Surface mass transfer processes using activated date pits as adsorbent

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Abstract

The factors affecting the initial rate of adsorption of some organic compounds onto activated date pits, have been investigated in detail. Phenol, aniline, methylene blue, procion red and humic substances were employed to test this adsorbent.

The applicability of the Langmuir isotherm for the present system has been tested and the surface mass transfer coefficient and the surface diffusion coefficient at 20°C determined. The kinetics of adsorption indicates that the process is diffusion controlled.

Nomenclature

D : effective pore-volume diffusion coefficient (L^2/T)
D_{eff}^p : effective surface diffusion coefficient (L^2/T)
e : intraparticle-void fraction (dimensionless)
    : radial coordinate (L)
r : initial liquid concentration (M/V)
C : external liquid concentration at time t (M/V)
  r : liquid equilibrium concentration (M/V)
c : surface-phase concentration (M/V)
   : time (T)
C_{eq} : apparent density of adsorbent (M/V)
t : solid-phase concentration (M/M)
q_a : solid equilibrium concentration (M/M)
q_e
K : Langmuir constant (V/M)
   : Langmuir constant related to the adsorption capacity
Q_o (M/M)
   : Langmuir constant related to the energy of adsorption
b (V/M)
   : Freundlich isotherm parameters
k, n : average solid-phase concentration (M/M)
l : mass transfer coefficient between bulk liquid and outer surface of particle *(LIT)*
m : mass of adsorbent particles per unit volume of liquid (M/V)
S_s : outer surface area of adsorbent particles per unit volume of particle-free liquid (M^{-1})
V : volume of liquid in the adsorber (V)
M : mass of particles in the adsorber (M)
τ : rate constant for adsorption (T^{-1})
ϕ : rate constant for pore diffusion (T^{-UI})

Introduction

Many organics in water and waste water may be toxic to man and aquatic inhabitants.

Adsorption on activated carbon is an acceptable treatment method for the removal of these organic substances. The adsorption process in water and waste-water purification usually involves fixed-bed columns for which the equilibrium and kinetic design

parameters are usually determined in laboratory studies.

The kinetic parameters govern the physical size of the adsorber. The external and internal mass transfer coefficients, usually represented as p_s and D_{eff} for film transfer resistance and intra-particle diffusion respectively, can be estimated for design purposes.

The objective of the present study was to determine these coefficients for an adsorption system using activated date pits as adsorbent.

Agitated baffled vessels were employed to contact aqueous solutions of organic substances (phenol, aniline, methylene blue, procion red and humic substances) with activated carbon particles.

Theory

Kinetic studies

The study of the kinetics of adsorption at the solid-solution interface is of great significance in water and waste-water treatment as it defines the solute uptake rate, which in turn governs the residence time of the adsorption process.

It is necessary to study the kinetics of adsorption in batch systems in order to determine the rate-limiting step in the adsorption process.

The mechanism of solute adsorption onto an adsorbent comprises several steps. For the purposes of this work the overall adsorption process is assumed to occur in the following three steps:

• mass transfer of solute from bulk solution to the particle surface;
• adsorption of solute onto sites; and
• internal diffusion of solute via either a pore diffusion model, or a homogeneous solid phase diffusion model.

The rate constants of adsorption and pore diffusion were determined using equations of Lagergren and BHI(1868) and Weber and Morris (1963) respectively, which are as follows :

Rate constant for adsorption
$$\log(q_e - q) = \log q_e - (\tau/2,3)t \qquad \textbf{(1)}$$

Rate constant for pore diffusion
$$C_r/C_u = \phi t^{0.5} \qquad \textbf{(2)}$$

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