Evaluation of Water Pollution Caused by Different Pig-Farming Systems in Hungyen Province of Vietnam

Ho, Thi Lam Tra
Faculty of Natural Resources and Environment, Hanoi University of Agriculture

Cao, Truong Son
Faculty of Natural Resources and Environment, Hanoi University of Agriculture

Luong, Duc Anh
Faculty of Natural Resources and Environment, Hanoi University of Agriculture

Vu, Dinh Ton
Faculty of Animal Science and Aquaculture, Hanoi University of Agriculture

他

https://doi.org/10.5109/26176

出版情報：九州大学大学院農学研究院紀要. 58 (1), pp.159-165, 2013-02. Faculty of Agriculture, Kyushu University
バージョン：

J. Fac. Agr., Kyushu Univ., **58** (1), 159–165 (2013)

Evaluation of Water Pollution Caused by Different Pig–Farming Systems in Hungyen Province of Vietnam

Thi Lam Tra HO[1], Truong Son CAO[1], Duc Anh LUONG[1], Dinh Ton VU[2], Kiyoshi KUROSAWA* and Kazuhiko EGASHIRA[3]

Institute of Tropical Agriculture, Kyushu University, Fukuoka 812–8581, Japan
(*Received October 30, 2012 and accepted November 8, 2012*)

In recent years, pig breeding has developed very fast in Hungyen Province, located in the Red River Delta of Vietnam adjacent to the capital of Hanoi. The following four pig–farming systems are performed there: 1) VAC system: a combination of fruit cultivation, fish culture with pig farming; 2) AC system: a combination of fish culture with pig farming; 3) VC system: a combination of fruit cultivation with pig farming; and 4) C system: only pig farming, respectively. Among these systems, VAC system had the highest occupancy (45.6%), followed by AC system (23.3%) and then by C system (21.5%), and VC system had the lowest occupancy (9.6%) in number in the investigated two districts of the province. The level of the pollution of the surface and groundwater was monitored for the four systems. The monitoring was done six times with a two–month interval during February to December in 2010. As the result, the surface water was evaluated to be strongly polluted in each pig–farming system, i.e. the chemical oxygen demand (COD), biological oxygen demand (BOD), and ammonium–N and phosphate–P concentrations on average exceeded the national technical regulation standard, and the dissolved oxygen (DO) on average was very low. For the groundwater, the average ammonium–N concentration exceeded the standard in each pig–farming system. However, the level of the surface and groundwater pollution was not similar among the pig–farming systems. In general, the level of surface and groundwater pollution was high in C and VC systems, intermediate in VAC system and low in AC system, respectively.

Key words: groundwater, Hungyen Province, pig–farming system, pollution, surface water

INTRODUCTION

In recent years, the most remarkable feature of livestock industry in Vietnam is the establishment and development of livestock breeding in a farm or a collective farm. This is a widespread trend and an important indication of economic efficiency in Vietnamese agriculture, especially encouraged by the resolution 03/2/2000 NQ–CP concerning farm economic development issued by the government on February, 2000.

In the last 3 years, the number of livestock–raising farms tended to increase steadily with the realization of the positive correlation between profit and number of livestock. Of the livestock–raising farms, pig–breeding farm has the highest number with a total of 7,475 in the country, occupying 42.2% of all livestock raising farms. In the pig breeding, the northern Vietnam has 3,069 farms, accounting for 41.1% of the total number in the country, and the southern Vietnam has 4,406 farms, accounting for 58.9% of the total number. In sow raising, the scale of 20 to 50 head per farm is most popular, occupying 71.3% of all sow raising farms. In porker raising, the scale of 100 to 200 head per farm is most popular, occupying 75.5% of all porker–raising farms (Animal Husbandry Administration, 2007).

In the present, however, pig farming, which has made rapid industrialization and modernization, impacting seriously on the environment in the Red River Delta. The discharge of the excrement from pig–raising farms is considered to be the cause of surface water pollution, since the pig excrement contains 0.5% of nitrogen, 0.3% of phosphate and 0.4% of potash on average (Pahl–Wostl and Schaenborn, 2003). Waste water from pigsty is composed of excrement, garbage, mud, remaining feed, and solubilized nitrogenous and phosphorus substances due to mixing with solid waste. It was reported that the waste water from a pigsty contained 1,500 to 15,200 mg N/L of total nitrogen and 70 to 1,750 mg P/L of phosphate–P, and those concentrations were 50 to 150 times higher than those of the waste water from the urban areas (Mulder, 2003; Maurer and Schwegler, 2003).

