WASTEWATER TREATMENT IN TSUNAMI AFFECTED AREAS OF THAILAND BY CONSTRUCTED WETLANDS

Hans Brix*, Thammarat Koottatep**, Carsten H. Laugesen***

**Aarhus University, Department of Biological Sciences, 8000 Århus C, Denmark*
***Asian Institute of Technology, School of Environment, Resources & Management, Thailand*
**** Wastewater Management Authority, 10900 Bangkok, Thailand*

ABSTRACT

The tsunami of December 2004 destroyed infrastructure in many coastal areas in South-East Asia. In January 2005 the Danish Government gave a tsunami relief grant to Thailand to re-establish the wastewater management services in some of the areas affected by the tsunami. This paper describes the systems which have been built at three locations: (a) Baan Pru Teau: A newly-built township for tsunami victims which was constructed with the contribution of the Thai Red Cross. Conventional septic tanks were installed for the treatment of blackwater from each household, and its effluent and grey water (40 m^3/day) are collected and treated at a 220 m^2 subsurface flow constructed wetland. (b) Koh Phi Phi Don island: A wastewater collection system for the main business and hotel area of the island, a pumping station and a pressure pipe to the treatment facility, a multi-stage constructed wetland system, and a system for reuse of treated wastewater. The constructed wetland system (capacity 400 m^3/day) consists of vertical flow, horizontal subsurface flow, free water surface flow and pond units. Because the treatment plant is surrounded by resorts, restaurants and shops, the constructed wetland systems are designed with terrains as scenic landscaping. (c) Patong: A 5,000 m^2 constructed wetland system has been established to treat polluted water from drainage canals which collect overflow from septic tanks and grey water from residential areas. It is envisaged that these three systems will serve as prototype demonstration systems for appropriate wastewater management in Thailand and other tropical countries.

KEYWORDS

Constructed wetland; horizontal flow; tropical; tsunami; vertical flow; wastewater

INTRODUCTION

The tsunami of December 2004 destroyed infrastructure in many coastal areas in South-East Asia (Papadopoulos et al., 2006). A powerful earthquake in the bottom of the Indian Ocean created a huge wave travelling with a speed of about 800 kilometres per hour in the direction of Thailand and Indonesia to the East, and Sri Lanka, India and the African continent to the West. In Thailand, the South-West coast and a number of islands were hit by the wave. Many villages, hotels, shops as well as the main

infrastructure of the areas were destroyed and several thousands of humans were killed. Utility networks, roads, water supply, electrical power supply and the wastewater drainage system were all in ruins.

In January 2005 the Danish Government gave a tsunami relief grant to Thailand to re-establish the wastewater management services in some of the areas affected by the tsunami through the development of appropriate wastewater collection and treatment systems. The centralised, highly engineered wastewater treatment systems that have been established in Thailand and other South-East Asian countries during the past decades have generally been largely disappointing. There are more than ninety municipal wastewater treatment plants in Thailand and most of them are not functioning. One of the main reasons lies in the wastewater collection system. In Thailand, there is no law requiring residents to connect to the municipal sewer network of the centralized wastewater treatment plants, so many avoid the cost by using septic tanks exclusively. Therefore, high priority in the rehabilitation project was to secure sustainability through the fitting of the wastewater management system into the local settings and by applying low-cost, robust, ease of operation and appropriate technologies. The approach of the rehabilitation project was therefore to focus on decentralised nature-based infrastructure and wastewater management techniques and, where relevant, to promote the recovery and reuse of wastewater. Constructed wetland systems are known to fulfil many of these requirements as they are generally robust, reliant and cost-efficient (Brix and Schierup, 1989; Brix, 1999; Kadlec et al., 2000; Koottatep et al., 2005)

The present paper describes three wastewater management systems which have been established as a part of the tsunami relief grant from Denmark. The systems are (i) an integrated septic tank and constructed wetland system for the treatment of domestic sewage from the new-established village of Baan Pru Teau, Phang Nga Province; (ii) an integrated wastewater collection, treatment and reuse-system at the island of Phi Phi Don, Krabi Province; and (iii) a constructed wetland system treating polluted river water at the city of Patong, Phuket Province.

