



A-stage and high-rate contact-stabilization performance comparison for carbon and nutrient redirection from high-strength municipal wastewater

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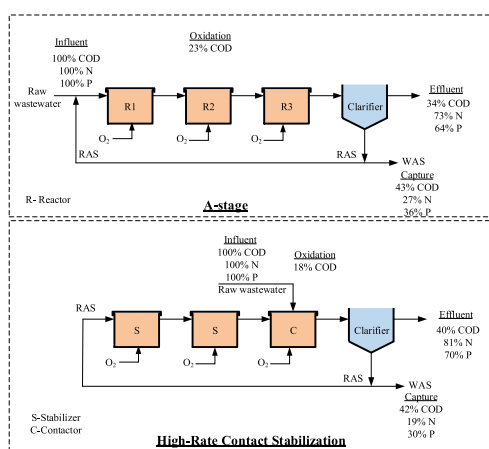
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HIGHLIGHTS

- A-stage and high rate CS achieved 43% of carbon harvesting from raw wastewater.
- Feast-famine regime play key role in CS for better performance at < 0.2 d SRT.
- A-stage and CS captured influent TN and TP by 19–26% and 30–36%, respectively, through WAS.
- F/M ratio was directly correlated with EPS in both A-stage and high-rate CS system.
- The best energy gain could be potentially reached with a combination of CEPT + CS.

GRAPHICAL ABSTRACT



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ABSTRACT

This study performed a parallel comparison of the A-stage (adsorption) and high-rate contact-stabilization (CS) technology for carbon and nutrient redirection, operating both systems at similar sludge retention time (SRT) of 0.16–0.3 d and treating high-strength raw wastewater. Overall at the average 0.22 d SRT condition, both A-stage and CS had similar carbon capture behavior (42–43%) and thus the similar potential for energy recovery. However, the A-stage had better effluent quality (67 mg VSS/L) through the growth of more heterotrophic biomass leading to increased oxidation (22% vs 18%), and increased fraction of nitrogen (26% vs 19%) and phosphorous (36% vs 30%) redirection compared to the CS. At biomass limited conditions and at lower SRT, CS maintained better performance, potentially through a better extracellular polymeric substance management under feast-famine conditions. Full-scale plant energy calculations based on this study results showed that chemically enhanced primary treatment (CEPT), A-stage, CS, primary treatment + CS and CEPT + CS could all

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lead to energy neutral plants as enough carbon can be redirected to generate the energy needed to support wastewater treatment. Given the superior performance of CS under lower loading or SRT limitation, the best energy gain (200%) could be potentially reached with a combination of CEPT and CS in series to enhance carbon capture up to 68% in combination with mainstream deammonification.

1. Introduction

The high-rate activated sludge system (HRAS) is becoming the backbone of the energy efficient wastewater treatment processes. The carbon removal technologies such as the A-stage of AB (adsorption-biooxidation) systems, contact-stabilization (CS), and conventional systems (step-feed, plug flow, completely mixed reactor system) as a form of HRAS are shifting the energy intensification process of a municipal wastewater treatment plant (WWTP) to low-energy and sustainable technologies. For recovering energy-rich organic carbon from wastewater, HRAS system is the key process technology for energy neutral or positive treatment processes [1]. The A-stage of an AB process is a well-known HRAS system which intends to minimize carbon oxidation and maximize carbon harvesting through biosorption at a very low sludge retention time (SRT) (0.1–0.6 d) conditions [2–6]. Since WWTPs are shifting more towards energy recovery, separate carbon management systems upfront of nutrient removal system regains interest in wastewater treatment processes. In addition, more research has been done to decrease the carbon needs for nitrogen removal by implementation of short-cut nitrogen (SCN) removal such as nitrification/denitrification [7,8] and mainstream deammonification [9–11] and thus creating more incentive for HRAS systems.

The fundamental literature on A-stage technology is still fairly scarce despite the full-scale applications of this technology. The AB process was mainly focused on full-scale B-stage performance [12–14] while very little studies investigated the mechanistic understanding of A-stage performance and its crucial design parameters. Recently de Graaff et al. [3] described carbon removal performance and sludge composition of four full-scale A-stage plants (0.27–0.65 d SRT). However, due to different operational parameters and influent

characteristics, it was hard to extract general design criteria for A-stage technology. The A-stage system was further investigated through automatic control and instrumentation [5] and for modeling [6] to predict the operational performance. Recently Kinyua et al. [4] and Kinyua et al. [15] studied the A-stage in a pilot-scale system to evaluate the role of extracellular polymeric substance (EPS) and intracellular storage under varying SRT, HRT (hydraulic retention time) and dissolved oxygen (DO) concentrations. The results of the later studies concluded that EPS had no role in HRAS systems [4] which is controversial to the results reported by Rahman et al. [16], Rahman et al. [17], Jimenez et al. [18] and Meerburg et al. [1]. Overall no general consensus on the role and importance of EPS in the HRAS system has been achieved so far.

