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Perchlorate uptake by wheat straw based adsorbent from aqueous solution and its subsequent biological regeneration

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HIGHLIGHTS

- ▶ The adsorption mechanism of perchlorate by MWS was ion exchange.
- ▶ Favorable properties of MWS for perchlorate adsorption were determined.
- ▶ The maximum adsorption capacity of perchlorate by MWS was relatively high.
- ▶ Maximum adsorption capacities of perchlorate decreased with increase in temperature.
- ▶ Biological-reduction of loaded MWS was feasible and efficient.

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ABSTRACT

A new innocuous disposal for perchlorate was presented in this study. Perchlorate was first concentrated by wheat straw based adsorbent, and then biologically reduced by mixing with heterotrophic bacteria. The physicochemical properties of modified wheat straw (MWS) were evaluated by SEM, BET specific area, TGA, ^{13}C solid state NMR and Raman spectra. The adsorption capacity for perchlorate was determined by the kinetics and isotherm tests. The surface areas of the raw wheat straw and MWS were in range of 4.6–5.9 $m^2\ g^{-1}$, which illustrated the absence of porous adsorption in potential adsorption mechanism. The uptake of perchlorate by MWS was based on ion exchange, which would benefit the biological reduction on surface of the biosorbent. The maximum adsorption capacity (Q_{max}) of perchlorate by MWS was about 119.0 mg g^{-1} (20 °C) and decreased as temperature grew. The mixed perchlorate-reduction bacteria could reduce about 91% of loaded perchlorate (23.94 mg g^{-1}) on MWS in the first biological-reduction cycle and 87% in second cycle, indicating an available method of innocuous disposal for concentrated perchlorate wastes.

1. Introduction

Perchlorate (ClO_4^-) is an alarming inorganic contaminant that has been detected in various public groundwater and surface water systems; environmental contamination by perchlorate has been reported at numerous locations in China, Unites States and some other countries [1–5]. Perchlorate has been found to occur in both naturally and man-made manufactured substance [6,7]. The sources of the perchlorate pollution are mainly due to the extensive use of perchlorate salts in manufactures of rocket propellants, fireworks, weapons, automobile airbags, batteries, analytical chemistry products and safety flashboards for highway construction [7–9]. Natural perchlorate exists in nitrate deposits and some kinds of fertilizers [6]. Perchlorate has raised public health concerns due to its potential toxicity. A draft toxicity assessment conducted by the USEPA indicates that the potential human risks of perchlorate exposures include effects on nervous systems, inhibition of thyroid activity and mental retardation in infants [10,11]. USEPA has also included perchlorate in the Contaminants Candidate List (CCL) with a reference dose of 0.7 μg/kg/day, which was equivalent to the level of 24.5 ppb in drinking water [12]. So a new drinking water standard of 24.5 μg/L was adopted for perchlorate in 2005; and several States in USA recommended a perchlorate standard in range of 1–20 ppb.

However, perchlorate is difficult to be removed from water due to its non-volatility, highly solubility, and kinetically inertness in water [9,13]. Substantial advances have been made recently in developing technologies which capable of removing perchlorate from water, including biological reduction, ion exchange, tailored activated carbon adsorption, membrane filtration and

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