Simultaneous nitrification and denitrification in biofilms of an engineered integrated fixed-film activated sludge (IFAS) system

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Abstract
Performance of a municipal activated sludge plant treating domestic wastewater was enhanced by the addition of synthetic looped cord media supporting fixed biofilm growth. Although intended only for the enhancement of nitrification, full-scale performance suggests an unexpected amount of total nitrogen removal occurs simultaneously within the biofilm despite significant bulk dissolved oxygen residual. An examination of the media surfaces suggests that a thick biofilm consistent with denitrification exists on the looped side of the media while the smooth side of the media promotes a thin biofilm supporting nitrifiers. This suggests that for IFAS systems the type of bacterial growth can be engineered by the surface characteristics of the media.

Keywords
Biofilms; looped cord media; nitrification; denitrification; IFAS.

INTRODUCTION
The Florida coastal community of Green Cove Springs is experiencing sudden growth pressures from the expanding suburbs of the city of Jacksonville. The engineering firm of Camp Dresser & McKee, Jacksonville, Florida was retained to plan a treatment upgrade of the Harbor Road Wastewater Treatment Plant. The objective was to meet a consent order from the Florida Department of Environmental Protection to meet an unionized ammonia limit of 0.02 mg/L for river discharge.

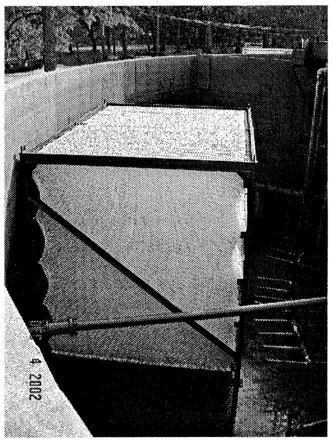
PLANT DESIGN CONSIDERATIONS
The existing plant was a circular contact stabilization process package plant built in 1986 with concentric aeration tank and inner settling tank. The outer aeration tank was divided into contact, sludge re-aeration and aerated digester. Aeration was by a ring header and coarse bubble diffusers. As is common in Florida the aeration tank is preceded by coarse screening only, i.e. no primary clarification is provided. Sufficient aeration time to develop the Solids Retention Time (SRT) necessary for biological nitrification was available by converting the portion of the plant reserved for aerated sludge holding but the increased Mixed Liquor Suspended Solids (MLSS) placed an unacceptably high load on the secondary clarifier. The designers considered a number of options both conventional and non-conventional for increasing the amount of biomass under aeration without impacting the secondary clarifier loading. Some of the options considered included rehabilitation of previously abandoned tanks.

Design Alternatives
New additional tankage, both aeration and clarification was the preferred option but was not possible with the available funds. A small clarifier was available to handle additional solids loading but combined with the operating clarifier was still insufficient for the anticipated increased MLSS. Another option was to convert the small existing clarifier into a primary clarifier to reduce the organic loading on the aeration tank thus reducing the solids inventory necessary to support nitrification. This option was also rejected because of the cost of the pumping of the wastewater to and from the proposed clarifier.

In addition to the conventional alternatives several types of new technology were considered. A membrane filtration unit replacing the conventional gravity secondary settling tank was examined but, while able to achieve higher than project goals, was found to be greater in cost and more complex than the selected alternative.

The planners studied two types of fixed media available to enhance the biomass population without impacting the operation of the secondary clarifier. A floating porous sponge media supports biofilm growth on the surface and within the pores when placed into the aeration tank. This type media requires screens within the aeration tank to separate the media from the mixed liquor and make-up material to be added to replace the media lost due to abrasion. The selected media is a fabric material available in both rope-like and netting configuration. In both configurations the media is attached to frames that can be lifted and placed in the aeration tank above the existing diffusers. The fabric is intended to be maintenance free. For diffuser maintenance the frames can be lifted from the tank or moved within the tank to allow access to the diffusers.

The media selected is AccuWeb® looped cord fabric. The fabric is knitted from polyester yarn in a 2.5 cm. hexagonal netting with loops approximately 8 mm. extending from one side of the material. The fabric is installed on frames of stainless steel or epoxy-coated carbon steel. For this installation four modules were required with approximately 5600 m^2 of media.



A.

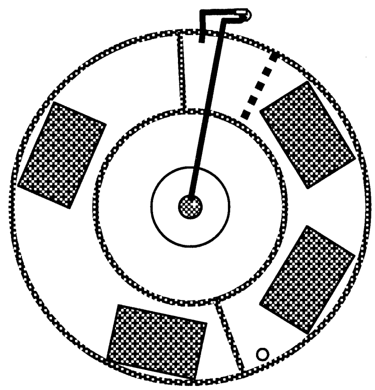


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Figure 1. A) Fabric media on frame placed in aeration tank prior to introduction of wastewater. B) Placement of four media frames in aeration tank.

Wastewater Design Parameters

The plant treats mainly household wastewater with only minor contributions from industry. The influent and permitted effluent are given in Table 1. It should be noted that denitrification was not one of the treatment objectives.

Table 1. Influent wastewater characteristics and permitted effluent.

	Units	Influent	Effluent
Flow	M^3/d (mgd)	2840 (0.75)	--
BOD	mg/L	220	10
Ammonia-N	mg/L	25	--
Unionized Ammonia	mg/L	--	0.02

RESULTS AND DISCUSSION

The plant started operating in December 2002 and was fully nitrifying within the first two weeks after introducing wastewater. The first year of performance is shown in Figure 1. Under the pH and temperature conditions experienced at the plant the effluent was well under the 0.02 unionized ammonia effluent limit.