At one time, the authors monitored the surface water quality in Laivu Commune, Kimthanh District, Haiduong Province, Vietnam, where pig breeding has been enhanced since 2001 in the level of the farm household, and found that the surface water was contaminated seriously by organic and inorganic substances (Ho *et al.*, 2008). In the commune, water quality was measured regularly at several times during a monitoring period, and it was found that the average values of dissolved oxygen (DO), biological oxygen demand (BOD), chemical oxygen demand (COD), and nitrate–N, ammonium–N and phosphate–P concentrations at different sites were in the ranges of 1.27–4.39, 4.96–19.38, 25–56, 0.17–2.88, 0.89–9.36, and 0.66–5.97 mg/L, respectively. Most of them exceeded the Vietnamese water standard for sur-

[1] Faculty of Natural Resources and Environment, Hanoi University of Agriculture, Gialam, Hanoi, Socialist Republic of Vietnam
[2] Faculty of Animal Science and Aquaculture, Hanoi University of Agriculture, Gialam, Hanoi, Socialist Republic of Vietnam
[3] Emeritus Professor, Kyushu University, Fukuoka 812–8581, Japan
* Corresponding author (E–mail: kurosawa@agr.kyushu–u.ac.jp)

face water quality (TCVN:5942/1995, column A), and the ammonium–N concentration exceeded the Vietnamese water standard for surface water quality for irrigation (TCVN:5942/1995, column B). Comparison of nitrate–N, ammonium–N and phosphate–P concentrations on the surface water between before and after the enhancement of pig breeding in the farm household indicated the decline of the surface water quality after the pig–breeding enhancement.

As described in the preceding paragraph, the enhanced pig breeding in the farm household provided pollution sources and deteriorated the surface water quality of adjacent canals and ponds in Laivu Commune. By following our previous study (Ho *et al.*, 2008), the present study was conducted in the districts of Hungyen Province, which aimed to clarify: 1) the present situation of pig–farming systems; 2) the pollutants of the solid and liquid waste from pig–farming systems; and 3) the environmental pollution level in the different pig farming systems, respectively.

MATERIALS AND METHODS

Study area

Vangiang and Khoaichau districts of Hungyen Province were targeted in the present study, because these districts had the highest number of livestock breeding households, occupying 24.7% and 22.5% of the total livestock breeding households of the province, which was 2,402 in 2010 (Statistical Administration of Vietnam, 2010). Hungyen Province is located in the center of the Red River Delta and adjacent to the northwestern part of Hanoi City (Fig. 1). Total area of the province is 923.5 km^2, and the population is 1,131,200 persons, i.e. the population density is 1,225 persons/km^2 in 2009 (Statistical Administration of Vietnam, 2010). In recent years, livestock breeding has been developed rapidly in the province. There were 1,535 livestock breeding farms in 2004, but the number of farms increased to 2,402 in 2010 in the province (Statistical Administration of Hungyen Province, 2010). The number of pig–breeding farms of the province was equivalent to 36.8% of that of the Red River Delta and 2.3% of that of the country in 2008 (Statistical Administration of Vietnam, 2008).

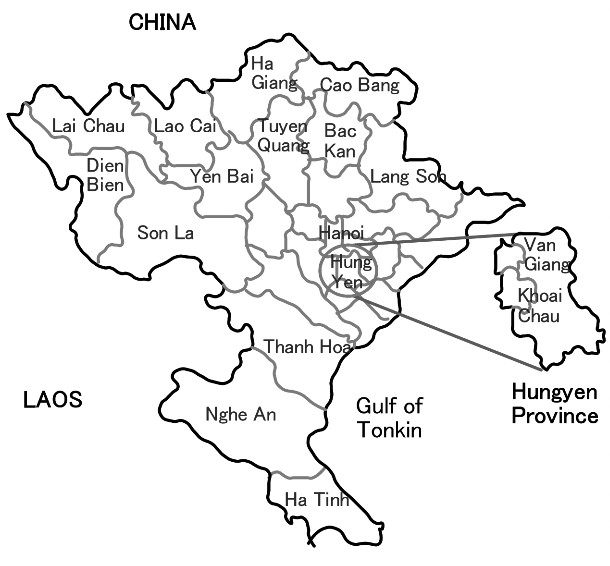

Fig. 1. Map of northern Vietnam and location of the study area.

