018530 - SWITCH

Sustainable Water Management in the City of the Future

Integrated Project
Global Change and Ecosystems

D4.1-11: Design report of a decentralised urban wastewater system for CMC New Campus, Chengdu - China

D4.1-12: Status Report of Chengdu Greywater demo and planning for subsequent activities

D4.1-13: Monitoring plan for Chengdu Greywater demo and experimental study on pilot scale constructed wetland

Start date of project: 1 February 2006 Duration: 60 months

Chong Qing University, P.R. China

Revision [final]

Project co-funded by the European Commission within the Sixth Framework Programme (2002-2006)		
Dissemination Level		
PU	Public	√
PP	Restricted to other programme participants (including the Commission Services)	
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This document contains three deliverables related with the design, status report and monitoring of a decentralised urban wastewater plan system for Chengdu Medical College (CMC) New Campus, Chengdu – China. The deliverables have been compiled to provide an overview of the demonstration case.

This large scale demonstration at the new CMC Campus, Chengdu, China, aims to demonstrate the potential of reusing grey water for landscaping. Although not finished by the end of SWITCH, it is expected that the demonstration will have a China wide exposure because it is part of a wider sustainable building program of the Chinese Ministry of Construction. As such it may contribute to alleviating water scarcity in over 450 cities in China which are currently faced with water scarcity.

The compiled deliverables are:

D4.1-11: Design report of a decentralised urban wastewater system for CMC New Campus, Chengdu - China

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SWITCH Deliverable Briefing Note Template

SWITCH Document 4.1.11 entitled **Design report of a decentralised urban wastewater system for CMC New Campus, Chengdu - China**
Audience This document is targeted mainly at engineers, scientists and technologists working on implementation of new sanitation approaches
Purpose This large scale demonstration at the new CMC Campus, Chengdu, China, aims to demonstrate the potential of reusing grey water for landscaping.
Background Deliverable 4.1.1 reported on the findings on the practical implementation and performance of ecosan systems. One of the chapters focused on the implementation of decentralised wastewater reclamation systems (DWRSs) in Beijing. It is estimated that approximately 300 decentralised wastewater reclamation systems (DWRSs) are in operation, producing 50,000 – 60,000 m3 / day of second quality water that is used for toilet flushing, landscape irrigation, street cleaning, car washing. The Ministry of Construction aims to upscale this approach across China within a current program on sustainable building. Various innovative aspects are included in this demonstration including the treatment technologies applied and the innovative approach of reusing the water for landscaping.
Potential Impact Deliverable 4.1.1 already showed the large potential for water saving when reclamation technologies are applied. This demonstration will have a China wide exposure because it is part of a wider sustainable building program of the Chinese Ministry of Construction. As such it may contribute to alleviating water scarcity in over 450 cities in China which are currently faced with water scarcity.
Issues Originally, this demonstration project was planned to be implemented in Beijing but because of various circumstances, it was delayed and replaced to Chengdu. But till present, the November of 2010, the construction of the whole campus and the demonstrated project is still ongoing. The indoor grey water pipe system and out door pipe system are already constructed. The outdoor landscape and the grey water treatment station will likely be finished in the spring 2011. Due to the delays, it was not possible to conduct the monitoring as was originally planned in this part of SWITCH.
Recommendations To conduct monitoring of this demonstration according the monitoring plan provided in Deliverable 4.1.13 and report on the results to the Ministry of Construction of PR China.

SUMMARY

Chengdu Grey water demo is a demonstration project of the Sustainable Water management Improves Tomorrow's Cities' Health (SWITCH), co-funded by the European Commission within the Sixth Framework Programme. The demonstrated technologies and system belong to Theme 4.1 Eco-sanitation and decentralized wastewater management in an urban context. The activity of Chengdu Grey water demo is technically implemented by Chong Qing Univeristy (CQU) of China, and supervised by Wageningen University of the Netherlands. Originally, this demonstration project was planned to be implemented in Beijing but because of various circumstances, it was delayed and replaced to Chengdu.

This demonstration project tries to utilize the new campus of Chengdu Medical College (CMC) in Xindu County as a showcase of the decentralized wastewater treatment and reuse onsite. In the new developed campus, the grey water from students dormitories planned to accommodate 7000 students is collected and treated within the campus. The compacted indoor Biological Aeration Filter and outdoor Wetlands are applied for grey water treatment. The storm run off from the teaching building area (around 1/4 of the total area of the campus) is captured with Vegetated Swales and Graved infiltration ditch and then treated by Constructed Wetlands, which is special designed for rain water treatment. Finally, the treated grey water and rain water flows into the scenic water body, named as Mingjing Lake. The later taking a core role of the whole outdoor landscape is designed as a storage tank for the treated grey water and rain water, and support a relative stable reclaimed water supply for miscellaneous use in the campus.

The demonstration project shows a paradigm of an integration of grey water reuse, rain water harvesting and landscape/aesthetic function. With the help of this sustainable water management system, there is no further need for municipal tap water for green irrigation and scenic water replenishment. The demonstrated system is hopefully scaled up among China with great potential.

Due to the public concerns about the treated water quality, the original proposed grey water for toilet flushing in teaching buildings was cancelled finally. And the black water collected in the campus is discharged into the municipal sewer system directly based on the worry about odour pollution and economic consideration. So finally, only the grey water and rain water will be collected and reused onsite. The main usage for the reclaimed water is for green irrigation and scenic water body replenishment.

Since June of 2006, the Chengdu demonstration project has started up with its design activity. But till present, the November of 2010, the construction of the whole campus and the demonstrated project is still on going. Now, most of the buildings in the campus have finished

their construction activity. The indoor grey water pipe system and out door pipe system have been finished as well. The outdoor landscape and the grey water treatment station are hopefully finished at the beginning of 2011. Due to the delays, it was not possible to conduct the monitoring as was originally planned.

Contents

1 INTRODUCTION

The site of Chengdu Greywater demo-project is located in the New Xindu Campus of Chengdu Medical College (CMC). The new campus is located in Xindu, a satellite town of Chengdu City, about 25 km to the center of Chengdu.

Xindu Campus is the new development area of CMC, which has a planning area of 73.67 hectare, where about 13,000 students and 3000 teachers will be accommodated.

The new campus of CMC has been selected as the demo-project for renewable energy (ground water source heating pump) utilization in building by MOC and MOF, China. Water saving is a content of the demonstration. Chongqing University is the technical support organization of the demonstration.

An integration scheme of grey water reuse and landscape/aesthetic purpose is proposed. The grey water from student buildings (70, 000 m^2) will be collected and treated through Biofilter and CW, the rainwater will be captured and treated onsite with shallow grass/cobble trenches, swales and CWs. The reclaimed water (both grey water and rain water) will be used as the source of landscape irrigation, toilet flushing in teaching buildings, and the complementary of the scenic water body. The water quality conservation of the scenic water is another issue in the whole water system, which will be considered.

High quality grey water is separately collected, treated and stored in the middle water tank, and then the water is pumped from the middle water tank and supply for landscape irrigation, road sprinkle and complementary of the artificial lake. If there is excess water, it overflows into the Constructed Wetland 2# and then flows into the artificial lake for complementary. When it rains, rainwater from teaching area is collected and treated through cobble ditch and landscape pool, then flows into the artificial lake. An overflow port is set in the artificial lake for discharging the excess rain water. If the treated grey water is insufficient , some water from the artificial lake will be pumped to the middle water tank for complementary. The water from the artificial lake is treated by the Constructed Wetland 1# circularly and flows into artificial lake again.

2 BACKGROUND

2.1 The demonstration project

The new campus of Chengdu Medical College (Chengdu, China) has been selected as a demonstration project for water and energy resources saving by the Ministry of Construction and the Ministry of Finance of the PR China. The water component of the demonstration is supported by the European Commission and serves as one of the demonstration projects within the EU 6th Framework project SWITCH. Chongqing University is the technical support organization of this demonstration. Originally, this demonstration project was planned to be implemented in Beijing but because of various circumstances, it was delayed and replaced to Chengdu.

This document presents a design for the demonstration project on water resources saving. The project aims to save approximately 125 thousand m^3 of tap water per year. It consists of a system for decentralised urban wastewater reclamation at the new campus site. The grey water of the students' buildings will be collected separately and treated by biological system plus constructed wetlands. The treated grey water and run-off water from the roofs of the students' buildings and from a square will be collected in a scenic water body (Mingjing Lake in the new campus). The water from this water body will be used for landscape irrigation.

Due to the delays, it was not possible to conduct the monitoring as was originally planned.

2.1.1 Chengdu Medical College (CMC)

CMC was founded in 1947 and was detached from the Third Military Medical University as an independent undergraduate college in August, 2004. The college consists of seven departments (departments of Preclinical Medicine, Humanities & Social Sciences, Clinical Medicine, Pharmacology, Medical imaging, Nursing and Lab Study), offering 3-year undergraduate programs in 8 majors, including Clinical Medicine, Nursing, Pharmacology, Lab Studies, Medical Imaging, Bio-technology, Pharmaceutical Analysis and Applied Psychology. It currently has an enrollment of 6,000 students.

2.1.2 The CMC New Campus

CMC is construction its new campus in Xindu District, Chengdu City. First phase of this new campus, with a construction area of about 400,000 m^2, was expected to be built by July 2009, but actually delay to 2011. The new campus is adjacent to the Southwest Petroleum Institute,

which is about 2 km away from Xindu own center, 20 km away from Chengdu North Railway Station, 40km away from Shuangliu International Airport.

The new campus will house 13,000 students with 380,700 m^2 of building, occupying 73.7 ha of land. The new campus will be constructed in two phases (Table2-1). The first phase will occupy 43.7 ha of land, and the second phase will occupy 29.3 ha. After the first phase of construction is being finished, around 7,000 students are expected to live in it.

The total investment of the CMC new campus is 777 million RMB. 49% of total investment, 377 million Chinese Yuan, is funded by CMC itself, and the remaining 51% of total investment, 400million Chinese Yuan, is loaned from bank.

Table 2-1 Planned construction contents and scale of the CMC new campus

Item	*Project*	*Building area（m^2）*			*Occupied Land area（m^2）*		
		Total	*Phase 1*	*Phase 2*	*Total*	*Phase 1*	*Phase 2*
Front campus	Hall	4500		4500	3375		3375
	Exchanging centre	11000		11000	8250	0	8250
	Skirt building	6000	6000		4500	4500	0
	Commercial street	7000		7000	5250	0	5250
	subtotal	28500	6000	22500	21375	4500	16875
Teaching area	Technology building	38000	38000		28500	28500	0
	Administration building	8000	8000		6000	6000	0
	Student centre	6000		6000	4500	0	4500
	Teaching building	30000	20000	10000	22500	15000	7500
	Lab building cluster 1	18000	18000		13500	13500	
	Lab building cluster 2	18000	18000		13500	13500	
	Lab building cluster 3	18000		18000	13500		13500
	School administration building	3000	3000		2250	2250	
	subtotal	139000	105000	34000	104250	78750	25500
Western student area	Western student dormitory cluster 1	15000	15000		7500	7500	0
	Western student dormitory cluster 2	15000	15000		7500	7500	0
	Western student dormitory cluster 3	15000	15000		7500	7500	0
	Western student dormitory cluster 4	15000	15000		7500	7500	0
	Western student dormitory cluster 5	10000	10000		5000	5000	0
	Dinning hall	14000	14000		9100	9100	
	Supermarket	1200	1200		1440	1440	
	Logistics comprehensive building	10000	10000		6000	6000	
	Apartment for young teachers 1	3550	3550		1775	1775	

Item	*Project*	*Building area（m²）*			*Occupied Land area（m²）*		
		Total	*Phase 1*	*Phase 2*	*Total*	*Phase 1*	*Phase 2*
	Apartment for young teachers 2	7100	7100		3550	3550	
	Apartment for young teachers 3	3550	3550		1775	1775	
	subtotal	109400	109400	0	58640	58640	0
Eastern student area	Eastern student dormitory cluster 1	10000		10000	5000	0	5000
	Eastern student dormitory cluster 2	20000		20000	10000	0	10000
	Eastern student dormitory cluster 3	10000		10000	5000	0	5000
	Eastern student dormitory cluster 4	15000		15000	7500	0	7500
	Dinning hall	12000		12000	7800	0	7800
	Supermarket	1000		1000	1200	0	1200
	subtotal	68000	0	68000	36500	0	36500
Teaching - assistant area	Anatomy building	4500	4500		3375	3375	0
	Animal centre	1300	1300		1105	1105	0
	Printing plant	2000		2000	1500	0	1500
	subtotal	7800	5800	2000	5980	4480	1500
Logistics and auxiliary building	Logistics and auxiliary building	15000	3600	11400	18000	4320	13680
	subtotal	15000	3600	11400	18000	4320	13680
Sports area	Track and field stand	3000		3000	2250		2250
	Gymnasium	10000	10000		7500	7500	0
	A covered sports field	0			19832	0	19832
	A 400m standard track and field site	0			19832	19832	
	15 volleyball courts	0			6279	4186	2093
	14 racket courts	0			13959	9971	3988
	31 basketball courts	0			24502	12646	11856
	subtotal	13000	10000	3000	94155	54135	40020
Road and square		0			163200	97920.0	65280.0
Green area		0			117236.4	70341.8	46894.6
Includes: water body		0			17585.5	10551.3	7034.2
	green space for special	0			99650.9	59790.6	39860.4
Total		380700	239800	140900	619336.4	373086.8	246249.6

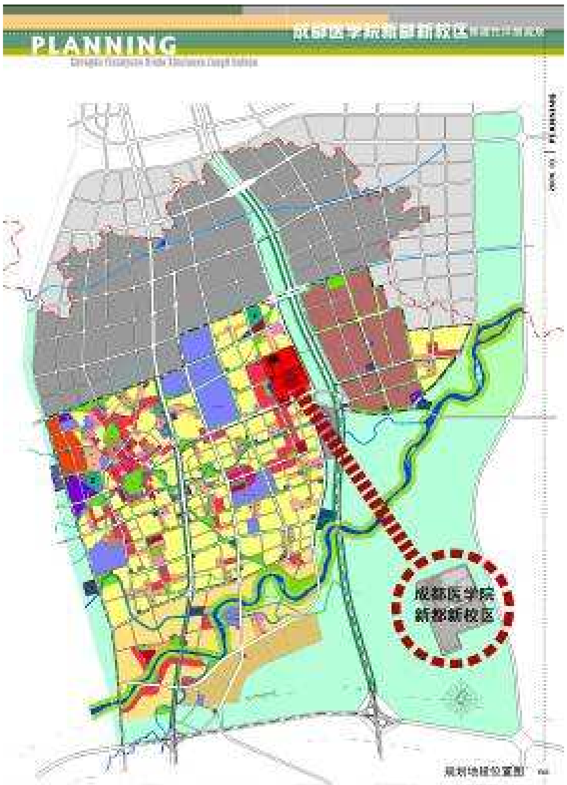


Fig. 2-1 The site location of CMC New Campus

Fig. 2-2 The Master Plan of CMC New Campus

Fig. 2-3 The Construction Phase Distribution of CMC New Campus

Fig.2- 4 The Function Distribution of CMC New Campus

2.2 Design Objectives and scope

2.2.1 Design objectives

The objective of this design is to develop a sustainable water system for CMC New Campus, which including:

- To develop and demonstrate a sustainable approach towards decentralised treatment and recycle of wastewater;
- To achieve 100% reduction of potable water consumption for landscape irrigation in the campus;
- To maintain qualified aquatic eco-environment in the community and control soil erosion;
- To demonstrate BMPs (Best Management Practices) for storm water management.

2.2.2 Design Scope

This design will focus on the area of Phase 1 new campus. The design content includes:

- Decentralized grey water collection from the student dormitories,
- Onsite wastewater treatment (only for grey water) and reuse for landscape irrigation,
- Best Management Practices (BMPs) for rain water,
- Water quality maintenance for the landscape water body in campus.

2.3 Basic Data Analysis

2.3.1 Climatic conditions

The CMC new campus is located in subtropics with monsoon climate and abundant rainfall. The annual mean temperature is 16.2°C, while the maximum temperature is 37.3°C and the minimum temperature is -5.9°C. On average, the site has more than 337 days of frostless days per year. The mean temperature in the coldest month (January) is 5.6°C. The mean annual precipitation is 828 mm. July and August are the two most highest precipitation months. While December and January have the smallest precipitation. The mean annual evaporation is

1021 mm. Table 2-2 illustrates the monthly precipitation and evaporation at the site of the CMC new campus.

Table2-2 Statistics for monthly precipitation and evaporation at the site of the CMC new campus (mean values for 1970~2005*)

	Jan	*Feb*	*Mar.*	*Apr*	*May*	*Jun*	*Jul*	*Aug*	*Sep*	*Oct*	*Nov*	*Dec*
Precipitation (mm)	7.8	12.6	19.9	42.1	69.9	101.3	216.0	192.5	110.5	33.4	17.3	5.1
Evaporation (mm)	30.1	36.8	65.8	105.4	149.8	138.1	132.8	133.6	92.3	63.8	44.0	28.8

*Source: Almanacs of Chengdu City.

2.3.2 Building area and population

The first phase of CMC new campus will be the design area of this sustainable water system. The buildings and the design land area have been listed out in the following table2-3.

