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Introduction

Constructed wetlands offer a cost-effective and sustainable solution for managing rainwater on sites where runoff currently escapes to rice production fields or flows back into the sea. These engineered ecosystems mimic the functions of natural wetlands, providing efficient wastewater treatment and enhancing freshwater storage capabilities. By harnessing the natural processes of sedimentation, filtration, and biological uptake, constructed wetlands effectively remove pollutants from wastewater, thus reducing the environmental impact on surrounding agricultural and marine ecosystems. Additionally, the ability to store and gradually release freshwater improves water availability for rice cultivation and other uses, promoting water security and resilience. However, careful consideration must be given to the choice of materials, particularly for the pond liners, to ensure long-term effectiveness and cost efficiency. This report will delve into the cost analysis of implementing constructed wetlands, emphasizing their dual benefits and the challenges associated with material selection.

Comparison of Synthetic Liners vs. Natural Liners (Clay) in Wetlands Construction

Constructed wetlands serve a variety of purposes, from water purification to habitat creation. When constructing a wetland over a large area, such as the example we explore here – 20,000 square meters, choosing between synthetic liners and natural clay liners involves a detailed analysis of costs, labor, and environmental impacts. This essay provides a rough estimation of labor and material costs for both options, and introduces an economical compromise using a bentonite-amended soil base under a synthetic liner. This approach balances initial cost savings with long-term maintenance considerations.

Project Context:
University of Antananarivo Garden of Eden Constructed Wetlands (circa 20,000 square meters of ponds)

The goal of the University of Antananarivo Garden of Eden Constructed Wetlands project is to create a sustainable and effective wetland area for wastwater treatement and also for Fresh water storage - in seperate areas of the large university landscape. The question here centers on whether to use a full clay liner, a synthetic liner, or a hybrid approach involving a bentonite-amended soil base under a synthetic liner.

Estimation of Labor and Material Costs

Synthetic Liners (e.g., EPDM, PVC)

Materials:
- Liner Cost: High-quality EPDM liner costs approximately $3 to $5 per square meter.
  - Total Cost: 20,000 m^2 x $4 (average) = $80,000.
- Geotextile Underlay: To protect the liner, a geotextile underlay is typically used, costing around $1 per square meter.
  - Total Cost: 20,000 m^2 x $1 = $20,000.
- Additional Materials: Adhesives, tapes, and other materials for seams and repairs, roughly estimated at $5,000.
  - Total Material Cost: $105,000.

Labor:
- Installation: Labor costs for installation are approximately $2 to $4 per square meter, considering the need for skilled labor to ensure proper installation.
  - Total Cost: 20,000 m^2 x $3 (average) = $60,000.
  - Total Labor Cost: $60,000.

Total Estimated Cost for 20,000 square meters installed Synthetic Liner: $165,000

Bentonite Clay Liner

Materials:
- Bentonite Cost: Bentonite clay costs about $0.50 to $1 per kilogram. Assuming a layer thickness of 10 cm and a density of 1.5 kg per liter:
- Volume Needed: 20,000 m^2 x 0.1 m = 2,000 m^3.
- Weight Needed: 2,000 m^3 x 1,500 kg/m^3 = 3,000,000 kg.
  - Total Cost: 3,000,000 kg x $0.75 (average) = $2,250,000.

Labor:
- Installation: Labor costs for spreading and compacting the clay are higher due to the volume and weight involved, approximately $5 to $7 per square meter.
- Total Cost: 20,000 m^2 x $6 (average) = $120,000.
  - Total Labor Cost: $120,000.

Total Estimated Cost for 20,000 square meters installed Bentonite Clay Liner: $2,370,000.

Bentonite-Amended Soil Base Under Synthetic Liner

Materials:
- Bentonite Amendment: Adding a bentonite layer (approximately 5 cm) under the synthetic liner to improve the sealing. This requires less bentonite.
- Volume Needed: 20,000 m^2 x 0.05 m = 1,000 m^3.
- Weight Needed: 1,000 m^3 x 1,500 kg/m^3 = 1,500,000 kg.
  - Total Cost: 1,500,000 kg x $0.75 = $1,125,000.
- Synthetic Liner Cost: As previously estimated.
  - Total Cost: $105,000.

Labor:
- Installation of Bentonite and Liner: Combined labor cost is lower than installing a full bentonite layer but higher than installing only a synthetic liner.
- Total Cost: 20,000 m^2 x $4 (average) = $80,000.
  - Total Labor Cost: $80,000.

Total Estimated Cost for Bentonite-Amended Soil Base and Synthetic Liner: $1,310,000.

Environmental Impact Assessment

Studies comparing the environmental impacts of synthetic and clay liners highlight several important factors:

Synthetic Liners:
- Environmental Impact: Production and disposal of synthetic liners contribute to plastic pollution and carbon emissions (Mitsch & Gosselink, 2015).
- Durability and Longevity: Synthetic liners are durable and require less frequent replacement, reducing long-term environmental impact (Kadlec & Wallace, 2008).

Bentonite Clay Liners:
- Environmental Impact: Bentonite is a natural material with a lower environmental footprint in terms of production. However, the mining and transportation of large quantities can still have significant impacts (Boyd, 2000).
- Ecological Integration: Clay liners integrate more seamlessly into the natural environment and support more natural wetland functions (Hammer, 1992).

Hybrid Approach:
- Environmental Impact: Using a bentonite-amended soil base reduces the volume of synthetic materials required and leverages the natural sealing properties of bentonite, minimizing overall environmental impact (Hammer, 1992).

Conclusions and Cost Comparison

The table below summarizes the costs for each option:

Option	Cost Per Square Meter	Total Projected Liner Cost (20,000 m2)
Synthetic Liner	$ 8.25	$165,000
Bentonite Clay Liner	$ 118.50	$2,370,000
Bentonite-Amended Soil Base and Liner	$ 65.50	$1,310,000

Cost Comparison - Qualitätive

Given the significant cost difference, the synthetic liner is the most economical option initially, followed by the hybrid approach. The full bentonite clay liner, while natural, is the most expensive. The hybrid approach using a bentonite-amended soil base under a synthetic liner provides a balanced solution, offering cost savings while leveraging the benefits of both materials.

Each of the three options for constructing the University of Antananarivo Garden of Eden Constructed Wetlands —using a synthetic liner, a bentonite clay liner, or a bentonite-amended soil base under a synthetic liner—is viable, with unique advantages and considerations. While this essay focuses on the economic aspects of liner construction, it is essential to recognize that the final decision will depend on a variety of factors beyond cost, including environmental impact, durability, and specific project requirements. This analysis solely compares the construction costs of the three liner options and does not address other critical issues such as water quality for drinking, showering, or research purposes, which are being thoroughly investigated in parallel.

References

Boyd, C. E. (2000). Water Quality: An Introduction. Springer Science & Business Media.

Hammer, D. A. (1992). Creating Freshwater Wetlands. CRC Press.

Kadlec, R. H., & Wallace, S. D. (2008). Treatment Wetlands. CRC Press.

Mitsch, W. J., & Gosselink, J. G. (2015). Wetlands (5th ed.). John Wiley & Sons.

Pond Construction with synthetic Liner. Photo Credit: Canva

Pond Construction with Bentonite amended soil. Photo Credit: Canva