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Water Management Strategies on Campus: An integrated approach

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Abstract. Water resource management strategies at National Pingtung University of Science and Technology (NPUST) are orientated towards water conservation, efficient water use and wastewater reuse. Ground water is the main water source on the university campus and the affiliated Tajen and Baoli experimental forest farms. To promote ground water collection from surface runoff water, permeable pavement, and multiple ponds have been installed. To achieve efficient water use, less efficient appliances have incrementally been replaced by more water-efficient ones. This has proven to be a feasible and effective way to achieve goals without bringing about inconveniences to campus users. Drought-tolerant trees have been planted and drip irrigation systems utilized on campus farms to save water. Our water reuse strategies aim to achieve a fully-recycling, zero emission water treatment system. Treated domestic sewage, swimming pool water and harvested rainwater are reused for flushing toilets or watering plants. Many facilities on campus, such as the Laifu Garden, Jingsi Lake, Green Park, Yingxia Lake, and Tajen Forest Farm, are more than just beautiful scenic spots; they all play major parts in the circular water ecosystem.

Keyword:
Water management, water conservation, water recycling, wastewater treatment

1. Introduction

No more than one percent of the water on this planet is easily accessible freshwater. Water management is a common concern around the world and will become even more important in the near future. Fortunately, water is a renewable resource which can be circularized and properly managed through strategies that focus on adequate resource allocation, conservation, usage efficiency, treatment, and education [1, 2]. When it comes

to campus water management at institutes of higher education, one unique challenge is that the "user pays" scenario is not easily applied. Therefore, incentives and infrastructures must be laid out in a way that allows consumers to conveniently conserve water without the economical reminder that a water bill provides. In addition to water conservation, thorough surveys of the campus ecosystem and water resources can reveal ways to increase water supply capacity. Depending on the geography and climate, water can be collected from previously neglected sources, including precipitation, runoffs, rainwater, and groundwater [3]. In this article, we discuss the integrated water management system developed on the NPUST campus and details of its implementation.

2. Water management approaches

2.1. Water conservation

Taiwan has always been a "water-starved country" even though its precipitation is higher than the average of many developed countries [4, 5]. Due to serious sedimentation, the capacity at six of Taiwan's 18 main reservoirs has been reduced by one third. In southern Taiwan, the rainy season mainly occurs in summertime; typhoons and rainstorms during July and August bring in huge amounts of water to refill the reservoirs. From the beginning of autumn on through to May or June, Taiwan always struggles with water shortages. Under the worst-case scenarios, water rationing measure become the inevitable decision that many cities must make. Another primary reason for this issue is water price. When something is constantly cheap, people tend to overuse it and take it for granted, as if it had an endless supply. The unreasonably low price for water in Taiwan and the general publics' misunderstanding of water resources have resulted in unnecessary waste in water use.

On our campus, approximately 11000 students and 1500 academic and administrative staff account for most of the domestic water consumption on campus. That includes drinking water, toilet flushing, washing, and water used in laboratories. Besides the buildings, the campus vegetation, experimental farms, greenhouses, and fish farms also consumes a large amount of water. However, 100% of the wastewater is re-collected and treated at a sewage treatment plant and used for non-contact purposes such as watering vegetation or flushing toilets.

Water management has been given heavy attention at NPUST not only on account of issues related to demand, but also due to the climatic and geographical factors inherent to the location of the university campus. NPUST's water sources include groundwater, mountain spring water and rain water. When heavy rainstorms occur, floods can cause serious damage to the campus grounds and surrounding areas, and even block traffic to the main road [6]. This puts campus users and residents in a dangerous situation. To mitigate flood damage and improve safety on the campus and in neighboring areas, permeable asphalt pavement has been utilized throughout the campus, including for parking space, sidewalk, and regular roads. Unlike with traditional pavement, the bottom and base layers of the permeable asphalt are gravel, and the concrete bottom is permeable. The subgrade is made of geotextiles and pervious materials. These materials allow the water to pass through to each layer and drain quickly during a downpour. The pavement has been well-tested for its bearing capacity and has been shown to resist damage even when carrying heavy trucks (Figure 1A&B).

On the sports fields and ball courts on campus, red clay has been utilized instead of PU fabric. The main component of the red clay surfacing is red brick powder, which has the

advantages of being water permeable, environmentally friendly, and low cost. Maintenance takes a lot of time, as the soil must be turned and weeded; however, this also allows the soil to breath. The effectiveness of water permeability can be assessed based on the color of the clay (Figure 1C).

Outside the campus, NPUST has an experimental forest farm where related research takes place. The Tajen Forest Farm is located in Eastern Taiwan (Taidong County) and serves as the experimental farm of Dept. Forestry in NPUST. At an altitude of 180-900m, the Tajen Forest Farm is part of a highly diverse ecosystem and is used to promote species conservation. The water reservoirs situated near the center of the farm not only provide natural habitats for wild animals, but also play an important role in water conservation. The water which is collected in these reservoirs can be used for irrigation and wildfire prevention.

