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Application of Sustainable Water System – the Demonstration in Chengdu (China)

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Abstract
The concept of sustainable water system is borne out of a need for an economic alternative to developing new sources of water and mitigating environment pollution. At present, it is a relatively new idea in China. Based on literature review and experience summarizing, a demonstration project of sustainable water system is designed and applied in new campus of Chengdu Medical College. Due to the notion that greywater is of better quality than wastewater and therefore does not need extensive treatment beyond addressing public health issues, in this project, greywater from student dormitory is separately collected and treated on-site while blackwater is discharged into urban sewage. Rainwater is transported and decentralized purified by cobble ditch. Finally, decontaminated greywater and rainwater is reused on-site for irrigation, road sprinkle and landscape impoundment in new campus. This project will make the first testing and demonstration for sustainable water system using greywater in China. It can provide the reference for the development of sustainable water system in architecture section.

Keywords: sustainable water system, greywater reuse, rainwater reuse

1 Introduction

As a part of sustainable development, sustainable water system is an integrated system including water intake, water utilization, wastewater discharge and treatment and water environment protection. It requires reducing freshwater and groundwater use in all sectors of consumption and substituting freshwater by reclaimed water by including economic factors. In today's world, developing sustainable water system is a tendency. It is accords with the national strategic policy of building a resources-conserving and environment-friendly society. It is beneficial to saving water, protecting environment, improvement living environment, and harmonious development of construction and ecosystem. It serves people's long-term benefits.

Nowadays, available non-traditional water resources in estate include storm water and domestic swage. Comprehensive utilization of those is an important way to reduce potable water use and

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wastewater discharge. Studies indicate that in the unconventional water resource using at the estate level, it is more suitable to collect water separately based on water quality and treat it step by step according to different reuse goals. It is coincidence with the requirement of sustainable development. In china, there are comparatively deep researches on city environment, domestic sewage water reuse, urban roof rainwater characteristics, rain water treatment and reuse at present. But there are little researches on sewage drained and treatment according to quality. The study on characteristics of greywater which is less polluted than traditional sewage, the process of greywater purification, and the practice in comprehensive utilization of sustainable water system, are still at an initial stage.

2 Treatment and reuse of greywater

Greywater is wastewater from baths, showers, sinks and wash basins. This water if well engineered serves as a source of water for uses other than drinking after adequate treatment has been done. Depending on the type of greywater and its level of treatment, it could be reused on-site for landscape water, irrigation, toilet flushing and road sprinkle. According to an investigation about the impacts of domestic greywater reuse on public health which is carried out by the New South Wales Health Centre in Australia in 2000, greywater contains less nitrogen and faecal pathogenic organisms than sewage, and the organic content of greywater decomposes more rapidly. As technology develops there will be a growing acceptance of this relatively new concept.

2.1 Characteristics of greywater

The investigation shows that average domestic swage discharge in china is 200~250L/(p.d), which including 60% of gray water. Because of large amount of chemical compounds and pathogenic microorganisms, gray water reusing may lead health issues when contacting with people. There are researches outside China in gray water quality characters and risk assessment and so on. But it is at the absence of similar report in China. Qualities of gray water range widely and it is impacted by the quality of water supply, water distribution network, family habits, and water using ways. Gray water qualities from different places were listed in Tab.1 (Eva Eriksson et al., 2002).

Tab. 1 greywater quality (in mg/L unless otherwise stated)

Type of greywater	Bathroom	Laundries	Kitchen sinks	Mixed sources
Temperature (□)	29	28—32	27—38	18—38
Colour (Pt/Co)	60—100	50—70	—	30—100 ($PtCl_6$)
Turbidity (NTU)	60—240	50—296	—	15.3—200
SS	48—120	88—250	4—185	6.4—330
PH	6.4—8.1	8.1—10	6.3—7.4	5—8.7
Alkalinity (as $CaCO_3$)	24—43	83—200	20—340	149—198
BOD_5	76—200	48—380	1040—1460	90—290
COD	100—633	725—1815	3.8—1380	13—549
TOC	40—104	100—280	600—880	60—92
Oil and grease	37—78	8.0—35	—	—
Chloride	9.0—18	9.0—88	—	3.1—30
TN	5—17	6—21	0.31—74	0.5—18.1