Table 2-3 Area of the Service Buildings and the Sustainable Water System

Item	*Project*	*Building area (m²) (the first phase)*	*Occupied area of function zone (m²) (the first phase)*
Teaching area	Technology building	38000	28500
	Administration building	8000	6000
	Teaching building	20000	15000
	Lab building cluster 1	18000	13500
	Lab building cluster 2	18000	13500
	Lab building cluster 3	3000	2250
	subtotal	105000	78750
Western student living zone	Western student dormitory cluster 1	15000	7500
	Western student dormitory cluster 2	15000	7500
	Western student dormitory cluster 3	15000	7500
	Western student dormitory cluster 4	15000	7500
	Western student dormitory cluster 5	10000	5000
	Dinning hall	14000	9100
	Supermarket	1200	1440
	Logistics comprehensive building	10000	6000
	Apartment for young teachers 1	3550	1775
	Apartment for young teachers 2	7100	3550
	Apartment for young teachers 3	3550	1775
	subtotal	109400	58640
Road and square			97920.0
Greenbelt			70341.8
Including water body			10551.3
Including green space for special use			59790.6
Total		214400	375993.7

About 70,000 m^2 of student dormitories will be constructed in the first phase and 55,000 m^2 in second phase. So it can be estimated that about 7,000 students will be accommodated in the first phase of the new campus. The design area for the sustainable water system of CMC New Campus is shown in Figure 2-5.

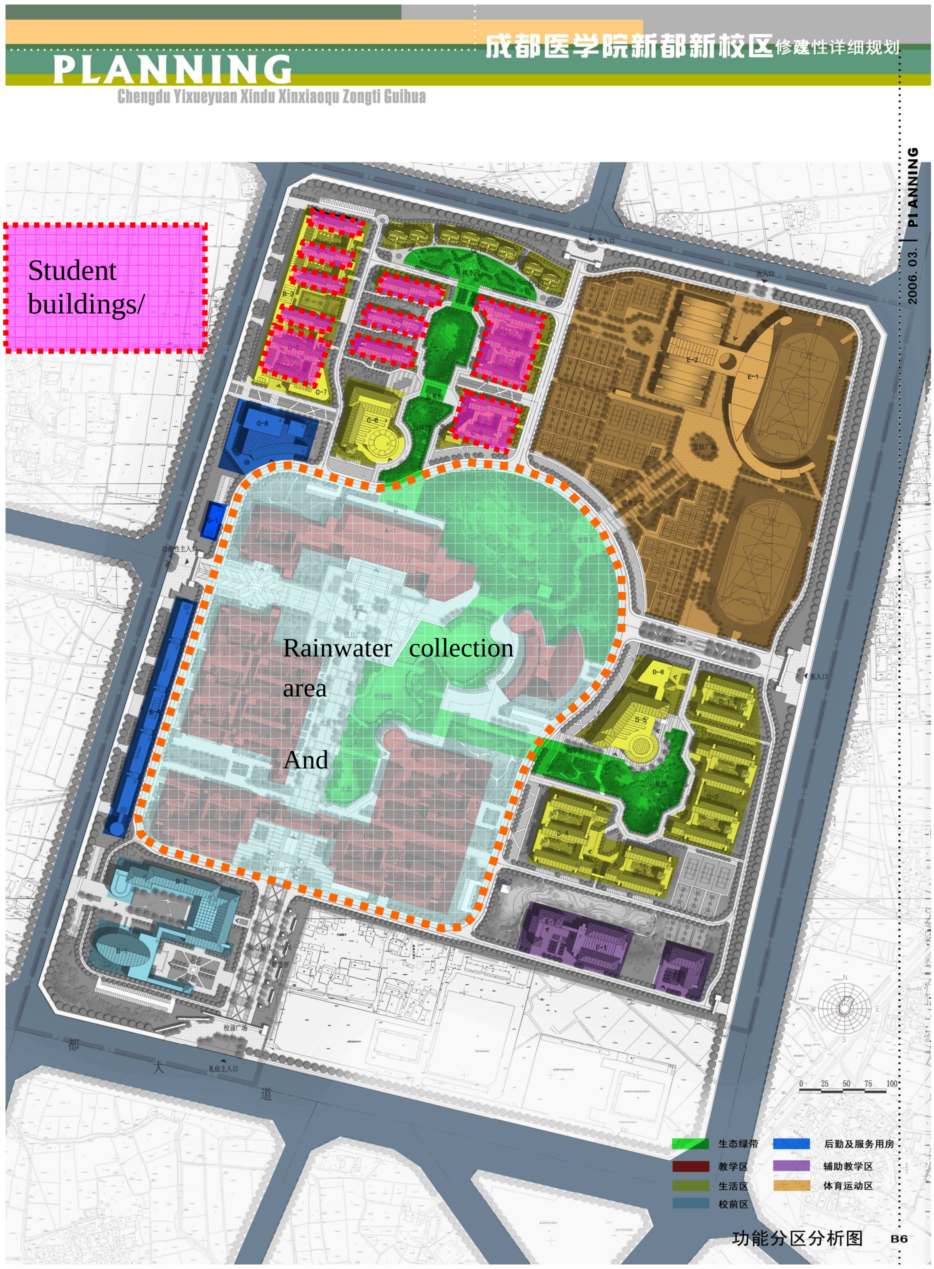


Fig. 2-5 Design area for Sustainable water system of CMC New Campus

3 METHODS

During the design activity of the Chengdu demonstration project, the conception of Decentralised Sanitation and Reuse (DESAR) was applied with careful water balance calculation and an integration of water technology and landscape.

3.1 DESAR

Decentralised Sanitation and Reuse (DESAR) is a new innovative approach to settle the water crisis at small community scale. By implementation of the decentralised approach in the public sanitation sector, stimulation of reuse of recovered by-products can be obtained. Decentralised sanitation focuses on source separated collection of waste (water), treatment on- or close to the location and maximization of the possibilities to recover and reuse nutrients, water and energy.

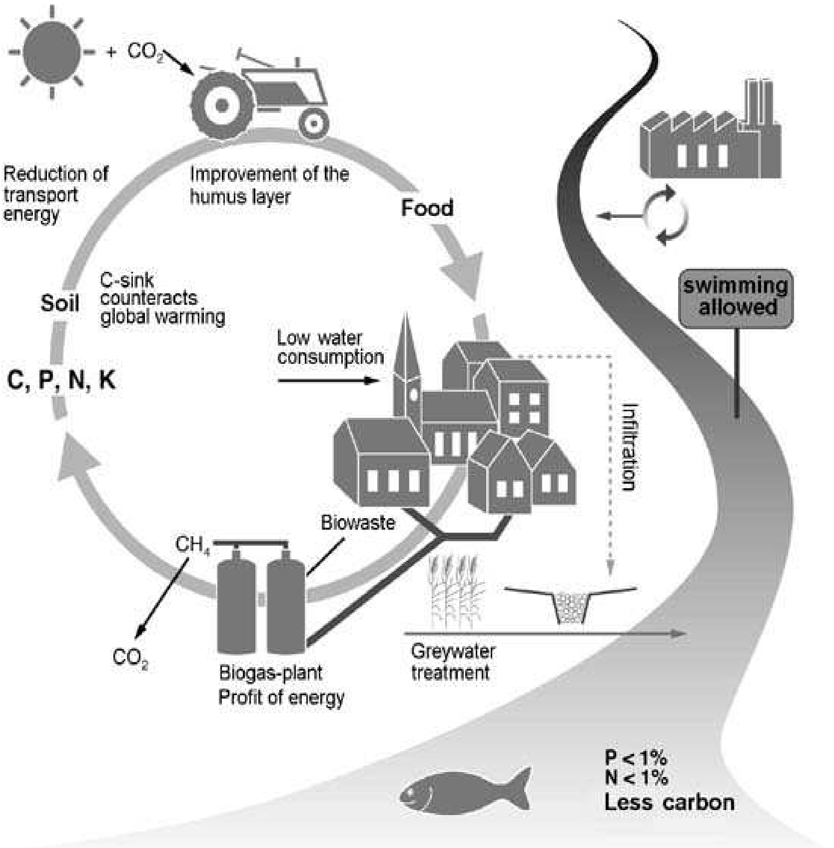


Fig. 3-1 Closing Cycles in Water Chain for the conception of DESAR system

In the Netherlands, Wageningen University and LeAF in cooperation with a large number of partners work on the development of DESAR systems. DESAR is based on separate collection and treatment of black water (toilet wastewater), organic, solid kitchen waste, grey water (washing- and cleaning wastewater) and storm water.

During the design activity of this project, the separate collection of black water, grey water and storm water was applied. Grey water and storm water will be treated and reused on site. The reasons for no black water treated and reused onsite are: 1) there are existing sewer system and public owned wastewater treatment plant. The black water discharged from CMC's Xindu new campus can be treated with low cost. 2) Relative more difficult and higher operation cost to treat the black water onsite, with higher risk to odour pollution in the campus. 3) The black water is in small scale, and is difficult to utilize the nutrients and energy containing in the black water in the economical way. 4) Public concern about the reclaimed water quality from black water treatment.

3.2 Water balance analysis

Water balance analysis applied in this project is an approach to study the monthly and yearly balance between the available reclaimed water supply and the water demand for non-drinking use. The US LEED® reference guideline (Version 2.2, ISBN #1-932444-04-1) was used as a reference for available collectable wastewater calculation. The calculation methods and parameter values in the guideline were applied this project. Chinese Design Guidelines for "Miscellaneous Water Quality Standards for Urban Wastewater Reuse (GB/T 18920-2002, and GB/T 18920-2002) " were applied for the designed reclaimed water quality. The Chinese design guideline for reclaimed water (GB50336-2002) was used as the main reference of the water quality of collected grey water.

The secondary water resource in this project includes the collectable storm water, grey water from Student Dormitories and Young Teacher Buildings. Due to reason that Student Dormitories produce most part of the grey water in a high density, only the grey water from Student Dormitory is collected for onsite treatment and reuse for economic consideration.

The area for rain water harvesting in this project only includes the teaching building area, where the scenic water body, Mingjing Lake, is located in the centre, which ease the rain water collection and the scenic water body can be utilized as the storage tank for the whole sustainable water system.

3.3 Integration of water engineering and landscape architecture

Cooperated with landscape architects, the demonstration project shows an integration of sustainable water system and landscape. The scenic water body, one of the main elements of landscape in the campus, is utilized as the storage and burring tank for reclaimed water. The wetlands for polish grey water treatment and for rain water treatment are changed into the core elements of landscape as well. So both landscape and water system improve with each other.

4 RESULTS AND DISCUSSION

4.1 Water Balance Analysis

4.1.1 Wastewater production

(1) Student dormitories

Occupants: 7000 students

Default male/female occupancy breakdown (50%, 50%)

Table 4-1 Sewage from Student dormitories

Fixture	*Design case fixture type*	*Gender*	*Fixture model*	*Flush Rate (LPF)*	*Percent of Occupants*	*Daily use per person*	*Sewage flow (m^3/d)*
1	Water closet	Female	conventional water closet	9	50%	3	94.5
2	Water closet	Male	conventional water closet	9	50%	3	94.5
3	sub-total						189.00

Table 4-2 Greywater from Student dormitories

Fixture	*Design case fixture type*	*Fixture model*	*Flow Rate (LPM)*	*Percent of Occupants*	*Duration (sec)*	*Daily use per Person*	*Greywater flow (m^3/d)*
1	washbowl	conventional washbowl	12	100%	15	3	63.00
2	Shower	conventional Lavatory	12	100%	300	0.1*	42.00
3	Washing machine	conventional Lavatory	12	100%	600	0.1	84.00
4	sub-total						189.00

* Note: The rate of daily use per person was selected as 0.1 based on the consideration of lowest use rate in winter for water quantity guarantee in the calculation of water balance.

(2) New Staff Buildings

Occupants: 300 Teachers

Default male/female occupancy breakdown (50%, 50%)

Table 4-3 Sewage from New staff buildings

Fixture	*Design case fixture type*	*Gender*	*Fixture model*	*Flush Rate (LPF)*	*Percent of Occupants*	*Daily use per person*	*Sewage flow (m^3/d)*
1	Water closet	Female	conventional water closet	9	50%	4	5.4
2	Water Closet	Male	Conventional water closet	9	50%	4	5.4
3	sub-total						10.80

Table 4-4 Greywater from New staff buildings

Fixture	*Design case fixture type*	*Fixture model*	*Flow Rate (LPM)*	*Percent of Occupants*	*Duration (sec)*	*Daily use per Person*	*Greywater flow (m^3/d)*
1	washbowl	conventional washbowl	12	100%	15	3	2.70
2	Shower	conventional shower nozzle	12	100%	300	0.1	1.80
3	washing machine	Conventional washing machine	12	100%	600	0.2	7.20
4	sub-total						11.70

(3) Teaching buildings

Occupants:

Full-time Equivalent (FTE): 2000 Teachers,

Visitor: 7000 students

Default male/female occupancy breakdown (50%, 50%)

Table 4-5 Sewage from Teaching Buildings

Fixture	*Design case fixture type*	*Gender*	*Fixture model*	*Flush Rate (LPF)*	*Percent of Occupants*	*Daily use per person*		*Sewage flow (m3/d)*
						FTE	Visitor	
1	Water closet	Female	Low-flow water closet	5	50%	3	2	50
2	Water Closet	Male	Low-flow water closet	5	50%	1	0.7	17.25
3	Urinal	Male	conventional urinal	4.5	50%	2	1.4	31.05
4	sub-total							98.30

Table 4-6 Greywater from Teaching Buildings

Fixture	*Design case fixture type*	*Fixture model*	*Flow Rate (LPM)*	*Percent of Occupants*	*Duration (sec)*	*Daily use per Person*			*Greywater flow (m3/d)*
						FET	Visitor	Custodian	
1	Lavatory	Low-flow Lavatory	8.5	100%	15	3	2	0	42.50
2	Custodial use tap	Conventional tap	12		300	0	0	30	1.80
3	sub-total								44.30

4.1.2 Amount of harvestable rain water

(1) Land use and runoff coefficient

The rainwater collection area for reuse is the area for teaching buildings and office buildings. The land use and runoff coefficient are shown in the following table.

Table 4-7 Land Use and Runoff Coefficient

Land use	*Road and Square*	*Green (Turfgrass)*	*building*	*water pond*	*Total/ average*
Area/m2	47009.1	59790.6	104250	10551.3	221601
Runoff Coefficient	0.8	0.15	0.9	1	0.68

(2) Collectable rainwater and irrigation water

Table 4-8 Collectable Rainwater and Irrigation Water

Month	*Collectable rainwater*		*Evaporation from water body*		*Irrigation water (m^3)*				
	Precipi-tation (mm)	Collectable rainwater (m^3)	Evaporation (mm)	Evaporation from pond (m^3)	Evapotran-spiration (mm)	Landscape Coefficient /KL	water lost via evapotran-spiration (m^3)	Drip	Sprinkler
Jan.	7.8	1177	30.1	317	30.1	0.8	1439	1599	23031
Feb.	12.6	1902	36.8	388	36.8	0.8	1760	1955	2816
Mar.	19.9	3003	65.8	694	65.8	0.8	3147	3497	5035
Apr.	42.1	6355	105.4	1112	105.4	0.8	5041	5601	8066
May	69.9	105516	149.8	1580	149.8	0.8	7165	7961	114649
Jun	101.3	15291	138.1	1457	138.1	0.8	6605	7339	10569
July	216	32605	132.8	1401	132.8	0.8	6352	7057	10163
Aug.	192.5	29058	133.6	1409	133.6	0.8	6390	7100	10224
Sep.	110.5	16680	92.3	973	92.3	0.8	4414	4905	7063
Oct.	33.4	5041	63.8	673	63.8	0.8	3051	3390	4882
Nov.	17.3	2611	44	464	44	0.8	2104	2338	3367
Dec.	5.1	769	28.8	303	28.8	0.8	1377	1530	2204
Total	828.4	125048	1021.3	10776	1021.3		48851	54279	78162

4.1.3 Water balance analysis

(1) Scheme description

The design is based on the following starting points:

- Grey water from the student dormitories is collected separately;
- The black water from student dormitories, and wastewater from teaching building, office building, and young teacher buildings are discharged into the municipal sewer system without onsite treatment.
- The high quality grey water (from washbowl and shower in student dormitories) is collected and treated onsite with a biological system and a constructed wetland (CW).
- Rainwater from the roofs of the students' buildings, the square and green land is captured and stored in a landscape water body and purified with CW.
- The treated water from CW will be reused for landscape irrigation, and water pond.
- Design irrigation type: sprinkler; irrigation Efficiency (IE=0.625).
- Low-flow fixtures are recommended in teaching building and office building.

(2) Water balance analysis

Based on the scheme described above, the water volume that can be captured and that demanded was calculated and analyzed as below.

