Floating Treatment Wetland Technology: Nutrient Removal from Wastewater

This case study illustrates the Floating Island International (FII) patented floating treatment wetland (FTW) technology and its ability to reduce nutrient levels in wastewater. Constructed of post-consumer polymer fibers ("matrix") and vegetated with native plants, FTWs mimic the ability of natural wetlands to clean water by bringing a "concentrated wetland effect" to any water body.

Since their initial implementation nearly a decade ago, one of the primary objectives of FII's floating treatment wetlands has been to reduce objectionable nutrient levels. Potential applications include waterways degraded by agricultural runoff, ponds and lakes impacted by waterfowl and/or septic systems, polishing of municipal wastewater and even treatment of raw wastewater.

The nutrients of concern discussed in this case study are ammonia, total nitrogen, total phosphorus, biochemical oxygen demand (BOD) and total suspended solids (TSS).

Table 1 illustrates ammonia removal at four sites equipped with FTWs. The table includes ammonia concentrations, percent removals and removal rates in pounds of ammonia-nitrogen removed per year per cubic foot of FTW material.

TABLE 1. FTW AMMONIA REMOVAL

	Ammonia-N Concentration (mg/L)			Percent Removal		Removal Rate (lb/yr/ft^3)	
Study	**Influent**	**FTW**	**Control**	**FTW**	**Control**	**FTW**	**Control**
MBRCT Tank Test	149	40	NA	73%	NA	0.4	NA
MBRCT Test Pond	172	22	112	87%	40%	0.9	0.4
Wiconisco	47.8	19.3	25.6	60%	51%	2.5	1.9
Rehberg Ranch	44.1	7.2	18.7	84%	58%	1.3	0.9

All four systems presented in Table 1 are variations of wastewater lagoons at different scales. The earliest study conducted by FII researchers for a Montana Board of Research and Commercialization Technology (MBRCT) grant was a small-scale FTW which did not include a "control" lagoon. The other three studies included controls, which were parallel lagoons treating the same influent wastewater but without FTWs.

Ammonia removal ranged from 60% to 87% in the four systems. The Rehberg Ranch FTW removed 26% more ammonia than the control lagoon, while the Wiconisco FTW was 9% better than the control. The highest ammonia removal rate, 2.5 lb/ft^3/yr, was observed with the Wiconisco FTW. Ammonia concentrations at Rehberg Ranch are shown in Figure

1. Nitrification (biological conversion of ammonia to nitrate under aerobic conditions) is the primary mechanism for ammonia removal in these systems.

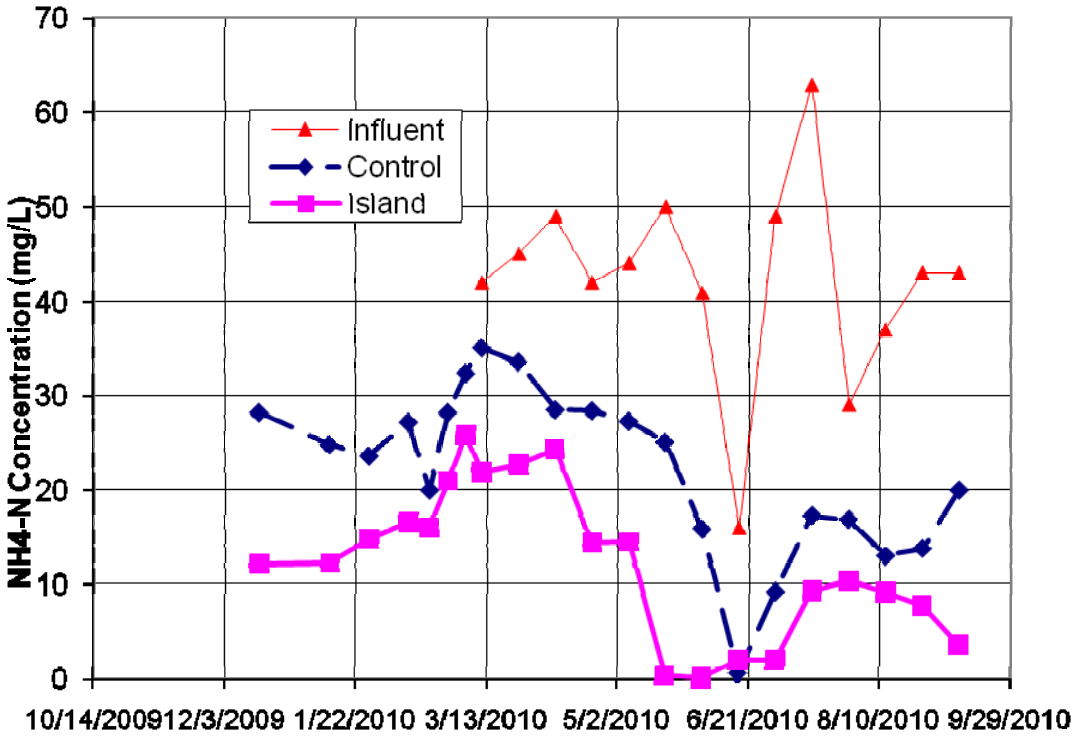

Figure 1. Rehberg Ranch - Ammonia

Table 2 illustrates total nitrogen removal in five studies equipped with FTWs.

