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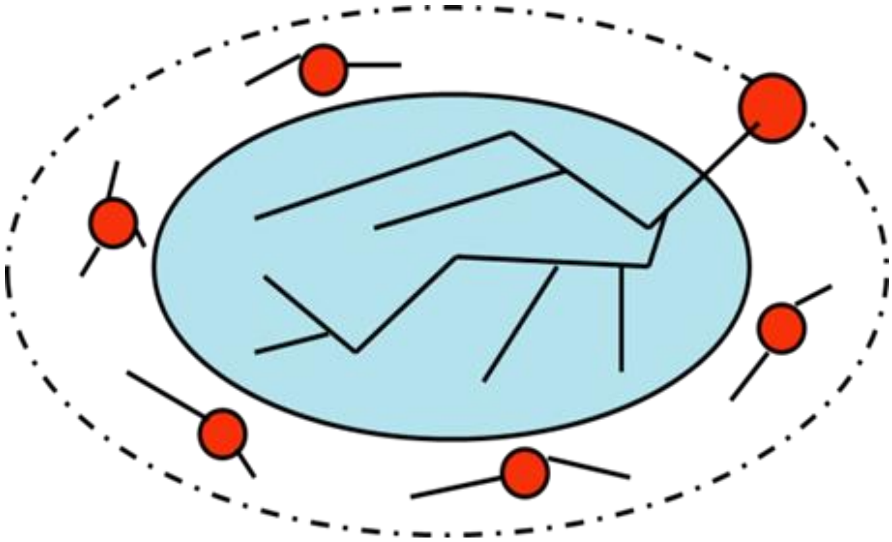

DECENTRALISED WASTEWATER TREATMENT

Lessons-learnt from Five Years Project Implementation

Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

Hợp tác Đức
DEUTSCHE ZUSAMMENARBEIT

Wastewater and Solid Waste Management in Provincial Centres

Ministry of Construction – Hanoi

in cooperation with

Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

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Abbreviations

ABR	Anaerobic Baffled Reactor
AF	Anaerobic Filter
AP	Aerated Pond
BOD	Biological Oxygen Demand
BoQ	Bill of Quantities
CAPEX	Capital Investment
COD	Chemical Oxygen Demand
CPC	City People’s Committee
CSO	Combined Sewer Overflow
CSS	Combined Sewer System
d	Day
D	Depth *(always related to water level, hence level of outlet pipe)*
DN	Diameter
DoC	Department of Construction
DoF	Department of Finance
DoNRE	Department of Natural Resources and Environment
DPC	DPC
DWWT	Decentralised Wastewater Treatment
FS	Feasibility Study
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH
GoV	Government of Vietnam
h	Hour
HPGF	Horizontal Planted Gravel Filter
HRT	Hydraulic Retention Time
IEC	Information, Education and Communication
IWA	International Water Association
KFW	Kreditanstalt für Wiederaufbau / German Development Bank
kg	Kilogram
l	Litre
L	Length
min	Minute
mm	Millimetres
m	Meter
m^2	Square Meter
m^3	Cubic Meter
mg	Milligram
MoC	Ministry of Construction
MoNRE	Ministry of Natural Resources and Environment
OHS	Operational Health and Safety

O&M	Operation and Maintenance
OPEX	Operational Expenditure
PPC	Provincial People's Committee
QCVN	Vietnamese National Technical Regulation
SOP	Standard Operation Procedure
SS	Suspended Solids
SSS	Simplified (Separate) Sewer System
ST	Septic Tank / Settler
UPWC	Urban Public Works Company
URENCO	Urban Environmental Company
UV	Ultraviolet
W	Width
WMP	Wastewater and Solid Waste Management Programme
WWTP	Wastewater Treatment Plant
WSP	Waste Stabilization Pond
WSSC	Water Supply and Sewerage Company

1. Introduction

The "Wastewater and Solid Waste Management in Provincial Centres" Programme (WMP) is a technical cooperation (TC) programme financed by the German Government and jointly implemented by Vietnam Ministry of Construction (MoC) and Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH. Parts of the TC are subcontracted by GIZ to the private consulting firm GFA Consulting Group GmbH. The TC services provided by WMP are commissioned to support a financial cooperation (FC) infrastructure investment programme consisting of a line of loans provided by Deutsche Kreditanstalt für Wiederaufbau (KfW) to the Government of Vietnam (GoV). FC funds are allocated to the construction of municipal wastewater treatment plants (WWTPs) and centralised sewerage collection systems in nine provincial cities in Vietnam[1]. TC (WMP) commenced in 2005 and focuses in a multi-level approach on the improvement of wastewater management conditions and related public services. It consists of three components: Component 1 focuses on the creation of suitable **legal framework conditions**. Its main counterpart and beneficiary of services is the Ministry of Construction (MoC). Component 2 focuses on improving **institutional framework conditions** on local government level. Its main counterparts are Provincial People's Committees (PPC), City People's Committees (CPC) as well as local government departments such as Department of Construction (DoC), Department of Finance (DoF) etc. Component 3 focuses on **capacity development** of the respective utilities (urban wastewater management companies) that are (or will be) assigned to operate the KfW-financed WWTPs in the nine provinces. All three components work hand-in-hand as the solution to many issues relates all levels of government and management. Therefore, vertical and horizontal cooperation, learning and exchange processes are facilitated and contribute to the success of the entire programme. For example, Component 3 also addresses, in coordination with Component 2, local authorities in provinces to perform programme-related activities, particularly in the area of decentralised wastewater management.

Within the scope of Component 3 activities, the decentralised wastewater management approach was developed and introduced as a supplement to centralised WWTPs. It is important to note, that decentralised wastewater management is not regarded by WMP as being in contradiction to or in competition with centralised wastewater collection and treatment. WMP rather promotes the idea that due to the specific topographic and technical conditions in Vietnam's cities, a best-fit solution would include a combination of both approaches, centralised collection for urban centres and decentralised collection and treatment in outskirts or for other difficult-to-connect single or cluster dischargers. WMP has therefore set up five decentralised wastewater treatment (DWWT) demonstration projects in Bac Ninh, Vinh, Can Tho, Soc Trang and Son La. These projects intend to create awareness of local decision makers, service providers and the population about the DWWT approach, to develop capacities of planners, designers and service providers regarding the implementation of DWWT systems and its operation and maintenance (O&M) and finally to operate as door-openers for the large-scale implementation of such systems.

WMP also worked on national government level to create suitable conditions for the dissemination of DWWT, e.g. by including DWWT as suitable wastewater treatment approach into the Government Decree 88/2007/ND-CP and its successor Decree[2] on Urban Wastewater Management, as well as by inviting the national government to create more suitable legal framework conditions for DWWT dissemination, i.e. by applying more suitable discharge standards for WWTPs that take the capacity of the treatment systems into account.

The on-hand report aims to support the scaling-up and institutionalization of the DWWT approach by sharing lessons-learnt that WMP collected during planning, implementing, constructing and operating DWWT plants over the last years. This paper is supposed to initiate and speed-up the discussion among experts and stakeholders on how to proceed with DWWT issues in Vietnam. After discussions with GIZ it was agreed that this paper also acts as replacement for the initially planned guideline that was supposed to be published by MoC with GIZ's support, as stipulated in the indicator of component 1, phase 3, of WMP.

[1] Supported cities are: Son La, Lang Son, Hoa Binh, Bac Ninh, Hai Duong, Vinh, Can Tho, Soc Trang and Tra Vinh.

[2] The new Decree that will replace Decree 88/2007/ND-CP is scheduled to be promulgated in mid 2014

2. Decentralised Wastewater Treatment

The International Water Association (IWA) Specialist Group on DWWT **defines DWWT** as follows: “Decentralised wastewater management refers usually to the opposite approach to a centralised wastewater management. Centralised wastewater management is characterized by the existence of one centralised WWTP for the largest possible confined catchment area in a region. Decentralisation means then any **break-up of the largest possible catchment area in smaller areas**. Hence, the terms ‘centralised’ and ‘decentralised’ cannot be equalled with the terms ‘large’ and ‘small’, but with ‘larger’ and ‘smaller’. The smallest possible decentralised system would be on-site systems”.

DWWT systems are principally not connected to a conventional underground sewer system. The wastewater is treated and discharged (or reused) **directly at or near the point of generation**. DWWT systems include a large range of sizes and technologies, and can also include a simplified sewer system (SSS) as feeding pipes.

DWWT is gaining gradually ground in Vietnam, not only in means of new technologies but also in regard to institutional management, awareness on government and local level, financing issues, design standards, ownership and O&M activities.

Legislative regulations, legal framework conditions and effluent standards related to DWWT begin to change in order to create suitable conditions for the dissemination of DWWT. For example a new MoC Decree on “Drainage and Wastewater Treatment” is expected to replace the old Decree 88/2007/ND-CP on urban and industrial wastewater drainage in 2014. An innovation compared to Decree 88 is that DWWT is particularly defined as an alternative to centralised solutions.

DWWT is also discussed and considered in many donor studies, e.g. in World Bank’s “Urban Wastewater Sector Review” (2014), and proposed to become a part of expanded centralised networks. Also Asian Development Bank (ADB) has recently committed a 1 billion USD credit line for urban wastewater investment and management projects, and specifically considers decentralised options in their capacity development technical assistance[3] (CDTA) inception report, published September 2013.

Three demonstration plants implemented with support of GIZ WMP in Bac Ninh, Can Tho and Vinh earned much interest and support of the local government regarding to completion of pilot activities and up-scaling of the approach; meanwhile two additional demonstration projects in Son La and Soc Trang, which are financed entirely by provincial government funds, are under construction during the preparation of this report. All WMP supported demonstration projects provided the opportunity for involved stakeholders, service providers as well as the donor community to collect numerous practical experiences and lessons-learnt.

The following points summarize the **concept of DWWT**:

- DWWT is a concept to provide sanitation solutions in areas not (yet) connected to centralised WWTPs, or areas that do not allow a connection to centralised WWTPs (for technical, financial or institutional reasons), and where wastewater is treated at or near the point of generation;
- The term DWWT also applies to applications where wastewater needs to be treated prior to discharge into existing sewer systems (hospitals, factories, etc.);
- DWWT requires continuous multi-level stakeholder involvement (local government, service providers, etc.) and expertise from the very beginning of project planning. Community participation is crucial for success;
- DWWT is a holistic approach that also looks into people’s hygiene behaviour, living standards, production processes, utilization of resources, etc.; and
- A DWWT system does not need a conventional sewer system but small-scale feeding pipes.

Chapters 4.2 and 4.3 provide more detailed information about the scope for DWWT, suitable areas for application, as well as particular advantages and disadvantages.

[3] Socialist Republic of Viet Nam: TA7885-VIE Support to Central and Local Governments to implement Urban Environmental Improvement Programs (Financed by the Japan Fund for Poverty Reduction) Inception Report – Revised Final, by Jan Jelle van Gijn, Pham Quang Tien and John Block, September 2013.

3. WMP Pilot Projects

GIZ WMP has set up five **DWWT demonstration projects** in Vietnam with the following objectives:

- Use sub-projects for capacity development and training purposes for the state management and service providers on wastewater issues in general, and O&M of treatment plants in particular;
- Disseminate the DWWT approach as complementation to centralised WWTPs;
- Kick-off a discussion on alternative sanitation solutions;
- Learn from project implementations and operations; and
- Collect data and experiences from the demonstration projects in order to facilitate the process of improving the legislative and regulatory framework in Vietnam.

Additionally, WMP has implemented one **study on up-scaling the DWWT approach** for urban and peri-urban areas with the following objectives:

- Investigate a more comprehensive approach to DWWT on a larger scale, rather than focusing on single on-site solutions;
- Identify locations that are suitable for the scaling-up of the DWWT approach;
- Present technical options for different DWWT solutions that are suitable for up-scaling;
- Elaborate investment and O&M costs for the proposed DWWT solutions; and
- Evaluate possibilities of centralised management of the DWWT solutions.

This report is based on experiences made during planning, implementation, construction and operation of DWWT plant demonstration projects in five locations in Vietnam, namely in Can Tho, Vinh, Bac Ninh, Son La, and Soc Trang; as well as on the development of an up-scaling study for the city of Vinh.

The table below provides details on the demonstration projects and up-scaling study that have been carried out under WMP, serving as a basis for this lessons-learnt report.

Location	Techno-logy	Features	Design capacity	Year of construction	Owner	Operator
Vinh City, Nguyen Truong To School	ABR + AF + HPGF	Wastewater from school and Kindergarten	18 m^3/d	2010	Nguyen Truong To School	INFRAVI Vinh
Can Tho City, Cai Khe Market	ABR + AF	Wastewater from market	20 m^3/d	2011-2012	Cai Khe Market Adminis-tration	Can Tho WSSC
Bac Ninh City, Viem Xa Village	ABR + AF + aerated WSP	Domestic wastewater + livestock; peri-urban residential area with separate sewer system (SSS)	40 m^3/d	2010-2011	Bac Ninh WSSC	Bac Ninh WSSC
Son La City, To Hieu School	ABR + AF + HPGF	Wastewater from school and supplementary sources	18 m^3/d	2014	Son La City People's Committee	Son La URENCO (proposed)
Soc Trang, Tran De District, Lich Hoi Thuong School and market	ABR + AF + HPGF	Wastewater from school toilets and market incl. public toilet	24 m^3/d	2014	Tran De DPC	Soc Trang UPWC (proposed)
Nghe An Province Vinh City	various	Wastewater from residential peri-urban areas and hot spots	1,290 m^3/d (12 DWWT systems)	n/a	Vinh City People's Committee (proposed)	INFRAVI Vinh (proposed)

The map to the right shows the geographical distribution of WMP's DWWT demonstration projects and the up-scaling initiatives over Vietnam.

It must be mentioned that all WMP demonstration projects were set up in an **urban or peri-urban environment** as the GIZ WMP focuses on provincial cities. Results and experiences from projects in rural areas might differ remarkably.

Experiences and lessons-learnt are based on only a few case studies, and findings may not represent DWWT applications in Vietnam in general. Furthermore, this report does not cover privately financed and operated DWWT projects, which may show other results.

Nevertheless, this report may serve as summary of results and experiences, and might serve different stakeholders to up-scale and improve the DWWT approach in Vietnam.

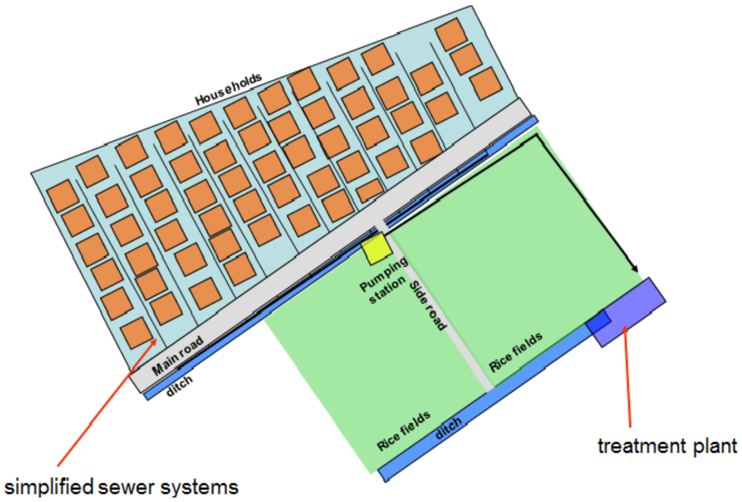
More detailed information as well as individual lessons-learnt of WMP's demonstration projects as well as the up-scaling study is presented in the following sub-chapters.

3.1 Demonstration Project in Bac Ninh

3.1.1 Project Description

The selected location in Bac Ninh consists of a residential cluster of 5 alleys in Viem Xa village, Hoa Long commune. The selected area includes 60 households, equivalent to 200 residents. Prior project start a simple combined sewerage system in form of narrow ditches (W=100mm, D=200mm) running along alleys existed, which discharged into an open public channel leading to rice fields. Each household has different wastewater discharge points in front and/or behind, depending on the disperse design of in-door structures. This fact made the collection of wastewater very demanding. The domestic wastewater in Viem Xa includes black water from septic tanks and grey water from kitchens and bathrooms. Besides, the sewer system receives the wastewater from animal husbandry, after pre-treatment in individual anaerobic chambers. Not only odour from the open ditches but also the pollution of the rice fields constituted tremendous environmental and public health risks.

WMP constructed a DWWT plant to ensure proper treatment of the connected households. In order to avoid mixing with storm water a new SSS was built, connecting the various wastewater sources to the DWWT plant. This collection and conveyance system includes house connection boxes as well as tertiary and secondary sewer lines. The existing ditches were kept for rainwater drainage. The below graphic shows the general layout of the project area in Viem Xa village[4]:



[4] Exemplified depiction

According to the implemented baseline survey performed during the project preparation period, the following design data were collected for the DWWT project.

Parameter	Value	Unit
Wastewater quantity	40	m^3/d
Influent BOD_5	304	mg/l
Influent COD	761	mg/l
Influent SS	380	mg/l
Inflow time	10	h/d
Temperature	25	^oC
Effluent BOD_5 (*)	50	mg/l
Effluent SS (*)	100	mg/l

(*) According to QCVN 14:2008/ BTNMT

3.1.2 Institutional Issues

The Bac Ninh Provincial People's Committee (PPC) and the Viem Xa community management expressed a high interest in and support for the demo project, hence it can be said that the project was demand-driven from institutional point of view. The investment cost was borne by GIZ. It was agreed during the project preparation phase, that Bac Ninh PPC is in charge of future O&M expenses. Since 2012, PPC allocates a sufficient annual O&M budget to the operator (Bac Ninh Water Supply and Sewerage Company) of the system in Viem Xa, ensuring a high financial sustainability of the project.

WMP provided mostly consulting and supply services such as (i) proposing a suitable DWWT technology, planning and preliminary design (calculations & drawings), (ii) supplying equipment (pump with control unit, floating filter materials, sludge measuring pipe), (iii) commissioning of the DWWT plant, as well as (iv) general technical advice on request during O&M of the pilot system.

The Bac Ninh Water Supply and Sewerage Company (WSSC) is assigned by Bac Ninh PPC as WMP's project partner during project implementation, as well as owner and operator of the DWWT system after completion. WSSC was responsible for (i) the preparation of a project proposal including an assessment of the socio-economic situation of Bac Ninh city, (ii) preparation of detailed designs of the SSS and DWWT plant in cooperation with WMP, (iii) implementation of household connections and construction of the SSS and DWWT plant, (iv) O&M of the DWWT system, as well as later (v) the supervision of construction works of a new interceptor channel and guard house.

The Hoa Long Commune People's Committee contributed land for the construction of the DWWT system. Additionally it implemented many Information, Education and Communication (IEC) activities in collaboration with WMP and WSSC, such as dissemination of leaflets, environment awareness raising, behaviour change communication, etc.

A local Sanitation Team consisting of (female) community members was established and assigned to clean household connection boxes and storm water ditches along the alleys.

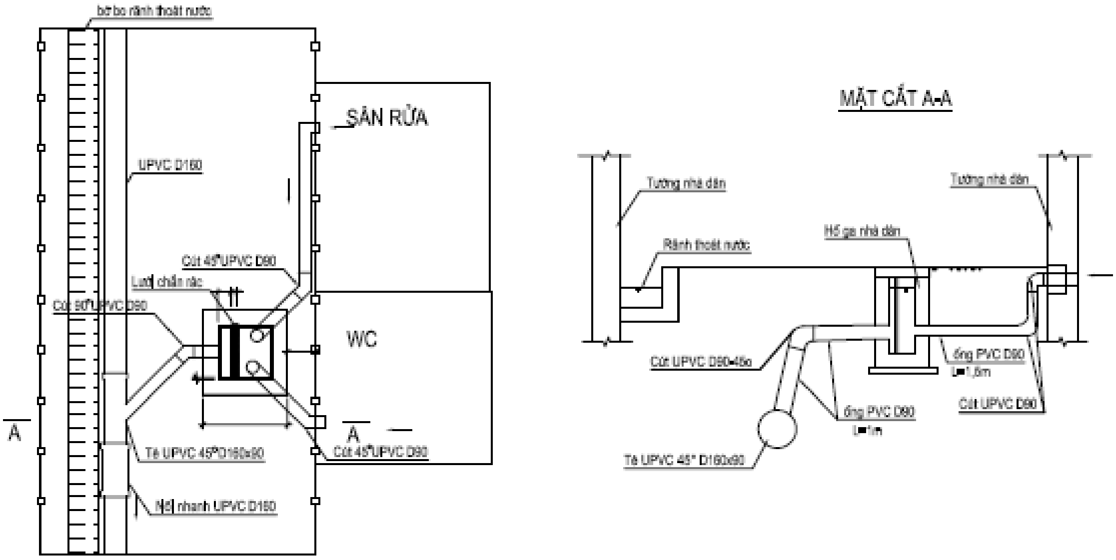
3.1.3 Technical Issues

<u>Design of the DWWT System</u>

The new collection system collects the wastewater from the households separately. The three main elements of this new collection and conveyance system are (i) household connection boxes, (ii) the SSS incl. inspection chambers itself, and (iii) an interceptor channel which was built later.

From the private households' property the wastewater discharges firstly into newly built house connection boxes that were constructed to separate solid waste and sludge from the liquid wastewater. Inside each box, a screen is installed. Thus, the box has two functions: sedimentation of heavy solids and filtration of large solid waste before the wastewater enters the SSS. Each concrete house connection box has the dimensions of 500 x 500 x 300 (L x W x D). Boxes are partly shared by two households, depending on the location of individual discharge points. The inlet and outlet pipe of these household boxes are made by PVC with a diameter of DN90. The following pictures show an example house connection box as well as an inspection chamber used in Bac Ninh.

The following technical drawings show a typical house connection box and its connection to the SSS:



The SSS was installed along the alleys, using PVC pipes of DN160. The pipes were installed in a shallow depth. As the SSS consists of light materials they cannot bear heavy loads and were therefore installed under sidewalks behind the yards. The inspection chambers play a vital role as access point to inspect and clean the SSS, if required. They were installed every 15m. All pipelines of the SSS were installed with a slope of 1% to ensure gravity flow.

The last unit of the collection system is an interceptor pipe of DN200. The wastewater flowing through the SSS from five alleys discharges in the interceptor before entering into the DWWT plant. With this interceptor, mixing of the collected wastewater with water collected in open channels and agricultural channels is prevented. Additionally the interceptor prevents the backflow of wastewater to the households during heavy rains. Initially, after construction of the DWWT system, a high amount of sludge and solid waste (not coming from the SSS but from open drainage channels) still entered the grid chamber located upstream the pumping station. Manual sludge removal at high frequencies was required. Poor appearance and bad smell resulted in complaints by the residents. This situation has been improved after the construction of the interceptor. Additionally, before completion of the interceptor, the wastewater pump (see next paragraph) and the aerator in the wastewater pond (see below) had to work around the clock because of a high wastewater flow rate. With the interceptor, a stable quantity and quality of wastewater has been achieved, which enables a reduction of the running time of the pump and aerator, which in turn saves electrical energy.

Because of a long distance between the wastewater catchment area to the DWWT plant (situated where land was allocated), a pumping station with a combined collection tank is required. The station has the dimensions of 1800 x 1800 x 4500 (L x W x D). Two submerse pumps (Flygt CP3045.181 and DP 3045) with capacities of $8m^3/h$ and $4m^3/h$ were provided, which are used in turn in case of repairs.

A floating switch was installed in order to protect the pumps from running dry. The running time of the pumps can be set via a relay box, installed in a guard house. From the pump sump the wastewater is pumped through a HDPW pressure pipe (DN75) into the DWWT plant over a distance of 340m.

In order to protect the pumps from solid waste and sludge, the wastewater from the collection tank flows first into a grid chamber. This chamber has the dimension of 2440 x 1640 x 3700 (L x W x D) and ensures sedimentation as well as filtration of solid waste due to a screen with the span of 10mm.

