UPFLOW SLUDGE BLANKET FILTRATION (USBF)
NITROGEN REDUCTION MEMORANDUM

Nitrogen is removed by nitrification and denitrification processes. Nitrification is autotrophic and all USBF integrated bioreactors deliver complete nitrification of ammonia to nitrate provided that certain minimum temperature is maintained [1] and alkalinity is available. [2] Denitrification is heterotrophic and requires carbon source. Processes using "separate-sludge denitrification" require that carbon is added. USBF technology "single-sludge denitrification" approach uses an endogenous carbon source to maintain the denitrifiers. Influent is combined with nitrified mixed liquor in the anoxic compartment providing the carbon source needed for denitrification.

The conditions that affect the process of denitrification are (not in the order of priority):

- Volumes or HRTs - The required 'biological' volume is divided into anoxic and oxide volumes. The ratio of the two varies depending on the degree of denitrification desired. The anoxic volume or HRT must allow for DO exertion and for the provision of anoxic conditions needed for fermentation.

- Mixing of the Anoxic Volume - Good mixing and roll of the anoxic compartment is important. Mixing should be 'gentle' so as not to break up the sludge flocs.

- DO Control - DO control throughout the bioreactor is the most important factor. The 'plug' flow of the mixed liquor in the oxide compartment allows for manual adjustment of individual aeration diffuser sections, and the overall air flow is typically controlled by a continuous DO monitor modulating the blower RPM via variable frequency drive (VFD). Anoxic compartment DO is 'controlled' only indirectly by the oxide compartment DO adjustment and control, and by providing sufficient compartment volume (see above).

- RAS Recycle - Mixed liquor containing nitrite/nitrates is recycled from the bottom of the clarifier to the anoxic compartment where the incoming BOD serves as the carbon source or electron donor for the reduction of nitrate to elemental nitrogen. The efficiency of the overall nitrogen reduction has been determined to be a function of the RAS flow multiple (the higher the multiple the higher efficiency). However, the recycle has to be balanced against other factors and based on experience a multiple of 2 to 4 provides a 'safety factor' for typical domestic wastewater while moderating the negative effects. RAS pumps are typically airlift pumps for smaller plants, and low head (low Hp), axial flow pumps provided with VFD drives for larger plants.

- Temperature – Low temperatures and dramatic changes in temperature inhibit or stop the process of denitrification.

- Carbon – Incoming wastewater is the source of carbon. [3] Carbon deficiency is typically not an issue with most municipal or domestic wastewater.

CASE STUDIES

The following USBF plant operating data have been recorded:

MARCO SHORES, FLA

Effluent	Nitrate as N (mg/l)	Nitrite as N (mg/l)	Ammonia as N (mg/l)	TIN (mg/l)	TKN (mg/l)	TN (mg/l)
August 13, 2003	3.2	0.044U	0.05U	3.29	1.0	4.29
August 27, 2003	2.8	-	0.05U	2.8	0.74	3.54
September 10, 2003	3.1	-	0.05U	3.1	0.7	3.8
Design Parameters						**10**

Notes: 1. U denotes Under Detectable Limit
2. The plant is not equipped with SCADA, continuous DO monitor and VFD drives.
3. Official lab analysis available

[1] Nitrification was observed to function at temperatures as low as ~3 deg C
[2] Nitrification consumes 7.1 mg/l of alkalinity as $CaCO_3$ for each mg/l of ammonia oxidized.
[3] Reduction of l gram of nitrogen requires approximately 3 – 6 grams of BOD (or equivalent carbon)

KICKING HORSE SKI RESORT, BC

Effluent	Nitrate as N (mg/l)	Nitrite as N (mg/l)	Ammonia as N (mg/l)	TIN (mg/l)
March 15, 2007	4.8	1.9	0.778	7.5
March 22, 2007	3.0	0.07	0.149	3.22
March 29, 2007	3.4	0.0	0.142	3.54
April 2, 2007	5.8	0.67	0.097	6.57
April 9, 2007	3.0	0.2	0.035	3.24

Notes:
1. Nitrogen reduction was not the plant design objective (small anoxic compartment)
2. The plant serves a ski resort where flows, temperatures and biological loadings vary significantly from weekends to weekdays
3. Official lab analysis available

ISLAMORADA, FLA

2005						2006					
April	May	June	July	August	Sept	January	February	March	April	June	July
1.7	3.7	3.1	2.9	3.8	2.8	6.6	3.3	2.1	3.5	2.4	4.7

Notes:
1. The plant is a small plant without any automated controls
2. Due to wide influent flow fluctuations, small plant's denitrification is typically more difficult to manage than with larger plants
3. Official lab analysis available

SNUG COVE, BC

	2005				2006		
	March	June	Sep	Dec	March	June	Sep
TN	7.83	4.44	6.54	8.27	2.78	4.41	6.2
TKN	2.2	1.9	5.2	4.7	2.3	3.8	4.3

Notes:
1. This plant is a very basic rendition of the USBF configuration. It was not designed for nitrogen reduction (small anoxic volume), and it is not equipped with continuous DO monitor and VFD drives.
2. Official lab analysis available

MILL BAY, BC

Mill Bay Effluent	Nitrate / Nitrite as N (mg/l)	TKN (mg/l)	TN (mg/l)
April 17, 2007	1.8	0.9	2.7
May 22, 2007	4.0	1.8	5.8
June 25, 2007	5.17	1.5	6.7
July 17, 2007	2.75	1.5	4.2
August 7, 2007	3.38	1.5	4.9
September 11, 2007	7.12	1.4	8.5
October 16, 2007	4.11	1.2	5.3
November 6, 2007	3.9	2.2	6.1
Design Parameters			**10**

Notes:
1. The plant is a water reclamation plant where the permitted effluent Total Nitrogen (TN) is <10 mg/l.
2. The plant is relatively small (150 m^3/d; 40,000 gpd) and experiences high infiltration.
3. Official lab analysis available