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Applying the Theory of Planned Behavior to Determine the Influencing Factors of Recycling Pig Wastewater for Crop Cultivation in Hanoi City

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Abstract

The study was conducted to analyze the factors affecting the use of pig wastewater for crop cultivation in Hanoi city. Through the application of the Theory of Planned Behavior to develop the theoretical framework and structural equation modeling, the study showed that the behavior intention influenced the recycling behavior. Attitude toward the behavior (AT), social norms (SN), and perceived behavioral control (PBC) were important influencing factors on the intention to perform this behavior with standardized regression coefficients of ß = 0.96 (*P* <0.001), ß = -0.826 (*P* <0.001), and ß = -0.34 (*P* <0.001), respectively. These research results serve as the initial reference for policies and studies related to the use of pig wastewater.

Keywords

Pro-environmental behavior, SEM modeling, recycling pig wastewater, planned behavior

Introduction

In the last few decades, the livestock industry has contributed significantly to rural development in Vietnam. However, the waste load generated from livestock farming has produced massive environmental challenges, especially in rural areas and intensive farming zones (Zhu, 2006; Cassou *et al.*, 2017a; Monre, 2018; World Bank Group, 2019; Cao *et al.*, 2021; Ngo *et al.*, 2021). According to the Ministry of Natural Resources and Environment, the swine production sector may release around 6.6 million m^3 of wastewater annually (MONRE, 2018).

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Recycling livestock wastewater has been recently promoted as a potential approach to reduce the environmental impact and the loss of nutrients contained in the effluent. According to the most recent research conducted in four representative provinces of Vietnam, namely Hanoi, Thai Binh, Ha Tinh, and Dong Nai, recycling swine wastewater has been popularly practiced by many swine farms (Giang *et al.*, 2021). However, the backgrounds related to wastewater reuse by farmers in these provinces have not been mentioned in any research. More specifically, which factors determine the application of wastewater reuse remains unknown. This gap needs to be filled in the field of waste management research in Vietnam.

Hanoi is a city with a high swine population, reaching 1.3 million by 2021, concentrated mainly in suburban districts such as Gia Lam, Son Tay, and Ba Vi (Hanoi People's Committee, 2022). Pollution caused by the waste generated from pig production is alarming and needs to be addressed (Cassou *et al.*, 2017b). The government has urged functional departments to deal with the pollution from livestock in general and pig farming in particular. In this context, wastewater reuse is a multi-purpose solution to solve the environmental pollution problem while taking advantage of nutrients that can be used for other components within the agricultural system towards a circular economy. Therefore, the implementation of this study not only contributes to filling the scientific gap on the reuse of wastewater from swine farming but also provides a basis for proposing solutions to Hanoi city.

In this paper, we have attempted to explore the factors affecting farmer decision-making in recycling wastewater. The findings from this research promise to help policymakers understand more about the internal factors that might create behavioral changes in recycling pig wastewater. Thus, they could help produce appropriate policies to support the behavioral changes toward circular-based wastewater management.

Methodology

Study approach

The study applied the Theory of Planned Behavior (TPB) of Ajzen (1991) for its theoretical framework development. According to the TPB, an individual's behavior (B) is influenced directly by the intention to perform that behavior. The behavior intention (BI), which indicates the willingness to perform the behavior, in turn, is the result of a psychological process with the collective involvement of attitudes (AT), subjective norms (SN), and perceived behavior control (PBC).

The BI can be stated as (Ajzen, 1985; 1991)

$$BI = w_{AT}AT + w_{SN}SN + w_{PBC}PBC$$

where BI is the behavioral intention, AT is the attitude toward the behavior, SN is the subjective norm, PBC is the perceived behavioral control, and w is the empirically derived weight/coefficient. AT, SN, and PBC potentially have endogenous interactions with each other before exerting their impacts on the BI. Their relationships are depicted in **Figure 1**.