The DWWT system itself consists of a modular setup consisting of an Anaerobic Baffle Reactor (ABR) + Anaerobic Filter (AF) + Aerated Pond (AP). Upstream the ABR inlet, a small valve was installed to adjust the wastewater flow rate pumped into the DWWP. The following graphic shows the general arrangement of the DWWT modules:

The ABR includes a total of five consecutive concrete chambers, where sedimentation and biological treatment processes take place. The first chamber works principally like a septic tank, where big particles are given time to sediment and organic matter can partly be degraded. After leaving the sedimentation chamber, the wastewater enters a series of four real ABR chambers, in which the main anaerobic treatment process is encouraged by the special structure inside the tanks: the wastewater is forced by down-flow distribution pipes to flow upstream in the chambers. By this, the wastewater is forced to flow through a layer of activated sludge accumulating at the bottom of each tank. The organic matter is degraded by the biomass in the sludge layer.

The second treatment module consists of three AF chambers. The tanks are filled with bamboo pieces, whose surface acts as carriers for anaerobic bacteria. The wastewater is again channelled with PVC pipes to the bottom of each chamber and flows then upwards through the filter material.

Subsequently, the wastewater is further treated in a wastewater stabilization pond (WSP) to remove pathogens through disinfection due to UV-light. One third of this pond is aerated by an aerator, whose running time can be set via an electrical box. In the last two thirds of the pond, two walls were built in order to create a zigzag flow to increase the hydraulic retention.

In the following table the dimensions of the DWWT modules and its numbers are shown:

Modular	Number of tanks	Dimensions of each tank in mm (L x W x D)
Sedimentation Tank	1	3,250 x 1,650 x 2,600
Anaerobic Baffle Reactor (ABR)	4	3,250 x 1,300 x 2,600
Anaerobic Filter (AF)	3	3,250 x 1,300 x 2,600
Aerated Pond (AP)	1	324,400 x 15,000 x 1,000

Note: The water level in the ABR and AF is 1.80m; the water level in the HPGF is 0.80m

More information about the treatment principles of ABR, AF and WSP can be found in Chapter 4.4.

Wastewater after treatment is directly discharged into a rice field. Biogas generated in the ABR and AF is released into the air via plastic pipes located on the top of each chamber.

O&M of the DWWT System

Implementation of a proper O&M program is a precondition to ensure a stable and effectively performing DWWT plant, to extend its life time, and to save cost for repairs and spare parts.

WSSC is providing adequate sources and is dedicated in running the system well. All elements of the system are checked and cleaned regularly. Responsibilities are shared between the WSSC staff (SSS, interceptor, pumping station, DWWT plant) and the sanitation team (house connections). Checking and cleaning of the SSS and interceptor require technical devices and skilled workers, while sanitation works for house connection boxes and storm water ditches can be done with simple equipment. In order to raise awareness of the community about the new system, this sanitation team was established with WMP support from the solid waste group of the village. WMP has provided them with various tools, equipment, safety working clothes and a short training on their duties. The sanitation team works one day per week. Apart from cleaning the house connection boxes, they are also responsible to identify unusual phenomena such as broken screens or illegal discharges of wastewater into storm water ditches. A dewatering push cart was developed and provided to the sanitation team. This modified push cart was developed based on a normal cart used for solid waste transport. A metal bearing grid was installed parallel to the push cart's bottom in a distance of about 20 cm, on which a nonwoven used for dewatering the sludge was fixed. The liquid sludge is separated by this nonwoven into its solid and fluid compartments, which are then kept on different parts of the push cart. Through a valve installed under the cart's bottom, the fluid part can be discharged into household connection boxes. As originally planned, the sludge could have been transported and disposed of together with regular solid waste by Bac Ninh Urban Environmental Company (URENCO). Unfortunately, despite interventions by the Commune People's Committee, URENCO rejected to transport the dewatered sludge because of the remaining water content and associated odour. The sludge disposal is therefore an open issue because no sludge drying bed has been constructed so far. The sanitation team is therefore pouring the sludge into a natural pond and part of this sludge is used by the village residents for their fish ponds.

Due to biological processes the sludge volume in the ABR and AF chambers increases gradually, which causes a reduction of used tank volume and a risk of sludge being flushed out with the wastewater flow. Regular checking and removing of sludge is a crucial requirement of this system. WSSC measures the sludge level every two weeks. Once the sludge volume in the ABR exceeds 60% of tank volume the sludge is pumped out down to about 30% (some activated sludge needs to remain to ensure consistent functioning). The sludge in the first chamber (sedimentation tank) and the AF is emptied completely. In the AF chambers, sludge will accumulate on the bamboo pieces during treatment process, which should also be removed by stirring the bamboo layers. After about 5 years, the bamboo should be replaced. For checking the sludge level, WMP has provided a plastic sludge pipe. This is an extendable and graduated pipe with a small rubber valve at the end, which helps to keep the profile of sludge and water layers similar to inside the tanks after removal from the tank.

The sludge from the DWWT plant is currently disposed of in a landfill. This is no sustainable solution because the available landfill in Bac Ninh is already overloaded. Additionally the untreated sludge will cause environmental problems. During project implementation, a concrete drying bed located next to the DWWT plant had been discussed to dry the removed sludge prior to transport. However, due to lack of space as well as anticipated odour nuisance for residents this plan has not been realized.

The pictures show pipes for measuring the sludge level as well as WSSC staff measuring the level in the ABR and AF.

Besides, all physical constructions should be checked and maintained regularly. This includes checking the tightness of the system, maintaining the functional record of the pump and aerator (time of restarting and running time), as well as checking the water at the sampling hole of the WSP. One of the most important and sensitive equipment is the pump. WSSC often rechecks the flow rate of the pump using a manual method to calculate the real capacity of the DWWT system. According to the last measuring results, the total running capacity of the DWWT plant is about 25m^3/d.

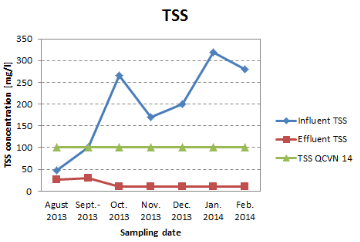
Performance of the DWWT System

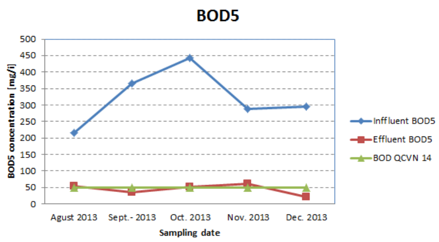
For evaluating the treatment performance, samples were taken since the commissioning of the DWWT plant on a monthly basis by WMP. Starting from the completion of the interceptor in August 2013, WSSC has fully taken over the system and implements O&M and the sampling programme self-dependently.

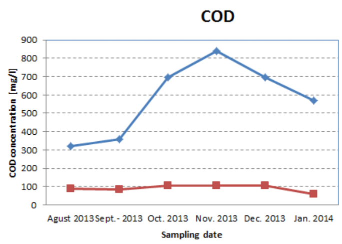
Samples are taken monthly by WSSC. The laboratory analyses are realized in the laboratory located at the centralised WWTP of Bac Ninh, which is also operated by WSSC. The considered parameters are BOD, COD, TSS, N-total and PO_4-P. The sampling results are used for fine-tuning the treatment process.

The following graphics and tables present the sampling results from the DWWT plant in Bac Ninh. A good purification result for BOD and SS is proven by complying with the QCVN14 effluent standard and high treatment efficiencies. The average reducing rate for BOD, COD and SS are 85%, 83% and 83% respectively.

The following graphics show the sample results for TSS, BOD and COD between August 2013 and February 2014, in which the blue lines show the concentration in the WWTP inlet, the red lines the outlet concentrations, as well as the green lines the required QCVN 14:2008/ BTNMT standard.







Above graphics already show that the required direct discharge standard for TSS and BOD are usually achieved with the DWWT system (no QCVN standard for COD). The following two tables present the detailed sampling results for the same sampling period.

Time	Treatment Capacity [m3/d]	Parameter										
		pH (5-9)			TSS (mg/l) (100)				COD (mg/l) (-)			
		Infl. (Pumping Station)	End of ABR	Effl.	Infl. (Pumping Station)	End of ABR	Effl.	Treatment Efficiency (%)	Infl. (Pumping Station)	End of ABR	Effl.	Treatment Efficiency (%)
Agust 2013	65	6.85	7.52	7.46	47	23	26	44.7	320	112	88	72.5
Sept.- 2013	44	7.6		8	100		30	70.0	360		85	76.4
Oct. 2013	33	7.79	7.23	8.17	265	30	10	96.2	264	188	_	
Nov. 2013	13	7.7	7.5	7.9	170	20	10	94.1	694	206	106	84.7
Dec. 2013	14	7.6	7.2	7.9	200	30	10	95	841	211	106	87.4
Jan. 2014	19	7.9	7.2	8	320	30	10	97	694	123	105	84.9
Feb. 2014	18	7.85	6.93	8.12	280	35	10		571	128	60	89.5
Average	**29.4**				197	**28.00**	15	83	535	**156.0**	92	83

Time	Parameters											
	BOD_5 (mg/l) (50)				N total (mg/l)				PO4-P (10)			
	Infl. (Pumping Station)	End of ABR	Effl.	Treatment Efficiency (%)	Infl. (Pumping Station)	End of ABR	Effl.	Treatment Efficiency (%)	Infl. (Pumping Station)	End of ABR	Effl.	Treatment Efficiency (%)
Agust 2013	216	78.5	55	74.5					15.22	11.26	13.42	
Sept.- 2013			32		220		70	68	32.6		14.2	
Oct. 2013	_	_	60		272	132	92	66	50.8	32.2	23.2	54
Nov. 2013	365		36	90.1	236	186	125	47	50.8	40	25.6	50
Dec. 2013	442		52	88.2	272	196	164	40	43	42	35	19
Jan. 2014	289		60	79.2	166	141	113	32	30	27	25.4	15
Feb. 2014	296	98	21	92.9	172	138	120	30	39.6	28.6	27.6	30
Average	322		43	85	223	**158.60**	114	47	37	**30.18**	23	34

3.1.4 Financial Issues

Capital investment cost for all construction works has been paid by GIZ. The total cost of 2,836,363,000 VND (135,065 USD) had been allocated for the following constructions works:

No.	Item group	Cost [VND]	Percentage [%]
1	Collection system	1,409,745,000	49.7
2	Treatment system	1,426,618,000	51.3

The construction cost of the collection system includes personnel cost, machinery and material costs required for the construction of house connection boxes, the SSS as well as the interceptor channel. The construction items of the treatment system consists of the grid chamber, the collection tank / pumping station (incl. pump), as well as all of DWWT modules (ABR, AF, AP).

From the first operation time in June 2011, monthly O&M cost was subsidized by Bac Ninh PPC. However, the budget for O&M of the DWWT plant was not separated clearly from the total annual budget that WSSC received from the PPC; hence WSSC has allocated required resources by themselves.

Costs for the Sanitation Team (salary, equipment) were originally reimbursed by GIZ project budget. For a sustainable long-time solution, however, the introduction of a local wastewater fee, that would cover the salary of the Sanitation Team, paid by the households connected to the DWWT system in the 5 alleys was agreed on and implemented; for a sustainable operation it was seen as important that the community contributes to at least some parts of the O&M costs. The total costs for salaries of the Sanitation Team were equally divided by the total number of connected households, resulting in a fee of VND 15,000 (USD 0.7) per month and household. The Sanitation Team itself started fee collection in 5 connected alleys in April 2013. Willingness-to-pay in the first couple of months was relatively high. 53 out of 57 connected households paid the full amount of the fee. The remaining 4 households also contributed but argued that the amount of wastewater their houses discharged were much lower than that of other households. Hence, they only accepted to pay VND 5,000 or 10,000 respectively. The remaining budget gap for the Sanitation Team's salary was covered by Bac Ninh WSSC's O&M budget.

After a wastewater tariff according to Decree 88/2007/ND-CP became effective in the entire city of Bac Ninh in July 2013, every household in the village of Viem Xa (as it is administratively considered a part of Bac Ninh city) was now required to pay the (much higher) wastewater tariff, regardless of a sewer connection or a connection to the DWWT system or not. Hence, the local DWWT wastewater fee collected by the Sanitation Team was abolished. Since then, Bac Ninh WSSC covers all costs for O&M, including salaries of the Sanitation Team, by money collected via the city-wide wastewater tariff.

It should be noted, that after the introduction of the global and much higher wastewater tariff in Bac Ninh city, willingness-to-pay that new tariff was lowest in Viem Xa. Almost all households in Viem Xa refused to pay this new tariff, arguing that they are not connected to the city's central sewerage connection system and that actual O&M costs for the DWWT in the village would be much lower than the money collected via the new tariff. Bac Ninh WSSC answered to this low willingness-to-pay with increased information and communication campaigns and many community meetings to explain the reasons for the new tariff collection, resulting in constantly rising rates of tariff payment in Viem Xa.

Based on data collected between 11/2013 and 02/2014, the monthly average O&M cost of the DWWT system is about 11,000,000 VND (524 USD). This figure includes the following items:

- Personal cost for one worker at the DWWT plant and one manager sitting in the WSSC office;
- Energy cost for pump and aerator;
- Sludge removal and transportation cost;
- Cost for sampling and analysis;
- Cost for repairs and spare parts; and
- Reimbursement for sanitation team.

3.1.5 Community Issues

During project implementation, a large range of information, education and communication (IEC) campaigns and events was implemented in Viem Xa, steered by the IEC expert of WMP in close collaboration with Hoa Long People's Committee and Bac Ninh WSSC. The IEC measures served the specific objectives to:

- raise awareness of the community about sanitation hygiene and water recourse protection;
- provide information to the community about the importance as well as implementation of activities of the demonstration project;
- mobilize the community to agree on and cooperate during the construction phase connecting households to the connection boxes of the SSS;
- mobilize the community to participate in works related to operation and maintenance of the drainage system;
- mobilize the community to pay the local wastewater fee to cover salaries for the Sanitation Team.

IEC activities included, besides surveys, numerous community meetings, a study tour to a similar DWWT demonstration system in a commune in Gia Lam, Hanoi, the establishment of a construction supervision team consisting of three selected residents, coaching on trouble-shooting and safe do-it-yourself sludge removal from connection boxes, should congestion occur during the absence of the Sanitation Team.

The thorough involvement of the community in the Viem Xa project is considered, besides the high commitments of PPC, local government and WSSC, a crucial factor for the success and sustainability of the project. For example, it was originally planned to install household connection boxes within the premises (courtyards) of private households. As most households refused this option, via community meetings and discussions, project planners and residents could agree on the technically more complex and more challenging option of installing the boxes in the public sphere, in front of the households inside the alleys.

3.1.6 Individual Lessons-learnt from this Pilot

The following lessons-learnt can be drawn from this demonstration project:

- A very **high commitment of all involved stakeholders**, the dedicated allocation of O&M budget by PPC, the pro-active and enthusiastic management of WSSC and the close involvement of the community resulted in a high **sustainability** of the project. However it must be mentioned, that most CAPEX and initially also OPEX were taken over by GIZ.
- From technical point of view, the chosen **SSS demonstrates a perfectly suitable solution** to erect a stable and sustainable DWWT system. This is mainly based on the fact that the quality of the collected wastewater is more or less constant as the sewage is not being diluted with rainwater and groundwater. Therefore the pollution level in the influent of the DWWT plant is as

assumed; hence the DWWT plant works properly. After the completion of the interceptor, the originally assumed wastewater quantity collected from the five targeted alleys has been achieved, without other wastewater sources flowing uncontrolled into the DWWT system.

- The average actual flow rate of the DWWT plant is $25m^3/d$, although the original design capacity is $40m^3/d$. That means that more alleys can still be connected to reach the design capacity of the DWWT plant. Also the fact that effluent values keep the required standard shows that the **system can still be used more efficiently**.
- The construction of the **interceptor pipe has turned out as very successful** due to the fact that co-treatment of rainwater and wastewater entering from uncontrolled sources is avoided. Due to the decreased wastewater flow also the sludge amount and sludge removal frequency has been reduced. Furthermore, with less required pumping time, the average operation time of the aerator in the AP, and therewith energy consumption, could be reduced.
- The **DWWT system operates simply and automatically**. However, a number of **O&M activities are required on a regular basis** to ensure proper operation. With husbandry prevalent at the connected households, the wastewater has a high solid content which requires regular cleaning and sludge removal activities, especially from house connection boxes. The sanitation team turned out as a suitable option to provide for weekly cleaning. Also the screens installed inside these boxes turned out to be suitable elements to prevent the DWWT system from excessive sludge accumulation and potential clogging. However, due to corrosion and high accumulation of sludge inside the boxes, the screens showed quick erosion and need for exchange.
- Another observation provided by the sanitation team is that in some house connection boxes the outlet pipes were laid much higher than the bottom of the box, which results in odour due to stagnating wastewater. A **proper design of the house connection boxes** is therefore required.
- The **SSS + ABR + AF + AP combination proved to be an adequate transport and treatment technology** to treat domestic wastewater.
- **Treatment efficiencies for BOD, COD and TSS proved to be very good**, averagely above 80%, which complies with the current Vietnamese standard QCVN 14:2008/BTNMT (although this standard is considered to be too strict, especially for small-scale systems).
- A **lower reduction of nutritional parameters** (i.e. N-total with 47% and PO4-P with 34%) compared to BOD, COD and SS can be interpreted as normal as these parameters were not considered during the design phase. However, based on international experience no parameters for nutrients are required for small-scale systems as the noxiousness of the wastewater is limited due to the low pollution load. The usage of a wetland system instead of the AP could have resulted in larger nutrient removal rates; however due to the fact that the treated wastewater is discharged into rice fields, in which the nutrients are taken up by plants, the higher nutrient values in the effluent do not constitute a systematic failure but are rather instrumental.
- Through the demonstration project, the **Bac Ninh WSSC acquired many skills and know-how on design, construction and O&M** of a DWWT plant. They also were appointed by a management contract as operator of the system. Therefore the demo project enabled the company to act as a replicator for this technology and a resource centre in the province. The recommended WMP policy "**decentralised treatment but centralised management**" has been therefore achieved in the case of Bac Ninh.
- The demo project had to face not only with wastewater but also **solid waste related problems**. The removed sludge causes a new environmental pollution without proper treatment. The possibility of treating the sludge at the centralised WWTP could be a potentially proper solution that was often discussed with WSSC but unfortunately did not realise until today. Anyhow, this demo project shows that a **holistic project approach is required** that takes all issues and stakeholders into account.
- Although the land was made available by the Hoa Long Commune People's Committee, a **high investment cost** was required for this relatively small demonstration project. In this context it is remarkable that the **collection system and the treatment system hold nearly the same portions in CAPEX** (49.7% and 51.3%). This shows that in order to establish a suitable DWWT solution (for which a proper SSS is a pre-condition) the collection and transport must be taken into account instead of focusing on end-of-pipe solutions.
- Despite the generally simple construction of the SSS, ABR, AF and AP, the construction process at Viem Xa did not go along as originally planned. A wall of the aeration pond was built in the wrong direction and had to be rebuilt. The **construction process must be closely supervised by trained and suitable staff** in order to make sure that everything is build according to the planned specifications. It is not always easy to give clear instructions to local workers. This may be due to language difficulties or due to their different working approaches.

3.2 Demonstration Project in Can Tho

3.2.1 Project Description

The demonstration project is implemented at Cai Khe Market, comprising more than 400 shops offering a large variation of products. Shops using water and thus generating wastewater sell mainly fish, seafood, meat, poultry, and vegetables. These shops are all located opposite to the main market entrance at the back of the market; close-by the Cai Khe canal. Most of the shops use river water, but tap water is also used by vegetable sellers. River water is used for cleaning the market floor and the market drainage system at frequent intervals. Two public toilets exist, one inside the market and one next to Cai Khe canal. An area of approx. $100m^2$ was used for the construction of the DWWT plant.

The maximum water consumption of the market was estimated with $120m^3/d$. Before the implementation of the WMP demonstration project, 100% of the generated wastewater was routed untreated into the canal. Due to the fact that the total wastewater quantity was considered too big (and expensive) for a DWWT demonstration project, which mainly serves for awareness building and capacity development purposes, the DWWT plant was only designed for $20m^3/d$; the remaining amount of wastewater was foreseen to be continuously discharged directly into the canal.

According to the implemented baseline survey performed during the project preparation period, the following design data were collected:

Parameter	Value	Unit
Wastewater quantity	20	m^3/d
Influent BOD_5	1250	mg/l
Influent COD	1950	mg/l
SS/COD	0.42	-
Inflow time	10	h/d
Temperature	25	^oC
Effluent BOD_5 (*)	50	mg/l
Effluent SS (*)	100	mg/l

(*) according to QCVN 14:2008/BTNMT

3.2.2 Institutional Issues

Right from the project start, without having any design documents in hand, the idea of the project was supported from the local political level, particularly the Chairman of the Can Tho City People’s Committee (CPC); hence it can be said that the project was demand-driven from an institutional point of view. During an official visit of the CPC and subordinated departments during the commissioning period, the local government further expressed the high interest of Can Tho City on the outcome of the demonstration project as well as their commitment.

For the project implementation phase, CPC as project owner agreed to establish a task force including staff of Ninh Kieu District Provincial People’s Committee, the Cai Khe market manager, the Can Tho WSSC and GIZ WMP.

WMP provided mostly consulting and supply services such as (i) preparation of the project concept and preliminary design (calculations & drawings), incl. proposal of the DWWT technology, (ii) supply of equipment (i.e. wastewater pump with control unit, plastic tanks for ABR and AF, as well as floating filter materials for the AF), (iii) commissioning of the DWWT plant after construction, and (iv) continuous technical advice regarding O&M on request by the selected operator (WSSC).

Ownership of DWWT plant and the new SSS belongs to the Ninh Kieu District People’s Committee (DPC). This government body is also project owner and mainly responsible to (i) bear all costs for O&M activities, (ii) instruct Cai Khe Market management to cooperate closely with the plant operator (WSSC) and (iii) develop and issue official O&M costs for the DWWT system.

As target group for project-related capacity development Can Tho WSSC was assigned to join major parts of the project such as baseline survey, construction and operation of the DWWT plant. The wastewater division of WSSC had taken over the following tasks during project implementation: (i) construction of manholes, pumping station and DWWT plant and installation of equipment, (ii) other services such as obtaining the building permission and other administrative procedures, (iii) construction supervision and quality assurance in cooperation with WMP, as well as (iv) O&M of the DWWT demo plant under assignment of Ninh Kieu DPC.

The Can Tho City Planning and Architecture Institute was nominated by the Can Tho WSSC to provide engineering and consultancy services related to the construction of the DWWT plant, pumping station and its connection to the existing sewer system of Cai Khe Market. The service products were (i) review of the pre-design as provided by WMP, (ii) detailed design for the DWWT plant, pump sump, connection of public toilets to the pump sump, piping works, foundation of the DWWT plant, fence surrounding the area, roof structure above the DWWT system, and electrical lighting, (iii) preparation of Bill of Quantities (BoQ) and cost estimation, and (iv) preparation of technical drawings, both in electronic version and hard copies.

Wastewater samples taken at Cai Khe market were analysed by staff of DoNRE Can Tho. Samples are taken during normal market operating hours as well as during floor cleaning in the evening.

3.2.3 Technical Issues

Design of the DWWT System

The location of the DWWT plant is very close to the river and the groundwater table is therefore very high. The underground construction of the DWWT plant would have been therefore difficult and expensive in order to be safe against flooding and backwater running into the DWWT system. Therefore the DWWT system was designed above ground; hence the wastewater has to be pumped into the system as not sufficient natural slope is available between the wastewater sources and the DWWT plant.