Table 4-9 Water Balance Analysis

Month	*Collectable rainwater (m^3)*	*Grey water (m^3)*	*Evaporation from pond (m^3)*	*Irrigation water (m^3)*	*Toilet flushing (m3)*	*Water balance (m3)*
Jan.	1177.43	5670	317.59	2303.6	2949.0	1277.22
Feb.	1902.00	5670	388.29	2816.4	2949.0	1418.33
Mar.	3003.95	5670	694.28	5035.8	2949.0	-5.13
Apr.	6355.09	5670	1112.11	8066.5	2949.0	-102.49
May	10551.56	5670	1580.58	11464.5	2949.0	227.48
Jun	15291.45	5670	1457.13	10569.1	2949.0	5986.26
July	32605.67	5670	1401.21	10163.4	2949.0	23762.01
Aug.	29058.29	5670	1409.65	10224.7	2949.0	20144.97
Sep.	16680.21	5670	973.88	7063.9	2949.0	11363.43
Oct.	5041.80	5670	673.17	4882.7	2949.0	2206.89
Nov.	2611.47	5670	464.26	3367.4	2949.0	1500.81
Dec.	769.86	5670	303.88	2204.1	2949.0	982.86
Total	125048.78	68040	10776.04	78162.1	35388.0	68762.6

Based water balance analysis, there are enough grey water and collectable rainwater for the reuse of landscape irrigation and water pond conservation.

(3) Designed scale of the grey water treatment system

Based on the results of water balance analysis, it is known that the average daily grey water treatment quantity is 189 m^3. The designed grey water treatment scale is $200m^3/d$.

4.2 Design of the Demo-project

4.2.1 Designed water quality

(1) Designed water quality of grey water

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.

Table 4-10 The Designed Grey Water Quality Parameter

Parameters	*COD*	*BOD_5*	*SS*	*TN*	*TP*
Water quality value / $mg.L^{-1}$	225	130	75	15	4

(2) Rainwater quality

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

Table 4-11 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/ $mg.L^{-1}$	50～150	80～500
3	Colour	20	40
5	PH	5.8～7.0	5.8～7.0
6	CODcr/ $mg.L^{-1}$	20～150	50～300
7	NH_3-N / $mg.L^{-1}$	2.5～15	3.0～40
8	Free Residual Chlorine/ $mg.L^{-1}$	0	0
9	Total Coliform / $n.L^{-1}$	0	10

(3) Reclaimed water

For this project, greywater is designed to used for green irrigation, landscape water body compensation, road washing and toilet flushing etc. Water quality requirements for green, landscaping, road washing and toilet flushing are listed in Table 4-12. Water quality for planting and road splashing refers to “Miscellaneous Water Quality Standards for Urban Wastewater Reuse (GB/T 18920-2002); water quality for landscaping refers to “Miscellaneous Water Quality Standards for Urban Wastewater Reuse: on scenic water body purposes (GB/T 18921-2002). Design Values for recycled water in this project are listed in Table 4-12 as well.

Table 4-12 Recycled Water Quality Standards and the Design Values for the Chengdu Demo-Project

No.	*Items / unit*		*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 / $mg.L^{-1}$	≤	——			10	10
6	turbidity (NTU)	≤	5	10	10	——	10
7	Dissolved Total Solids / $mg.L^{-1}$	≤	1500	1500	1000	——	1000
8	BOD_5 / $mg.L^{-1}$	≤	10	15	20	6	10
9	Total phosphorous / $mg.L^{-1}$	≤	——			0.5	0.5
10	Total nitrogen / $mg.L^{-1}$	≤	——			15	15
11	Nitrogen, ammonia (based on N) / $mg.L^{-1}$	≤	10	10	20	5	5
12	anion surface active agent / $mg.L^{-1}$	≤	1.0	1.0	1.0	0.5	0.5
13	Petroleum / $mg.L^{-1}$	≤	——			1.0	1.0
14	Fe / $mg.L^{-1}$	≤	0.3	——			0.3
15	Mn / $mg.L^{-1}$	≤	0.1	——			0.1
16	dissolved oxygen / $mg.L^{-1}$	≥	1.0			1.5	1.5
17	Faecal coliform bacteria (n/L)	≤	——			2000	2000
18	Total coliform bacteria (n/L)	≤	3			——	3

4.2.2 System scheme description

The proposed sustainable water management system for CMC’s new campus is a decentralized system with grey water and rainwater treatment and reuse onsite. The grey water from student dormitories is designed to be separately collected from black water with an independent grey water pipe system, and be treated in a Grey Water Treatment Station(GWTS) with the technologies of Coagulation + Biological Aeration Filter(BAF)

+sand-filter and a polish treatment of wetlands. The rainwater is designed to be captured and treated onsite with Vegetated Swales, Graved infiltration ditches and CWs. The reclaimed water (both grey water and rain water) will be used as the source of landscape irrigation, and replenishing the scenic water body, Mingjing Lake in this case. The water quality conservation for the scenic water was considered in the whole water system. An artificial circulation of the lake will be established with a pump lifting and filtration through a CW. The black water from toilet flushing and wastewater from kitchen is designed to discharge into the municipal sewer system and then be treated by centralized WWTP.

Rain water harvesting system is deigned in CMC's new campus. Roof rain water and runoff from the teaching building area are captured and purified by vegetated swales and cobble ditches, and then discharge into the artificial lake. Several small wetlands are to be built up to treat the runoff in decentralization before its flowing into the scenic water body. A CW in large size is used to maintain the water quality of Mingjing Lake. There is spill port in the lake through which the excess stormwater could overflow into the municipal rainwater system.

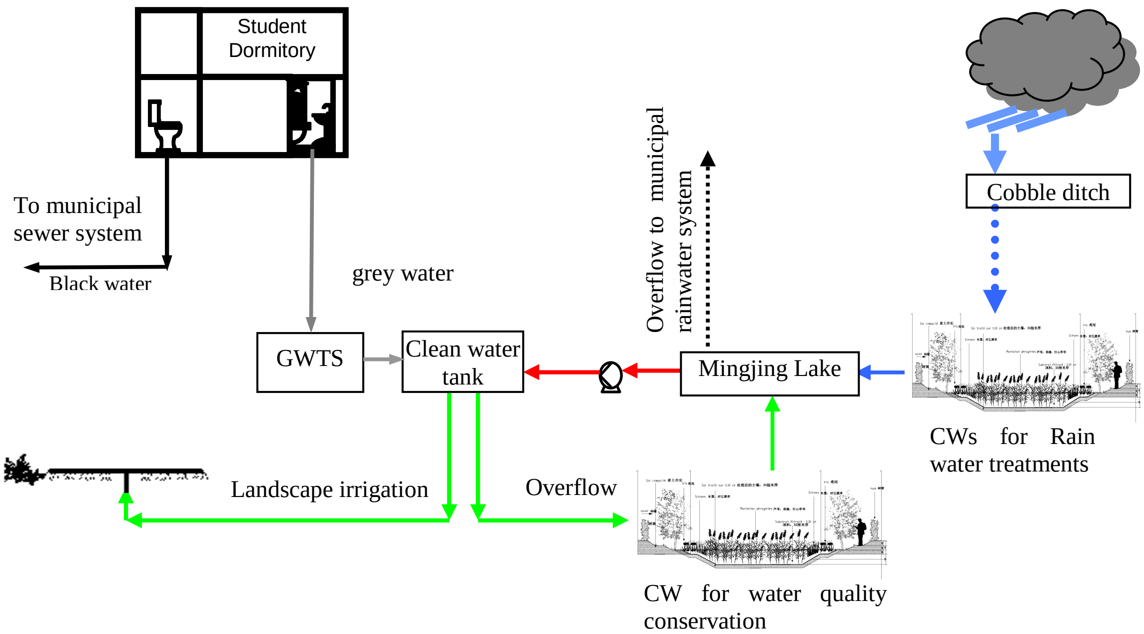


Fig. 4-1 Scheme Drawing of the Whole Decentralized Water Reuse System Applied for CMC-Demo-Project

4.2.3 Grey water collection and treatment system

(1) Grey water collection pipe networks

All grey water from student dormitories will be collected. A two-pipe drainage system is set indoor. One is used to collect grey water (from shower and washing machine) and the other is used for collecting black water (from toilet flushing). Grey water is collected and discharged into a buffering tank of the treatment system. The black water from student dormitory and wastewater from teaching building, office building, and other buildings are discharged into municipal sewer system directly without onsite treatment. Fig. 4-2 shows the lay out of the out-door grey water collection pipe system.

Fig.4-2 Grey Water Collection Pipe Network

Grey water

(3) Grey water treatment process

The grey water treatment process is shown in Fig.4-3. Collected grey water from student dormitories will be firstly balanced in a buffering tank and then go through a hair filter to stabilize the quantity and quality of grey water for subsequent treatment and remove hairs from the grey water. Because the hair is difficult to be removed with coagulation and sedimentation and will impact the running of BAF, a hair filter is necessary for the system. Coagulation and sedimentation tank are the pre-treatment for BAF, which will reduce the Suspended Solid (SS) concentration and optimize the running of BAF. BAF is the core of the whole treatment process, which will remove the organic compounds and N, P via biodegradation. To guarantee the effluent quality of the GWTS, a sand filter is designed to remove the residential solid in the water, and Chlorine Dioxide (ClO_2) is to be added into a clean water tank for disinfection. The treated grey water will pump to landscape irrigation and the overflow at spare time will flow into wetlands for residential nutrient removal and finally flow into Mingjing Lake.

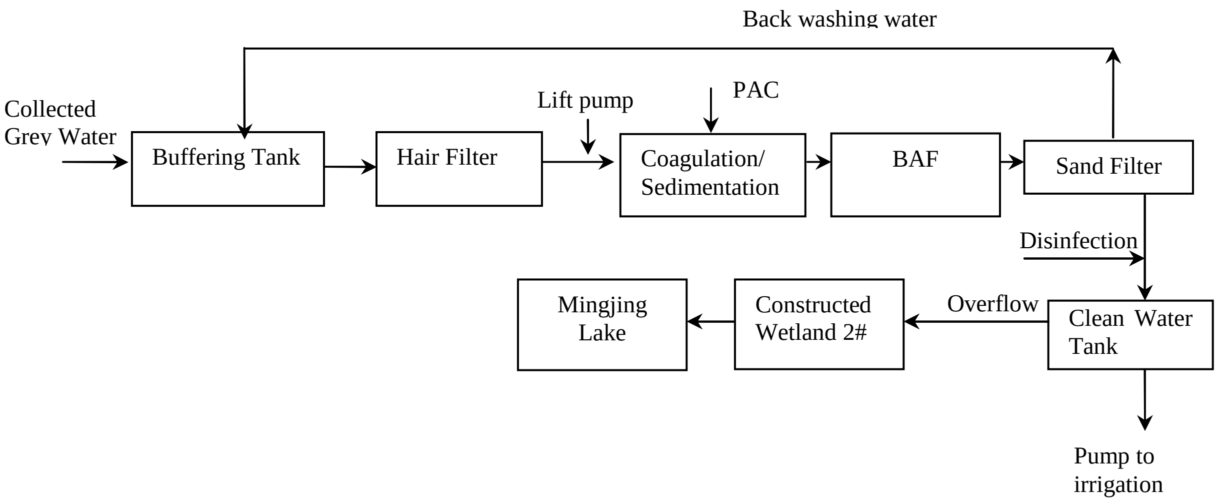


Fig.4-3 Grey Water Treatment Processes Applied for CMC Demo-Project

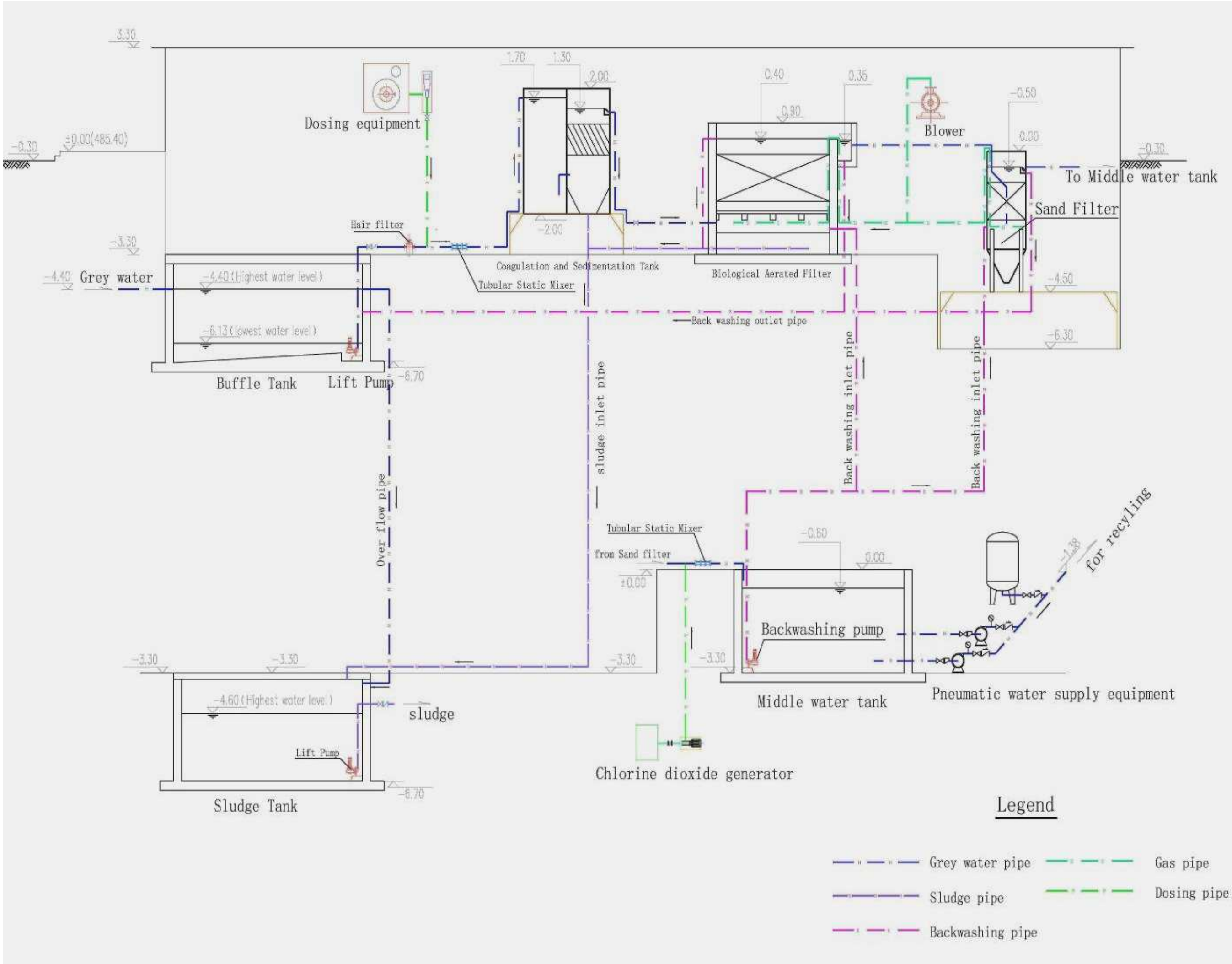


Fig.4-4 Design schematic drawing of grey water treatment station (GWTS)

4.2.4 Grey Water Treatment Units

(1) Buffering Tank:

Buffering tank is used for equalize the fluctuation of influent both in quality and quantity. The buffering tank is designed like a septic tank with two walls in the tank. The water flows through the middle holes in the two walls. The flow rate of the grey water will slow down in the buffering tank, and the floating contents, such as paper and fat in the grey water will float up and be stopped in the first cabin of the tank, and the contents with higher density than water will be settled down as well. Table 1 illustrates the main design parameters and dimensions of the buffering tank.

Table 4-13 Design Parameters and Dimensions of the Buffering Tank

Items	*Description*
Flow rate (m^3/d)	200
Hydraulic Retention Time, HRT (h)	8, effective volume equal to 1/3 of the daily reclaimed water consumption
Influent	Located at tank top
Effluent	Lifted via pumps at the tank bottom
Size, L×B×H (m)	6.9 × 5.1 × 3.4
Effective Height, H_E (m)	1.7
Height for sludge storage, H_S (m)	1.2
Height for safety, H_G (m)	0.5
Capacity of sludge storage, (days)	90
Slope of tank bottom, (%)	5
Equipments	Pump: 1 submersible sewage pump; Capacity, Q=18 m^3/h; Head of delivery, H=15m.

(2) Hair Filter

Hair filter is designed to remove hair and bigger suspending articles from the grey water. Hair filter is installed in the outlet pipe of the lifting pump.

Table 4-14 Design Parameters and Dimensions of the Hair Filter

Items	*Description*
Flow rate (m^3/h)	12.5 in average; 30 in maximum
Dimension of the inflow hole	φ=200mm
Proof-pressure	<0.2MPa
Height, H (m)	0.5
Weight, W(kg)	35

(3) Coagulation and Sedimentation Tank

In this design, the tanks for coagulation and sedimentation are jointed together to reduce the occupied space and reduce the construction cost as well. Coagulation and sedimentation are applied as the pre-treatment of the BAF to remove the colloidal particles and suspended solids in the grey water.

In this project, a pre-constructed steel tank produced by an environmental equipments manufacturer, named as Jiang Yu, is selected as the coagulation sedimentation tank. The

model no. is JYSB1-15. Dosing kit and mixer are pre-installed to matching the coagulation and sedimentation tank.

Table 3 shows the dimensions of the coagulation and sedimentation tanks applied in Chengdu demonstration project.

