

Reuse of wastewater in construction projects

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Abstract. Wastewater generated in construction projects such as hotels, resorts, high-rise apartments, mixed-use commercial centers, etc. accounts for a significant amount, including domestic wastewater and rainwater. The reuse of wastewater for domestic use, irrigation, fire fighting, and cooling purposes is being encouraged and applied to save the amount of freshwater used, reduce production costs, lower management and operating expenses of construction works, protect the environment, and save energy and chemicals. In this article, the author introduces solutions for reusing domestic wastewater and rainwater from construction projects, meeting the trend of developing green, eco-friendly, and energy-renewable constructions for both present and future.

Keywords: Reuse of wastewater, Blackwater, Greywater, Rain water.

1 Introduction

1.1 Concept of wastewater reuse

The reuse of water is the activity of reusing treated wastewater that meets the national technical standards suitable for the intended purpose of reuse[14].

The reuse of rainwater for different purposes must meet the appropriate water quality standards and technical regulations [12].

1.2 Wastewater types in construction projects

Types of wastewater from construction works can be collected from Hotels, high-rise apartments, mixed-use commercial office areas, villas etc. The study area, wastewater is divided into the following types: black water, greywater, and rainwater (considered as clean wastewater).

Blackwater: Blackwater is wastewater from toilets and bathrooms that contain feces and urine. Also known as sewage or brown water, it can carry harmful bacteria that can cause diseases in humans.

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Greywater: Graywater is wastewater from sinks, washing machines, and bathtubs. It contains fewer pollutants than blackwater and is easier to treat.

Rainwater: Rainwater is water collected from roofs, gutters, and yards. It contains a lower amount of pollutants than greywater and is easier to treat.

2 The legal basis and encouragement for wastewater reuse

2.1 Foreign country

The experience of water reuse in some countries is shown:

Australia: As part of the Environmental Protection Act 1994, the Water Pollution Control (Queensland) Policy 2009 is responsible for managing the water resources of Queensland, Australia.

Philippines: In the Philippines, Republic Act 9275, also known as the Philippine Clean Water Act of 2004, is the law governing wastewater management. This law outlines the state policy of protecting, conserving, and rehabilitating the quality of freshwater, inland, and marine waters, in which wastewater management plays a crucial role.

United States: The Clean Water Act is a federal law in the United States that manages surface water pollution. The law is enforced by the United States Environmental Protection Agency in cooperation with other states, territories, and tribes. The provisions for protecting groundwater are included in the Safe Drinking Water Act, Resource Conservation and Recovery Act, and Superfund Act.

Nigeria: In Nigeria, the Water Resources Act of 1993 is the law responsible for all forms of water resource management.

2.2 In Vietnam

Some regulations of the Vietnamese government on water reuse:

Decree No. 54/2015/ND-CP dated June 8, 2015 on regulations for incentives for efficient and economical use of water (Article 3) [14].

Decree No. 80/2014/ND-CP dated August 6, 2014 on drainage and wastewater treatment (Article 20) [12].

Decree No. 38/2015/ND-CP dated April 24, 2015 on the management of waste and scrap materials (Article 40) [13].

3 Forms of reusing domestic wastewater

The World Health Organization (WHO) recommends the use of treated domestic wastewater for reuse in the following four areas:

1. **Urban reuse**: A large amount of water used in urban areas does not require high-quality water such as drinking water. Treated domestic wastewater can be reused for purposes such as irrigation, street cleaning, toilet flushing, firefighting, and urban landscape restoration depending on the demand.
2. **Agricultural reuse**: Agriculture is the most important sector for Vietnam's development, and it is also the sector that uses the most water. The use of treated wastewater for irrigation needs to take into account the quality of the wastewater, especially the levels of nitrogen, potassium, and various trace elements such as zinc and sulfur, which are essential for plant growth. However, in some cases, these substances must not exceed the requirements of the crops to avoid polluting the groundwater.

3. Industrial reuse: Industrial wastewater accounts for about 20% of global freshwater resources. The demand for water is predicted to increase by 1.5 times by 2025. Therefore, the reuse of industrial wastewater not only brings general environmental benefits but also significantly reduces production costs, recovers water resources, and reduces the costs associated with wastewater treatment and discharge into receiving water bodies.
4. Aquifer recharge: Recharging the groundwater can help prevent land subsidence, reduce groundwater levels, prevent saltwater intrusion, and maintain groundwater resources for future needs.

