Ⅶ-179 OPTIMIZATION OF A GRANULAR SLUDGE UPFLOW SLUDGE-BLANKET REACTOR FOR DENITRIFICATION OF A SOFT GROUNDWATER

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Introduction

Retention of biomass is an important factor in upflow sludge blanket (USB) reactors. Granular sludge growth in conjunction with mineral precipitation results in heavier sludge with improved retention. Others have shown that with hardness ranging from 200 to 250 mg $CaCO_3$ l^{-1} difficulties occurred due to sludge wash-out and that with very hard waters (260 to 400 mg $CaCO_3$ l^{-1}) improved retention was possible [1,2]. Recently, however, we demonstrated that denitrifying granular sludge with good retention characteristics can be maintained in marginally hard water (ca. 120 mg $CaCO_3$ l^{-1}) [3]. A high influent pH (about 8.5) was a key factor. An increase in pH (or alkalinity, calcium (Ca), or temperature) results in an enhanced tendency for Ca to precipitate, i.e., precipitation potential (PP). The objective of this work was to optimize a denitrifying USB system with the goal of minimizing chemical additions to a soft groundwater.

Materials and Methods

The USB reactor was made of glass and had a 1.70 l volume with a 7.0 cm diameter [3]. It was operated in the dark at 25 to 30°C. A mechanical stirrer with a bent wire shaft was rotated at 20 rpm (5 minutes on, 15 off). Influent groundwater was fed at 3 l hr^{-1} and supplemented with nitrate ($NaNO_3$ to 20 mg N l^{-1}, exception noted in text), phosphate (KH_2PO_4, 1.0 mg PO_4 l^{-1}), and varying concentrations of Ca ($CaCl_2$) and alkalinity ($KHCO_3$). Adjustments to pH were made with 10 N NaOH. Ethanol was fed from a separate influent tank at 0.1 l hr^{-1}.

Bed sludge and biomass levels were estimated as MLSS and MLVSS, respectively. PP was determined graphically [4] using effluent characteristics to estimate reactor conditions. The seed granular sludge in this research was from a preceding project [3] and had been stored at 4°C for seven weeks. Experiments were conducted in two phases: Phase I (Table 1) treating a water with a low total hardness and Phase II (Table 2) with a soft water.

Table 1. Phase I operating conditions: pH, alkalinity, Ca and hardness are influent values.

	Run 1	*Run 2*	*Run 3*
Days	0 - 24	24 - 55	55 -142
pH	8.5	8.6	8.6
Alkalinity (mg $CaCO_3$ l^{-1})	192	176	143
Ca (mg l^{-1})	37	30	30
Hardness (mg $CaCO_3$ l^{-1})	123	107	105
PP(mg $CaCO_3$ l^{-1})	24	14	10

Table 2. Phase II operating conditions: pH, alkalinity, Ca and hardness are influent values.

	Run 4	*Run 5*	*Run 6*
Days	142-191	191-265	265-310
pH	8.6	9.0	9.0
Alkalinity (mg $CaCO_3$ l^{-1})	122	132	115
Ca (mg l^{-1})	19	17	17
Hardness (mg $CaCO_3$ l^{-1})	77	73	73
PP(mg $CaCO_3$ l^{-1})	9	20	18

Results and Discussion

Phase I. Figure 1 shows the time course of sludge components during Phase I. Conditions used in *Run 1* (see Table 1) were similar to those in previous work [3]. With a reduction in alkalinity and Ca (and thus PP), successful operation (complete nitrate removal with good sludge retention) continued for one month during *Run 2* (PP = 14 mg $CaCO_3$ l^{-1}). MLSS and MLVSS, however, gradually decreased during this period. Influent nitrate was thus increased to 40 mg N l^{-1} for one week at the beginning of *Run 3* (days 55 to 61) to boost

Key Words: denitrification, upflow sludge blanket (USB), granular sludge, precipitation potential.
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sludge biomass levels, which were effectively sustained for three months.