NH_4—N	<0.1—15	<0.1—11.3	0.002—23	0.03—25.4
NO_3 和 NO_2	<0.05—0.20	0.1—0.3	—	<0.1—2.1
TP	0.11—2	0.062—57	0.06—74	0.16—27.3

Overseas studies indicate that medicine and personal care products could be mixed in gray water by washing activities. Eriksson A Z (2003) found about 200 kinds of chemical compounds in washing gray water. Wide use of household medicine makes the quality of gray water more complicated. Many kinds of shampoos lead high concentration of XOCs in gray water. Based on analyses of Household Chemicals, Eva Eriksson A Z (2002) detected that the amount of XOCs mixed in greywater is potentially more than 900 kinds. Palmquist H (2005) analyzed hazardous chemicals contained in discharged water from Vibya°senliving, Sweden, where discharged gray and black water separately. The results showed that for 105 kinds of hazardous chemicals (including 24 kinds of elements and 81 kinds of hazardous compounds), 22 kinds of elements and 46 kinds of hazardous organic pollutants were found in the gray water, while 23 kinds of elements and 26 kinds of hazardous organic pollutants were found in the block water. It is a potentially threaten to safe reuse of gray water. Treating greywater before using it is recommended, even in places where this is not a requirement.

2.2 Treatment of greywater

Physico-chemical process

This process is mainly used to treat greywater containing lower organic matter concentration, water from bathroom for example. The process flow is: hair filter – regulating tank – sand filter – disinfection – reuse. But the research of Friedler E (2006) indicates its' low-efficient.

Physicochemical-Biological process

Biological Aerated Filter (BAF), Sequencing Batch Reactor (SBR), Rotating Biological Contactor (RBC) and Membrane Bio-Reactor (MBR) are 4 major water-treat processes at present. Studies and long-time running showed that these processes are capable to treat graywater well and stably. SS, COD_{cr}, BOD_5, turbidity, and microbiological index of treated water can meet the requirement of quality standard for reused water. Stably running RBC system can remove chemicals from detergents and personal care products in graywater. The effluent quality even reaches the drinking water standard and the growth of microorganisms was not obvious in working pipes (Jefferson B, 2001. M. Lamine, 2007. Nolde E, 2005. Friedler E, 2005).

Besides, there are some studies in anaerobic biological process cleaning greywater. Tarek A. (2007) studied the feasibility of Up-flow Anaerobic Sludge Blanket (UASB) is used to purifying graywater. The result showed that the operation was stable and the removal rates of COD, total nitrogen and total phosphorus were 52-64%, 22-30% and 15-21%, respectively.

Ecological treatment system

Ecological treatment system has merits such as low energy consumption, convenient maintenance, and varied scenery. There are many applications for ecological treatment system in graywater reuse, such as reedbeds, slanted soil treatment systems and plant –filters, etc. Operation results showed that these processes have broad application prospects in greywater reuse because of easier maintenance and higher removal rates of organic, turbidity, ammonia nitrogen and phosphorus.

3 Demonstration project

3.1 Background

Chengdu Medical College (CMC) was founded in 1947 and was detached from the Third Military Medical University as an independent undergraduate college in August, 2004. Now, CMC expropriated new land in Xindu district to construct new campus. The new campus will be built up in two steps. The first phase will occupy 437487.2m^2, and the second phase will occupy 293183.1m^2. Design scale of new campus is: 13,000 students, 73.66703 hm^2 of total occupied area, and 380,700m^2 of total building area.

Xindu is a satellite town of Chengdu City, about 25 km away from the center of Chengdu. CMC new campus locates in subtropical zone with monsoon climate. Annual mean temperature is 16.2℃, extreme maximum temperature is 37.3℃, extreme minimum temperature is -5.9℃, more than 337 days in one year is frostless day, and mean temperature of the coldest mouth (January) is 5.6℃. It has abundant rainfall, and the mean annual precipitation is 828.4mm, most of which falling between July to August. December and January has lowest rainfall in whole year. The mean annual evaporation is 1021.3mm.

