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Comparison of Two Pig-Farming Systems in Impact on The Quality of Surface and Groundwater in Hanoi, Vietnam

Ho Thi Lam Tra
Vietnam National University of Agriculture, Gialam district, Hanoi City, Socialist Republic of Vietnam

Cao Truong Son
Vietnam National University of Agriculture, Gialam district, Hanoi City, Socialist Republic of Vietnam

Nguyen Hai Nui
Vietnam National University of Agriculture, Gialam district, Hanoi City, Socialist Republic of Vietnam

Bui Phung Khanh Hoa
Department of Agriculture and Rural Development, Hanoi City, Socialist Republic of Vietnam

***Abstract* – The present study aimed to clarify the differences in the quality of surface and groundwater between two pig-farming systems of (a) a piggery combined with fruit garden and fishpond, abbreviated as VAC in Vietnam, and (b) a piggery combined with fruit garden, abbreviated as VC in Vietnam. Three administrative districts of Sontay city and Unghoa and Gialam districts were targeted in Hanoi City, the capital of Vietnam, and total forty one pig farms (18 VAC and 23 VC) were selected for surveying and water sampling on site in 2014. Surface water was sampled from water bodies surrounding the pig farms and groundwater was taken from wells inside the pig farms. In addition, questionnaire survey was conducted to 41 pig farms to obtain necessary information about pig farming. It was estimated that the amount of waste discharged from a piggery was 1,624 kg/day/farm as solid and 324.8 m^3/day/farm as liquid for the VAC system and 890 kg/day/farm as solid and 178.0 m^3/day/farm as liquid for the VC system, based on the mean number of pigs fed in a farm. The wastes were used for biogas production, composting, application to the fruit garden as organic fertilizers, and feeding fishes in a fishpond and/or collected for sale. The wastes discharged from a piggery were treated insufficiently and a low proportion of pig farms conducted waste treatment. This is supported by the results that 7 out of 9 parameters monitored for the surface water, namely DO, BOD_5, COD, PO_4^{3-}-P, NH_4^+-N, TSS and–coliform, did not reach the goal of QCVN08-Column B1 for both pig-farming systems. It means that the quality of surface water was deteriorated for both VAC and VC systems. The WQI calculation gave the same results as water quality monitoring and indicated that only 22.0% of pig farms among 41 farms had the surface water quality in the third level (can be used for irrigation) and that remaining 78.0% of pig farms had the surface water quality in the fourth (only used for hydro-transportation) or fifth level (must be treated). The quality of groundwater declined under pig farming and the average NH_4^+-N concentration (1.3 mg/l) of groundwater exceeded by 13 times the QCVN09. Deterioration of both the surface and groundwater qualities was much more serious for the VC system than for the VAC system.**

Keywords – **Hanoi, Pig Farming, VAC System, VC System, Water Quality.**

I. Introduction

In recent years, the *"New rural program*" has been implemented throughout the country in Vietnam. Hanoi City is one of the pioneer Cities/provinces in the program. In developing the new rural areas, increase in income of local people while keeping the environment can be a very challenging matter.

Promotion of livestock raising is a good way to make products for the commodities market. This helps to increase income and to improve living standard for people in rural areas. At the end of 2014, 919 livestock farms existed in Hanoi City, of which 216 (23.5%) were pig farms *[1]*. On the other hand, the development of livestock farming enhances the negative impact on the quality of the surrounding environment due to increase in pollution sources from farming areas. Many scientists have reported water pollution caused by livestock farming in Vietnam [2] - [6]. However, they only noted the water quality and did not refer to the factors which impact the water pollution levels. They focused on the matters such as water quality monitoring in the targeted farming areas and did not implement appropriately the study on the factors impacting water pollution. In fact, factors such as the scale of livestock farming and operation of waste treatment or not and its type and frequency seriously affect the water pollution levels in farming areas. Using Water Quality Index (WQI) to assess water quality was done more general on the world, for example [7] applied WQI to assess underground water quality in Maikunkele area of Niger state of Nigeria. In addition, WQI was used to evaluate quality of surface-water in Goa of India [8] and water quality of Dokan Lake in Iraq [9]. These studies were showed that WQI is a good tool for assessing water quality. This study aims to examine the differences in the water pollution levels between different pig-farming systems. Based on the results clarified in the present study, managers and farmers can select the best farming system for pig-raising.