According to the meteorological data recorded from 1998 to 2008 at the Hydrometeorological Centre in Hungyen Province (2010), the mean rainy season rainfall (April to October) ranged from 1,200 to 1,300 mm, and the mean dry season rainfall (November to March) from 200 to 300 mm, and the mean annual rainfall ranged from 1,500 to 1,600 mm. The mean annual air temperature ranged from 22 to 23°C. The relative humidity was very high throughout the year with an annual mean of 80–90%.

There are two main groundwater aquifers in the Red River Delta (World Bank, 1995). One aquifer is embedded in Holocene sediments and the other in Pleistocene sediments. The former aquifer is located at a depth of 0.5 to 2 m from the ground surface during the rainy season and at a depth of 2 to 8 m during the dry season. Its thickness ranges from a few to 40 m. The latter aquifer is confined and underlies the former with a thickness of 10 to 100 m.

Collection of information on pig farming and discharge and treatment of wastes

Interview was done to 270 pig–farming households in Vangiang and Khoaichau districts in December, 2009 for collecting information on pig production, pig–farming area, number of pigs bred, waste discharge, waste treatment, etc., on the four pig–farming systems, i.e. VAC system: a combination of fruit cultivation, fish culture with pig farming; AC system: a combination of fish culture with pig farming; VC system: a combination of fruit cultivation with pig farming; and C system of only pig farming, respectively.

Sampling of water

Water sampling was done six times with a two–month interval from February to December in 2010 in the districts. At each sampling, five hundred milliliters of surface and groundwater, respectively were sampled from 25 sites at eleven pig farms in the pig–farming systems. In each pig farm, surface water was sampled from fishpond, natural pond and/or ditch at one or two sites, respectively, while groundwater was sampled from tube–well set in each pig farm at one site. The sampling depth of groundwater varied from 20 to 35 m. From these depths, the sampled groundwater was thought to belong mostly to the aquifer embedded in Holocene sediments.

Analytical procedures

Parameters of pH, DO, BOD, COD, and nitrate–N, ammonium–N and phosphate–P concentrations were analyzed for surface water, and those of nitrate–N and ammonium–N concentrations were done for groundwater. The pH and DO were analyzed on site immediately after the sampling by a portable pH meter and a DO meter (D–50

Series, Horiba, Co. Ltd), respectively. The other parameters were analyzed at the laboratory of the Department of Environmental Technology, Hanoi University of Agriculture. Ammonium, nitrate and phosphates ion concentrations were determined by using a spectrophotometer (UV/VIS–EVOLUTION, Model EV0300PC), by the Nesslerization method (American Public Health Association, 1992), the Catald method (Catald *et al.*, 1975) and the Oniani method (Oniani *et al.*, 1973), respectively. BOD_5 and COD were determined by the Dilution and Seeding method (ISO, 1989) and the Dicromate method (Cr^{6+}), respectively (American Public Health Association, 1992). The determination was made in duplicate and the relative deviation of the duplicate values was usually less than 5%.

RESULTS

Present situation of pig farming

According to the interview to 270 pig–farm households of the districts conducted in 2009, the four pig breeding systems of VAC, AC, VC and C systems were observed. Number of pig–farm household in each system and its ratio of the total interviewed households are shown in Table 1. Here, VAC was the highest in the number of 123 or 45.6% of the total households; the number of AC and C systems was 63 and 58 or 23.3% and 21.5% of the total households, respectively. Number of VC system was the lowest of 26 or 9.6% of the total households.

The total area and each area used for house, piggery, fishpond, fruit garden and waste treatment in each pig–farming system on average are shown in Table 2. Total area and each respective area varied with pig–farming system. The total area was the largest in AC system with an area of 16,086 m^2/farm, followed by 8,931 and 3,335 m^2/farm in VAC and VC systems, and the smallest in C system of 962 m^2/farm on average, respectively.

In VAC system, the area of fishpond, fruit garden and piggery occupied about 56%, 34% and 7% of the total area, respectively (Table 2). The area used for waste treatment was very small, occupying 1.45% of the total area. In AC system, the area used for fishpond occupied the main part with 95% of the total area, and the area used for piggery occupied only 4.05% of the total area. No area was used for waste treatment in AC system. In VC system, the area of fruit garden, piggery and waste treatment occupied about 71%, 26% and 2% of the total area, respectively. Naturally, the area used for piggery occupied the main part in C system. There was no area used for waste treatment in C and AC systems.

