Vetiver Grass Technology (VGT) as an Alternative to Mechanical Waste Water Treatment

[1]Mohammad H. Golabi and [2]Manuel Duguies

[1]WPTRC,University of Guam, [2]Agriculture and Natural Resources, Cooperative Extension Service, University of Guam, Guam-USA, 96923
Mohammad H. Golabi <mgolabi@uguam.uog.edu>

Abstract: Numerous economic reports indicate that a good portion of Guam's tourism dollars depend upon healthy marine resources and its waters. Storm water run-off in addition to non-treated or semi-treated wastewater causes adverse impacts to marine water quality, essential fish habitats, and aesthetics. The islands' and scientific communities recognize nonpoint source pollution is a pressing issue for Guam and the other islands of the western pacific not only from the environmental point of view but economy too. Given the lack of appropriate infrastructure, the need to find low-cost innovative methods for protecting Guam's waters and living marine resources has never been so important to the survival of the islands' economies. In this regards, use of the Vetiver System (VS) for waste water treatment is a new and innovative nutrient removal technology recently developed in Queensland by the Department of Natural Resources and Mines, NRM, (Truong and Hart, 2001). Vetiver grass system is a green and environmentally friendly wastewater treatment technology as well as an effective natural recycling method.

The Inarajan Sewage Treatment Plant (ISTP) in southern Guam (Fig. 1)) is of particular concern due to its high intake volume serving southern villages. Aerial images like the one shown in figure 1, illustrate the condition of the facility. The facility uses an aerated facultative lagoon with effluent disposal through an overland flow evapo-transpiration/percolation system to achieve a secondary treatment objective. The Inarajan Sewage Treatment Plant is a secondary wastewater treatment facility employing a four-cell aerobic lagoon treatment system. The facility was built in 1989, with a design capacity of 0.191 mgd (GWA, WRMP 2006). Major unit processes include four aerated lagoons, three percolation basins, and six sludge drying beds.

In this project the vetiver grass is used for treating wastewaters and polluted waters due to its ability to take up contaminating nutrients and other contaminants. The goal was to use a low-cost vetiver grass technology to remove the nutrients (i.e., Phosphorus and Nitrogen) as well as some of the heavy metals from the lagoon before the treated water is released to the percolating field and eventually to the ocean.

The vetiver grass was grown in pots and placed in floating panels (Pontoons). Conditions at the initial stage were closely monitored weekly by the graduate student. Floating panels were taken to the project site during the month of June and 4 inch pots were placed in the already drilled holes in the floating panels. Each floating panel consisted of 20 holes as each hole would hold one 4 inch pot. Three to four seedlings were planted in each pot and placed in the floating panel before the panels were allowed to float in the pond or cells.

The Vetiver grass responded extremely well to the new environment (sewage water pond) and growth rates were rapid and healthy during the experimental period. Nutrient analysis was conducted at the University of Guam (UOG) Soil Laboratory. Sewage water was analyzed for pH, electro-conductivity (EC), nitrate (NO_3), ammonia (NH_3), nitrite (NO_2), phosphate (PO_4), and potassium (K).

A brief glance over the data indicates that the vetiver grass is effective in removing pollutant including heavy metals (data not shown). However, due to unsteady conditions and the presence of numerous unexpected factors such as duckweeds, and variables beyond our control the result of this experiment needs to be evaluated accordingly.

Introduction: Guam's economy relies heavily upon tourism for its socio-economic livelihood. The local economy was greatly depressed by the drop in the Japanese economy during the late 1990's. The island economy has still not recovered and environmental as well as economy might have played a big role in that slow recovery. Numerous economic reports indicate that a good portion of Guam's tourism dollars depend upon healthy marine resources and its waters. Storm water run-off in addition to non-treated or semi-treated wastewater causes adverse impacts to marine water quality, essential fish habitats, and aesthetics. The islands' and scientific communities recognize nonpoint source pollution is a pressing issue for Guam and the other islands of the western pacific not only from the environmental point of view but economy too. Given the lack of appropriate infrastructure, the need to find low-cost innovative methods for protecting Guam's waters and living marine resources has never been so important to the survival of the islands' economies. In this regards, use of the Vetiver System (VS) for waste water treatment is a new and innovative nutrient removal technology recently developed in Queensland by the Department of Natural Resources and Mines, NRM, (Truong and Hart, 2001). VS are a green and environmentally friendly wastewater treatment technology as well as an effective natural recycling method.