Conclusively, there are about 13,000 students will centralized live in CMC new campus, which will discharge abundant greywater. In addition, it has plenty rainfall. Therefore, demonstration project of sustainable water system was decided to be constructed in CMC new campus.

3.2 Introduction of the Demo-project

The sustainable water system for CMC New Campus is aimed to achieve sustainable cycle of water, nutrient and energy. It will reuse rainwater and grey water discharged from dormitories for landscape irrigation, road sprinkle and complementary of the artificial lake. In this system, appropriate treatment technologies and best management practices (BMPs) for storm water management is integrated in to maintain qualified aquatic eco-environment in community and control soil erosion.

Mechanical measure of the sustainable water system includes:

- Grey water collection pipeline networks from the western student dormitories to grey water treatment station.
- A grey water treatment station.
- Rainwater harvesting and purifying system for teaching area.
- Water quality maintenance system for the artificial lake in campus.

Introduction of the procedure of the sustainable water system

High quality grey water discharged from western student dormitories is collected by networks, and treated in greywater treatment station and stored in the middle-water tank to supply to landscape irrigation, road sprinkle and complementary of the artificial lake. If treated greywater excess, it overflow into the Constructed Wetland 2#, from there, water will flow into the artificial lake for complementary. When it rains, rainwater from teaching area is collected and treated through cobble ditch and flow into the artificial lake. An overflow port is set in the artificial lake for discharging the excess water to municipal storm sewer. If there is lake of reuse water in middle-water tank, water in the artificial lake will be pumped to complementary. The artificial lake water is treated by the Constructed Wetland 1# circularly and flows back again. The procedure of the whole system is shown in Fig. 1.

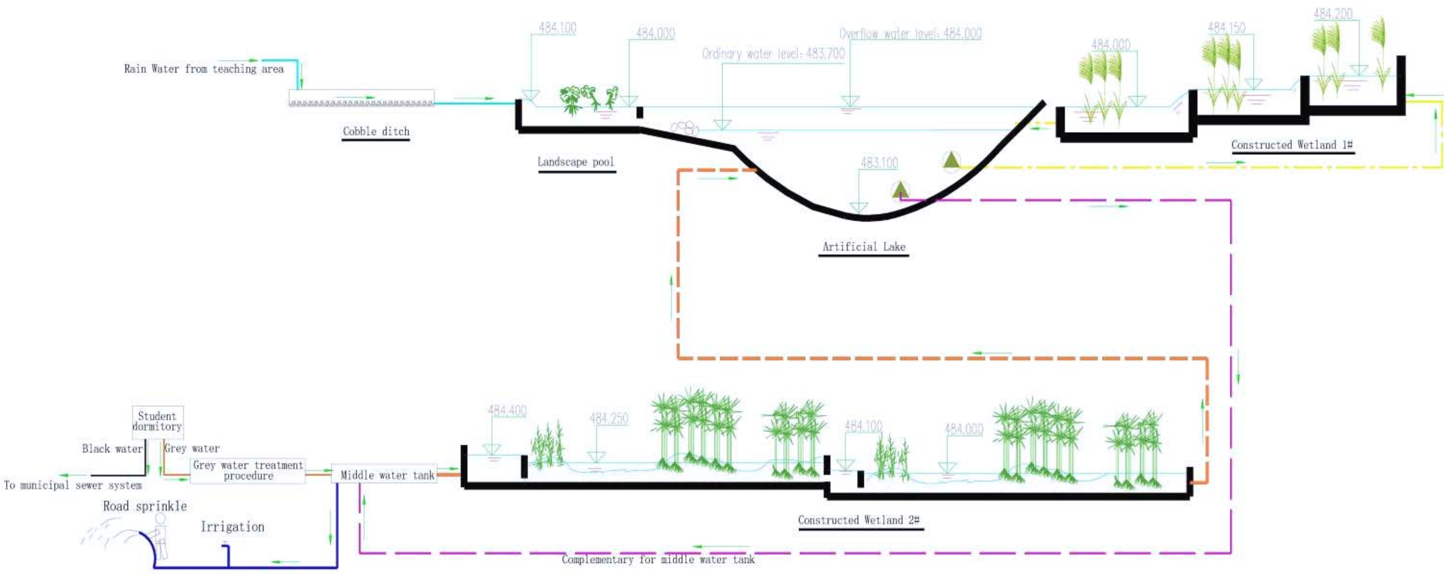

Fig.1: The procedure of the whole system

Designed water quality

Greywater

Based on the data from Chinese design guideline for reclaimed water (GB50336-2002), the water quality of collected grey water from student building can be designed as the following table.