The pumping station is designed with a submerged pump (CP 3045) of the flow rate of $21m^3/h$. The stand-by pump (CP 3045.181 HT) of a flow rate of $23.5m^3/h$ was provided to replace the other pump in case of repairs. This high flow rate was chosen to make sure that no clogging occurs due to solid waste being flushed into the pump sump. The design dimensions of the pump sump are 1600mm x 1600mm x 2700mm (L x W x D). The running/stop time of the pump can be set on-site via a relay box. The pump is connected to a floating switch installed in the pump sump to avoid that the pump is running dry, which is important as the pumps' flow rate is much bigger than the average wastewater design flow rate. To better adjust the flow rate into the DWWT plant, a gate valve was installed in the pump sump. This valve is operated manually in order to optimize the flow rate via adjustment of both, the gate valve and the relay box.

The wastewater flows through a SSS made from PVC pipes from the different collection points within the market area into the pump sump. The rainwater accumulating outside of the market hall is also drained into the system through open collecting points. Because of high amounts of debris and coarse materials, three previously available manholes had been renovated and equipped with screens in order to protect the pump. From the pump sump, a PVC pressure pipe (DN50, 60m long) is used to pump the wastewater into the DWWT plant.

The DWWT plan was originally planned in two parallel and independent lines; lying at the embankment of the Cai Khe market. Due to the risk of embankment failures the plant had to be build a little further away from the river and with only one line instead of two. Hence the extremely weak and partly eroded embankment led to a reduction of the original capacity ($40m^3/d$ to be treated in two parallel lines) by 50%. Additionally a more expensive and sophisticated foundation for the DWWT plant became necessary compared to the originally planned structure.

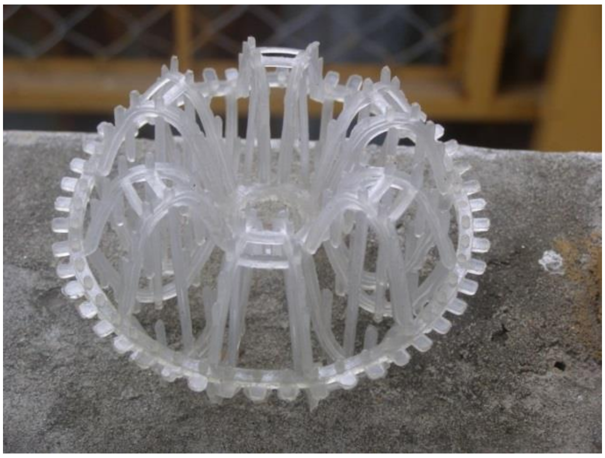
Because of lacking space, only two treatment levels had been designed; hence no tertiary treatment which usually has a larger footprint. The primary treatment step was designed in form of an ABR, followed by a secondary step consisting of an AF. The ABR + AF combination was included in a total of seven plastic tanks standing above ground.

The following graphic demonstrates the general arrangement of the DWWT modules:

The first tank is used as sedimentation tank to pre-treat the wastewater; the subsequent tanks were used as ABR and AF respectively. Initially only the last tank (tank 7) had been used as AF. Bamboo pieces were filled inside the tank as biological carrier. In order to prevent the bamboo pieces from being flushed out, a grid had been installed in front of the outlet pipe. The bamboo material became rotten after some time which reduced the treatment efficiency. In 2012, WMP replaced the bamboo with a new plastic carrier and increased the total AF volume by converting tank 6 (so far ABR) into an additional AF chamber.

The treated wastewater is collected in a sampling tank before being discharged into the canal via an overflow pipe.

The following pictures show the arrangement of plastic tanks as well as the AF plastic carrier:



The dimensions of the ABR/AF tanks are shown in the following table:

Tanks	Sedimentation tank	ABR (4 tanks)	AF (2 tanks)	Sampling tank
Volume of Tank	3 m^3	3 m^3	3 m^3	1 m^3
Height of Tank	2,070 mm	2,070 mm	2,070 mm	1,150 mm
Diameter Tank	1,440 mm	1,440 mm	1,440 mm	1,200 mm

Note: The water level in the ABR and AF is 1.80m; the water level in the HPGF is 0.80m

Sludge generated in the ABR and AF tanks is removed from its bottoms. Each tank connects to a sludge chamber, via a connection pipe. Sludge is removed by opening a small valve. The sludge chamber located outside of the plant has a volume of 6 m^3 and is emptied regularly with a suction modern suction truck owned by WSSC.

Initially the generated biogas was planned to be used for lighting of the treatment plant. A pipe collecting the biogas is running along the tanks. After the burning device got destroyed an electrical lamp got installed for lighting. The biogas is now directly released into the environment, disturbing residents with odour. Sunlight caused fast deterioration of the PVC connection pipes, especially on the T-pieces and valves located between the tanks. Therefore a roof was installed to protect the system from UV radiation.

O&M of the DWWT System

In order to save energy and hence operational cost, decision makers of the Ninh Kieu DPC limited operation time of the DWWT plant to 10 hours daily. Therefore the DWWT plant operates from 7am to 5pm. On days of flooding the plant is not taken into operation at all. The overflow pipe is installed within the pumping station in order to discharge the residue wastewater directly into the river. In case of flooding, the river water flows back into the system and causes flooding in the market. Four pipe branches are connecting the market area with the pumping station, of which only two are equipped with tidal gates to prevent the backflow of river water into the system. However, due to technical failures these gates do not work properly. The WSSC is planning to install gates for the two other branches and repair damaged gates.

In principle, the system operates automatically after starting the pump. Even though, a number of O&M activities must be implemented regularly.

Every Monday the sludge levels in the 7 tanks are measured with a sludge pipe by WSSC. If the sludge reaches a certain level it is removed from the bottom of each tank via the de-sludge pipe (possible as the tanks are constructed above ground). As the valve is located at the tanks' bottom, no turbulences are caused during the de-sludging process. The sludge chamber has a volume of $6m^3$ and is located next to the DWWT plant. According to the sludge removal schedule recorded by WSSC, this sludge chamber is emptied after five weeks. Postponing de-sludging could cause accumulation of sludge in the ABR and AF, which reduces the usable tank volume and negatively affects the treatment efficiency. Can Tho WSSC owns a modern cleaning vehicle, which is used for sludge removal from the sewer system and the sludge chamber of the DWWT plant. Recently, removed sludge is disposed of in the landfill.

The most serious problem of the DWWT plant in Can Tho is not the wastewater but the solid waste flushed towards the system from the market. Due to the prevailing habit of Cai Khe market shop owners and market visitors to throw all solids and liquids to the floor, nearly all wastes end up in the drainage system and finally in the pump sump. During one year of operation, pump failures have happened various times due to solid waste. To tackle this major challenge, WMP and WSSC together conducted a range of IEC campaigns targeted at market vendors and the management board and supplied 10 new garbage bins to the market (for more details see sub-chapter "3.2.5 Community Issues").

Although three screens were installed in the grid chamber, many small debris and solid waste such as fish scales and intestines still can enter the pump sump and damage the pump. The operator is therefore also responsible for removing and dredging them out from the pump sump every 15 days and from grid chambers every five days. The collected solid wastes are collected in baskets and dried under the sun light before deposited together with the regular market solid waste. Solid waste collection (sweeping) within the market is conducted by a sanitation team of the market; for outside areas of the market, URENCO of Ninh Kieu district agreed to sweep adjacent streets and empty the newly installed waste bins. Both, URENCO and the market sanitation team are reimbursed for their services via a fee collected by the market management board from each vendor (more details see sub-chapter "3.2.4 Financial Issues").

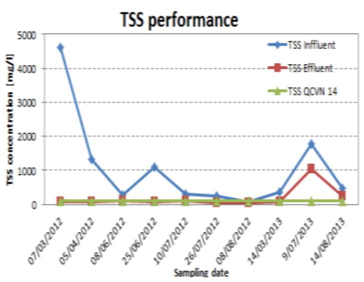
<u>Performance of the DWWT System</u>

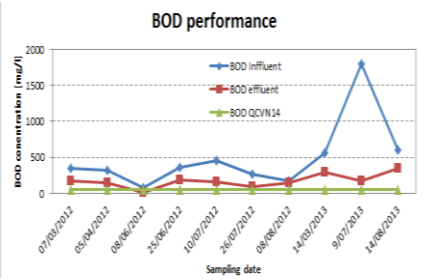
The Centre of Resource and Environment Monitoring, belonging to Can Tho DoNRE, held a contract with WMP to take and analyse samples regularly. Random samples were taken at the pump sump (influent) and the sampling tank (effluent). The operator of the DWWT plant (WSSC staff) was assigned to support the laboratory staff during sampling. Beginning of the year 2014, WMP stopped paying for sampling and it was agreed that the cost of this task should be taken over by WSSC. Unfortunately, two pumps got broken at the same time; hence the DWWT plant has been brought out of operation. During preparation of this report repairing of pumps is under discussion within WSSC and no further information has been provided to WMP so far.

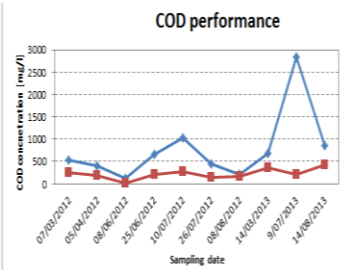
As per available sampling results, the influent quality was not very uniform. The influent values fluctuate around the design data within large ranges. The wastewater quality varies frequently depending on actual proceedings at the market as well as the water level of the receiving body. The reason for the latter is that through the overflow pipe surplus wastewater is discharged from the pump sump into the canal. Vice versa, river water from the canal can also flow back into the pump sump in case of high tides, which results in dilution of wastewater in the pump sump. Also the floor cleaning activities at the market produce a high water amount with low pollution content, which ultimately dilutes the wastewater in the pump sump (influent). The exact time of taking the sample can therefore make a large difference in the inlet concentrations and hence in the calculated treatment performance of the DWWT plant. Therefore, all actual local conditions should be considered and recorded in the sampling record when taking samples, what did not happen always. Long-term wastewater monitoring as well as occasional mixed sampling over a couple of hours was required in order to get a more accurate overview of the performance of the DWWT plant.

Low treatment performance in regard to BOD, COD and SS with average values of 57%, 61% and 67% are caused by lacking tertiary treatment (which was not feasible due to lack of space). The sludge level of the ABR and AF tanks has been measured every Monday, but the sludge removal seems not to be implemented properly. Too long retention times of sludge in the tanks, resulting in reduced reactor volume for the wastewater, cause an improper treatment process. On the other hand, the high ambient temperature of Can Tho speeds up the biological treatment processes in the DWWT plant, resulting in high sludge amounts generated in comparatively short time.

The following graphics show the sample results for TSS, BOD and COD between March 2012 and August 2013, in which the blue lines show the concentration in the WWTP inlet, the red lines the outlet concentrations, as well as the green lines the required QCVN 14:2008/ BTNMT standard.







Above graphics show that the required direct discharge standard for TSS and BOD are not always achieved with the DWWT system due to lack of a tertiary treatment step. The following table presents the detailed sampling results for the same sampling period.

Time	Parameter														
	pH (5-9)		TSS (mg/l) (100)			COD (mg/l) (-)			BOD_5 (mg/l) (50)			Amoni (NH4-N) (mg/l) (10)			
	Infl. at pumping station	Eff. at sampling tank	Infl. at pumping station	Eff. at sampling tank	Treatment efficientcy (%)	Infl. at pumping station	Eff. at sampling tank	Treatment efficientcy (%)	Infl. at pumping station	Eff. at sampling tank	Treatment efficientcy (%)	Infl. at pumping station	Eff. at sampling tank	Treatment efficientcy (%)
07/03/2012	6.85	6.86	4604.1	64	99	530	243	54	350	165	53	186	147	21
05/04/2012	6.89	7.14	1332.3	67	95	400	191	52	320	150	53	239	191	20
08/06/2012	7.28	7.78	280	110	61	119	17	86	80	11	86	51	46	10
25/06/2012	6.79	6.84	1085	73	93	663	219	67	360	180	50	88	149	-69
10/07/2012	7.82	8.23	311	113	64	1023	276	73	460	160	65	98	80	18
26/07/2012	6.7	7.01	255	62	76	453	137	70	270	90	67	205	162	21
08/08/2012	7.03	7.08	63.8	53	17	211	165	22	170	140	18	212	211	1
14/03/2013	6.65	6.77	364	82	77	690	355	49	560	290	48	123	144	-16
9/07/2013	7.27	7.34	1790	1055	41	2836	218	92	1800	165	91	74	100	-35
14/08/2013	7.08	7.32	466	242	48	848	424	50	600	350	42	191	91	52
Average			**809**	**185**	**67**	**743**	**369**	**61**	**479**	**273**	**57**	**128**	**115**	**-4**

3.2.4 Financial Issues

Total capital expense for the DWWT plant and the sewer system is about 700,000,000 VND (33,330 USD), funded by GIZ. Some additional items like grid chamber with screens, dust bins and other small devices had to be installed due to poor solid waste handling at Cai Khe market. This caused unexpected additional expenses.

According to Can Tho WSSC, monthly O&M cost are about 10,000,000 VND (475 USD). This figure includes staff, energy cost for pumping, cost of potable water for cleaning tools and equipment, cost for sludge removal and disposal with the cleaning vehicle, as well as repair costs. The cost for sludge removal and disposal is calculated based on the sludge amount. The DWWT plant is out of operation at night time, therefore no energy for lighting is necessary; hence the pump requires most of the electricity.

A fee system to recover O&M costs for the DWWT system, collected from shop owners in the market could not be implemented. All vendors already pay a fee for sanitation, solid waste, security and other services, which is collected by the market management board. This fee is used to pay for the market sanitation team in charge of solid waste collection within the market and for URENCO of Ninh Kieu district in charge of solid waste collection and waste bin emptying in outside areas surrounding the market. Also, the market management board occasionally hires Can Tho WSSC to clean the feeding pipe and the pump sump of the DWWT system, whenever it is congested. As of July 2014, however, cleaning of the market-internal drainage pipe feeding system has entirely been taken over by the market management board. WSSC's O&M activities now only focus on the pump sump, the pump and the plant itself.

The question on costs for O&M of the remaining system (e.g. pump costs, desludging of ABR tanks, etc.) remains unanswered, though more recently, positive developments were reported. When the question of budgets for O&M of the DWWT system had been raised early during the project planning process, Ninh Kieu DPC had agreed with WMP and Can Tho WSSC that an O&M budget would be provided to WSSC and that costs would not have to be borne by the market vendors. However, after WSSC submitted several O&M budget requests to DPC, no decision by DPC has been taken and no budget has been allocated to WSSC so far. This resulted in a difficult situation for WSSC who had to cross-subsidize O&M costs from water supply revenues and therewith do O&M without being paid for it since several years. As DPC failed to approve an O&M budget, WSSC went as far as to even threaten to stop O&M entirely, should they not be reimbursed, as promised.

According to information from WSSC in July 2014, CPC has reallocated budget responsibility for the plant to DoC and WSSC has submitted a new budget request to DoC for approval. Should this request be approved, WSSC will receive a steady annual budget for O&M and will also be reimbursed for the O&M costs of past years.

Asset ownership of the DWWT plant belongs to the Ninh Kieu DPC and this government body should bear the O&M costs according to the agreement documented in the handing-over protocol, signed on 30 March 2012. Due to lack of a base for O&M cost calculation the People's Committee requested WSSC to pay all O&M expenses in advance until the end of 2012. Actually, this phenomenon has already lasted for two years (until end of 2013) and caused many financial problems for WSSC, which is therefore not able and willing to operate the DWWT efficiently anymore. Up to the end of 2013, the People's Committee was collecting invoices and information about expenses paid by WSSC and WMP in order to elaborate the unit rates and cost norms for O&M activities.

3.2.5 Community Issues

As discussed above, solid waste entering the feeding pipes and the pump sump of the DWWT system have been the major challenge for the project in Can Tho. To counter these, a range of IEC measures was implemented in cooperation with the management board of the market, WSSC and WMP. These ranged from the supply of 10 garbage bins, the arrangement with URENCO of Ninh Kieu district to take care of solid wastes in surrounding areas, awareness and behaviour change communication meetings with market vendors, the amendment of the internal market regulation to daily loudspeaker announcements on solid waste problems and behaviour reminders.

As a direct result, each vendor purchased small garbage bins for their stalls, fish and crustacean sellers started using small trays or other tools to prevent scales and shells from entering the drainage channels that lead to the pump sump. At the same time, the market management board was urged to increase patrols by security guards, checking adherence to new regulations and reminding vendors of proper behaviour.

As of July 2014, information provided by WSSC revealed a positive long-term impact of the IEC measures. Vendors show improved behaviour patterns and the market management board is taking over a stronger role in managing solids in the market and the situation of waste entering the drainage pipes and the pump sump has eased. This, combined with an increased maintenance frequency of the pump sump through WSSC results in a stable operation of the system.

3.2.6 Individual Lessons-learnt from this Pilot

- The local government, particularly CPC and DPC, as well as Can Tho WSSC were **strongly interested in this demonstration project** and **provided adequate support** to complete the construction of the system.
- WMP, by means of many trainings and IEC activities, provided knowledge and skills on construction and O&M of the DWWT plant to the staff of WSSC as well as enhanced environmental awareness to the community. Hence, although the demo project may not have huge environmental significance due to the small wastewater flow rate; it shows that **a simple DWWT plant can be built under local conditions without the mobilization of great funds.**
- **Pre-fabricated plastic tanks can be used** for construction instead of concrete and bricks, especially in places where frequent flooding occurs.
- Due to the unexpected existence of inappropriate soil conditions, the unforeseen construction of a new sewer system, as well as due to the environmental habits of the vendors causing permanent clogging of sewers and breaking of pumps, both **CAPEX and OPEX turned out to be higher than originally estimated**.
- The **sampling and performance monitoring programme should be considered very carefully**. Due to (i) external phenomena such as high tides, (ii) momentum activities/conditions such as flushing of the market surface or (iii) delaying the sludge removal from the treatment tanks, the wastewater quality in the influent as well as the treatment performance of the DWWT can vary significantly. Hence, local conditions and the operational status of the DWWT plant should be considered and recorded in the sampling protocol in order to facilitate and enable the evaluation and interpretation of sampling results.
- The **improperly selected pumps consume unnecessary amounts of energy** as only a small wastewater amount is pumped into the DWWT plant and the rest is discharged directly into the canal without treatment.
- Besides that, **flow rates should be checked** regularly to ensure that the plant works within the designed capacity. Only if minimum hydraulic retention times as well as maximum flow velocities within the tanks are kept, the DWWT system is able to achieve the anticipated effluent results.
- The treatment efficiency has been achieved only up to 60% of the required effluent standard due to the **lack of a tertiary treatment module**. Besides, odour problems are caused due to the lack of a final aerobic treatment step.
- Removed and untreated **sludge is improperly deposited** in a landfill, which causes further environmental problems.
- Although all involved stakeholders, incl. the state management bodies, were very interested and engaged in the project from the early start, the O&M cost coverage did not work out as originally agreed. Delays in paying the agreed OPEX by the asset owner to the service provider create financial difficulties for WSSC and subsequently endanger the project's sustainability. Therefore it should be imperative that already during the first implementation step O&M costs are calculated and that an allocation schedule for OPEX is already clarified and realized. An important lesson learnt is therefore that a clear **O&M contract** and **fee system** must be in place before a project is started.
- **Remote assessment and decision making** of WMP experts concerning local technical and institutional conditions **created complications and timely delays**, e.g. in regard to interpretation of sampling results or in regard to the clarification of operational errors.
- Although some negative lessons regarding institutional, financial and technical issues were learnt, the **service provider (WSSC) as well as the local decision makers (DoC) expressed their motivation in the up-scaling of the DWWT approach** by replicating DWWT systems in other suitable locations of the city and have already taken first steps to actually do so.

3.3 Demonstration Project in Vinh

3.3.1 Project Description

The DWWT demonstration project in Vinh includes the collection and treatment of wastewater generated at a school and a kindergarten with the objective to demonstrate the DWWT concept and suitable technologies in the city. Nguyen Truong To School is the secondary school in Hung Dong Commune. The Commune is located in the north west of Vinh City. At the back of the school is the Hung Dong Kindergarten, separated from the school by a road. Both locations, the kindergarten and the school, were selected to be connected to one DWWT system.

The school hosts a total of 820 pupils and 68 teachers, half of which attend school during morning hours and another half in the afternoon. In the kindergarten all 280 children and 23 teachers attend classes for the whole day. In the kindergarten lunch is cooked in a kitchen located in the backside of the main building. The DWWT plant was built within the school premises to treat the wastewater from school toilets, kindergarten toilets, the kindergarten kitchen and bathroom.

Since no reliable data for water consumption or pollution loads were available, these had to be estimated based on the number of children, pupils and teachers as well as operating hours. The water consumption was estimated with 15 l/person/day. The design data were considered as follows:

Parameter	Value	Unit
Wastewater quantity	18	m^3/d
Influent BOD_5	250	mg/l
COD/ BOD ratio	1.90	-
SS/ COD ratio	0.42	-
Inflow time	10	h/d
Temperature	25	^oC
Effluent BOD_5 (*)	50	mg/l
Effluent SS (*)	100	mg/l

(*) Effluent standard according to QCVN 14:2008/BTNMT

3.3.2 Institutional Issues

The direct project partner is Vinh City Infrastructure Development and Management Joint Stock Company (INFRAVI). INFRAVI is a utility managed by Vinh City People's Committee and has been assigned with the management and operation of the drainage system for the whole city since 1993. INFRAVI is one of WMP's core counterparts in the province, so also in this case for the development of the DWWT demo project. The demonstration project was promoted by WMP by establishing a task force including staff of INFRAVI, WMP as well as Dai Viet Construction Investment and Consulting Company, a private design and consulting company from Vinh City. No political authority participated in this project.

WMP provided mainly consulting and supplying services such as (i) development of the DWWT concept and preliminary design (calculations and technical drawings) as well as a proposal of suitable treatment modules, (ii) supply of equipment, (iii) commissioning of the DWWT plant, as well as (iv) technical advice on request.

Dai Viet Construction Investment and Consulting Company provided the engineering and consultancy services related to the construction of a small pumping station and the DWWT. The service products were (i) review of the pre-design as provided by WWP, (ii) detailed design of the connections to toilets, piping works, the pumps sumps, the foundation of the treatment plant and the DWWT modules, (iii) cost estimation (based on BoQ and current unit rates), as well as (iv) preparation of technical drawings both in electronic version and hard copies. The Dai Viet Company was also responsible for construction supervision and quality assurance.

As part of WMP's capacity building objective, INFRAVI was assigned to join major parts of the project, incl. baseline survey. INFRAVI's wastewater division has accepted the tasks of (i) construction and installation of equipment, and (ii) O&M of the DWWT plant. However, neither a formal assignment for O&M service provision nor a strategy for O&M costs coverage was developed.

The investment cost was entirely covered by GIZ. Nguyen Truong To school, on which premises the system was built, was selected as asset owner.

3.3.3 Technical Issues

Design of the DWWT System

The wastewater collection system in form of a SSS was constructed to collect wastewater from the kindergarten and the school. Inside the school, PVC collection pipes of DN110 were laid with a slope of 1%, connecting the septic tanks of the existing school toilets to the inlet of the DWWT plant. The short distance between the school toilets and the adjacent DWWT system allow a flow by gravity.

The wastewater generated within the kindergarten (toilets with septic tank, kitchen and bathroom) is collected in a small pumping station of 1,300mm x 1,300mm x 2,200mm (L x W x D), located in the back garden of the kindergarten, and pumped from there into the DWWT plant via a pressure pipe of DN50. No detailed specification about the pump, which was selected by INFRAVI and funded by GIZ, is available. A simple control box was installed which indicates the functional state of the pump via two lamps. An automatic floating switch was installed to protect the pump from running dry.

The chosen DWWT technology includes an ABR + AF + HPGF combination, as displayed in the following figure. The treatment modules are constructed underground in a series of a total of eight ABR and AF chambers made of concrete.