Pig–farming land was distributed inside and outside

Table 1. Number and the ratio of different pig–farming systems in Vangiang and Khoaichau districts of Hungyen Province in 2009

Pig–farming system	Number	Ratio to the total interviewed pig–farming households (%)
VAC	123	45.6
AC	63	23.3
VC	26	9.6
C	58	21.5
Total	270	100.0

Table 2. Averaged total and individual land areas and the ratio to the total land area in different pig–farming systems in Vangiang and Khoaichau districts of Hungyen Province in 2009

Parameter		Unit	VAC	AC	VC	C
Total land area		m^2	8,931.20 ±4.94	16,086.34 ±8.01	3,334.94 ±3.09	961.89 ±9.40
		%	100.00	100.00	100.00	100.00
Land area for individual use	House	m^2	139.42 ±1.23	117.22 ±1.21	47.84 ±0.25	335.47 ±1.53
		%	1.56	0.73	1.43	34.88
	Piggery	m^2	647.43 ±4.50	651.07 ±6.66	854.62 ±4.36	626.42 ±3.14
		%	7.25	4.05	25.63	65.12
	Fishpond	m^2	5,012.00 ±8.16	15,318.05 ±3.8	0.00	0.00
		%	56.12	95.22	0.00	0.00
	Fruit garden	m^2	3,002.54 ±3.34	0.00	2,369.15 ±9.8	0.00
		%	33.62	0.00	71.04	0.00
	Land for waste treatment	m^2	129.81 ±54.54	0.00	63.33 ±43.42	0.00
		%	1.45	0.00	1.90	0.00
Inside residence		%	15.00	17.07	29.41	92.11
Outside residence		%	85.00	82.93	70.59	7.89

Table 3. Number and production of pig in different pig–farming systems in Vangiang and Khoaichau districts of Hungyen Province in 2009

Pig–farming system	Sow	Piglet		Porker	
	Number (head)	Production (head/year)	(tons/year)	Number (head/year)	Production (head/year)
VAC	18.95±3.43	111.42±6.57	1.08±0.50	396.33±3.19	41.62±1.65
AC	17.02±4.88	92.20±5.23	0.78±0.30	492.68±4.08	52.12±6.99
VC	37.88±3.12	165.88±7.79	1.16±0.23	107.23±2.05	52.83±2.9
C	17.89±3.87	44.87±9.74	0.31±0.20	518.95±3.43	54.06±9.4

Table 4. Estimates of solid waste and wastewater discharged from pig farms in different pig–farming systems in Vangiang and Khoaichau districts of Hungyen Province in 2009

Pig–farming System	Solid waste (tons/year)	Wastewater (1,000 m^3/year)		
		Winter	Summer	Whole year
VAC	58.70±4.13	1.68±0.25	3.72±0.31	5.39±4.10
AC	67.11±6.19	1.69±0.10	4.93±0.21	6.63±2.37
VC	86.95±3.08	1.57±0.01	3.10±0.37	4.68±5.26
C	70.96±4.64	1.59±0.25	3.44±0.65	5.03±5.32

the residence. The percentage of the pig–farming land distributed outside the residence was 85%, 83% and 71% in VAC, AC and VC systems, respectively (Table 2), indicating that pig breeding is mainly an outside–residence activity. However, pigs were mainly bred inside the residence in C system and the percentage of the pig–farming land distributed inside the residence occupied 92%.

The number and production of pigs in each pig–farming system are shown in Table 3. In Table 3, the average number of sow was 38, 19, 18 and 17 head/farm in VC, VAC, C and AC systems, respectively. The average production of piglet was the highest in VC system with 166 head/year, followed by VAC and AC systems with 111 and 92 head/year, and the lowest in C system with 45 head/year, respectively. The average production of porker was 54, 53, 52 and 42 head/year in C, VC, AC and VAC systems, respectively, and was not much different with one another among the pig–farming systems.

Waste discharge

Solid waste and wastewater discharged from the pig–farming systems, estimated from the 270 interviewed pig–farm households, are shown in Table 4. The discharged solid waste amount was the largest in VC system, followed by C and AC systems, and the smallest in VAC system, and the amount on average was about 87, 71, 67 and 59 tons/year, respectively. The discharged amount of wastewater was the highest in AC system with about 6.6 thousands m^3/year and the lowest in VC system with 4.7 thousands m^3/year on average. The amount was larger in summer than in winter, due to the difference of water use with the season.