II. Materials and Methods

2.1. *Study Areas*

Hanoi City, the capital of Vietnam, is located in the center of the Red River Delta and has land area of 3,324.52 km^2 and population of over seven million with population density above 2,000 people/km^2. Hanoi City slopes down from northwest to southeast and is divided into two parts. The first part is dominated by low mountains and includes Sontay town and Bavi and Socson districts. The second part is alluvial plains to which others districts and urban districts belong. Climatic conditions are favorable to the economic and social development of Hanoi City, with mean annual temperature of 24.1^{o}C (28.1^{o}C in summer and 17.4^{o}C in winter), mean annual rainfall of 1,800 mm, concentrated on summer from May to September (occupying 75 to 80% of the total rainfall amount), and mean annual humanity of 79% *[1]*.

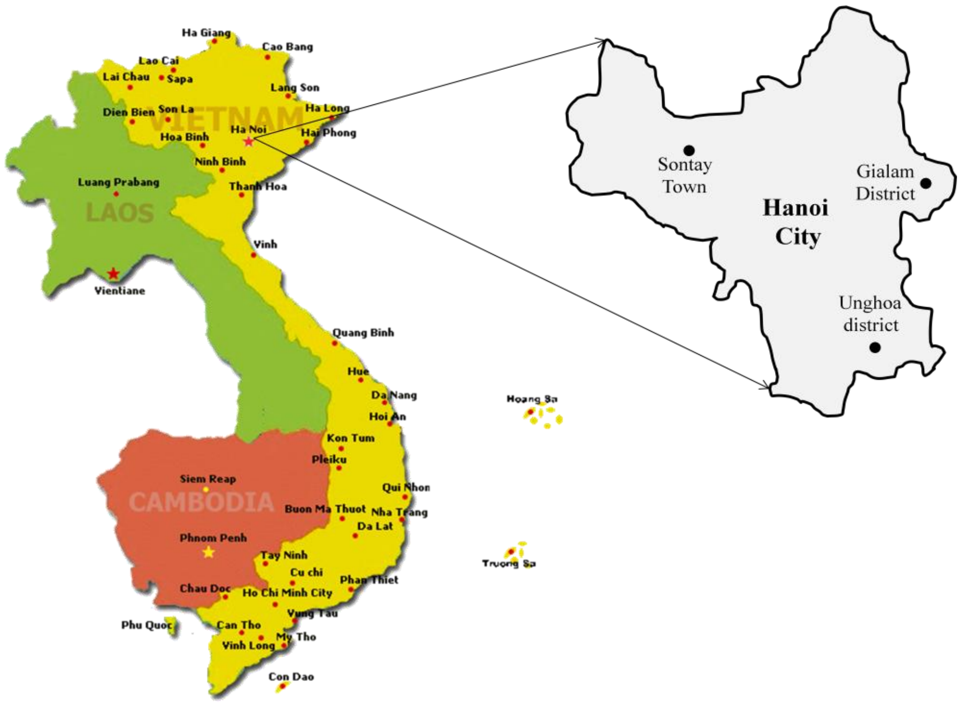

Fig. 1. Location of study areas on the map of Vietnam

Hanoi City is the capital of Vietnam but has a high proportion of rural people (58%). The rural areas are distributed around the central urbanized region of Hanoi City. These areas have intensively developed livestock farming to supply food to the central region of Hanoi City. In the present study, we focused on three administrative districts: Sontay town in the western region, Gialam district in the eastern region and Unghoa district in the southern region of Hanoi City (Figure 1). All three administrative districts have a large number of pig farms. In 2014, the number of pig farms in the three administrative districts was 57 with making up 26.4% of the total pig farms in Hanoi City. We selected 41 out of 57 pig-farms for the present study. The selected pig farms were divided into two pig-farming systems. The first is a combination of pig farming with fruit cultivation and fish culture and commonly called the VAC system. The second is a combination of pig farming with fruit cultivation and commonly called the VC system. Detailed information about the two pig-farming systems will be presented later.

2.2. *Study Methods*

2.2.1. *Data Collection*

Both primary and secondary data collection methods were used in the study.

a. Questionnaire Survey

We designed a structural questionnaire to obtain information about farming situations, waste sources, operation of waste treatment and its type and frequency, and basic things from pig farms in the study areas. This questionnaire was collected from 41 pig farms in all, and 14 from Gialam district, 12 from Sontay town, and 15 from Unghoa district.

b. Secondary Data Collection

Data and documents in relation to the study were collected from several relevant organizations and quoted from science reports and published articles. The relevant organization are as follows: General Statistics Office of Vietnam, Breeding Office of Vietnam, Department of Agriculture and Rural Development of Hanoi, People Committees of Sontay town and Unghoa and Gialam districts.

