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Chapter 5
Challenges of Recycling Swine Wastewater in Vietnam to Approach a Circular Economy

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Abstract: This research presents a comprehensive synthesis and detailed analysis of existing literature on swine wastewater management in Vietnam, aiming to promote sustainable agricultural practices through wastewater recycling. The primary goal is to reduce waste generation and enhance the sustainable utilization of water resources by integrating livestock wastewater into other economic activities. The study identifies major challenges in reusing livestock wastewater, drawing on both scientific evidence and practical considerations. Key issues include variations in farm characteristics, such as size and operational scale, as well as climatic conditions that influence wastewater treatment processes. Additionally, the analysis evaluates existing wastewater treatment technologies and their effectiveness in addressing the unique characteristics of swine wastewater. Current regulations and policies related to livestock waste management are also reviewed to identify gaps and barriers to the implementation of circular economy practices in agriculture. To address these challenges, the research proposes specific policies and regulatory frameworks aimed at fostering the safe and effective reuse of swine wastewater and livestock waste. These recommendations include incentivizing the adoption of advanced and cost-effective wastewater treatment technologies, establishing clear guidelines for wastewater recycling practices, and enhancing monitoring and enforcement mechanisms to ensure compliance with environmental

standards. Moreover, tailored policies that consider the diversity of farm operations and regional climatic differences are suggested to improve the feasibility of implementation. By providing actionable insights, this study contributes to the development of sustainable livestock farming practices in Vietnam, aligning with global efforts to achieve environmental protection, resource conservation, and a circular economy in agriculture.

Keywords: *reusing livestock effluent, swine wastewater, circular economy, sustainable agriculture*

1. Introduction

In recent years, the circular economy has emerged as a promising approach to minimizing waste and promoting the sustainable use of natural resources (Morseletto 2020; Murray et al. 2017). Within the agricultural sector, livestock wastewater is increasingly recognized as a valuable resource that can significantly contribute to the circular economy by facilitating nutrient recycling and reducing environmental pollutant loads. This recognition is particularly critical in the context of extreme weather events, water scarcity, and the global push to enhance water use efficiency. The reuse of wastewater, including livestock wastewater, represents a vital strategy for mitigating water depletion while supporting sustainable agricultural practices (Jaramillo and Restrepo 2017).

However, the implementation of livestock wastewater recycling is influenced by several factors. These include farm characteristics, local environmental conditions, the availability and efficiency of wastewater reuse technologies, and the regulatory frameworks governing wastewater management. Moreover, recycling livestock wastewater involves inherent risks, such as potential food safety concerns and broader environmental impacts, which must be carefully addressed to

ensure sustainable practices (Lahlou et al. 2021).

In Vietnam, livestock farming, particularly swine farming, serves as a cornerstone of the agricultural economy. The country ranks sixth globally in terms of swine population, producing approximately 3 million tons of pork annually. This thriving sector generates nearly 60 million cubic meters of nutrient-rich wastewater daily. Recycling this wastewater offers immense potential for nutrient recovery, environmental protection, and resource efficiency. However, it also poses significant challenges, including technical, economic, and regulatory barriers, as well as public health and ecological concerns.

This research explores these challenges, drawing on empirical evidence and insights from studies conducted by the authors and other researchers specializing in livestock waste management in Vietnam. It aims to provide a comprehensive understanding of the opportunities and constraints surrounding swine wastewater recycling, emphasizing its role in advancing sustainable agricultural practices and contributing to the circular economy.

2. Study Methodology

This research primarily employs a literature review methodology to identify the challenges associated with reusing livestock wastewater for crop cultivation. The main data sources include the Vietnam Journal of Science Online, ResearchGate, Google Scholar, and ScienceDirect. Additionally, the study utilizes the online database of legal documents (http://vbpl.vn) for policy analysis. Statistical data from the General Statistics Office of Vietnam regarding the current status of the livestock industry and other relevant figures are also incorporated. The collected information is synthesized and presented using charts, tables, analytical matrices, and evaluations to provide a comprehensive overview and achieve the research objectives.

3. Results and Discussions

(1) The Need to Reuse Swine Wastewater in Vietnam

The livestock sector plays a vital role in Vietnam, providing essential food products and contributing significantly to the country's economic and social development. Over the past decade, Vietnam's population has grown at an average annual rate of 1.03%, increasing from 89.8 million in 2012 to 98.56 million in 2021. During this period, the country's per capita income rose from USD 1,540 to USD 4,000 per year (GSO 2022). This population and economic growth have driven a rising demand for livestock products such as meat, eggs, and milk.

