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Contents

1. WATER QUALITY REPORT FOR HANOI AND PHNOM PENH – MICROBIOLOGY

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1.1 Introduction

Wastewater used for irrigation of aquatic vegetables and as water source for fish cultivation in Thanh Tri district, a peri-urban commune in the South of Hanoi, is of both domestic and industrial origin. In Bang B village in the Thanh Tri district where the water analysis was carried out, about 50% of the households cultivate aquatic vegetables. Untreated wastewater from the To Lich river is pumped into the fields near the village to irrigate and fertilize mainly morning glory crops but also water dropwort, water cress and water mimosa. Wastewater from the river is also used for fish culture as has been common in Vietnam since the 1960's.

Phnom Penh, located on the banks of the Mekong River, has a population of nearly one million people. Similar to many cities in Southeast Asia, the peri-urban areas of Phnom Penh are very important for food production and for feeding the city. The peri-urban wetlands of Phnom Penh supplies edible aquatic plants and fish for the city and areas around Phnom Penh. These wetlands are mostly fertilized by sewage/wastewater discharged from the city (Borin C. 2004). The sewerage and wastewater treatment facilities to serve this population are inadequate. The sewage networks, mostly built in the 1960s, are a combined sewage overflow from many sources including households, storm water, and industrial effluents. There are about 160 km of sewer networks in the city centre including 2.6 km of open channels (JICA 1999). There is no wastewater treatment plant, so 10% of the effluents flow directly into the Mekong River without any treatment. The remaining 90 percent is discharged into natural surrounding wetlands that act as retention basins.

Every day, about 55,600 m^3 of household wastewater (equivalent to 2,414 tons per year of biological oxygen demand (BOD_5) discharge) and nearly 1 million m^3 of storm water are discharged into three wetlands; Boeng Trabek, Boeng Tumpun and Boeng Cheung Ek. The wetland of Boeng Cheung Ek is the largest. Its surface area is as large as the centre of Phnom Penh (about 2,000 ha) in the wet season, and shrinks to 1,300 ha in the dry season (Muong 2000). Effluents from the wetlands of Boeng Trabek and Boeng Tumpun are discharged into this wetland, together with industrial effluents from the surrounding areas.

The aim of this study was to assess the microbiological water quality of water used for irrigation of fields and ponds as well as the capacity of the Phnom Penh and Hanoi wastewater use systems to reduce faecal bacterial indicators and parasite numbers.

1.2 Materials and Methods

1.2.1 Field site and microbiological analyses in Hanoi

Microbiological water quality was assessed in fish ponds and in agricultural fields located in Hoan Liet commune, Bang B village. Fields sampled in the aquatic vegetable study were household designated numbers 1, 2, 3, 4, 5, and 6 of Bang B village. Only wastewater entry points were sampled as it was not possible to clearly identify outlets from fields, e.g. on outlet from one field served as inlet to the next field, etc.

Sampling points:

1. At pumping station, where the wastewater entered the major concrete canal
2. At the wastewater entry point for first row of fields
3. At the wastewater entry point for each of the 6 household fields

Parameters and microbiological analyses
Water quality was assessed by measuring numbers of thermotolerant coliforms, helminth eggs and protozoan parasite in water samples from fields at Hoang Liet and Long Bien commune, in water samples from various selected fish ponds in the Thanh Tri area and in water samples from two markets in and around Ha Noi.

Water samples in the fields were taken as three grab samples on the sampling day; collected within 2 hours interval. A composite sample was prepared upon return to the laboratory of the National Institute of Hygiene and Epidemiology (NIHE), Hanoi. The composite sample served as the water source for the bacteriological and parasitological analysis. Numbers of thermotolerant coliforms were measured in all samples by the MPN method described by the WHO.

In the market samples and some samples from the fishponds and the river, the numbers of helminth eggs and protozoan parasites were also enumerated. The Bailinger method as described by the WHO was used for helminth egg enumeration whereas protozoan parasites were detected by an immunofluorescent antibody test.

Field sites
Fields F1 to F6 in the Bang B village were selected as study sites and all receives untreated wastewater from the To Lich River which is pumped into the fields through a feeding system of concrete canals. Water samples were collected during a total of seven sampling times during a 4-month period from the end of August to the middle of December 2005.
Figure 1.1 shows a map of the location and characteristics of the six fields sampled.