Table 4-15 Design Parameters and Dimensions of the Coagulation And Sedimentation Tanks

Items	*Description*
Flow rate (m^3/h)	12.5 in average; 30 in maximum
Dimension of the inflow pipe	φ=75mm
Dimension of the outflow pipe	φ=75mm
Size, L×B×H (m)	3.2 × 2.2 × 4
HRT of flocculation zone (min.)	20
Hydraulic of the sedimentation tank, m^3/m^2.h	9
Weight, W(kg)	1500

(4) Biological Aerated Filter, BAF

BAF is the main treatment unit in the grey water treatment station with biological degradation of the organic compound contained in the grey water. BAF has the double function of biological degradation and physical filtration. BAF was originally developed for nitrogen elimination in secondary and tertiary treatment and is capable of attaining the highest discharge quality standards. In this project, BAF is applied to produce high quality of reclaimed water to meet the high water quality requirement of closed scenic water body (the water quality stand for water discharge into the closed scenic water is very high in China, seeing the national standard GB/T 18921-2002).

The BAF process consists of upflow filtration through a submerged fine granular medial. Air is injected either to the base of the bed or into the media itself. In the latter case, the filter can simultaneously nitrify and denitrify with the intermittent operation the air blower. It is capable of removal biodegradable pollutants: carbon pollution (COD and BOD), suspended solids (SS), ammonia ($N\text{-}NH_4$) and nitrates ($N\text{-}NO_3$).

The bacteria present in the effluent to be treated attach themselves to the packing material that simultaneously acts as a filter. The pollution is broken down into cellular material, which is retained in the filtering bed by physical retention.

In contrast with other upflow filters (where the media is denser than water) the head loss in the filter ensures that the effluent to be treated is equally distributed without the need for

nozzles (which are likely to become clogged) or distribution pipework, and without the need to sieve the effluent before treatment.

Filtration takes place in a direction that compacts the media rather than expanding it, thus enhancing the capture of the suspended material. Periodic back-washing eliminates excess biomass and suspended solids filtered, without passing it through the whole bed.

Table 4-16 Design Parameters and Dimensions of BAF

Items	*Description*
Design parameters	
Flow rate (m^3/h)	12.5 in average; Running time: 16 hours a day
Designed water quality for influent	
BOD_5 (mg/L)	130
Total Nitrogen, TN (mg/L)	15
Designed water quality for effluent	
BOD_5 (mg/L)	10
Total Nitrogen, TN (mg/L)	5
BOD_5 volume load of the packing material, kg BOD_5 /(m^3 • d)	1
Sludge yield coefficient, (kg sludge/kgBOD_5)	0.2
Ratio air to water	5:1
Washing intensity for backwashing , L / (m^2 • s)	6
Washing time for backwashing , (min)	15
Dimensions	
Size, L×B×H (m)	4.2 × 4.2 × 4.2
Filter bed height, H_E (m)	1.5
Height for safrty, H_G (m)	0.5
equipments	
Air blower for bio-degradation	Capacity, Q=1.67m^3/h; Head of delivery, H=5m.
Pump for backwashing	Capacity, Q=360m^3/h; Head of delivery, H=15m.

(5) Sand Filter

Sand filter can effectively remove the residual suspended solids, colloidal, organic compounds, pesticides, manganese, bacteria, viruses and other pollutants in the treated grey water. A type sand filter equipment produced by Environmental Protection Science and Technology Co., Ltd. is Selected, with the type of DTCF-15 type, in this project. The selected type of sand filter has a small filtration resistance, large specific surface area, and also has a unique advantage by optimizing the filter and filter design, implementing operation of the

adaptive filter. Besides it has a strong adaptability of raw water concentration, operating conditions, pre-treatment process, that is, automatically form sparse in the top and dense at the bottom, which is beneficial in all kinds of operating conditions to ensure water quality. When backflush, quartz sand is fully spread out so that can have a good cleaning effect. Sand filter with a fast filtering speed, high filtration precision and interception capacity and so on. The sand filter device has a simple structure, large processing flow, automatically backflush, high filtration efficiency, easy maintenance and so on.

Table 4-17 Design Parameters and Dimensions of Sand Filter

Items	*Description*
Flow rate (m^3/h)	12.5 in average; Running time: 16 hours a day
Diameter (mm)	1435
Total height, H (mm)	4450
Filtration area, (m^2)	1.5
Size of filter media (mm)	0.6-1.2

(6) Reclaimed water tank

Capacity of the reclaimed water tank is designed according to 30% of the daily water consumption in reclaimed water system.

Dimension of the reclaimed water tank: 6.6 × 5.1 × 3.3m

(7) Sludge tank

Sludge tank is used for storing sludge and wastewater from grey water treatment station, which are discharged into municipal sewer network in time.

In order to combine the dimension of buffering tank and biological aerated filter, the size of sludge tank is determined: 6.9 × 4.2 × 2.85m. Similar to buffering tank, the actual height of sludge tank is 3.4m.

(8) Disinfection equipment

Chlorine dioxide is used as the disinfection agent, which is generated onsite with a chlorine dioxide generator. The dosage for ClO_2 is 0.8mg/L water. The ClO_2 generator is selected with the type of KWII-5, which is manufactured by Qinghua Environmental Protection Equipment Co., Ltd.

Table 4-18 Design Parameters and Dimensions of ClO_2 Generator

Items	Description
ClO_2 dosage (g/h)	100
salt consumption rate (g/g gas)	1.6
Size, L×B×H (mm)	800 × 650 × 1200

(9) secondary pump for reclaimed water supply

In this project, two pumps combined with a pressure tank are used for the reclaimed water supply in the new campus. The size of the air pressure tank is determined according to the maximum flow rate at peak hour.

The maximum water consumption for flushing: $15.39m^3/h$; the maximum water consumption for irrigation occurred in May, June, July and August, water consumption: $245.8m^3$ / d, irrigation twice per day, two hours each time; water consumption for road sprinkle: 90.6 m^3 / d, 2 hours to complete the work every day, then the largest total amount of the reclaimed water is:

$$15.39 + 246 / 4 + 90.6 / 2 = 122.2m^3 / h$$

The needed greatest head for reuse: 38m.

Referring to equipment swatch provided by Guangzhou Baiyun Pump Manufacturing Co., Ltd, BQS120-45-type air pressure feed water system is selected.

4.2.5 Rainwater harvesting system

Swale, cobble ditch, and pervious paving (including pervious concrete) are recommended for rainwater management. In the project firstly runoff will be collected by cobble ditch and swale etc., then the harvested runoff will be treated in constructed wetland (or other kinds of treatment facilities), and will be stored in landscape water body in campus, finally will be reused for landscape irrigation. The procedure of storm water harvesting and treatment is shown in Fig.4-5.

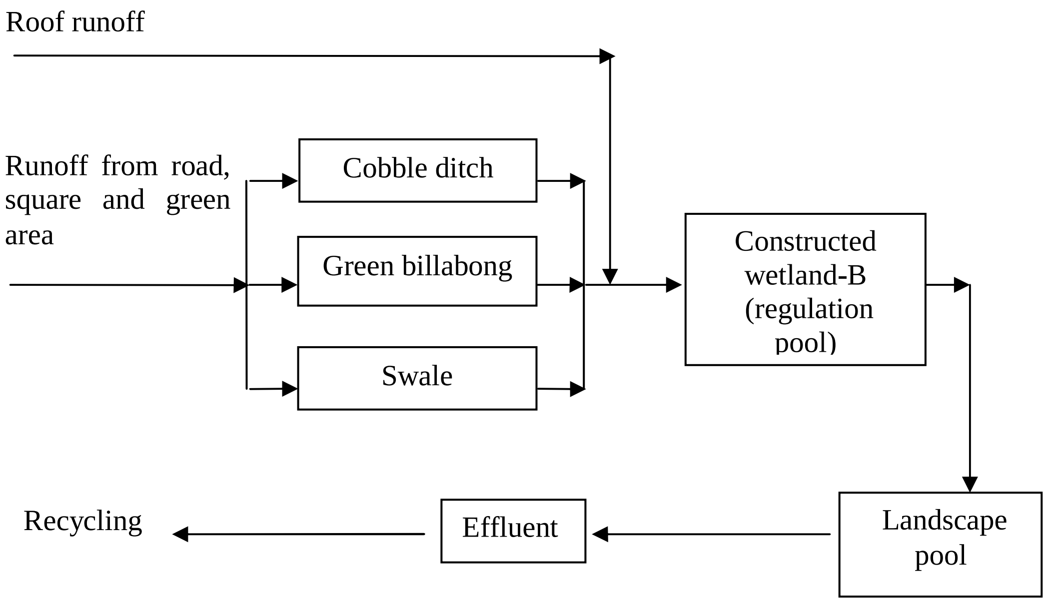


Fig.4-5 Rainwater Treatment Procedure

(1) Swale and cobble ditch

Swale and cobble ditch are mostly used beside the road, which can enhance the infiltration of earlier runoff.

There are three kinds of cobble ditches are applied in this project. The cobble ditches used at the side of the road, near the building, beside the square have their own features.

① Road-side Cobble ditch (Arc Style)

The depth is h=300mm，the surface width is b=600mm

Two layers of filler from top to bottom：

on surface: Φ=40-50mm，cobble; at the base: Φ=15-30mm，gravel

The design slope is≮0.5%

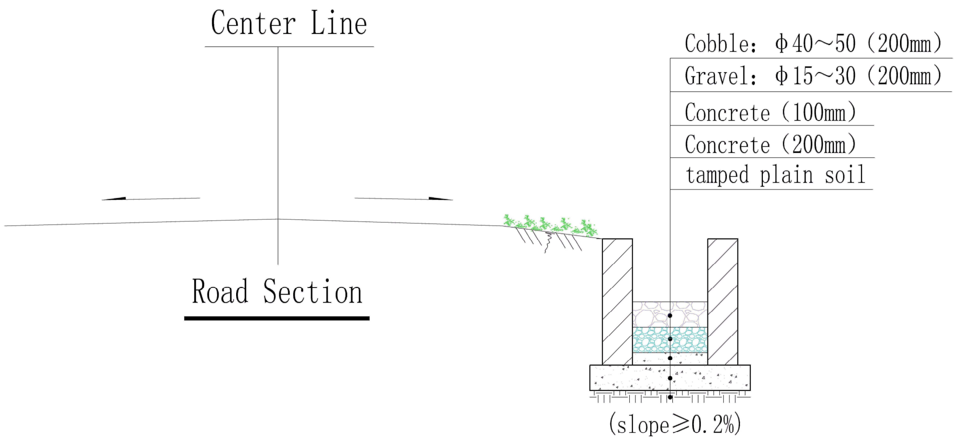


Fig.4-6 Road-side Cobble ditch

② Building-around Cobble ditch（Rectangle Style）

The depth is h=300mm，the breadth is b=200mm

Two layers of filler from top to bottom：

on surface: Φ=40-50mm，Cobble; at the base: Φ=15-30mm，gravel

The design slope is i≮0.5%

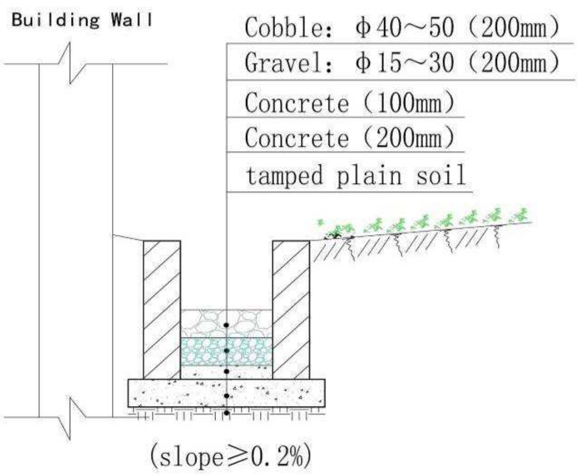


Fig.4-7 Building-around Cobble ditch

③ Square-side Cobble ditch（Rectangle Style）

The width has three kinds: b=400mm, 600mm, 680mm

Two layers of filler from top to bottom：

on surface: Φ=40-50mm，Cobble; at the base: Φ=15-30mm，gravel

The design slope is i≮0.2%.

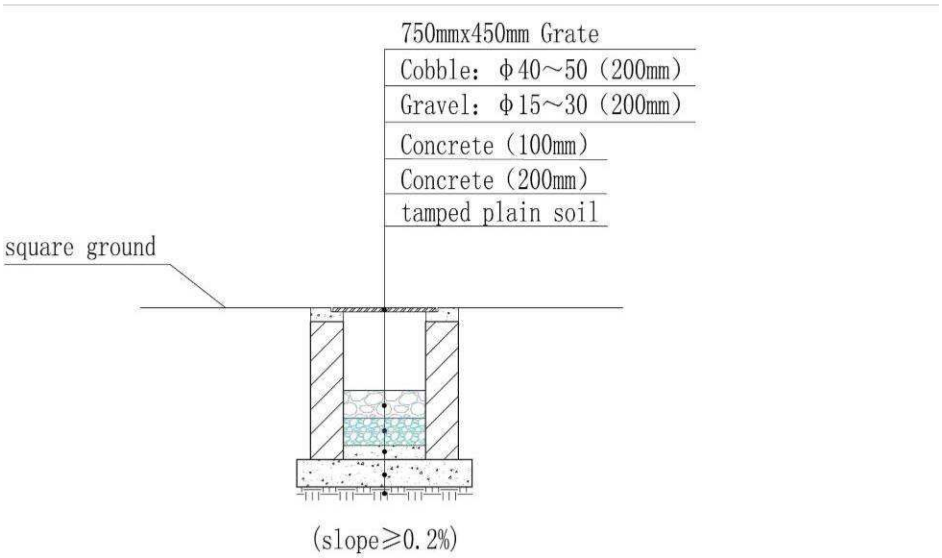


Fig.4-8 Square-side Cobble ditch

(2) pervious paving

Pervious paving will be developed to enhance the infiltration of rain water, so as to decrease the storm runoff, and maintain the water supply for local eco-system.

(3) Landscape pools

After being treated by green area 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 catchments area.

(4) overflow well

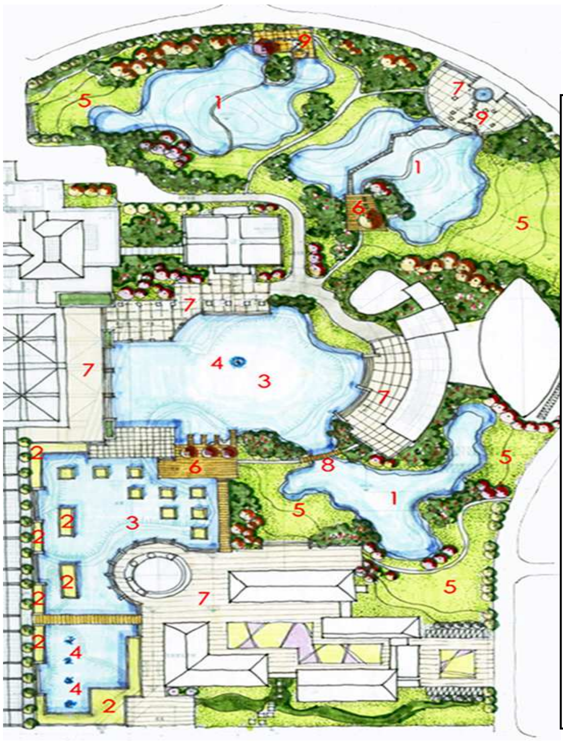
The rainwater, which is collected from the roofs, the road surface and green area, firstly passes through the overflow well, and then enters the sedimentation pond, which will be further processed. During the heavy storm time, the rainwater flow exceeds the current design capacity of the treatment facilities, and then it will overflow via the overflow-well, so that the normal operation of subsequent treatment structures can be guaranteed.

Before flowing into the sedimentation pond, rainwater passes through two overflow wells to carry on overflowing.

4.2.6 Runoff purification system

During the collection of the storm runoff, the rain water will be filtrated by swale, cobble ditch. Then the rainwater runoff will flow into the constructed wetlands which are specially designed for rain water treatment before its discharging into the scenic water body. The rainwater treatment constructed wetlands are located around the scenic water body.

According to water balance analysis, maximum rainwater treatment demand occurs in July. Total rainwater amount in July is 32605.67 m^3, and averagely daily amount is 1087 m^3/d.



Legend:

1. Constructed Wetlands for grey water polish treatment
2. Constructed wetlands for rain water purification
3. Scenic water body, Mingjing Lake
4. fountain for aeration
5. lawn

Fig. 4-9 The General Layout of the Runoff Purification System and Scenic Water Quality Maintenance System

The structure of the constructed wetlands for rain water purification is one kinds of down flow wetland land. The normal flow rate of rain water can be filtered through the wetland land filter bed, while during heavy storm; the rain water can directly overflow into the scenic water body.