Figure 1. A. Permeable pedestrian pavement, B. The permeable asphalt pavement help standing water drain quickly after a heavy rain. C. Red clay surface of the race track.

2.2. Efficient water usage

Daily water usage is one of the most underrated methods in water management. By consciously adopting water saving habits and installing water saving appliances, great amounts of water can easily be saved (Table 1). As of 2020, water-efficient appliances accounted for 93% of on-campus installations. These include dual flush toilets, water-saving urinals with sensors, nano-coated no-flush urinals, and water-saving faucets (Figure 2). Dual flush toilets reduce water consumption simply by providing two different water volumes for flushing liquid and solid waste. They can save up to 68% more water than conventional toilets. For urinals, passive sensors are used to detect urinal usage. The sensors control solenoid valves that allow a pre-set amount of water into the cisterns. When the cisterns are full, the urinals flush. Use of this type of passive infrared sensor can save up to 75% of the water that would normally be used to flush urinals. Nano-coated no-f lush urinals automatically keep basins clean with the special coating that is applied to the surface of the urinal. The coating creates a highly slippery surface that requires just a fraction of the water used for regular basis. Tests show that the coating can last for about 500 uses before requiring a new application of the surface spray. With incremental new installations, NPUST hopes to minimize the water use in campus buildings without compromising sanitation standards.

Table 1. The number of water efficient appliances on campus.

Appliance	Total Number	Water Efficient Appliances	Percentage
Flush toilets	1743	1287	73.8%
Water-saving urinals with sensors	790	790	100%
Nano-coated no-flush urinals	20	20	100%
Water-saving faucets	1850	1850	100%
Total Percentage			**93.45%**

Figure 2. Water-saving appliances. A&B. Dual flush toilet, C. Urinals with sensors, D. Nano-coating non-flushing urinal.

NPUST has the largest campus grounds out of all other universities in Taiwan. With almost 300 hectares of land, and the activities of more than 11000 people, water usage can be appreciable when compared with regular household and outdoor water consumption. Plant irrigation and swimming pool operations are the two biggest factors when it comes to outdoor water usage. To effectively control the amount of water used, drought tolerant plants were the best option when it came to campus landscaping. Throughout the NPUST campus, a wide variety of drought tolerant trees have been planted, such as Taiwan aglaia, common jasmin orange, Taiwan ebony, five-stamens China laurel, reticulate-veined cinnamon tree, Formosan nato tree, Formosan ash, pongam tree, looking glass tree, odourbark cinnamomum, sweet gum, cryptocarya concinna, large-leaved nanmu, common garcinia and small-leaved barringtonia.

2.3. Water-saving technology for rice irrigation

Water scarcity has always been a challenge for agriculture in Taiwan; and now with extreme weather and disasters caused by climate change, these challenges are only increasing. To cope with unstable and dwindling water supplies, a team from the Smart Agriculture Center at the NPUST Dept. of Civil Engineering developed a water-saving irrigation system that uses digital monitoring devices to produce non-toxic white rice. The

new method allows farmers to use small amounts of water to produce the same quantities of rice they were producing using traditional methods. Different irrigation methods, including perforated pipe sprinkler irrigation, alternate wet and dry irrigation and traditional flooding irrigation, were performed in the field to determine the best water-efficiency. The team also collected methane in the field to measure differences in emissions when using these three methods. The results show that alternate wet and dry irrigation can save up to 40% of the water required for traditional flood-irrigation, while perforated pipe sprinkler irrigation can reach up to 60% in water savings (Figure 3A).

During the experimental cultivation, wireless transmission equipment was used to accurately monitor the water consumption, soil moisture tension, electrical conductivity, and surface temperature. Soil moisture tension can be used in crop water demand calculations and to make precise adjustments for water usage. Electrical conductivity can be converted into soil fertility to find the best timing for fertilization. Surface temperature can be used as an important signal for rice blast disease prevention (Figure 3B).

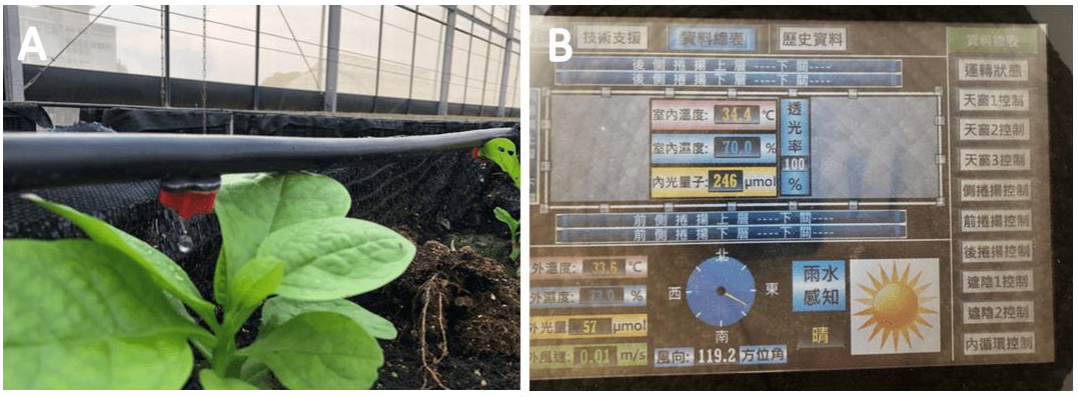

Figure 3. Smart irrigation system. A. Drip irrigation facility. B. A real-time monitoring system