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The Inarajan Sewage Treatment Plant is a secondary wastewater treatment facility employing a four-cell aerobic lagoon treatment system. The facility was built in 1989, with a design capacity of 0.191 mgd (GWA, WRMP 2006). Effluent disposal is through percolation, so there is no requirement for NPDES permit. Because there is no NPDES permit, flow and wastewater quality information was not available. Major unit processes include four aerated lagoons, three percolation basins, and six sludge drying beds. Additional equipment includes a weir box, two dosing chambers, a decant well, and portable pumps (GWA, WRMP, 2006.

Fig.1: Aerial view of Inarajan sewage treatment plant before planting the Vetiver grass in May 2008.

The general process description of the Inarajan treatment plant, including liquid and solid streams, is as follows (GWA, 2006):

Liquid Stream: Raw influent from the influent pump station flows to four aerated lagoons via a 5-inch force main. The flow is designed to pass through the lagoon in series and exit the last cell to a weir box unit. The cell can also be operated in parallel. The facilities are designed such that any cell can be completely isolated for maintenance purposes. Each cell is aerated by floating mechanical surface aerators (Fig. 2). The treated wastewater flows through the weir box to dosing chambers. A 60-degree V-notch weir is equipped with an ultrasonic level sensor to measure the influent flow rate (although the meter is not operational). The dosing chambers are designed to alternate flow into each percolation pond (GWA, 2006) (Fig 1).

Fig. 2: At the Inarajan sewage treatment plant each cell is aerated by floating mechanical surface aerators running daily for 24 hours.

Solid Stream: Solids that accumulate in each lagoon are anaerobic ally stabilized in the lagoon. The stabilized solids are transferred to the decant well for thickening, where they are allowed to settle. The top layer of water is decanted back to cells 1 or 2, and the thickened waste sludge is pumped to the sludge drying beds (GWA, 2006). Dried sludge is raked and transported by truck to the landfill.

Goals of the proposed alternative system

The **goal** of this project is to use a low-cost vetiver grass technology to remove the nutrients (i.e., Phosphorus and Nitrogen) as well as some of the heavy metals from the lagoon before the treated water is released to the percolating field and eventually to the ocean.

Project objectives:

The specific measurable objectives are: 1) regular analysis of effluent followed by the treated wastewater using vetiver system will show a percentage reduction in nitrates and ortho-phosphates as compared with the control lagoon over an 12-month time period; 2) regular analyses of the wastewater lagoon will show the efficiency factor of using Vetiver system as a natural wastewater treatment technique when it is compared with the wastewater in the control cell treated with the floating mechanical surface aerator. 3) Although the cost analysis of the system was not among the objectives of the project, using natural systems as a wastewater treatment strategy especially in northern Guam would prove to be a financial advantage when aerators are replaced with the Vetiver system.

Materials, Methods and Monitoring Procedures:

The Vetiver Grass: Characteristics:

In this project the vetiver grass is used for treating wastewaters and polluted waters due to its ability to take up contaminating nutrients and other contaminants. Extensive research in over 100 countries including Australia, China, Vietnam, and Thailand, has demonstrated that vetiver is tolerant of a wide range of soil pH and elevated levels of salinity, sodicity, aluminum, manganese, arsenic, cadmium, chromium, nickel, copper, mercury, lead, selenium and zinc.

Vetiver grass also has associated nitrogen-fixing mycorhiza (Truong and Baker, 1998) with an exceptional ability to absorb and tolerate high concentrations of nutrients and agrochemicals. These attributes make vetiver highly suitable for treating polluted wastewater from discharges, making it an ideal plant for terrestrial and aquatic environmental applications such as the one proposed (Hengchaovanich, 1999). In contrast with conventional engineering structures, the efficiency of vetiver improves with time as the vegetative cover matures; it is virtually maintenance free (Truong, 2006).

Planting, and Monitoring:
Propagation Techniques: Vetiveria zizanioides, commonly referred to as vetiver was harvested from the University of Guam's research station located in Ija, a remote region in southern Guam. Seedlings were prepared (Fig. 3) and used from July 2008 through August 2008 (Guam's rainy season). Propagation took place at the Western Pacific Tropical Research Center (WPTRC) and the Cooperative Extension nurseries at the Inarajan research station in southern Guam.

