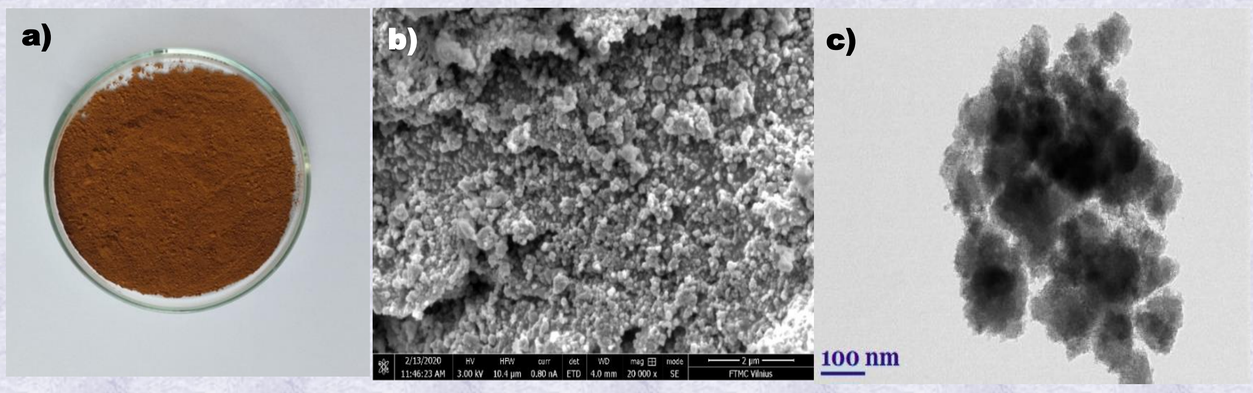

Fig. 1. Image of GWTW (a); SEM (b) and TEM (c) images of GWTW before dye removal.

Table 1. Elemental composition of GWTW.

Elements	Mass %	
	WDXRF	EDS
O	44.91	46.02
Fe	43.53	42.85
Ca	3.961	4.570
P	2.513	3.002
Si	1.914	2.740
S	0.174	0.297
Mn	0.266	0.280
Mg	0.150	0.252
Cl	0.009	0.005

Results and discussion

GWTW main components are ferrihydrite ($Fe(OH)_3$), goethite (α-FeOOH) and hematite (α-Fe_2O_3) that can activate the decomposition of peroxide and radical formation (Fig. 2). The dye anions (RSO_3^-) are electrostatically attracted by the positive catalyst surface, where the dye degradation process in the presence of H_2O_2 occurs. The activity of GWTW catalyst in oxidative degradation of metal complex dye has been investigated depending on the reaction time (Fig. 3), catalyst loading (Fig. 4), pH and temperature. The rate of the dye degradation increased with an increase in catalyst dose from 0.5 to 1.0 g L^{-1}. The rise in temperature from 20 to 60 ˚C and solution acidity from pH 5 to pH 3 positively influenced the dye removal process.

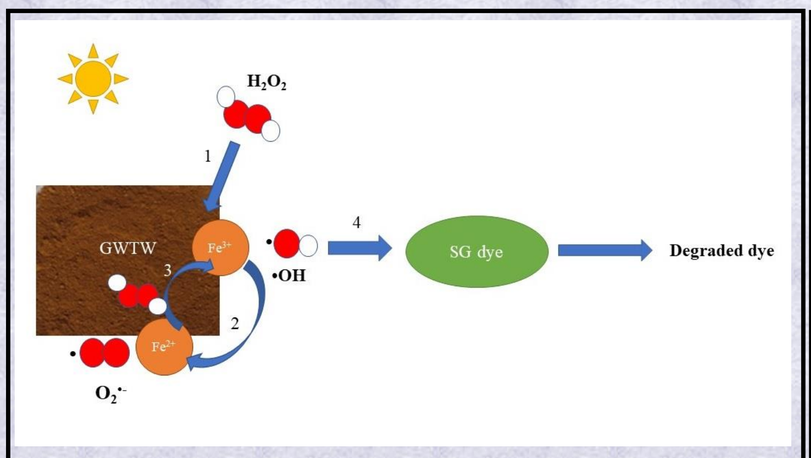

Fig. 2. Scheme of the degradation of the SG dye using the heterogeneous Fenton-like catalyst prepared from groundwater treatment waste (GWTW).