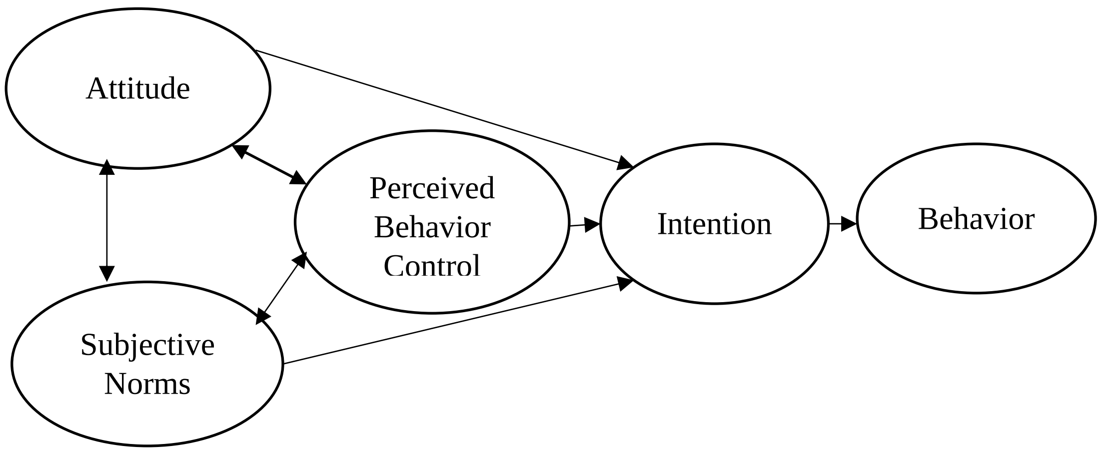


Figure 1. Framework to predict pig wastewater recycling based on the Theory of Planned Behavior (TPB)

Data collection methods

The study was conducted in the city of Hanoi, which is located in one of the two provinces with the largest number of pig production farms in Vietnam. The survey area was selected based on the city livestock development planning (Decision No. 3215/QD-UBND of Hanoi city) and Hanoi's agricultural development zoning orientation for the period of 2022-2025 (Decision No. 731/QD-UBND Hanoi) with three main ecological areas: floodplain, delta, and hilly areas. Three representative districts, namely Gia Lam, Son Tay, and Ba Vi, were selected for household interviews. In each district, we selected the community which had the biggest pig population to conduct the survey. In each community, we randomly selected 60 swine owners to conduct the survey. However, only 177 questionnaires were filled in for data processing, in which, Gia Lam had 60, Son Tay had 60, and Ba Vi had 57 samples.

The questionnaire was constructed based on the Theory of Planned Behavior (TPB) whereby the attitude toward recycling behavior (AT) depended on four observed variableṣ (AT1, AT2, AT3, AT4), which were measured by four questions as suggested by previous research (Chu & Chiu, 2003; Ioannou *et al.*, 2013; Rezaei-Moghaddam *et al.*, 2020) (**Table 1**). Similarly, the social norms (SN) depended on three variables (SN1, SN2, SN3), which could be observed by two normative beliefs that salient social referents (friends, neighbors) think he or she should perform a particular behavior and by motivations or responsibilities to comply with those referents (Ioannou *et al.*, 2013; Wang & Lin, 2020). The perceived belief control (PBC) was measured by four variables (PBC1, PBC2, PBC3, PBC4), and was associated with the questions about the constraints on land, technology, and time (Chu & Chiu, 2003, Ioannou *et al.*, 2013).

The behavioral intention (BI) was, in the same manner, determined by its antecedent variables (BI1, BI2, BI3, and BI4) and the questions associated with them. Because behavior (B) is related to the practical decision, the yes-no question was therefore used to obtain information about recycling swine wastewater. In total, there were 15 variables measured by a Likert five-point scale and one yes-no question as suggested by previous research (Chu & Chiu, 2003; Ioannou *et al.*, 2013; Han *et al.*, 2015; Giang, 2018; Qian *et al.*, 2020; Wang & Lin, 2020; Lahlou *et al.*, 2021) and some additional suggestions of the authors.

The total number of samples was 177, satisfying the criterion of a minimum of five samples per observed variable in SEM computing, which was suggested by Bentler and Chou (1987).

Research hypotheses

The study aimed to test seven hypotheses among BI, AT, SN, and PBC, which were proposed according to the TPB, as follows:

Hypothesis 1 (H1): BI has a positive impact on B. If the swine breeders intend to recycle wastewater, it probably leads to action in reality.