The dimensions of the ABR and AF chamber are shown in following table:

Tanks	Sedimentation (1 tank)	ABR (6 tanks)	AF (2 tanks)	HPGF
Dimension (L, W, D)	230 x 2000 x 2150	850 x 2000 x 2,150	1500 x 2000 x 2150	10750 x 1950 x 1300

Note: The water level in the ABR and AF is 1.80m; the water level in the HPGF is 0.80m

The two AF chambers are filled with bamboo filter material. The HPGF severs as tertiary treatment module, which consists of a sand layer of different diameters, a gravel zone and reed plants on the surface. The wastewater coming from the AF is distributed equally over the entire width of the HPGF via a perforated distribution pipe and flows from there horizontally through the filter material.

The following pictures show the DWWT modules in Vinh, as well as the outlet box with the clear effluent:

O&M of the DWWT system

Regular simple O&M activities must be implemented to ensure the operation of the system. Most important tasks are measuring the sludge level inside the ABR and AF chambers on a monthly basis, as well as de-sludging the tanks - particularly the sedimentation tank and the first chambers of the ABR - every 18 to 24 months.

The following pictures show INFRAVI staff taking sludge samples in the ABR and AF:


Depending on the effluent quality, the filter material in the AF chambers has to be replaced when the maximum allowable effluent concentration is reached. This is required roughly once a year.

On a monthly basis, the inlet to the sedimentation tank and the ABR and AF chambers should be checked in order to avoid clogging.

The reed plantation in the HPGF should be cut after 3 months to avoid mosquito breeding. Solid waste should be removed from the HPGF surface as needed.

Although INFRAVI had been assigned based on the initial project agreement to take over O&M responsibility, it seems that no staff are assigned and no regular O&M activities are implemented due to lack of a dedicated O&M budget. No O&M budget was planned and no subsidization for O&M expenses was mobilized.

Performance of the DWWT System

The effluent of the DWWT system is free of odour. Due to the very transparent outlet water via visual evaluation and in order to save money, SS were not analysed.

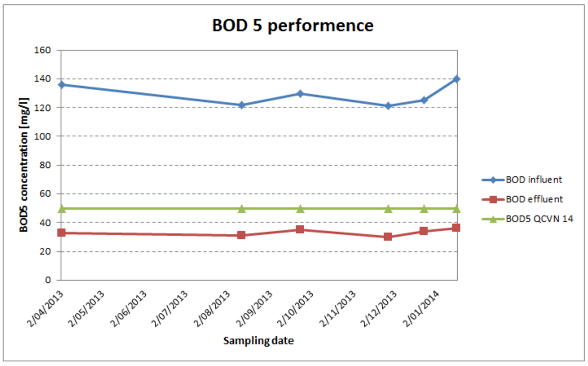
The average reduction rates of COD and BOD are 75% and 74% respectively, which achieves required direct discharge standards as formulated in QCVN14.

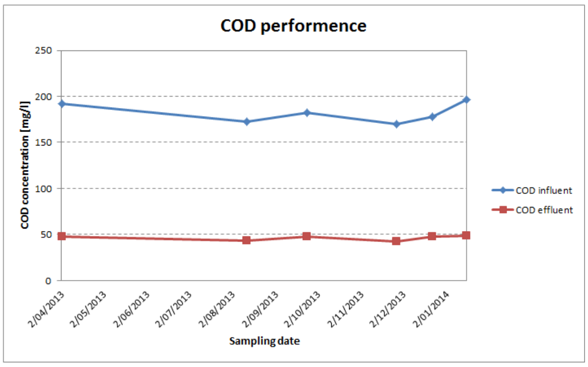
A high reduction of nutrients (above 70%) can be interpreted as a very efficient nutrient metabolism by the reed plantation in the HPGF.

The effluent water is discharged directly into a drainage channel located outside of the school yard, which leads to adjacent rice fields. Hence, the effluent water is used for irrigation without any possibility to get in direct contact with humans.

Since 2014, the sampling activities were handed over to INFRAVI. Since then no further sampling results were provided, which can be lead back on the missing budget for O&M.

The following graphics show the sample results for BOD and COD between April 2013 and January 2014, in which the blue lines show the concentration in the WWTP inlet, the red lines the outlet concentrations, as well as the green lines the required QCVN 14:2008/ BTNMT standard.





Above graphics already show that the required direct discharge standard for TSS and BOD are usually achieved with the DWWT system (no QCVN standard for COD). The following table presents the detailed sampling results for the same sampling period.

No.	Date	Parameter																
		pH		COD (mg/l) (-)			BOD_5 (mg/l) (50)			Amoni (N - NH4) (mg/l) (10)			Nitrat (NO3-N) (mg/l) (50)			PO_4-P (10)		
		Influent (in pumping station)	Eff. In discharg hole	Influent (in pumping station)	Eff. In discharg hole	Treatment efficient (%)	Influent (in pumping station)	Eff. In discharg hole	Treatment efficient (%)	Influent (in pumping station)	Eff. In discharg hole	Treatment efficient (%)	Influent (in pumping station)	Eff. In discharg hole	Treatment efficient (%)	Influent (in pumping station)	Eff. In discharg hole	Treatment efficient (%)
3	2/04/2013			192	48	75	136	32.8	76	10.7	2.5	77						
4	12/08/2013	7.57	7.38	172.8	43.2	75	122	31	75	4.83	1.05	78	19.23	7.84	59	5.69	1.1	81
5	24/09/2013	7.21	7.15	182.4	48	74	130	35	73	5.06	1.54	70	20.11	6.92	66	7.17	1.26	82
7	27/11/2013	7.84	7.53	170	42.5	75	121	30	75	6.6	1.7	74	18.2	4.9	73	5.7	1.4	75
8	23/12/2013	7.67	7.56	177.6	48	73	125	34	73	7	1.9	73	21.2	6.4	70	5.8	1.6	72
9	16/01/2014	6.78	7.34	196.8	48.4	75	140	36	74	9.51	2.02	79	28.5	6.1	79	6.5	1.68	74
Average				**181.93**	**46.35**	75	**129.00**	**33.13**	**74**	**7.28**	**1.79**	**75**	**21.45**	**6.43**	**70**	**6.17**	**1.41**	**77**

3.3.4 Financial Issues

Total investment cost of the DWWT plant in Vinh was about 590,000,000 VND (28,100 USD), including the following components:

Component	Cost [mill. VND]
Pumping station and pressure pipe	93
ABR and AF chambers	351
HPGF	140
Pump	6

Due to the small scale of the DWWT plant and simple civil works as well as equipment, no considerable follow-up cost appeared.

After handing over the DWWT plant to the asset owner, INFRAVI took very limited action on O&M. Therefore, no comprehensive information on O&M had been collected. Therefore, WMP had to estimate O&M cost under the assumption of 9 h/d pumping, and 2 d/month for manpower. The estimated O&M cost of this plant is about 800,000 VND/month (40 USD/month).

3.3.5 Community Issues

A comprehensive IEC package accompanied the demo project in Vinh, targeting teachers and pupils of both school and adjacent kindergarten, serving the following objectives:

- Build capacities of teachers in education and communication on environmental sanitation through positive teaching methods;
- Raise awareness and change behaviour on environmental sanitation of students through practical activities in schools;
- Develop school toilet management plan with the active participation of students.

Activities included a two-day training course for teachers on systematizing knowledge about sanitation, teaching methods, communication skills, environmental sanitation for different age-groups. Result of the course was an agreed communication plan and a management plan for the school toilets the DWWT system is connected to.

The communication plan developed during the training was subsequently implemented by teachers during extra-curricular hours, supported by staff of INFRAVI and the WMP IEC expert. The range of communication activities included:

- Development of teaching materials, colouring books, posters, picture sheets
- Introduction of a toilet regulation
- A competition on environmental sanitation with 800 participating students
- Regular hand-washing campaigns in the kindergarten
- Hanging up of posters and pictures in toilet rooms
- A painting competition
- Art performances

- Teaching sections in each class on environmental sanitation and using the toilet

The pictures below are examples of some of the communication activities:




3.3.6 Individual Lessons-learnt from this Pilot

- Due to very good treatment efficiencies – even without proper O&M – the DWWT plant in Vinh shows the opportunity to construct small **DWWT plants that are able to treat wastewater generated at hot spots with low CAPEX and OPEX** to the required legal direct discharge limits.
- The good treatment results of the **HPGF show a simple but effective technology for tertiary treatment** that is able to (i) eliminate odour from the effluent after anaerobic treatment, as well as (ii) efficient removal of nutrients. The module furthermore showed low demand for O&M.
- However, a rather supply driven project setup resulted in an unsustainable institutional project setup. Due to the **lack of the participation of political authorities**, no official assignment for an asset owner and – more importantly – for a service provider for O&M was allocated. Also, due to the **lack of a clear budget allocation** for O&M the DWWT system is not operated properly after handover. The sustainability of this particular demonstration project is therefore limited.
- An important lesson learnt is therefore, that **clear institutional responsibilities must be appointed during the project implementation phase** in order to ensure sustainable operation of the project. This includes clearly appointing the future asset owner, operator and service provider for the DWWT system. A **management contract** between the asset owner and the service provider is therefore a requisite. A proper **financing system for OPEX** is a crucial element for the financial sustainability of a DWWT project.

3.4 Demonstration Project in Son La

It should be highlighted that this demonstration project, as well as the project in Soc Trang, is part of a second round of demonstration projects initiated by WMP and is an important cornerstone of the scaling-up strategy of the programme. The projects in Son La and Soc Trang were planned, having the above presented lessons-learnt from the previous three projects in mind. An important innovation and pre-condition for this second round of projects is that all CAPEX are to be covered by local budgets, no financial contributions to investments costs are made by WMP. Only ideas and advice are presented to local stakeholders who bare the full implementation responsibility and are fully in the driver’s seat of all activities. The project in Son La is under implementation at the time of preparation of this lessons-learnt paper. The DWWT plant is under construction while this paper is being written; hence no lessons-learnt can be presented about e.g. O&M or performance of the system.

3.4.1 Project Description

The DWWT demonstration project in Son La is designed to collect and treat wastewater generated from To Hieu Primary School. The school was selected by local counterparts, including the City People’s Committee and Son La Son Urban Environment Company (URENCO), as the location will not be connected in a foreseeable timeframe to the KfW-financed centralised WWTP, which is currently under design. The DWWT plant is located at the backyard of the school, adjacent to the boundaries of the school premises and next to a canteen and kitchen that was under construction meanwhile the DWWT was planned.

At the time of the baseline data collection 580 pupils and 41 teachers were present at this school. In close future, the number of pupils and teachers will be increase to 840 and 45 relatively. The DWWT plant was therefore designed for the future wastewater quantity and is built to treat the wastewater generated from two existing in-building school toilets, future external toilet blocks, as well as the kitchen and canteen. The design capacity of the DWWT plant is $18m^3$/day.

3.4.2 Institutional Issues

The project partner in Son La City is Son La URENCO. According to the official document No.2418/UBND-KTN, issued on 20 September 2013 by Son La PPC, the PPC generally agreed to implement a Feasibility Study (FS) for a DWWT demonstration project within Son La and requested WMP to provide consulting services for carrying out related survey and for the preparation of this FS Report in collaboration with Son La URENCO. Son La PPC also assigned Son La DoC and DoF for appraising the technical and financial aspects of the FS accordingly. As a result, a task force including staff of URENCO, DoC as well as the Urban Management Bureau of Son La CPC was established in order to implement this project.

According to Circular No. 12/2012/TT-BXD, dated 28 December 2012, on National Technical Norms and Principles for categorizing the class of civil and industrial constructions and technical infrastructure, this DWWT demo project belongs to “urban technical infrastructure” class V. Hence, only a so called “Economic-technical Report” instead of a full-scale FS, which is only required for bigger investment projects, is required. With the official Document No. 454/QD-UBND, dated 13 March 2014, Son La PPC officially assigned Son La URENCO as project implementer to prepare the Economic-technical Report, including survey and design, and then to submit the report to relevant provincial stakeholders for appraisal and approval. Construction supervision works were also appointed to Son La URENCO.

WMP provided mostly consulting services such as (i) surveying and baseline data collection, as well as (ii) preparation of project conception and preliminary design. All WMP inputs were implemented in close collaboration and participation with experts from URENCO. Son La URENCO prepared based on WMP’s pre-design, related technical drawings of the collection, transport and treatment modules, as well as the related BoQ and investment cost. URENCO prepared independently the Economic-technical report and submitted it for appraisal and approval.

WMP’s main input during the planning and design phase was (i) conducting a design workshop with URENCO and other project counterparts to build awareness and capacities about the design and construction of the DWWT modules, and (ii) on-the-job training and coaching during the preparation of the detailed design and technical drawings.

Son La CPC was appointed as future asset owner in the same PPC decision that assigned CPC to provide financial resources from provincial state budget for the construction of the infrastructure.

After financial and technical appraisal and project approval, construction works were implemented by an eligible and reputable local private company, which was contracted within a single-source selection process. URENCO is in charge of construction supervision.

As the project is still under construction during preparation of this report, Son La CPC has not yet assigned an operator for the DWWT system. It is intended that Son La URENCO will be in charge for O&M under a proper performance contract.

3.4.3 Technical Issues

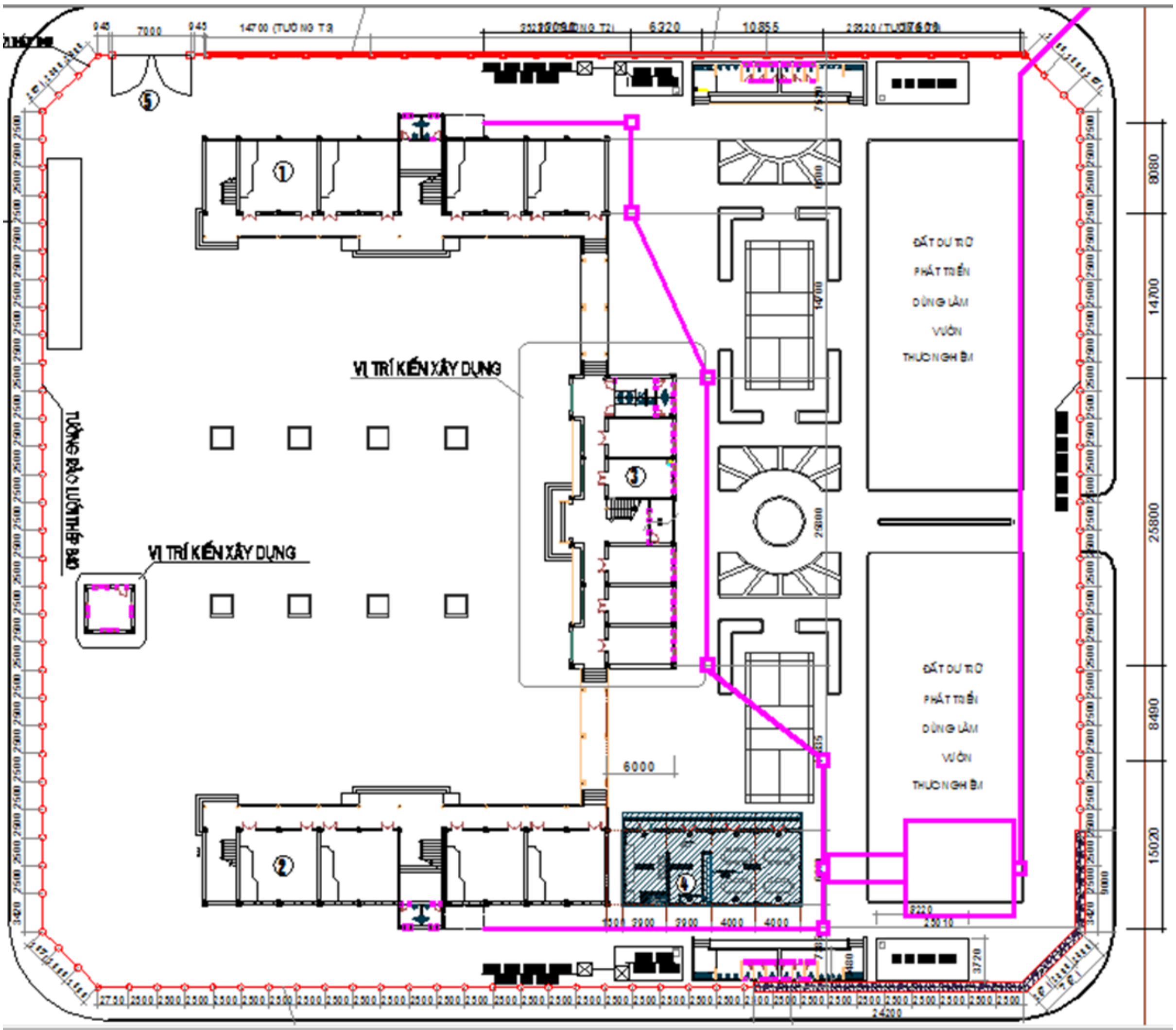
<u>Design of the DWWT System</u>

The project incorporates existing septic tanks connected to the in-house toilets of the two existing school building for pre-treatment. A new SSS is installed with 1% slope and PVC pipes of DN150-200, connecting the outlets of the two existing septic tanks, the collection tank of the canteen, the toilets of the future third school building and external toilet blocks to the DWWT plant. The future toilets will be equipped with settlers for pre-treatment to avoid clogging within the SSS. Junction boxes with the dimension of 1,200 x 1,200 x 760 (L x W x D) are installed within the SSS where pipes join or direction changes occur. Additional inspection chambers are located every 30m to allow for cleaning of the SSS. The inspection chambers are built with a concrete superstructure, and an underground chamber made by large-diameter PVC pipes that are connected by PVC-joints to the SSS-pipes.

The DWWT plant includes two general treatment processes: an anaerobic secondary treatment in ABR and AF, as well as aerobic tertiary treatment in a HPGF. The ABR and AF tanks are constructed by bricks and concrete mortar grade 75. Their bottom and cover are made by reinforced concreted grade 200. The AF will be filled with cheap and locally available materials such as bamboo or rough gravel. The HPGF will be filled with gravel of different grades and planted by appropriate vegetation.

The treated wastewater will be discharge to an existing underground drainage channel running along the school premises via a DN200 PVC pipe laid at 1% slope. Inspection chambers are built every 30m within this effluent discharge pipe. The flooding level in the final drainage channel was considered during planning the topographic levels of the entire system. Due to sufficient natural slope, no pumping is required; hence the entire DWWT system runs without any electrical consumption.

The following figure shows the entire system layout at To Hieu School:



The collection and transport system consists of collection boxes and a SSS with junction boxes and inspection chambers. The chosen DWWT technology consists of an ABR + AF + HPGF combination, constructed underground, as demonstrated in the following:

The DWWT plant was constructed underground with a series of 6 concrete tanks (ABR and AF) and a HPGF located at the surface level. The dimensions of each module are shown in following table.

Tanks	ABR (5 tanks)	AF (1 tank)	HPGH
Diameter of each tank in mm (L x W x D)	750 x 2,400 x 2,690	1,200 x 2,400 x 2,690	8,640 x 10,470 x 1,090

Note: The water level in the ABR and AF is 1.80m; the water level in the HPGF is 0.80m

O&M of the DWWT System

Due to the applied simple and low-tech technology of the constructed DWWT system and no need for electrical or mechanical equipment, no considerable O&M tasks and related costs are required. Hence, after handing over of the plant, Son La URENCO will only need to take limited action on O&M in future.

The monthly O&M cost of this plant are estimated with VND 900,000, including removal of solid waste from the SSS, de-sludging of the ABR and AF, regular replacement of AF filter material, occasional cleaning of the HPGF inlet material, as well as regular check of structural conditions and small repair works.

3.4.4 Financial Issues

The project is fully in hands of the local government. This also applied to coverage of CAPEX and later OPEX.

The project setup strictly follows the existing Vietnamese regulations related to investment procedures, including preparation, appraisal and approval of an Economic-Technical Report. Financing, after appraisal by DoC and DoF and approval by Son La CPC, is done via provincial financial budget.

The total investment cost of this project is about VND 505,000,000 (24,000 USD), covering all expenditures for design, construction materials and construction, as well as construction supervision.

Coverage of O&M costs via a wastewater fee was discussed between CPC, DoC and DoF. It was decided to add the O&M costs for the DWWT system to the annual O&M budget of the CPC for the entire sewerage system of the city of Son La. However, detailed information about future O&M cost coverage is still pending because the city authority (CPC and both provincial department (DoC and DoF) asserted that this will be defined after new wastewater asset are hand over as well as after a future operator is appointed.

3.4.5 Community Issues

Activities related to IEC, have not yet been implemented in To Hieu school. It is, however, recommended to apply a similar IEC package, as was successfully developed and implemented in Nguyen Truong To school in Vinh.

3.4.6 Individual Lessons-learnt from this Pilot

As the DWWT demo project is under implementation during preparation of this lessons-learnt paper, only a limited number of lessons-learnt could be drawn. Despite of that, good lessons collected during the project preparation and design phase, including the institutional setup, are presented in the following:

- Son La URENCO has been designed a DWWT system for the very first time. With very limited input from WMP, which consisted mainly of general guidance and on-the-job training/coaching, URENCO was able to design the system properly, which proves that **DWWT related capacity development with local wastewater companies is feasible**. From now on URENCO has this specific knowledge and should be able to replicate DWWT systems in this locality with limited efforts. URENCO especially showed great skills in the preparation of structural design of the SSS and DWWT modules, preparation of technical drawings, calculation of BoQ, as well as calculation of the required CAPEX. Also construction supervision can be managed by URENCO appropriately. Only limited external support, e.g. in the form of review of the process design of the DWWT modules might still be required for large-scale replication, provided that trained staff remain in the company to avoid losing institutional know-how.

- By closely involving URENCO in the design process, the company was able to **bring in their local experience, point of view and knowledge**, which helped to adapt the system to the local conditions and needed.
- Due to the close involvement of URENCO during the project preparation, design and implementation, URENCO was able to pick up knowledge about the general functioning and required O&M of DWWT systems; which will **help URENCO during their O&M tasks once they are appointed as operator**.
- The **total investment cost, incl. expenses for survey, design and construction, was much cheaper than in similar demo projects** at other locations. Reason is that survey and design works were directly implemented by Son La URENCO after being trained by WMP. No external contractor was assigned. The system was implemented exclusively with the involvement of local stakeholders, with limited capacity development support by WMP.
- Local implementers are now able to **keep the acquired knowledge for later replication**, and can even transfer know-how within the province, which none external implementer could do. This integrated approach, involving local decision makers and implementers, ensures sustainability of the project.
- The **institutional setup of this project was more complicated than in previous demo projects**. The PPC, the highest provincial authority, was involved in the primary decision regarding project implementation incl. allocation of required investments, and assigned the lower provincial authorities like CPC, DoC, DoF and URENCO to implement this project. This setup requires more coordination and care during the initial project phases; however ensures sustainability of the project.
- **O&M cost coverage is not yet solved** because the project is under construction while this paper is prepared. This issue was addressed to the provincial counterparts throughout the preparation of the Economic-Technical Report by WMP experts. However, the provincial authorities claimed that it is too early to discuss about this issue until the construction has been finished and an operator is assigned.
- The **capacity development approach in this project can be considered successful** as URENCO acquired the know-how about the applied DWWT technology and should be able to implement other similar projects within their locality.
- PPC intends to **replicate this demonstration project** in other locations; hence a potential for scaling-up exists, which would lead to the sustainability of the DWWT approach in general and applied technologies within the province.