Waste treatment

The process of solid waste and wastewater treatments, derived from the interview to the pig–farm households, are shown in Figs. 2 and 3, respectively. Only about 20% of solid waste and 35% of wastewater were treated in the pig–farm households. There are two ways

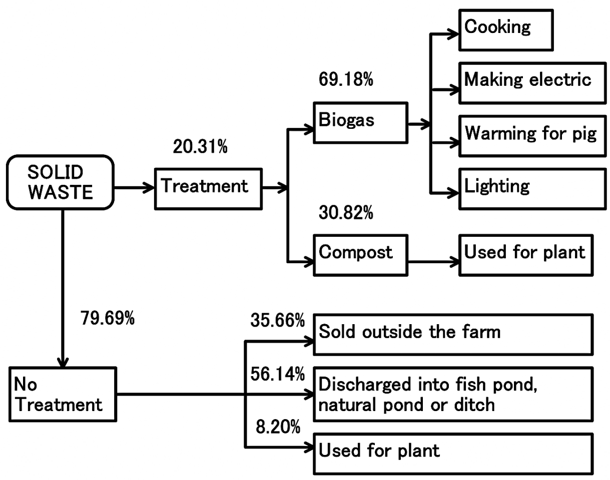

Fig. 2. Solid waste treatment in Vangiang and Khoaichau districts of Hungyen Province in 2009.

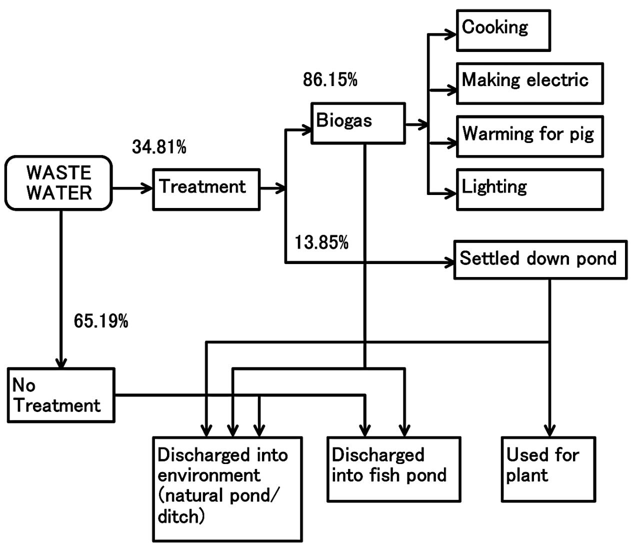

Fig. 3. Wastewater treatment in Vangiang and Khoaichau districts of Hungyen Province in 2009.

to treat the waste, which are the biogas production and compost formation. In treating solid waste, about 69% of it was used for the biogas production and the remaining 31% was used for the compost formation. While in treating waste water, about 86% of it was used for the biogas production and the remaining 14% was used for the compost formation.

The solid waste and wastewater discharged without treatment occupied as large as 80% and 65% of their total amount, respectively. The untreated waste water is generally discharged to fishpond in VAC and AC systems and to water body (natural pond and ditch) located around pig farms in VC and C systems.

Quality of water discharged from pig farms in each pig–farming system

*Surface wate*r

Quality of the surface water discharged from 11 pig farms in each pig–farming system, monitored from February to December in 2010, is shown in Table 5. Here, the parameters at each monitoring time are the averages of the farms, where VAC, AC, VC and C system are performed. In Table 5, pH ranged from 7.17 to 7.98, DO from 0.83 to 4.84 mg/L, BOD_5 from 12 to 860 mg/L, COD from 17 to 1,030 mg/L, ammonium–N concentration from 1.32 to 36.04 mg/L, nitrate–N concentration from 0.08 to 6.91 mg/L, and phosphate–P concentration from 0.02 to 16.25 mg/L, respectively.

For the average of 6 times monitoring, DO was the highest in AC system (3.54 mg/L), followed by VAC system (2.72 mg/L) and the lowest in VC+C systems (1.49 mg/L). On the other hand, BOD_5 was 543, 90 and 53 mg/L, and COD was 871, 124 and 78 mg/L, respectively, in VC+C, VAC and AC systems. The ammonium–N and phosphate–P concentrations were higher in VC+C systems (20.74 mg/L for ammonium–N and 6.97 mg/L for phosphate–P) than in AC system (5.21 mg/L for ammonium–N and 2.05 mg/L for phosphate–P) and in VAC system (5.09 mg/L for ammonium–N and 1.86 mg/L for phosphate–P), respectively. The nitrate–N concentration was a low of 1.85, 0.94 and 0.75 mg/L in VAC, VC+C and AC systems, respectively.

