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Mosquito larvae density and pollutant removal in tropical wetland treatment systems in Honduras

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Abstract

Constructed wetlands offer a low-cost wastewater treatment option for tropical developing countries. The vast majority of published treatment wetland research has been conducted in temperate regions. Because the function of treatment wetlands is related to the environmental conditions, more research specific to the tropics should be completed. A six-cell free water surface (FWS) wetland mesocosm was constructed in Santa Rosa de Copán, Honduras that received input from an open-sewer/wastewater-impacted stream. Three cells were planted with *Typha domingensis* Pers., and three cells were left unplanted. Both planted and unplanted wetlands were constructed with three different surface areas to concurrently study different hydraulic retention times (HRTs) and hydraulic loading rates (HLRs).

Results from 6 months of operation showed improved water quality and mosquito larvae populations affected by their specific environment. Five-day biochemical oxygen demand (BOD) removal appeared to be proportional to HRT and HLR, and BOD concentration in the effluent was higher in unplanted cells than in planted cells ($P<0.05$). BOD removal approached 60% for greater than 3.5 days HRT. Total phosphorus (P) removal and coliform bacteria removal were found to be correlated with pollutant load, and P removal was found to be correlated with HRT but not HLR. A second municipal wastewater FWS treatment wetland in Copán Ruinas, Honduras that had been established for 15 years, was also evaluated. BOD removal in the Copán Ruinas system was determined to be 93% with 2.6 day HRT. These pollutant removal rates are higher than would be expected in temperate regions. Mosquito larvae density was correlated with depth of the wetland. Mosquito larvae densities were higher in cells that were operating below design depth of 0.2 m ($P<0.005$). Results indicate that it is possible to design FWS wetlands in the tropics for effective BOD removal and reduced mosquito larvae development.

Keywords: Constructed wetland; Phosphorus; BOD; Developing country; Coliform bacteria; Mosquitoes

1. Introduction

Treatment wetlands have been extensively researched during the past 25 years. More than 650 full-scale systems are in place throughout the world, and considerably more pilot and laboratory systems have been studied (Juwarkar et al., 1995; Kadlec and Knight, 1996). The majority of published treatment wetland work has been concentrated in temperate regions of Europe, the United States, and Australia. Tropical treatment wetland research is limited in comparison (Kivaisi, 2001; Lim et al., 2001; Meutia, 2001; Abira et al., 2003; Kaseva, 2004).

Differences between a tropical environment and a temperate environment can have important impacts on treatment wetland function. In much of the tropics, humidity is high year-round, a wet season and a dry season exist, or only a wet season closer toward the equator, and the temperature does not dip below freezing at any time in the year (Pearce and Smith, 1990). Treatment wetlands have been shown to be affected by hydrologic (Livingston, 1989) and temperature variations (Kadlec and Reddy, 2001; Zdragas et al., 2002). Renewal rate and frequency of inundation influence the

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chemical and physical properties of wetland substrates. The substrate variation may affect species diversity and abundance, primary productivity, organic deposition and nutrient cycling. Hydrology may also influence the sedimentation, aeration, biological transformation, and soil adsorption processes (Livingston, 1989). In a tropical region, where rain is seasonal, and can be heavy during the wet season all these factors could be affected. The lack of periodic freezes could affect treatment wetland performance. Surface et al. (1993) described decreases in BOD removal and nitrogen removal in a temperate zone during winter due to decreased microbial activity in reduced temperature substrate. Kadlec and Reddy (2001) note that microbially mediated reactions are most affected by temperature below 15 °C. In the tropics temperatures at low and medium altitudes never fall below freezing and remain fairly constant throughout the year. Thus, fewer temperature extremes in the tropics would be expected to positively affect pollutant removal.

Mosquito density and control in treatment wetlands have not been well studied in the tropics (Kivaisi, 2001). Because mosquitoes can carry malaria, dengue fever, yellow fever, and encephalitis, they are a threat to public health in the tropics (WHO, 1995). Greenway et al. (2003) began addressing some of these public health concerns with an evaluation of mosquito larvae in a tropical treatment wetland in Australia; however, the research to date on vector control in tropical treatment wetlands is inadequate given the severity of the potential for disease (Kivaisi, 2001).

Treatment wetlands offer a low-cost wastewater treatment technology (Meutia, 2001). Much of Africa, Southeast Asia, Oceania, and Latin America lie within the tropics, and many of the countries in these regions are impoverished (Thornton et al., 2002). A low-cost wastewater treatment technology like treatment wetlands that removes organics, pathogens, and nutrients would be useful in these areas (Denny, 1997; Haberl, 1999; Meutia, 2001; Sundaravadivel and Vigneswaran, 2001).

