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High rate aerobic treatment of synthetic wastewater using enhanced coagulation high-performance compact reactor (EC-HCR)

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Abstract

The high-performance compact reactor (HCR) is a type of JLR system for wastewater aerobic biological treatment processes. HCR has demonstrated outstanding performance with respect to space–time yield in more than 20 industrial applications, whereas, it has the disadvantage of cloudy effluent because of the disappearance of filamentous organisms in the HCR reactor. This study examined the potential of a new enhanced coagulation HCR (EC-HCR) system to improve the effluent quality of HCR. Results showed that, when 20–25 mg/L $FeCl_3$ was added as coagulant into the coagulation tank, the effluent turbidity of EC-HCR system was lower. EC-HCR system could be operated at high organic loading and had high COD removal efficiency under short hydraulic retention time. When influent COD varied at 300–450 and 500–650 mg/L, there was no obvious difference on effluent COD compared with and without coagulant added. When influent with high COD concentration of 1000–1600 mg/L was treated, the COD removal efficiency could be improved obviously when 20 mg/L coagulant was added. There was no obvious difference between the nitrogen concentration in the effluent with and without coagulant, whereas, the phosphorus removal efficiency improved markedly when 20 mg/L coagulant was added into coagulation tank.

Keywords: High-performance compact reactor (HCR); Enhanced coagulation HCR (EC-HCR); Coagulant; Turbidity; COD; Nitrogen; Phosphorus

1. Introduction

With growing industrialization and density of population in the last decades, wastewater treatment has become more and more important. For the purification of moderately and highly loaded sewage and industrial wastewater, high-performance aerobic biological reactors have been developed which are marked, compared to conventional plants, by high degradation performance, a compact construction and an operation favorable to the environment [1]. The use of vertical compact reactors is an interesting alternative to the classical activated sludge tanks. Jet-loop reactors (JLR), the efficiency of which has already been shown in both chemical and biochemical processes, represent an ideal reactor typology for an effective solution to sewage and industry wastewater since they have higher oxygen transfer rates at lower energy costs [2,3].

The high-performance compact reactor (HCR) is a type of JLR system for wastewater aerobic biological treatment processes [1–3]. Already, HCR has demonstrated outstanding performance with respect to space–time yield in more than 20 industrial applications [2]. HCR is a jet-loop-type reactor with a draft tube and two-phase nozzle (Fig. 1). HCR is able to deal with very high organic loading rates due to the high efficiency of oxygen transfer, mixing and turbulence achieved, which make the use of jet aeration systems more efficient than conventional surface aerators. As such, these characteristics make the HCR extremely effective for the treatment of wastewater of high strength [1,4–7].

However, when activated sludge is to be separated from the treated wastewater by sedimentation following HCR reactor, the effluent quality deteriorates with high SS concentration under certain operating conditions because of the hydraulic shear stress applied by nozzle and high mixing action, which results in the disappearance of filamentous organisms and lack of flocculation [4]. The potential of membrane system coupled with HCR (MHCR) had already been examined to take advantages of both systems and improve the effluent quality of HCR system, but the MHCR system will increase the expenses of installation costs and maintenance when it is used in operation [5].

Many sludge-separation problems that can occur with activated and their devastating impacts often lead operators to find

