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ANALYSIS

A comparative evaluation of money-based and energy-based cost–benefit analyses of tertiary municipal wastewater treatment using forested wetlands vs. sand filtration in Louisiana

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Abstract

Forested wetlands have been used to provide advanced secondary and tertiary treatment for municipal wastewater for a number of cities in southern Louisiana. Wetland assimilation provides the same services as conventional methods in improving wastewater quality, while having positive impacts on wetlands. Suspended solids and nutrients in wastewater increase net primary productivity (NPP), which leads to increased organic soil formation. This leads to increased elevation that offsets subsidence, a major cause of coastal wetland loss in Louisiana. The City of Breaux Bridge, LA, has discharged secondarily treated municipal wastewater into a forested wetland since 1950, and wetland assimilation was permitted by the Louisiana Department of Environmental Quality and the US Environmental Protection Agency (US EPA) in 1997. We compared benefits and costs of utilizing forested wetlands and conventional sand treatment using money-based and energy-based cost–benefit analyses (CBA). The wetland method had a higher benefit–cost ratio than conventional treatment by 6.0 times based on dollar-based CBA, and by 21.7 times from the energy analysis. Methodologically, dollar-based CBA is a market price-based assessment, liming to an anthropocentric framework, while embodied energy analysis accounts for monetary and nonmonetary values such as carbon sequestration by wetlands, which contributes a more complete assessment of the interaction between the natural environment and the human economy. Wetlands treat more wastewater per unit of energy and with less financial cost than conventional methods, because the wetland method utilizes natural energies such as sunlight, wind and rain, while conventional treatment methods depend on imported nonrenewable energies and materials such as chemicals and electricity and require additional capital investment. Increasing application of natural energies is becoming more important with depleting fossil fuels. Further, wastewater addition increases NPP and wetland elevation, which has potential for wetland mitigation credit.

Keywords: Wetlands; Energy analysis; Municipal wastewater treatment; Louisiana; Cost–benefit analysis

1. Introduction

Both wetlands and conventional treatment methods rely on biological and physical processes to treat

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wastewater. Natural wetlands improve wastewater quality by utilizing natural energies, which drive the multiple functions and mechanisms of effluent treatment in wetlands including physical settling, chemical precipitation, adsorption, and biological processes such as uptake and denitrification. A number of studies have shown that wetlands provide an efficient means of nutrient and suspended sediment assimilation (Nichols, 1983; Ewel and Odum, 1984; Breaux and Day, 1994; Kadlec and Knight, 1996; Boustany et al., 1997; Zhang et al., 2000; Day et al., 2003) (Fig. 1).

Conventional methods of municipal wastewater treatment (e.g., grit chamber, clarifier, aeration tank, anaerobic digesters, sand filtration, sludge thickener) depend mostly on nonrenewable energy sources (e.g., electricity and chemicals) (Tchobanoglous and Burton, 1991; Viessman and Hammer, 1998). Further, capital investments to build a facility (e.g., reactivator and pump) are required. For example, the sand filtration method consists of the three major steps of treatment: flocculation, sedimentation, and filtration. These functions take place inside reactors, powered by electrical power, and controlled by inputs of chemicals (Fig. 2).

The benefits of using natural wetlands for municipal wastewater treatment include improved effluent water quality, increased vegetation productivity, financial and energy savings, and lower requirements for expensive capital investments (Breaux and Day, 1994; Hesse et al., 1998; Cardoch et al., 2000; Rybczyk et al., 2002; Day et al., 2003). Additionally, land loss in the coastal zone of Louisiana, due largely to lack of nutrients and sediments, is one of the major environmental problems in Louisiana (Baumann et al., 1984; Templet and Meyer-Arendt, 1988; Day et al., 2000a). Settled solids in wetlands and active organic soil formation due to increased root growth enhanced by nutrient uptake increase accretion rates in impacted wetlands to help offset subsidence in wetlands, which prevents or slows down wetland loss (e.g., Rybczyk et al., 2002).

We had two general objectives in this paper. First, we attempted to clarify differences between monetary and biophysical assessments using dollar-based and energy-based cost–benefit analysis (CBA) by applying these two analyses to a case study of wastewater treatment. Additionally, we demonstrated some of the benefits of ecological engineering that employs natural free energies (e.g., sun, wind, rainfall, and tides)

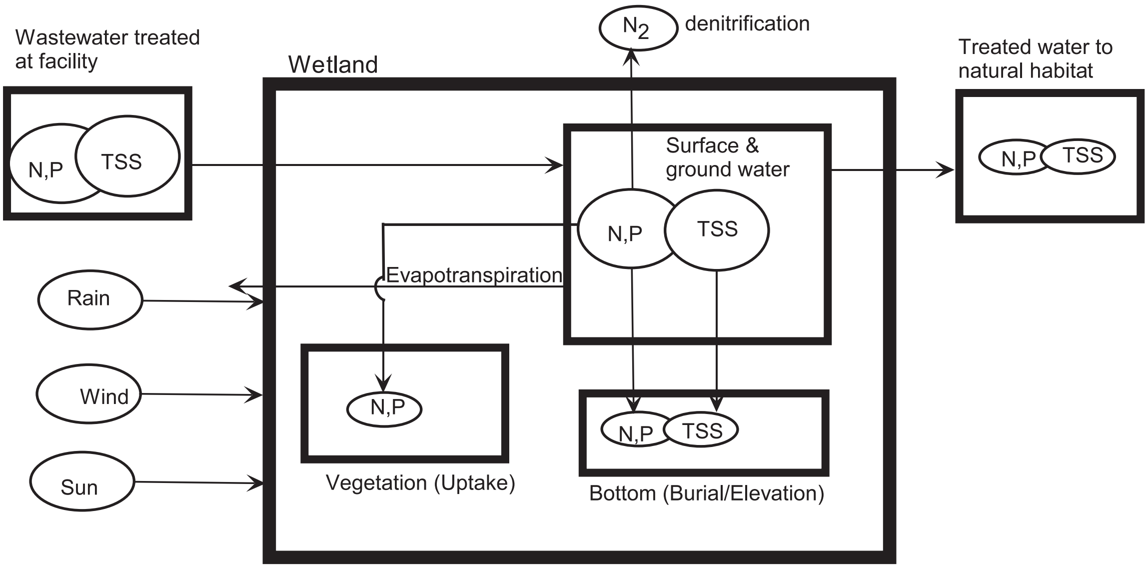

Fig. 1. Diagram of the wetland treatment method. Wetlands remove nutrients and retain suspended solids by physical settling, chemical precipitation, adsorption, and biological metabolism. The processes are controlled by natural energies such as sunlight, wind, and rain. Permanent nutrient pathways are burial, vegetation uptake, and denitrification.