3.5 Demonstration Project in Soc Trang

It should be highlighted that this demonstration project, as well as the project in Son La, is part of a second round of demonstration projects initiated by WMP and is an important cornerstone of the scaling-up strategy of the programme. The projects in Son La and Soc Trang were planned, having the above presented lessons-learnt from the previous three projects in mind. An important innovation and pre-condition for this second round of projects is that all CAPEX are to be covered by local budgets, no financial contributions to investments costs are made by WMP. Only ideas and advice are presented to local stakeholders who bare the full implementation responsibility and are fully in the driver’s seat of all activities. The project in Soc Trang is under implementation at the time of preparation of this lessons-learnt paper. The DWWT plant is under construction while this paper is being written; hence no lessons-learnt can be presented about e.g. O&M or performance of the system.

3.5.1 Project Description

The demonstration project in Soc Trang is intended to collect and treat the wastewater generated at Lich Hoi Thuong Market and the Secondary School in Tran De District (40 km away from Soc Trang City). The location is not connected to a centralised WWTP and no plans for future connection exist. The DWWT plant will be located in the backyard of Lich Hoi Thuong Secondary School.

The school hosts 865 pupils and 48 teachers, half of which are in the school during morning hours and another half in the afternoon. The market consists of 162 vendors plus two management staff and is operated throughout the day. The DWWT plant will be built within the school premises and will treat the wastewater generated from the school and the market toilets, as well as wastewater generated from the market stand, as well as cleaning water used for floor cleaning. Rainwater is separated and not co-treated in the DWWT plant.

Water consumption for both the school and market is estimated with $24m^3$/day, based on site visits and interviews with the management of the school and the market. The wastewater pollution levels are estimated with BOD: 325mg/L, COD: 650mg/L and SS: 260mg/L, constituting a medium-strength wastewater. The temperature of wastewater is assumed with 25°C for the entire year.

3.5.2 Institutional Issues

WMP's official project partner in Soc Trang City is the Soc Trang Urban Public Work Company (UPWC). According to the Official Document No. 403/CTUBND-HC, issued on 01 April 2014 by Soc Trang PPC, the PPC agreed to implement the demonstration project and assigned Tran De DPC to be the project investor and future asset owner. The DPC was furthermore assigned to take full responsibility for ensuring the quality and schedule of the DWWT project as well as for implementing the procurement process. As a result, a Task Force was established in order to implement this demonstration project with the participation of DPC, Soc Trang DoC and UPWC.

After preparation by UPWC, Tran De DPC will receive the Economic-Technical Report and collect comments/feedback from DoC for appraising the technical suitability and from DoF for appraising the financial suitability prior to take a decision regarding approval of the demonstration project.

Following a single-source selection, Soc Trang UPWC was appointed for the design and construction of the DWWT plant. This PPC assignment consists of the implementation of a baseline survey, preparation of the Economic-Technical Report and construction of the demonstration project as main contractor.

Soc Trang DoC was appointed by PPC for overall project management and coordination with WMP related to technical inputs and capacity development measures for Soc Trang UPWC.

DoC is appointed by PPC to summarize and assess the results (advantage/disadvantage and experiences) of this demonstration project after completion in order to propose a suitable model for replicating this DWWT concept in the whole province.

3.5.3 Technical Issues

<u>Design of the DWWT System</u>

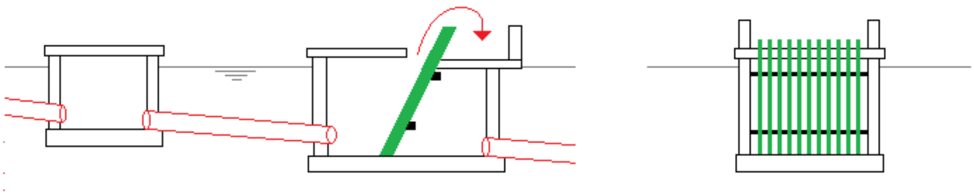
The following wastewater sources will be connected to the DWWT plant:

- Public toilet building located at the backside of the market (existing septic tank directly connected to the new collection tank via a SSS);
- Market stands (connected via existing above-ground wastewater channels, a screen box, and afterwards via an underground SSS to the new collection tank);
- Rehabilitated boys' toilet and new girls' toilet at the school (new settler connected directly connected via a short SSS to the new collection tank);
- Rehabilitated teachers' toilet (existing septic tank connected via a SSS to the new collection tank).

The wastewater generated at the public toilet was previously discharged into the existing open drainage channel, resulting in public health issues and odour nuisances. The toilet' septic tank will be de-connected from the existing channels and the wastewater will be routed in a new underground SSS laid at 1% slope towards the planned collection tank.

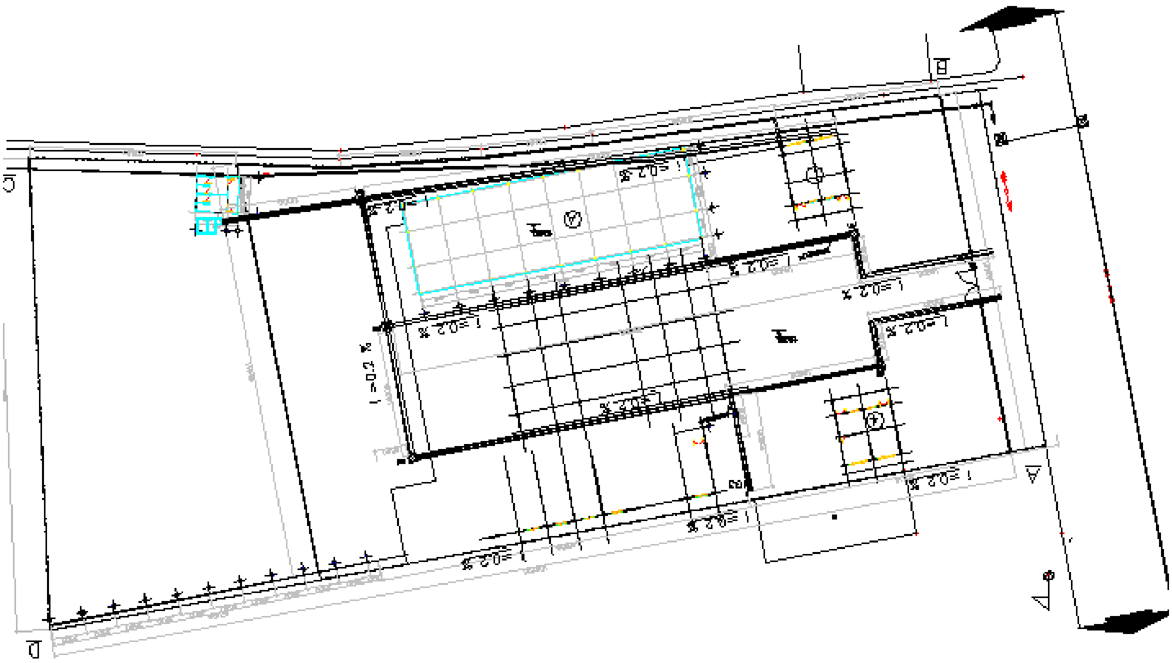
For collecting the wastewater generated at the market stands, three existing concrete drainage channels, laid with 0.2% slope, will be used. These channels are currently used to drain all wastewater and rainwater from the market area. The channels will be reconnected and used exclusively for wastewater drainage. Rainwater collecting at the backyard of the market (without roof) and rainwater collected from the market's roof will be drained separately and will not be mixed with the wastewater. A new cross channel will be constructed in front of the market hall, collecting wastewater from the existing drainage channels.

This cross channel will be connected to a screen box, where solid wastes (which constitute a high risk for clogging) will be removed from the market wastewater. Behind the screen box the pre-treated market wastewater is mixed with the wastewater coming from the public toilet and routed together via an underground SSS, made by DN220 PCV pipes laid at 1% slope, to the collection tank. The pre-design of the screen box is demonstrated in the following picture:



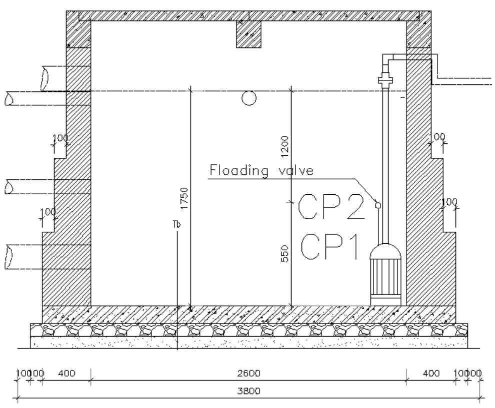
side view front view

The following figure shows an overview of the setup of the market, including the location of the public toilet, SSS and wastewater channels:



Junction boxes with the dimension of 1,200mm x 1,200mm x 760mm (L x W x D) will be placed within the SSS where changes in the flow direction occur, as well as where the distance exceeds 30m, in order to provide access for cleaning.

The collection concepts includes the construction of a underground collection tank and pumping station, in which wastewater from all sources is collected before it is pumped into the DWWT system. The pump is chosen as small as possible to reduce peak flows, but as powerful as necessary to avoid clogging through solid waste and sediments. A screen box will be placed around the suction of the pump to avoid clogging. The pumping station will be equipped with two automatic switches that allow for short pump intervals to reduce peak flows in the DWWT plant to the extent possible, in order to reduce up-flow velocities in the ABR and AF and to prevent flushing out of activated sludge. The collection tank incl. submerged pump is demonstrated in the illustration to the right.

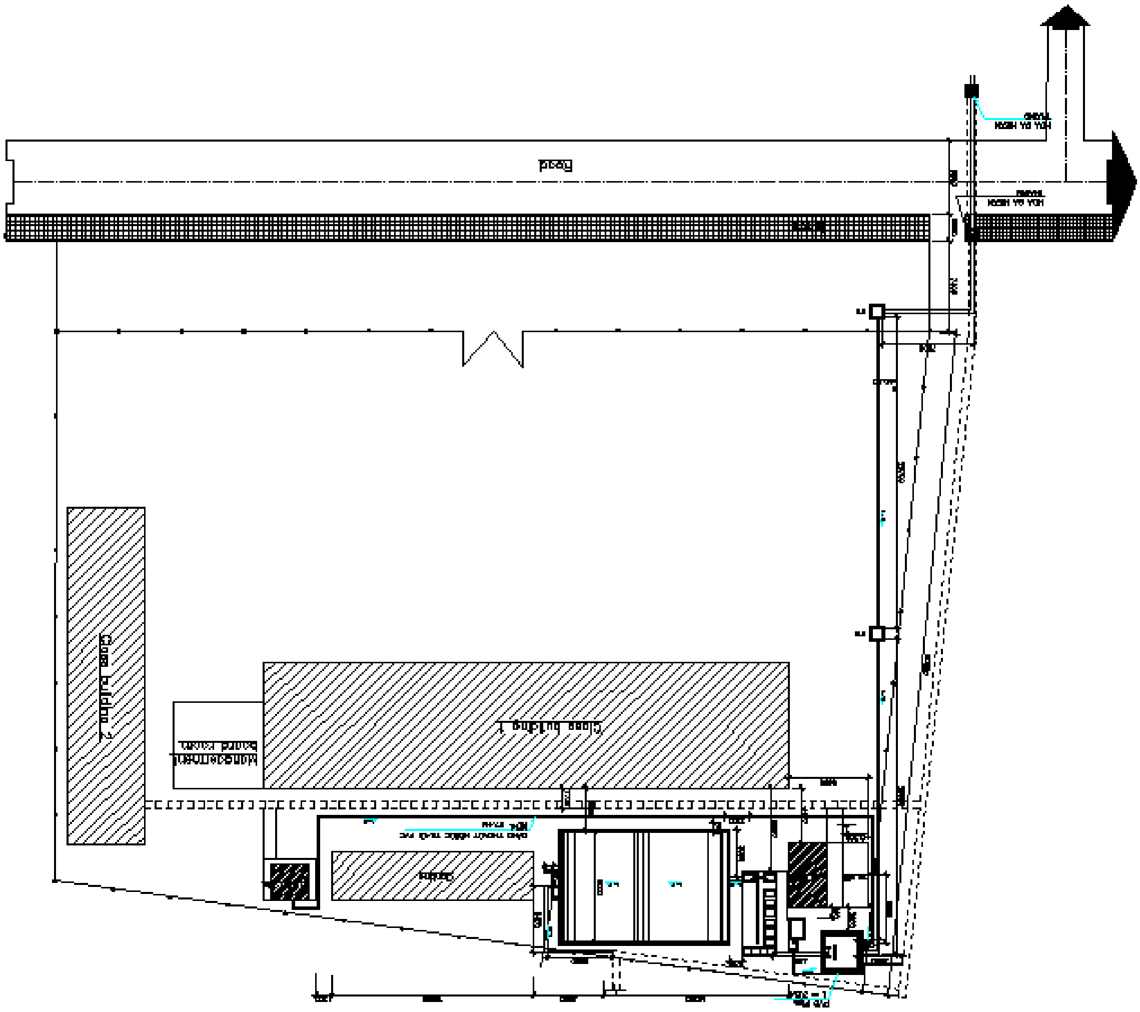


The collection and transport system consists of the following elements:

- Existing septic tank (market toilet) and new settler (school toilet);
- Concrete wastewater collection channels (market);

- Screen box;
- Simplified sewer system consisting of underground PVC pipes, incl. junction boxes;
- Collection tank with submerged pump.

The following figure shows the setup of the collection, transport and treatment modules located at the school, including rehabilitated boys' toilet, new girls' toilet, rehabilitated teachers' toilet, collection tanks with pumping station, as well as DWWT modules:



The chosen DWWT technology consists of an ABR + AF + HPGF combination as demonstrated in the following:

The DWWT modules consist of two treatment processes: anaerobic secondary treatment in ABR and AF, as well as tertiary aerobic treatment in a HPGF. ABR and AF tanks will be constructed by bricks and concrete mortar grade 75. Their bottom and cover will be reinforced concreted grade 200. The AF tanks will be filled with low-cost, locally available materials such as bamboo and rough gravel.

The DWWT plant was constructed underground with a series of 7 concrete tanks (ABR and AF) and a HPGF located at the surface level. The dimensions of each module are shown in following table.

Tanks	ABR (5 tanks)	AF (2 tanks)	HPGH
Diameter of each tank in mm (L x W x D)	700 x 3,200 x 2,600	1,200 3,200 x 2,600	9,400 x 14,700 x 1,040

Note: The water level in the ABR and AF is 1.80m; the water level in the HPGF is 0.80m

The treated wastewater will be discharged into a drainage channel located behind the school via a PVC pipe of DN200 laid at 1% slope. The channel leads to a nearby river. The flooding level of the river is considered in the topographical design of the entire system.

O&M of the DWWT System

Due to the applied simple and low-tech technology of the constructed DWWT system, no considerable O&M tasks and related costs are required for the maintenance of the treatment modules itself. Hence, after handing over of the plant, Soc Trang UPWC will only need to take limited action on O&M in future.

However, some O&M of the DWWT plant will be required, including removal of solid waste from the SSS, de-sludging of the ABR and AF, regular replacement of AF filter material, occasional cleaning of the HPGF inlet material, as well as regular check of structural conditions and small repair works.

The pumping station will require regular O&M of the pumps, as well as repair and replacement in case of pump failures. Regular de-sludging of the pump sump is required in order to avoid clogging of the pump, as well as cleaning of the screen placed around the suction.

The screen box located at the market is the only element in the entire system that requires regular, if not daily, maintenance. Solid waste accumulating in the screen must be removed regularly in order to prevent clogging of the screen and flooding of the market. Although all O&M works should be performed by the dedicated operator (probably UPWC), cleaning of the screen should be done by the market caretaker.

3.5.4 Financial Issues

The project is fully in hands of the local government. This also applied to coverage of CAPEX and later OPEX.

The project setup strictly follows the existing Vietnamese regulations related to investment procedures, including preparation, appraisal and approval of an Economic-Technical Report. Financing, after appraisal by DoC and DoF and approval by Tran De DPC, is foreseen to be done via provincial financial budget.

The total investment cost of this project is not known at the time of writing this paper as Soc Trang UPWC is preparing the BoQ and detailed cost estimation. Also the future O&M cost are not known at the time of preparation of this paper.

Coverage of O&M costs via a wastewater fee was discussed between DoC, Tran De DPC and UPWC. However, detailed information about future O&M cost coverage is still pending because the city authority asserted that this will be defined after the new assets are handed over to the DPC as well as after the future operator is appointed.

3.5.5 Community Issues

Activities related to IEC, have not yet been implemented in the Soc Trang project. It is, however, recommended to apply a mixture of activities from both Vinh and Can Tho projects. Especially the solid waste situation in the market should be of concern in an early stage in the process to avoid operational failures and other problems experienced in Can Tho in the past.

3.5.6 Individual Lessons-learnt from this Pilot

As the DWWT demo project is under design during preparation of this lessons-learnt paper, only a limited number of lessons-learnt could be drawn. Despite of that, good lessons collected during the project preparation and design phase, including the institutional setup, are presented in the following:

- Soc Trang UPWC has designed a DWWT system for the very first time. With very limited input from WMP, which consisted mainly of general guidance and on-the-job training/coaching, UPWC was able to design the system properly, which proves that **DWWT related capacity development with local wastewater companies is feasible**. From now on UPWC has this specific knowledge and should be able to replicate DWWT systems in this locality with limited efforts. UPWC showed good skills in the preparation of structural design of the collection, transport and DWWT modules, as well as in the design of the new and rehabilitated toilet blocks. Only limited external support, e.g. in the form of review of the process design of the DWWT modules might still be required for large-scale replication, provided that trained staff remain in the company to avoid losing institutional know-how.

- By closely involving UPWC and DoC in the design process, both local counterparts were able to **bring in their local experience, point of view and knowledge**, which helped to adapt the system to the local conditions and needed.
- The close involvement of UPWC during the project preparation, design and implementation phase will enable **UPWC during their O&M tasks once they are appointed as operator**.
- Local implementers, especially UPWC and DoC, are now able to **keep the acquired knowledge for later replication**, and can even transfer know-how within the province, which none external implementer could do. This integrated approach, involving local decision makers and implementers, ensures sustainability of the project.
- The **institutional setup of this project was more complicated than in previous demo projects**. The PPC, the highest provincial authority, was involved in the primary decision regarding project implementation incl. allocation of required investments, and assigned the lower provincial authorities like DPC, DoC, DoF and UPWC to implement this project. This setup requires more coordination and care during the initial project phases; however ensures sustainability of the project.
- **O&M cost coverage is not yet solved** because the DWWT system is under design while this paper is prepared. This issue was addressed to the provincial counterparts throughout the project preparation phase by WMP experts; however, the provincial authorities claimed that it is too early to discuss about this issue until the construction has been finished and an operator is assigned.
- **DoC intends to replicate this demonstration project** in other locations; hence a potential for scaling-up exists, which would lead to the sustainability of the DWWT approach in general and applied technologies within the province.

3.6 Up-scaling Study in Vinh

3.6.1 Project Description

Following the implementation of demonstration projects in Bac Ninh, Can Tho and Vinh, WMP had pursued up-scaling initiatives with the aim of developing the DWWT concept for more locations. Vinh City was chosen to develop a feasibility study for up-scaling of the DWWT in many suitable locations within the city. This study was prepared in November/December 2012. The study aimed at elaborating whether the up-scaling of the DWWT approach to residential clusters and independent premises (e.g. public institutions) that are not connected to the centralised WWTP is feasible in large scale in regards to technical, economical and institutional feasibility. The study intended to:

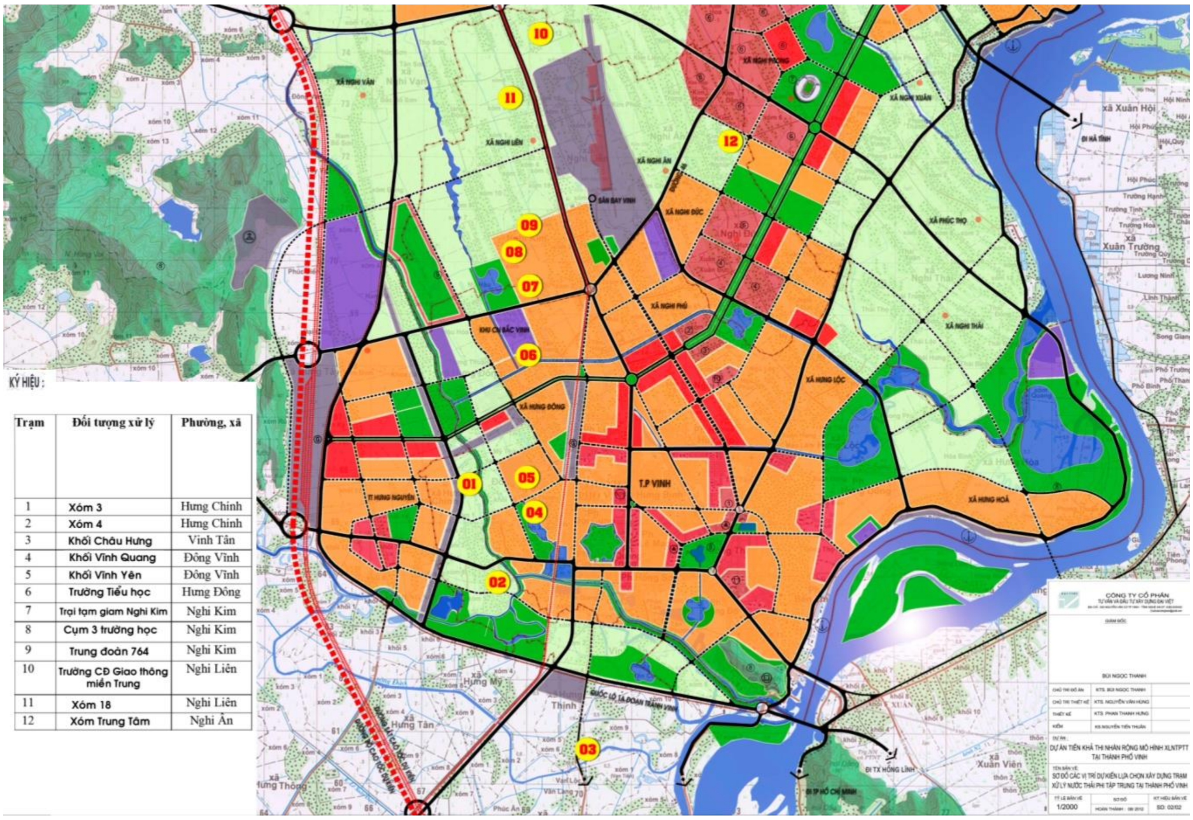
- Investigate a more comprehensive approach to DWWT on a larger scale, rather than focusing on single on-site solutions;
- Identify locations that are suitable for the scaling-up of the DWWT approach;
- Present technical options for different DWWT solutions that are suitable for Vinh City as well as other urban areas, including describing its functionality, individual advantages and disadvantages, O&M requirements, etc. (technical feasibility);
- Elaborate investment and O&M costs for the proposed DWWT solutions and verify whether O&M costs can be covered trough applied WW tariffs (economic feasibility);
- Evaluate possibilities of centralised management of the DWWT solutions through an operator at city level (institutional feasibility);
- Create awareness of local authorities and operators about the DWWT concept and possibilities for scaling-up;
- Create commitment of a local wastewater operator for the future O&M of proposed systems;
- Serve as a basis for investment fund allocation for proposed systems as well as for future technical, institutional, operational and managerial project proposals.

The sites selected for the envisaged construction of DWWT systems were supposed to meet the following selection criteria:

- The site is a hot spot in terms of environmental pollution of which wastewater is the main cause, negatively affecting the life and production activities of people;
- The area is not connected to the central treatment system, neither exists commitment from the local authority to invest in a respective system in future;
- Space availability for the construction of the plant;

- Both the local government and people (e.g. residents) agree on the construction of a DWWT plant;
- The size of the plant is in line with the project conditions.