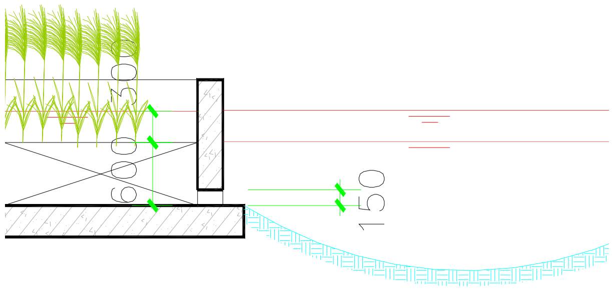


Fig. 4-10 The Schematically Drawing of the Structure of the Constructed Wetlands for Runoff Treatment

4.2.7 Water quality maintenance for the scenic water body

In order to maintain the scenic water body in a good water quality condition, an artificial water circulation with wetland filtration during the process is applied. Natural ecological bank with small natural type of wetland is applied as well (see Fig. 4-11).

Based on literature review and the experience of the designers, the renewable frequency of the scenic water body to minimum the stagnant water zone is designed as 20 days, which means that the water in Mingjing Lake will be renewed averagely in 20 days. Through estimation, a internal circulation flow rate of 750m^3/d is needed. The wetland for scenic water quality maintenance is design by both the water engineer and the landscape architect with an area of 2296 m^2.

A submersible pump is installed to cycle scenic lake water, with a flux of 32 m^3/h and lifting head of 5m.

Fig. 4-11 Pictures of Ecological Bank with Small Natural Wetland as References for this Project

5 BUDGET ESTIMATION

Base on draft cost calculation, the total investment for CMC new campus demonstration project is 430,840 EURO. This budget will be funded by SWITCH project, CMC, and CQU. About 72,220 EURO will be from EU fund. CMC will contribute 325,120 EURO for Construction; CQU will contribute 33,500 EURO for Laboratory. The operation cost of the reclaimed water (including the reused rainwater and grey water) generating is estimated as 0.02 EURO/m^3.

6 ENVIRONMENTAL BENEFITS

6.1 Saving of municipal tap water

With the reuse of decentralized treated rainwater and grey water onsite, the consumption of tap water supply, and discharge of contaminated sewage and rainwater will be significantly reduced. The reduction of the tap water consumption, sewage discharge and storm runoff is estimated and illustrated in Table 6-1.

Table 6-1 Municipal Water Supply Saving, Sewage and Rainwater Discharge Reduction

Unit: m^3

Month	*Municipal water supply saving*	*Sewage discharge reduction*	*Rainwater discharge reduction*
1	5570.21	5570.21	——
2	6153.66	5670	483.66
3	8673.95	5670	3003.95
4	12025.09	5670	6355.09
5	15994.07	5670	10324.07
6	14975.20	5670	9305.20
7	14513.66	5670	8843.66
8	14583.32	5670	8913.32
9	10986.79	5670	5316.79
10	8504.91	5670	2834.91
11	6780.66	5670	1110.66
12	5457.00	5457	——
Total	124218.52	67727.21	56491.32

Based on the above calculation, 124,219m^3/year of municipal tap water supply can be replaced via the onsite grey water and rainwater collection and treatment.

The estimated average cost for rainwater and grey water collection and treatment is RMB 0.2/m^3, while the corresponding municipal tap water price is RMB 1.35/m^3. Therefore, there is a RMB 1.15/m^3 financial saving for the water consumption, and correspondingly, RMB 142,800 per year of water supply cost will be saved. Considering that water price will be increased in the near future, the potential economical benefits are remarkable.

6.2 Environmental impact

After reusing grey water, a reduction of annual sewage discharge will be around 67727m^3, bringing remarkable environmental benefits (estimated with contaminants of COD, a reduction of COD 23,000kg/y can be achieved). Nowadays, Xindu is raising sewage charges,

from RMB 0.15/m^3 to RMB0.35 /m^3. By reusing grey water, sewage charge reduction will be 67727×0.35=RMB 23704. Water saving has great benefits.

Rainwater infiltration and emission reduction is a key indicator to measure sustainable building. In this project, total rainwater reused is: 56491m^3/year, reducing 45% of total rainwater in teaching building area. Municipal rainwater network size can be reduced accordingly, and environmental impacts from pollutants, as well as the soil erosion will be controlled in the demonstration area.

6.3 Potential impact after scaling up

If the Chengdu greywater demo was replicated at 1000 sites in China it would reduce the consumption of potable water by 1 billion m^3 per year. According to statistics of water consumption of 2006 in china, there was about a consumption of 70 billion m^3 of municaipal water supply, and is assumed that there will be 80 billion m^3 of municipal water consumption in the future. So, if the demonstrated system in Chengdu Demo-Project can be scaled up in 1000 times, there will a significant help to release the water crisis for China in future.

7 CONCLUSION

Following conclusions can be obtained in this demonstration project of decentralized sanitation in urban context.

7.1 Innovation and main achievements

- A showcase of DESAR system is implemented in China, with slight adaptations to Chinese actual situation of public concerns and economic consideration.
- Integration scheme of grey water reuse, rain water harvesting and landscape/aesthetic.
- Using ecological theory and people-oriented acts as the foundation of design, to create a clean, safe and comfortable water circumstance.
- Significant environmental and financial benefits can be obtained in the demonstration projects.

7.2 Significance

- A successful integration of grey water reuse and landscape/aesthetic purpose will be a good paradigm for Universities/Colleges to learn.
- The demo-project will also become a study case for students, who will improve 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 finishing the construction work by Chongqing University.

8 APPENDIX

8.1 Tables of Civil Construction Contents and Equipment List

8.1.1 Table of Civil Construction Contents and Equipments in GWTS

Table 8-1 List of Civil Construction Contents and Equipments in Grey Water Treatment Station

Catalogue	*S. N.*	*Items*	*Size*	*Structure or material*	*Unit*	*Amount*	*Notes*
Structures	1	Buffering tank	6.9×5.1×3.4	concrete	m	1	Inside dimension
	2	Biological Aerated Filter	4.2×4.2×4.2	concrete	m	1	
	3	Reclaimed water tank	6.6×5.1×3.3	concrete	m	1	
	4	Sludge tank	6.9×4.2×3.4	concrete	m	1	
Buildings	5	Building for Grey water treatment station	17.7×14.1×6.6	Frame structure	m	1	Half-underground
		Control room and assay room	10.5×4.2×3.3	Frame structure	m	1	In grey water treatment station
		Chemical room	4.2×3.6×3.3	Frame structure	m	1	In grey water treatment station
		Chlorination room	4.2×3.6×3.3	Frame structure	m	1	In grey water treatment station
Main equipments	6	Hair filter	Q=12.5m^3/h	steel		1	
	7	Coagulation and sedimentation tank	Q=12.5m^3/h		set	1	Suite of equipment
	8	Sand filter	Q=12.5m^3/h		set	2	Suite of equipment
	9	Submersible sewage pump	H=8m, Q=12.6m^3/h			2	Power of the motor 0.75KW
	10	Submersible sewage pump	H=15m, Q=18m^3/h			2	Power of the motor 1.5KW
	11	Submersible sewage pump	H=15m, Q=360m^3/h			1	Power of the motor 30KW
	11	Pneumatic water supply equipment	H=30m, Q=18m^3/h		set	1	Match 2 pumps, each motor power 2.2KW
	12	Blower	Blast volume 1.67m^3/min			1	
	14	Chemical feeding equipment	Addition dosage 12.5m^3/h		set	1	Suite of equipment, adding PAC

Catalogue	S. N.	Items	Size	Structure or material	Unit	Amount	Notes
							or PFS
	15	Chlorine dioxide generator	Occurrence quantity 100g/h		set	1	Suite of equipment, mains input 1.2YD
	16	Pipeline mixer	DN80	UPVC		2	
	17	Pipeline mixer	DN150	UPVC		1	
Pipes	18	Greywater pipe	DN50	UPVC	meter	8	
	19	Greywater pipe	DN80	UPVC	meter	50	
	20	Greywater pipe	DN150	UPVC	meter	10	
	23	Greywater pipe	DN300	UPVC	meter	12	
	24	Greywater pipe	DN400	UPVC	meter	5	
	21	Grey water pipe	DN200	PVC	meter	60	
	22	Sludge pipe	DN150	PVC	meter	20	
	23	Sludge pipe	DN200	PVC	meter	10	
	24	Air pipe	DN50	PPR	meter	80	
	25	Air pipe	DN65	PPR	meter	10	
	26	Air pipe	DN80	PPR	meter	30	
	27	Reclaimed water supply pipe	DN65	PPR	meter	15	
	28	Chemical feed pipe	DN25	PPR	meter	20	
	29	Service pipe	DN25	PPR	meter	22	

8.1.2 Tables of civil construction contents of rain water harvesting and treatment

Table 8-2 Civil construction contents of Cobble Ditches

Serial number	Items	Size	Unit	Amount	Notes
1	Square-side cobble ditch	B=400mm	meter	292	
2		B=600mm	meter	140	
3		B=680mm	meter	569	
4	Road-side cobble ditch	B=400mm	meter	205	
5		B=600mm	meter	603	
6		B=680mm	meter	942	
7	Building-around cobble ditch	B=400mm	meter	12	Designed by architect
8		B=600mm	meter	575	
9		B=680mm	meter	493	
10	Rainwater decanting	750mm×450mm		1932	Cast iron

Table 8-3 Main Equipments and Pipes applied for scenic water quality maintenance

Sequence	Items	Size	Material	Unit	Amount	Notes
1	Overflow pipe of reclaimed water tank	DN80	HDPE	meter	60	
2	Drainage pipe of	DN100	HDPE	meter	200	

	wetland pond-bed					
3	Drainage pipe of wetland pond-bed	DN110	HDPE	meter	16	
4	Circulating water pipe	DN110	HDPE	meter	15	
5	Water supplement pipe for reclaimed water tank	DN125	HDPE	meter	175	
6	Connection pipe	DN100	PPR	meter	25	
7	Gate valve	DN65			3	
8	Gate valve	DN80			2	
9	Gate valve	DN100			6	
10	Gate valve	DN110			2	
11	Gate valve	DN125			2	
12	Gate valve	DN150			1	
13	Water meter	DN65			1	
14	Back pressure valve	DN65			1	
15	Slow closure back pressure valve	DN110			1	
16	Slow closure back pressure valve	DN125			1	
17	Cast iron rainwater decanting	750mm×450mm			22	
18	Water meter well	φ700	Brick setting		1	Detailed drawing: 05S502
19	Circular-vertical type valve well	φ700	Brick setting		14	Detailed drawing: 05S502
20	Rectangular valve well				2	
21	Circulating pump for lake water	100QW70-7-3			1	Submersible sewage pump
22	Water pump for supplementing reclaimed water tank	WQ100-7-4			1	Submersible sewage pump
23	Inspection well with sand settling function	φ1250			5	

8.1.3 Additional construction contents for the demonstration project

Table 8-4 Additional civil construction contents

NO.	Description	Specification	Structure	Quantity
1	Hair Filters	Q=200m^3/d	Stainless steel	1
2	Coagulation sedimentation tank	Q=200m^3/d	Steel-concrete	1
3	Bio-filter	A=6.4m^2, H=2.5m	Steel-concrete	2
4	CW-A	250m^2	Brick-concrete	1
5	Sludge tank	L×B×H = 2×2×2m	Steel-concrete	1
6	Cobble ditch	3000	gravel/soil	m
7	Green billabong	2000	soil	m
8	Swale	1000	soil	m2
9	Head tank	L×B×H=16×16×1.5m	PVC	1
10	CW-B	1276m^2	Brick-concrete	1

Table 8-5 Addition Equipments and Pipes

No.	Description	Specification	Structure	Quantity
1	Chemical adding and mixing system	Q=200 m^3/d	Stainless steel	1
2	Submersible sewage pump	Q=1m^3/h	Stainless steel	1
3	Reclaimed water lifting pump	Q=43m^3/h H=45m	Stainless steel	2 (1 use 1 standby)
4	Rainwater, circulation water lifting pump	Q=40 m^3/h , H=5 m	Stainless steel	1
5	Ultraviolet sterilizer	Q=11 m^3/h ,	Stainless steel	1
6	Greywater collection pipes	DN110	PVC pipe	1200m
7	Supply pipe for toilet flush	DN25	PP-R pipe	1000m

8.2 Table of Budgetary Estimate

Table 8-6 Budgetary Estimate for the extra construction contents for the demonstration project

Item	*Account*	*Investment (Thou. EUR)*	*EU Budget (Thou. EUR)*	*Matching Fund (EUR)*	
				CMC	*CQU*
	Direct Construction cost				
1	Civil construction cost	162.15	0	162.15	0.00
	Equipments and Pipes	139.38	0	139.38	0.00
	sub-total	301.53	0.00	301.53	0.00
2	Indirect construction cost				
2.1	Construction management cost	15.08	14.49	0.59	0.00

2.2	Design cost	45.23	22.23	23.00	0.00
2.3	lab Equipments	35	5	0	30.00
2.4	Publication / information transmission / intellectual property	4	4	0	0
2.5	Travel charge	7.5	7.5	0	0.00
2.6	work shop	8	8	0	0
2.7	Expert consulting fee	8	8	0	0
2.8	Others	6.5	3	0	3.50
2.9	Total	430.84	72.22	325.12	33.50

8.3 Present progress of the construction of the demonstration project

Most of design contents have been constructed in this demonstration project except the grey water treatment station. Currently the grey water treatment station has been started to construct, and will be finished in the beginning of 2011. Student dormitories have been finished (see Fig8-1. Fig8-2), in which the grey water collection pipe has been installed. The rainwater collection system have been fulfilled in the demo-project. The teaching building has also been finished (see Fig8-3), in which the students has studied. The following pictures show parts of the buildings or structures of demo-project. The outdoor pipe system has been finished till present.

Fig. 8-1 Pictures for Students Dormitories

Fig. 8-2 Washing Bowl and the two-drainage pipes in Student Dormitories

Fig. 8-3 Pictures for Teaching Buildings

Fig. 8-4 Picture for the outdoor grey water and black water pipe

018530 - SWITCH

Sustainable Water Management in the City of the Future

Integrated Project
Global Change and Ecosystems

D4.1-12: Status Report of Chengdu Greywater demo and planning for subsequent activities

Start date of project: 1 February 2006 Duration: 60 months

Chong Qing University, P.R. China

Final Version

Reviewer: Adriaan Mels, Wageningen University, The Netherlands

SWITCH Deliverable Briefing Note Template

Project co-funded by the European Commission within the Sixth Framework Programme (2002-2006)		
Dissemination Level		
PU	Public	√
PP	Restricted to other programme participants (including the Commission Services)	
RE	Restricted to a group specified by the consortium (including the Commission Services)	
CO	Confidential, only for members of the consortium (including the Commission Services)	

SWITCH Document 4.1.12 entitled **Status Report of Chengdu Greywater demo and planning for subsequent activities**

Audience This document is targeted mainly at the Central Management Unit and members of the SWITCH consortium

Purpose To inform the consortium about the current status and planning of the construction of the demonstration project on reusing grey water for landscaping at CMC Campus, Chengdu.

Background Chengdu Grey water demo is a demonstration project within SWITCH, co-funded by the European Commission within the Sixth Framework Programme. The demonstrated technologies and system belong to Theme 4.1 Eco-sanitation and decentralized wastewater management in an urban context. Originally, this demonstration project was planned to be implemented in Beijing but because of various circumstances, it was delayed and replaced to Chengdu. The detailed information about the project design can be found in the SWITCH deliverable report: D4.1-11a: Design report of a decentralised urban wastewater system for Chengdu Medical College (CMC) New Campus.

Since June of 2006, the Chengdu demonstration project has started up with its design activity. But till present, the November of 2010, the construction of the whole campus and the demonstrated project is still on going. Most of the buildings in the campus have finished their construction activity November 2010. The construction activities of the whole campus are very near to accomplishment. The indoor grey water pipe system and out door pipe system have been finished as well. The outdoor landscape and the grey water treatment station are hopefully finished at the beginning of 2011. This report shows the current status of the Chendu Greywater Demo and the planning for next step activities.

Potential Impact Although not finished by the end of SWITCH, it is expected that the demonstration will have a China wide exposure because it is part of a wider sustainable building program of the Chinese Ministry of Construction. As such it may contribute to alleviating water scarcity in over 450 cities in China which are currently faced with water scarcity.

Issues Originally, this demonstration project was planned to be implemented in Beijing but because of various circumstances, it was delayed and replaced to Chengdu. But till present, the November of 2010, the construction of the whole campus and the demonstrated project is still ongoing. The indoor grey water pipe system and out door pipe system are already constructed. The outdoor landscape and the grey water treatment station will likely be finished in the spring 2011. Due to the delays, it was not possible to conduct the monitoring as was originally planned in this part of SWITCH.

Recommendations To conduct monitoring of this demonstration according the monitoring plan provided in Deliverable 4.1.13 and report on the results to the Ministry of Construction of PR China.

Contents

1 INTRODUCTION

Chengdu Grey water demo is a demonstration project within SWITCH, co-funded by the European Commission within the Sixth Framework Programme. The demonstrated technologies and system belong to Theme 4.1 Eco-sanitation and decentralized wastewater management in an urban context. The activity of Chengdu Grey water demo is technically implemented by Chong Qing University (CQU) of China, and supervised by Wageningen University of the Netherlands. Originally, this demonstration project was planned to be implemented in Beijing but because of various circumstances, it was delayed and replaced to Chengdu. The detailed information about the project design can be found in the SWITCH deliverable report: D4.1-11a: Design report of a decentralised urban wastewater system for Chengdu Medical College (CMC) New Campus.