2.2.2. *Environmental Monitoring and Analysis*

a. Water Sampling

Surface and groundwater samples were collected two times in 2014 according to the TCVN 5994-1995 and TCVN 6000-1995 procedures of Ministry of Natural Resources and Environment in Vietnam. Each time, samples of surface and groundwater were collected from every pig farm in the study areas. Surface water samples were taken at a depth of 20 to 40 cm from the surface in ponds, lakes and canals into which wastewater from pig farms flows. Groundwater samples were taken from wells inside the pig farms. The surface and groundwater sampling was done in the morning.

b. Water Quality Analyses

The pH, turbidity, DO and temperature were determined on site immediately after sampling by a portable pH/turbidity/DO/t^o meter (D-50 Series, Horiba, Co. Ltd). Other parameters were analysed at the laboratory of the Faculty of Environment, Vietnam National University of Agriculture. Ammonium, nitrate and phosphates ion concentrations were determined by using a spectrophotometer (UV/VIS-evolution, Model EV0300PC), according to the nesslerization method [10], the Catald method [11] and the Oniani method [12], respectively. COD was measured by the dicromate method

(Cr^{6+}) [10] and BOD_5 was analysed by the dilution and seeding method [13]. TSS and coliform were determined by the filtraion through glass fibre filters method [14] and the membrane filtration method [15], respectively. The analyses were done in duplicate and the relative deviation of the duplicate values was usually less than 5%.

2.2.3. *Data Analyses*

a. Surface Water Quality Assessment

Comparison with QCVN08: results of the surface water quality monitoring were compared with QCVN08-Column B_1 [16].

Water quality index (WQI): the score of WQI was calculated according to the guide procedure of Ministry of Natural Resources and Enviornment in Vietnam *[17]* using a following equation:

$$WQI = \frac{WQI_{pH}}{100}\left[\frac{1}{5}\sum_{a=1}^{5} WQI_a \times \frac{1}{2}\sum_{b=1}^{2} WQI_b \times WQI_c\right]^{1/3}$$

in which,

- WQIa: WQI score of five paremeters: DO, BOD_5, COD, $N\text{-}NH_4^+$ and $P\text{-}PO_4^{3-}$;
- WQIb: WQI score of two paremeters: TSS and turbidity;
- WQIc: WQI score of coliform parameter;
- WQIpH: WQI score of pH parameter.

The water quality is divided into following five levels, based on the the WQI score which ranges from 0 to 100:

- 1st level (Bright green): WQI of 91 to 100 - potable water.
- 2nd level (Green): WQI of 76 to 90 - water acceptable for household use with a suitable treatment solution;
- 3rd level (Yellow) : WQI of 51 to 75 - water quality for irrigation;
- 4th level (Orange): WQI of 26 to 50 - water quality for hydro-transprotation;
- 5th level (Red): WQI of 0 to 25 - water is extremely polluted and needs treatment.

b. Groundwater Quality Assessment

Results of the groundwater quality monitoring were compared with QCVN09 [18].

c. Statistical Analysis

The 12th Stata software was used to make descriptive statistics and to analyse t-tests of farming norms and water quality levels at significant levels of 1%, 5%, and 10% between the VAC and VC systems.

III. Results

3.1. *Situation of Pig Farming in the Study Areas*

3.1.1. *Main characteristics of pig-farming*

As shown in Table 1, among 41 pig farms, 18 farms (making up 44%) were under the VAC system and 23 farms (making up 56%) were under the VC system. In respective administrative districts, the VAC system was double of the VC system for Unghoa district, while the VC system was double of the VAC system for Gialam district and Sontay town.

Table 1. The number and proportion of the pig-farming systems in the study areas

District/town	VAC		VC		Total	
	Number	Proportion (%)	Number	Prooprtion (%)	Number	Proportion (%)
Gialam	5	36	9	64	14	100
Unghoa	8	67	4	33	12	100
Sontay	5	33	10	67	15	100
Total	18	44	23	56	41	100

In this study, we focused on the differences between the VAC and VC systems throughout the study areas. Main characteristics of the two systems are shown in Table 2.

Table 2. Main characteristics of the pig farming systems in the study areas

Characteristics	VAC ($\overline{X}$ ± SD)	VC ($\overline{X}$ ± SD)	Difference between the VAC and VC systems	
			Difference	P-value
Pig-farm area (m^2)	20,735 ± 6,029	5,098 ±1,156	15,637***	0.0100
Piggery area (m^2)	3,164 ±1,681	1,106 ±241	2,058	0.8793
Number of pig (pig)	812 ±273	455 ±77	356	0.8883
Number of pig/farm area (pig/m^2)	0.058 ±0.011	0.186 ±0.043	0.128 ***	0.0037
Number of pig/piggery area (pig/m^2)	0.431 ±0.060	0.479 ±0.050	0.048	0.2702

Note: $\overline{X}$: mean; SD: standard deviation.