According to the Ministry of Health, the average daily meat consumption per person increased from 51 g/day in 2000 to 84 g/day in 2010, reaching 134.5 g/day in 2020. Urban residents tend to consume more meat compared to their rural counterparts. Notably, pork remains the most widely consumed meat in Vietnam, with swine farming dominating the livestock sector. Pork output consistently surpasses that of other types of livestock, accounting for over 45% of the country's total meat production over the years (GSO 2022).

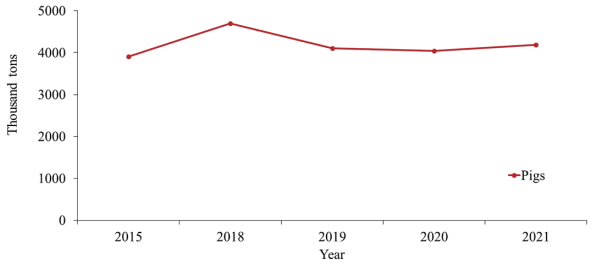


Figure 1: Pork production in Vietnam from 2015 to 2021. Source: GSO 2022

Along with the increase in meat production, there have been significant changes in the number of swine in Vietnam. From 2010 to 2021, the average growth rate of agricultural production value in the livestock sector was 5%–6%, making it a crucial contributor to the agricultural economy (Cao et al. 2022).

While the growth of the livestock sector brings substantial economic benefits to Vietnam, it also increases pressure on waste management, particularly wastewater. Dinh (2017) estimated that over 80 million tons of manure are generated annually by the livestock sector, with swine farming contributing the largest share at 30.3%. Swine farming is also considered a high-water consumption sector. Results from the LCASP project survey of 281 livestock facilities in 10 provinces indicated that the average water usage per swine is 42.5 liters per day (Nguyen et al. 2020). In Binh Dinh, the water usage coefficient for swine farming was as high as 74.5 liters per swine per day. The study also found that household-scale swine farming has a higher water usage coefficient, averaging 44.8 liters per swine per day, compared to 33.9 liters per swine per day for farm-scale swine farming. Another estimate from the General Department of Environment indicates that the wastewater generation coefficient for swine farming is approximately 20 liters per swine per day, whereas the coefficient for buffalo and cattle farming is only 12.5 liters per animal per day (MONRE 2018). The estimated wastewater generation based on these coefficients is calculated as shown in Table 1.

Table 1: Estimation of wastewater volume generated from swine and buffalo raising in the period 2010–2022

Year	Buffalo (in thousand heads)	Estimated wastewater (l/day)	Swine (in thousand heads)	Estimated wastewater (l/day)
2010	8.685	108.566.000	27.373	547.466.000

2011	8.148	101.857.500	27.056	541.120.000
2012	7.822	97.775.000	26.494	529.880.000
2013	7.716	96.452.500	26.264	525.288.000
2014	7.755	96.946.000	26.761	535.228.000
2015	7.891	98.640.000	27.750	555.014.000
2016	8.016	100.200.000	29.075	581.506.000
2017	8.146	101.832.500	27.406	548.134.000
2018	8.228	102.850.000	28.151	563.038.000
2019	8.447	105.598.750	19.615	392.310.000
2020	8.563	107.041.250	22.027	440.558.000
2021	8.574	107.178.750	22.688	453.774.000
2022	8.570	107.125.000	24.684	493.680.000

Swine farming generates the largest volume of wastewater compared to other types of livestock farming in Vietnam. Swine waste contains high levels of organic matter, nutrients, and microorganisms. The pollutants in swine wastewater include BOD_5, COD, total nitrogen (TN), total coliform (CF), and total phosphorus (TP). Poor management and inadequate treatment of this waste are major contributors to pollution in areas surrounding swine farming operations, as highlighted by previous studies (Ho 2017; Tien et al. 2009). In this context, promoting the recycling of livestock wastewater is regarded as a promising solution to mitigate pollution by utilizing the nutrients present in the wastewater.