Hypothesis 2 (H2): AT has a positive impact on BI. If the swine breeders are aware of the benefits of wastewater, they will probably have recycling intentions.

Hypothesis 3 (H3): SN has a negative impact on BI. If the swine breeders are aware of their responsibility in handling wastewater, they might not intend to reuse it for other activities.

Hypothesis 4 (H4): PBC has a negative impact on BI. If the swine breeders are aware of difficulties with recycling wastewater, they might not intend to reuse it.

Hypothesis 5 (H5): AT and SN have a positive relationship. If the swine breeders are aware of the benefits of wastewater, they might also be aware of their responsibility in handling wastewater.

Hypothesis 6 (H6): AT and PBC have a negative relationship. If the swine breeders are aware of wastewater benefits, they might be less concerned about the difficulties of using it.

Hypothesis 7 (H7): SN and PBC have a negative relationship. If swine breeders are aware of the responsibilities of handling wastewater, they might be less concerned about its difficulties.

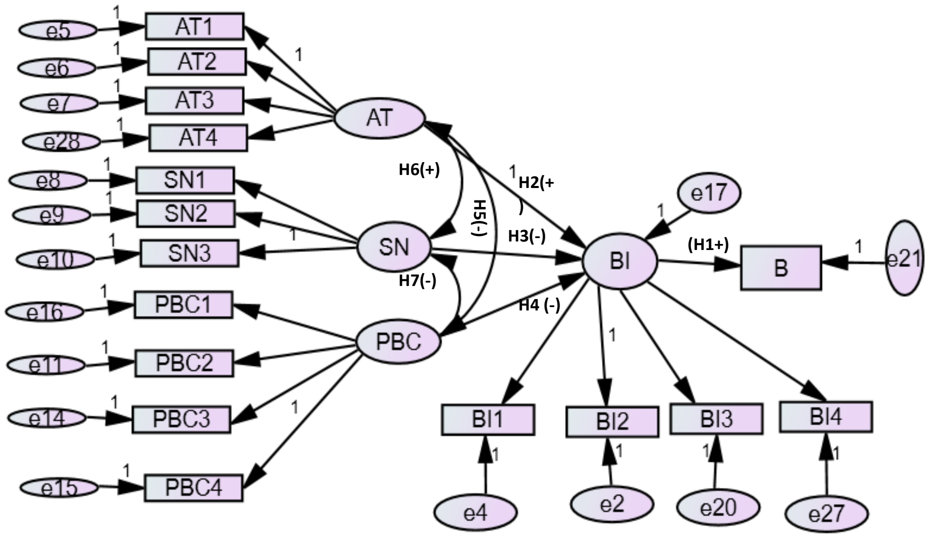
Table 1. Variables in the models

Names of variables	Questions	References
AT	**Attitudes**	
AT1	I think recycling swine waste helps to conserve natural resources (Likert 5 points)	Chu & Chiu (2003); Ioannou *et al.* (2013); Rezaei-Moghaddam *et al.* (2020)
AT2	I think recycling swine waste helps to save money (Likert 5 points)	Chu & Chiu (2003); Ioannou *et al.* (2013); Rezaei-Moghaddam *et al.* (2020)
AT3	I think recycling swine waste helps to raise the income for the farm (Likert 5 points)	Chu & Chiu (2003); Ioannou *et al.* (2013); Rezaei-Moghaddam *et al.* (2020)
AT4	I think recycling swine waste brings benefits to the community (Likert 5 points)	Chu & Chiu (2003); Ioannou *et al.* (2013); Rezaei-Moghaddam *et al.* (2020)
SN	**Social Norms**	
SN1	My friends and relatives think I should handle waste effectively (Likert 5 points)	Ioannou *et al.* (2013); Wang & Lin (2020)
SN2	My neighbors think I should handle waste effectively (Likert 5 points)	Ioannou *et al.* (2013); Wang & Lin (2020)
SN3	I think I am mainly responsible for waste handing at my swine farm (Likert 5 points)	Ioannou *et al.* (2013); Wang & Lin (2020)
PBC	**Perceived Behavior Control**	
PBC1	I cannot recycle due to the lack of farming land (Likert 5 points)	Chu & Chiu (2003); Ioannou *et al.* (2013)
PBC2	I cannot recycle due to the complexities of technologies (Likert 5 points)	Chu & Chiu (2003); Ioannou *et al.* (2013)
PBC3	I cannot recycle due to the lack of labor (Likert 5 points)	Chu & Chiu (2003); Ioannou *et al.* (2013)
PBC4	I cannot recycle because it is time-consuming (Likert 5 points)	Chu & Chiu (2003); Ioannou *et al.* (2013)
BI	**Behavior Intention**	
BI1	I intend to upgrade and repair my wastewater collection system (Likert 5 points)	Author's suggestion
BI2	I intend to upgrade and repair my waste separation system (Likert 5 points)	Author's suggestion
BI3	I intend to upgrade my knowledge in recycling wastewater technologies (Likert 5 points)	Author's suggestion
BI4	I intend to use swine wastewater for cultivation (Likert 5 points)	Ioannou *et al.* (2013); Han *et al*. (2015); Wang & Lin (2020)
B	**Behavior**	
B	My farm uses swine wastewater for cultivation (Yes/No)	Author's suggestion