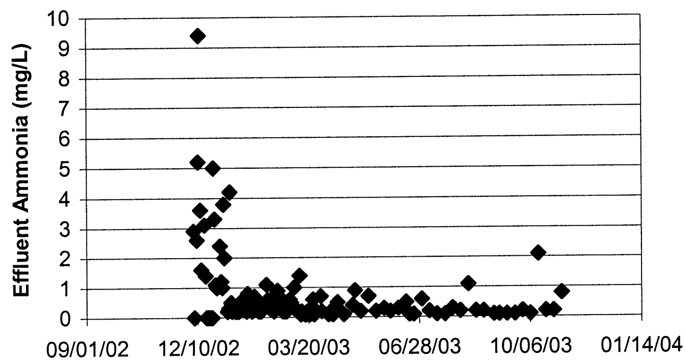

Figure 2. Plant effluent ammonia during first year of operation showing start-up period in December 2002.

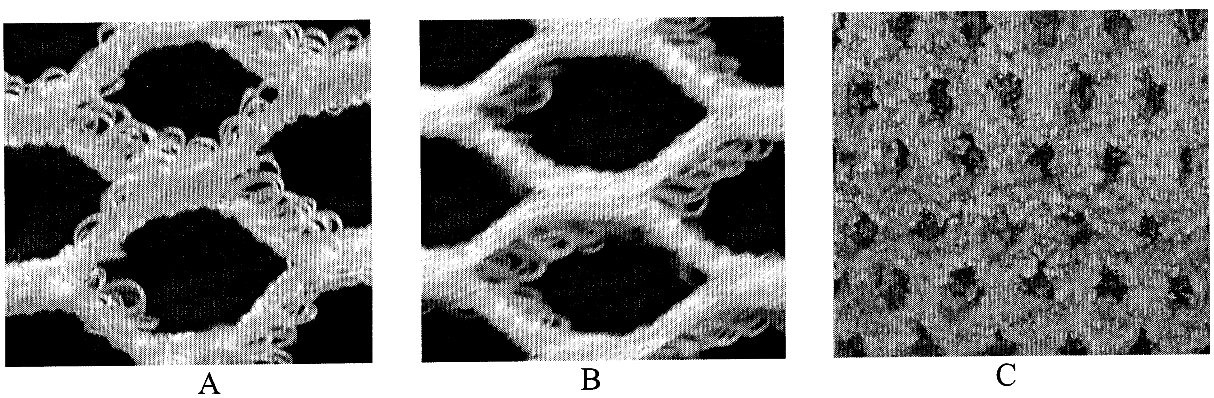

Figure 3. A) Looped front surface of media. B) Tight knit back surface of media. C) Bioflm growth on looped surface of media. Media in photo is submerged in water to show expanded biomass.

In addition, an unexpected result in the effluent oxidized nitrogen was found. While the average influent ammonia nitrogen averaged 30 mg/L for the year, the nitrate+nitrite averaged only 7.0 mg/L over the first year. Since no deliberate anoxic zones are contained within the plant the operating data was examined for possible unintentional areas of low dissolved oxygen. The aeration tank is separated into two discrete zones by a watertight baffle with an opening for flow of mixed liquor between the zones. The operators routinely monitor both zones daily with a portable dissolved oxygen probe. An examination of the plant records does not indicate any sustained periods of low dissolved oxygen. In general the dissolved oxygen is maintained quite high in the range of 4-6 mg/L.

Examination of the biofilm growth at this plant and in the laboratory under controlled conditions reveals a thick growth on only the side with the loops. It would be expected that a similar but perhaps thinner mass would grow on the unlooped side but surprisingly no such film is detected with casual observation. Subsequent observations in the laboratory showed a thin transparent slime on the "back" side of the media where nitrifying bacteria would survive without mass transport limitations of oxygen, alkalinity and acid dissipation.

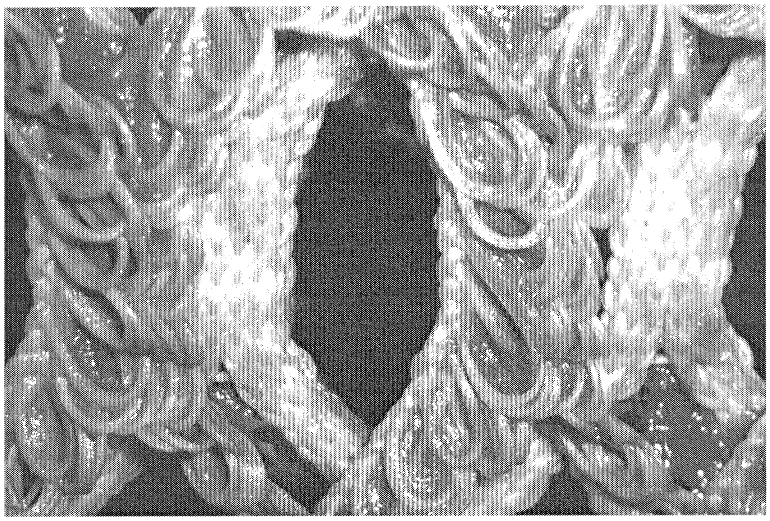

Figure 4. Thick biomass on the looped side of the media and the thin biomass on the tightly knit smooth face.

CONCLUSIONS

Simultaneous nitrification-denitrification can be accomplished in properly engineered municipal wastewater treatment plants without external recirculation of nitrified wastewater, thus providing additional treatment at small added cost. Biofilms that de-nitrify in the presence of bulk oxygen must be necessarily thick but must be physically retained by the structure of the media while smoother surfaces promote nitrifier growth.

REFERENCES

Zammataro, R., Lynn, A.G., Mauer, D.E., and Reardon, R.D.(2004). Upgrading a contact stabilization treatment plant to a nitrifying activated sludge process by using integrated fixed-film activated sludge (IFFAS) media. Presented at Florida Resources Conference, April 4-7, 2004.