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Potential of Wastewater Reclamation to Reduce Fresh Water Stress in Ho Chi Minh City-Vietnam

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ABSTRACT

Excess groundwater exploitation for domestic and industrial uses leads to groundwater table drawdown, water quality depletion, salt intrusion and water shortage in dry season in Ho Chi Minh City. Moreover, untreated wastewater discharge and huge fresh water exploitation from industrial, residential and agricultural activities of provinces in the upstream of SaiGon and Dong Nai rivers have resulted in degradation of surface water quality. Water Stress Index (WSI) was used in this study to assess water scarcity of Ho Chi Minh City and the neighboring provinces of Dong Nai river basin. WSI of Dong Nai River basin was 13% in 2010 and increasing to 23% in 2025. This showed that cities of the Dong Nai river basin are under a stress of fresh water use, which may limit local economic development and require the authority of the local area to reduce the use of fresh water resource. The use of reclaimed wastewater for non-portable water demand in HCMC may reduce significantly WSI. Therefore, this paper aims to assess potential of wastewater reusein HCMC in the future.

Keywords: Reclaimed water; Wastewater reclamation; Central wastewater treatment plant (CWWTP); Water users; Water stress index; Raw water exploitation rate

1. INTRODUCTION

Increasing need of alternative water resources and strict effluent quality standards have promoted water reclamation, which considered as a vital measure of integrated water resource management and sustainable social development in the world (Bahri, 1999). In Mediterranean countries, the treated wastewater as an alternative water source, has been used due to increasing irrigation water demand and urban water shortage (Angelakis et al., 1999). In Europe, reclaimed water has been predominantly reused for agricultural, urban and environmental applications due to increase of water demand, water supply costs, and competition of good quality fresh water resources (Bixio et al., 2006).

The biggest challenge of large cities for water and environmental utilities is wastewater treatment targeted at low cost and wastewater reuse for community, agriculture and industry (Richard and Rafik, 2003). Similarly, owing to the fast urbanization and industrialization, Ho Chi Minh City (HCMC), with population of over 8 millions in 2010, has faced to challengesforwater supply and wastewater treatment due to fresh water scarcity and water pollution.

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Water scarcity in HCMC was observed due to (i) impact of climate change that seawater intrusion into the aquifers and rivers, (ii) overexploitation of underground water resources for industrial and domestic uses in HCMC and the neighboring provinces and (iii) Degradation of river water quality by agricultural aquaculture activities in the upstream area (Dan et al. 2007). To overcome the water scarcity, water reclamation is one of effective water and wastewater management strategies for sustainable development of HCMC. This study aimed to: (i) determine fresh water scarcity of HCMC based onwater stress index (WSI), and (ii) estimate potential of wastewater reuse in HCMC.

2. METHODS

Water Stress Index (WSI) was used to assess water scarcity in the context of rapid development of HCMC and neighboring provinces located in Dong Nai river catchment basin. WSI is a ratio of total water demand to freshwater available (Angelakis et al., 2003).

Water stress is considered low at WSI values less than 10%. WSI value ranging from 10% to 20% shows that the fresh water availability becomes a constraint on eco-social development and that huge investments are neededto supply sufficient fresh water demand. At WSI above 20%, the community needs comprehensive management efforts to balance supply and demand, and conductsactivities to solve conflicts between competitive consumers (Angelakis et al., 2003).

Estimation of wastewater reusepotential in HCMC was based on (i) Possible quantity of alternative reclaimed water from the treated domestic wastewater treatment plants to mitigate WSI, (ii) Demand of wastewater treatment, (iii) Feasibility of wastewater reuse as strategic alternative freshwater resource, and (iv) Feasibility of build-up of wastewater reclamation facilities.

3. RESULT AND DISCUSSION

3.1 Raw Water Exploitation in HCMC

Table 1 presents change of the water consumption of HCMC versus time. The water consumption was approximately 2.5 million m^3/day in 2009 and it may increase 4.75 million m^3/day in 2025. The biggest water consumption was household use and the second was public services and commerce in 2009. The household water demand is 200 litres/capita/day. In the future planning, HCMC will enhance development of services and commerce, whereas, industries will be transferred to the surrounding provinces such as Long An, Dong Nai and Binh Duong. Therefore, the water use of industry may be about 11% of total water demand in 2025.