Within this study, 12 areas appropriate for DWWT were identified within the city of Vinh. These areas include seven residential areas and 3 institutions like schools, a prison and an army camp, as described in the following graphic:



3.6.2 Institutional Issues

Based on the above mentioned selection criteria, the Commune/Ward People's Committees have agreed on the selection of 12 sites for the study, supported by Dai Viet Construction Investment and Consulting Company in regard to site selection. Both the local authorities and the management of the selected sites have committed to create favourable conditions for site clearance, and this has been recorded in minutes of meetings.

For the preparation of the study, Dai Viet Company provided general information of the current situation in regard to wastewater management in Vinh. The company also supported WMP during baseline data collection at the 12 selected locations. The company later prepared BoQ for the 12 pre-designed DWWT systems, as well as an estimation of required CAPEX for the construction of the 12 systems.

WMP was responsible for the elaboration of the study. This included verification of the provided baseline data for the 12 pre-selected locations, selection of appropriate DWWT technologies based on local conditions, pre-design of the 12 treatment systems, calculation of the dimensions of the different treatment modules, calculation of estimated O&M cost, description of required institutional responsibilities, as well as general elaboration of the study.

3.6.3 Technical Issues

<u>Design of DWWT system</u>

The survey data of the 12 selected DWWT sites showed that the areas share the common topographic, geological, climatic, and hydrological characteristics of the city of Vinh. The differences lied in the pollution loads (organic and inorganic pollutant concentrations), hydraulic loads (average flows, peak flows) as well as specific site conditions such as land availability for the construction of the DWWT plants and conveyance systems, which were taken into account for the selection of the most efficient and economical solution.

The proposed DWWT systems for Vinh City generally are a combination of different modules, arranged based on survey results; e.g. number of connections, wastewater flow, peak flows, space availability, topography, O&M requirements. Different modules of DWWT systems were combined and arranged in order to be perfectly suited for the respective sanitation scenario and individual needs.

The individual sanitation concepts include also the conveyance of the raw wastewater from the point of generation (e.g. households, institutions) to the DWWT plant. The conveyance system generally consists of SSS, house connection boxes and inspection chambers. These components were proposed for all of 12 sites.

Preliminary designs of the recommended DWWT plants had been prepared based on surveyed data. Considered technologies included settler, biogas settler, ABR, AF, HPGF, trickling filter, anaerobic pond, aerated pond and polishing pond.

The 12 proposed DWWT plants were designed to treat wastewater generated from a total of 12,930 people and 560 animals from livestock breeding. A total of 1,290 m^3/d of wastewater were supposed to be treated at the 12 selected sites. The average treatment capacity of the proposed DWWT plants was 108m^3/d; hence larger than the average size of WMP's demonstration plants.

A collection tank, followed by an ABR + AF combination was commonly suggested for all sites. HPGF was recommended for tertiary treatment in 7 cases; a WSP was suggested in 5 cases (depending on local conditions). Two biogas digesters were recommended to treat wastewater generated from livestock breeding.

<u>O&M of DWWT system</u>

All components of a public wastewater and drainage system such as treatment plants, pumping stations and sewer networks need constant and professional O&M, in order to ensure functionality of the system and sustainability of investment.

An overview of the required O&M works for the identified DWWT sites, the approximate time and effort, as well as proposed responsibilities to carry out the works was provided in this study.

As for the O&M responsibilities, it was suggested to assign a professional entity based on a performance based management contract (following the principle of decentralised treatment, but centralised management).

<u>Performance of the DWWT system</u>

No real data about the systems' performance can be presented due to the fact that the systems were only designed, not yet built. However, in the following the anticipated performance is presented, based on which the DWWT systems were designed.

All 12 DWWT plants were primarily designed to meet the effluent standards regulated in QCVN 14:2008/BTMNT – Column B, which is valid for all kind of WWTPs. However, international experience and best practices show the limitations of the current Vietnamese direct discharge standard. It is common practice to apply the pollution load principle and allow less strict discharge values for smaller WWTPs compared to larger plants. For this reasons, GIZ WMP works on creating related awareness within the MoC and MoNRE at the time of preparing this paper by means of a "Policy Roundtable Paper". The objective is to define less strict standards for small-scale DWWT systems. This proposed effluent standard was already considered for the pre-design of the 12 DWWT plants in this up-scaling study, according to which no discharge limits for nutrients are adopted. Keeping in mind the final discharge of the DWWT effluents (channels leading to agricultural land), remaining nutrients in the effluent is rather positive effect as the effluent introduces nutrients to the agricultural lands what reduces the need for artificial fertilization.

3.6.4 Financial Issues

The total investment cost of all 12 DWWT plants was calculated at VND 53,640,000,000 (2,554,000 USD), corresponding to averagely VND 4,100,000 (195 USD) per connected person equivalent. Total investment costs are significantly higher in case of residential areas with a weighted average of VND 6,800,000 (324 USD) per person equivalent, compared to institutional uses with a weighted average of VND 2,800,000 (133 USD) per person equivalent. This is explained through long house connections and SSS in case of residential areas as the cost for PVC pipes is a determining cost factor.

The total monthly O&M costs for all 12 sites sum up to VND 152,000,000 (7,240 USD), corresponding to averagely VND 3,927 (0.187 USD) per cubic meter of treated wastewater. This calculated O&M cost is equivalent to approximately VND 70,500 (3.35 USD) per household and month. Calculated O&M costs include regular and periodic maintenance, electricity supply and re-investment costs. In case of institutional use, re-investments were calculated for the complete system consisting of house connections, SSS and the DWWT plant. In case of residential areas, required re-investments in house connections were left to the house owner and accordingly not included in the cost calculation. Average O&M costs for residential areas are at VND 4,045 (0.193 USD) per cubic meter, while O&M costs for institutional DWWT concepts is at VND 3,747 (0.178 USD) per cubic meter; hence almost same.

Compared to the proposed wastewater tariff for wastewater discharges connected to the centralised WWTP in Vinh of VND 2,377 (0.113 USD) per cubic meter, the required financial contribution from households/institutions connected to the proposed DWWT plants is 65% higher. However, this is not surprising as many smaller DWWT systems are always more expensive in total than one large centralised WWTP (more civil works that require maintenance and re-investments, many small pumps instead of less big pumps, many operating staff instead of less staff in large automated systems, etc.). However, the O&M costs of the DWWT plants were calculated based on one trained person per DWWT plant, which includes a big safety factor as one staff could operate various systems due to minimal O&M needs.

All in all, considering the average O&M costs of VND 3,927 (0.187 USD) per cubic meter of wastewater, or VND 70,500 (3.35 USD) per household and month (accounting for roughly 2% of the monthly average income in Vinh City), affordability-to-pay and economic feasibility seem assured.

3.6.5 Individual Lessons-learnt from this Pilot

- The study was prepared by WMP and Dai Viet as sub-contractor, with **little direct involvement of provincial decision makers and INFRAVI**. INFRAVI took over the next step of distributing and submitting the study to the related water authorities such as PPC, CPC and water departments for approval. However until now no further actions have been realized.
- Although the Commune/Ward People’s Committees participated in the selection of the 12 study locations, agreed on the locations, as well as confirmed that they would make the land available once it comes to construction, **no higher political authorities took over the steering role** that would be required for the implementation process due to the fact that they were not involved from the start of the project.
- The study was intended to elaborate and investigate the potential for up-scaling of the DWWT approach in Vinh. The **outline of the study did not fit into the Vietnamese system**, which only knows Economic-Technical Reports (for small infrastructure projects) and Feasibility Studies (for large infrastructure projects). Hence, the Vietnamese regulation and standard for the preparation process was not strictly followed, which resulted in a lack of follow-up and acceptance of the study.
- The fact that no proper legal assignment was taken during the preparation process caused **difficulties for further submission and approval of the study and subsequently funding** of the infrastructure. At the time of writing this lessons-learnt report, no further action from INFRAVI is indicated and the document seems to become internal study.
- Nevertheless, the study **clearly show the technical, institutional, environmental, financial and economic feasibility of up-scaling the DWWT approach** in Vietnamese cities with close-to-nature and easy-to-replicate DWWT solutions. National and provincial governments as well as donors are welcome to pick up the lessons-learnt from this study and use them in other up-scaling initiatives.

4. Overall Lessons-learnt

After describing the demo projects and individual lessons-learnt obtained during preparation and implementation of demo projects described above, Chapter 0 presents overall lessons-learnt that WMP drew on DWWT. These include general lessons made on different levels during promotion and dissemination of the DWWT approach, experiences on the different areas of applicability as well as advantages and disadvantages of DWWT, lessons-learnt about suitable technologies for DWWT and related O&M requirements, as well as important experiences on the required institutional framework conditions required for the implementation of DWWT projects.

4.1 General Experiences from WMP Demo Projects

In Chapter 0, individual lessons-learnt obtained from the pilot systems implemented in Bac Ninh, Vinh, Can Tho, Soc Trang and Son La are presented. However, WMP has identified more general lessons-learnt that cannot be directly linked to a particular demo project. These experiences are presented in this sub-chapter, broken down into lessons-learnt related to different topics.

Legal Background

- The legal framework still needs improvement and adaptions to local conditions. It is almost non-existent. Particularly, reasonable effluent standards for DWWT plants must be introduced that take the pollution load into account. DWWT outflow creates less noxiousness to the environment as DWWT dispose of smaller wastewater amounts compared to large-scale centralised WWTPs. International legislation has taken this into account by defining discharge standards based on the design flow rate of the WWTP, by defining less strict effluent concentrations for small-scale DWWT systems. WMP has issued a “Policy Roundtable Paper” in 2014 to invite MoC and MoNRE to work over and adapt current legislation in this regard.

Finance

- Allocation of public budgets for O&M remains an ongoing challenge. As a result stakeholders tend to save as much running costs as possible, e.g. by turning off aeration or pumping stations. This may lead to insufficient effluent quality.
- It is therefore crucial to involve local decision makers from the beginning in project design to ensure public budgets not only for the investment cost, but also for O&M of the system through an appointed service provider. Including the O&M budget into yearly budget plans of the respective asset owner is therefore crucial, as is a proper cost-based management contract between the asset owner and the selected service provider.

Project Management and Implementation

- For the successful project implementation, the involvement of different institutions and individuals is required. This includes the designer, funding agency, future asset owner, future service provider, etc. Typical stakeholder on local government level are PPC or CPC as project owner and funding agency, as well as DoC and DoF for technical and financial appraisals. Another typical stakeholder is the wastewater company, who shall act, as promoted by WMP, as service provider. Another stakeholder is the designer, which can be either the wastewater company, a donor funded project expert, a private company or e.g. VWSA or an associated trainer or designer. Having different institutions involved in project management might lead to some difficulties in project planning and delays in project progress.
- Committed local decision makers help to speed up the implementation of a DWWT project, hence are an essential stakeholder. The role of the local government is crucial for e.g. the selection of the location, approval of the economic-technical report, allocation of CAPEX, appointment of an asset owner and a service provider for O&M, as well as allocation of a budget for OPEX. Involvement from the early project start through a consultative process is therefore essential for successful project implementation.
- Using local resources for the construction process increases the acceptance of the community. This refers e.g. to contracting or sub-contracting local companies for the construction of the house connections, SSS and DWWT plant.

Social Economic Issues, Public Awareness and Community Education

- It became obvious that the cooperation with local authorities and the awareness of the people on sanitation issues is most important for the success of DWWT projects. Information, Education, Communication (IEC) campaigns carried out within the scope of WMP demonstration projects - e.g. in the school and kindergarten (Vinh), on village level (Bac Ninh) and among market vendors (Can Tho) - contributed to better understanding, improved environmental behaviour and commitment.
- Wastewater treatment still has very low priority on local and provincial levels. Creating awareness and attitude among the general public and public stakeholders is therefore essential.
- The resistance of both politicians and population against the introduction of wastewater fees is still enormous, which is particularly true for North Vietnam, where a planned economy and government subsidy systems prevailed for many more decades than in the South. Politicians do not want to make themselves unpopular with the implementation of new fees. Again, IEC is therefore essential to create sustainable framework conditions for DWWT.
- Poor solid waste management and waste awareness is a problem for sewer systems in Vietnam. Due to the prevailing habit of the population (e.g. shop owners and market visitors) to throw all solids and liquids to the floor, nearly all wastes end up in the drainage system, pump sumps and finally the WWTP. By providing awareness on solid waste management (e.g. organized meetings, loudspeaker announcements, control systems) and promoting a whistle-blower culture, this problem can be tackled.

Planning and Design of DWWT Systems

- The planning and design of DWWT plants and SSS, hence the compilation of basic data, requires lots of estimations and “best guesses” since design standards do not meet local conditions or are not meant to be applied to DWWT projects. For example sampling wastewater from houses proofs to be impossible or very difficult, due to local conditions of house connections and sewers hidden under concrete covers and hence not being accessible. Sampling wastewater from open ditches is in many cases the only alternative, but might be highly inaccurate (mixed with rainwater, solid waste, sludge, animal faeces, etc.).
- Wastewater quality and quantity often changes dramatically within a few hours, adding another challenge to proper design. Long-term wastewater monitoring is required in order to get an accurate overview on local conditions, adding to increased project costs.
- In order to obtain reliable qualitative design data it becomes necessary to collect as much secondary information as possible about the composition of the wastewater, e.g. by interviews with residents (in case of residential areas), operators (in case of markets), management (in case of schools). It is furthermore recommended to add a good safety factor to the estimated wastewater quality in order to ensure that the DWWT system is designed in order to keep the required effluent standards. Luckily, most DWWT systems are rather designed on hydraulic than on biological requirements, or differently said, if the hydraulic requirements (e.g. maximum flow velocities or minimum hydraulic retention times inside the system) are assured, the biological treatment efficiency is usually guaranteed unless the raw wastewater is very strong.
- Besides determining the qualitative design criteria it is therefore even more important to obtain reliable data on the wastewater quantity as most DWWT modules are rather designed based on hydraulic requirements. To obtain reliable data, extensive baseline data collection is required, incl. interviews with reliable sources, direct measurement of flow rates (e.g. by measuring the flow within a certain time with a bucket, by calculating the flow based on the water level and profile of the flume, by checking the water supply, etc.) and then double-checking whether obtained information seem realistic. It is highly recommended to add a safety factor to ensure sufficient hydraulic retention times in the DWWT system.
- Besides the daily wastewater quantity, considering peak flows is very important to ensure that flow velocities in the DWWT modules do not exceed maximum limits as this could result in flushing out activated sludge. To determine the peak flows (e.g. hours of most wastewater flow per day) as realistic as possible, it is of utmost importance to carefully obtain information about wastewater generating activities (e.g. daily marker hours, hours of attendance in schools and kindergartens, working/operational hours of businesses, sleeping habits in private households,

etc.). This can only be done by thorough interviews with the population living in the target area, as well as the management/operators of e.g. markets, schools, businesses, etc.

Quality and Progress of Construction Works

- Overall Construction quality is acceptable if not scaled with European standards. The construction process can be very fast if everything is clear to the local contractor, but even little misunderstandings and ambiguities can lead to remarkable delays and to incorrect execution. Deviation from design documents is common. Intensive construction supervision, especially checking of topographic levels and water tightness, is therefore essential.
- Construction site supervisors often lack the overall understanding of the functionalities of DWWT modules, and are hence often unable to give clear instructions. It is therefore recommended to perform workshops and meetings with the supervisors prior to start of construction to make them understand about the functionality of different treatment modules as well as general design criteria. Only if the contractor and especially the supervisor have a basic understanding about the treatment processes, they are able to perform construction appropriately.
- Enforcing too high quality standards and “sophisticated” solutions just leads to delays and makes the construction much more expensive. As WMP promoted simple technologies, moderate quality standards are usually sufficient. However, particular attention must be paid to topographic levels to avoid flooding and to ensure proper flows inside the WWTP, as well as on water-tight construction to avoid leakages.
- Construction of the sewer network is always very expensive. The construction costs for sewers normally exceed the construction costs for the WWTP. This is a problem because many cities in Vietnam have a very insufficient sewer system. For the success of a DWWT project, it is therefore crucial to discuss the capital investment (CAPEX) needs with the decision makers and the potential financier in an early project phase. Particularly due to the fact that DWWT systems require a SSS, which does often not exist prior to the project; the financial requirements are of utmost importance.

Construction Site Management

- The management of construction sites is a major problem: Work flow procedures, Operational Health and Safety (OHS) measures and quality control are widely neglected. Construction sites strongly interfere with neighbours and traffic. Construction site management regulations are either not existing, or not enforced by local DoCs. Compliance with design documents is not regularly checked.

O&M Issues

- O&M costs turned out to be much higher than estimated in the first place, partly due to the massive amounts of solid waste ending up in the sewer channels and grid chambers (additional man-power for cleaning required), but also because it became obvious that 24/7 attendances was needed for some of the DWWT plants. Theft of equipment and vandalism is an issue.
- Generally, O&M of the DWWT plants is relatively easy and doesn’t take a lot of effort. O&M teams quickly picked up the required knowledge and skills. Especially DWWT plants with ABR-AF combinations demand very little effort for O&M. Usually the sewer system and the pumping station is of major concern.

Technical Issues

- The technologies chosen (SSS, ABR, AF, HPGF, aerated ponds) have proofed reliable and easy to operate. Keeping the technology of the DWWT plants very simple helped to minimize technical issues. Only minor problems occurred, and the risk of something breaking that cannot be repaired by local personnel is low.
- It became obvious that poor sanitation conditions cannot fully be eased and improved by technical applications alone. If not accompanied by IEC campaigns, self-organized cleaning activities and highly committed authorities, intervention through technical upgrading of the overall DWWT system will fail.

- As usual, construction works in an older existing system is always more challenging than a complete new construction. However, it should be tried to incorporate appropriate infrastructure (e.g. existing concrete channels in a market) to the extent possible into the DWWT concept.

Functionality and Effluent Quality

- The combination of ABR and AF is perfectly suited for DWWT plants in Vietnam. They are easy to build with limited potential errors during construction, relatively simple and hence inexpensive in construction. Additionally O&M requirements are very low and the systems' footprint is relatively small. High temperatures all over the year speed up the biological processes and help to make the treatment more efficient.
- Treatment efficiencies of ABR-AF range between "low" and "very good" for carbon removal (COD, BOD). With HPGF as tertiary treatment step, better results can be achieved due to nutrient uptake by plants. Additionally coliforms will be efficiently removed within HPGF through UV-radiation, natural die-off and antibiotic releases from roots.
- Nevertheless, existing effluent standards for nutrients (NH4) are too high and very difficult to achieve. For this reason WMP started a policy discussion with MoC and MoNRE in order to reduce discharge requirements for small-scale systems, which is common practice in other countries. This recommended new discharge standards take the pollution load on the receiving water body, hence the effluent concentration as well as the design capacity of the WWTP, into account. Lower standards for carbon parameters and no standards for nutrients are therefore recommended for small, DWWT systems.
- All DWWT plants required fine-tuning of the treatment process after initial construction, e.g. increasing aeration time in case of aerated ponds, adding filter materials to AF or HPGF, etc.
- The five demonstration projects WMP has implemented in cooperation with local stakeholders may have no environmental significance, but show that a simple DWWT plant can be built under local conditions without having to mobilize great funds.

Level of Education and Enthusiasm of Stakeholders, and Stakeholder Participation

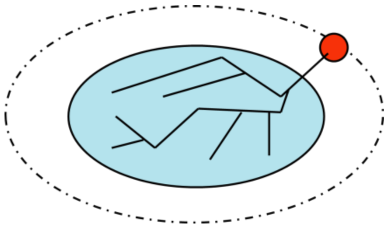
- The participation of local stakeholders is a precondition for success. Good and mutual relationships with all stakeholders and decision makers are very important for successful project implementation.
- Involving all stakeholders from the very beginning through a consultative process showed to be successful. Full transparency is crucial in this regard, e.g. by not hiding upcoming CAPEX and OPEX.
- Decision makers on PPC level have supported the demonstration projects, and show continued interest in the matter. Local governments have seen the advantages of DWWT and are starting to look into up-scaling options of this treatment approach. Appropriate up-scaling options are therefore required. This might be the dissemination of DWWT solutions via competence centres (e.g. VWSA, selected and trained wastewater companies or experienced private service providers), or through adequate self-learning materials like this "Lessons-learnt Paper" or WMP's "A-Z Guide on Implementation of DWWT Projects". Also a more technical documentation, e.g. in the form of a "DWWT Toolbox" that can be used to design appropriate DWWT systems seems required to build technical capacities on design and management of DWWT systems. In this regard, standardization (and eventually later pre-fabrication of DWWT modules) seems to be a promising step forward that should be taken up by other TA projects in future.

4.2 Scope for DWWT and Suitable Areas of Application

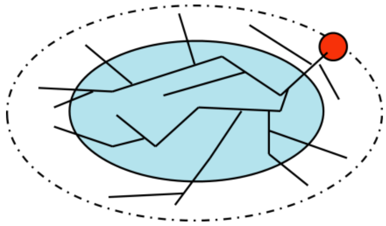
DWWT offers various benefits if applied correctly and under appropriate conditions. DWWT is generally suitable for rural as well as for urban and peri-urban areas. Described lessons-learnt of the GIZ WMP refer however to urban and per-urban applications.

In the urban context, generally the following four sanitation approaches are possible:

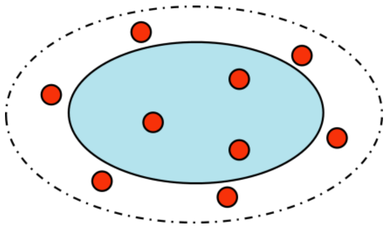
- Connection of urban centres to a centralised WWTP. This is in Vietnam usually done via a combined sewer system (CSS), either with our without combined sewer overflow (CSO). Peri-urban areas remain usually unconnected as the transport of wastewater from those remote and less densely populated areas to the WWTP is usually technically difficult and economically not feasible. This is until today the most common scenario in Vietnam’s cities, if wastewater collection, transport and treatment exist at all.

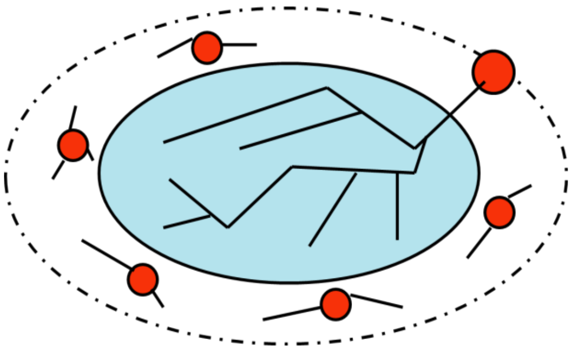


- Another, rather theoretical, approach would be the connection of the entire urban area, incl. urban centres and peri-urban areas, to the centralised WWTP. This concept is never implemented so far in Vietnam and even in industrialized countries this approach is considered inefficient for technical, economic, topographical, environmental, operational, etc. reasons.



- Another wastewater treatment approach would be the coverage of the entire urban area by DWWT plants. Although this approach is theoretically possible and would create certain advantages such as local reuse potential of treated wastewater and considerably reduced wastewater transport and related expenses, it implicates also different disadvantages. Restricted land availability in densely populated urban centres as well as the high total investment cost for the WWTPs are such two disadvantages.