However, since the early 2000s, changes in the scale and techniques of livestock farming and waste treatment have significantly affected the use of wastewater in livestock facilities. The proportion of facilities utilizing wastewater for other activities remains low. According to a survey of 720 livestock facilities conducted by Tien et al. (2009), more than 70% of households directly discharged liquid waste and wastewater into the environment across various types of livestock

farming. Similarly, a study by Son et al. (2014) in Hung Yen, which covered 42 livestock facilities of different scales, found that 38% of farms used manure and wastewater for crop fertilization, while 52% used liquid manure as fish feed. A more recent survey by Giang et al. (2021), involving 123 swine farming facilities with herds of 50 or more in four provinces—Hanoi, Thai Binh, Ha Tinh, and Dong Nai—reported that only 50% of facilities reused livestock wastewater. This percentage varied significantly by region, with Hanoi at 18%, Dong Nai at 43%, Ha Tinh at 73%, and Thai Binh at 66%. These findings indicate that the rate of livestock wastewater reuse in Vietnam remains relatively low.

There are numerous challenges to reusing livestock wastewater for crop cultivation in Vietnam. The following sections will examine the main challenges related to farm conditions, the quality of treated livestock wastewater, and the legal regulations governing wastewater reuse for crop cultivation.

(2) The Available Farmland for Wastewater Reuse in Crop Cultivation on Livestock Farms in Vietnam

According to the findings of various researchers, farm characteristics, particularly the availability of production land, are significant factors influencing the decision-making processes of households (Belayneh 2023; Tey and Brindal 2022; Wittstock et al. 2022).

Table 2: Average area statistics of swine farms in Vietnam

No.	Locations	Statistic
1	National average area	Livestock farms with an area of less than 5,000 m² account for 65%-70% of the total. Farms with an area of more than 10,000 m² comprise only 10%-15% of the total. Livestock farms in Vietnam have an average area of 3,000-5,000 m², whereas in Thailand, the average is 6,000 m² (JICA 2013)

2	Hung Yen Province (Van Giang)	Based on a survey of 42 livestock farms, the garden-pond-cage (VAC) system farms have an average area of 11,648 m², pond-cage (AC) farms have an average area of 12,657 m², VC farms have an average area of 1,673 m², and C farms have an average area of 461 m². Additionally, 33% of the interviewed farms are located within residential areas (Son et al. 2014).
3	Ha Noi (Gia Lam, Ung Hoa, Son Tay)	The survey results from 41 swine farms show that those under the VAC system have an average area of 20,735 ± 6,026 m², while those under the VC system have a lower average area of 5,098 ± 1,106 m² (Ho et al. 2016).
4	Dong Nai Province	The area among FDI farms, cooperatives, joint-stock companies, and household farms differs significantly. FDI farms have an average area of 44,000 m², cooperative farms have an average area of 38,000 m², joint-stock companies have an average area of 44,000 m², and household farms have an average area of 5,800 m² (Le 2017).
5	Hung Yen, Hai Duong, and Bac Ninh Province	A survey of 90 livestock farms in Hung Yen, Hai Duong, and Bac Ninh shows that the average area of a farm was 4,833 m². Among them, swine farms in Hung Yen had an average area of 4,875 m², farms in Hai Duong had an average area of 5,545 m², and farms in Bac Ninh had an average area of 4,082 m² (Vu et al. 2007).
6	Bac Giang Province	The survey of 125 swine farms, including both household-scale and large-scale farms, shows that the average area of the swine farms ranges from 150 to 10,800 m². The distance from swine barns to residential areas ranged from 10 to 500 meters (Ngo et al. 2021).
7	Dong Nai, Ha Tinh, Thai Binh and Ha Noi	The survey of 123 small, medium, and large-scale farms shows that the average area of swine farms in Hanoi was 5,796 ± 10,098 m², in Thái Bình was 4,723 ± 9,898 m², in Ha Tinh was 42,446 ± 45,377 m², and in Dong Nai was 27,955 ± 31,106 m² (Giang et al. 2021).

Research indicates that farm size positively impacts the implementation of environmental protection measures by farmers. Livestock farms require a suitable land area to recycle waste for cultivation. However, the land available on most livestock farms in Vietnam presents limitations for waste reuse. The 2020 Agricultural and Rural Survey, involving over 9,000 agricultural households nationwide, found that the average production area per household is approximately 5,000–6,000 m², with each household managing 2.8 plots of land on average (GSO 2021). Swine farming facilities generally have smaller production land areas compared to other types of agricultural operations. Son et al. (2014) reported that 65%–70% of swine farms occupy areas smaller than 0.5 hectares, while only 10%–15% cover more than 1

hectare. However, there are significant regional differences in farm size and farming scale. Livestock farms in the Red River Delta and Mekong Delta tend to have smaller areas compared to those in the midland, mountainous, central coastal, and Central Highlands regions. Statistical results from various studies show that livestock farms are generally small and located within residential areas.