Table 1 Water demands of HCMC in the past and the future

Type of Use	1995 (VIWASE, 2001)		2005 (DPA, 2007)		2009 (DPA, 2007)		By 2025 (DPA, 2007)	
	m^3/d	%	**m^3/d**	%	**m^3/d**	%	**m^3/d**	%
Household	383,558	85	1,260,000	66	1,600,000	64	3,400,000	72
Industrial zone	50,413	11	64,500	3	145,000	6	476,000	10
SMEs	19,624	04	380,000	20	263,000	10	40,000	1
Services and commerce	NA	NA	205,000	11	492,000	20	830,000	17
Total	**453,625**	**100**	**1,910,000**	100	**2,500,000**	**100**	**4,750,000**	**100**

Note: SMEs – Small and medium scale enterprises/industries; NA – not available

Water resources for agriculture use in HCMC mainly are (i) raw water taken from irrigation canals system of SaiGon and Dong Nai rivers and (ii) storm water in the rainy season. Groundwater use for agriculture has been insignificant in HCMC, because of (i) availability of fresh raw water of the irrigation canals located in the West and South-East of HCMC and (ii) unsuitability of groundwater quality for irrigation such as high concentration of iron, salinity and low pH.

Two fresh water resources used for HCMC are (i) surface water, including DauTieng reservoir, SaiGon River, and Dong Nai River and (ii) groundwater. Table 2 shows the balance of raw water resources and their water exploitation rate. The main raw water resource used for the current water supply for HCMC is Dong Nai river and SaiGon river. 64% and 36% of total raw water were taken from the surface water and groundwater, respectively. The master plan of water supply (VIWASE, 2008) shown that the upstream reservoirs of SaiGon and Dong Nai rivers (DauTieng and Tri An reservoirs) will be the main raw water resources used for HCMC in 2025.

Table 2 Freshwater exploitation rate in Dong Nai river basin versus time (VIWASE, 2008)

No	Raw water resources	2007		2010		2015		2025	
		$m^{3/}$day	%	$m^{3/}$day	%	$m^{3/}$day	%	$m^{3/}$day	%
1	Dong Nai river	900,000	47	1,562,000	62	2,277,000	59.2	1,610,000	34
2	Tri An reservoir	-	0		0	0	0	1,500,000	32
3	SaiGon river	320,000	17	320,000	17	500,000	13	500,000	11
4	Dong Channel	-	0	220,000	9	0	0	0	
5	DauTieng reservoir	-	0		0	825,000	21.6	1,100,000	23
6	Groundwater	692,000	36	437,000	17	240,000	6.2	0	0.8
Total		**1,910,000**	**100**	**2,537,000**	**100**	**3,842,000**	**100**	**4,750,000**	**100**

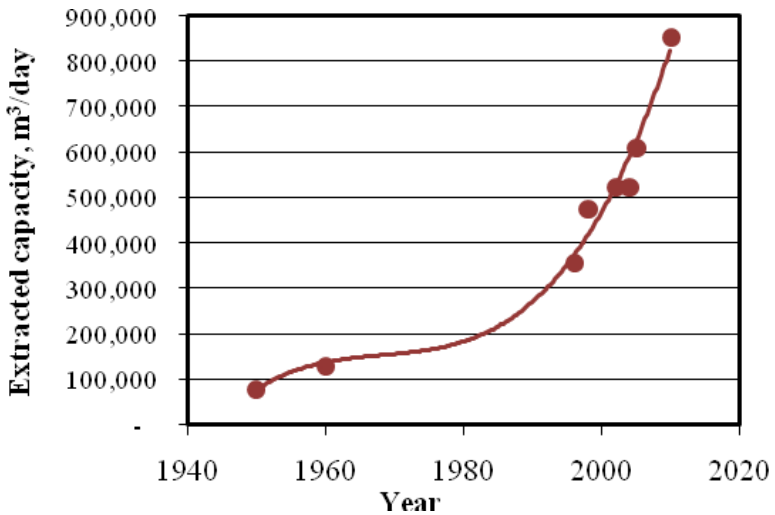

Figure 1 Change of groundwater use of HCMC (Dan et al., 2008)