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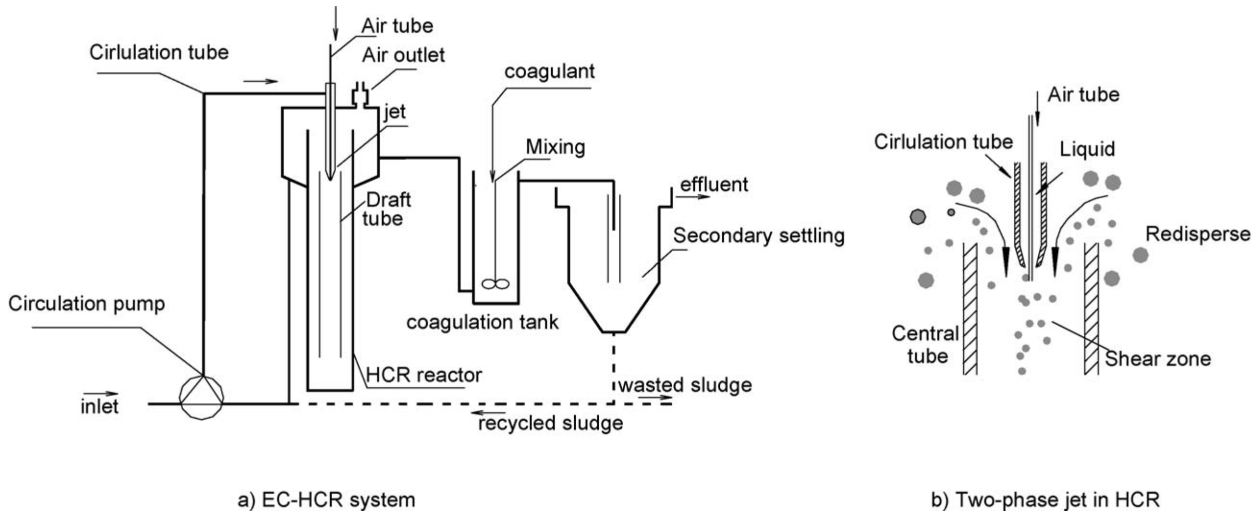

Fig. 1. Schematics of an EC-HCR system.

quick-fix solutions. A common economical example is the addition of coagulant to the mixed liquor in order to enhance flocculation, settling, and compaction. It is particularly effective for relief from scrappy-floc. In addition, the addition of coagulant to the mixed liquor maybe helpful to improve phosphorus removal. If the unique properties of the two processes, HCR and chemical enhanced coagulation, are combined to create a novel enhanced coagulation HCR (EC-HCR) system, it may offer various advantages to compensate the weakness of each process. Chemicals are added into mixed liquor to enhance the formation of the normal structure of good-settling activated sludge by coagulation.

The purpose of this study was to develop a new EC-HCR system through coupling chemical enhanced coagulation process into the HCR and to examine the potential of pollutants removal by incorporating a chemical dosing facility in HCR biological treatment process.

2. Materials and methods

2.1. EC-HCR system

A bench-scale study was used to investigate the performance of the EC-HCR in laboratory. EC-HCR system, as shown in Fig. 1(a), consists of HCR reactor, coagulation tank and secondary settling tank. HCR reactor consists of a cylindrical vessel with a height to diameter ratio of about 6:1 and carries a central tube open at both ends. The working volume of HCR reactor was approximately 17 L with diameter 150 mm and height 1200 mm.

The HCR process is a modification of the activated sludge process. A compact loop reactor with an inner central tube replaces the standard aerated bioreactor tank. The inlet water is mixed with the water in circulation and return sludge before entering the reactor through a two-phase jet. The jet generates a shear zone within the central tube, as shown in Fig. 1(b). Within this shear zone, the air stream drawn in by the pressure drop across the jet is dispersed to yield ultra fine bubbles (primary dispersion). The bacterial agglomerates contained in the water/sludge mixture are simultaneously disintegrated into small flocs, thus creating the desired large contact surface between the liquid phase and the bacteria. The mixture of air bubbles, wastewater and bacterial flocs flow downwards through the central tube, is deflected at the bottom of the reactor, and flow uniformly upwards through the outer annulus. At the upper end of the central tube, a portion of the mixture is recycled into the central tube by the jet stream. The gas bubbles and bacterial flocs are thereby re-dispersed (secondary dispersion). Most of the overflow is recycled into the circulation tube by the sucking action of circulation and reentered the reactor through two-phase jet, while the remainder is discharged to coagulation tank.

The temperature of bioreactor content was maintained around $24 \pm 2\,^{\circ}C$ by circulating tap water through a stainless steel heat exchanger.

2.2. Synthetic wastewater and analysis methods

Table 1 list the compositions of the synthetic wastewater used in bench-scale experiment. Tap water was used as dilution water.

Table 1
Compositions of the synthetic wastewater (unit: mg/L)

Composition	Low concentration	Medium concentration	High concentration
COD	300–450	500–650	1000–1600
BOD_5	150–200	200–300	500–700
Total N (as influent NH_4^+-N)	20–30	30–40	60–80
Total P	3–5	6–8	8–10

Note: Turbidity of influent is 0 because tap water was used as dilution water.