4 Methods

4.1 The wastewater flow generated in construction sites

Water quality standards

- Domestic water (Vietnamese standard 4513/1988/The Ministry of Construction - Interior water supply, design standards) [4]:
Hotel: qtc = 300 l/person/day and night;
Apartment: qtc = 200 l/person/day and night;
Villa: qtc = 300 l/person/day and night;
Residential house: for Hanoi (special urban area): 200 l/person/day and night (Vietnamese standards 33/2006/ The Ministry of Construction) [2;5];
- Irrigation water (Vietnamese standards 33/2006/ The Ministry of Construction): 1.5 liters/1m²;
- Pool refill water: 10% of the pool volume (Vietnamese standards 4513/1988/ The Ministry of Construction) [4];
- Laundry water: 90 liters/kg.
- Water for meeting rooms, canteens, and refreshments: 25 liters/1 seat (or 1 person).

Drainage standards (Vietnamese standards 4474:1987/ The Ministry of Construction - Interior drainage, design standards) [6].

- Drainage standards are calculated based on water supply standards.
- The amount of drainage water is determined by the water supply flow rate (after deducting irrigation water and pool refill water).
- Rainwater: calculated according to the q5 standard: rainfall intensity (l/s.ha) calculated for the locality with a rainfall time of 5 minutes and a frequency exceeding the calculated intensity for 1 year (p=1 year).

Formulas for determining flow rate

- Average daily household water consumption:

$$Q_{\text{day}}=(N \times \text{qtc})/1000; \text{ m}^3/\text{day} \tag{1}$$

Where: N - number of people calculated; person. qtc - Water supply standard; liters/person/day and night. 1000 - conversion from liters to m³.

- Maximum daily household water consumption:

$$Q_{\text{(max day)}}=Q_{\text{ng}} \times K_{\text{day}}; \text{ m}^3/\text{day} \tag{2}$$

Where: K_{day} - Non-air-conditioned factor for maximum day; K_{day}= 1.2 ÷ 1.3.

- Irrigation water flow:

$$Q_{\text{irrigation}}=(F \times \text{qtc})/1000; \text{ m}^3/\text{day} \tag{3}$$

Where: F - Area to be irrigated; m². qtc - Irrigation water supply standard; liters/m²/day and night. 1000 - conversion from liters to m³.

- Rainwater flow on the roof:

$$Q = K \times F \times q_5 / 10000 \text{ (l/s)} \tag{4}$$

Where: Q: roof rainfall (l/s). F: rainwater collection area (m²). F = Froof + 0.3

Fwall Froof: projected area of the roof (m²). Fwall: area of the wall in contact with the roof or built higher than the roof (m²). K: coefficient taken as 2. q5: rainfall intensity (l/s.ha) calculated for the locality with rainfall time of 5 minutes and the period exceeding the design intensity equal to 1 year (p=1 year). For Hanoi: q5 = 484.6 (l/s.ha) (Vietnamese standards 4474:1987 - Internal drainage - Design standard) [3]

With a diameter of D110mm (Upvc plastic), the rainwater flow can be discharged about 15 liters/s.

4.2 Wastewater treatment technology chain for reuse

Quality requirements for treated water according to Vietnamese standards and regulations. To compare, analyze, and identify important indicators for developing standards for recycled water quality, certain wastewater quality indicators based on the primary values in column A of Vietnamese standards will be considered.

- Vietnamese Standards 14:2008/ Ministry of Natural Resources and Environment column A specifies the values of pollution parameters as the basis for calculating the maximum allowable values in wastewater and exhaust gas into water sources used for domestic water supply purposes [9].
- Vietnamese Standards 14:2008/ Ministry of Natural Resources and Environment column A specifies the pollution parameters in industrial wastewater discharged into water sources used for domestic water supply purposes [7].
- Vietnamese Standards 14:2008/ Ministry of Natural Resources and Environment column A specifies the parameters in the source water used for domestic water supply, conservation of aquatic plants and animals [8]. Some important indicators for assessing the quality of Class A water according to the above regulations are summarized in Table 1.

Table 1: Some important criteria for evaluating the quality of Type A water according to Vietnamese standards [7-9].

