3+1 Approach for Greening Works at Sha Tin Sewage Treatment Works

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Abstract:

"3+1 Approach" is adopted for the greening works at Sha Tin Sewage Treatment Works. This involves three greening elements, namely at-grade planting, vertical greening and green roofs, together with one initiative on use of reclaimed water for irrigation of plants. R&D studies on vertical greening and green roofs serve as good examples of knowledge transfer and collaboration between a government department and tertiary educational institutions. The greening works offer an excellent opportunity to establish a close connection with stakeholders. The Department's image is enhanced and the community relations are strengthened.

Keywords:

At-grade Planting, Vertical Greening, Green Roofs, Reclaimed Water

INTRODUCTION

Sha Tin Sewage Treatment Works (Sha Tin STW) is the largest secondary sewage treatment works in Hong Kong. To serve Sha Tin and Ma On Shan Districts, Sha Tin STW is designed with daily treatment capacity of 340,000m^3. Sha Tin STW is located adjacent to the Sha Tin Race Course. Its southwest and southeast sides are bounded by Shing Mun River Channel and Tolo Harbour respectively. Occupying approximately 28 hectares of land, Sha Tin STW has a footprint as large as one and a half Victoria Park or 39 standard football fields.

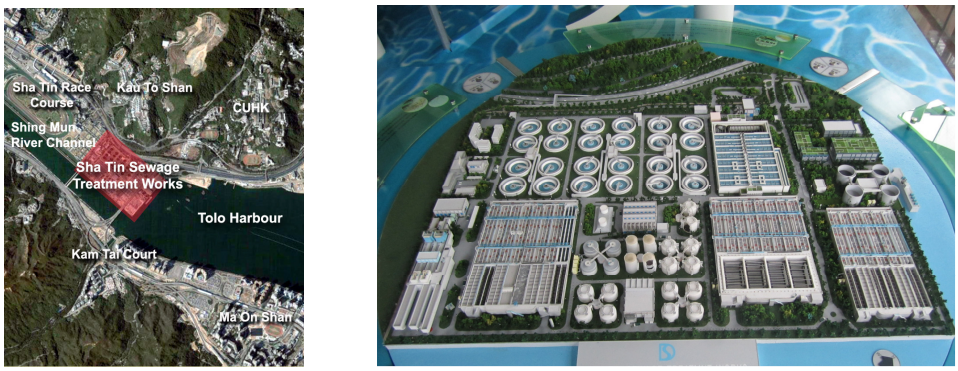

Figure 1: Location and Layout of Sha Tin Sewage Treatment Works

Sha Tin STW was commissioned in 1982 and has undergone several extensions. In recent years, Drainage Services Department (DSD), has carried out greening of the sewerage facilities and made the STW "green"! Innovation is the key of successful implementation of the greening works. In doing so, we adopt a "3+1 Approach", which involves three greening elements, namely at-grade planting, vertical greening and green roofs, together with one initiative on use of reclaimed water for irrigation of plants. Details are described in the following paragraphs.

AT-GRADE PLANTING

Extensive at-grade planting has been carried out at Sha Tin STW. Since 2008, we have planted more than 1,800 trees and 430,000 shrubs to maximize greening opportunities for the sewage treatment works. They not only bring significant aesthetic enhancement to the nearby environment but also considerable ecological benefits to the surroundings.

Figure 2 : Large Trees and Colourful Shrubs

The planting design concept is to create a seasonal colourful palette throughout the year. This is achieved by use of different types of plants to blend with the STW. The selected plants match, physically and visually, with the surrounding natural environment including Shing Mun River Channel. Formal and lined avenue trees of various species are planted on both sides of the primary driveway to create a green corridor and act as a natural greening screen.

Figure 3 : Greening Master Plan

The colour palette for the four seasons is as follows:

Spring	***Summer***	***Autumn***	***Winter***
Bauhinia variegata (宮粉羊蹄甲), *Syzygium jambos* (蒲桃) and *Tabebuia pentaphylla* (紅花風鈴木) as theme trees to create a romantic spring and blossoming atmosphere	Shade evergreen trees, fragrant flowering *Michelia alba* (白蘭) and *Plumeria acutifolia* (雞蛋花) become the focus. Together with various shrubs and groundcovers constitute the summer colour	Autumn foliage and patches of red leaves of *Liquidambar formosana* (楓香) and *Terminalia catappa* (欖仁樹) create the unique autumn scenery	Deciduous and evergreen trees create the winter view, accented with blossoms of *Magnolia denudata* (玉蘭) and bright red *Bixa orellana* (胭脂樹)

Table 1 : Colour Palette of Greening Works

As we all know, at-grade planting is often limited by the presence of existing underground utilities. Without adequate depth of soil cover, the plants, especially their roots, cannot grow well. There is no difference at Sha Tin STW where some of the underground spaces are occupied by congested pipes and cables. To overcome such constraints, we have explored alternative greening methods. Vertical greening and green roofs are feasible solutions.