The farm size in Vietnam is considerably smaller compared to many other countries in the region and worldwide. According to Lowder et al. (2016), 70% of farms in the wealthiest countries have an area greater than 20 hectares, while 70% in the poorest countries have an area greater than 5 hectares. Additionally, in Vietnam, agricultural land is often fragmented and located far from livestock farming areas. This spatial separation significantly affects the construction and installation of waste treatment facilities, as well as the reuse of livestock waste for other economic activities, particularly the use of livestock wastewater in crop production.

(3) Actual Demand for On-Farm Irrigation Water in Vietnam

Recycling wastewater in livestock areas is particularly critical in regions experiencing water scarcity. In such areas, recycling wastewater generated from livestock activities helps reduce pollution and addresses the issue of irrigation water shortages (Elahi et al. 2017; Jaramillo and Restrepo 2017). However, irrigation water scarcity is not a pressing issue across all ecological regions of Vietnam, especially during the rainy season.

Studies have shown that the periods when farms generate the most wastewater coincide with the rainy season in Vietnam. Due to its tropical monsoon climate, the country experiences abundant rainfall, which is distinctly seasonal. Most regions receive between 1,400 and 2,400 mm

of rainfall from May to October. This period also brings high average temperatures nationwide, ranging from 25 to 30°C, during which farms consume substantial amounts of water for cleaning and cooling. Hinh (2017) reports that in the North, livestock households use an average of 30–40 liters of water per swine per day during the summer, while in the South, the average is 15–30 liters per swine per day for cooling. Additionally, livestock households in Vietnam use an average of 5–10 liters of water per swine per day for cleaning, with cleaning frequencies being higher in the summer than in the winter. During the rainy season, the water supply often exceeds demand, which reduces the potential for using livestock wastewater for irrigation.

Farm economic activities have become less diverse after a period of agricultural development focused on specialization, combined with limited land availability. Many farms now concentrate solely on livestock production, lacking other activities such as crop cultivation and aquaculture. This situation reduces the demand for irrigation water, even when wastewater is generated and available. As a result, many livestock farms discharge excess wastewater into the environment when biogas digesters and storage tanks become overloaded, leading to environmental pollution around livestock farms.

Another reason for the low demand for reusing swine wastewater is that irrigation services are heavily subsidized, leading to a low price for irrigation water. On the other hand, swine wastewater must be treated adequately to comply with current national technical standards for irrigation water, which adds additional costs to wastewater usage. Additionally, extra costs such as labor and transportation may be incurred if the livestock farm is far from the cultivation area. Therefore, farmers often find more cost-effective alternatives for swine wastewater disposal.





Figure 2: Collection of Livestock Wastewater for Crop Cultivation in Van Duc Commune, Gia Lam, Hanoi. Source: Author

(4) Quality of Swine Wastewater after Treatment

Swine wastewater in Vietnam primarily includes excrement, urine, pen wash water, cooling water, and effluent from biogas tanks and other treatment systems. Although it contains high levels of TN and TP, it also harbors numerous pathogens, parasite eggs, and bacteria. Therefore, if livestock wastewater is not properly treated or is lost during reuse processes, it becomes a source of pollution for the surrounding environment and poses risks to human and animal health.

Recently, due to the efforts of local authorities to address environmental pollution in livestock farming, most livestock facilities in Vietnam have implemented waste treatment measures. The most commonly adopted solution is the construction of biogas tanks. According to statistical data from various studies, the adoption rate of biogas tanks increased from 57% in 2010 to over 90% a decade later (Cao et al. 2011; Giang et al. 2021; Ngo et al. 2021). Except for large-scale farms, most biogas tanks in Vietnam have a capacity of less than 15 m^3 (Hinh 2017).