The hypotheses of the research are presented in **Figure 2**.

Structural equation modeling

The study used SPSS 22 to compute the data and AMOS 20 for structural equation modeling (SEM). The study used Cronbach's Alpha test to assess the scale's reliability to measure each group of variables. The reliability was measured by the following scale: $\alpha \geq 0.9$ (excellent); $0.7 \leq \alpha < 0.9$ (good); $0.6 \leq \alpha < 0.7$ (acceptable); $0.5 \leq \alpha < 0.6$ (poor); and $\alpha < 0.5$ (unacceptable). Confirmatory factor analysis (CFA) was used to access the proposed model. The indices to measure the goodness of the model included the chi-square (CMIN, chi-square/df), the root mean square error of approximation (RMSEA), goodness-of-fit index (GFI), the comparative fit index ((CFI), the Tucker–Lewis index (TLI), and the P value of close fit (PCLOSE).



Note: (+): Positive relationship; (-): Negative relationship

Figure 2. Hypotheses of the research

Results

Characteristics of pig farming and pig wastewater management at the study sites

According to statistical reports, the swine population in Hanoi in 2021 was approximately 1.3 million (Hanoi People's Committee, 2022). According to the recommended emission coefficient of the Environmental Department (Hoang Van Thuc *et al.*, 2019), the swine population in Hanoi can generate 18,980 thousand m^3 of wastewater, containing 9,490 tons of TN (total nitrogen) per year. The baseline rate of swine waste treatment in Hanoi is approximately 80%. However, it differs between commercial farms and households. In commercial farms, the rates of waste treatment using bio-cushion, biogas digesters, composting, and treatment with bioproducts were 5.6%, 89.8%, 34.1%, and 8.7%, respectively. In households, the rates of these treatments were 0.5%, 76.8%, 9.0%, and 14.7%, respectively (Bui Phung Khanh Hoa, 2019).

For the three surveyed communes, the current statuses of swine waste and gas from biogas digester usage are summarized in **Table 2**. The synthesis of results showed that manure and gas were the types of waste most commonly used by farmers, with a rate of 56%, while wastewater was only used at 37%. Son Tay had the highest household use of manure and wastewater among the three surveyed locations. Both Ba Vi and Son Tay had a proportion of surveyed households using gas for domestic purposes over 60%, while this rate in Gia Lam was only 35%.

However, the survey results also indicated that the majority of swine farms were unable to fully utilize the amount of waste generated. The excess was stored in biogas tanks, ponds, or discarded into the environment.

Demographic characteristics of interviewees

Table 3 and **Table 4** present the demographic characteristics of the interviewees and the farms, respectively. Males represented 62% of the participants. Most interviewees had secondary education (67%), and farmers with college or higher degrees only represented 10% of the sample. The average age of interviewees was 51 years old; the youngest was 26 years old and the oldest was 82. The average experience in pig breeding was 17 years. The average farm area was 2,600m^2 and the average number of pig heads per breeding circle was 112.