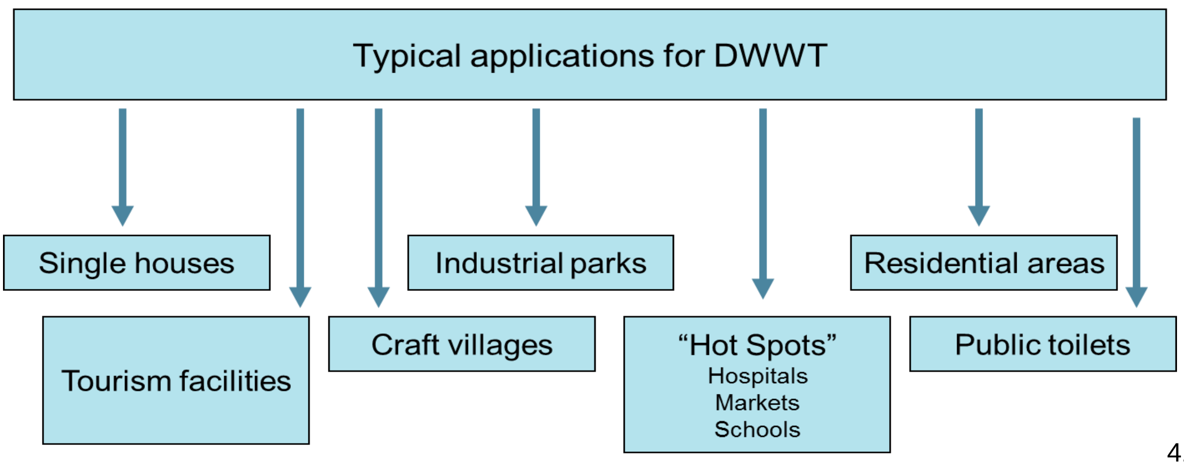




- A major lesson learnt is that the **combination of centralised and decentralised WWTPs** is the most beneficial wastewater management approach for urban / peri-urban areas in Vietnam, which is in line with experiences made around the globe. Connecting core city areas, generating the majority of the total urban wastewater, to centralised WWTPs located outside the central area, and connecting the omitted areas locally to DWWT systems is the option of choice.

Hence, the DWWT approach is a **supplementation to centralised treatment**. Centralised solutions are of highest relevance for the cities in Vietnam, but DWWT features specific advantages, that will be further highlighted in the following sub-chapter. The centralised and the decentralised wastewater management approach need to go hand-in-hand to achieve environmental, economic, and public health improvements and sustainable impacts.

After coming to the conclusion that DWWT is an important puzzle piece in urban sanitation, typical **areas of application** for DWWT system are demonstrated in the following figure:



As described in Chapter 3, WMP pilot projects and up-scaling concepts included hot spots like markets and schools (Vinh, Can Tho, Son La and Soc Trang) as well as residential areas (Bac Ninh, Vinh). The following list summarizes **typical scenarios** in which DWWT should be considered or selected:

- Where urban areas are not connected to centralised WWTPs and where no specific plans for future connection exist;
- Where existing WWTP capacity is limited and financing is not available for expansion;
- Where the O&M of existing WWTPs must be improved;
- Where individual on-site systems (e.g. septic tanks) are failing and no budget is available for a conventional wastewater management system;
- Where the urban area or facility is remote from existing sewers (peri-urban areas / outskirts);
- Where localized water reuse opportunities are available (e.g. irrigation in the urban periphery or urban recreation areas);
- Where topographic or environmental conditions do not allow for wastewater transport to the centralised WWTP; and
- Where residential density is spare (outskirts, peri-urban areas).

4.3 Advantages and Disadvantages of DWWT

As mentioned in the previous chapter, DWWT should not be considered as a stand-alone wastewater management approach for urban areas, or as an alternative to centralised wastewater treatment. DWWT systems offer specific advantages but also disadvantages, which define its scope and area of application depending on local conditions. The advantages of the DWWT approach can be summarized as follows:

- DWWT usually does not require large and capital intensive sewer trunks, pumping stations, etc. Due to the short transport distances and the use of separate sewer systems (which are imperative for DWWT), in which the wastewater is not getting mixed with storm or groundwater, **inexpensive sewer systems with small diameters** are sufficient**.** Reason for that is that the treatment units are usually constructed at or near the point of wastewater generation and final discharge after treatment. For that reason the local topography is often (but not always) sufficient to avoid pumping to bridge required level differences.

- DWWT **broadens the variation of technological options**. Meanwhile centralised WWTPs usually treat large amounts of wastewater (which gets usually diluted with storm water and rainwater in the combined sewer systems) DWWT usually treats much smaller amounts of wastewater, which opens the door for many technologies, incl. low-tech treatment options. Also the fact that the Vietnamese government is invited to consider the implementation of less strict direct discharge standards for small-scale WWTPs (e.g. no standard for nutrients and pathogens) as indicated in the new Wastewater Decree (successor of Decree 88), DWWT requires less advanced treatment technologies than large-scale centralised systems. This creates incentives for investments in DWWT infrastructure and speeds up the coverage with proper sanitation.

- DWWT **reduces the water requirements** for waste transportation. As mentioned earlier, DWWT systems shall be connected to a SSS as the mixture of wastewater with non-polluted rain and groundwater is contra-productive and reduces the treatment efficiency of the DWWT units (as it does for centralised systems as well). Based on WMP lessons-learnt, SSS shall therefore be a pre-condition for DWWT. The reduced water requirement results in smaller, hence less expensive, DWWT systems, as well as in local reuse potential for rainwater.

- DWWT is **adaptable to a broad range of effluent requirements**. As per current Vietnamese legislation, differently strict direct discharge standards exist for effluents discharged into water bodies used for drinking water reclamation as well as other water bodies. Apart from that, the Government is considered to issue differently strict discharge standards depending on the size of the WWTP. The large technology choices for DWWT systems allow the implementation of tailor-cut treatment solutions, depending on the local conditions and needs.

- DWWT **reduces the risk of environmental damages** associated with system failure. Due to the fact that DWWT systems usually treat smaller amounts of wastewater, system failures such as broken sewer lines or temporary shut-down of the treatment system for repairs, which might require discharge of the untreated wastewater into the receiving water body, do not have a large environmental or public health impact compared to centralised WWTPs that treat huge wastewater quantities.

- DWWT systems rather require **mechanical than automatic equipment**. Due to the smaller treatment volume and related technology options, DWWT systems can often be built as close-to-nature and low-tech treatment systems.

- DWWT increases **wastewater reuse opportunities** (e.g. fish ponds, irrigation in agriculture or landscape, toilet flushing) due to the fact that the treated effluent is generated at or near the point of wastewater generation. Centralised WWTPs on the other hand generate large amounts of effluent at one remote location, which usually can only be routed into a receiving water body.

- DWWT allows **phased development and investment** of the urban sanitation system. As DWWT systems cover only a defined, usually rather small, part of an urban environment, the systems can be introduced gradually, depending on the local demand as well as available resources. Centralised systems on the other hand are usually constructed for a future design capacity and require therefore significant immediate capital investment.

- DWWT allows for promoting **awareness on wastewater related issues** in the neighbourhood due to the fact that a particular DWWT project only covers a clearly localized target group. This opportunity for Information, Education and Communication (IEC) campaigns allows the target group to get better involved in decision-making processes and facilitates a sustainable operation of the infrastructure, e.g. by increasing the willingness to pay for sanitation service provision, i.e. wastewater tariffs.

- DWWT is a **flexible approach and allows for temporary solutions**. Due to relatively small investment cost compared to centralised treatment systems, DWWT solutions can be implemented in urban areas, that will not be connected to the centralised system within short- or medium term but require improved sanitation services immediately to ensure public health and avoid environmental degradation. Here DWWT offers a flexible, interim solution that could be integrated into the centralised sanitation concept at a later stage (e.g. as pre-treatment).

- DWWT produces **sludge of high quality** that could be used, after adequate processing, as soil conditioner or fertilizer. The DWWT solutions implemented by WMP produce sludge of high nutrient value, which is suitable for usage in e.g. agriculture, as the applied technology generates nutrient-rich sludge in certain modules that is applicable for reuse after proper treatment (e.g. drying or composting). This is particularly true for DWWT systems treating domestic, non-industrial, wastewater, which is usually not contaminated with heavy metals.

- DWWT requires **very little energy** if sufficient floor space available. Most DWWT technologies WMP has introduced do not require energy for aeration and the treatment process itself. The proposed treatment technologies (see Chapter 4.4) are close-to-nature systems that only use natural processes for wastewater treatment. Only for the wastewater transport via SSS (no mixing and co-treatment of rainwater and groundwater) energy for pumping might be required if local conditions do not allow for gravity-born conveyance.

However, WMP's experiences gathered since 2005 also elaborated some disadvantages and bottlenecks of the DWWT approach that should be considered when identifying the most suitable sanitation concept for a given situation. Those lessons-learnt are presented in the following:

- For decades centralised WWTPs were considered the technology of choice when it came to urban sanitation management. Only recently a **paradigm shift** in sanitation management is underway, both in industrialized and developing countries. Due to that reason, lack of reliable information on design standards, costs, performance and operating procedures of DWWT persists. WMP has gathered a lot of information for DWWT in the Vietnamese context, which is presented in the on-hand paper; however large-scale dissemination (up-scaling) is yet to come.

- Although WMP and other donors are working on promoting DWWT, still **restricted knowledge** on the concept of DWWT exists among decision makers, planners, investors, etc. Fortunately WMP and other donors were able to significantly increase the awareness of decision makers, e.g. by including DWWT as suitable wastewater management concept into the new Decree on Urban Wastewater Management (successor of Decree 88/2007/ND-CP), as well as by implementing successful demonstration and pilot projects all over Vietnam. Despite the progress, further knowledge and capacity building is required in order to up-scale the approach.

- Many **regulations and policies hinder innovative new approaches** for DWWT. Especially the existing direct discharge standard, i.e. QCVN 14, is not suitable for DWWT for various reasons. These include (i) that the required effluent concentrations in Vietnam are not depending on the pollution load (hence the flow rate of a WWTP) but are the same for all sizes of WWTPs, (ii) that effluent standards are generally too strict compared to international experience (especially for small systems), and (iii) that too many parameters are regulated, which is especially contra-productive for DWWT systems and slows down investments in sanitation coverage. Based on lessons-learnt, WMP suggested a reviewed direct discharge standard to MoNRE and MoC by means of a "Policy Dialogue Paper", dated July 2014.

- Due to the fact that DWWT systems are often low-tech or close-to-nature treatment systems, proper functioning depends on O&M. **Adequate and professional O&M** is the core issue for sustainability of DWWT systems. This requires that besides the initial investment, the institutional preconditions for proper O&M must be assured from both, the state management and service provision (see Chapter 0).

- As those DWWT systems promoted by WMP are close-to-nature systems (which is true for all WMP demo systems), **chemicals and pharmaceutical products may damage the treatment process**. However, as long as the DWWT system is connected to domestic wastewater sources the inlet of chemicals and pharmaceutical products should be limited. The operator of the DWWT system shall control and regulate the indirect dischargers to protect the sewer as well as treatment infrastructure. This, however, applies to centralised WWTPs as well.

4.4 Suitable Technologies for DWWT

DWWT is not a specific technology, but a wastewater management approach. Many different technologies exist, from very simple close-to-nature solutions to complex high-tech systems. Various factors decide on the suitability of a certain technology for a specific area of application, including financial resources (for investment and O&M), technical resources for design, construction and O&M, land availability, topography, wastewater origin and characteristics, effluent requirements, etc.

Regarding the selection of a suitable DWWT technology, WMP has gathered the following lessons-learnt:

- DWWT systems should fulfil the **following criteria** to the extent possible:
  - The systems should be suitable for diverse local conditions and versatile in application.
  - They should be easy to erect and operate; as well as easy to upgrade in order to fulfil higher treatment demands.
  - The DWWT system must provide long-term reliable and efficient treatment of wastewater and meet the legal discharge requirements.
  - The systems must provide reliable and efficient treatment of wastewater even with fluctuating hydraulic and biological influent loads.
  - The chosen technology shall only require short planning and implementation phases, and have moderate investment costs.
  - The system should be robust and have limited requirements for O&M.
  - Finally, the DWWT system should have minor management requirements for sludge disposal.

- In this sense **septic tank treatment** as a stand-alone solution is not considered an appropriate DWWT system, able to fulfil the required discharge standards. Commonly used septic tanks shall rather be seen as a pre-treatment unit on household level but not as full-scale DWWT solution.

- Various **technological modules** are suitable for DWWT. In general two or more modules or treatment units - generally a combination of mechanical and (anaerobic and/or aerobic) biological treatment - have to be combined to achieve the legally required discharge standards.

- An important aspect when selecting a DWWT system is **energy consumption**. "Close-to-nature" treatment solutions have the lowest energy consumption. Low-energy solutions should always be given priority to the extent possible when considering and selecting DWWT solutions.

- **Non-technological or less technological** treatment systems should always be preferred. Technical or rather mechanized treatment systems offer better treatment results but at considerably higher O&M costs, which is usually neither feasible nor sustainable under current conditions in Vietnam.

- Connecting less wastewater generators, e.g. smaller clusters of households, to a DWWT plant offers more **flexible treatment** options.

The GIZ WMP has never proposed any kind of high-tech solutions, but simple, close-to-nature, easy-to-replicate systems, including the following elements:

Source → Primary treatment in existing STs → Conveyance in SSS → Anaerobic Secondary Treatment → Aerobic Tertiary Treatment → Discharge into receiving body

Due to the fact that WMP has always focused on simple solutions, only lessons-learnt with close-to-nature and low-tech technologies are presented in this paper. It should however be mentioned that many other, more high-tech, DWWT technologies exists, which include:

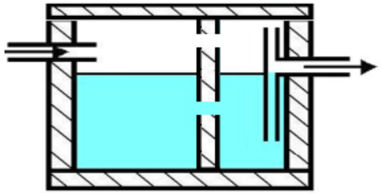
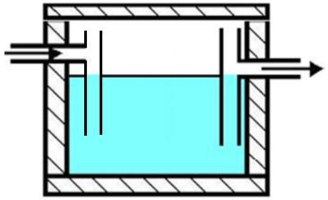
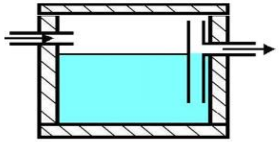
- Biogas Digester or Biogas Settler,
- Trickling Filter,
- Oxidation Ditch,
- Vertical-flow Wetland,
- Up-flow Anaerobic Sludge Blanket (UASB),
- Sequenced Batch Reactor (SBR),
- Rotating Biological Contactor (RBC), etc.

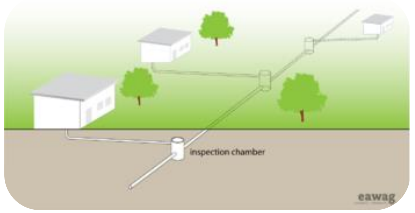
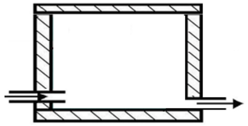
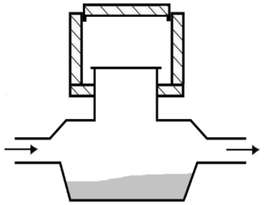
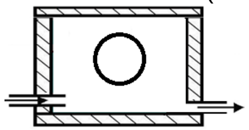
Most of mentioned technologies, however, are presently hardly feasible under Vietnamese conditions due to lacking willingness to cover O&M costs (energy and spare parts).

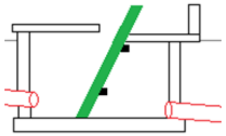
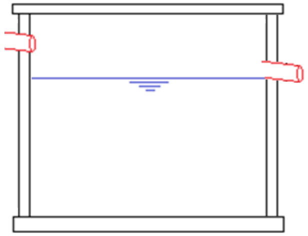
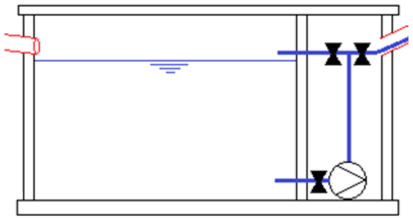
The following table offers a short overview on **suitable DWWT systems** that were proposed and successfully implemented by GIZ WMP in demonstration and pilot projects, including (i) basic descriptions of the modules, (ii) their design criteria, as well as (iii) their strengths and weaknesses.

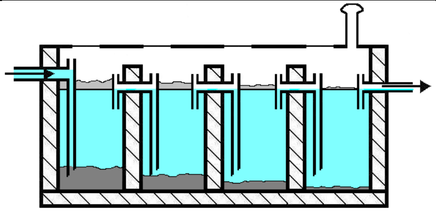
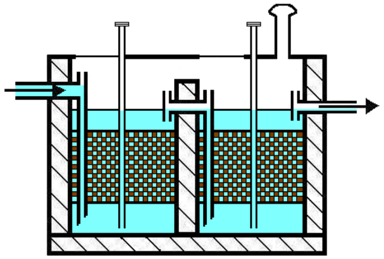
This summary table includes s step-wise listing of potential modules in a DWWT concept, from the wastewater source to the point of disposal, incl.:

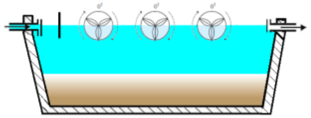
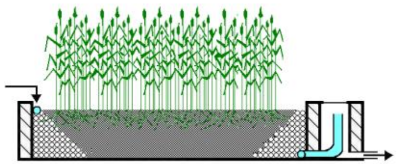
- Pre- or primary treatment modules;
- Collection and conveyance modules;
- Supplementary modules;
- DWWT modules.

Module	Description	Design criteria	Advantages	Disadvantages
Pre- or Primary Treatment Modules				
Septic Tank  *(considered primary treatment)*	• sedimentation • flotation • sludge stabilization	• existing septic tanks to be used (if not existing, a settler should be built for pre-treatment)	• simple and durable, long service life • little space requirement, not visible (underground) • low investment and O&M cost • no skilled labour required • outlet free of settleable solids	• low treatment efficiency • very low reduction of pathogens • effluent not odourless • must be de-sludged regularly • effluent requires secondary treatment
Settler (ST)  *(considered pre-treatment)*	• sedimentation • flotation • sludge stabilization	• 1 chamber • de-sludging 1 - 3 years • (pre-fab) concrete module • HRT: 2h • D=1.5m, • L/W-ratio: 3:1 – 2:1 • Incl. vent pipe / manhole	• simple and durable, long service life • little space requirement, not visible (underground) • low investment and O&M cost • no skilled labour required • outlet almost free of settleable solids	• low treatment efficiency (only pre-treatment) • very low reduction of pathogens • effluent not odourless • must be de-sludged regularly • effluent requires secondary treatment
Collection and Conveyance Modules				
House Connection Box 	• inspection of flow into SSS • access for checking • removal of solids • removal of floating materials (in case of screen)	• one per each wastewater discharge point • storm water to be drained separately • optional built-in screen • (pre-fab) concrete box with RCC cover lid	• can be connected easily to existing septic tank (pre-treatment) by PVC pipe • existing septic tank could be bypassed if required • easy and inexpensive to build	• for connection to existing septic tank (or other wastewater sources) opening of the floor inside the house might be required
Simplified Sewer System (SSS)	• transport of wastewater from point of origin to DWWT system • no mixing with rainwater and groundwater • gravity-born sewer (in many cases no	• laid with 1% slope (0.5% possible for clean effluent) • laid >0.4m under pavement (deeper if laid under streets, or within concrete pipe) • pipe diameter typically DN110 – DN250 • build in PVC (gravity part)	• strictly separated system, hence small pipe diameter • laid in shallow depth at a flatter gradient • use of local material possible • capital cost 50-80% lower than for in-road systems • operational cost low	• removal of blockages required more frequently • junction boxes / inspection chambers required in regular distances for access/cleaning

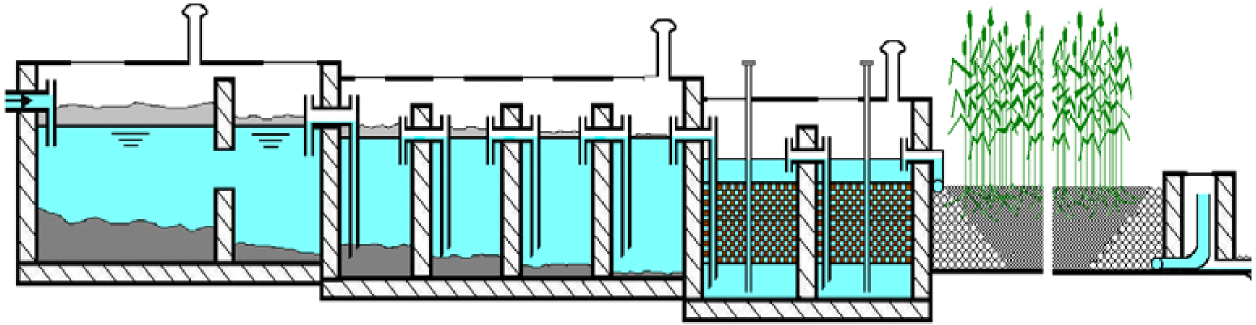
Module	Description	Design criteria	Advantages	Disadvantages
	pumping required)	or PE (pressure part)	• no groundwater infiltration (no breaks in pipes)	
Junction Box (element of SSS) 	• connection of various SSS lines • access for checking of SSS • access for cleaning of SSS from solid waste and floating materials	• located where various SSS lines join together • build as regular concrete box with removable RCC cover slab • (pre-fab) concrete box with RCC cover lid	• easy and inexpensive to build • pre-fabrication possible • hardly no O&M required (no sedimentation of solids)	
Inspection Chamber (element of SSS) 	• access for checking of SSS • access for cleaning of SSS from settleable solids and solid waste	• located every 30m within SSS • pre-fab PVC chamber (collection chamber) • (pre-fab) concrete box with RCC cover lid (superstructure)	• easy and inexpensive to build • pre-fabrication possible	• regular O&M required, particularly de-sludging
Supplementary Modules				
Overflow chamber (CSO)  *(only in case of high peak flows; not foreseen to separate rainwater)*	• discharge / drainage of surplus wastewater • avoid backflow of wastewater into SSS	• located upstream of SSS / DWWT system • (pre-fab) concrete box with RCC cover lid • elevated outlet/drainage PVC pipe (pipe level determines flooding level in catchment area)	• avoids hydraulic overcharging of DWWT system • avoids excessive flooding in catchment area • easy and inexpensive to build • pre-fabrication possible • hardly no O&M required (no sedimentation of solids)	• no separation of rainwater-wastewater mixture possible; hence rainwater shall not be routed into SSS in case of DWWT project (strictly separate system to be designed)
Screen box	• removal of solid waste • prevents clogging of SSS/pump • reduces organic	• located upstream of SSS / pump • metal screen, W=0.4m • bars in 30mm distance • collection drip pan for easy	• easy and inexpensive to build • pre-fabrication possible • easy O&M (only manual removal of solid waste) • removed organic matter might	• frequent O&M (depending on solid waste generation) required

Module	Description	Design criteria	Advantages	Disadvantages
 *(only in case of large amounts of solid waste in wastewater, e.g. in case of markets)*	load on DWWT system in case of organic solid waste (e.g. vegetables rests)	cleaning • (pre-fab) concrete box with RCC cover lid and metal screen inside	be suitable for reuse, e.g. composting	
Buffer Tank  *(only as safety measure)*	• provision of buffer / storage volume	• located upstream of DWWT system • capacity: 24h • D=1.5-2.0m • concrete with water-tight plastering or plastic • manholes for easy access • vent pipe	• ensure buffer in case of system failure • easy and inexpensive to build • use of plastic tanks possible • easy O&M (de-sludging)	• frequent de-sludging required • might create smell pollution
Pumping Station with Collection Tank  *(only if not sufficient natural slope)*	• bridge topographic level difference • ensure continuous wastewater flow (elimination of peak flows) • provision of buffer / storage volume	• consider all criteria for buffer tank • floating switch • impellor pump (dry pump shaft) or submerged pump • pump capacity: continuous wastewater flow over 24h • bypass pipe to collection tank and pressure pipe to DWWT system • ball valves in inflow, bypass and pressure pipes • optional screen in front of inflow pipe	• reduce volume of DWWT system • ensure buffer in case of system (pump) failure • enable DWWT at all locations, irrespective of topography • use of plastic tanks possible	• electricity required • frequent de-sludging of collection tank required • frequent O&M required • noise pollution
DWWT Modules				
Anaerobic Baffled Reactor (ABR)	• anaerobic degradation • sludge stabilization	• 4-5 up-flow chambers (D=1.8m, L=0.7m) • up-flow velocity in chambers: 0.9-1.5m/h • HRT: >12h	• simple to build and operate • durable, long service life • resistant against organic and hydraulic shock loads • high treatment efficiency	• pre-treatment (e.g. in a septic tank/settler) required in order to prevent clogging • lower efficiency at lower pollution loads

