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MIT researcher seeks to design better 'constructed wetlands' to fight water pollution

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Eelgrass and cattails may evoke images of supernatural creatures, but they're actually ordinary plants being used for some pretty extraordinary work -- to help clean up human-made messes at the marshy juncture where wetlands meet open waters.

Heidi Nepf, a professor of hydrodynamics at MIT, has created a mathematical model that describes the hydrodynamics -- or water movement -- through those aquatic grasses in wetlands. This new model may enable more accurate prediction of wetland filtering capacity, and thus improve wetland design and management.

"Coastal wetlands protect surface water quality by acting as natural filters for both dissolved and particulate-born nutrients and contamination. It is only by understanding how the water moves that we can understand where particles and contaminants are going, and how plant/flow interaction affects the fate of the nutrients and contaminants in wetlands," said Dr. Nepf, who recently published two papers on her research, in *Water Resources Research* (February) and *Limnology and Oceanography* (April).

Ecologists, botanists and environmental engineers know that vegetation can be planted in certain configurations and densities to create constructed wetlands that absorb and dissipate runoff pollution before it makes its way into the open waters of lakes and oceans. The design of these systems is currently limited by a poor understanding of the impact of vegetation on the water movement.

Professor Nepf is addressing this limitation through her field and laboratory research.

HOW PLANTS DO IT

Sometimes the plant canopy "captures" contaminants by creating still regions that allow particulate material to accumulate around stems and leaves. But if these regions of still water are suddenly disturbed by stronger flows, as may happen in storms, those same contaminants could be let loose all at once, with the potential to cause even more problems.

Another effect of the plant/flow interaction is the creation of small wakes behind plant stems. This bit of turbulence may improve the plants' uptake of elements like phosphorous and nitrogen, or may accelerate the uptake of chemicals by microbial communities living on the plants' surfaces. These processes are key to wetland function, and they are controlled in part by the characteristics of the flow.

"When you stir your coffee, you get curls coming off the back of your spoon. With plants, that's reversed. The plants are still and the water moves around them, leaving little wakes behind," she said.

Dr. Nepf, of MIT's Department of Civil and Environmental Engineering, and co-author Evamarie Koch, a seagrass biologist at the Horn Point Environmental Laboratory at the University of Maryland, found that secondary flows created by the interaction of plant stems with the primary flow can have an accumulated effect in surprising ways.

For instance, in their paper in *Limnology and Oceanography*, they show how pressure created by the water flowing against the base of the stem can cause water to be pushed into the soil under a plant, through its roots and emerge again in a vertical flow on the opposite side of the stem. This vertical flow of water could carry nutrients out of the sediment and deliver them to the growing portions of the plant tissue.

The paper in *Water Resources Research*, which is based on the laboratory and field work of four graduate students -- Al Tarrel, Jennifer Sullivan, Christophe Mugnier and Becky Zavistoski -- presents for the first time the model that describes the relationship between vegetative drag, turbulence and mixing within a canopy that may improve wetland design and management.

"We're still at an early stage in this work where physicists are just beginning to seriously interact with ecologists and biologists," said Dr. Nepf, a physicist, who cautions that they don't yet have an exact model of the perfect wetland.

IMITATING NATURE

To make their studies, Dr. Nepf and the graduate students used wooden dowels, strips of plastic and rubber bands to make model beds that mimic different types of aquatic grasses in a 66-foot-long flume at MIT's Parsons Lab.

The flume, which looks like a very long fish tank, currently holds 1,500 gallons of water and 850 small "plants" -- actually short pieces of wooden dowel stuck in holes in the bottom of the tank, each with six slender strips of plastic affixed with rubber bands. The plastic strips wave about in the tank exactly as seagrass blades would in a coastal embayment. A hydraulically-driven paddle produces waves in the flume; a four-beam laser doppler measures the turbulence as the water moves around and over the plastic plants growing out of the bottom of the tank.

For each of their three experiments -- on emergent grasses (reeds or cattails), stiff submerged grasses (Bermuda grass) and now submerged, flexible eelgrass -- Dr. Nepf and her students spend many weeks determining the appropriate materials to make a scaled model of plants growing in either fresh or saltwater. By choosing materials of the appropriate density, geometry and elasticity, they are able to build model grasses that bend and move just like the real thing.

The current flume experiment of submerged eelgrass was designed and built by graduate student Marco Ghisalberti, who scaled exactly the imitation bed of 6 inch-high eelgrass to the actual 3 feet-high grasses.

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