Groundwater

The ammonium–N and nitrate–N concentrations of groundwater, sampled at 11 pig farms in each pig–farming system and monitored from February to December in 2010, are shown in Table 6. Here, the parameters at each monitoring time are the averages of the farms, where VAC, AC, VC and C systems are performed. In Table 6, the ammonium–N concentration varied widely from 0.75 to 25.83 mg/L. The ammonium–N concentration in average of 6 times monitoring was the highest in C system (10.93 mg/L), followed by VC (6.37 mg/L) and VAC (4.25 mg/L) systems, and the lowest in AC system (3.29 mg/L), respectively. The ammonium–N concentra-

Table 5. Quality of surface water discharged from pig farms of different pig–farming systems in Vangiang and Khoaichau districts of Hungyen Province in 2010

Parameter (unit)	Pig–farming system	n	Monitoring time: Feb.	Apr.	Jun.	Aug.	Oct.	Dec.	Average of 6 times monitoring
pH	VAC	3	7.30	7.63	7.37	7.35	7.42	7.29	7.39
	AC	3	7.98	7.40	7.73	7.78	7.77	7.78	7.74
	VC+C	5	7.19	7.75	7.17	7.18	7.25	7.31	7.31
DO (mg/L)	VAC	3	4.52	2.83	2.49	2.16	2.93	1.41	2.72
	AC	3	4.06	3.40	4.84	3.94	2.83	2.18	3.54
	VC+C	5	1.80	1.67	1.79	1.80	1.06	0.83	1.49
BOD_5 (mg/L)	VAC	3	110	180	120	35	85	12	90
	AC	3	92	18	100	65	30	18	53
	VC+C	5	860	570	90	520	680	540	543
COD (mg/L)	VAC	3	160	236	160	53	120	17	124
	AC	3	130	21	150	90	48	26	78
	VC+C	5	1,030	730	120	835	941	827	871
NH_4^+–N (mg/L)	VAC	3	3.00	1.33	8.15	8.57	2.24	7.24	5.09
	AC	3	1.32	1.58	4.37	9.71	7.06	9.05	5.21
	VC+C	5	13.14	24.51	9.13	22.85	36.04	18.79	20.74
NO_3^-–N (mg/L)	VAC	3	2.20	6.91	0.12	0.13	0.87	0.89	1.85
	AC	3	1.82	1.76	0.18	0.17	0.13	0.44	0.75
	VC+C	5	1.72	2.43	0.08	0.18	0.15	1.09	0.94
PO_4^{3-}–P (mg/L)	VAC	3	3.20	1.81	0.28	2.91	2.03	0.91	1.86
	AC	3	0.02	0.16	0.26	0.89	9.17	1.18	2.05
	VC+C	5	16.25	4.55	0.51	4.43	8.06	8.04	6.97

Note: n in the parenthesis is the number of VAC, AC and VC+C systems monitored.

Table 6. Ammonium–N and nitrate–N concentrations of groundwater monitored for pig farms of different pig–farming systems in Vangiang and Khoaichau districts of Hungyen Province in 2010

Parameter (unit)	Pig–farming system	n	Monitoring time						
			Feb.	Apr.	Jun.	Aug.	Oct.	Dec.	Average of 6 times monitoring
NH_4^+–N (mg/L)	VAC	3	1.28	0.75	5.11	7.56	6.40	4.41	4.25
	AC	3	3.33	2.04	3.58	1.83	4.67	4.30	3.29
	VC	3	7.43	4.19	4.17	8.02	8.53	5.89	6.37
	C	2	10.87	7.01	10.94	7.78	3.17	25.83	10.93
NO_3^-–N (mg/L)	VAC	3	0.58	0.41	0.24	0.16	0.07	0.55	0.33
	AC	3	0.21	0.33	0.26	0.05	0.05	0.43	0.22
	VC	3	0.49	0.42	0.34	0.12	0.10	0.58	0.34
	C	2	1.16	0.44	0.25	0.09	0.03	0.32	0.38

Note: n in the parenthesis is the number of VAC, AC, VC and C systems monitored.

tion of C system was higher by 3.3, 2.6 and 1.7 times than those of AC, VAC and VC systems, respectively.

While, the nitrate–N concentrations ranged from 0.03 to 1.16 mg/L. According to the average of 6 times monitoring, the nitrate–N concentration was 0.33, 0.22, 0.34 and 0.38 mg/L in VAC, AC, VC and C systems, respectively, and was not much different with one another among the four systems. The nitrate concentrations were always lower than the ammonium–N concentrations at each monitoring time.