Along with A-stage, the high-rate CS technology gained renewed interest in the form of a HRAS process to maximize carbon harvesting for energy neutrality. Recent studies showed that high-rate CS has promising outcomes of high carbon redirection (carbon diversion from wastewater to sludge matrix) and harvesting (carbon capture through waste activated sludge) with improved bioflocculation and balanced biomass inventory [17,19–21]. Both high-strength synthetic wastewater [20,21], municipal high-strength [19] and low strength wastewater [16,17] have been tested for application of high-rate CS. In addition, the mechanistic understanding of the feast-famine conditions on carbon redirection, bioflocculation, and settleability has been studied before for low strength domestic wastewater (chemical oxygen demand, COD < 200 mg/L) and biomass limited conditions [16,17]. It was observed that for the high-rate CS technology, a rapid EPS production response when going from famine to feast conditions was essential to enhance bioflocculation and thus carbon harvesting efficiency [17,22]. It is however unclear if these mechanisms are the same under high

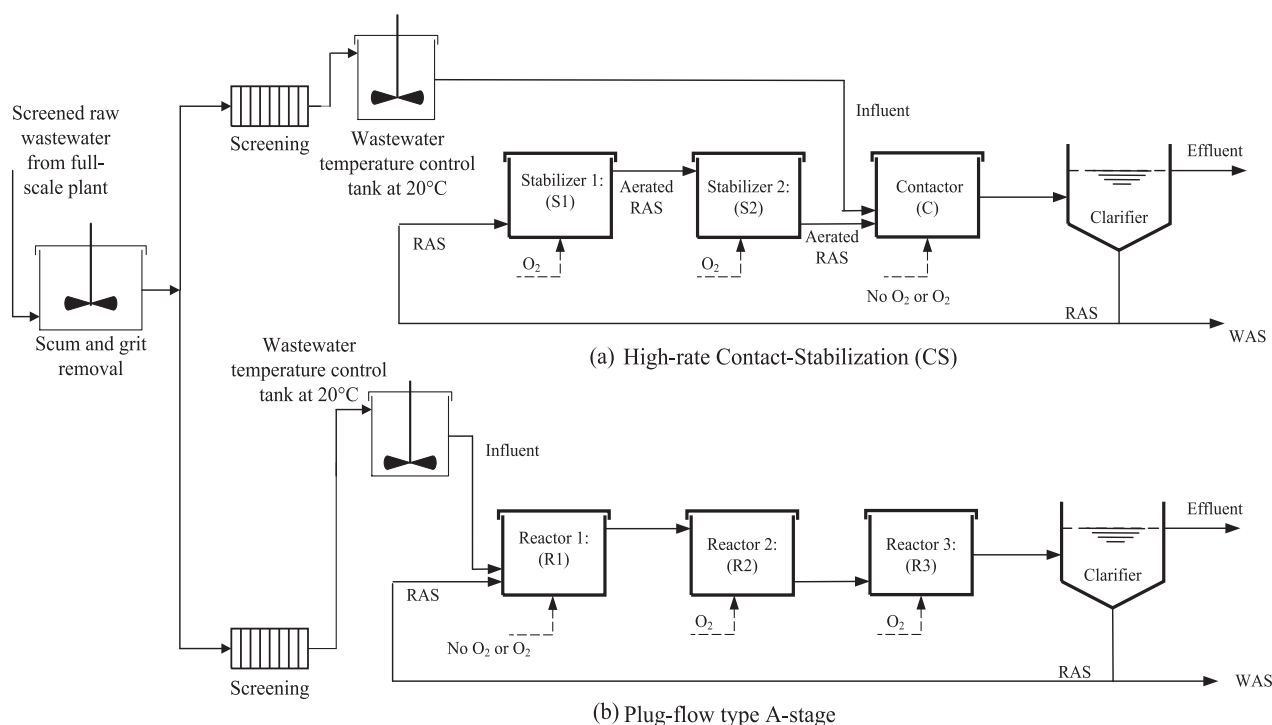


Fig. 1. Pilot-scale reactor setup of high-rate (a) contact-stabilization (CS) and (b) plug-flow A-stage configurations operated in this study.

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