Table 2 showed that the mean area of a pig farm was 20,735 m^2 (over 2.0 ha) for the VAC system and 5,098 m^2 (over 0.5 ha) for the VC system. The mean area of a piggery was 15.26% (3,164m^2) and 21.69% (1,106m^2) of the mean pig-farm area for the VAC and VC systems, respectively. The mean number-of-pig/piggery-area was 0.431 and 0.479 pig/m^2 for the VAC and VC systems, respectively, and was nearly equal with each other. However, the mean number-of-pig/farm-area was greatly diffrent between the two pig-farming systems and was considerably smaller for the VAC system (0.058 pig/m^2) than for the VC system (0.186 pig/m^2).

3.1.2. *Waste Treatment*

Solid-waste and waste-water management is very important to protect environment against pollution in the concentration area of pig farming. Table 3 shows the proportion of different waste treatments conducted by pig farms in the study areas. The proportion of pig farms to separate waste into solid and liquid portions was very low with only 15.42% for the VAC system and 22.35% for the VC system. Biogas production was the most popular waste treatment with proportions of 40.26 and 38.08% for the VAC and VC systems, respectively. Some other treatments which have been generally conducted are composting, application to the fruit garden as organic fertilizers, and collection for sale. However, the proportion of pig farms to conduct these waste treatments was fairly low. Use for feeding fishes in a fishpond is another practice for waste treatment but was only conducted in the VAC system with a proportion of 11.50%.

Among the three administrative districts, pig farms of Unghoa district were the most positive to conduct waste treatment, followed by pig farms of Sontay city, and pig farms of Gialam district were least positive to conduct waste treatment (Table 3). Pig farms of both the VAC and VC systems were active to conduct waste treatment for Unghoa district, whereas pig farms of either the VC or VAC system was active to conduct waste treatment for Gialam district and Sontay city.

Table 3. The proportion of different waste treatments conducted by pig farms in the study areas in relation to the pig-farming systems

Waste treatment	VAC		VC		Tổng số	
	Number	Ratio (%)	Number	Ratio (%)	Number	Ratio (%)
Separation into solid and liquid wastes	6	15.42	9	22.35	15	37.77
Use for biogas production	17	40.26	16	38.08	23	78.34
Use for composting	2	3.92	1	1.52	3	5.44
Collection for sale	3	6.51	8	18.94	11	25.45
Use as organic fertilizers to apply to fruit trees	3	7.64	7	17.42	10	25.06
Use for feeding fishes in a fishpond	5	11.50	0	0.00	5	11.5

3.2. *Water Quality Monitoring*

3.2.1. *Surface Water*

Table 4. Quality monitoring of the surface water under the two pig farming systems in the study areas

Pig-farming system		pH	DO	BOD_5	COD	PO_4^{3-}-P	NO_3^--N	NH_4^+-N	TSS	Coliform
			mg/L							MNP/100 mL
VAC (n = 18)	$\overline{X}$	6.62*	3.69**	52.14*	108.00**	1.26**	0.26	2.26	521.80	3,714*
	±*SD*	*±1.24*	*±1.37*	*±57.12*	*±72.32*	*±0.97*	*±0.28*	*±2.57*	*±372.63*	*±3,787*
VC (n = 32)	$\overline{X}$	7.12*	2.68**	159.93*	326.09**	1.99**	0.34	3.12	546.22	30,851*
	±*SD*	*±0.68*	*±1.42*	*±300.42*	*±560.24*	*±1.64*	*±0.44*	*±3.50*	*±399.60*	*±61,218*
Total (n = 41)	$\overline{X}$	6.90	3.13	112.61	230.34	1.67	0.31	2.74	537.50	18,325
	±*SD*	*±0.98*	*±1.47*	*±232.29*	*±432.27*	*±1.42*	*±0.38*	*±3.12*	*±375.68*	*±46,318*
Standerd value of QCVN08-B1		5.5-9.0	≥4.0	15	30	0.3	10	0.5	50	7,500

Note: n = number of surface water samples; Note: $\overline{X}$: mean; SD: standard deviation; (*) and (**) = the statistical difference at the 10% and 5% significant levels, respectively.

Results of quality monitoring of the surface water in the study areas are described in Table 4. Mean values of quality prameters of the surface water were considerably high with following values: pH, 6.90; BOD_5, 112.93 mg/L; COD, 230.34 mg/L; NH_4^+-N, 2.34 mg/L; $PO^{3-}{}_4$-P, 1.67 mg/L; TSS, 537.50 mg/L; and coliform, 18,325 MNP/100 mL. It was as low as 3.13 mg/L for DO. Standard deviation of quality parameters of the surface water was high. It means a wide variation of quality parameters. All quality parameters of the surface water were larger for the VC system than for the VAC system.