Vietnamese Standards	Total Coliforms MPN/100 ml	BOD 5 mg/l	COD mg/l	TDS mg/l	DO mg/l	pH	Chloride mg/l	Total Phospho mg/l	Total Nitrogen mg/l
Vietnamese Standards 14:2008	3000	30	-	500	-	5-9	-	-	-
Vietnamese Standards 40:2011	3000	30	75	-	-	6-9	500	4	20
Vietnamese Standards 08:2015	2500	4	10	-	>=6	6-8.5	250	-	-

5 General process flow diagram for wastewater treatment for reuse

5.1 Regarding the treatment of general blackwater and greywater:

The water treatment process is shown as follows:

Wastewater (including black and grey water) -> Inlet screening -> Grit removal -> Sand sedimentation -> Equalization (with hydraulic mixing, aeration, or mechanical mixing) -> Anaerobic treatment -> Anoxic treatment -> Aerobic treatment (with mobile media) -> Clarification -> Biological flotation -> Disinfection -> Storage of reclaimed water (meet column A according to Vietnamese standards 14:2008/ Ministry of Natural Resources and Environment) -> Reuse for purposes such as irrigation, street washing, landscape irrigation, fire protection, and cooling of central air-conditioning condenser [6;9;16-18].

5.2 For the treatment of black water

For black water and grey water are separated into two distinct wastewater streams:

Wastewater (black water) -> Receiving tank -> Bar screen -> Conditioning (with hydraulic mixing, air aeration, or mechanical mixing) -> Treatment of volatile organic compounds -> Treatment of nitrogen deficient compounds -> Treatment of nitrogen rich compounds (with moving bed biofilm reactor) -> Sedimentation -> Biological flotation filtration -> Disinfection -> Reuse storage tank (meet column A according to Vietnamese standards 14:2008/ Ministry of Natural Resources and Environment) -> Reuse for purposes such as irrigation, street cleaning, toilet flushing, and agriculture [6; 9; 16-18].

5.3 For greywater treatment

For blackwater and greywater are treated in separate systems:

Household wastewater (gray water) -> Receiving tank -> Screening -> Sand settling -> Conditioning (with hydraulic mixing, aeration or mechanical mixing) -> Removal of coarse bubbles -> Removal of fine bubbles -> Removal of very fine bubbles (with mobile media) -> Settling -> First-stage biological floating bed -> Second-stage thorough filtration -> Disinfection -> Reuse tank (complying with Column A of Vietnamese standard QCVN 14:2008/ Ministry of Natural Resources and Environment) -> Reused for purposes such as fountains, irrigation, road washing, landscape ponds, fire protection, central air conditioning cooling, swimming pools (in some cases, it can also be used for domestic water supply according to Vietnamese standard QCVN 02/2009/ Ministry of Health) [10].

Note:

- Greywater discharged from the Kitchen area: before entering the Receiving Tank, it needs to go through an oil and grease separator tank.
- Greywater discharged from the Laundry area contains chemicals: before entering the Receiving Tank, it needs to go through a pH balancing tank and a foam separator tank.

5.4 Regarding rainwater treatment

For the rain water, the treatment process is shown as follows:

Rainwater -> Receiving tank -> Debris screen -> Sand settling tank -> Rapid gravity filter -> Disinfection -> Reclaimed water storage tank -> Reuse for purposes such as fountain, irrigation, street washing, landscape pond, firefighting, cooling of central air-conditioning, swimming pool, and can be used for domestic purposes (according to Vietnamese standard QCVN 01-1/2018/ Ministry of Health) [11].

Note: If using rainwater for domestic purposes, the following points should be noted:

The first rainwater of the rainy season is separated and sent to a pH balancing tank (lime may need to be added to raise the pH in case of acid rain).

Rainwater after 15-30 minutes of rainfall, after treatment, can be used for domestic purposes.

5.5 Results

Below is a typical example of water supply calculation for a planned area of FPT Hoa Lac Software Park in Hanoi, the water supply flow rate for the project is presented in Table 2.