Granular bed height was maintained at about 32 cm and sludge production was estimated to be 0.8 g MLVSS per g N removed. While sludge retention was excellent, the mineral levels here (ca. 50 %) are higher than those shown to be necessary (e.g., 20 to 30 %) [1,3].

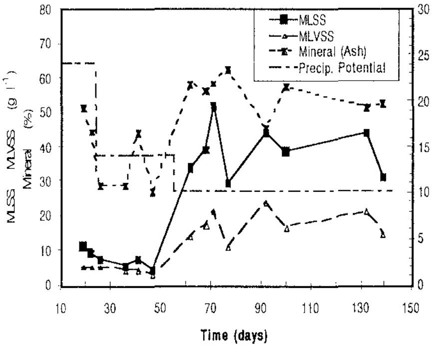

Figure 1. Phase I: Operation with low influent hardness (approx. 123 mg $CaCO_3 l^{-1}$ through day 24, 106 mg $CaCO_3 l^{-1}$ thereafter).

Influence of carbon loading on effluent quality (TOC and nitrogen) was investigated during Phase I (Figure 2). 100 % nitrogen removal occurred at all C:N ratios except 1.0, where only 20 % removal was achieved with about half of the effluent nitrogen in the form of nitrite. More work is needed to determine if safe operation under carbon limiting conditions is possible. All further assays were conducted with a C:N of 1.2.

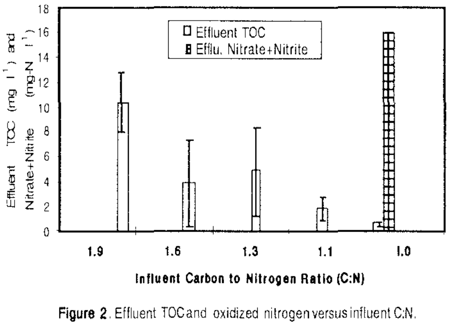

Figure 2. Effluent TOC and oxidized nitrogen versus influent C:N. Effluent nitrogen was zero at all C:N values greater than 1.0. Ranges of plus/minus one standard deviations shown for TOC data.

Phase II. Figure 3 shows Phase II results as a continuation from Figure 1 (Phase I). With hardness reduced to the level of a soft water, all sludge components progressively decreased during *Run 4* (PP = 9 mg $CaCO_3$ l^{-1}). A subsequent increase in influent pH to 9.0 was the main factor in boosting PP to 20 mg $CaCO_3$ l^{-1} in *Run 5* and 18 mg $CaCO_3$ l^{-1} in *Run 6*. Under these conditions, the rate of decrease in sludge mineral content was arrested.

Although nitrate reduction was complete during *Run 5*, bed height was intentionally reduced to about 25 cm for *Run 6* to increase the biomass loading rate with the intent of enhancing the effective biomass concentration. As shown in Figure 3, substantially higher MLSS and MLVSS levels were maintained for over six weeks during *Run 6* (following day 265) than during the course of *Run 5*.

Conclusion. Maintenance of denitrifying granular sludge using soft groundwater in an USB reactor was demonstrated for the first time. A high pH (9.0) was shown to be important for mineral precipitation and generation of a sludge with high ash content and good biomass retention characteristics.

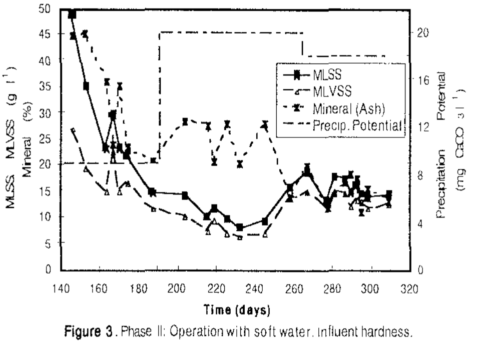

Figure 3. Phase II: Operation with soft water. Influent hardness, 73 to 77 mg $CaCO_3 l^{-1}$; pH, 8.6 through day 191, 9.0 thereafter.

References

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