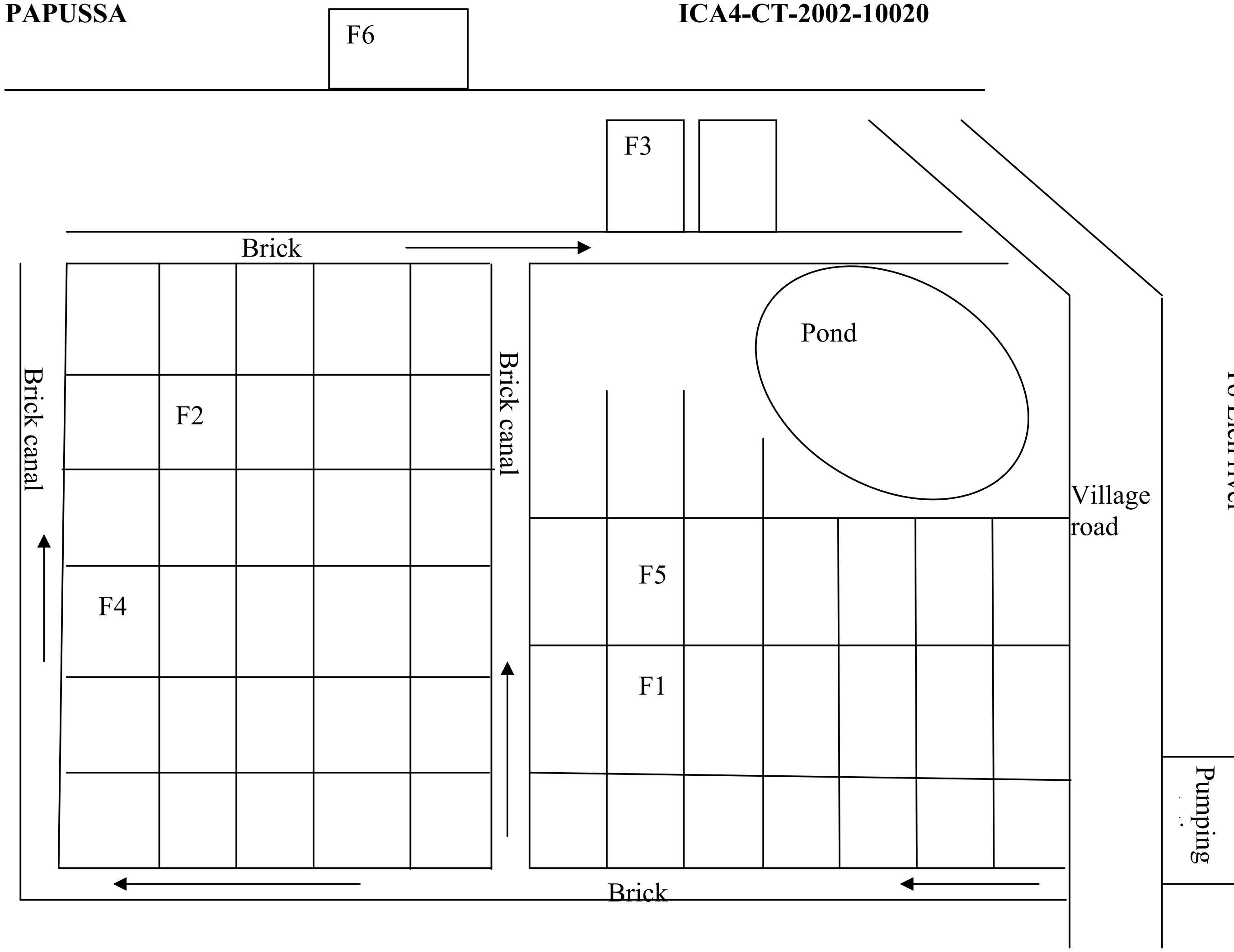

Figure 1.1 Map of six studied aquatic vegetables fields in Bang B village, Hoang Liet commune, Hanoi, Vietnam

<u>Fish ponds</u>

Three fishponds located in Bang B village, Hoang Liet commune were selected for microbiological water quality studies. Wastewater from inlet and outlet points was collected by using a composite sampling method whenever wastewater was pumped from the To Lich river to the brick canal which supplied the fishponds.