3.2.2. *Groundwater*

In quality monitoring of the groundwater, we forcused on two parameters of the NO_3^--N and NH_4^+-N concentrations. The nitrate-N concentrations were very low and showed insignificance between the VAC and VC systems. On the other hand, the ammonium-N concentrations were high and the mean value was 1.30 mg/L (0.64 and 1.82 mg/L for the VAC and VC systems, respectively) (Table 5).

Table 5. The ammonium-N concentrations of groundwater in pig-farming systems

Pig-farming system	Value	NH_4^+-N (mg/l)
VAC	$\overline{X}$	0.64
(n = 18)	*±SD*	*±0.57*
VC	$\overline{X}$	1.82
(n = 32)	*±SD*	*±2.42*
Total	$\overline{X}$	1.30
(n = 41)	*±SD*	*±1.93*
QCVN 09		0,10

3.3. *Score of WQI*

Calculated WQI scores for the surface water under the two pig-farming systems are shown in Table 6. The mean WQI score of the surface water quality was 29.88 for all 41 pig farms and 32.66 for the VAC system and 27.71 for the VC system. These WQI scores indicate that the surface water quality belongs to the 3rd, 4th or 5th level. The quality of surface water discharged from a piggery of both 39% of pig farms belonged to the 4th and 5th levels and from 22% of pig farms to the 3rd level. Surface water whose quality belonged to the 4th and 5th levels occupied 47 and 39%, respectively, of pig farms for the VC system and 23 and 39%, respectively, for the VAC system. Percentages of pig farms whose corresponding surface water quality belongs to 3rd and 4th levels were different between the VAC and VC systems but the percentage of pig farms belonging to the 5th level was the same between them.

Table 6. Assessment of the surface water quality under the two pig-farming systems according to the WQI *score*

Pig-farming System	Score of WQI		Level of the surface water quality			
		Score		3rd (Yellow)	4th (Orange)	5th (Red)
VAC	$\overline{X}$	32.66	Number	6	5	7
(n = 18)	*±SD*	*± 24.25*	*Ratio (%)*	*33*	*23*	*39*
VC	$\overline{X}$	27.71	Number	3	11	9
(n = 23)	*±SD*	*± 22.73*	*Ratio (%)*	*13*	*48*	*39*
Total	$\overline{X}$	29.88	Number	9	16	16
(n=41)	*±SD*	*± 23.25*	*Ratio (%)*	*22*	*39*	*39*

Note: n = number of surface water samples; Note: $\overline{X}$*: mean; SD: standard deviation.*

IV. Discussion

4.1. *Waste Sources*

Table 2 showed that the mean number of pig per pig-farm was 812 and 445 for the VAC and VC systems, respectively. They are equivalent to waste sources of 1,624 kg/day/farm as solid waste and 324.8 m^3/day/farm as liquid waste for the VAC system and 890 kg/day/farm as solid waste and 178.0 m^3/day/farm as liquid waste for the VC system. Solid and liquid wastes discharged from a piggery can easily contaminate surrounding water bodies, because pig excrement contains 0.5% N, 0.3% P_2O_5 and 0.4% K_2O on average [19] and wastewater contains N and P having the average concentration of 1,500 to 15,200 mg N/L and 70 to 1,750 mg P/L, respectively [20].

As shown in Table 2, the mean numbers of pigs and pig/piggery-area were 812 pigs/farm and 0.431 pig/m^2 for the VAC system and 455 pigs/farm and 0.479 pig/m^2 for the VC system analysis indicated that those values were statistically insignificant between the two systems. It means that conditions of waste discharge are almost the same between the VAC and VC systems. Conversely, the mean pig-farm area and the mean number of pig/farm-area were statistically different between the VAC and VC systems at the 1% significant level with P-values of 0.0100 and 0.0037, respectively. This result suggests a significant difference in conditions of waste receiving between the two pig-farming systems. The VAC system has a higher waste-receiving and equating capacity than the VC system due to its large mean pig-farm area and low mean number of pig/farm-area compared with the VC system. This has an important difference in the impact on the water quality of surrounding environment.

Different waste treatments conducted by pig farms in the study areas are shown in Table 3, and waste was used for biogas production, applied to fruit trees as organic fertilizers, used for composting, and collected for sale. Waste was additionally used for feeding fishes in a fishpond in pig farms under the VAC system. Waste treatment exhibited diversity under both pig-farming systems but a proportion of pig farms conducted waste treatment was still low. Under the VAC system, 40.26% of pig farms adopted biogas production, 3.92% did composting, 6.51% did collection for sale, 7.64% did application to fruit trees as organic fertilizers, and 11.5% did feeding fishes in a fish pond. The corresponding percentages under the VC system were 38.08; 1.52; 18.94; and 17.42%, except feeding fishes in a fish pond. These low percentages of waste treatment solutions application point out that waste sources producing from pig farming are insufficiently controlled and treated. This is a key cause to bring about serious pollution of water environment around pig farms.