Table 2: Water supply flow rate for the project area [15]

No	Water users	Demand scale	Water quality standards	Calculated flow rate
<i>I</i>	<i>Domestic water</i>			
1	Meeting room	3500 person	25 liters/person.day	87.5 m ³ /day
2	Recreation area/canteen	1750 person	25 liters/person.day	43.75 m ³ /day
3	Expert room	60 person	300 liters/person.day/room	18 m ³ /day
4	Water for cleaning the basement floor	2994 m ²	0.5 liters/m ²	1.497 m ³ /day
5	Service staff	50 person	25 liters/person.day	1.25 m ³ /day
6	Laundry area	50 kg	90 liters/kg	4.5 m ³ /day
7	Total domestic water demand: (7) = (1) + ... + (6)			156 m ³ /day
8	Water for treatment plant	10%		15.6 m ³ /day
9	Leakage water	10%		15.6 m ³ /day
10	Total demand for domestic water supply, treatment plant and leakage Qsh: (10) = (7) + (8) + (9)			188 m ³ /day
11	The total demand for domestic water supply with the air conditioning factor of K=1.2 (K is the non-air conditioned factor for daytime)			225 m³/day
<i>II</i>	<i>Irrigation water</i>			

12	Indoor irrigation (for plants)	150	m2	1.5	liters /m2	0.2	m ³ /day
13	Drip irrigation (on the roof)	0	m2	1.5	liters /m2	0.0	m ³ /day
14	Drip irrigation for plants on 1st floor - inner courtyard	1400	m2	1.5	liters /m2	2.1	m ³ /day
15	Irrigation (1st floor - outside the house)	1700	m2	1.5	liters /m2	2.6	m ³ /day
16	Total water supply for the project					4.9	m ³ /day
III	Firefighting water flow rate						
17	Firefighting water flow rate basement	Fire flow rate	liters/second				
18	Fireproofing walls	2	5			108	m ³
19	Automatic fire sprinkler system	240	0.24		liters/second-m2	207.36	m ³
20	drencher fire suppression system	25	1				
21	Total capacity of fire-fighting water tanks					315.36	m ³

Flow rate of drainage water for the project is presented in Table 3.

Table 3: Drainage water flow rate for the project area [15]

No.	Water users	Demand scale		Water quality standards		Calculated flow rate	
1	Meeting room	3500	person	25	liters/person.day	87.5	m ³ /day
2	Recreation area/canteen	1750	person	25	liters/person.day	43.75	m ³ /day
3	Expert room	60	person	300	liters/person.day/room	18	m ³ /day
4	Service staff	50	person	25	liters/person.day	1.25	m ³ /day
5	Laundry area	50	kg	90	liters/kg	4.5	m ³ /day
6	The total demand for domestic water supply: (6) = (1) + ... + (5)	Q _{TB}				155	m ³ /day
7	The total demand for domestic water supply with air conditioning factor K=1,2	Q _{Max}				186	m ³ /day
8	Rainwater flow rate calculated by formula (4)	Q _{rain}	F _{roof} = 9846 (m2); F _{wall} = 1100 (m2); q ₅ = 484.6 (l/s.ha)			986,12	liters/second

The solution for reusing wastewater and rainwater of FPT Hoa Lac project is as follows:

Domestic wastewater -> Collection, transportation -> Centralized water treatment plant according to item (5.1) reaching Column A of Vietnamese Standard [9] -> Storage tank -> Pump -> Reuse for watering green trees, cleaning streets in the project area.

Rainwater -> Collection, transportation -> Treatment according to item (5.4) meeting Vietnamese Standard [10] -> Storage tank -> Pump -> Reuse for watering green trees, cleaning streets, landscape lake, and fountain in the project area.

6 Discussion

The drainage flow rate is calculated as 100% of the supplied water flow rate (after subtracting various types of water such as floor washing water, leakage, water for the treatment plant, irrigation water, and fire-fighting water). The drainage water flow rate of the project is shown in (Table 3).

With the total drainage capacity for the project, it is expected that the black wastewater flow rate (from toilets, urinals) will account for 30%, while the grey wastewater flow rate (from showering, washing, and laundry) will account for 70% of the total maximum daily drainage flow rate.

Therefore, the amount of wastewater that can be reused accounts for up to 70 ÷ 90% of the supplied water for various purposes in the construction project.

7 Conclusions

The amount of wastewater that can be reused in construction projects accounts for a relatively large proportion compared to the supplied water for various uses. Depending on the requirements for water flow rate, water quality for reuse, and intended use, the type of wastewater or rainwater that needs to be reused can be selected, along with the appropriate technological solution.

Reusing wastewater brings many benefits to the project, such as reducing the cost of water use, lowering management and operational expenses, saving electricity, and contributing to long-term sustainable environmental protection. This field is currently being encouraged by the Vietnamese government for implementation by organizations, private companies, conglomerates, and state agencies.

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