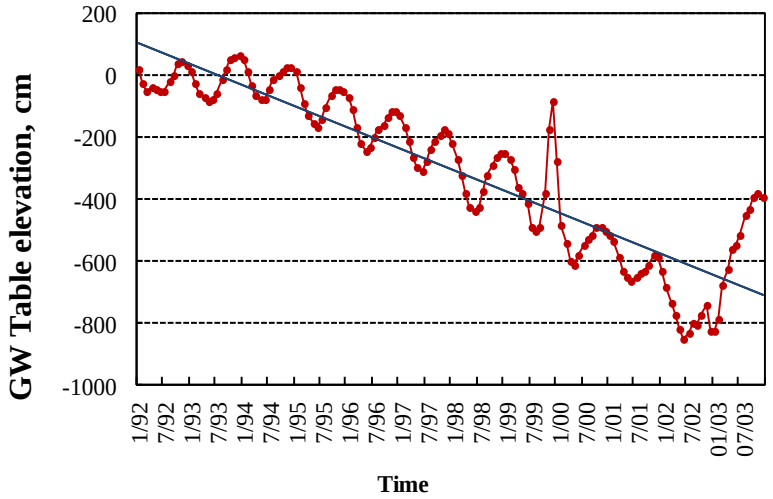

Figure 2 Change of GW table of monitoring well at BinhChanh District, HCMC (Dan et al., 2008).

Groundwater has been exploited since 1920 in HCMC. Rapid increase of the groundwater use started since 1990 when economic policy of Viet Nam was opened. High industrialization and urbanization resulted in the quick increase of water demands. The expansion of surface water works in HCMC has not met this rapid increase. Moreover, until now the free of GW charge and uncontrolled exploitation have more and more augmented the exploitation rate (Figure 1).

Nga (2006) reported that the water table of aquifers decreased extremely. Average annual descent was about 1.5-2.0 m since 2000 (Figure 2). Apart from HCMC, Dong Nai river and SaiGon River are also the main fresh water resources used for other provinces in the Dong Nai river basin (Binh Duong, Song Be, TayNinh and Dong Nai, Ba Ria-Vung Tau provinces).

3.2 Water Stress Index

Determination of WSI of Dong Nai river basin until 2025 is based on water demands and the total safe fresh water exploitation rate of two large rivers of Dong Nai river system: (i) Dong Nai river and (ii) Saigon river. The total water demand of the Dong Nai river basin was 384 l/capita/day in 2010. The predicted value is 394 l/capita/day in 2025 (VIWASE, 2008). The total water demand includes that of domestic, industrial and agricultural uses. Agricultural water uses in 2010 and 2025 in Dong Nai basin are 68% and 60%, respectively (Dan et al., 2009).

JICA (2000) assessed total safe exploitation rate of fresh water of Dong Nai river and SaiGon river were 389 m^3/s and 59 m^3/s at Hoa An and Ben Than water intakes, respectively. The safe freshwater exploitation rate, considered as renewable freshwater availability, at which seawater intrusion to these raw water intakes is prevented in the dry season. Nga (2006) claimed that safe groundwater exploitation rate at which impacts of land subsidence and seawater intrusion were not significant was 10 m^3/s. Thus, the total safe freshwater exploitation rate of HCMC is 458 m^3/s, equivalent to 14,400 million m^3/year. Water stress index of water use of HCMC and provinces in the Dong Nai river basin is shown in Table 3.

Table 3 shows that SWI of provinces and cities in Dong Nai river basin was above 10% in 2010 and up to 23% in 2025. The main reason of increase of SWI is rapid increase of population growth due to fast urbanization

Table 3 WSI of HCMC and neighboring provinces in Dong Nai river basin.

Items	unit	1995	2000	2010	2025
Population(*)	million people	7.8	8.8	13.4	22
Renewable freshwater availability per capita	lit/capita/day	5058	4483	2944	1715
Total water demand	million m^3/year	0.99	1.80	1.88	3.31
Total water demand per capita	lit/capita/day	347	360	384	394
Water Stress Index (WSI)	**%**	6.9	8.0	13.0	23.0

Source: (*)DPA, 2007.

and industrialization of HCMC, Dong Nai, Binh Duong and Ba Ria-Vung Tau provinces, which are located in the downstream region of Dong Nai river basin. HCMC will suffer the serious water scarcity in 2025 with the population over 10 million (DPA, 2007).