4.2. *Assessment of the Quality of Surface and Groundwater*

4.2.1. *Comparison of surface water quality parameters with QCVN08-Column B_1*

According to the Vietnam National Technical Regulation on Surface Water Quality-water for irrigation (QCVN08-Column B_1), the water standard is 5.5 to 9.0 for pH, 4.0 mg/L for DO, 15 mg/L for BOD_5, 30 mg/L for COD, 0.3 mg/L for PO_4^{3-}-P, 10 mg/L for NO_3^--N, 0.5 mg/L for NH_4^+-N, 50 mg/L for TSS, and 7,500 MNP/100 mL for coliform. Comparison of surface water quality parameters with the standards of QCVN08-Column B_1 revealed that only pH and NO_3^--N fulfilled the standard and seven parameters (including BOD_5, COD, DO, PO_4^{3-}-P, NH_4^+-N, TSS and coliform) unaccepted with the corresponding standards of QCVN08-Column B_1 (Table 4). A mean value of DO under the VAC and CV systems was 3.69 and 3.13 mg/L, respectively, and lower than the standard of 4.0 mg/L of QCVN08-Column B_1. Conversely, mean values of BOD_5, COD, PO_4^{3-}-P, NH_4^+-N, TSS and coliform were over the corresponding standards of QCVN08-Column B_1. BOD_5 was by 3.5 and 10.7 times, COD by 3.6 and 10.9 times, PO_4^{3-}-P by 4.2 and 6.6 times, NH_4^+-N by 4.5 and 6.2 times, TSS by 10.4 and 10.9 times, and coliform by 0.5 and 4.1 times higher than the corresponding standards of QCVN08-Column B_1 for the VAC and VC systems, respectively. Based on the finding that 7 out of 9 (78%) parameters representing the surface water quality exceeded the standards of QCVN08-Column B_1, we can conclude that the quality of surface water surrounding pig farms is polluted severely. The pollution level of surface water was lower for the VAC system than for the VC system. It suggests that pig farming under the VC system impacts the quality of surface water more severely than does pig farming under the VAC system. This matter is discussed clearly in the 4.3 part.

4.2.2. *WQI Assessment*

According to calculation of WQI scores shown in Table 6, the quality of surface water taken from water bodies surrounding pig farms belonged to following three levels: 3rd level (Yellow) - water quality for irrigation; 4th level (Orange) - water quality for hydro-transportation; and 5th level (Red) - water is polluted severely and needs treatment. This means that the quality of surface water under the VAC and VC systems was very bad. The quality of surface water discharged from only 22% of pig farms was in the 3rd level and from both 39% of pig farms was in the 4th and 5th levels. Percentage of pig farms whose surface water quality belonged to the 4th and 5th levels was higher than that of pig farms belonging to the 3rd level. Comparison of the quality of surface water between pig farms under the VAC and VC systems showed that the proportion of pig farms with the surface water quality ~~at~~ in the 3rd level was higher for the VAC system (33%) than for the VC system (13%). The proportion for the 4th level of the surface water quality was conversely lower for the VAC system (23%) than for the VC system (48%). The proportion for the 5th level of the surface water quality was equal between the VAC and VC systems with a proportion of 39%. These results suggest that the quality of surrounding surface water is better for the VAC system than for the VC system. This conclusion is compatible with assessment of the quality of surface water by comparison with QCVN08-Column B_1, which was described above.

4.2.3. *Comparison of NH_4^+-N Concentrations in the Groundwater with QCVN09*

According to the Vietnam National Technical Regulation on Groundwater Quality (QCVN09), the water standard of NH_4^+-N is 0.1 mg/L. Monitoring of the groundwater showed that the mean concentration of NH_4^+-N exceeded by 13.0 times the standard of QCVN09 (Table 5). It exceeded the standard by 6.4 times for the VAC system and by 18.2 times for the VC system. This means that groundwater inside the pig farm under the VC system was polluted more severely than groundwater under the VAC system. This matter is discussed clearly in the 4.3 part.

