A simulation-based optimisation approach to control nitrogen discharge by activated sludge under winter seasonal peak load

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Abstract

Wastewater treatment systems located in cold areas are under increasing pressure to remove nitrogen from their wastewater. As constraining operating conditions like dramatic influent load increases exacerbated by cold temperatures can occur (e.g. winter tourist resorts, ski resorts), specific technical treatment solutions have to be adapted. The objective of this research is to determine the maximal magnitude of load variation which can be applied in winter to an activated sludge treatment system. It aims at analyzing the effects of high influent load variations on the nitrogen removal capacity. Two operating strategies are investigated by dynamic simulations performed with ASM1:

- A fixed aeration tank volume with a fixed MLTSS concentration
- A variable aeration volume tank with a variable MLTSS concentration

It is demonstrated that the variable aeration tank volume strategy is more efficient than the fixed volume strategy to face long-term peak load. To meet an effluent ammonia nitrate concentration of below 10 mgN·ℓ$^{-1}$, a maximum input load increase by a factor 2 should be applied with the first strategy; whereas with the second strategy a load increase by a factor 4 should be applied (with constant oxygen presence time). If the oxygen presence time can be increased by 50% the maximum input load increase could reach a factor 6.

Keywords: activated sludge, ASM1, dynamic simulation, nitrification, variable loading rate

Nomenclature

COD	Chemical oxygen demand (mg O_2·ℓ$^{-1}$)
F/M	Organic carbon loading rate (kgBOD_5.kg $MLVSS^{-1}$·d^{-1})
NH_4-N	Output ammonia nitrogen concentration (mg N·ℓ$^{-1}$)
NO_3-N	Output nitrates+nitrites nitrogen concentration (mg N·ℓ$^{-1}$)
MLTSS	Concentration of sludge suspended solid (mg TSS·ℓ$^{-1}$)
S_i	Soluble inert COD concentration (mg COD·ℓ$^{-1}$)
S_{ND}	Soluble biodegradable organic nitrogen concentration (mgN·ℓ$^{-1}$)
S_{NH}	Ammonia concentration (mgN·ℓ$^{-1}$)
SRT	Sludge retention time or sludge age (day)
S_s	Rapidly biodegradable COD concentration (mg COD·ℓ$^{-1}$)
t_a	Duration necessary for the autotrophic biomass concentration to reach its initial value (d)
t_h	Duration necessary for the heterotrophic biomass concentration to reach its initial value (d)
TKN	Concentration of total organic nitrogen concentration (mg N·ℓ$^{-1}$)
TSS	Concentration of total suspended solid (mg SS·ℓ$^{-1}$)
VSS	Concentration of volatile suspended solid (mg VSS·ℓ$^{-1}$)
WWTP	Wastewater treatment plant
$X_{B,A}$	Concentration of autotrophic biomass (mg COD·ℓ$^{-1}$)
$X_{B,H}$	Concentration of heterotrophic biomass (mg COD·ℓ$^{-1}$)
X_{ND}	Slowly biodegradable organic nitrogen concentration (mg N·ℓ$^{-1}$)

Introduction

The activated sludge process operated at an F/M ratio of lower than 0.10 kgBOD_5·kg$MLVSS^{-1}$·d^{-1}, with intermittent aeration, is a solution commonly used in France to treat nitrogen from domestic wastewater. It performs biological nitrification and denitrification at low temperature and provides treated water quality in agreement with the European Union Directive 91/271 (1991). This system provides complete nitrification even under rain event conditions where input load increases by a factor 2 (Lagarde, 2003; Stricker et al., 2003). But for higher input load increase, very little information can be found in the literature.

Wastewater treatment systems located in tourist resorts are under increasing pressure to remove nitrogen from their wastewater. In winter, the received wastewater volume can represent 70% of the annual effluent volume discharged (Tonkovic and Jeffcoat, 2002) which can lead to long-term deterioration of water quality without treatment. In these areas, high daily inflow variations are observed between the off-season period (few inhabitants, huts and restaurants closed, 8 months a year) and peak-season period (commercial activity and tourists in lodges, 4 months a year). The organic load (both carbon and nitrogen) usually increases by a factor 6 during the last week of December (Christmas days and New Year), to reach a factor 10 within two months during the February school vacations (Canler et al., 2002). To achieve carbon pollution removal, trickling filters at

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