DISCUSSION

Sources of pollutants in the surface and groundwater

The amounts of solid waste and wastewater discharged from pig farms, estimated from the interview to the pig–farming households in the target districts, were very large (Table 4). While, from Figs. 2 and 3, only small portion, i.e. 20.31% of solid waste and 34.81% of wastewater, were treated. The remaining amounts were discharged without any treatment into fishpond (in VAC and AC systems) and natural pond and/or ditch (in CV and C systems).

It was reported that pig excrement contained 0.5% of N, 0.3% of P_2O_5 and 0.4% of K_2O on average (Pahl–Wostl and Schaenborn, 2003). The concentrations of N and P of pig wastewater ranged from 1,500 to 15,200 mg N/L and from 70 to 1,750 mg P/L, respectively (Eum and Choi, 2002). Solid waste and wastewater are considered as a source of pollutants. It probably influences adversely the surface and groundwater quality, promoting eutrophication and/or deteriorating water body.

Comparison of the surface and groundwater quality with the water standards

Comparison of the surface water with QCVN08–Class A_2

According to the national technical regulation of surface water – class A_2–quality surface water for protected life of bio–hydrology in Vietnam (QCVN08–Class A_2), the water standard for each parameter is as follows: pH is 6 to 8.5; DO is equal to or more than 5 mg/L; BOD_5 is equal to or less than 6 mg/L; COD is equal to or less than 15 mg/L; ammonium–N concentration is equal to or less than 0.2 mg/L; nitrate–N concentration is equal to or less than 5 mg/L; and phosphate–P concentration is equal to or less than 0.2 mg/L, respectively.

The quality of the surface water discharged from pig farms in each pig–farming system is shown in Table 5. When these qualities are compared with the above mentioned standards, DO satisfied the standard in each monitoring time in each pig–farming system, and average of 6 times monitoring was 30%, 54% and 71% of the standard for VC+C, VAC and AC systems, respectively. BOD_5, COD, and ammonium–N and phosphate–P concentrations exceeded the respective standards in each monitoring of each pig–farming system, except two cases of phosphate–P concentration. According to the averages of 6 times monitoring, BOD_5 exceeded the standard by 91, 15.0 and 8.8 times in VC+C, VAC and AC systems, COD exceeded the standard by 58, 8.3 and 5.2 times in VC+C, VAC and AC systems, ammonium–N concentration exceeded the standard by 106, 25 and 26 times in VC+C, VAC and AC systems, and phosphate–P concentration exceeded the standard by 35, 9.3 and 10.3 times in VC+C, VAC and AC systems, respectively. On the contrary, pH and nitrate–N concentration satisfied the respective standards in each monitoring time, except one case of nitrate–N concentration.

As seen from the comparison with the standard, the surface water discharged from pig farms was found to be seriously polluted in terms of DO, BOD_5, COD, and ammonium–N and phosphate–P concentrations in each the pig–farming system. Surface water is in a critical state in terms of ammonium–N concentration. The use of the surface water for drinking and cooking purposes is prohibited at present at the districts, and clean water is distributed to the households by the local government. However, special attention should be paid to the alarmingly high level of ammonium–N of the surface water in the intensive livestock–raising area of the districts.

Comparison of the groundwater with the national technical regulation of groundwater of Vietnam

According to the national technical regulation of groundwater of Vietnam, the water standard for the ammonium–N and nitrate–N concentrations are equal to or less than 0.1 and 15 mg/L, respectively. As understood from Table 6, ammonium–N concentration of groundwater far exceeded the standard in each monitoring time, irrespective of the pig–farming systems. The average ammonium–N concentration of the 6 times monitoring exceeded the standard by 109, 64, 33 and 43 times in C, VC, AC and VAC systems, respectively. The concentrations also far exceeded the value of 0.78 mg/L, above which human internal organ system may be damaged from long–term ingestion (Oregon Department of Human Services, 2000). On the contrary, nitrate–N concentration of groundwater always satisfied the standard in each monitoring time in each pig–farming system.

Therefore, groundwater of pig farms is evaluated to be in a critical state in terms of ammonium–N concentration in each pig–farming system. Therefore, attention should be paid to the alarmingly high level of ammonium–N of groundwater in the intensive livestock–raising area of the districts.