Since June of 2006, the Chengdu demonstration project has started up with its design activity. But till present, the November of 2010, the construction of the whole campus and the demonstrated project is still on going. Most of the buildings in the campus have finished their construction activity November 2010. The construction activities of the whole campus are very near to accomplishment. The indoor grey water pipe system and out door pipe system have been finished as well. The outdoor landscape and the grey water treatment station are hopefully finished at the beginning of 2011. This report shows the current status of the Chendu Greywater Demo and the planning for next step activities.

2 CURRENT STATUS OF CHENGDU GREYWATER DEMO

Till present, November 2010, most of buildings planned to be constructed in the first phase have been finished. Currently, the grey water treatment station has been started to construct, and will be finished in the beginning of 2011. Student dormitories have been finished (see Fig. 1, Fig. 2), in which the grey water collection pipe has been installed. The rainwater collection system has been fulfilled in the demo-project except the rainwater treatment constructed wetlands and the landscape system. The teaching building has also been finished (see Fig. 3), in which the students will study. The following pictures show parts of the buildings or structures of demo-project. The outdoor pipe system has been finished as well. Table 1 illustrates the information about current status of the construction contents in CMC's new campus.

Fig. 1 Students Dormitories

Fig. 2 Washing Bowl and the drainage pipes in Student Dormitories

Fig. 3 Teaching Buildings

Fig. 4 Manholes for the grey water and black water pipes

Table 1 construction status of CMC New Campus in November 2010

Name of buildings	*Sub-item of project*	*Current status*
Teaching building 26603m^2	Main structure construction	Finished
	Outdoor engineering construction	Finished
	Green sub-item	Finished
	Tender for premise distribution(pipe) system	Finished
	Premise distribution(pipe) system installation	Finished
	Tender for multimedia system	Finished
	Multimedia system installation	Finished
Anatomizing	Preparation of construction	Finished

Name of buildings	*Sub-item of project*	*Current status*
building 5657m^2	Main structure construction	Finished
	Outdoor engineering construction	Finished
	Tender for special sewage treatment system, detailed design	Finished
	Construction of special sewage treatment system	Finished
	Green sub-item	Finished
	Tender for premise distribution(pipe) system	Finished
	premise distribution(pipe) system installation	Finished
A5 laboratory building 16896m^2	Tender for construction	Finished
	Preparation of construction	Finished
	Main structure construction	Finished
	Outdoor engineering construction	Finished
	Tender for power distribution station	Finished
	Construction of power distribution station	Finished
	Tender for premise distribution(pipe) system	Finished
	Premise distribution(pipe) system installation	Finished
C8 logistic service centre 11005m^2	Main structure construction	Finished
	Outdoor engineering construction	Finished
	Construction of special sewage treatment system	Finished
	Green sub-item	Finished
	Tender for premise distribution(pipe) system	Finished
	Premise distribution(pipe) system installation	Finished
C6 student cafeteria 15751m^2	Main structure construction	Finished
	Outdoor engineering construction	Finished
	Purchase for processing equipment of refectory and tender for construction	Finished
	Process installation	Finished

Name of buildings	*Sub-item of project*	*Current status*
	Green sub-item	Finished
	Tender for premise distribution(pipe) system	Finished
	Premise distribution(pipe) system installation	Finished
C1,C2,B3 student dormitories 37815m^2	Main structure construction	Finished
	Outdoor engineering construction	Finished
	Green sub-item	Finished
	Tender for premise distribution(pipe) system	Finished
	Premise distribution(pipe) system installation	Finished
C4,C5 student dormitories 28414m^2	Main structure construction	Finished
	Outdoor engineering construction	Finished
	Green sub-item	Finished
	Tender for premise distribution(pipe) system	Finished
	Premise distribution system installation(pipe)	Finished
Library 23680m^2	Tender for construction	Finished
	Preparation of construction	Finished
	Main structure construction	Finished
	Outdoor engineering construction	Finished
	Tender for water well with ground source heat pump	Finished
	Construction of water well	Finished
	Tender for central air conditioning system installation	Finished
	Central air conditioning system installation	Finished
	Tender for design of the second decoration	Finished
	Tender for construction of the second decoration	Finished
	Construction of the second decoration	Finished

Name of buildings	*Sub-item of project*	*Current status*
	Tender for control system of the firefighting centre	Finished
	Construction of control system of the firefighting centre	Finished
	Tender for power distribution station	Finished
	Construction of power distribution station	Finished
	Tender for premise distribution system	Finished
	Construction of premise distribution system	Finished
	Tender for central computer room	Finished
	Construction of central computer room	Finished
	Tender for equipments of computer room	Finished
	Installation of equipments in computer room	Finished
Switching station	Tender for civil engineering construction	Finished
	Civil engineering construction	Finished
	Tender for installation	Finished
	Equipment installation	Finished
	Laying of high-voltage cable from switching station to each of power distribution stations	Finished
Outdoor box-type substation	Tender for installation	Finished
	Laying of outdoor box-type substation and high-voltage cable	Finished
	Installation of low-voltage cable from outdoor box-type Substation to each of buildings	Finished
Vehicle Dispatch room	Scheme, detailed design	Finished
	Tender for construction	Finished
	Project construction	Finished
Floodwater drainage channel	Tender for construction	Finished
	Project construction	Finished

Name of buildings	*Sub-item of project*	*Current status*
Repairing of road base in the campus, construction of heavy and light current pipe drain, construction of sidewalk, laying of road asphalt surface	Tender for construction	Finished
	Project construction	Finished
Main pipe of water supply, firefighting pressuring water pipe, the laying of hydrant on the loop road	Tender for construction	Finished
	Project construction	Finished
Street lamp	Scheme, detailed design	Finished
	Tender for construction	Finished
	Project construction	Finished
Greywater and rainwater collection system	Tender for construction	Finished
	Project construction	Finished
Greywater and rainwater treatment system	Tender for construction	Finished
	Project construction	On going
Artificial lake	Tender for construction	On going
	Project construction	On going
Gate	Scheme, detailed design	Finished
	Tender for construction	Finished
	Project construction	Finished
Enclosure	Tender for construction	Finished
	Project construction	Finished
Gymnasium	Scheme, detailed design	Changed to the 2nd phase
	Tender for construction	Changed to the 2nd phase
	Project construction	Changed to the 2nd phase
Swimming pool	Scheme, design of detailed design	Finished

Name of buildings	*Sub-item of project*	*Current status*
	Tender for construction	Finished
	Project construction	Finished
Playing court	Scheme, detailed design	Finished
	Tender for construction	Finished
	Project construction	Finished
Power supply system	Tender for main cable of light current	Finished
	Main cable of light current installation	Finished
	Tender for weak current operating	Finished
	Construction of weak current operating	Finished
Outdoor landscape system	Tender for construction	On going
	Project construction	On going
Roads	Tender for construction	Finished
	Project construction	Finished
	Green sub-item	Finished

3 PLANNING FOR SUBSEQUENT ACTIVITIES

Based on the information delivered from the project owner, CMC, the greywater treatment station is planned to be finished its construction in February 2011, and the outdoor landscape system is planned to be finished in August 2011. The more detailed information can be found in Table 2. The monitoring activity will be implemented by Chongqing University after SWITCH project. The planning about the monitoring and commissioning activities ban be fund in the report of D4.1-13 monitoring plan for Chengdu greywater demo and experimental study on pilot scale constructed wetland.

Table 2 planning for subsequent construction activities in CMC's new campus

Name of items	*Sub-items of project*	*2010*		*2011*											
		11	*12*	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*
Artificial	Tender for														

lake(including constructed wetland)	construction														
	Project construction														
Rainwater treatment facility	Cobble ditch														
	Others														
Greywater treatment station	Tender for construction	√													
	Project construction														

Note: √ means the corresponding activity has been finished.

018530 - SWITCH

Sustainable Water Management in the City of the Future

Integrated Project
Global Change and Ecosystems

D4.1-13: Monitoring plan for Chengdu Greywater demo and experimental study on pilot scale constructed wetland

Start date of project: 1 February 2006 Duration: 60 months

Chong Qing University, P.R. China

Revision [final]

Project co-funded by the European Commission within the Sixth Framework Programme (2002-2006)		
Dissemination Level		
PU	Public	√
PP	Restricted to other programme participants (including the Commission Services)	
RE	Restricted to a group specified by the consortium (including the Commission Services)	
CO	Confidential, only for members of the consortium (including the Commission Services)	

SWITCH Deliverable Briefing Note Template

SWITCH Document 4.1.13 entitled **Monitoring plan for Chengdu Greywater demo and experimental study on pilot scale constructed wetland**
Audience This document is targeted mainly at the Central Management Unit and members of the SWITCH consortium
Purpose To provide a monitoring plan of the demonstration project on reusing grey water for landscaping at CMC Campus, Chengdu.
Background Chengdu Grey water demo is a demonstration project within SWITCH, co-funded by the European Commission within the Sixth Framework Programme. The demonstrated technologies and system belong to Theme 4.1 Eco-sanitation and decentralized wastewater management in an urban context. Originally, this demonstration project was planned to be implemented in Beijing but because of various circumstances, it was delayed and replaced to Chengdu. The detailed information about the project design can be found in the SWITCH deliverable report: D4.1-11a: Design report of a decentralised urban wastewater system for Chengdu Medical College (CMC) New Campus. Since June of 2006, the Chengdu demonstration project has started up with its design activity. But till present, the November of 2010, the construction of the whole campus and the demonstrated project is still on going. The construction of most of the buildings was finished by November 2010. The indoor grey water pipe system and out door pipe system have been finished as well. The outdoor landscape and the grey water treatment station are hopefully finished at the beginning of 2011. This deliverable provides a monitoring plan for the demonstration project An experimental study on a pilot scale constructed wetland system is introduced in this report as the pre-evaluation on the performance of the wetlands which are applied in the demonstration project. Chongqing University will implement the commissioning and monitoring actives after SWITCH based on its own fund.
Potential Impact Although not finished by the end of SWITCH, it is expected that the demonstration will have a China wide exposure because it is part of a wider sustainable building program of the Chinese Ministry of Construction. As such it may contribute to alleviating water scarcity in over 450 cities in China which are currently faced with water scarcity.
Issues Due to the delays, it was not possible to conduct the monitoring as was originally planned in this part of SWITCH.
Recommendations To conduct monitoring of this demonstration according the monitoring plan provided in Deliverable 4.1.13 and report on the results to the Ministry of Construction of PR China.

SUMMARY

Chengdu Grey water demo is a demonstration project of SWITCH, co-funded by the European Commission within the Sixth Framework Programme. The demonstrated technologies and system belong to Theme 4.1 Eco-sanitation and decentralized wastewater management in an urban context. The monitoring activity on Chengdu Grey Water Demonstration Project will be implemented by Chong Qing University (CQU) of China. Chengdu Grey Water Demonstration Project tries to demonstrate the new conception of DESAR and an onsite grey water treatment system with the technologies of Biological Aeration Filter and Constructed Wetland. The demo-project is located in the new developed campus of Chengdu Medical College (CMC) in Xindu District, Chengdu City, China. The detailed information about the project design can be found in the SWITCH deliverable report: D4.1-11: Design report of a decentralised urban wastewater system for CMC New Campus.

Since June of 2006, the Chengdu demonstration project has started up with its design activity. But till present, the November of 2010, the construction of the whole campus and the demonstrated project is still on going. By now, the construction of most of the buildings is finished. The indoor grey water pipe system and out door pipe system have been finished as well. The outdoor landscape and the grey water treatment station are hopefully finished at the beginning of 2011. Due to the delays, it was not possible to conduct the monitoring as was originally planned.

This deliverable provides a monitoring plan for the demonstration project once it is finished. An experimental study on a pilot scale constructed wetland system will be introduced in this report as the pre-evaluation on the performance of the wetlands which are applied in the demonstration project.

Chongqing University will implement the commissioning and monitoring actives after SWITCH based on its own funds.

Contents

1 INTRODUCTION

Monitoring and test are very important activities for SWICH to evaluate and demonstrate the developed technologies and approaches. The water quality of raw grey water and treated effluent and the information including operation cost and the evaluation from the end-users and stakeholders will be collected and analyzed. Base on careful appraisal and study, the significances, failures, advantages and disadvantages of selected technologies applied in the demo-project can be concluded and contribute the experiences for further improvement and promotion.

Chongqing University (CQU) will fulfil the monitoring task in Chengdu Demonstration Project located in Xindu District, Chengdu City, China. This demonstration project tries to utilize the new campus of Chengdu Medical College (CMC) in Xindu County as a showcase of the decentralized wastewater treatment and reuse onsite. In the new developed campus, the grey water from students dormitories planned to accommodate 7000 students is collected and treated within the campus. The compacted indoor Biological Aeration Filter and outdoor Wetlands are applied for grey water treatment. The storm run off from the teaching building area (around 1/4 of the total area of the campus) is captured with Vegetated Swales and Graved infiltration ditch and then treated by Constructed Wetlands, which is special designed for rain water treatment. Finally, the treated grey water and rain water flows into the scenic water body, named as Mingjing Lake. The later taking a core role of the whole outdoor landscape is designed as a storage tank for the treated grey water and rain water, and support a relative stable reclaimed water supply for miscellaneous use in the campus.

Due to the delays of construction activities, it was not possible to conduct the monitoring as was originally planned. A new updated monitoring plan based on the present construction progress of the demonstration project can be prepared. A pilot scale study on a new developed constructed wetland (CW) system which is applied in Chengdu demonstration project was conducted in Chongqing University to pre-evaluate the CW’s performance on wastewater treatment.

2 MONTORING PLAN OF CHENGDU GREYWATER DEMO

2.1 The demonstration project

The site of Chengdu Greywater demo-project will be located in the New Xindu Campus of Chengdu Medical College (CMC). The new campus is located in Xindu, a satellite town of Chengdu City, about 25 km to the centre of Chengdu.

Xindu Campus is the new development area of CMC, which has a planning area of 73.7 hectare, where about 13,000 students and 3000 teachers will be accommodated. First phase of this new campus, with a construction area of about 400,000 m^2 and 7000 students accommodated was expected to be built by July 2009, but actually delayed to 2011. Starting from September 2010, the first class of students began their new study in this new campus.

The new campus of CMC has been selected as the demo-project for renewable energy (ground water source heating pump) utilization in building by Ministry of Construction and Ministry of Finance, China. Water saving is a content of the demonstration. Chongqing University is the technical support organization of the demonstration.

The grey water from student dormitories is designed to be separately collected from black water with an independent grey water pipe system, and be treated in a Grey Water Treatment Station (GWTS) with the technologies of Coagulation + Biological Aeration Filter(BAF) +sand-filter and a polish treatment of wetlands. The rainwater is designed to be captured and treated onsite with Vegetated Swales, graved infiltration ditches and Constructed Wetlands (CWs). The reclaimed water (both grey water and rain water) will be used as the source of landscape irrigation, and replenishing the scenic water body, Mingjing Lake in this case. The water quality conservation for the scenic water was considered in the whole water system. An artificial circulation of the lake will be established with a pump lifting and filtration through a CW. The black water from toilet flushing and wastewater from kitchen is designed to discharge into the municipal sewer system and then be treated by centralized WWTP.

Rain water harvesting system is designed in CMC's new campus. Roof rain water and runoff from the teaching building area are captured and purified by vegetated swales and cobble ditches, and then discharge into the artificial lake. Several small wetlands are to be built up to treat the runoff in decentralization before its flowing into the scenic water body. A CW in large size is used to maintain the water quality of Mingjing Lake. There is spill port in the lake through which the excess storm water could overflow into the municipal rainwater system.

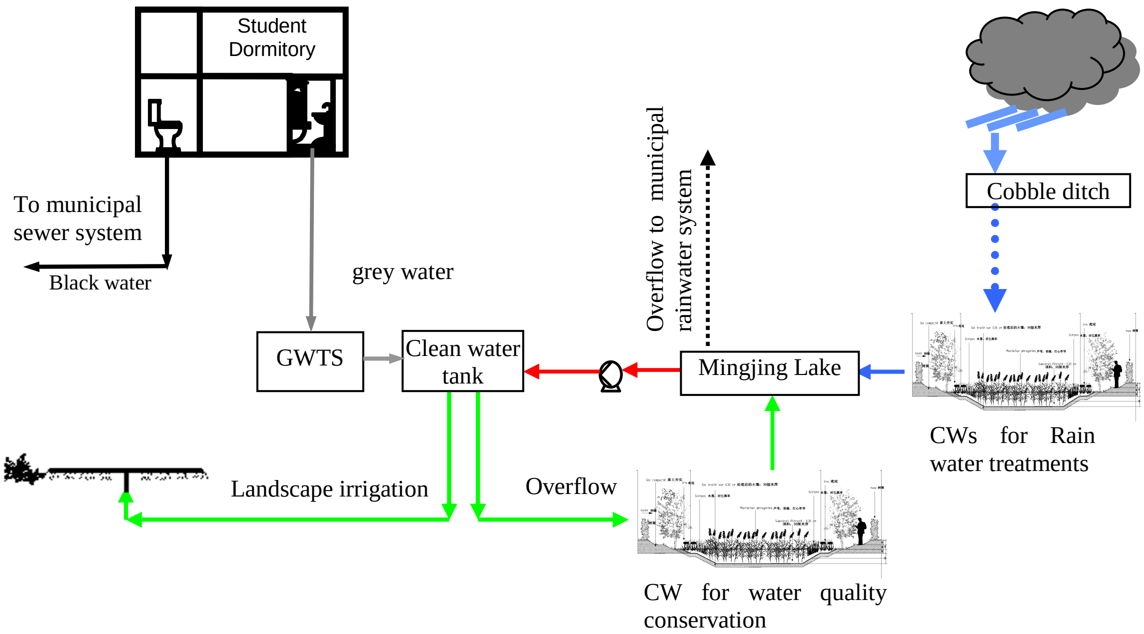


Fig. 4-1 Scheme Drawing of the Whole Decentralized Water Reuse System Applied for CMC-Demo-Project

2.2 Designed water quality of influent and effluent

2.2.1 Designed influent Grey water quality

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.