4.3. *The Difference in the Water Quality Between the VAC and VC Systems*

Based on the results of comparison of water quality parameters with QVCN08 and QCVN09 and calculation of WQI scores, we concluded that the quality of water affected by pig farms under the VC system was deteriorated more severely than the quality of water affected by pig farms under the VAC system. The t-test was made to assert this conclusion definitely and the difference of water quality parameters between the VAC and VC systems was examined at the statistically significant levels of 1%, 5% and 10% with two hypotheses (Ha and H0). Here, the H0 hypothesis is no difference in the mean value of water quality parameters between the VAC and VC systems; and the Ha hypothesis is that the mean value of water quality parameters for the VAC system is lower than that for the VC system, except DO in which the mean value is higher for the VAC system than for the VC system in the Ha hypothesis. Results of the t-tests are described in Table 7.

Table 7. Two-cluster t-test equality of the mean values of water quality parameters between the VAC and VC systems

Hypothesis	Difference (VAC-VC)	T-value	P-value	Conclusion	Significant Level
Surface water					
H0: pH (VAC) = pH (VC) Ha: pH (VAC) < pH (VC)	-0.5042	-1.5523	0.0666	Rejection of H0	10%
H0: DO (VAC) = DO (VC) Ha: DO (VAC) > DO (VC)	1.0086	2.2981	0.0136	Rejection of H0	5%
H0: BOD_5(VAC) = BOD_5(VC) Ha: BOD_5 (VAC)<BOD_5(VC)	-107.7822	-1.6822	0.0527	Rejection of H0	10%
H0: COD (VAC) = COD (VC) Ha: COD (VAC) <COD (VC)	-218.087	-1.8473	0.0388	Rejection of H0	5%
H0: coliform (VAC) = coliform (VC) Ha: coliform (VAC) < coliform (VC)	-27,137.36	-1.655	0.0608	Rejection of H0	10%
H0: PO_4 (VAC) = PO_4 (VC) Ha: PO_4 (VAC) < PO_4 (VC)	-0.7374	-1.7911	0.0408	Rejection of H0	5%
H0: NO_3 (VAC) = NO_3 (VC) Ha: NO_3 (VAC) < NO_3 (VC)	-0.0856	-0.7579	0.2266	Acceptance of H0	
H0: NH_4 (VAC) = NH_4 (VC) Ha: NH_4 (VAC) < NH_4 (VC)	-0.8578	-0.9047	0.1856	Acceptance of H0	
H0: TSS (VAC) = TSS (VC) Ha: TSS (VAC) < TSS (VC)	-24.4222	-0.1145	0.4557	Acceptance of H0	
Groundwater					
H0: NH_4^+ (VAC) = NH_4^+(VC) Ha: NH_4^+ (VAC) < NH_4^+ (VC)	-1.1823	-2.2595	0.0016	Acceptance of H0	1%

Examination by the t-test manifested that the mean values of six out of nine surface water parameters were statistically different between the VAC and VC systems. Among them, three parameters of pH, BOD_5 and coliform showed a difference at the significant level of 10% and DO, COD and PO_4^{3-}-P did at the significant level of 5%. None of them were different at the significant level of 1%. The mean values of NO_3^--N, NH_4^+-N and TSS were insignificantly different between the VAC and VC systems. These results of the t-test allow us to confirm that the quality of surface water affected by pig farms under the VAC system was better than the quality of surface water affected by pig farms under the VC system. In other words, the VC system affects more severely on the quality of surrounding surface water than does the VAC system.

Concerning the groundwater, examination by the t-test pointed out that the mean NH_4^+-N concentration was statistically lower for the VAC system than for the VC system at the significant level of 1% (P-value = 0.0016). It is confirmed that the quality of groundwater inside the pig farm under the VAC system was better than the quality of groundwater inside the pig farm under the VC system.

In the study areas, as shown in Table 2, the mean piggery area and the mean number of pig/piggery-area were not statistically different between the VAC and VC systems. However, the mean pig-farm area and the mean number of pig/farm-area showed a significant difference at the 1% level between the VAC and VC systems. They can be considered as key factors to be responsible for the difference in the quality of water affected by pig farming between the VAC and VC systems. Because the VAC system has a fishpond, it has the larger total area of a pig farm than the VC system. It is easily understood that increase in the pig-farm area enhances its receiving and decomposing capacity. This statement is supported by the study targeting pig farms in Hungyen province [21]. In addition, a fishpond is available for waste treatment and 12% of pig farms under the VAC system used waste for feeding fishes in a fishpond (Table 3). This helps to reduce the amount of waste discharged to surrounding water bodies. Development of pig farming according to the VAC system not only reduces the feeding density of pigs (the number of pig/farm-area) but also increases the receiving capacity of waste and the diversity of solutions for waste treatment. The VAC system is a good suggestion for managers to advise farmers in developing their pig farms for reducing negative impacts on environment.