2.4. Water recycling

Water recycling allows treated water to be reused for beneficial purposes such as agricultural irrigation, toilet flushing or industrial processes. This reduces the energy required to move water from longer distances or the risk of land subsidence caused by pumping groundwater. Treated water can also be used for building natural wetlands or habitats for wildlife. To achieve the goal of full recycling of water with zero emissions, NPUST designed sewage treatment facilities to treat drinking water, sewage and wastewater and manage water resources and prevent flooding (Figure 4).

The sewage treatment plant, 'Laifu Garden', collects domestic waste water from eight student dormitories, 2 student restaurants, and various other buildings. The ecological design incorporates a trash rack, sedimentation tank, equalization tank, and aeration tank. Sewage is collected and properly treated for use as a water source for toilet flushing, gardening and irrigation. Furthermore, a rainwater storage and recycling system collects rainwater for green wall water maintenance. The sewage treatment plant processes approximately 800 tons of waste water per day, and the water purification and reuse is carried out at with low energy consumption. By incorporating the environmental park and Jingsi Lake into the sewage treatment system, the waste water from experimental fish farms can be purified and reused to increase water sources. The design reduces pollution loads in the Niujiaowan Creek, cuts BOD loads by 1,461 kg and reduces secondary water

consumption by about 127,000 tons a year.

Figure 4. A. Wastewater recycle processing areas. B. Domestic wastewater treatment and recycling strategies.

In 2009, NPUST converted the abandoned mango farm into a domestic sewage treatment plant. Without affecting recycling activities, Yingxia Lake was constructed to allow for wetland ecological diversity. A recreational nature area was designed with ponds, streams, waterfalls, trails, and terraces and natural habitats for wild life, plants, and aquatic vegetation. In 2009, an ecological survey showed that there were 15 families and 21 species of birds, 2 families and 3 species of reptiles, 3 families and 3 species of amphibians, 6 families and 7 species of fish and shrimps, 18 families and 48 species of insect, and 22 families and 31 species of plants living in the area. The combined total comes to 66 families, 113 species of animals and plants. Yingxia Lake has also become a place for teachers, students, and the public to relax and enjoy nature.

Jingsi Lake is located on the southwest side of the NPUST. Formerly an abandoned breeding pond, in 2003 NPUST redesigned the area using subsidies from the Ministry of Education's "Sustainable University Project". The road on the top of the embankment area was separated to build up 3 ponds. The upper pond, which serves as a purification pond, consists of machine-made gabions, submerged plants, bank protections and weir walls to process the first step of purification and to detain and settle sedimentation of the surface runoff water from adjacent bamboo forests and the breeding ponds. The middle pond is the main water area and includes a weir wall. To achieve energy dissipation and increase dissolved oxygen, the elevation of the weir wall changes to allow the water to overflow and undergo purification by scouring the stones placed along the upper edge. The different elevations of the weir wall and water depths also create an ecological wetland with an area of 3.6 hectares. The lower pond is controlled by a gate which is also used to control the overflow of the middle pool. The storage capacity of the pond can directly supply and maintain water for the middle pond during the dry season. Suitable plants are grown around the Jingsi Lake, including water willow, banyan tree, fire tube tree, stinky lady, Kulizhen, honeysuckle, Pingpo, and kapok (Figure 4).

Enhanced hydrological observations have shown that these artificial ponds have made contributions to flood mitigation and water purification while also providing a public area to conduct environmental education and enjoy leisure and recreation. It's not only an

important national wetland but also a successful demonstration of sustainable universities practices of Taiwan.

3. Summary/ Concluding Remarks

National Pingtung University of Science and Technology (NPUST) has consistently valued sustainable practices which are aligned with the UN Sustainable Development Goals. Among these goals, “Clean Water and Sanitation” (SDG 6) looks to ensure that accessible and sustainable use of water can be achieved for all people. It addresses the importance of safe and affordable drinking water, sanitation and hygiene, conscious and efficient water use, and eco-friendly measures. The practices adopted by NPUST show that integrated water management can help reduce water waste in a variety of ways. By incrementally replacing higher consumption appliances with water-saving ones, campus users gain awareness of the need to conserve while adopting new habits. Drought-tolerant trees can keep campuses green without requiring large quantities of water and new irrigation methods allow for reduced water usage and improved ecosystems. On the larger scale of adaptations, it is important to consider the system as a whole. While taking natural settings and energy cost into consideration, wastewater can be recycled and reused responsibly for other purposes without unnecessary emissions. With a vision of fulfilling university social responsibility, NPUST will continue to focus on research projects that resonate with SDGs and other desired sustainable water management outcomes so that it can continue to have a positive impact on society.

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