Table 2. Swine waste usage in the study area

District	Manure usage		Wastewater usage		Gas usage	
	Frequencies	*%*	*Frequencies*	*%*	*Frequencies*	*%*
Gia Lam	31	52	8	13	21	35
Son Tay	43	72	32	53	38	63
Ba Vi	25	44	26	46	40	70
Total	99	56	66	37	99	56

Table 3. Characteristics of pig breeders

Content	Frequencies	Percent (%)
Gender		
Male	110	62
Female	67	38
Education		
Primary	13	7
Secondary	107	61
High school	40	23
College, university, or higher	17	10
Location		
Gia Lam	60	34
Ba Vi	60	34
Son Tay	57	32
Farming scale		
Pig heads <50	59	33
Pig heads 50-150	55	31
Pig heads >150	63	36

Table 4. Characteristics of pig farm

Criteria	Unit	N	Minimum	Maximum	Mean	Std. Deviation
Farm area	m^2	177	72	54,000	2,609.7	5,599.6
Age	Years	177	26	82	51.6	11.3
Experience	Years	177	2.0	50	17	10.4

Scale reliability analysis

Results of the scale reliability analysis showed that the variables that measured AT, SN, PBC, and BI all had a Cronbach's Alpha > 0.6 (**Table 5**). These α values fell within the range of $0.679 \leq \alpha < 0.797$ indicating the acceptable scale. This means that the measurement scales of the variables in this research were reliable for further analysis.

Accessing the fit of the model

Confirmation factor analysis (CFA) was computed to assess the fit of the prediction model. The goodness indices of the model are

Table 5. Results of the scale reliability assessment

Variables	Questions	Cronbach's Alpha
AT	**Attitudes**	
AT1	I think recycling swine waste helps to conserve natural resources	
AT2	I think recycling swine waste helps to save money	0.787***
AT3	I think recycling swine waste helps to raise the income for the farm	
AT4	I think recycling swine waste brings benefits to the community	
SN	**Social Norms**	
SN1	My friends and relatives think I should handle waste effectively	
SN2	My neighbors think I should handle waste effectively	0.679***
SN3	I think I am mainly responsible for waste handing at my swine farm	
PBC	**Perceived Behavior Control**	
PBC1	I cannot recycle due to the lack of farming land	
PBC2	I cannot recycle due to the complexities of technologies	0.787***
PBC3	I cannot recycle due to the lack of labor	
PBC4	I cannot recycle because it is time consuming	
BI	**Behavior Intention**	
BI1	I intend to upgrade and repair my wastewater collection system	
BI2	I intend to upgrade and repair my waste separation system	0.797***
BI3	I intend to upgrade my knowledge of recycling wastewater technologies	
BI4	I intend to use swine wastewater for cultivation	

presented in **Figure 3**. The results showed a good fit for the suggested model according to the recommendations of Hair *et al*. (2014) and Hu & Bentler (1999): chi-square = 176.555, P <0.001, chi-square/df = 1.839 < 3 (good); GFI = 0.890 > 0.8 (acceptable); TLI = 0.931 > 0.9 (good); CFI = 0.945 > 0.9 (good); RMSEA = 0.069 < 0.08 (good); and PCLOSE = 0.028 > 0.01 (acceptable) (**Figure 3**). Although the GFI was slightly lower than the suggestion of Hair *et al*. (2014) (GFI > 0.9), some other researchers have asserted that this value is acceptable in the case where samples are smaller than 200 (Baumgartner & Homburg, 1996). Thus, these criteria suggest that our model in **Figure 3** was acceptable and can be used to examine the hypothesized relationships among the variables.

Results of examining the hypothesized relationships among the variables

The results showed that hypotheses H1 (ß = 0.59, P = 0.00), H2 (ß = 0.957, P = 0.00), H3 (ß = -0.826, P = 0.00), H4 (ß = -0,340, P = 0.00), and H5 (ß = 0.898, P = 0.003) were acceptable. However, hypotheses H6 (ß = 0.49, P = 0.558) and H7 (ß = -0.45, P = 0.700) were not confirmed as these relationships were not statistically significant.

Hypothesis 1 (H1): BI has a positive impact on B

The model showed that BI positively influenced B with the standardized regression coefficient of ß = 0.59 (P = 0.00). The coefficient presented a strong relationship between the B and BI. With the P-value = 0.00, hypothesis H1 was confirmed. This means that an increase in the recycling intention of swine breeders might result in recycling behaviors.