VERTICAL GREENING

Vertical greening has a lot of merits! It not only brings significant aesthetic enhancement to the nearby environment but also ecological benefits. In addition, it helps to reduce urban heat island effect which in turn saves energy consumption, especially in hot summer time. Furthermore, the vertical climbers can filter particulates to improve the air quality, and hence our health.

The experience of vertical greening in Hong Kong is rather limited. In this regard, we, in collaboration with the University of Hong Kong, decided to carry out a Research and Development (R&D) study to investigate the application of vertical greening at sewerage facilities. The R&D study commenced in July 2009 and is targeted for completion by end 2011. Four circular sludge holding tanks at Sha Tin STW are chosen for on-site testing of the growth and performance of various climber species. Each tank is of 27m diameter and 13m high. This height is similar to that of a four-storey high low-rise building.

Figure 4 : Vertical Greening at Sludge Storage Tanks

In the R&D study, the performance of various climber species is investigated. Some key growth parameters such as aspects, supporting systems, growing medium and horticultural maintenance requirements are evaluated. The cooling effect of green wall is monitored by using a combination of environmental monitoring equipment. Three experiments are designed to test the site factor effect, climber species trial and monitoring of cooling effect. Details of the experiments and the interim observations are as follows:

Experiment I : Site Factor Effect

The orientation, climber attachment mode and soil type are studied systematically in this experiment.

For the orientation, climbers growing in the south and west quarters tend to perform better than the east and north quarters. This is demonstrated by the growth height and speed of the climbers.

Regarding the climber attachment mode, the mesh method proves to provide a secure framework for climbers. It offers a more facilitating habitat for plant growth than bare concrete surface. The mesh is made of 75mm x 75mm x 3mm diameter stainless steel wires. The support brackets are evenly distributed at 1.25m x 1.25m square grid, and are also made of stainless steel to enhance durability.

Figure 5 : Wire Mesh Support at Alternate Plots

For the soil type, some plots with original soil are replaced down to 600mm by a high-quality soil mix enriched with mature compost. Plants growing in improved soil corridor tend to perform better than in original soil in terms of growth height and vigour.

Figure 6 : Improved Soil Corridor with Irrigation System

Experiment II : Climber Species Trial

This experiment studies the growth and performance of the following climber species:

Quisqualis indica (使君子)
Lonicera japonica (金銀花)
Antigonon leptopus (珊瑚藤)
Vitis vinifera (葡萄)
Pseudocalymma alliaceum (蒜香藤)
Podranea ricasoliana (紫雲藤)
Bougainvillea spp.(簕杜鵑)
Wisteria sinensis (紫藤)
Bauhinia corymbosa (首冠藤)
Pyrostegia venusta (炮仗花)
Parthenocissus dalzielii (異葉爬山虎)
Hedera helix (常春藤)
Philodendron scandens (蔓綠絨)
Ficus pumila cv. variegata(花葉薜荔)
Epipremnum aureum (黃金葛)
Sygonium podophyllum (合果芋)
Hedera nepalensis var. sinensis (中華長春藤)
Trachelospermum jasminoides (絡石)
Campsis grandiflora (淩霄)
Ficus pumila (薜荔)

According to our interim observation, *Quisqualis indica* (使君子) is the best performer. It has grown quickly to reach the top of the tank (13.3m high) within several months. Its growth rate, foliage density and vigour have outstanding performance.

Figure 7 : *Quisqualis indica* (使君子) reaching the Top of Tank (13.3m High)

Other good performance species include *Antigonon leptopus* (珊瑚藤) and *Wisteria sinensis* (紫藤). However, they are deciduous (i.e. lost some of its foliage in winter). The leaf cover will resume with the return of warmth and rainfall in summer.