Figure 3: Vetiver seedlings for propagation and planting purposed were prepared at the University of Guam's research Station in Inarajan.

Panel construction: Vetiver grass (*Vetiveria zizanioides*) was propagated from stock plants at the Ija Tropical Research Center. Stock plants were divided and individual plantlets were planted into 4 inch plastic pots for propagation (Fig. 3). The bottoms of the pots were later cut off so that plant roots could grow directly into the water. A total of 480 plants were planted into the system throughout the month of July, 2008.

In order to ensure that a sufficient number of seedlings survive for transplantation propagation of up to 2000 seedlings was supervised by University of Guam researcher (M. Golabi) and the agricultural extension field workers. Graduate and undergraduate students were taught how to build 4-feet by 4-feet floats to support the vetiver seedlings. It was estimated that 20 to30 floats would be needed for "planting" in the lagoon under study. This would allow for quick replacement of dieing or "failed floats" with fresh "seeded floats" to keep within the project timeline.

Figure 4: The vetiver grass is being placed in Paton and prepared for floating.

The vetiver grass was grown in pots and placed in floating panels (Pontoons) (Fig. 4 and 5). Conditions at the initial stage were closely monitored weekly by the graduate student. Floating panels were taken to the project site during the month of June and 4 inch pots were placed in the already drilled holes in the floating panels. Each floating panel consisted of 20 holes as each hole would hold one 4 inch pot. Three to four seedlings were planted in each pot and placed in the floating panel before the panels were allowed to float in the pond or cells (Fig. 5, 6).

The Vetiver grass responded extremely well to the new environment (sewage water pond) and growth rates were rapid and healthy during the experimental period (Fig. 5, 6, 7, and 8). As shown in figure 1, the presence of duckweed was a concern from the beginning as it was an unwanted plant growing in the sewage pond interfering with the vetiver experiment causing variation in data evaluation. Despite many attempts for removing the duckweed from the pond, it kept growing as fast as the vetiver grass itself (Fig. 7). Although the duckweeds were not analyzed for nutrient uptake, it is believed that duckweed can take up considerable amount of nutrient (N, P) from the sewage water ponds. However, it also can create anaerobic condition hence reducing the dissolved oxygen in the sewage water during the process affecting phosphorous availability for uptake by vetiver grass during the experiment.

Fig. 5: Initial Planting of vetiver at Inarajan Sewage Treatment Plant in July of 2008.

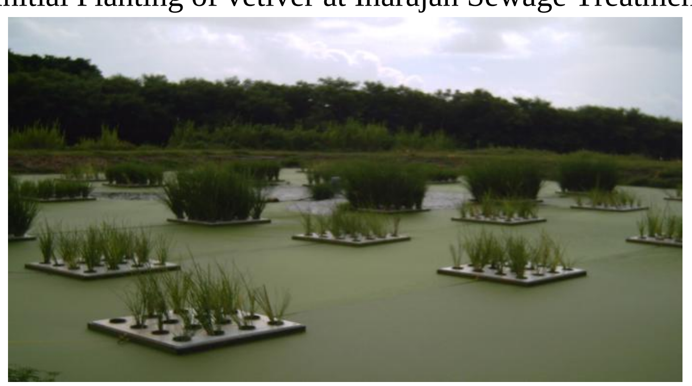

Figure 6: Planting was completed during August of 2008

Figure 7: Vetiver grass at it mature growth stage three months after the initial planting.

Figure 8: Roots as well as upper shots growth performance three weeks after planting

Water Quality Analysis:

Before the vetiver is transplanted, samples from the effluent ponds were collected (Fig. 9) in order to establish baseline levels of biological oxygen demand (BOD), salinity, nitrates, orthophosphates, and turbidity. Water samples were collected Bi-weekly thereafter until the end of the project period. The nutrient levels were analyzed over time and compared to baseline levels in order to determine if the goals of contaminant reduction have been met.

Figure 9: Water samples were collected in order to establish baseline levels of biological oxygen demand (BOD), salinity, nitrates, orthophosphates, and turbidity.