However, studies evaluating the quality of livestock wastewater

have shown that the effectiveness of these treatment measures is very limited. According to a study by Tien et al. (2009), treated livestock wastewater still had very high levels of coliform. The coliform levels in household and farm livestock waste exceeded permissible limits by 278 times and 630 times, respectively. A study by Cao et al. (2021) which evaluated the quality of livestock wastewater from 130 swine farms, 80 poultry farms, and 40 cattle farms in Hanoi, revealed that livestock waste exceeded the national quality standards for livestock wastewater (QCVN-62) and was not safe for irrigating certain crops. The study found average concentrations of BOD_5 at 660.2 ± 400.6 mg/l, COD at 1107.7 ± 701.6 mg/l, TN at 56.7 ± 58.7 mg/l, TP at 118.7 ± 75.5 mg/l, TSS at 248.2 ± 94.7 mg/l, and CF at 8.8e+04 ± 7.1e+04 MPN/100ml. These results indicate that many parameters of swine farming wastewater exceed the current limits of national technical standards for permissible discharge into the environment, with BOD_5 levels exceeding the allowable limit by 6.6 times, COD by 3.7 times, TSS by 1.6 times, and Coliform by 17.6 times. However, the analysis also showed significant variations in wastewater quality among swine farming facilities. Over 85% of samples had BOD_5, COD, TSS, and CF levels exceeding standards, except for TN, which exceeded standards in 22% of samples (Cao et al. 2021).

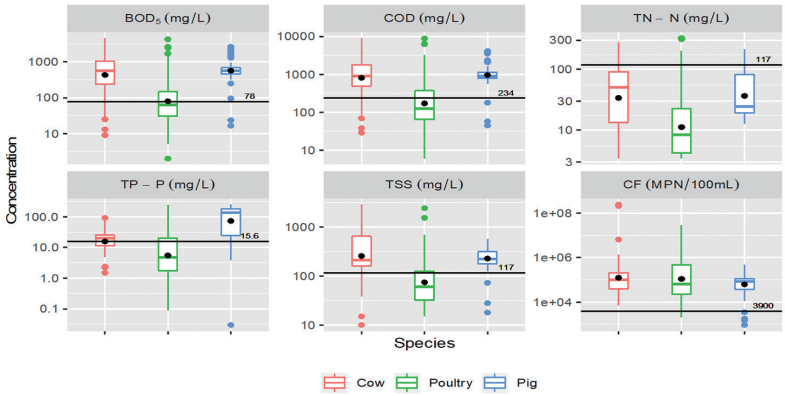


Figure 3: Quality of wastewater from swine, cow and poultry farms in Ha Noi. Source: Cao et al. 2021

In 2021, a study on wastewater reuse in swine farms in Hanoi, Thai Binh, Ha Tinh, and Dong Nai found that the Coliform concentration in swine wastewater after treatment exceeded the standard threshold. The average coliform value from wastewater samples was 49,000 ± 88,000 MPN/100mL, which is 66 times higher than the standard for livestock wastewater and far exceeds the allowable limits for crop irrigation water according to the QCVN01-195:2022/BNNPTNT standard (Giang et al. 2021). Therefore, proper treatment to ensure the quality of swine wastewater for safe use in crop irrigation presents a major challenge in Vietnam. A study by Dung et al. (2020) concluded that most biogas tanks on livestock farms in Vietnam are ineffective in reducing greenhouse gas emissions and treating husbandry waste. Other studies provide further evidence of environmental pollution around livestock areas, supporting this claim. Some studies have proposed a solution for treating liquid farm waste by combining biogas tanks with a bio-pond system. After biogas treatment, the wastewater would remain in the

ponds for 3-4 months to eliminate pathogens and break down organic matter into nutrients that plants can easily absorb, while the remaining sludge can enrich the soil. However, this solution requires a large area and significant investment, making it unsuitable for most small-scale livestock farms in Vietnam. Therefore, finding an appropriate wastewater treatment technology that meets current livestock farming conditions and ensures treated water quality for irrigation and other purposes is a pressing need in Vietnam to achieve sustainable livestock wastewater reuse.

(5) Legal Regulations for Recycling Swine Wastewater

Implementing the recycling of swine wastewater, as well as other types of waste, is currently in the process of establishing a comprehensive legal framework. The recycling of livestock waste, including wastewater, is emphasized in the revised Environmental Protection Law of 2020 and the Livestock Production Law enacted in 2019, along with related guiding documents. The principles regarding the use of livestock waste from these documents can be summarized as follows:

- Livestock farming must be integrated with crop production and other sectors to form a circular economic chain in agriculture.
- Livestock waste, agricultural by-products, and valuable resources must be efficiently utilized.
- The treatment and use of livestock waste and agricultural by-products are the shared responsibility of the entire society.
- Maximizing the use and efficiency of agricultural by-products and livestock waste to achieve sustainable development, reduce greenhouse gases, and protect the livestock farming environment.