Table 1 the Designed Grey Water Quality Parameter

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

2.2.2 Designed collectable rainwater quality

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

Table 2 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	Color (chroma)	20	40
5	PH	5.8 ~ 7.0	5.8 ~ 7.0
6	COD_{Cr}/ $mg.L^{-1}$	20 ~ 150	50 ~ 300
7	NH_3-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

2.2.3 Designed reclaimed water quality

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 3. 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 3.

Table 3 Recycled Water Quality Standards and Design Values

No.	*Items (mg/L)*		*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	Colour (chroma)	≤	30			30
4	Smell		No offensive odour			
5	SS	≤	——		10	10
6	Turbidity (NTU)	≤	10	10	——	10
7	Soluble total solid	≤	1500	1000	——	1000
8	BOD_5	≤	15	20	6	10
9	Total phosphor	≤	——		0.5	0.5
10	Total nitrogen	≤	——		15	15
11	Nitrogen, ammonia (based on N)	≤	10	20	5	5
12	Anion surface active agent	≤	1.0	1.0	0.5	0.5
13	Petroleum	≤	——		1.0	1.0

14	Fe	≤	——		0.3
15	Mn	≤	——		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

2.3 Time program of commissioning and monitoring plan

The commissioning and monitoring activities are planned to start in February 2011. The whole task of commissioning and monitoring can be divided into four inter-related phases: Start-up, Commissioning, Training, Conclusion and post-evaluation. During post-evaluation phase, the user's reception and appreciation on the demonstrated project will be surveyed. The detailed program about the activities is illustrated in Table 4.

Table 4 Monitoring plan for Chengdu demo-project

No	Task	2011											2012				
		2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5
1	**Start-up**	■	■														
1.1	Single and online machine trial run	■	■														
1.2	Bio-filter start-up	■	■														
2	**Commissioning**			■	■	■	■	■	■	■	■	■	■				
2.1	commissioning			■	■	■	■	■	■	■	■	■					
2.2	Monitoring			■	■	■	■	■	■	■	■	■					
2.3	O&M mannual												■				
2.4	Commissioning report												■	■			
3	**Training**	■	■	■	■	■	■	■	■	■	■	■	■				
3.1	Introduction of the treatment Process	■															
3.2	Lectures for Decentrialized sainitation		■	■													
3.3	Laboratory testing				■	■											
3.4	Operational trainning						■	■	■	■	■	■	■				
4	**Post evaluation**													■	■	■	

2.4 Commissioning contents

The purpose in commissioning phase is to start-up the whole grey water treatment system and optimises the operation to improve the treatment performance with low running cost and maintenance. The main contents involved in commissioning phase include:

1. Trial running with load (including single and online machine trial run), resolves problems influencing continuous duty. It lays good foundation for the future work, and its object is normal running of the grey water treatment station.

2. Raise the artificial wet land plant, and bio-film formation. Its goal is to accumulate and choose aquatic plants which can adapt the local climatic conditions;

3. Determine the optimum working condition of bio-filter and artificial wetland confirming to the inflow quality and quantity; under the condition that guarantees the effluent water quality to reach the standards, reduces the cost as far as possible.

4. Record dates of daily precipitation during the rainy season, and test the rain water quality of cobble ditch in certain of distance.

5. Test the water quality of influents and effluents in artificial wetland in order to determine the water quality conditions of scenic water body which is the receiving water.

6. Record the runoff frequency of artificial wetland and artificial lake.

7. Record the clogging situation of collection system so that it can be used for working out the cleaning cycle. Record the condition of plants growing and sedimentation so that it can be used for compiling the operation and maintenance measurements.

8. Analyze the above collected dates so that it can be used for compiling the measurements about daily operation and maintenance.

2.5 Monitoring contents

2.5.1 Grey water treatment system

The water quality and flow quantity of the grey water, reclaimed water and even the water quality of scenic water body will be monitored. The following table is the monitoring water quality parameters in the grey water treatment system of Demo-project.

Grab samples were taken on a daily basis at different treatment units (showing at the following table). COD_{cr}, SS, Turbidity, NH_3-N, TN, TP, DO, pH are tested once a day , BOD_5 is tested once a week。

Table 5 Daily operation record table of grey water treatment system of Chengdu Demo-Project

Data： Weather: Atmospheric temp.: ℃ Water temp.: ℃ Flow: m^3/d

Sampling point	*COD_{cr} (mg/L)*	*BOD_5 (mg/L)*	*SS (mg/L)*	*Turbidity (NTU)*	*NH_3-N (mg/L)*	*TN (mg/L)*	*TP (mg/L)*	*DO (mg/L)*	*PH*	*Coli-group*
Raw grey water										
Baffle Tank effluent										
Coagulation Tank effluent										
Biofilter effluent										
Sandfilter effluent										
Constructed wetland 2# influent										
Constructed wetland 2# effluent										
Scenic water body										
Grey water volume (m^3/d)										
Vegetation collection in the system (kg/m)										
Power consumption (kw.h/d)										
Coagulant(kg/d)										
Disinfectant(kg/d)										

The record of main operation：

2.5.2 Rain water treatment system

The collected data of rainwater quality in artificial wetland and its receiving water -artificial lake will be monitored. The following table is the monitoring water quality parameters in the rainwater system of Demo-project.

Table 8 Daily operation record table of rainwater system of Chengdu Demo-Project

Data： Weather: Atmospheric temp.: ℃ Water temp.: ℃ Flow: m^3/d

Sample dot	*COD (mg/L)*	*BOD_5 (mg/L)*	*SS (mg/L)*	*NH_3-N (mg/L)*	*TN (mg/L)*	*TP (mg/L)*	*PH*	*Turbidity (NTU)*	*DO (mg/L)*
Gravelled ditch runoff									
Artificial wetland influents									
Artificial wetland effluents									
Artificial lake influents									
Artificial lake									
Daily precipitation (mm)									
Runoff quantity of gravel ditch (m^3/d)									
Rainwater quantity of Artificial wetland (m^3/d)									
Rainwater quantity of Artificial lake (m^3/d)									

The record of main operation：

2.5.3 Questionnaire on user's reception and appreciation

The feedback from the end users is a very important for post evaluation on the performance of the demonstrated technologies. So a survey on the user's reception and appreciation on the demonstrated technologies and procedures will be conducted during the phase of post-evaluation. A questionnaire is prepared for the survey.

QUESTIONNAIRE SAMPLE

Questionnaire on Chengdu Medical College Greywater (CMC) Demonstration

Name of interviewee:_______________ Title & Organization: _______________________

1. Do you known that there is a greywater treatment and reuse system in CMC? (Y/N)	If "Y", how did you get the information

2. Do you know which types of wastewater have been treated and reused onsite? A. Greywater; B. Rain water; C. Black water; D. Two or more type of the above, includes ____________________.

Note: **Greywater** is wastewater generated from domestic activities such as laundry, bathing, and dishwashing. **Black water** is wastewater generated from toilet flushing.

3. Do you know where the reclaimed water reused ?

4. Do you feel it is meaningful to install a decentralized wastewater treatment and reuse system? If yes, can you explain the reasons?

5. Do you think the water quality reused for green irrigation is acceptable for you? Please give a your overall evaluation:

Poor				Excellent
1	2	3	4	5

6. Do you think the water quality in Mingjing Lake is acceptable for you? Please give a your overall evaluation:

Poor				Excellent
1	2	3	4	5

7. Do you think the greywater treatment station has some negative influence to you? If Yes, please explain it:

8. If the reclaimed water will be used for the toilet flushing in teaching building, do you think that is acceptable for you? Please explain the reasons in detail.

9. If the reclaimed water will be used for the toilet flushing in student dormitories, do you think that is acceptable for you? Please explain the reasons in detail.

10. If all the wastewater including black water in student dormitories will be treated and reused in the campus, do you think it is necessary? Please explain the reasons in detail.

3 PILOT-SCALE STUDY ON A HYBRID CONSTRUCTED WETLAND FOR WATSTERWATER TREATMENT AND REUSE

This chapter of the report tries to introduce the experimental results of a pilot scale constructed wetland system as the pre-evaluation on the performance of the wetlands which are applied in the demonstration project.

3.1 Introduction

Compared with conventional electrical-power-consuming technologies, constructed wetlands (CWs) are ecological wastewater treatment systems with both aesthetic and educational values(*Browne et al., 2005*), which owns the advantages of low cost both in construction and operation, low maintenance, and generating aquatic plant products such as fertilizer or animal feed (*Solano et al., 2004; Zhang et al., 2010*). Thus CWs have been widely used for the treatment of domestic wastewater(*Steinmann, 2003; Hans,2005; Zurita et al., 2009*), industrial wastewater (*Hadad et al., 2006; Cristina et al., 2007*), landfill leachate (*Craiget et al., 1999; Mays et al., 2001; Vymazal, J., 2009*), urban or agriculture runoff (*Miklas, 2003; Kristen et al., 2002; Ying et al., 2005*), and greywater (*Stewart et al., 2004; Masi et al., 2010*). However, application of CW in China has several constraints. One of the obvious constraints is the large land requirement, as a result of lower treatment efficiency than conventional biological technologies such as activated sludge systems. The hydraulic loading rate of traditional CWs for domestic wastewater treatment varies from 0.2 to 30 cm/d (*Wood, 1995; Kadlec and Knight, 1996*), and mostly varies from 1 to 6 cm/d (*Song et al., 2006; Li and Jiang, 1995*). As microbial activity is primarily responsible for removal of carbon, nitrogen, and sulfur compounds in CWs (*Faulwetter et al., 2009; Kadlec, 2001*), it was concluded that aeration would enhance aerobic degradation of hydrocarbon and then improve removal of organic compounds consequently **(***Wallace et al., 2005*).

In order to improve the treatment efficiency and minimize the land requirement, a new type of hybrid constructed wetland nominated as VBFW+HSFW has been developed in Chongqing University (CQU) and was awarded a Chinese patent. This new type of CW was experimentally studied in pilot scale for over one year. The objective of this report is to pre-evaluate the performance of this innovated hybrid CW system treating decentralised wastewater.

3.2 The hybrid constructed wetland system

Based on the theory of biological nitrification and denitrification and the proved fact that aeration can improve the performance of CWs, the new hybrid CWs consisting of two stages of wetland cells in series (Fig. 2) was developed. The first stage is a Vertical-Baffled Flow Wetland (VBFW), which has a gravel media in depth of 1m and is dominated by anaerobic condition. VBFW is typically composed of 4-6 vertical flow wetlands, which are interconnected with each other step by step. Wastewater flows through the filter substrate in a "U" style, as a guide wall is installed in each step of the wetland. The second stage is a Horizontal Subsurface Flow Wetland (HSFW), which is typically composed of 4-6 sections of horizontal subsurface wetland beds. Each section of HSFW was baffled with 3 walls, so a long flow ditch was formed, in which water flows in a "S" style. Between every two beds, there is a Natural Aeration Ditch (NAD) constructed to increase the Dissolved Oxygen (DO) concentration within HSFW. An internal circulation (IC) system is installed, which can alternatively pump the effluent back to the entrance of VBFW in order to enhance denitrification process. *Cyperus alternifolius* was selected as macrophyte in VBFW+HSFW. *Cyperus alternifolius* is one kind of aesthetic local plant species commonly fund in Southern China, which can remain growing even in winter. Several researches have shown that this type of water plant can improve the removal of heavy metals (*Shuiping Cheng, 2002*), N, P and organic contaminants (*Selma et al. 2001, Jing et al. 2004)* in wetlands.

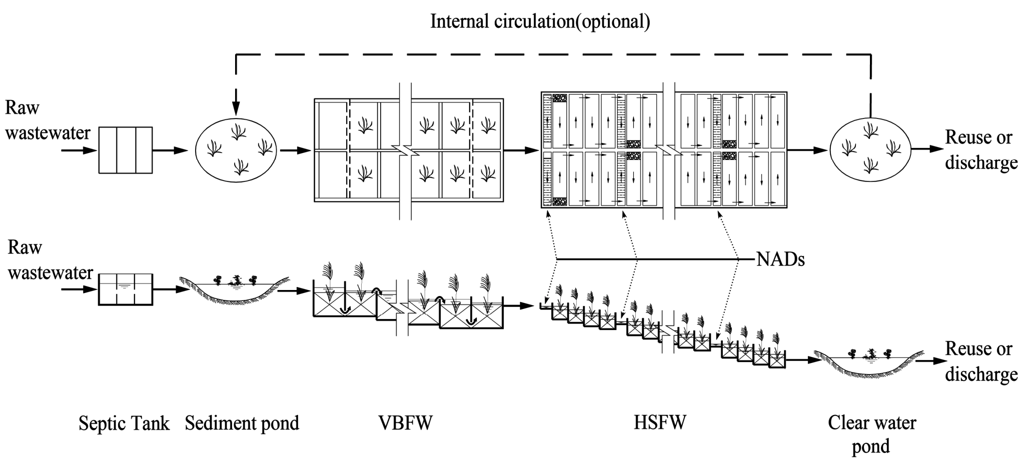


Fig. 2 A typical Schematic drawing of the Hybrid CW: VBFW+HSFW

3.3 Methods

A VBFW and a HSFW in pilot scale were established in the campus of Chongqing University. The raw wastewater was collected from the students' dormitories. The wastewater is a typical domestic wastewater from small communities, with considerable fluctuation in both quality and quantity.

The VBFW of the pilot system was composed of 6 vertical flow wetland cells in series. Each cell was 0.5m wide by 0.5 m long by 1.0m deep. Gravel was filled in VBFW in a depth of 500-700mm as the substrate with particle sizes decreased step by step from 15mm to 5mm in the serial wetlands. The pilot HSFW was composed of 4 sections of horizontal subsurface flow wetland beds. Between each two sections of HSFWs, a Natural Aeration Ditch (NAD) was established. The HSFW was provided with gravel as well as a substrate, with particle sizes ranging from 3-8mm, decreasing in the serial of wetlands. Each section of HSFW was 2 m wide by 2 m long by 0.6m deep. Three guide walls were established to generate an 8m long and 0.4m wide water route, in order to make full use of the volume of the HSFW. VBFW is planted with *Cyperus alternifolius*. HSFW is planted with *Cyperus alternifolius* and *Canna indica Lin* (another local water plant with red or yellow flowers, but doesn't keep green in winter).

Grab samples were taken on a daily basis from inlet and outlet of the system(Figure 1) Samples for Chemical Oxygen Demand (COD), Ammonium Nitrogen (NH_4-N), Total Nitrogen (TN), Total Phosphorous (TP), Dissolved Oxygen (DO), pH, and Turbidity were collected and analyzed in accordance with Chinese national standard methods. DO concentration was measured using a Hach Dissolved Oxygen Probe (HQ30d5331500).

3.4 Results and discussion

This new hybrid constructed wetland system in pilot scale was operated from April 2005 to June 2006 on order to test pollutant removal efficiency under different hydraulic loads and to compare the relative effects of operating with or without IC. Further, the aeration efficiency of NAD in this system was also investigated. During the course of operation, the pilot system was operated without IC from April to June 2005, and with IC in the remaining study period from July 2005 to May 2006. Data from the pilot system was segregated into periods with and without IC.

3.4.1 General performance

The pH Values were between 6.5~7.0 in the whole experiment study. Turbidity averaged in influent 44.2±7.6 NTU, effluent of VBFW 21.4±5.6 NTU, and effluent of HSBW 1.5±0.3 NTU. The values of four parameters of COD, NH_4^+-N, TN, and TP in the influent (In), Effluent of VBFW (VBFW_EFF), Effluent of HSFW (HSFW_EFF) in ther period without IC (from April 5[th] to Jul. 8[th] in 2005) and in the period with IC (from Jul. 11[th] 2005 to Feb. 3[rd] in 2006) were illustrated from Fig. 3-6.