V. Conclusions

(1) The proportion of the VAC and VC systems in pig faming under the study areas was 44—and 56%, respectively. A pig farm under the VAC system had the mean farm area of 2.0 ha, the mean feeding number of 812 head, the mean piggery area of 3,164m^2, and the mean feeding density of 0.058 pig/m^2 per farm-area and of 0.431pig/m^2 per piggery-area. The corresponding values for a pig farm under the VC system are as follows: about 0.5 ha, 455 head, 1,106 m^2, and 0.168 pig/m^2 per farm-area and 0.479 pig/m^2 per piggery-area. There was observed no significant difference in the mean feeding number of pig and the mean feeding density of pig per piggery-area between the VAC and VC systems. On the other hand, the mean farm area and the mean feeding density of pig per farm-area showed a significant difference at the 1% level between the two pig-farming systems.

(2) It was estimated that the amount of waste discharged from a piggery was 1,624 kg/day/farm as solid and 324.8 m^3 /day/farm as liquid for the VAC system and 890 kg/day/farm as solid and 178.0 m^3/day/farm as liquid for the VC system, based on the mean number of pigs fed in a farm. Main waste treatments which have been conducted by pig farms in the study areas are use for biogas production, use for composting, application to fruit trees as organic fertilizers, feeding fishes in a fishpond and collection for sale. However, wastes produced in the pig farming were treated insufficiently, because a proportion of pig farms to conduct waste treatment was very low. Under the VAC system, 40.26% of pig farms adopted biogas production, 3.92% did composting, 6.51% did collection for sale, 7.64% did application to fruit trees as organic fertilizers, and 11.5% did feeding fishes in a fish pond. The corresponding percentages under the VC system were 38.08; 1.52; 18.94; and 17.42%, except feeding fishes in a fish pond.

(3) The surface water affected by pig faming was contaminated severely with seven quality parameters which exceeded the corresponding standards of QCVN08-Column B_1. A mean value of DO under the VAC and CV systems was 3.69 and 3.13 mg/L, respectively, and lower than the standard of 4.0 mg/L of QCVN08-Column B_1. Conversely, mean values of BOD_5, COD, PO_4^{3-}-P, TSS and coliform were over the corresponding standards of QCVN08-Column B_1. BOD_5 was by 3.5 and 10.7 times, COD by 3.6 and 10.9 times, PO_4^{3-}-P by 4.2 and 6.6 times, TSS by 10.4 and 10.9 times, and coliform by 0.5 and 4.1 times higher than the corresponding standards of QCVN08-Column B_1 for the VAC and VC systems, respectively.

(4) Calculation of WQI scores for the surface water of all pig farms indicated its poor quality and the quality of surface water discharged from 22% of pig farms was in the 3rd level (water quality for irrigation) and from both 39% of pig farms was in the 4th (water quality for hydro-transportation) and 5th (water is polluted severely and needs treatment) levels.

(5) Groundwater inside the pig farm was contaminated with NH_4^+-N. The mean concentration of NH_4^+-N was 1.30 mg/L for all pig farms (0.64 mg/L for the VAV system and 1.82 mg/L for the VC system) and exceeded by 13.0 times the standard of QCVN09 (6.4 and 18.2 times for the VAC and VC systems, respectively).

(6) Both the surface and groundwater qualities were better for the VAC system than for the VC system. According to the examination by t-test, the mean values of six surface water quality parameters were significantly different between the VAC and VC systems at the 5% level for DO, COD and PO_4^{3-}-P and at the 10% level for BOD_5, pH and coliform. In the groundwater, the mean concentration of NH_4^+-N was significantly different at the 1% level between the VAC and VC systems.

VI. Recommendations

The present study clarified that the negative impact of the VC system on water environment surrounding a pig farm was more critically than the negative impact of the VAC system. Thus it is recommended that policy makers should advise farmers to develop their pig farms according to the VAC system for reducing negative impact on environment.

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AUTHORS' PROFILES

As.Pro. HO THI LAM TRA
Office:
Faculty of Land Management, Vietnam National University of Agriculture.
Position: Lecturer
Major: Land Management
Email: holamtra@vnua.edu.com

MSc. CAO TRUONG SON
Office:
Faculty of Environment, Vietnam National University of Agriculture.
Position: Lecturer
Major:
Environmental science.
Email: caotruongson.hua@gmail.com

MSc. NGUYEN HAI NUI
Office:
Faculty of Accounting and Business Management
Position: Lecturer
Major: Management
Email: hainui@gmail.com

MSc. BUI PHUNG KHÁNH HOA
Office:
Hanoi Department of Agriculture and Rural, Development, Vietnam.
Position: Staff
Major: Environmental science.
Email: khanhhoa0710@gmail.com