Hypothesis 2 (H2): AT has a positive impact on BI

The results of the SEM defined a very strong positive relationship between AT and BI (ß = 0.96, P = 0.00). The statistic said that when the awareness regarding the benefits of recycling

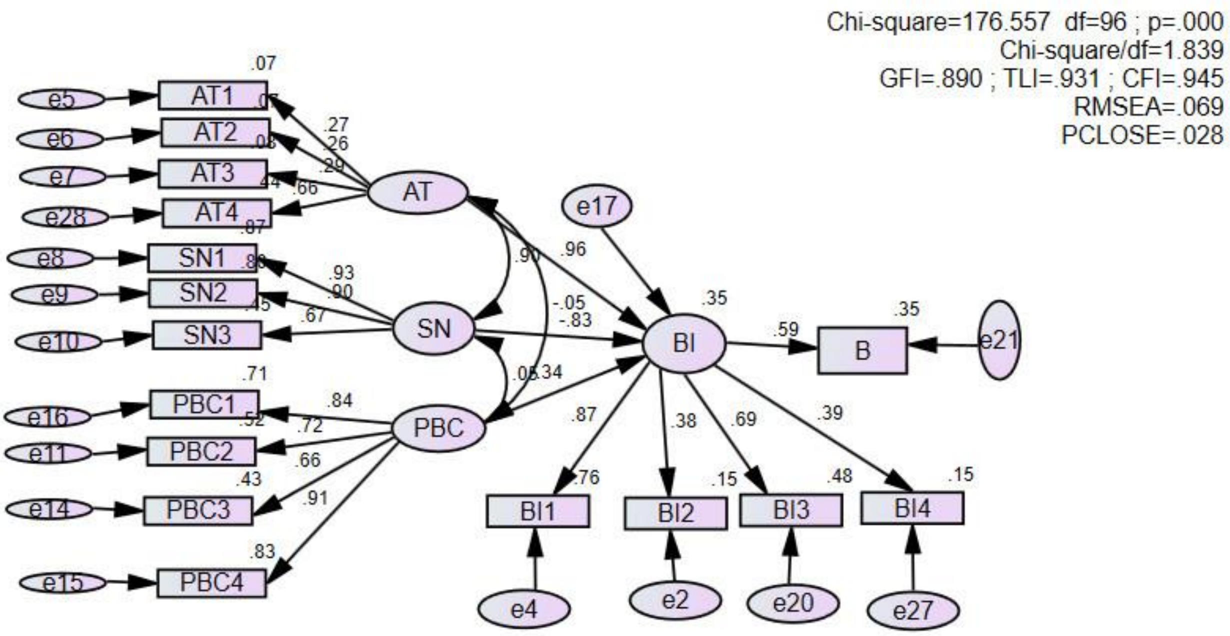


Figure 3. Recycling swine wastewater behavior prediction model

wastewater increases, farmers might intend to recycle wastewater. The *P*-value = 0.00 confirmed the statistical significance of hypothesis H2.

Hypothesis 3 (H3): SN has a negative impact on BI

BI and SN had a negative relationship (ß = -0.826, *P* = 0.00). By using the question to cross-assess the awareness of farmers regarding their responsibility in wastewater treatment, the results showed that the farmers were aware of their responsibility in handling wastewater, but they might not intend to reuse it for other activities. The ß = -0.826 result showed a very strong relationship between BI and SN with the *P*-value = 0.00. Thus, hypothesis H3 was confirmed.

Hypothesis 4 (H4): PBC has a negative impact on BI

The standardized coefficient of regression (ß = -0.34, *P* = 0.00) resulted in a negative relationship between BI and PBC. The results meant that if the farmers perceive more difficulties, they might have less intention of recycling wastewater. Hypothesis H4 was statistically significant. However, the ß = -0.34 showed a relatively weak relationship between the two factors.

Hypothesis 5 (H5): AT and SN have a positive relationship

The standardized coefficient of regression (ß = 0.869, *P* = 0.003) confirmed that SN and AT had a strong positive relationship. If the swine breeders were aware of the benefits of wastewater, they might also be aware of their responsibility in handling wastewater. The result showed a statistically significant relationship with *P*-value = 0.003, and, thus, hypothesis H5 was confirmed.