Fishpond no 1 had an average depth of the main pond around 1.5 - 1.6 metres with an estimated area of approx. 14,000 m^2. Fish species cultured included colosoma, tilapia, silver carps, mrigal, grass carp and common carp. The distance from the pumping station to the pond was approx. 1.5 km with the pond being connected to the end point of the brick canal.

Fishpond no 2 was located about 1 km from the Bang B pumping station and wastewater from To Lich River is pumped and supplied to the ponds through the brick channel. Average depth of the main fishpond was estimated of 1.3 metres with an area of 32,000-33,000 m^2. Polyculture is practiced mainly with common carp, tilapia, and silver carp.

Fishpond no 3 actually includes two small fishponds. Water samples were obtained from two inlets and two outlets. Wastewater that has been used for irrigation of fields are pumped into the two fish ponds which also receive wastewater directly from the To Lich river typically every two days. In one of the small ponds (no 1), fish are cultured together with water spinach and water mimosa in rotational culture. In the other small pond (no 2), fish are cultured together with water mimosa. The following indicates the water sampling locations in the studied fishponds.

Sample code	Sampling location
C1	inlet - fishpond no 2
C2	outlet – fishpond no 2
N1	inlet - fishpond no 1
N2	outlet – fishpond no 1
P1	At the pumping station
P2	Sampling point in the brick canal 2 km away from the pumping station
T1	inlet - fishpond no 3
T2	inlet - fishpond no 3
T3	outlet – fishpond no 3
T4	outlet – fishpond no 3

Further information can be seen about the fishponds and sampling points in the following maps (Figure 1.2 – 1.4).