CONSTRUCTED WETLAND SYSTEM DESIGN

Baan Pru Teau township

Several small villages along the coast of the Phang Nga province were completely devastated by the tsunami. Those of the inhabitants that survived lost their home and property and were in many cases moved to new townships. The Bann Pru Teau

constructed wetland system treats the wastewater from a newly-built township which was established with the contribution of the Thai Red Cross. The new township includes 80 households with an estimated population number of four per house. The average daily flow rate is estimated to about 40 m^3. Each house has a conventional concrete septic tank for blackwater treatment. Effluent from the septic tanks and all greywater is discharged into a new-established drainage network that leads the wastewater to the constructed wetland treatment system.

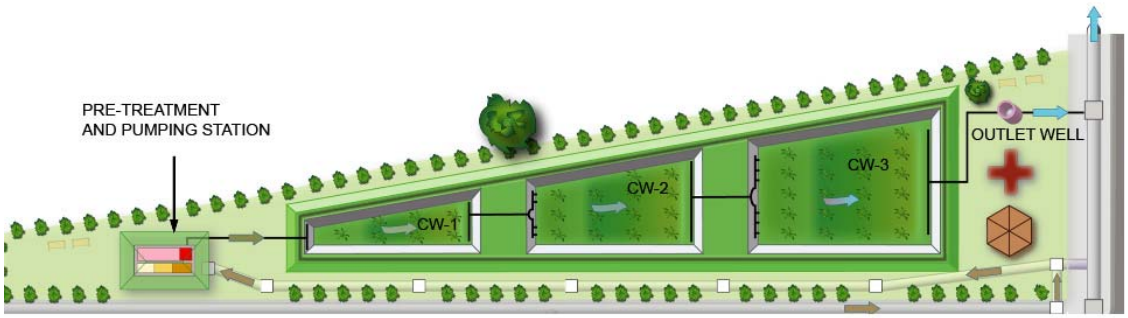

Fig. 1: General layout of the constructed wetland systems at Baan Pru Teau consisting of a pre-treatment unit comprising screening, a sand trap, grease and oil trap and a pumping station; three horizontal subsurface flow constructed wetlands in series (CW-1 to CW-3), and an outlet regulation well

The wastewater treatment system (Fig. 1) consists of the following components: (i) An overflow weir to prevent flooding and overloading of the wetland during heavy rain; (ii) a stainless steel screen with a bar spacing of 10 mm to collect garbage and prevents these from entering and blocking the pumps; (iii) a sand trap; (iv) an oil and grease trap (v) a pumping station with two pumps that lifts the wastewater into the constructed wetland cells; (vi) three wetland cells with horizontal subsurface flow that operate in series; and (vii) an outlet well for regulation of water level in the wetland cells and discharge of effluent to the drainage system along the road.

The three wetland cells have a total surface area of 220 m^2 and are filled 0.6 m deep with 8-40 mm diameter gravel. A piped tee discharges the wastewater onto the surface of the three gravel filters. From the outlet tee the wastewater seeps into the gravel filter and flows evenly through the filters 3-10 cm below the surface of the gravel. Underground outlets connect to the inlet in the next gravel filter through a PE-pipe. The water level can be adjusted at the inlet in the next gravel filter with the adjustable tees. Pipes for inspection of water level in each gravel filter are installed near the outlet. The wetlands are lined with a polyethylene liner to avoid water loss and provide an equal water level. The filters are planted with Cannae lilies to assist in the treatment and make the treatment plant more aesthetically pleasing (Brix, 1994; Brix, 1997; Koottatep and

Polprasert, 1997). Furthermore, the treatment plant area is planted with grass and wetland edges and the perimeter of the area is planted with trees and shrubs. A small house, benches, and an information board have also been installed.

Untreated wastewater and pumping of wastewater can produce an offensive odour. To reduce it, an odour reduction box is installed at the pumping station. An electrical ventilator fan draws air from the pumping station and ventilates the air through a container mounted under the pump house roof. The container is filled with pieces of charcoal and chopped woods to reduce the odour.