Tab. 2: the Designed Grey Water Quality Parameter

Parameters	COD	BOD	SS	TN	TP
Water quality (mg/L)	100	60	80	10	15

Rainwater

Due to the actual monitoring data in Chongqing University, the quality of roof rainwater and ground rainwater can be designed as the following table.

Tab. 3: the Designed Rain Water Quality Parameter

No.	*Water-quality index/unit*	*Roof rainwater*	*Ground rainwater*
1	Turbidity/NTU	20 ~ 200	20 ~ 200
2	Suspended solid SS	50 ~ 150	80 ~ 500
3	colourity	20	40
5	PH	5.8 ~ 7.0	5.8 ~ 7.0
6	COD_{Cr}/ $mg.L^{-1}$	20 ~ 150	50 ~ 300
7	NH3-N / $mg.L^{-1}$	2.5 ~ 15	3.0 ~ 40
8	free residual chlorine/ $mg.L^{-1}$	0	0
9	The total number of bacillus coli（n/L）	0	10

Reclaimed water

For this project, grey water is used for landscape irrigation, road sprinkle and complementary of the artificial lake. Water quality requirements on planting, landscaping, road sprinkle are listed in Table 4. Water quality for planting and road sprinkle refers to "Urban Mixed Water Quality Standards for Urban Wastewater Reuse (GB/T 18920-2002); water quality for landscaping refers to "Urban Mixed Water Quality Standards for Urban Wastewater Reuse (GB/T 18921-2002). Design Values for recycled water in this project are listed in Table 4.

Tab. 4: Recycled Water Quality Standards and Design Values

No.	*Items (mg/L)*		*Toilet Flushing*	*Road Cleaning, fire fighting*	*Urban Planting*	*Landscaping*	*Designed values*
1	Basic requirements		——			No floating objects	No floating objects
2	pH	≤	6.0 ~ 9.0				6 ~ 9
3	color (chroma)	≤	30				30
4	smell		No offensive odor				
5	SS	≤	——			10	10
6	turbidity (NTU)	≤	5	10	10	——	10
7	Soluble total solid	≤	1500	1500	1000	——	1000
8	BOD5	≤	10	15	20	6	10
9	Total phosphor	≤	——			0.5	0.5
10	Total nitrogen	≤	——			15	15
11	Nitrogen, ammonia (based on N)	≤	10	10	20	5	5
12	anion surface active agent	≤	1.0	1.0	1.0	0.5	0.5
13	petroleum	≤	——			1.0	1.0
14	Fe	≤	0.3	——			0.3
15	Mn	≤	0.1	——			0.1
16	dissolved oxygen	≥	1.0			1.5	1.5
17	Faecal coliform bacteria (quantity/L)	≤	——			2000	2000

18	Total coliform bacteria (quantity/L)	≤	3	——	3

Greywater collection pipe networks

All grey water from student dormitory is collected. Two pipe networks are set indoor. One is connected grey water (shower and wash water) and another is connected with black water (other sewer except shower and wash water). Grey water is collected and discharged into the baffle tank of the treatment system. The black water from student dormitory and wastewater from teaching building, office building, and other buildings discharge into municipal sewer system

Greywater treatment station

The procedure of greywater treatment is shown in Fig. 2.