Figure 8 : *Wisteria sinensis* (紫藤) – Climb over the Tank?

It is interesting to note that vertical greening is not restricted to "green" only. The following photos indicate that the picture could be very colourful!

Figure 9 : *Pseudocalymma alliaceum* (蒜香藤), Pyrostegia venusta (炮仗花) and *Podranea ricasoliana* (紫雲藤)

Experiment III : Monitoring of Cooling Effect

The cooling effect resulting from vertical climbers on the tank structure is monitored by the following equipment:

Equipment	Measurement Parameter
Infrared radiometer	Surface temperature of tank covered / uncovered by climbers
Thermometer/Hydrometer	Air temperature and relative humidity near tank surface and tank top
Pyranometer	Solar radiation (visible and infrared) on tank surface and tank top
PAR meter	Photosynthetically Active Radiation (PAR) on tank top
Soil moisture	Soil moisture content at 100mm and 500mm depth
Data Logger	High-end data logger to store data

Table 2 : List of Equipment used in the R&D Study

To measure the surface and air temperature, various sensors are installed on the surface and top of the tank structure. The effect of living foliage on surface temperature is monitored by infrared radiometer. As a baseline for comparison with the situation without vegetation cover, readings on the concrete surface of the tank structure are also taken. The air temperature, relative humidity, solar radiation and photosynthetically active radiation (PAR) are monitored by thermometer, hydrometer, pyranometer and PAR meter respectively.

Figure 10 : Equipment used in the Monitoring of Cooling Effect

As the vertical climbers grow up, the plant coverage of the tank and hence the cooling effect will be more prominent. More readings of the cooling effect will be taken for further analysis in due course.

GREEN ROOFS

In a congested city like Hong Kong, roof areas are quite under-utilized spaces. To increase the green coverage to the densely distributed buildings in the urban area, the retrofitting of green roofs is a good option. This is achieved by adding a layer of growing medium and plants on top of a traditional roofing system.

Figure 11 : Green Roof at Air Blower House

The benefits of green roofs are numerous. For instance, they provide cooling effect to combat urban heat island effect and save energy consumption inside the building. Besides, they can filter fine air particulate and absorb greenhouse gases to improve the water and air quality. Furthermore, they can bring significant aesthetic and ecological benefits to the surroundings and nearby residents.

However, green roofs are more costly to install and maintain when compared with conventional flat roofs. Besides, some existing buildings cannot be retrofitted with green roofs due to structural concern. The additional weight of substrate and vegetation may exceed the limit of original design load and the structural capacity of the roof.

To address the above concerns, we consider that comprehensive studies including experiments and numerical models are needed to obtain more local information for developing reliable green roof design guidelines for Hong Kong's unique climate conditions and building forms. Since December 2010, we have been carrying out a R&D study on green roofs in collaboration with the Hong Kong Polytechnic University. The primary objectives of the study is to establish design guidelines for Hong Kong green roof systems and investigate the benefits of green roofs in runoff water quality improvement and peak runoff mitigation.

We select the Sludge Thickening House and its Extension at Sha Tin STW as the site for this study of green roofs, since its roof area is as large as 1,500m^2, which is equal to 3 standard basketball courts.

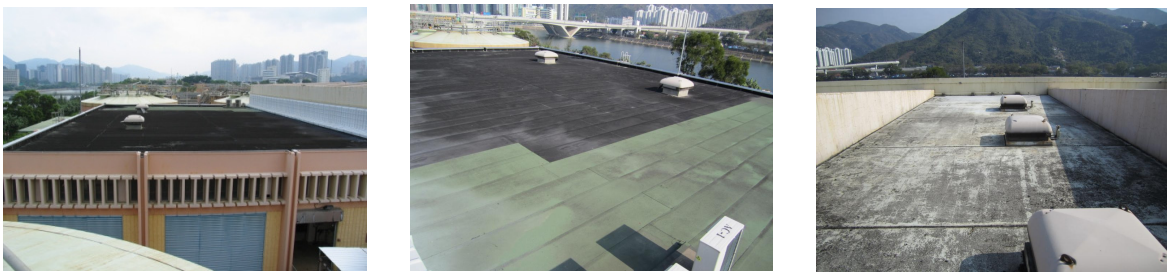

Figure 12 : R&D Study at Sludge Thickening House and its Extension

In the R&D Study, field measurements are planned to be carried out to obtain the data of soil moisture and rainfall-runoff and making use of their relationship to calibrate and verify stormwater numerical models. The stormwater retention performance of different green roof systems under different growing medium depths, roof slopes, antecedent moisture conditions and number of layers will also be investigated by using hydrology apparatus. Some key water quality parameters such as pH, colour, turbidity, hardness, metals and additional nutrients will be monitored.