In order to address the need for tropical treatment wetland research, a six-cell experimental FWS wetland system was constructed in Santa Rosa de Copán, Honduras and was operated for 6 months between November 1995 and May 1996. For comparison, a second, full-scale, 15-year-old system in Copán Ruinas, Honduras was also studied. The research focused on BOD, P, and coliform bacteria removal, and mosquito larvae densities within these two tropical treatment wetlands.

2. Methods

The study site outside of Santa Rosa de Copán, Honduras, was located at 14°50′ N, 88°45′ W and at an elevation of 1100 m. Monthly mean temperature ranges between 12 and 29 °C, and mean relative humidity is 80%. The rainy season begins in June and lasts through December, and the dry season runs from January to May. The average annual precipitation is 1.3 m (FUNDEMUN, 1994).

The wastewater that was generated in Santa Rosa was released into two streams, which began in Santa Rosa and flowed through town. One of these streams provided the wastewater inputs for the wetland. The flow of this stream consisted of approximately 75% wastewater during the dry season and 25% wastewater during the rainy season (K. Jaanke, PLAN International, Santa Rosa de Copán, Honduras, June 1995, personal communication). The study site was located 1.5 km downstream from town. The influent water was directed by gravity through a 400-m pipe into the wetland. Distribution boxes were used to direct wastewater into the six wetland cells through v-notch weirs (Fig. 1). Two wetland cells measured 1 × 5 m (5 m^2), two 1.5 × 7.5 m (11.25 m^2), and two 2 × 10 m (20 m^2). The sides of the wetland cells were constructed of wood. Clay spread over 2 mil (50 μm thick) plastic sheeting formed an impermeable layer at the wetland base. A substrate of 0.25 m sandy loam was added. After water flow into the wetland cells had begun in November 1995, a 0.025 m layer of clay was distributed over each cell to aid in preventing subsurface drainage. For each cell size, one cell was planted with *Typha domingensis* Pers., and one cell was left unplanted. Mean water depth in the cells was approximately 0.2 m (0.16 m at the inlet and 0.24 m at the outlet). After construction was nearly complete, it was realized that the largest unplanted cell was at a greater angle than the other cells (0.03 m depth at the inlet, 0.1 m mean depth). Also during the study, the largest and the medium-sized planted cells experienced water depth fluctuations resulting in intermittent low later depths, or depths below design water depth. Both the largest unplanted cell and these cells with some periods of low water (Fig. 1) were recorded as Low Water for statistical analysis of mosquito larvae density effects.

Flow through the six v-notch weirs at the inlet to wetland cells were designed to be equal. Thus, three HRTs and HLRs could be

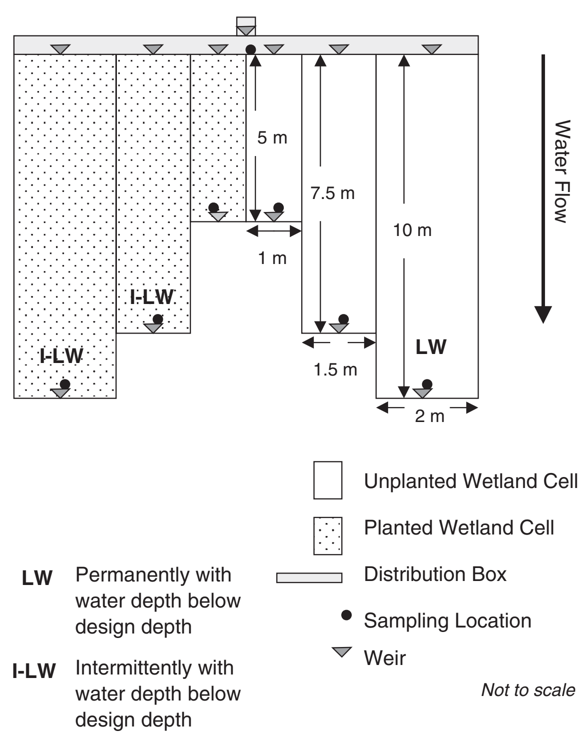

Fig. 1. Plan view of Santa Rosa de Copán FWS wetland mesocosm system showing sampling locations, surface dimensions of each cell, and cells that experienced water depth below mean design depth of 0.2 m. Diagram is not to scale.