

# Practical consideration for design and optimization of the step feed process

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**Abstract** Based on the anoxic/oxic (A/O) step feed process, a modified University of Cape Town (UCT) step feed process was developed by adding an anaerobic zone and adjusting sludge return pipeline. Performance evaluation of these two types of processes was investigated by optimizing operational parameters, such as the anaerobic/anoxic/oxic volumes, internal recycle ratios, and sludge retention times, for removal of chemical oxygen demanding (COD), nitrogen, and phosphorus. Results showed high removal efficiencies of COD of  $(85.0 \pm 1.7)\%$ , ammonium of  $(99.7 \pm 0.2)\%$ , total nitrogen (TN) of  $(85.5 \pm 1.7)\%$ , phosphorus of  $(95.1 \pm 3.3)\%$ , as well as excellent sludge settleability with average sludge volume index of  $(83.7 \pm 9.5) \text{ L} \cdot \text{mg}^{-1}$  in the modified UCT process. Moreover,  $(61.5 \pm 6.0)\%$  of influent COD was efficiently involved in denitrification or phosphorus release process. As much as 35.3% of TN was eliminated through simultaneous nitrification and denitrification process in aerobic zones. In addition, the presence of denitrifying phosphorus accumulating organisms (DNPAOs), accounting for approximately 39.2% of PAOs, was also greatly beneficial to the nitrogen and phosphorus removal. Consequently, the modified UCT step feed process was more attractive for the wastewater treatment plant, because it had extremely competitive advantages such as higher nutrient removal efficiencies, lower energy and dosages consumption, excellent settling sludge and operational assurance.

**Keywords** step feed, anoxic/oxic (A/O), University of Cape Town (UCT), simultaneous nitrification and denitrification (SND), denitrifying phosphorus removal, biological nutrient removal (BNR)

## 1 Introduction

Increasingly stringent effluent pollutants (particularly nitrogen and phosphorus) in wastewater treatment plants (WWTPs) are controlled all around the world owing to the eutrophication of receiving waters. In China, the maximum nutrient concentrations in effluent of the first-A level discharge standard (GB 18918-2002) are definitely permitted as follows: ammonium ( $\text{NH}_4^+-\text{N}$ )  $\leq 5 \text{ mg} \cdot \text{L}^{-1}$ , total nitrogen (TN)  $\leq 15 \text{ mg} \cdot \text{L}^{-1}$ , total phosphorus (TP)  $\leq 0.5 \text{ mg} \cdot \text{L}^{-1}$ , and chemical oxygen demand (COD)  $\leq 50 \text{ mg} \cdot \text{L}^{-1}$ . Therefore, enhanced nitrogen and phosphorus removal should be specially considered for new WWTPs and a considerable number of existing WWTPs have to be retrofitted.

At present, biological treatment processes are relatively dominant over all other physical-chemical methods for municipal wastewater. The biological anaerobic/anoxic/oxic (A/A/O) process has been modified to improve the nutrients removal through sequencing the bioreactors of anaerobic, anoxic, and aerobic units in last decade. The nitrified liquor in the last anoxic unit must be introduced to anoxic units for denitrification, however, and external carbon sources are necessary to achieve higher TN removal [1,2]. All improvements seem to be at the expense of operational cost and accordingly the applications are limited. Consequently, an anoxic/oxic (A/O) step feed is developed without any extra dosages in terms of the conventional A/O process [3]. It consisted of several A/O stages in sequence and the influent was divided into several streams into each anoxic zones. In our preliminary study, the performance and optimization of A/O step feed process was investigated with the synthetic wastewater and municipal wastewater, respectively [4,5]. Chang et al. reported the substrates/nutrients were successfully consumed without recycling either nitrified effluent or external carbon source in A/O/A/O step feed process [6]. Larrea et al. studied the optimal efficient design and operational

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