Module	Description	Design criteria	Advantages	Disadvantages
 *(secondary treatment)*		• organic load: <3kg COD/m^3*d • inlet-outlet level difference: 0.1-0.2m • down-flow pipes: approx. 0.2m horizontal distance, 0.15m vertical distance to floor	(>80% BOD reduction is possible) • little space requirement (underground) • hardly any blockage • relatively cheap compared to AF • can be efficiently designed for an inflow up to 200 m^3/day • no skilled labour required	• low reduction of pathogens and nutrients • start-up time is long (full operation capacity is reached only after 3 to 6 months) • effluent requires secondary treatment
Anaerobic Filter (AF)  *(secondary treatment)*	• anaerobic degradation	• 1-2 up-flow chambers (D=1.8, L=1.2m) • up-flow velocity in chambers: 1.0-1.5m/h • HRT: 24h (pref.) • organic load: <4kg COD/m^3*d • inlet-outlet level difference: 0.1-0.2m • down-flow pipes: approx. 0.2m horizontal distance, 0.15m vertical distance to floor • filter made of gravel, bamboo, or plastic elements	• simple and durable if wastewater is properly pre-treated • high treatment efficiency (>80% BOD reduction is possible) • little space requirement (underground) • reliable and robust, long service life • resistant against organic and hydraulic shock loads • no skilled labour required	• costly in construction (special filter material required) • pre-treatment is required to prevent clogging of filter • start-up time very long (full operation capacity is reached only after 6 to 9 months) • filters have to be cleaned when efficiency decreases • O&M costs are higher than for ABR • low reduction of pathogens and nutrients • effluent requires secondary treatment
Waste Stabilization Ponds (WSP) (Anaerobic, Facultative, Aerobic WSP)  *(usually used as secondary treatment, aerobic ponds can be used as polishing ponds for tertiary treatment)*	• anaerobic, facultative and aerobic degradation • nutrient reduction (algae growth) • pathogen reduction (UV)	• linked in series of >2 ponds • HRT: 1-20d (anaerobic – aerobic), depending on purpose (secondary or tertiary treatment) • D: 1-5m (aerobic – anaerobic)	• SS and BOD reduction up to 90% • due to serial building upgrading is possible • de-sludging required only every 5 to 10 years • resistant against organic and hydraulic shock loads • very efficient in warm, sunny climates • reduction of pathogens • effective reduction of nutrients • long service life • no electrical energy required	• require large land area; not appropriate for very densely populated or urban areas • pre-treatment with grease traps may be required to prevent scum formation • effluent (may) requires secondary treatment • mosquitos possible • increase in BOD/COD possible due to algae

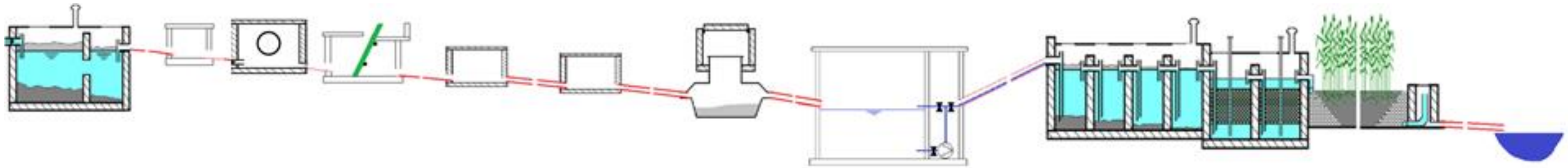
Module	Description	Design criteria	Advantages	Disadvantages
			• low O&M costs • low to moderate capital cost (depending on the price of land) • no skilled labour required	
Aerated Pond (AP)  *(secondary or tertiary treatment)*	• aerobic degradation • nutrient reduction • pathogen reduction (UV)	• linked in series of >1 ponds • HRT: 1-10d, depending on purpose (secondary or tertiary treatment) • D: 2-5m	• high BOD reduction • some nutrient reduction occurs • high reduction of pathogens • good resistance to organic shock loads	• pre-treatment (screening or/and sedimentation) is required to prevent aerator damage • subsequent settling tank or pond may be required to separate the effluent from the solids • requires large land area; (but still smaller then WSP) • O&M costs are high due to skilled personnel (full time) and electricity • constant source of electricity is required • moderate high capital cost depending on the price of land
Horizontal Planted Gravel Filter (HPGF)  *(secondary but more frequently tertiary treatment)*	• filtration • sedimentation • aerobic-facultative-anaerobic degradation • pathogen reduction (UV, antibiotics, die-off) • nutrient reduction (plant uptake)	• consist of plants & filter materials (e.g. graded gravel) • D (filter): 0.6-0.8m • D (water): 0.5-0.6m • W: calculated via cross-section area and depth (D) • Cross section area: calc. with hydraulic conductivity of filter, flow rate and bottom slope • L: calc. via required width (W) and surface area • Surface area: approx. $4m^2/m^3$ of wastewater • bottom slope: 1% • organic load: <8kg COD/m^2*d	• high treatment efficiency • pleasant landscaping possible • no wastewater above ground • no nuisance through odour or mosquito • pathogen and nutrient removal • no electrical energy required • filter material may have to be replaced every 8 to 15 or more years • low operating costs	• pre-treatment is required to prevent clogging (water has to be well settled before inflowing) • requires (large) land area (appropriate for small sections of urban areas, peri-urban and rural communities) • great knowledge and care required during construction • intensive maintenance and supervision during first 1 – 2 years • regular maintenance is necessary with focus on the primary treatment • moderate capital cost depending on land, liner, fill, etc.

As mentioned earlier, a DWWT system consists of a minimum of two treatment modules, usually consisting of a secondary and a tertiary treatment step. The secondary step mainly removes organic pollution, whereas the tertiary step focuses on the removal of pathogens and nutrients. Up-stream a typical DWWT plant, usually a pre- or primary treatment is required, which is located at the point of wastewater generation (e.g. on the property of households in case of residential areas). A typical DWWT combination, which has shown positive results in WMP's demo projects, is the arrangement of a pre- / primary treatment module (settler or septic tank) followed by an ABR + AF combination for secondary treatment, followed by a HPGF or a pond for tertiary treatment. The following figure shows a suitable DWWT solution consisting of ST + ABR + AF + HPGF.



The major idea of the DWWT approach is to cover omitted areas (e.g. peri-urban areas that are/cannot be connected to the central WWTP) with adequate sanitation. The DWWT systems itself is usually located within or close-by the wastewater catchment area. However, also in case of DWWT it is necessary to collect the wastewater from the various points of origin and transport them to the treatment modules via the conveyance modules described in the table above. An entire DWWT solution includes therefore besides pre- or primary treatment and the secondary and tertiary treatment modules also certain collection and conveyance modules, as well as supplementary modules. The selection of collection and transport modules, as well as particularly the required supplementary modules, depends on the local conditions. When developing a DWWT approach, all side conditions need to be carefully considered and taken into account in order to assemble a suitable DWWT solution that is entirely feasible and hence sustainable. The following figure shows a full-scale DWWT solution, incl.:

- Primary treatment via ST,
- Collection and transport via house connection box, SSS, CSO, screen, junction boxes, inspection chamber, collection tank and pumping station,
- Secondary and tertiary treatment via ABR + AF + HPGF, as well as
- Final direct discharge into an open water body.



Various lessons-learnt were collected by GIZ WMP on the proper selection of DWWT modules based on the **individual treatment objective**, which are summarized in the following table:

Treatment objective	Treatment process	Treatment system / method
Reduction of suspended solids (SS)	Sedimentation	Septic Tank / Settler (ST) Anaerobic Baffled Reactor (ABR) Anaerobic Filter (AF) Ponds (WSP) (Horizontal Planted Gravel Filter (HPGF))
Reduction of organic pollution (BOD, COD)	Anaerobic	Septic Tank Anaerobic Baffled Reactor (ABR) Anaerobic Filter (AF) Anaerobic WSP
Reduction of organic pollution (BOD, COD) and nutrients (ammonium, nitrogen)	Aerobic	Aerated WSP Facultative and aerobic WSP Horizontal Planted Gravel Filter (HPGF)
Reduction of phosphorus	Plant-uptake	Horizontal Planted Gravel Filter (HPGF)
Removal/reduction of pathogens (bacteria, viruses, parasites)	Disinfection	Aerated WSP Horizontal Planted Gravel Filter (HPGF) Aerobic (Polishing) WSP

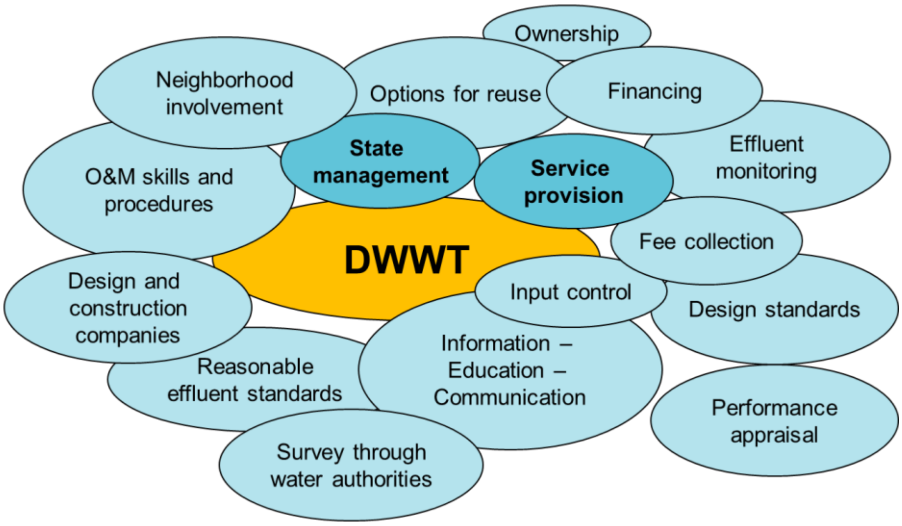
4.5 O&M Requirements for DWWT Modules

GIZ WMP also collected lessons-learnt on required O&M of selected and implemented DWWT modules. Presenting all required O&M steps for the different modules would go beyond the scope of this paper. However, the following table shortly summarizes the O&M requirements of previously presented technologies:

Module	O&M Requirement	Frequency
House Connection Box / Junction Box	• Removal of floating materials • Removal of solid waste • Removal of sediments	At least 1/month
Inspection Chambers	• Removal of sediments • Removal of floating materials	monthly, at least every 6 months
SSS	• Removal of blockages/ clogging	As required (e.g. complaints from residents, backflows), but At least 1/year
DWWT system (collection tank, ABR, AF, HPGF, WSP)	• De-sludging of ABR and AF • Removal of scum in ABR and AF • Removal / cleaning of HPGF filter materials (mainly inlet zone) • Cleaning of HPGF/cutting plants • Inspection of structural conditions of collecting tank/ ABR/ AF/ HPGF, e.g. water tightness • Cleaning of pipes	1/year, or As required Visual checks weekly

4.6 Required Institutional Setup for DWWT

Introducing DWWT in urban management is a complex task. Successful DWWT projects involve the efficient collaboration of various stakeholders, incl. governing bodies and decision makers, as well as service providers. Besides the involvement of all counterparts right from the start it is crucial to consider and address all required elements of a DWWT system, which are displayed as follows:



As demonstrated in the above figure, the **state management** is a main stakeholder for DWWT projects. The state management function might be taken over, depending on the individual setup of the DWWT project, by various government bodies, including the Provincial People's Committee (PPC) and/or the City People's Committee (CPC) and/or the District People's Committee (DPC), supported by different government departments, including the Department of Construction (DoC), the Department of Finance (DoF), and/or the Department of Natural Resources and Environment (DoNRE). The following list summarizes important state management functions and responsibilities that need to be thoroughly considered and addressed from the project start to facilitate the successful implementation of a DWWT project:

- Creation of an **enabling policy and regulatory environment** for the implementation of DWWT and related service provision. The intervention level depends on the scope of the DWWT project and can be either on provincial, city, district or ward level. Crucial is that national regulation (e.g. the new Decree on Wastewater Management) and related standards (i.e. indirect/direct discharge standards, by MoC/MoNRE) are taken into account on local level in order to ensure that the implementation of DWWT project is in compliance with regulatory and legal necessities;
- In practical terms this might include the consideration of DWWT as suitable wastewater management approach in the preparation and implementation of **Provincial or City Orientation and Master Plans**.
- Delegation of **asset ownership** of DWWT infrastructure is a required state management task, as is the decision about allocation of **capital investment and O&M financing**.
- The state management function includes the allocation of responsibility for the preparation of required Economic-Technical Reports (or Feasibility Studies), which might be done either by the future operator or a private contractor. The related technical appraisal of the report is usually done by DoC, meanwhile DoF is usually appointed for the financial appraisal.
- Another state management function is the actual **project implementation**, including the inclusion of projects into DoC/DoF annual plans as well as into socio-economic development plans from the financial point of view.
- Regarding technical aspects of DWWT project implementation, it is a state management responsibility to **appoint the contractor** for construction, as well as the responsible entity for construction supervision.
- Finally the state management is responsible for the selection of an **O&M service provider** to ensure sustainable operation of the DWWT infrastructure. The selection of a suitable service provider includes the signing of a management contract between the asset owner and the service provider, as well as a system for cost recovery for O&M costs, e.g. in the form of a fee system for DWWT.

Besides state management, **service provision** is a crucial component of the required institutional setup for sustainable DWWT. The service provider, who shall be appointed by the asset owner, might be a private contractor or a state-owned company (e.g. URENCO, Water Supply and Sewerage Company, etc.). Considered the current situation in Vietnam, WMP promotes the idea of **decentralised treatment but centralised management**. This means that it is recommended to select one operator to be responsible for many, if not all DWWT systems in a defined area, e.g. a city or province. Managing, operating and maintaining DWWT systems requires profound technical expertise and a trained and skilled workforce. Hence, one service provider should be selected and trained to become a central entity with professional knowledge on DWWT. Over time, as public and private investments into DWWT systems increase, more and more service providers will evolve naturally and a proper market for service provision can develop. Having, however, only one single entity in charge of O&M gives many advantages with regards to technical professionalism and supervision and control of adherence to standards and regulations, such as, e.g. the handling and disposal of sludge removed from the systems. Easy and safe tasks, such as the removal of sludge from connection boxes in SSS can be allocated to community-driven task forces, such as the Sanitation Team in Viem Xa, Bac Ninh. This, however, needs to be decided on a case by case basis and depends on local conditions.

The roles and responsibilities of the appointed qualified service provider are based on the provider's business registration and the respective government decision on related services (e.g. defined in the management contract) and include:

- Preparation of **economic-technical report**, incl. detailed design (if appointed by state management);
- **Construction and/or construction supervision** of the DWWT system works (if appointed by state management);
- **Management of the DWWT system**, incl. of the collection, transport, treatment and disposal infrastructure;
- **O&M of the DWWT infrastructure**, incl. cleaning/de-sludging of sewer system and DWWT, as well as regular and on-demand maintenance/repairs;
- Collection of **wastewater fee / tariff** (if appointed by state management).

5. Conclusions and Recommendations

Based on the experience gathered by GIZ WMP over the past years in developing and implementing DWWT projects, incl. consideration of legislative, institutional, technical-operational as well as financial-economic aspects, the following guiding principles for successful DWWT were developed:

- All involved stakeholders - incl. state management, service provision, private contractors, and donors if any - need to understand that **wastewater treatment is a complicated process**, and so is DWWT. There is no “one-size-fits-all” solution or technology. Every project needs careful consideration of local conditions, incl. involved stakeholders, available land and budget, available O&M resources, etc.
- Before starting with the design and construction of a DWWT system, it must be assured that the facility can be operated with **available funds and resources**. This includes financial budgets for O&M, a cost recovery system, skilled and trained staff for O&M, etc. Many DWWT projects fail to be sustainable because they run out of money after some time of operation. It is therefore crucial that all relevant stakeholders, particularly the state management, are involved in the project planning from the beginning.
- It is essential to closely **cooperate with all relevant authorities** from the very beginning of the project development. These generally include the Provincial People’s Committee (PPC), which might delegate authority to the City People’s Committee (CPC) or the District People’s Committee (DPC), as well as government departments such as the Department of Construction (DoC), the Department of Finance (DoF) as well as the Department of Natural Resources and Environment (DoNRE). It is essential to agree with the state management functions on all project-relevant parameter, such as applicable effluent standards, land availability, asset ownership, future service provision, responsibilities for project implementation (incl. for design, appraisals, construction, construction supervision, and overall project supervision), available financial resources for CAPEX and OPEX, cost recovery for O&M, etc. Setting up a working group or task force with the relevant authorities in order to take decisions and share information is essential to create a basis of trust, for successful project implementation as well as for sustainable operation.
- Collecting **accurate and reliable data** for the design and engineering of a DWWT project is the most important task, especially in case of close-to-nature DWWT solutions. Real life field data shall always be preferred over textbook figures. Therefore, investing resources in proper data collection, including household surveys and workshops with relevant stakeholders, finally pays off. Local knowledge should be collected and used to the extent possible; all figures obtained from third parties should be cross-checked on feasibility. In that regard planners of DWWT system must be aware of the fact that accurate data on raw wastewater quality and quantity is hard to get, why carrying out own sampling campaigns are a suitable option of choice to obtain urgently needed reliable data. All involved stakeholders, particularly funding agencies, need to understand that this is a time consuming and costly task that needs a lot of expertise.
- It is essential to pay attention to the right **work flow order**. It is important not to confuse or skip steps in the project development chain. The project preparatory face is essential to avoid misunderstandings or shortcoming during project implementation and later during operation. Institutional responsibilities should be, for example, clarified before the technical work starts. Financial resources shall be allocated before time is spent in starting with the detailed technical project implementation.
- The DWWT system should be made **as simple as possible**, and at the same time as sophisticated as necessary. Electrical equipment like pumps, aerators, etc. should be avoided to the extent possible to keep CAPEX and OPEX as low as possible. Robust technologies that need little attention should be preferred, even though they might need a larger footprint. Imported equipment shall be avoided in order to ensure sustainable operation and reduce O&M cost in the long run.
- **Separation of storm water and groundwater from wastewater** is essential. No storm water or groundwater should ever be allowed to enter a DWWT system. This is a very important pre-condition for success of a DWWT project. In order to minimize the dimensions of the DWWT system and, more importantly, to ensure proper functioning of the DWWT system, a separate sewer system is essential for every DWWT project.
- It must be assured that the **wastewater reaches the DWWT plant**. Any investment in DWWT infrastructure is pointless, if the wastewater does not find its way into the treatment or even into the sewer system (i.e. because of non-existing house connections, non-existing tertiary sewer lines, or broken concrete sewer lines). To ensure that the pollutants reach the DWWT unit, a

sophisticated collection and transportation system is required. It must be understood by all decision makers, that house connections and tertiary sewer lines are always a challenge and need special attention, from financial, technical and managerial point of view. Instead of focusing on end-of-pipe solutions, suitable wastewater collection and conveyance should be included in every DWWT project. The operation of the collection system requires a proper management system, sufficient funds and trained staff.

- As long as design skills are lacking on local level such as in wastewater companies or in the private sector, and as long as appropriate design standards for DWWT are note elaborated by the government authorities, the **required expertise for DWWT should be hired and consulted**. This refers particularly to the collection of correct baseline data, the selection of appropriate collection, transport and treatment technologies, as well as the detailed design of the modules. This expertise can be brought in by appropriately trained service providers, as well as from external sources like NGOs, universities or ODA projects. A vast amount of literature and information on DWWT is available online; thousands of DWWT systems have been successfully constructed in industrialised, but also developing countries, such as India or Indonesia. Nevertheless, the Vietnamese government should provide suitable technical framework conditions for the up-scaling of DWWT as soon as possible in order to reduce and later eliminate the need for external resources.
- The **selection of capable and experienced contractors** is of upmost importance since DWWT systems may require special skills and experiences. The references and capabilities of contractors must be checked carefully. In this regard, a close collaboration with the state management is required, as the contractor is usually selected and contracted by the local government / funding agency.
- The **sludge generation, treatment and disposal** shall not be forgotten in implementing a holistic DWWT project. It should be clarified how much sludge will be generated, as well as how this sludge will be treated and disposed/reused. Treatment technologies that produce less sludge should be generally preferred, if possible. Anaerobic treatment produces e.g. less sludge due to the higher degradation of organic matter in the sludge. Sludge should be treated as close to the DWWT system as possible in order to avoid additional and costly transportation. Also low-cost, close-to-nature solutions for sludge treatment (e.g. sludge drying beds, composting) should be considered as part of DWWT projects; these solutions help avoiding high O&M costs and skills.
- The **reuse of effluents, sludge and other side products** generated during the DWWT process should be considered; e.g. effluent water for irrigation, conditioned sludge as compost or soil conditioner, biogas for energy generation. The sale of those products might improve the financial viability of a DWWT project. However, respective awareness building (i.e. IEC) and product marketing will be required, which absorbs additional financial resources. Respective reuse options must be considered by decision makers and implementers from the project start in order to design the project accordingly.
- It is recommended to develop **Standard Operation Procedures** (SOP) for the O&M of the DWWT system, including rules for Occupational Health & Safety (OHS). The main target group for these SOPs is certainly the selected service provider. SOPs need to individually designed and adapted to the applied DWWT technology and modules. The SOPs should be developed by the service provider itself, with the support of the designer of the WWTP and based on existing and available standardized SOPs, and should then be integral part of the **O&M training** for the operational staff of the service provider.
- **Community participation and involvement** is crucial for success. It must be ensured that the population living in the project area is informed about the project in general (e.g. objective, intended impact, activities, planned infrastructure, timeline), but also about their rights (e.g. access to improved sanitation, participation in decision making processes as possible) and obligations (e.g. getting connected to the system, payment of wastewater fees). Direct involvement of community members might also be possible in construction (e.g. of the house connections and tertiary sewer lines) and in simple parts of O&M (e.g. removal of sludge from house connection boxes). IEC campaigns are a suitable tool to enhance and ensure the participation and involvement of the community. During preparation and implementation of IEC campaigns, collaboration with the state management, future service providers, intended beneficiaries (e.g. school management), as well as social groups is recommended.
- Beneficiaries, implementers, donors, asset owners and service providers need to understand that a DWWT system might not function well from the very beginning. Every DWWT system needs **fine-tuning** over several months and permanent attention. Besides regular O&M, this fine-tuning requires special expertise and knowledge that may need to come from specialized, maybe

external, experts. The designer of a DWWT solution should be able to do the fine-tuning. Approximately one year of fine-tuning might be considered before a stable operation can be expected.

- A **monitoring system** on the performance of the DWWT should be set up. Although (centralised or decentralised) WWTPs in Vietnam do not require an operation permit, the asset owner and the operator need to ensure that the direct discharge standards[5] (defined by MoNRE on national level, implemented by DoNRE on local level) are followed. This can only be assured by a proper monitoring system. DoNREs are in charge of monitoring the WWTPs and related discharges into the environment; however, also for the operator regular monitoring is crucial to identify shortcomings and areas for improvement.
- **Sharing of lessons-learnt** with other stakeholders that have carried out DWWT projects already shall be considered a huge source of knowledge. This includes state management bodies, service providers, private contractors, donors, external advisors, etc. Each group of stakeholders can contribute essential information in their specific working area. This exchange of information can be done e.g. by inviting them to project preparation workshops and other consultation processes.

[5] If a DWWT system is used to pre-treat (e.g. industrial) wastewater prior to discharge into a sewer system (indirect discharge), MoC is in charge of issuing respective standards and DoC for the monitoring of the WWTP.