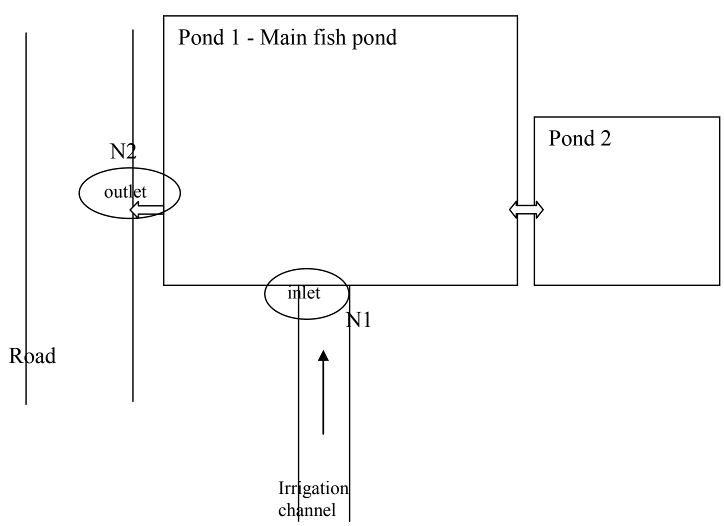

Figure 1.2 Map of Fishpond no 1

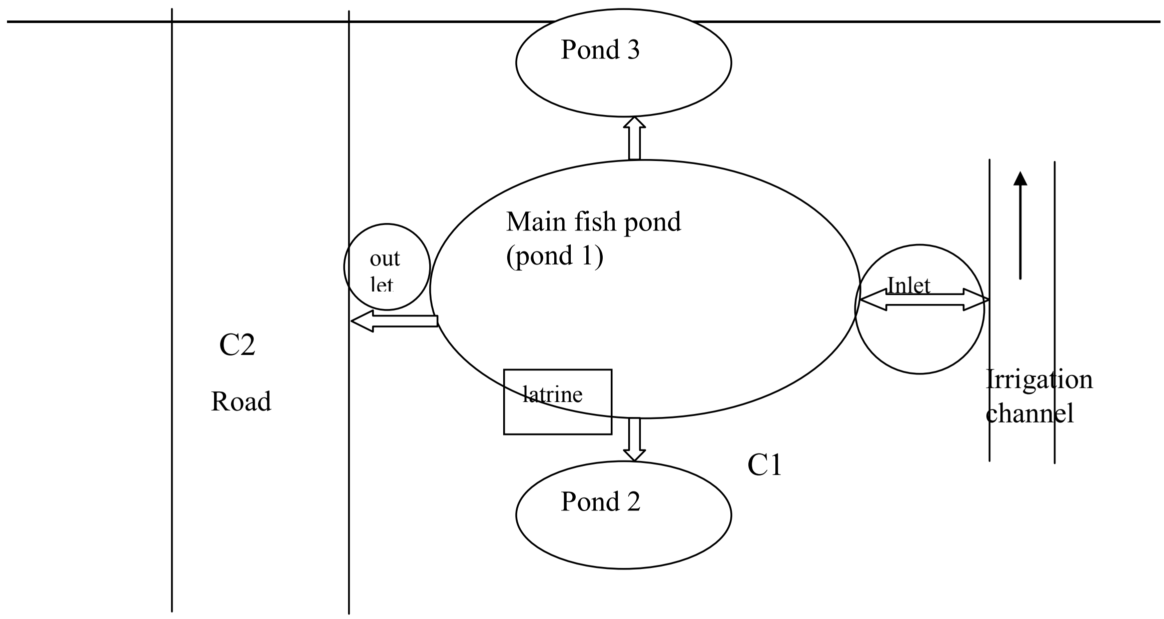

Figure 1.3 Map of Fishpond no 2

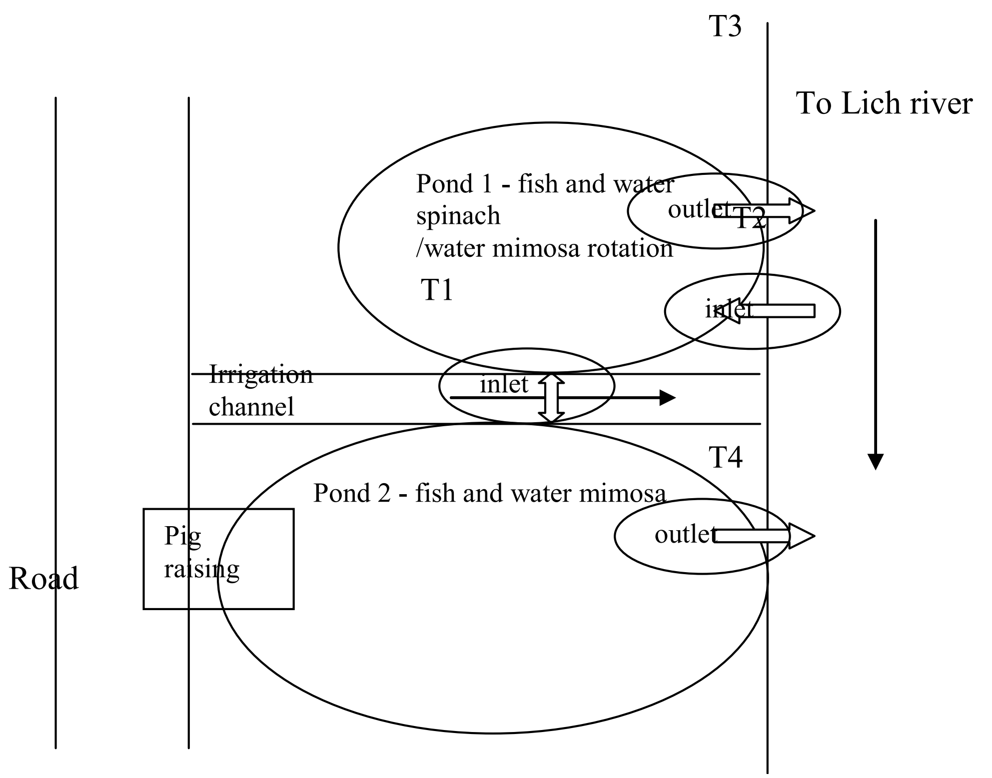

Figure 1.4 Map of Fishpond no 3

1.2 Field site in Phnom Penh

Boeng Cheung Ek Lake is located West of Phnom Penh city, the capital of Cambodia. Wastewater from Phnom Penh's urban population and industries as well as rain water run-off is discharged into the lake. There are two main wastewater inlets of Boeng Cheung Ek lake. One is Boeng Trabek pumping station which was constructed in 1986 and the other inlet (called Tumpun Station) was constructed in 2004 with support from the Japanese government (JICA). The lake has two main outlets with the outlet water running into the Prek Thnaot river through a stream named Steung Chrov.

Morning glory (white stem morning glory)/water spinach is the main crop grown in the Boeng Cheung Ek Lake and is used for human and animal consumption. Morning glory is harvested in the early morning by farmers and then at the end of the day collected by the wholesalers transport who then sell the produce to the local markets.