Koh Phi Phi Don island

The island of Phi Phi Don is located off the west coast of the Thai-Malayan peninsula. Even before the tsunami ravaged the island, which accommodates up to 1.2 million tourists per year, its 3,000 to 4,000 residents faced appalling conditions: standing wastewater, strong odours, and groundwater pollution from overflowing septic tanks. After the tsunami, the Danish Embassy allocated funds to rebuild and improve the island's wastewater management system.

A 6,000 m^2 parcel of land located alongside one of the island's main traffic routes was the only place on the island that the municipality had available for the plant. The new treatment system is therefore visible to the many tourists of the island, and therefore a major concern during planning was to make the plant look appealing and to avoid bad odours. These concerns have been accommodated in the design by specific aesthetic requirements and provision of odour control units and closed drainage systems without exposure of untreated wastewater to the atmosphere.

From the air the wastewater treatment system resemble a giant butterfly fluttering next to a flower (Fig. 2). The system has been designed not only to provide a long-term solution to the small island's wastewater problems, but also to help rebuild its infrastructure after the tsunami. The wastewater management system comprises a separate wastewater collection system, an underground pumping station, siphon distribution systems, polishing ponds, water reuse storage tanks, and three types of constructed wetlands: vertical subsurface flow wetlands, horizontal subsurface flow wetlands, and free-water surface flow wetlands. The chosen design segments each phase of the treatment process into a different portion of the flower and butterfly, and beautiful flowers, such as Cannae and Heliconia, are planted in the wetlands to make it aesthetically pleasing (Fig. 3).

Fig. 2. Sketch of the 'butterfly' wastewater treatment system at Koh Phi Phi Don. (1) Distribution tanks with siphons; (2) vertical flow constructed wetland cells with distribution systems, (3) horizontal flow constructed wetland cells, (4) surface-flow constructed wetland cells, and (5) polishing ponds.

Fig. 3. The 'butterfly' wastewater treatment system at Koh Phi Phi Don is planted with beautiful flowers, such as Cannae and Heliconia to make it aesthetically pleasing.

To control the odours, the pumping station is built underground and caps the primary treatment units (screen, sand trap, oil/grease trap, and pump sump) inside the pumping house. Air inside the cap is removed to the odour reduction box composed of charcoal and chopped wood. As the air passes through the box and into the atmosphere, it will be naturally deodorised.

The wastewater management system comprises several components. The first is each individual residence's or commercial structure's septic tank that receive the blackwater. From there the wastewater enters the main separate collection system, which connects to the pumping station. To reduce maintenance and minimise costs of operation, the pumps are solar powered. The pumps deliver the collected wastewater to three elevated siphons (the centre of the flower), which distributes the wastewater in intervals to three vertical subsurface flow wetlands (the first petal of the flower), where it seeps downward through gravel filters. The flow is then directed via pipelines to three horizontal flow wetland cells (second petal of the flower). From there, the wastewater flows to three surface flow wetlands (the wings of the butterfly), and then enter the polishing ponds (the butterfly body and head), the last stage of treatment through which the effluent passes before it is stored in nearby water storage tanks. Treated effluent is reused as irrigation water, which is in high demand on the island. The main treatment process takes place in the planted gravel filters. Three different sizes of crushed stone, all shipped to Koh Phi Phi from the mainland, are used in the gravel filters. The wastewater treatment plant has the capacity to treat 400 m^3 of water daily.

Treatment of river water at Patong

Patong is the largest and most famous tourist city on the west coast of Phuket Island. During the tsunami, Patong was seriously hurt and the infrastructure on the coast, including sewer systems and pumping stations, were destroyed. The sewer system and pumping stations were reconstructed by the Thai authorities, but even after that less than half of the inhabitants of the city and the suburbs are connected to the sewage treatment system. The remaining wastewater (grey as well as overflow from septic tanks) is discharged to city drainage canals and the rivers Khlong Pak Bang and Khlong Pak Lak, which discharge their water into Patong Bay. As a result, the water quality of the rivers is poor and the level of pathogens in the river water is very high. This reduces the water quality in Patong Bay and may affect the tourist industry.