Discussion

Behavioral intentions and recycling behavior

Through applying the TPB (Ajzen, 1991), the analysis confirmed that the proposed variables were reasonable for explaining the hypothesized relationship. The analyzed results provided by SEM confirmed that five (out of the seven) hypotheses were accepted, confirming the significant relationships among the TPB variables. Specifically, B and BI had a moderate ß coefficient (ß = 0.59) because B was also influenced by other factors, especially the farms' characteristics and other related factors as found by other researchers (Giang, 2018; Liu *et al.*, 2018; Ngo *et al.*, 2021).

Overall, the study's result in examining the TPB's effectiveness in predicting recycling behavior was not astonishing because other researchers have widely approved it. In the study of Chu & Chiu (2003) on household waste recycling, researchers found that behavioral intention and recycling behavior had a close relationship with similar standardized regression coefficients (ß = 0.62). Similar results on assessing the effectiveness of TPB were also found in (Taylor & Todd, 1997; Ioannou *et al.*, 2013; Yuriev *et al.*, 2020; Liu *et al.*, 2021). The findings of this study suggest that policymakers should consider the factors that affect behavior intention to design appropriate policies which promote recycling behavior.

Determinants of recycling behavioral intention

Behavioral intention (BI) has a strong relationship with attitude (AT) and subjective norms (SN) with ß > 0.8 for both. These results are somewhat consistent with previous research such as the findings of Taylor and Todd (1995) and Ioannou *et al.* (2013) who reported that AT is a vital factor that determines the BI. However, the findings of Chu & Chiu (2003) pointed that AT was less important compared to other components of the TBP. According to Taylor & Todd (1995), the influence of SN was relatively weak in determining the recycling behavioral intention. Ioannou *et al.* (2013) even found that the relationship between SN and BI was not significant. However, overall, the vital roles of AT and SN in predicting BI has been widely asserted by other studies (Taylor & Todd, 1997; Chu & Chiu, 2003; Ioannou *et al.*, 2013; Giang, 2018; Liu *et al.*, 2018; Ngo *et al.*, 2021). This result suggests that to target improvements in recycling wastewater, raising farmers' awareness of wastewater benefits and personal responsibility are essential. They are two key components of BI and the key drivers of the success of recycling swine wastewater policies.

Although PBC had a weaker impact on BI than AT and SN, it had a significant influence on recycling intention with ß = -0.34. Compared to the results of other studies (Chu & Chiu, 2003; Ioannou *et al.*, 2013), the role of PBC might be less important than other components. However, PBC still presented a significant influence on recycling behavioral intention according to the results of this study. If the farmers perceive that they have self-control over the difficulties in recycling wastewater, the probability of recycling intention might be higher and thereby lead to actual behaviors. The findings suggest that, policymakers should take the difficulties that the farmers experienced into account to develop the policies that capture the challenges.

The study also assessed the relationship among the independent variables AT, SN, and PBC. The results confirmed the strong positive relationship between AT and PBC. However, the relationships between AT and PBC, and AT and SN were not statistically significant. Thus, the relationships between these sets of variables was not confirmed.

Conclusions

This study validates the effectiveness of Ajzen's Theory of Planned Behavior in understanding swine wastewater recycling. It developed a predictive model using SEM and AMOS software to analyze the influencing factors of recycling swine wastewater behaviors. The results highlight the following key factors: farmers' perception of wastewater benefits (AT) (ß = 0.957, *P* = 0.00), social norms (SN) related to self-responsibility (ß = -0.826, *P* = 0.00), and perceived behavior control (PC) linked to technologies, land cultivation, labor, and time cost (ß = -0.340, *P* = 0.00). To promote recycling, it is crucial to enhance the swine breeders' understanding of the value of wastewater and consider the influence of community pressure on reuse behavior. Balancing wastewater use and treatment is essential to avoid environmental conflicts and sustain waste utilization. Guidelines for proper wastewater reuse practices and targeted communication programs are necessary to support policy implementation. Our findings can inform the development of communication campaigns and agricultural policies for sustainable wastewater reuse. Additionally, understanding recycling behavior can contribute to future studies using agent-based approaches or machine learning to explore human decision-making in recycling livestock wastewater.

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