In the dry season, the water level in Boeng Cheung Ek Lake drops and several areas of the lake will dry out. Accordingly, morning glory is rarely grown during the dry season due to water shortage. In the rainy season, the entire lake area is usually flooded making identification of outlets difficult except for the Stoeng Chrov stream.

Phnom Penh urban wastewater discharged into the Boeng Cheung Ek lake is not undergoing any formal wastewater treatment. Thus, the wastewater passage through the Boeng Cheung Ek Lake and the associated treatment will be important in reducing any possible negative impacts of the wastewater on recipient rivers.

In summary, there are always two inlets of Boeng Cheung Ek Lake in both seasons. In the rainy season, wastewater from the lake flows into recipient rivers via both outlets but in the dry season, wastewater only flows into recipient rivers via STEUNG CHROV stream.

Another lake, Boeng Samrong (Prek Phnov) lake, was selected as a control site. It is located 15 km away from the centre of Phnom Penh city and does not receive wastewater. Non-wastewater samples were collected and analysed for comparison purposes during both seasons.

1.3 Results

1.3.1 Hanoi

Levels of thermotolerant coliforms (TC) in water samples from the fields showed high variations between sampling times. The highest numbers found were between 10^5- 10^6 CFU/100 ml (Figure 1.5). There was no clear pattern in the levels of TC during the sampling period, except that fields no 1 and 6 generally had lower TC levels.

Helminth eggs could not be detected in any of the water samples from the field, indicating that eggs may have been removed by sedimentation upstream, i.e. during the transport of the water through the canal system.