TABLE 2. FTW TOTAL NITROGEN REMOVAL

	Nitrogen Concentration (mg/L)			Percent Removal		Removal Rate (lb/yr/ft³)	
Study	**Influent**	**FTW**	**Control**	**FTW**	**Control**	**FTW**	**Control**
MBRCT Test Pond	172	22	112	87%	35%	0.9	0.4
Rehberg Ranch	50.2	14.1	24.5	72%	51%	1.2	0.8
Wiconisco	46.3	18.6	20.9	60%	55%	2.5	2.3
McLean's Pit	NA	NA	NA	40%	NA	2.4	NA
Shepherd Pond	0.5	0.1	NA	80%	NA	0.1	NA

The first four systems presented in Table 2 are relatively small wastewater lagoons, while the Shepherd Pond is a lake restoration effort. Total nitrogen removal ranged from 40% to 87% in the five systems. The MBRCT, Rehberg Ranch and Wiconisco studies included

"control" lagoons, which were parallel lagoons treating the same influent wastewater but without FTWs. FTW total nitrogen removal was better than the control by 52% and 21% in the MBRCT and Rehberg Ranch studies.

Figure 2. Rehberg Ranch FTW, July 2010

Figure 3. Mature FTWs at Wiconisco, 2009

The Rehberg Ranch and Wiconisco FTWs are full-scale systems treating average flows of 12 and 16 gallons per minute (gpm), respectively (Figures 2 and 3). The Rehberg Ranch system, installed in late 2009, is the latest-generation FTW as it includes a pump for circulation and aeration. The Wiconisco system was one of the first full-scale FTWs installed in 2005.

The McLean's Pit (New Zealand) and Shepherd Pond (Montana) systems have FTWs but no parallel lagoons to serve as controls. Monitoring data at McLean's Pit is limited to the percent removal and removal rate.

The Wiconisco and Rehberg Ranch FTWs treated municipal wastewater, which contained high ammonia concentrations but low initial nitrate concentrations. In all five systems listed, ammonia was reduced to nearly zero while the nitrate concentrations (including the nitrate converted from ammonia by biological nitrification) were still relatively low after treatment.

For total nitrogen removal, both aerobic and anoxic conditions (either in different locations or in treatment stages) are required. Nitrification (biological conversion of ammonia to nitrate under aerobic conditions) is the primary mechanism for ammonia removal in these systems. Denitrification (biological reduction of nitrate to nitrogen gas under anoxic conditions) is the primary mechanism for nitrate removal. Although the Rehberg and Wiconisco FTWs were aerated for ammonia removal, both systems achieved anoxic conditions (and subsequent nitrate removal) in the presence of dissolved carbon in the wastewater, which acts as a food source for denitrifying bacteria. Both the Wiconisco (Pennsylvania) and Rehberg Ranch (Montana) FTWs are located in cold-weather climates, which has traditionally limited biological nitrate removal.

Table 3 shows total phosphorus removal in five studies equipped with FTWs.

TABLE 3. FTW TOTAL PHOSPHORUS REMOVAL

	Phosphorus Concentration (mg/L)			Percent Removal		Removal Rate (lb/yr/ft^3)	
Study	**Influent**	**FTW**	**Control**	**FTW**	**Control**	**FTW**	**Control**
MBRCT Tank Test	15.9	1.5	NA	91%	NA	0.52	NA
MBRCT Test Pond	13.6	5.2	6.4	62%	53%	0.13	0.08
Wiconisco	8.1	4.7	5.1	42%	37%	0.30	0.26
Shepherd Pond	0.6	0.2	NA	67%	NA	0.05	NA
Yingri Lake	0.93	0.29	NA	69%	NA	NA	NA

Total phosphorus removal ranged from 42% to 91% in the five systems. FTWs in the MBRCT and Wiconisco studies improved phosphorus removal by 9% and 5% compared to

the control lagoons. Efforts are currently underway at FII to further enhance FTW phosphorus removal through biological, chemical and physical mechanisms.

Table 4 illustrates Biochemical Oxygen Demand (BOD) removal in four studies equipped with FTWs.

TABLE 4. FTW BOD REMOVAL

	BOD Concentration (mg/L)			Percent Removal		Removal Rate (lb/yr/ft³)	
Study	Influent	FTW	Control	FTW	Control	FTW	Control
MBRCT Test Pond	330	230	NA	30%	NA	0.7	NA
Wiconisco	176	17	15	90%	91%	14	14
Rehberg Ranch	218	20	28	92%	87%	6.8	6.5
McLean's Pit	NA	NA	NA	46%	NA	0.8	NA

BOD removal ranged from 30% to 92% in the four systems. BOD removal was impressive with the Wiconisco and Rehberg Ranch FTWs but removal in the control lagoons was nearly as good. It appears that FTWs offer BOD removal equivalent to traditional lagoons while providing improved nitrogen and phosphorus removal.

