Elucidating the impact of upgrading wastewater treatment for nitrogen removal on eutrophication and toxic algal bloom in Long Island Sound - 2012MA347B

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Problem and Research Objectives:

Long Island Sound (LIS), like many other estuarial and coastal areas in the U.S., has experienced excessive algal blooms and subsequent hypoxia problems each summer. To improve the conditions of LIS, stringent N permits were placed on wastewater effluents discharged to LIS (USEPA, 2011). To comply with the new regulatory permit, the affected wastewater treatment plants (WWTPs) had to upgrade their main treatment systems to biological nutrient removal (BNR) processes, which have resulted in spending more than $1 billion over the last two decades (O'Shea and Brosnan, 2000). Despite these efforts, it has been reported that the LIS area affected by hypoxia has actually expanded in recent years (O'Shea and Brosnan 2000; Stelloh, 2007).

The objective of this research was to quantify and evaluate the true impact of upgrading WWTP for N removal (i.e., from a conventional activated sludge system to biological nutrient removal processes) on the algal blooms in Long Island Sound.

Methodology:

The current research has involved two main study components: operation and study of bench-scale activated sludge systems, and conducting bioassay on effluents using Long Island Sound water. For a lab reactor study, we operated one system in a conventional activated sludge (CAS) process and the other in a biological nutrient removal (BNR) process, both of which were fed the same influent wastewater. This approach was necessary because in this way we could generate effluents with different levels of N from the same source of wastewater (i.e., CAS vs. BNR). This further means that we could control the effect of different influents on the bioassay, which was not feasible for our earlier field bioassay study (Park et al., under review). During the period of the current research the Amherst WWTP underwent retrofitting to BNR processes to comply with a new N permit implemented in fall 2012. This was a great opportunity for our research because we had conducted the bioassay on the Amherst effluents multiple times when the plant was operated in CAS. Consequently, the comparison of recent and old Amherst effluents and subsequent bioassay data were expected to enable us to examine the effect of upgrading a wastewater treatment system to BNR on algal blooms in LIS in a field scale.

The laboratory CAS and BNR reactors were operated in sequencing batch reactors (SBRs) feeding on the primary effluent from the Amherst WWTP. The CAS system was operated in 6 days of SRT and only aerobic condition was available for wastewater treatment. In contrast, the BNR system had about 18 days of SRT with repeating anoxic and aerobic conditions to support nitrification and denitrification. Multiple bioassay experiments were conducted on the lab effluents and field effluents from the Amherst WWTP following the method, described in Park et al. (under review), with slight modification. Briefly, bioassay was performed by incubating 0.5 L of both filtered (0.45 µm) and unfiltered effluents with 1.5 L of LIS water. Algal blooms were measured by increase in total COD and total suspended solids. Soluble N concentrations were measured at various points along the incubation period by ion chromatography (IC) and total organic carbon/total nitrogen (TOC/TN) analyzer.

Principal Findings and Significance:

Figure 1 shows concentrations and composition of N in effluents from lab-scale CAS and BNR reactors. As expected, CAS effluent had higher soluble total N (TN) (18.5 mg/L) with a lower portion of organic N (1.1 mg/L, 5.8%), while the BNR effluent had lower soluble TN (10.4 mg/L) with greater nitrate-N (7.2 mg/L, 68.6%) and organic N (2.8 mg/L, 26.4%). Observing higher concentration and proportion of organic N in BNR effluents is consistent with our earlier study (Westgate and Park, 2010) that showed that BNR effluents contained greater proportion and diversity of organic N (in the form of proteins and enzymes) than CAS effluents, reflecting more complex microbial processes occurring in the BNR process.

