

# Removal of Nitrate by 'Anoxic Absorbent Filtration' and Carbon Addition

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## Introduction

Nitrogen removal using a new technology suitable for smaller and isolated flows is being tested at commercial sites in Ontario. The 'WaterNOx' system is a variant of the 'post-anoxic' biological anoxic filtration (BAF) process with carbon source addition to nitrified effluent (e.g., Crites and Tchobanoglous, 1998). The system utilizes absorbent filter medium in asphyxiant, stagnant air conditions to form an 'anoxic absorbent filter' (AAF). This article describes the nitrification-denitrification system retrofitted into existing commercial sewage treatment systems (Figure 1), using three carbon sources and different loading rates, discusses observed alkalinity stoichiometry, and predicts results expected at various stages of the process.

## Factory Site 1

At Site 1, a light industrial factory, three carbon sources were tried. Carbon 1, a monosaccharide carbohydrate, removed nitrate, but had plugging problems; Carbon 2, a disaccharide carbohydrate, was successful and easy to use; Carbon 3, an acetate, was successful though more expensive. Here, a Waterloo Biofilter nitrifies the 100-200 mg/L TKN sewage and the effluent used to test the 3.5 m<sup>3</sup> AAF. The AAF effluent is re-directed back through the nitrifying Waterloos to remove excess BOD from the carbon source.

## Site 1 Results

The system was inoculated on April 9, 2008 and was mature within 10 days. Over the 12-week trial using Carbon 2 (Table 1), NO<sub>2,3</sub>-N is reduced from 41 mg/L to <0.1 mg/L; alkalinity of 177 mg/L is increased to 289 mg/L, DO is reduced from >5 mg/L to <1 mg/L, and pH of 7.9 is lowered to 7.3 (not shown) between the inlet and outlet of the AAF (n = 11; medians). The excluded April 24 anomaly caused by tampering with control panels shows quick recovery after a disturbance.

Fluctuating influent TKN values make carbon addition rates uncertain. The AAF effluent contains excess carbon (100-150 mg/L cBOD) and this was polished to <10 mg/L cBOD and <10 mg/L TSS in the final effluent.

With this test of 25-35% of the flow, nitrogen is reduced from 100-200 mg/L TN to ~50 mg/L TN in the final effluent, compared to >100 mg/L TN before the AAF was installed.



**Figure 2** – Overall alkalinity balance during nitrification (alkalinity consumed) and denitrification by recirculation (alkalinity produced). Trend line is forced to zero.

**Figure 3** – Site 1 Carbon 2, alkalinity is produced in the AAF at ~3.3 mg/L per mg/L nitrate-N consumed, a stoichiometric relationship. Trend line is forced to zero.

**Figure 4** – Process diagram of the AAF denitrification system in a new installation, with a polisher added to remove excess BOD from the external carbon source.

microbial additives and by reducing the carbon input for a few days every 3-6 months. The carbon line and forcemain are 'pigged' out every 3-6 months to maintain clear flow.

## Alkalinity Budget

### **Stoichiometric Septic Tank Carbon**

Alkalinity is an important performance indicator in the AAF process. In a Massachusetts communal system without an AAF, 65% of TN is removed to ~18 mg/L TN with a Waterloo Biofilter and 50% recirculation to septic tank as internal carbon source (CWI, 2009). From the slope of the curve in Figure 2, ~3.7 mg/L alkalinity is consumed for each mg/L TKN nitrified in this 'pre-anoxic' process. Stoichiometrically, 7.14 mg/L alkalinity is consumed for each mg/L of TKN nitrified in a single-pass system (e.g., Tchobanoglous et al., 2003; p. 619). This site has full nitrification with very low alkalinity left, so it appears that denitrification in the septic tank produces ~3.5 mg/L alkalinity ( $1 \div 0.272 = 7.14 \div 3.5$ ), making up the deficiency in alkalinity and helping overall nitrification.

### **Stoichiometric Carbon 2**

From the slope of the curve in Figure 3 for single-pass denitrification between influent and effluent of the WaterNOx

with external carbon addition, alkalinity is produced at ~3.3 mg/L per mg/L nitrate-N removed, similar to that assumed for the non-AAF site in Figure 2, and similar to the stoichiometric value of 3.57 mg/L for denitrification reactions (Tchobanoglous et al., 2003; p. 618). In the retrofitted cases such as in this article, this additional alkalinity is directed upstream to improve nitrification efficiency.

### **Non-Stoichiometric Carbon 3 at Sites 1 & 2**

With Carbon 3, alkalinity is produced in the AAF at ~14 mg/L and ~71 mg/L for each mg/L nitrate-N consumed, in