3.3 Potential of wastewater reclamation

3.3.1 Reduction of WSI

To lower WSI from 23% to 15% and 10% in 2025, alternative fresh water sources must provide 1.4 and 2.3 million m^3/day for HCMC, respectively. To obtain low WSI, the government should have integrated regional strategic measures such as well control or restriction of freshwater exploitation rate, increase of water storage at upstream reservoirs in the dry seasons, rainwater use and wastewater reuse. DPA (2007) reported that discharge of municipal wastewater in HCMC in 2005, 2010 and 2025 were 1.5, 2.5 and above 3.0 million m^3/d, respectively. Thus, to reduce WSI from 23% to 15% and 10%, HCMC should reuse 47% and 77% of total discharge of domestic wastewater in 2025, respectively.

3.3.2 A feasible alternative resource

In comparison with increase of upstream water storage and rainwater use, wastewater reuse may be a feasible strategic alternative resource for situation of HCMC.

New construction or expansion of upstream reservoirs such as DauTieng and Tri An reservoirs may face the following difficulties: (i) high investment costs for construction of dams, reservoirs and raw water transport pipe lines to downstream area; (ii) using large area for reservoirs; (iii) increasing risk of flooding in downstream region in wet season; (iv) negative impacts on upstream region such as deforestation and relocation of local communities.

High rainfall in HCMC is good option for alternative freshwater source. However, collection, harvesting and use of rainwater may have drawbacks as follows: (i) High investment costs and large area for rainwater harvesting and storage; (ii) significant dependence on rainfall resulting low reliability in terms of sufficient water supply. In comparison with the above options, it is considered-wastewater reuse as the feasible option for HCMC, the largest and crowded city located in the downstream of Dong Nai river basin.

3.3.3 Demand of wastewater treatment

Demand of wastewater treatment is a factor driving further of wastewater reuse in HCMC. According to national environmental protection laws issued in 1994 and updated in 2005, all cities and towns must have domestic wastewater treatment plants. New apartments, hotels, service areas and industrial parks are requested to control wastewater pollution. Nghiem and Dan (2011) reported that there

were above 250 projects on new apartments and office buildings having on-site WWTP, meeting the secondary treatment level, prior to discharging effluent into the street sewer.

Master plan of sewerage system of HCMC (JICA, 2000) reported that HCMC was divided into two areas: (i) urban area having wastewater collection system and WWTP and (ii) the sub-urban area without wastewater collection system, but decentralized wastewater treatment is required. The urban area of 19,000 ha was divided into nine drainage catchment zones and each zone had a centralized WWTP at the end of the wastewater collection network. The predicted wastewater discharge of urban area and sub-urban area were 2,303,000 m^3/d and 780,000 m^3/day in 2020, respectively (JICA, 2000). Nine centralized WWTP will be located in the sub-urban areas. This facilitates wastewater reuse for agriculture areas in the sub-urban or the surrounding provinces. Since 2008, a decentralized domestic WWTP with capacity of 141,000 m^3/d, which is located in BinhChanh district, sub-urban district, has been run. Nghiem and Dan (2011) reported that this WWTP using activated sludge produced high quality effluent (BOD_5 =10-25 mg/l, SS = 20-40 mg/l and total coliform less than 20-200 MPN/100ml), which may be good enough for agricultural irrigation or urban tree watering if advanced treatment using sand filtration followed by chlorination. In fact, US.EPA (2001) claimed that the effluent after secondary treatment and disinfection with $BOD_5 \leq$ 30mg/l, SS $BOD_5 \leq$ 30mg/l and total coliform $\leq$ 240 MPN/100 ml was allowed to use for non-food crop irrigation or restricted urban reuse in Washington State.

The use of reclaimed water for non-potable purposes offers the potential for exploiting an alternative new resource that can be substitute for existing potable sources (US.EPA, 2001). Under high freshwater stress, which the water demand in HCMC exceeds the safe exploitation capacity of natural freshwater sources and additional sources are unavailable, lower quality water like treated domestic wastewater can be substituted to serve the non-potable purposes such as toilet flushing, cloth washing, road washing, garden and park irrigation, fire extinguishing, industrial cooling and construction activities, etc. Table 4 shows the predicted non-portable water demand in HCMC in 2025.