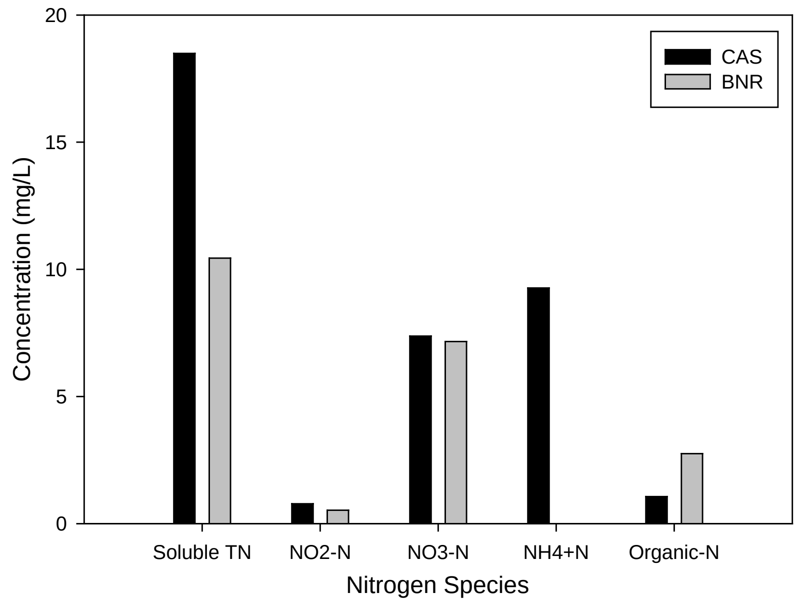
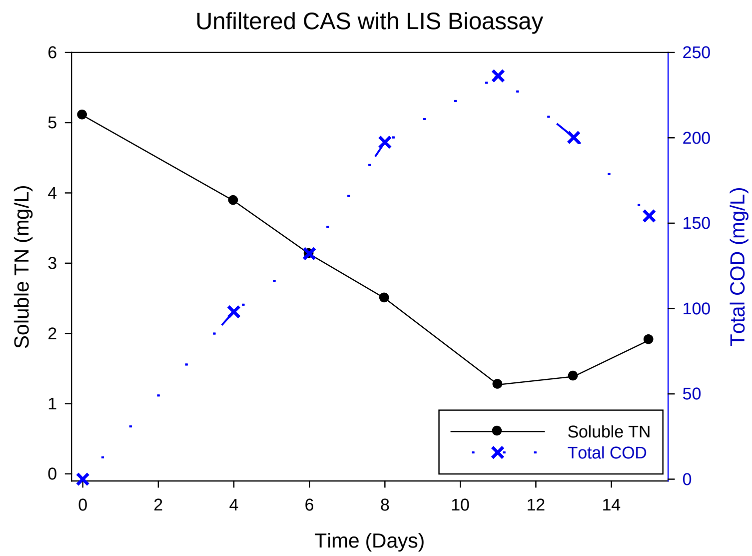


Figure 1. Concentration of nitrogen species in lab-scale CAS and BNR effluents

Figure 2 shows the growth of COD and consumption of soluble TN during the laboratory bioassays. The data clearly show that as soluble TN decreased, total COD increased, indicating that algae consumed available nitrogen for their growth. Table 1 presents the maximum COD yield data for bioassay sets with both filtered and unfiltered effluents. Regardless of filtration involved, BNR bioassays led to about 2 times greater yield than CAS bioassays. It is worth noting that not only COD yields (based on N consumption) but the total amount of COD generation was also higher for the BNR bioassay in spite of much lower N available in that bioassay. These results are consistent with our earlier study (Park et al., under review) relying on the field effluent sampling from different WWTPs and subsequent bioassays, which indicates that effluents from BNR process are more productive for algal blooms in the estuarial receiving water.

Table 1. Maximum COD growth yields in bioassays on lab-scale CAS and BNR effluents (Unit = mg total COD generated/mg soluble TN consumed)