- Aligning with the Livestock Development Strategy for the period 2021-2030, with a vision to 2045.

In addition to the policies, regulations, and guidelines mentioned above, several other policies aim to facilitate livestock farms, including household-scale operations, in implementing measures for waste treatment and utilization. These policies provide support in the form of financial aid, installation of facilities, technical guidance for waste treatment, land and tax incentives, and access to credit for large-scale livestock enterprises. The key documents are summarized as follows:

- Decision No. 50/2014/QD-TTg dated September 4, 2014, by the Prime Minister regarding policies to enhance the efficiency of household-scale livestock farming for the period 2015–2020.
- Decree No. 55/2015/ND-CP by the government on credit policies for agricultural and rural development.
- Directive No. 26/CT-TTg dated October 6, 2015, by the Prime Minister on accelerating the implementation of the agricultural sector restructuring scheme towards enhancing added value and sustainable development.
- Decree No. 57/2018/ND-CP, which replaces Decree No. 210/2013/ND-CP dated December 19, 2013, concerning mechanisms and policies to encourage businesses to invest in agriculture and rural areas.

However, livestock wastewater presents a unique challenge as it is difficult to immediately generate value from it. Furthermore, the recycling of livestock wastewater faces significant challenges, as discussed above. To effectively and sustainably implement the recycling of livestock wastewater, additional policies and regulations

are necessary. According to the authors, the key policies and regulations that need further development include:

- Specific policies for recycling livestock wastewater: Tailored policies are needed for small and medium-sized livestock farms, which are prevalent in Vietnam and remain a crucial segment in the current livestock development strategy. These farms are characterized by their small scale, proximity to residential areas, and distance from other agricultural production zones. The regulatory framework and monitoring systems for environmental protection and waste recycling for this group are still limited (Dinh 2017; Hinh 2017).
- Land use policies: While there are existing regulations and policies prioritizing land use for large-scale livestock farms, additional policies are needed to address land sharing for recycling livestock waste within communities. This would help mitigate the limitations related to land availability.
- Tools for evaluating circular economy practices: The development of tools to assess the implementation of circular economy principles in managing livestock wastewater and other waste is crucial. However, as with many economic sectors in Vietnam, these tools are still underdeveloped.
- Technical guidelines for nutrient-rich wastewater: it is essential to create technical guidelines for livestock farms to use the appropriate amounts of wastewater for irrigation. Incorrect dosage or loss of wastewater during irrigation can have adverse environmental impacts and hinder overall sustainability goals.
- Effectiveness of biogas digesters: Studies indicate that biogas digesters are not highly effective in treating liquid livestock waste, particularly in removing harmful organisms and ensuring

the safety of irrigation water. Therefore, future policies should prioritize scientific research on effective treatment technologies for this waste component, specifically tailored to the common characteristics of livestock farms in Vietnam.

- Cost pressures and regulations: The low cost of water for agricultural production in Vietnam contributes to the pressure on managing livestock wastewater. This leads farmers to use more water in livestock farming and to dispose of wastewater rather than recycling it due to cost-benefit considerations. To encourage farmers to practice wastewater recycling, mandatory regulations and specific incentive policies are needed to enhance their awareness of their responsibilities in wastewater reuse.

4. Conclusion

Based on analyses from practical observations and conducted studies, this paper highlights the critical necessity of reusing swine wastewater in Vietnam to achieve the goal of circularity in the agricultural sector moving forward. If effectively recycled, Vietnam could save a significant amount of water each day, which is rich in nutrients and valuable for other production purposes. However, the study also identifies several challenges that must be addressed to achieve sustainable reuse of wastewater in this crucial industry.

The major challenges stem from the typical production characteristics of swine farming: small production areas, proximity to residential areas but distance from agricultural production zones, and high water usage in swine care. Additionally, there are challenges related to the quality of wastewater and the availability of wastewater treatment technologies that meet irrigation water standards. The cost of treating and using swine wastewater may also exceed that of using

water from the national irrigation system. Moreover, the hot and humid climate with seasonal heavy rainfall reduces the demand for wastewater use, particularly during the rainy season. Alongside these challenges, policies and regulations concerning the reuse of swine wastewater and livestock waste in general still need to be developed and refined.

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Chapter 5. Challenges of Recycling Swine Wastewater in Vietnam to Approach a Circular Economy

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