Comparison of the quality of the surface and groundwater between the four pig–farming systems

The pollution level of the surface and groundwater varied with the pig–farming systems in the target districts. The pollution level of the surface water was the highest in VC+C systems, followed by VAC system and the lowest in AC system. Similar to the surface water, the pollution level of the groundwater was very high in C and VC systems and somewhat low in AC and VAC systems. Relatively low level of surface and groundwater pollution in VAC and AC systems is ascribable to the presence of fishpond in these systems. Wastes occurred in pig farming at first flow into the fishpond and then the wastes are diluted before release into the environment. However, the quality of the surface and groundwater exceeded the Vietnamese water standards in each pig–farming system. In this viewpoint, waste treatment should be encouraged in order to keep the environment clean.

CONCLUSIONS

In recent years, the pig farming has developed very fast in Hungyen Province. The pig–farming systems performed in the districts of the province are the following 4 systems, i.e. VAC system: a combination of fruit cultivation and fish culture with pig farming; AC system: a combination of fish culture with pig farming; VC system: a combination of fruit cultivation with pig farming; and C system: only pig farming, respectively. VAC system occupied the highest portion of 45.6%, followed by AC system of 23.3% and then C system of 21.5%, and the lowest in CV system of 9.6%, respectively. Number of pigs bred and area of the farm varied with the pig–farming systems.

The quantity of waste from pig farming was very large, and only 20.31% of solid waste was treated. The remaining waste was discharged into environment directly without any treatment.

The surface water contaminated with the waste discharged from pig farms was seriously polluted in terms of DO, BOD, COD, and ammonium–N and phosphate–P concentrations, respectively. Level of pollution was relatively high in C and VC systems, while low in VAC and AC systems.

Ammonium–N concentration in groundwater exceeded the standard by the national technical regulation on groundwater quality of Vietnam in each pig–farming system, whereas the nitrate–N concentration satisfied the regulation. Therefore, attention should be paid to the deterioration of the surface and groundwater quality due to the discharge of wasters in the pig–farming system.

REFERENCES

American Public Health Association 1992 Standard method for examination of water and waste water. 18th edition, Washington D.C.

Animal Husbandry Administration 2007 Summary report on livestock raising farm in period 2001–2006, directions and development solutions in period 2007–2015. Animal Husbandry Administration of Vietnam, Hanoi (in Vietnamese)

Cataldo, D. A., M. Haroon, L. E. Schrader and V. L. Youngs 1975 Rapid colorimetric determination of nitrate in plant tissue by nitration of salicylic acid. *Communications in Soil Science and Plant Analysis*, **6**: 71–80

Eum, Y. and E. Choi 2002 Optimization of nitrogen removal from piggery waste by nitrite nitrification. *Wat. Sci. Technol.*, **45**(12): 89–96

Ho T. L. T., T. S. Cao and T. L. Tran 2008 Influence of pig breeding in household to surface water quality. Science and Technology Journal of Agriculture and Rural Development. Ministry of Agriculture and Rural Development, Vietnam, No 10/2008, pp. 55–60 (in Vietnamese)

Hydrometeorological Centre in Hungyen Province 2010 Hydrometeorological Data of Hungyen Province, Vietnam (in Vietnamese).

ISO 1989 Water quality–Determination of biochemical oxygen demand after 5 days (BOD_5)–Dilution and seeding method.

Maurer, M. and P. Schwegler 2003 Nutrient in urine: energetic aspect of removal and recovery. *Wat. Sci. Technol.*, **48**(1): 47–56

Mulder, A. 2003 The quest for sustainable nitrogen removal technologies. *Wat. Sci. Technol.*, **48**(1): 37–46

Oniani, O. G., M. Chater and G. E. G. Mattingly 1973 Some effects of fertilizers and farmyard manure on the organic phosphorus in soils. *Journal of Soil Science*, **24**: 1–9

Oregon Department of Human Services 2000 Health Effects Information Ammonia. Technical Bulletin; Oregon Health Division, Department of Human Services, Portland, OR, pp. 2–4

Pahl–Wostl, C. and A. Schaenborn 2003 Investigating consumer attitudes towards the new technology of urine separation. *Wat. Sci. Tachnol*. **48**(1): 47–56

Statistical Administration of Vietnam 2008 Statistical data of Vietnam (in Vietnamese)

Statistical Administration of Vietnam 2010 Statistical data of Hungyen Province, Vietnam (in Vietnamese)

World Bank 1995 Red River Delta Master Plan Vol. 2. The Present Situation. Ministry of Science, Technology and Environment, Hanoi