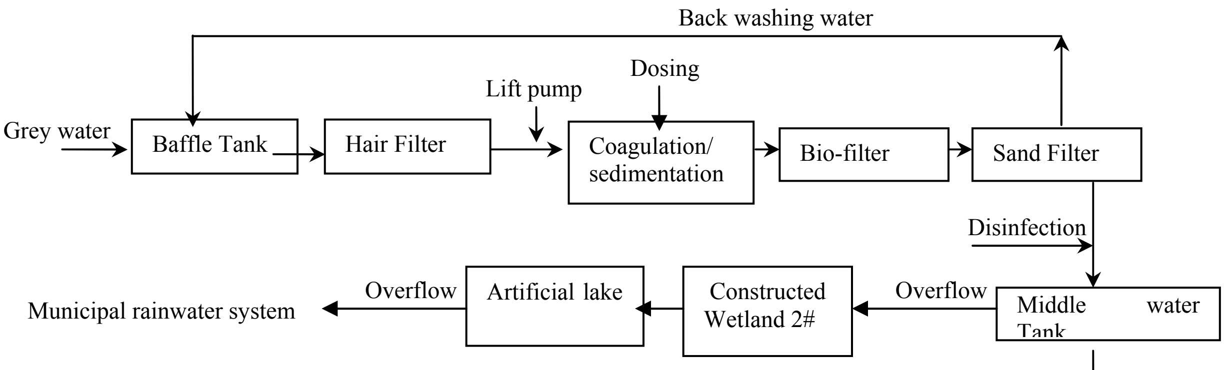

Fig.2 Grey water Treatment Procedure

Main design points of each part:

- ●Baffle Tank: Regulating flow and quality of grey water. Regulation Volume is 35% of the treatment capacity. (200 m^3/d) (Based on the data from Chinese design guideline for reclaimed water (GB50336-2002)
- ●Hair Filter : Removing hairs and bigger suspending articles from showering. Hair filter is set in the outlet pipe of the pump. Specification:DN200; main part height is 500mm; Reference weight 35kg.
- ●Coagulation and Sedimentation Tank: The suspended substance is removed and the flow is regulated. Using Complete Sets of Equipment (including flocculation tank、sedimentation tank 、filtration tank、disinfection tank、metrical instrument etc.)
- ●Biological Aerated Filter: The rector is a high load immobilized biofilm and three-phase reactor , which have the advantages of both activated sludge process and biofilm process. There are fillers and air blast. Oxic wastewater is purified through bio-membrane. Design flow is 200 m^3/d (12.5m^3/h , operating time is 16h/d) .
- ●Sand Filter: Using Complete Sets of Equipment. Filtering area is 1.5m^2.(Diameter of the sand granule 0.6 ~ 1.2mm).

- Middle water tank: The Volume is 30% of the of reclaimed water consumption (Based on the data from Chinese design guideline for reclaimed water (GB50336-2002)
- Sludge tank: The sludge from the grey water treatment station and wastewater is stored in sludge tank and transported to municipal sewage treatment plant regularly
- Dosing and mixing equipment: Dosing system use complete sets of equipment; mixing equipment use Tubular Static Mixer.
- Disinfection equipment: using chlorine dioxide disinfection，dosing quantity is 0.8mg/L.
- Pneumatic water supply equipment: the equipment is select according to maximum hourly consumption of reclaimed water and maximum lift.
- lift pump: lift pump is set in baffle tank and sludge tank separately, the lift is 10m，the flow is 12.5 m^3/h

Rainwater harvesting and purifying system

The procedure of the rainwater harvesting and purifying system：The Cobble ditch is laid beside the roads and surrounded the greenspace. The runoff of the road and greenspace is collected and purified initially. Green billabong is set to collect the rain water. Certain gradient in billabong is set towards the cobble ditch and decentralized landscape pool is set before the lake inlet. And the captured runoff will be treated through landscape pool and stored in artificial lake in campus in order to ensure the water quality of the lake. The procedure of rainwater harvesting and treatment is shown in Fig.3.