<u>NUTRIENT ANALYSIS AND LAB WORK</u>

Sample filtering: Nutrient analysis was conducted at the University of Guam (UOG) Soil Laboratory. Sewage water was analyzed for pH, electro-conductivity (EC), nitrate (NO_3), ammonia (NH_3), nitrite (NO_2), phosphate (PO_4), and potassium (K) using a Photometer (Model 9100, YSI Incorporated, Yellow Spring OH, USA). All water samples were filtered with Whatman #1 filter paper, prior to analysis (Fig. 10).

Figure 10: Student intern filtering water samples for nutrient analysis at the UOG Soil Lab

BOD analysis at the Agana wastewater Lab: Biological oxygen demand (BOD) test was also conducted at the Agana Wastewater Treatment Lab, in cooperation with the Guam Water Authority. The BOD test was performed by incubating a sealed wastewater sample for a standard five-day period for determining the change in dissolved oxygen (DO) content. The BOD value is then calculated from the results of the DO depletion rates.

Results and data analysis:
Some of the results from the data collected are presented in the following paragraph. Note that environmental variables such as Wind, Rain, Sunshine, and Cloud cover could not be controlled during the experiment. These variables changed throughout the year.

As shown in figure 11, the BOD content for Cell 2 (vetiver treated cell) was considerably lower than in the Cell 1 (aerator treated cell), an indication of low nutrient content in Cell 2 as the result of excessive uptake by Vetiver.

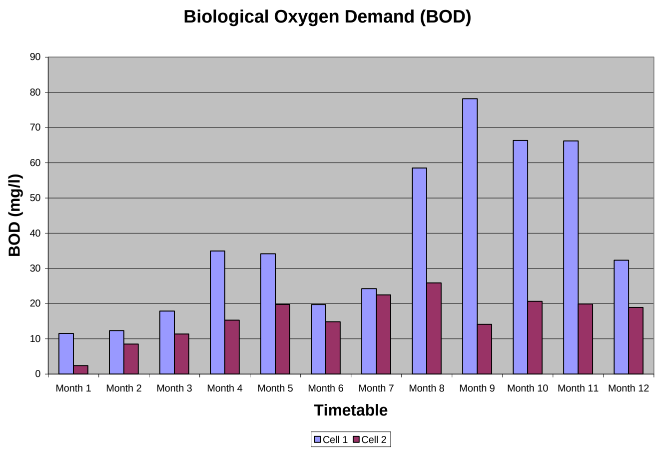

Figure 11: Data showing Biological Oxygen Demand (BOD) for both cells during the monitoring period.

As shown in Figure 12 the level of nitrite content in Cell-2 is considerably lower than in Cell 1. Also as shown (Fig. 12), the nitrite level in outlet-2 is considerably lower than in Cell-1. This is an indication of low level of nitrogen content in Cell-2 resulted from high nitrogen uptake by the Vetiver grass in Cell-2.

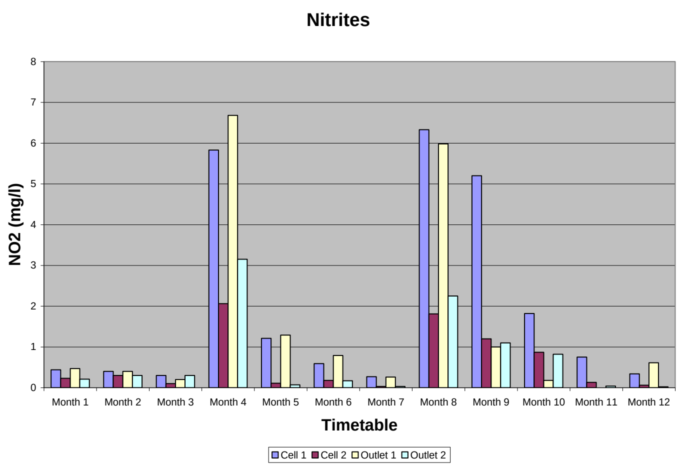

Figure 12: Data showing Nitrite content for both cells during the monitoring period.

As shown in figure 13, the nitrate levels in Cell-2 were always lower throughout the monitoring period. The nitrate level in outlet-2 is also lower than in outlet-1 throughout the monitoring period except during the month 9 and month10 that for an unexpected reasons the nitrate levels were higher in Cell-2 during those period (month 9, and 10).

