J Pharm Innov (2011) 6:202–216
DOI 10.1007/s12247-011-9114-6

RESEARCH ARTICLE

Quantifying Absorption Effects during Hydrogen Peroxide Decontamination

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Published online: 1 October 2011

Abstract Understanding mass transfer effects (e.g., condensation and absorption) of hydrogen peroxide is essential for clean room decontamination technology. For example, absorption of hydrogen peroxide in polymers often causes unwanted effects in the final aeration phase of a decontamination cycle. This currently leads to significant challenges in the design and operation of clean rooms or isolators. We address here the absorption of H_2O_2 in polymers, which is a key for an understanding of mass transfer effects. Specifically, we developed a novel experimental setup to measure the desorption rate from a polymer sheet. Together with a model for the diffusion in a polymer, we are able to theoretically predict the absorption and desorption kinetics of hydrogen peroxide. We then performed measurements of still unknown properties of hydrogen peroxide in polymers, i.e., the saturation concentration and the diffusion coefficient using our experimental setup. As expected, the diffusion in the polymer is the rate-limiting step for the absorption and the release of H_2O_2. We find that considerable amounts of H_2O_2 can be absorbed in certain polymers on a time scale of less than an hour and may lead to a temporary violation of the Occupational Safety and Health Administration safety level in a typical clean room.

Keywords Hydrogen peroxide · Decontamination · Modeling · Absorption · Diffusion

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Notation

Latin letters

C_{H2O2}	Concentration of hydrogen peroxide [kmol/m³]
D_i	Diffusion coefficient of species i [cm²/s]
$D_{H2O2,p}$	Diffusion coefficient of hydrogen peroxide in a polymer [cm²/s]
Fo	Fourier number
K_i	Partition coefficient
l_c	Characteristic length scale
L	Length scale of the flow
MW_i	Molecular weight of species i [g/mol]
$\dot{N}$	Mass flow rate [mol/s]
p	Pressure [Pa]
$r_{p,i}$	Mass transfer resistance of species i in phase p
Re	Reynolds number
Sc	Schmidt number
Sh	Sherwood number
t	Time
T	Temperature [K]
V_{Liquid}	Liquid volume [L]
$V_{Polymer}$	Polymer volume [m³]
x	Spatial coordinate (normal to the surface of a thin sheet) [m]
x^*	Dimensionless spatial coordinate

Greek letters

β	Mass transfer coefficient [m/s]
ν	Kinematic viscosity [m²/s]