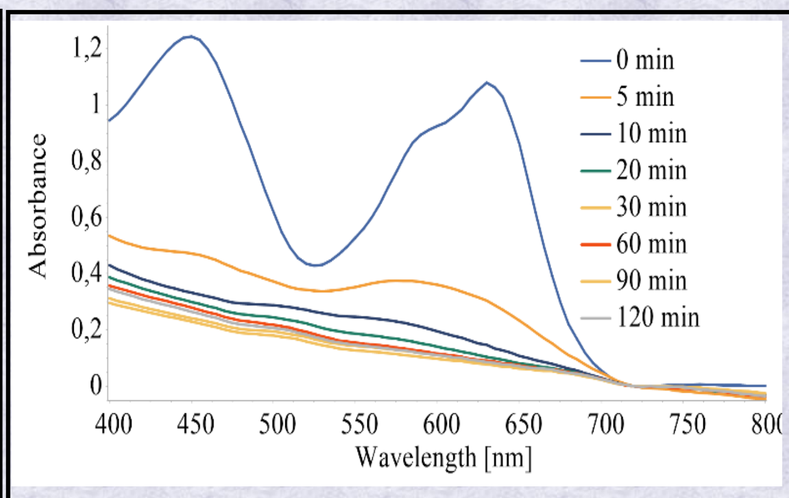

Fig. 3. Time-dependent absorption spectra of the dye solution during degradation reaction with H_2O_2 and GWTW catalyst

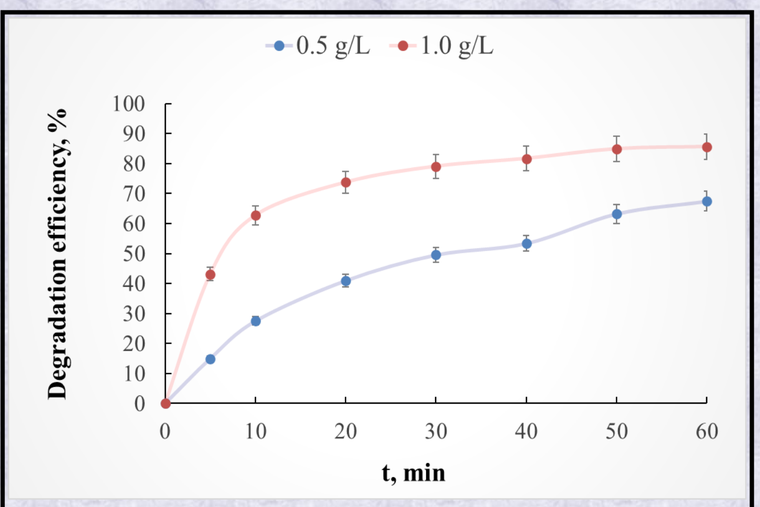

Fig. 4. The impact of GWTW catalyst loading and reaction time on the dye degradation efficiency.

Conclusions

The obtained results show that the nanostructures of GWTW produced as a result of the deironing of groundwater by cascade aeration are effective catalysts in the Fenton-like oxidation of metal complex dye in the presence H_2O_2 leading to discoloration of wastewater. The catalytic activity of GWTW in a Fenton-like reaction in sunlight is distinctly related to the pH of the system. The SG dye degradation increases with decreasing pH and increasing temperature. The maximum oxidative degradation rate of 70 % decoloration in the first 5 min and 92 % after 50 min of 100 mg L^{-1} SG dye solution was reached at 50 °C and pH 3.

References

1. N. Thomas, D.D. Dionysiou, S.C. Pillai. J. Hazard. Mater. 404 (2021) 124082.
2. E.G. Garrido-Ramírez, B.K.G. Theng, M.L. Mora. Appl. Clay Sci., 47 (2010) 182–192.