The new constructed wetland polishes the water (>1,000 m^3/day) of two polluted rivers: Khlong Pak Bang and Khlong Pak Lak. Intake structures in the two rivers and level and timer controlled pumps secure that water is taken in from the rivers only during low tide.

The constructed wetland system consists of three parallel planted gravel-based wetland cells (Fig. 4). The constructed wetland cells consist of an inlet pond for removal of sediments and other settleable particles, a horizontal subsurface flow constructed wetland section, and an effluent pond. A distribution line from the pumping station to

the wetland is constructed to distribute the water between the three wetland cells. The main layer of the gravel in the cells consist of 0.8 m of coarse 25-50 mm diameter gravel. On top of the coarse gravel are placed 0.1 m of 10-25 mm diameter gravel, and 0.1 m of 2-10 mm diameter gravel. A variable overflow weir controls the water level at the outlet to Khlong Pak Bang.

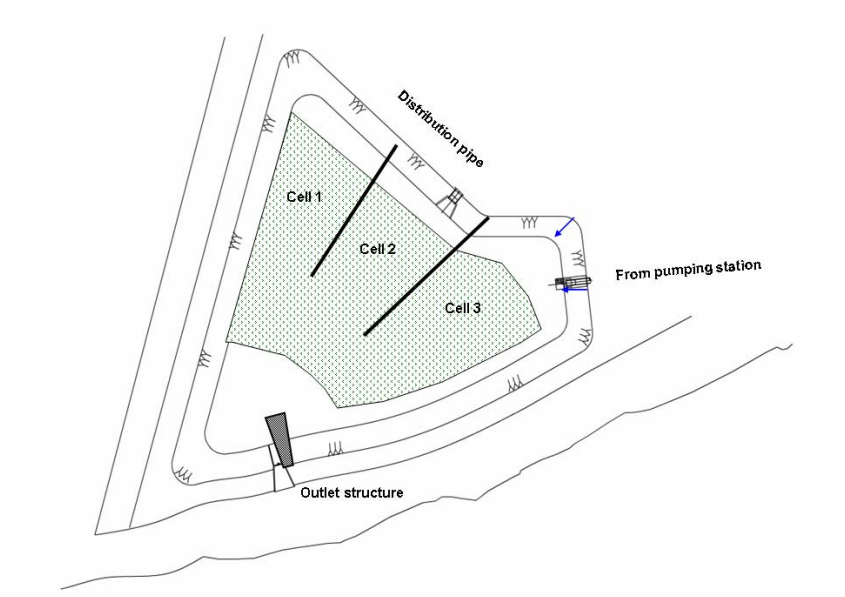

Fig. 4. Sketch of the constructed wetland system at Patong, Phuket Island, which treats >1,000 m^3/day of polluted river water. The total area of the system is about 5,000 m^2, and the surface area of the planted gravel filters is about 3,000 m^2.

DISCUSSION AND CONCLUSION

The wastewater management systems described here will probably be prototype systems for appropriate wastewater management in Thailand and other South-East Asian countries. The highly engineered and mechanized conventional wastewater collection and treatment systems, which require large capital investments and high maintenance costs, are not only impractical but also unsustainable for the developing world (Mara, 2004). Experience show that large western style centralised wastewater treatment systems in general are not appropriate for Thailand. The reasons are many, the most obvious being a lack of an efficient connection system and the lack of human capacity and funding ability to maintain and operate high-tech systems (Giri et al., 2006). Therefore, in future the focus of construction should be on robust, low-cost,

reliant, and cost-effective wastewater management systems. The wastewater management system at Koh Phi Phi island is a so-called recovery based closed-loop city system: Wastewater is collected, managed in a closed loop system, and reused. The use of energy is maintained at an absolute minimum, and the system is financial sustainable through the introduction of fees for the reused water. Such a system attempts to solve the previous weaknesses of centralized wastewater management systems introduced in tropical countries. The Danish Embassy will finance the operation and maintenance of the described systems for five years. As performance data becomes available from the systems, the knowledge of how to design and construct appropriate low-technology system will increase, and hopefully result in the establishment of more and better treatment facilities in Thailand and other tropical countries.

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