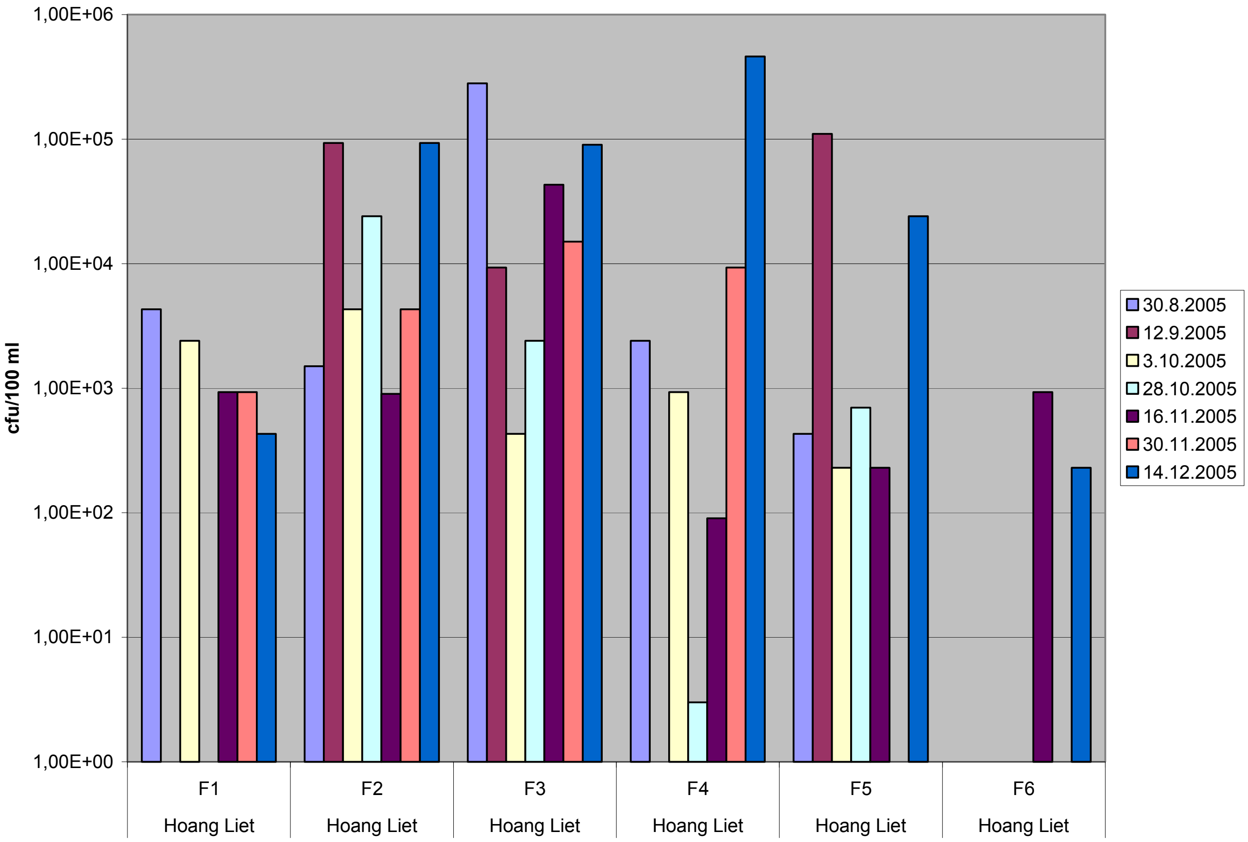

Figure 1.5 Thermotolerant coliform numbers (cfu/100 ml). Designations F1 to F6 refer to the individual household field numbers.

At the markets water samples were taken from the source, i.e. where the traders would go and fill up their containers with water for splashing their vegetables on display. Most traders got their water from a communal tap at the market, but a few would go to their household to get water. Levels of thermotolerant coliforms were very low in all water samples taken from the source water (Table 1.1). In contrast, water samples taken directly from the containers used for sprinkling vegetables had higher levels of thermotolerant coliforms. This suggests that a faecal contamination took place in the containers. Visual inspection of the containers used for water splashing revealed that they generally were dirty inside. Protozoan parasites were detected in some samples from Hang Be market in central Hanoi (Table 1.1).

Table 1.1 Water quality at a large urban market (Hang Be) and a small peri-urban market (Hoang Liet). Water containers tested were used for splashing the displayed vegetables with water.

Location (no of samples)	**Water source**	**Thermotolerant coliform bacteria (cfu/100 ml)**	**Helminth eggs**	**Protozoan parasites**
Hang Be market (n=6)	Water container	1.4×10^4	0	Detected in 2 out of 4 samples
Hang Be market (n=6)	Tap water	< 100	0	Analyses not done
Hoang Liet market (n=6)	Water container	4.3×10^4	0	0
Hoang Liet market (n=6)	Tap water	2.4×10^2	0	Analyses not done

Fishponds

Figure 1.6 show box-plots of logarithmic number of thermotolerant coliforms per 100 ml water sample. Negative samples (zero bacteria were detectable) were assigned the number 1 before logarithmic transformation. Small circles and stars with numbers attached were identified as co-called outliers. The box contains results found in 50% of water samples. The lines across inside the boxes represent the median thermotolerant coliform numbers.

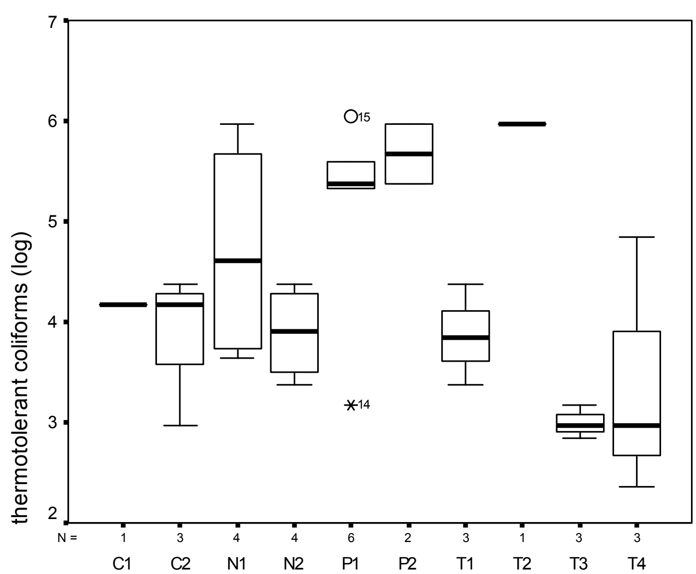

Figure 1.6 Results of the enumerations of thermotolerant coliforms in inlet and outlet water of the three types of fish ponds.

Thermotolerant coliforms median count in samples collected at the inlet of the fishpond no 2 (C1) was similar to counts found in water from the outlet (C2). Thermotolerant coliform counts found in samples collected at the inlet of the fishpond no 1 (N1) was a little less than one log unit higher than counts in the outlet water (N2). Similarly, thermotolerant coliforms counts in samples collected at the two inlets of the fishpond no3 (T1 and T2) were about 0.8-3.0 log units higher than the counts in samples collected at the two outlets (T3 and T4). It should be noted that thermotolerant coliform counts in wastewater samples collected directly from the brick canal (P1 and P2) prior running into the studied fishponds were significantly higher (10^5-10^6 CFU/100 ml) than counts in samples collected from the ponds (sampling at inlet and outlet points).