	CAS	**BNR**
Unfiltered effluent	**62**	**117**
Filtered effluent	**74**	**126**



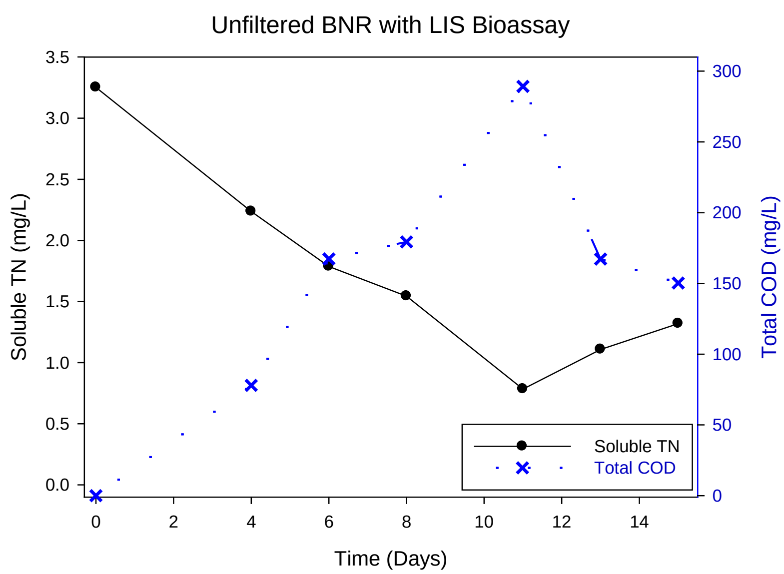


Figure 2. Changes in total COD and soluble total nitrogen during the bioassay. One part of unfiltered CAS or BNR effluent was incubated with three parts of Long Island Sound water.

Figure 3 shows that concentration and composition of N in effluents from the Amherst WWTP collected in March 2011 (earlier study) and March 2013 (current research). The 2011 effluent set had much higher soluble TN (19.8 mg/L), because the facility was operated in CAS, while the 2013 effluent showed much lower soluble TN (3.5 mg/L) with high organic N (1.7 mg/L, 47.5%). Table 2 shows a comparison of maximum COD growth yield between the Amherst effluent bioassays conducted in 2011 and 2013. The 2013 Amherst BNR effluent bioassay led to substantially greater COD yield compared to its old value and even lab-BNR effluent bioassay.

Table 2. Maximum COD growth yields in bioassays on full-scale Amherst WWTP effluents (Unit = mg total COD generated/mg soluble TN consumed)

March 2011 (CAS)	March 2013 (BNR)
31	414

In 2011, one part of unfiltered Amherst effluent was incubated with one part of Long Island Sound water (i.e., two time dilution) (Park et al., under review). In 2013, one part of unfiltered Amherst effluent was incubated with three parts of Long Island Sound water (i.e., four time dilution). See Figure 3 for concentration of N values in these two effluents.

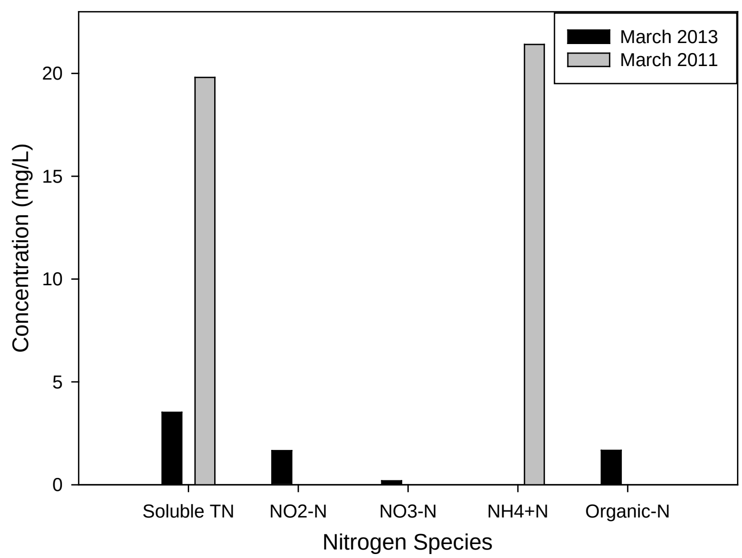


Figure 3. Concentration of nitrogen species from al full-scale Amherst Wastewater Treatment Plant in March 2011 and March 2013. In 2011, the plant was operated in CAS while the plant is currently operated in BNR.

The importance of this study is that we directly evaluated the effect of changing upstream wastewater treatment processes (i.e., CAS to BNR) on algal blooms in Long Island Sound water. It was found that incubation of low N-laden BNR effluents from both bench and field-scale systems actually brought higher algal growth than did the CAS effluents. These results indicate that reduction of N in wastewater effluents via BNR processes does not bring a positive effect on reducing algal blooms in the estuary. It is currently speculated that special types of organic N included in BNR effluents are responsible for this unexpectedly and undesirably high algal production despite much smaller quantity of N available in that effluent water. Further research is warranted to more carefully evaluate the impact of upgrading a WWTP to a BNR process on the impaired receiving estuary and coastal areas.