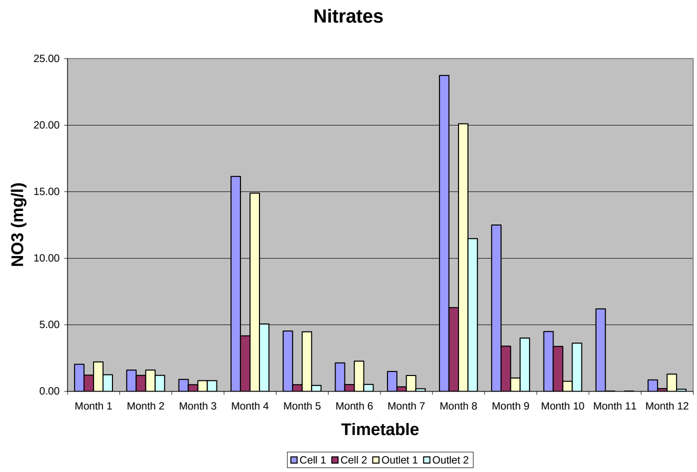

Figure 13: Data showing Nitrate content for both cells during the monitoring period.

With respect to phosphate level, the story is different. As shown in figure 14, the phosphate level in Cell-2 (Vetiver treated) is generally higher than in Cell-1 (aerated). This is due to the anaerobic condition created as the result of duckweeds covering the surface of the pond and possibly blocking the oxygen from entering the water below the surface in Cell-2. The reduced condition created by this process (low oxygen) is believed to be the cause of low phosphorous content in the water samples from Cell-2.

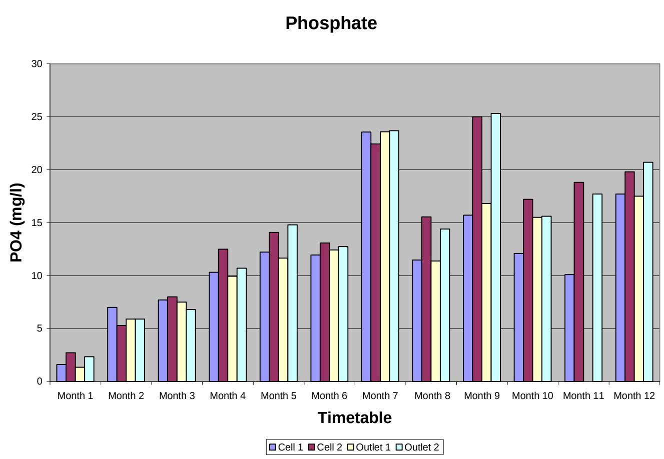

Figure 14: Data showing Phosphate content for both cells during the monitoring period.

<u>Discussions:</u>

Application of the Vetiver System for waste water treatment is a new and innovative nutrient removal technique that was developed in Queensland Australia by the Department of Natural Resources and Mines (NRM), (Truong and Hart, 2001). As indicated by Truong and Hart (2001), it is a green and environmentally friendly wastewater treatment system with low cost maintenances. Its end-product has several uses including animal fodder and material for organic farming.

VS is based on the use of vetiver grass (Vetiveria zizanioides L.), which was first recognised early in the 1990s for having a "super absorbent" characteristics suitable for the treatment of wastewater and leachate generated from landfill in Queensland (Truong and Claridge, 1996). Research conducted by NRM showed that Monto vetiver grass has a fast and very high capacity for absorption of nutrients, particularly nitrogen and phosphorus in wastewater. In addition it has a very high water use rate and tolerant to elevated levels of heavy metals in the effluent. As a result of these findings, presently VS has been used successfully for these purposes in Australia, China, Thailand, Vietnam, Senegal (Truong and Hart, 2001; Truong, 2000) and in Guam (Golabi, et al., 2009).

In Guam the use of vetiver grass technology as a wastewater treatment technique started in May of 2008. A monitoring system was developed to evaluate the effectiveness of vetiver grass for treating the waste water at the Inarajan Waste Water Treatment Plant (IWWTP). The Inarajan WWTP is located at the Inarajan village in southern Guam. The plant is consisted of four cells (72ft x 72ft x 17ft) designed to allow for settling the suspended solid and primary treatment using aerators. As explained earlier we selected cell-2 for using vetiver system as treatment methods.

A brief glance over the data indicates that the vetiver grass is effective in removing pollutant including heavy metals (data not shown). However, due to unsteady conditions and the presence of numerous unexpected factors such as duckweeds, and variables beyond our control the result of this experiment needs to be evaluated accordingly.

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