Helminth egg enumerations of both inlet and outlet water yielded only very few samples with eggs (data not shown). Thus, pollution with helminth eggs did not seem to represent a food safety or an occupational health risk.

1.3.2 Phnom Penh

Figure 1.7 shows that there was a reduction of TC counts in inlet compared with outlet water samples of the BCE Lake.

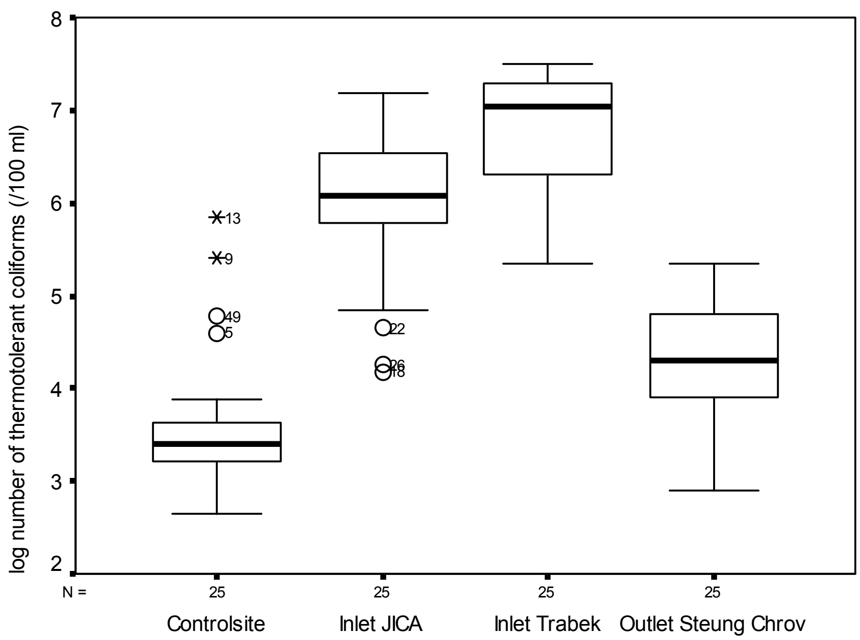

Figure 1.7 TC counts (logarithm transformed number) of water samples at inlets, outlet of the BCE lake and at the control site

Similar to counts of TC, *E. coli* counts were significantly lower in inlet wastewater compared with outlet water of the BCE Lake (Figure 1.8).

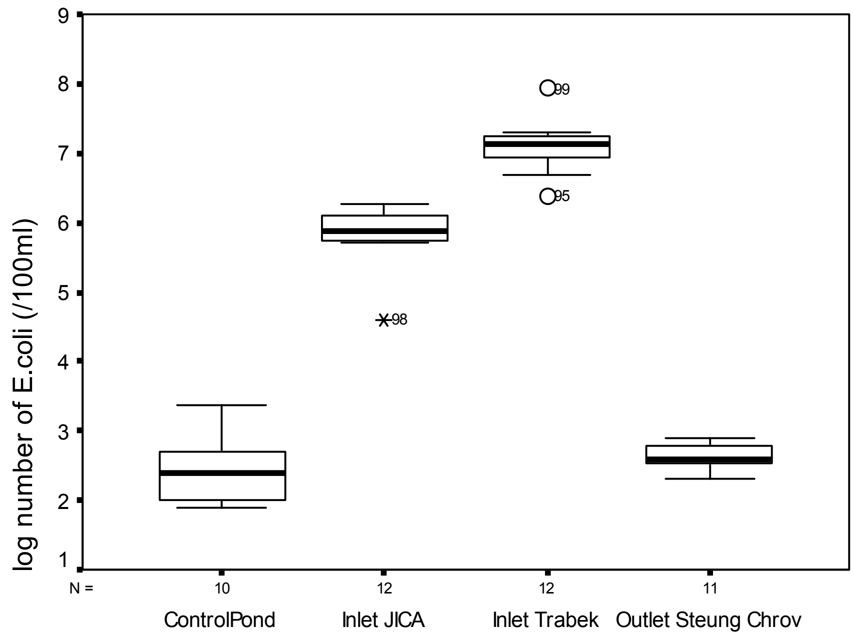

Figure 1.8 *E. coli* counts (logarithm transformed number) of water samples at inlets, outlet of the BCE Lake and at the control site

Table 1.2 shows that few water samples contained helminth eggs with positive samples containing between 20 to 400 eggs/L (data not shown). Wastewater samples at the inlets did not seem to contain higher helminth egg numbers compared with the outlets and the control sites. This indicates a sedimentation of any possible eggs in the wastewater transport canal system before the wastewater was discharged into the lake.