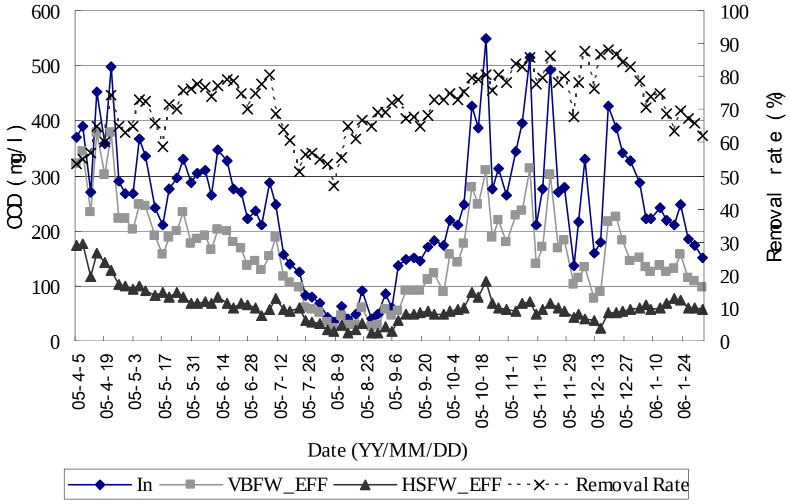


Fig. 3 COD concentration of influent and effluent of the Hybrid CW without IC and with IC

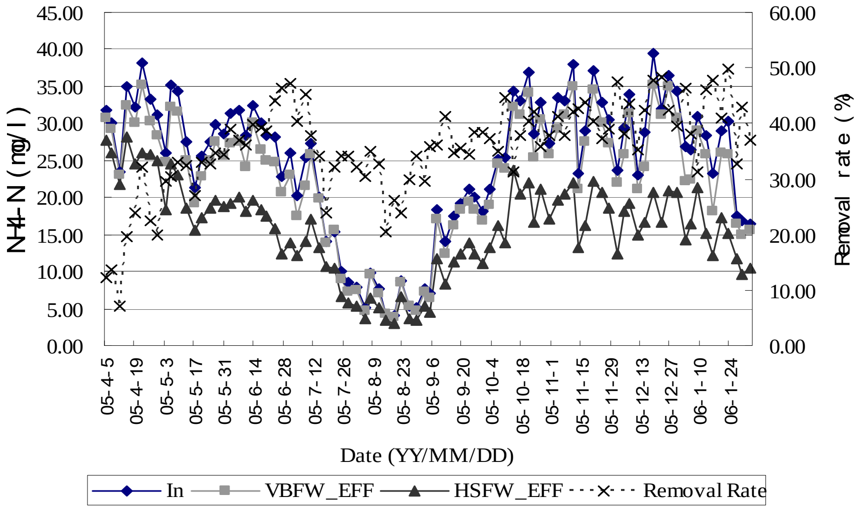


Fig. 4 NH_4-N concentration of influent and effluent of the Hybrid CW without IC and with IC

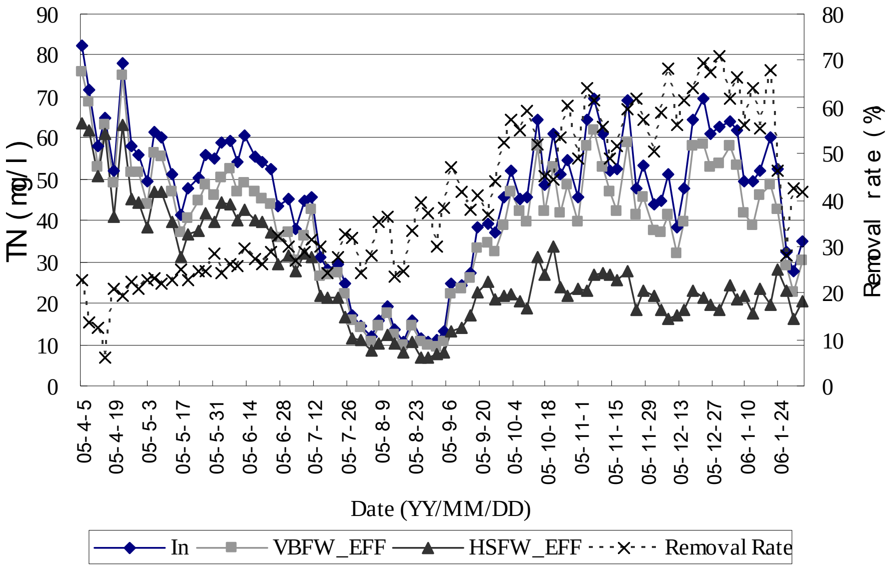


Fig. 5 TN concentration of influent and effluent of the Hybrid CW without IC and with IC

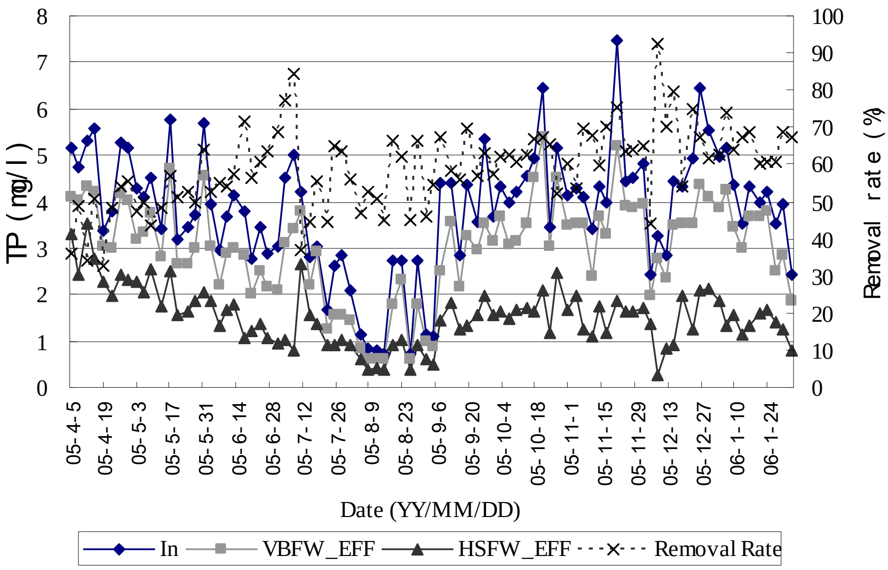


Fig. 6 TP concentration of influent and effluent of the Hybrid CW without IC and with IC

Base on the colleted data, the factors, Hydraulic Retention Time (HRT) / Hydraulic Loading Rate (HLR), Internal Circulation(IC), and DO that influence the treatment efficiencies of the Hybrid CW were analyzed.

3.4.2 Effect of HRT/HLR.

The pilot wetland was operated in 15 different HRT levels ranging from 20 hours to 90 hours with controlled flow rate into the system. In each hydraulic condition, four daily samples were tested. The average removal rate of COD, NH_4-N, TN, TP of the Hybrid CW with IC operated and their standard deviation at different hydraulic condition were presented in Fig. 3.

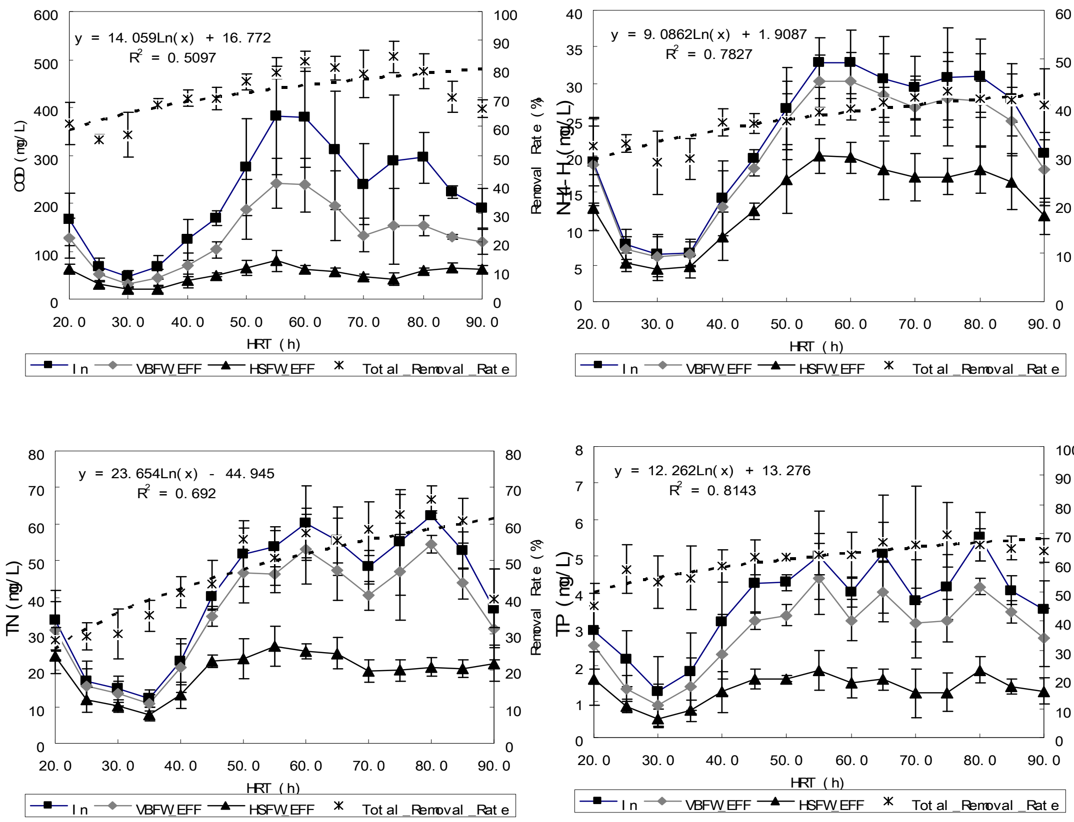


Fig. 3 The removal rates vs. HRT in the Hybrid CW with IC

From Fig.3, it can be concluded that the removal rate of COD, NH_4-N, TN, TP can be improved stably with increasing Hydraulic Retention Time (HRT). Based on pilot study, at the points of

HRT= 80, 85 and 90h in Fig.4, the removal rate decreased with the increasing of HRT. The reason for this phenomenon was attributed to the low temperature in winter.

3.4.3 Effect of internal circulation(IC)

The influence of internal circulation was analyzed by comparing the removal rate of CWs with IC and without IC. The study results were illustrated in Fig. 4. It is obvious that internal circulation has a very positive effect on pollutants removal. The removal rate of TN can double through an internal circulation, with flow rate of 1-2 times of the influent.

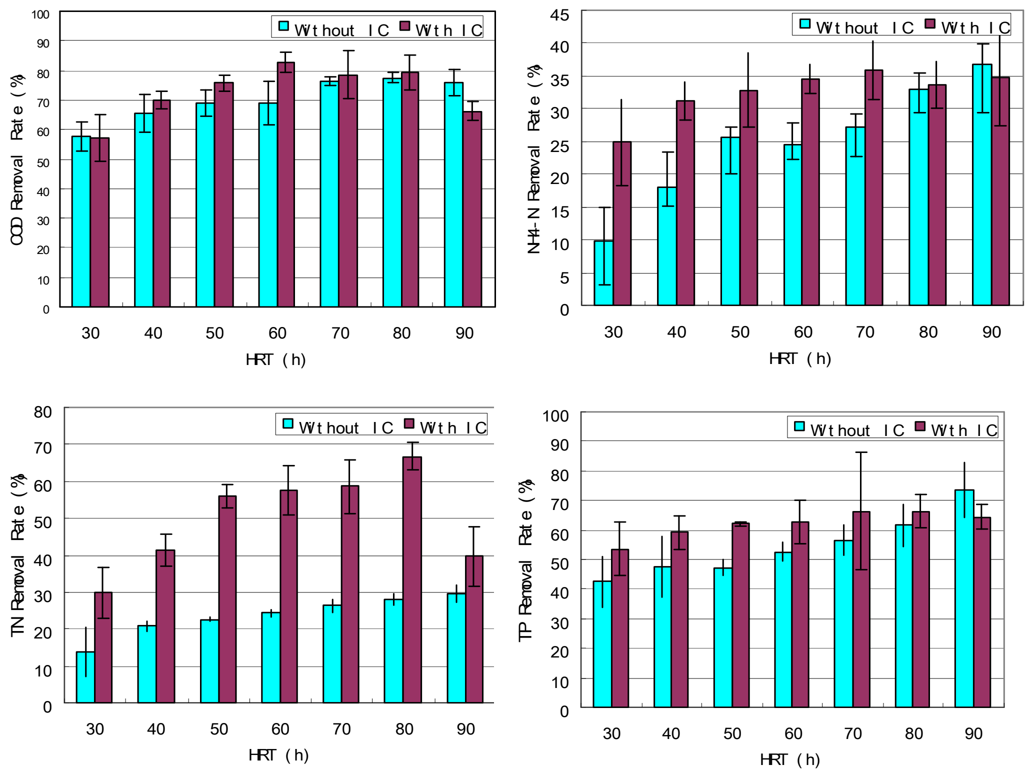


Fig. 4 Removal rates vs. HRT in the Hybrid CW with IC

3.4.4 Effect of Natural Aeration Ditches (NADs)

Several natural aeration ditches (NADs) were established between every two HSFWs in the pilot system, and the aeration effect was study. The NADs were around 350mm in width, 1.9~6m in length, 2~3mm for water depth. Thus sufficient contacting opportunity was obtained between air and treated wastewater, allowing oxygen in air phase to be transferred into the water phase. Fig. 5 shows the DO concentration, as well as the established trend line, in water after the different length of NADs.

After a 5 m long NAD, the DO can be increased from 0.3 to 3 mg/L, while in HSFW, the DO will be reduced back to 0.05~0.1mg/L just after 1m flow way, which means biological reaction in CW is strengthened after natural aeration.

3.4.5 Discussion

Despite quite large variations in influent concentration, a very high removal efficiency was achieved for SS and COD with efficiencies exceeding 96% and 85%, respectively, which was higher than the average level (94.9% and 78.5%) of wastewater treatment CWs in China *(Dongqing et al.,2009)* and slightly lower than that reported by J. Paing et al *(2005)* from 20 VFCWs in France with reporting values of 97 and 93%, and that reported by Gunther *(1997)* from horizontal subsurface flow CW in German with hydraulic rate below than 3 cm/d (with COD removal efficiency of above 90%). Measurement data in all the three hybrid CW systems indicated that most of SS (above 76%) and a large part of COD (above 60%) were removed in VBFW, the first stage of wetland cell. This was mainly due to the particulate compounds retention by filtering in gravel substrates. Water level elevation was observed at the entrance part of VBFW after operating for one year in Lugu Lake system and Baishiyi system and indicated the risk of clogging resulting from particulate compounds deposition and bio-film growing. No obvious clogging however was observed in the whole investigating period in these three full-scale systems.

Nutrients reduction has been the most critical test for the system because of the strict discharge limitations (see table 2). These three hybrid CW systems in full scale all provide rather higher removal rate for nitrogen with NH_4-N and TN of 72% and 76% which were considerably higher than that of other CWs reported in China (Dongqing et al.,2009) of 37.3% and 46.8%, and that of sub-surface CWs reported in North America of 24.6% and 55.6% and that in German of and 54% and 48%(Vymazal ,2002). This high efficiency is attribute to the fundamental design of NADs in HFSW and the IC system with a combination of vertical and horizontal subsurface flow wetlands

as proven by Gunther *(1997)* and Cooper *(1999)*, which can efficiently enhance DO concentration and bacteria process within the system. Average total phosphorus removal rate for these three full scale systems of 76.5% is slightly lower than that in other hybrid CW system reported in China with average removal of 79.7%, and much higher than that in sub-surface CWs reported in North America of 32.7% and that in German of and 65% *(Vymazal ,2002)*.

It is interesting to note that no significant differences were observed between performances measured LuGu lake CW, Baishiyi CW and Wulong Fairy Mountain CW whereas average ambient temperature of Baishiyi CW is much higer than the other two system. There are two reasons for that are considered. One is that a relativly longer HRT was designed in Lugu Lake and Wulong Fairy Mountain systems due to the low ambient temperature in winter. The second is that the sewage flow rate in winter declines significantly due to the tourism acticity decreasing in winter for these two senic sites.

3.5 Conclusions

Results from the application of both pilot-scale revealed that this new hybrid CW can achieve a high pollutant removal efficiency of COD, SS, NH_4-N, TN and TP with average removal rate of 85.7%, 96.8%, 80.5%, 76.1% and 76.5% under hydraulic load of 26.9-42.7 cm/d. Mean effluent concentration of these parameters could all meet the discharge regulation limits for wastewater treatment plants in China. This hybrid is competitive with other conventional vertical or sub-surface CWs system for its high efficiency and low areal requirement of 3-5 $m^2m^{-3}d$, and its application in south China has turned out to be a success.

Compared with traditional constructed wetland, this new type of hybrid constructed wetland has several advantages which are helpful to enhance the treatment efficiency for CWs. (1) A deep Vertical baffle flow constructed wetland, followed by a horizontal subsurface flow constructed wetlands with NADs established, shows an well designed DO distribution amonge the system, which was great helpful for improving bacteria process in the wetlands. (2) The hydraulic condition is optimized in this hybrid CWs. The reasonably installed baffled walls are helpful for making better use of the volume, and prevent stagnant water zone. (3) Internal circulation for HSFWs back to VBFW can elevate the removal rate of TN, through enhanced biological denitrification. Internal circulation can improve the treatment efficient of COD and NH_4-N as well, especially in case of relative high concentration of organic pollutant.