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Review

Applications of high gravity technologies for wastewater treatment: A review

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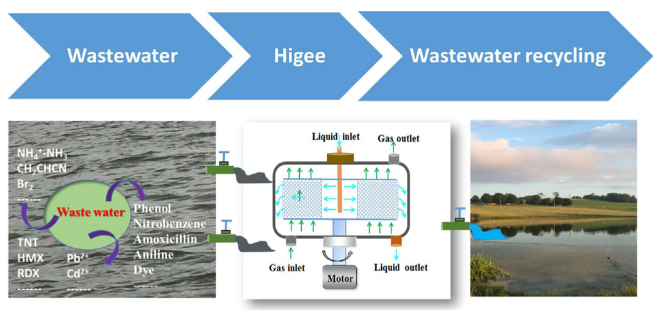
HIGHLIGHTS

- The mechanisms of Higee for enhancing wastewater treatment have been introduced.
- Integration of Higee with other technologies is presented and discussed.
- The advantages and challenges using Higee for wastewater treatment are assessed.
- Perspectives for advancing Higee-enhanced wastewater treatment are proposed.

GRAPHICAL ABSTRACT



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ABSTRACT

High gravity (Higee) has gained a great attention owing to its advantages of highly efficient mass transfer, energy saving and cost reduction. Higee technology has been studied extensively to improve mass transfer in the treatment of various wastewaters. Understanding the general theory and current status of the Higee-enhanced wastewater treatment will help with advancing this technology towards further development. In this review, the recent status of Higee development, various Higee configurations, working mechanisms of Higee technology in wastewater treatment have been introduced. The integration of Higee with other treatment technologies were described in detail, including coupling Higee with oxidants, electrolysis, advanced oxidation processes (AOPs), stripping, ozonation, electrochemical processes, photocatalytic oxidation, adsorption, or extraction. The effects of operating factors on the Higee coupled treatment systems were discussed with respect to the treatment efficiency, cost and facility. To move Higee technology towards practical applications, there is a need for improving the understanding of fundamental theories, investigation of residence time distribution, and more pilot studies of treating actual wastewater. The Higee-enhanced wastewater treatment can be promising to assist the conventional treatment with saving operational cost and improving treatment performance.

Contents

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Nomenclature

Abbreviations

AOPs	advanced oxidation processes
BOD	biochemical oxygen demand
CFD	computational fluid dynamics
COD	chemical oxygen demand
CSTR	completely stirred tank reactor
Cys–Fe_3O_4 MNPs	L-cysteine functionalized Fe_3O_4 magnetic nanoparticles
DNT	Dinitrotouene
DSA	dimensionally stable anode
ELM	emulsion liquid membrane
Higee	high gravity
IS-RPB	impinging stream-rotating packed bed
PIV	particle image velocimetry
RB-MCCE	rotating bed with multi-concentric cylindrical electrodes
RDX	hexahydro-1,3,5-trinitro-1,3,5-triazine
RPB	rotating packed bed
RSM	response surface methodology
RTD	residence time distribution
SDR	spinning disk reactor
STR	stirred tank reactor
TBP	tributyl phosphate
TNT	2,4,6-trinitrotoluene
US	ultrasound
UV	ultraviolet

Greek symbols

β [–]	high gravity factor
η [–]	extraction stage efficiency

Symbols

D′ [–]	stage partition coefficients
H [m]	height
K_La [1/s]	liquid volumetric mass transfer coefficient
K_xa [kmol/(m^3·s)]	average liquid overall mass transfer coefficient
L [mol/s]	liquid molar flow rate
r_1 [m]	inner diameter of rotor
r_2 [m]	outer diameter of rotor
x_1 [–]	molar fraction of liquid phase at the inner diameter of rotor
x_2 [–]	molar fraction of liquid phase at the outer diameter of rotor
X_s [–]	segregation index

Subscripts

1	inner
2	outer
L	liquid phase
s	segregation
x	molar fraction of liquid phase

1. Introduction

High gravity technology was first proposed as a process intensification, which was realized by using a rotating packed bed (RPB) and referred as "Higee" (an acronym for high gravity) [1]. RPB is to use high rotating speed to generate high centrifugal acceleration of 100–1000 times of general gravity for enhancing gas-liquid mass transfer and improving chemical reaction processes [2]. Liquid will be finally produced into the thinner liquid film or smaller droplets by the huge shear force under a high rotating speed [3,4]. Consequently, Higee increases the gas-liquid interfacial area and decreases the transfer resistance of gas into the liquid phase. The