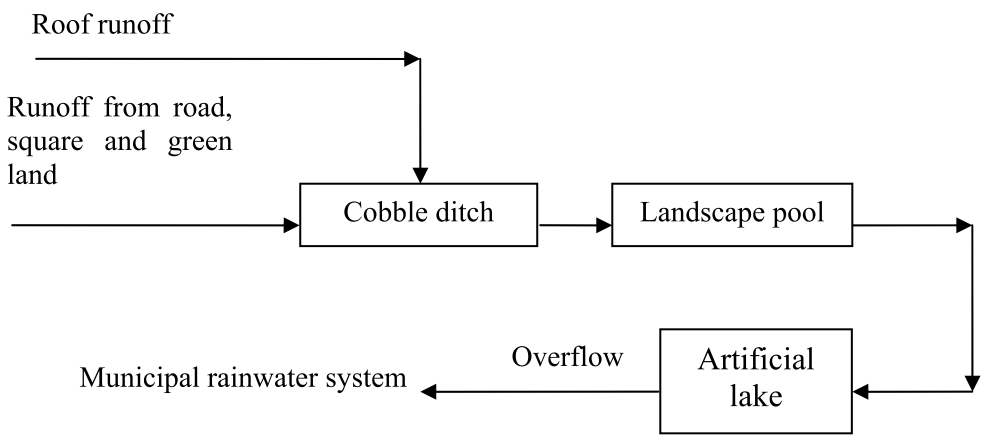

Fig.3 The procedure of rainwater harvesting and treatment

- cobble ditch

Cobble ditch are mostly used beside the road, can harvest and transport rainwater and enhance the infiltration of fist-stage rainwater.

- Landscape pools

After being treated by green billabong and cobble ditch, rainwater is treated through landscape pool. There are five decentralized landscape pools in this project. The size of the landscape pools are designed according to the 13mm runoff of the corresponding catchment area.

Reclaimed water supply system

A middle water tank in the greywater treatment station is proposed to store reclaimed water and steady the water pressure, which is connected with reclaimed water supply networks. The Water supply pump unit is selected according to the water consumption of landscape irrigation. If there is excess water except for irrigation, it overflows into the Constructed Wetland 2# and then discharge into the artificial lake for complementary.

Water quality maintenance measures for the artificial lake

In order to ensure the water quality of the artificial lake and recycling water, it is necessary to construct ecological lake bank. And It is also necessary to apply circulation wetland treatment for artificial lake i.e., lake water in the artificial lake will be pumped to wetland system 1# with circulation pumps and then treated through wetland system 1#。After that the water will be discharged into artificial lake again.

3.3 Innovation and Significance

Innovation

- Integration scheme of grey water reuse and landscape/aesthetic.
- A combination of grey water treatment system and rain water purifying system.
- A combination of rain water harvesting and purifying system and landscape design.
- Using ecological theory acts and human-oriented as the foundation of design, to create a clean, safety and comfortable water circumstance.

Significance

Training and Dissemination.

- The demo-project is a partial content of national demonstration as “resource saving campus” and “sustainable building”.
- A successful integration of grey water reuse and landscape/aesthetic purpose will be a paradigm for Universities/Colleges to learn from.
- The demo-project will also become a study case for students, who will influence the future society with the idea in their mind.
- The demo-project can be hopefully selected as a demonstration of “resource saving campus” in China, and training activities can be implemented after the construction work in Chongqing

Water saving, environmental and economic benefits analysis

- When utilizing greywater and rainwater, 97702.3 m^3/year municipal water will be replaced. Assume costs for rainwater and greywater collection and treatment are RMB 0.2 /m^3, municipal water supply price, according to Xindu city domestic water charge, is RMB 1.35/m^3. Therefore, for each ton, RMB 1.15 /m^3 will be saved, RMB 112,400 water charges will be saved in a year. Considering that water charges will be increased in the future, the potential economical benefits are remarkable.
- After using greywater, annual sewage discharge reduction will be 82252.8m^3/year, bringing remarkable environmental benefits. Nowadays, Xindu is increasing sewage charges, from RMB

0.15/m^3 to RMB0.35 /m^3. By reusing greywater, sewage charge reduction will be 82252.8×0.35 = RMB 28788. Water saving has great benefits.

In this project, total rainwater reused is24787.4 m^3/year, reducing 36% of total rainwater in teaching building area. Municipal rainwater network size can be reduced accordingly, and environmental impacts from pollutants on receiving waters can be controlled.

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