Table 5 shows total suspended solids (TSS) removal in three studies equipped with FTWs.

TABLE 5. FTW TSS REMOVAL

	TSS Concentration (mg/L)			Percent Removal		Removal Rate (lb/yr/ft³)	
Study	Influent	FTW	Control	FTW	Control	FTW	Control
MBRCT Test Pond	42	3	NA	93%	NA	0.5	NA
Rehberg Ranch	81	37	45	54%	44%	1.5	1.2
McLean's Pit	NA	NA	NA	89%	NA	0.2	NA

TSS removal ranged from 54% to 93% with the three FTWs; for Rehberg Ranch (the only study with a control), the FTW improved TSS removal by 10%.

Researchers have estimated that approximately 80% of the FTW efficacy is due to bacteria attached to plant roots and the FTW polymer matrix itself, with the other 20% attributed to nutrient uptake by plants. The plants create the platform for biological activity in a biofilm, while also contributing nutrient uptake and aesthetic benefits. This is illustrated in Figure 4.

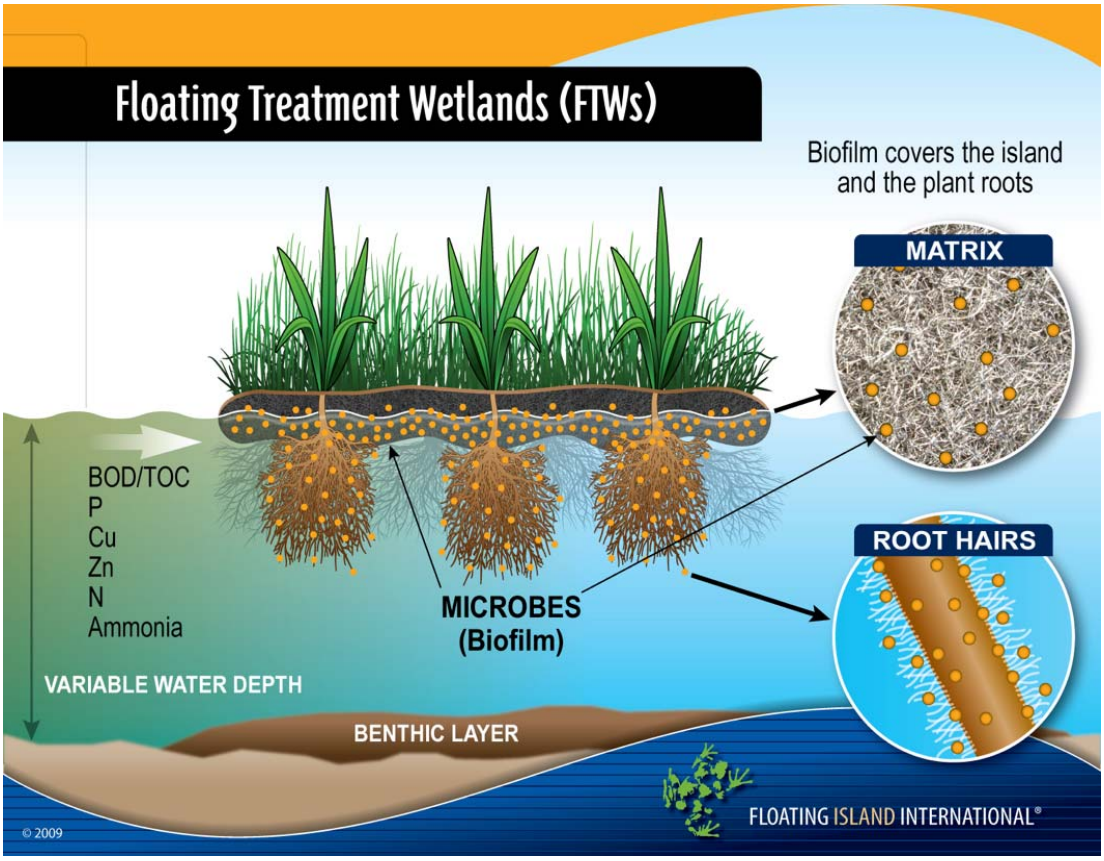

Figure 4. Illustration of FTW biological activity

Conclusion:

The need to reduce nutrient levels in wastewater is increasingly critical as rivers, lakes and coastal waters become more nutrient-loaded worldwide. This is the entry point for cutting edge, "green" floating treatment wetland (FTW) technology.

Although traditional wastewater lagoons effectively remove BOD and TSS, their ability to remove nitrogen and phosphorus from municipal wastewater is limited. FTW technology enhances these lagoons with the "concentrated wetland effect," facilitating compliance with increasingly stringent wastewater nutrient, BOD and TSS criteria.