Table 4 The predicted non-portable water demand in HCMC in 2025

Users	**Objects**	**Demand** (m^3/day)
	Road washing and fire extinguishing	340,000
	Garden & park watering	199,000
Urban	Toilet flushing and cloth washing	1,020,000
	watering golf courses and sport facilities	19,000
	Greening belt	58,000
Industry	Industrial use:	623,000
	- Cooling water	160,000
	- Others	249,000
Agriculture	Irrigation and aquaculture	1,391,000
Landscape creation	ponds, water parks Fishing ponds, boating and other entertainment activities	46,000

Notes:

1) Road washing and fire extinguishing ≥ $K_1.Q_1$

Including:

- K_1: ratio of water consumption for road washing and extinguishing to that for domestic use is 10% (MC, 2006).
- Q_1: water demand for domestic use will be 3,400,000 m^3/day in 2025 (VIWASE, 2008)

2) Toilet flushing and cloth washing= K_2. Q_1

Including:

- K_2: ratio of toilet flushing to household use is 19% (J.Y. Chu et al 2004) and ratio of cloth washing to household use is 21% (ASCE, 1998).

3) Garden and park watering= A_1. Q_2

Including:

- A_1: total area of the public parks/gardens in HCMC is 6,680 ha (DPA, 2007)
- Q_2: Water demand for garden and park watering: 3 L/m^2.day (MC, 2006).

4). Watering golf courses and sports facilities= A_2. Q_3

Including:

- A_2: total area of golf and sports facilities of HCMC is 380 ha (DPA HCMC, 2007)
- Q_3: Water demand of watering golf courses and sport facilities: 5 L/m^2.day (MC, 9006).

5) Cooling water

Parameters	**2010**	**2020**
A_3 (ha)	2,900	6,660
Q_4 (m^3/ha.day)	40	40
F = $A_3.Q_4$ (m^3/day)	115,000	267,000
K_3 (%)	60	60
G = F. K_3	69,000	160,000

Including :

- A_3 : area of industrial zones (DPA, 2007)
- Q_4 : Water demand of an industrial park = 50 m^3/ha/day (VIWASE, 2008)
- F : daily water volume for industry
- K_3 : ratio of cooling water demand and total water demand in industry = 60% (Chu, et al., 2004)
- G : volume of cooling water

6) Agricultural irrigation: agricultural area is 46,350 ha in 2025 and irrigation demand is 3 L/m^2.day (DPA, 2007).

7) Recreation: the area of ecotourism zone is 5,120 ha in 2025 (DPA, 2007) and water demand for recreation area is 29 m^3/ha/day (SCWAZ, 2006).

Excepting agricultural use, the biggest of non-portable water demand for the urban use is toilet flushing and cloth washing (Table 4). Urban green area including public parks, gardens and green belt will be 8,560 ha in 2025, corresponding to 4.1% of total area of HCMC (DPA, 2007). Thus, water volume for watering in the dry season may be over 257, 000 m^3/day.

3.3.4 Feasibility of water reclamation facilities

The construction of reclaimed water transmission and distribution lines to existing users in large city like HCMC is expensive and disruptive. As a result, wastewater reclamation and reuse will be most attractive in serving new residential, commercial, and industrial areas of a city, where the installation of dual distribution systems would be far more economical than in already developed areas (US.EPA, 2001). Until 2025, the developing urban area and sub-urban area are about 35,200 ha and

40,000 ha, respectively (DPA, 2007), it takes 36% of total area of HCMC. Therefore, if City Authority issues soon suitable policies on encouragement or forcing to use reclaimed water in these areas, the potential of wastewater reuse can exploit effectively.

With the agricultural area of 46,350 ha in 2025, the water demand of irrigation and aquaculture will be up to 1.4 million m^3/d. Therefore, use of reclaimed water for agricultural purposes near urban areas can be economically attractive. Besides, the remaining volume of effluent from WWTPs after reuse can be used to clear and renewing the current polluted canals in terms of urban aesthetic aspect.

CONCLUSIONS

The rapid increase of water use for urban, industry and agricultural activities in HCMC has resulted in depletion of groundwater and surface water quality. Therefore, searching alternative water sources are very necessary. Wastewater reuse is a feasible strategic alternative water source for situation of development of HCMC.

WSI of Dong Nai River basin was 13 % in 2010 and it may increase to 23% in 2025. It showed that cities in Dong Nai river basin are under lack of fresh water resources, which can restrict their eco-social development.

If HCMC authority has right policies to encourage and even forcing the wastewater reuse, total reclaimed water demand can be up to 2.3 million m^3/day, which lower WSI to 10%.

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