Other than field tests, a physical model of green roofs for testing in a wind tunnel will be conducted to determine the directional effects of peak wind loads produced at the return period of 50 years. A wind suction numerical model will also be developed to address the wind damages to the green roofs as well as the danger of lifting green roofs.

Upon the completion of R&D study, we aim to establish a design guideline for Hong Kong green roof systems to address some key issues including but not limited to structural loading capacity, wind suction forces, set back distance, legal considerations, selection of growing medium and substrate as well as maintenance requirements. The findings are expected to be available in mid 2013.

RECLAIMED WATER

Reclaimed water is a valuable resource in terms of environmental protection and sustainable development. The effluent, after secondary treatment and ultraviolet disinfection, is purified by reverse osmosis and used for irrigation in Sha Tin STW. At present, the water reclamation facilities can produce about 1,000m^3 of reclaimed water per day.

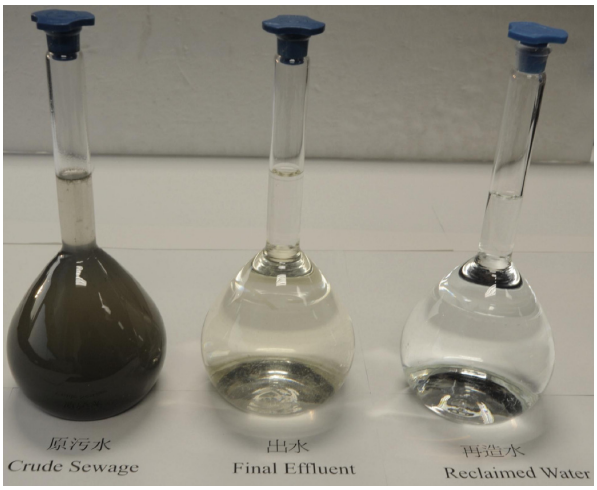

Figure 13 : Comparison between Crude Sewage, Final Effluent and Reclaimed Water

From the flow chart, we can see that the effluent will firstly flow through disc filters where particulates exceeding 130 micrometres in diameter are caught. The filtrate then passes through ultra-filtration membranes which do not allow the passage of particulates exceeding 0.03 micrometres in diameter. At this stage, most of the bacteria are separated. In addition, the particulate concentration of the filtrate is significantly reduced. Finally, the filtrate flows through reverse osmosis membranes which could effectively trap any remaining viruses, salts and substances exceeding 1 nanometre in diameter.

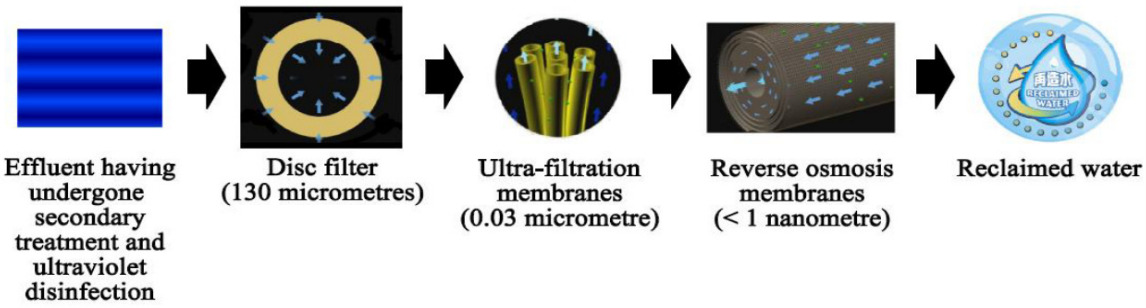

Figure 14 : Flow Chart for Production of Reclaimed Water

The Disc Filters, Ultra-filtration Membranes and Reverse Osmosis Membranes used for the production of reclaimed water at Sha Tin STW are shown on the following photos:

Figure 15 : Disc Filters, Ultra-filtration Membranes and Reverse Osmosis Membranes

The water quality requirement of the reclaimed water is stringent. Details are as follow:

Parameter	pH value	Total suspended solid	Total dissolved solid	E. Coli	Turbidity
Water quality requirement	6.2 – 8.0	< 2 mg/L	< 200 mg/L	Not detectable	<= 2 NTU

Table 3 : Quality of Reclaimed Water

RESULTS & DISCUSSION

The greening works at Sha Tin STW are well recognized. Sha Tin STW was awarded an exceptionally esteemed 'Golden Award' in addition to a 'Silver Award' under Environmental Design Category in "HKILA Landscape Design Awards Landscape 2010" organized by the Hong Kong Institute of Landscape Architects. More importantly, the greening works are much appreciated by the general public as seen from their positive responses during the DSD Open Day at Sha Tin STW. The public is also engaged in the planting activity. Through this exercise, the Department's relationship with the public is greatly enhanced.

Figure 16 : Public Engagement on Tree Planting on DSD Open Day

For vertical greening, the growth rate of the vertical climbers is one of our concerns. In our R&D Study, encouraging results are obtained from the on-site trial at Sludge Storage Tank. It provides us confidence in wider application of vertical greening for similar sewerage facilities. The following photos show that some climbers (e.g. *Wisteria sinensis* (紫藤)) are able to climb from the bottom to the top of the tank (i.e. 13.3m high) in around six months' time.

February April June August October

Figure 17 : Progress of Growth of Vertical Climber from February to October 2010

Most of the existing roofs are quite difficult to be accessed. To overcome this constraint, we objectively designed and retrofitted staircases and maintenance pathways to facilitate convenient access to the green roofs and routine inspection and maintenance works. The staircases are made of fiber-glass reinforced plastic (FRP) material. FRP is adopted due to its light-weight but relatively high-strength properties. Since the staircase is not a substantial structure, its footing including any foundation is also minimal. This greatly enhances its constructability.

Figure 18 : Staircase for Access to Green Roofs

In view that our experience on new technology on greening works are rather limited, we maintain close collaboration with the University of Hong Kong and Hong Kong Polytechnic University on R&D studies on vertical greening and green roofs respectively. Basically, the universities are tasked to carry out literature review on the subject and recommend schemes of various experiments for on-site trial at Sha Tin STW. We then arrange the detailed design, tender documentation and construction of the on-site trial greening works. During the construction period, the universities set up the various apparatus for monitoring works and take readings regularly for further analysis, while we are responsible for site supervision works and resolving technical problems encountered on site. Throughout the study period, the universities and our colleagues share the necessary theoretical and practical knowledge for the greening works. These two R&D studies serve as good examples of knowledge transfer and collaboration between a government department and educational institutions.

Sustainable development is a pattern of resource use that aims to meet human needs while preserving the environment so that these needs can be met not only in the present but also for our generations to come. To promote wider use of reclaimed water, DSD pay a lot of efforts in the technological development, operational experience, applications and benefits of reclaimed water. In doing so, an information centre of the water reclamation facilities is set up in Sha Tin STW. It not only provides a platform for public education on the benefits of recycling of waste water but also strengthens ties with the reclaimed water industry on technology development.

Figure 19 : Sha Tin Water Reclamation Information Centre

CONCLUSION

To enhance the quality of our living environment, DSD has been actively promoting greening to its sewage treatment facilities. At Sha Tin STW, the green coverage is substantially increased by not only the conventional at-grade planting but also new measures such as vertical greening and green roofs. To promote sustainability, reclaimed water is used for irrigation of the plants.

In conjunction with the greening works, two R&D studies on vertical greening and green roofs are being carried out in collaboration with the University of Hong Kong and Hong Kong Polytechnic University respectively. Large-scale on-site trial planting works for vertical climbers and green roofs are being carried out at four Sludge Storage Tanks and Sludge Thickening House and its Extension of Sha Tin STW. To date, encouraging interim results are obtained. We are proud of the achievements and we are excited about future opportunities for wider application of vertical greening and green roofs at other sewage treatment facilities as well as pumping stations.

The greening works offer an excellent opportunity to establish a close connection with stakeholders and promote the image of sewage treatment facilities. Through tree planting activities in DSD Open Day, community relations are strengthened. Valuable opinions from public about the greening works and the works of DSD are also solicited. To better serve the public, we are committed and will continue to strive for the highest possible quality of greening works at Sha Tin STW and other DSD facilites.

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