T**able 1.2.** Helminth egg counts of water samples

Sampling site	Helminth eggs		
	Hookworm	*Ascaris lumbricoides*	*Trichuris trichiura*
Control site (Prek Pneu Lake)	2 positive/12 samples	8 pos/12	0 pos/12
Inlet (JICA)	0 pos/12 samples	2 pos/12	0 pos/12
Inlet (Trabek pumping station)	1 pos/11 samples 1 sample: result missing	2 pos/11 samples 1 sample: result missing	0 pos/11 samples 1 sample: result missing
Outlet (Steung Chrov stream)	2 pos/12 samples	4 pos/12 samples	0 pos/12 samples

Figure 1.9 indicates that fewer samples containing TC counts of more than 100,000/100 ml are found at the outlet sampling site (BCE lake) compared with the inlet sampling sites. (Note. level 1: <1,000 CFU/100 ml; level 2: 1,000-100,000 CFU/100 ml; level 3: 100,000 - 1,000,000 CFU/100 ml; and level 4 > 1,000,000 CFU/100 ml).

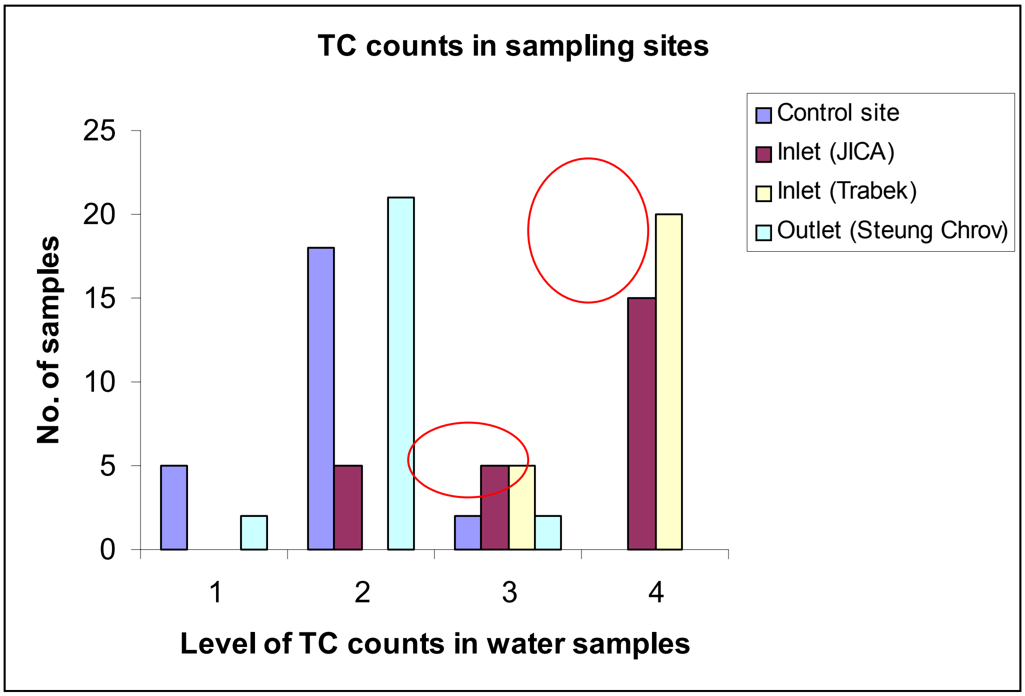

Figure 1.9 Level of TC counts in water samples in sampling sites

Figure 1.10 corroborates the findings of Figure 1.9 showing that no samples collected from the lake outlet contained more than 1000 *E.coli*/100ml (Note: level 1: <100; level 2: 101-1,000; level 3: 1,001 - 100,000; level 4: 100,000 - 1,000,000; level 5: >1,000,000)

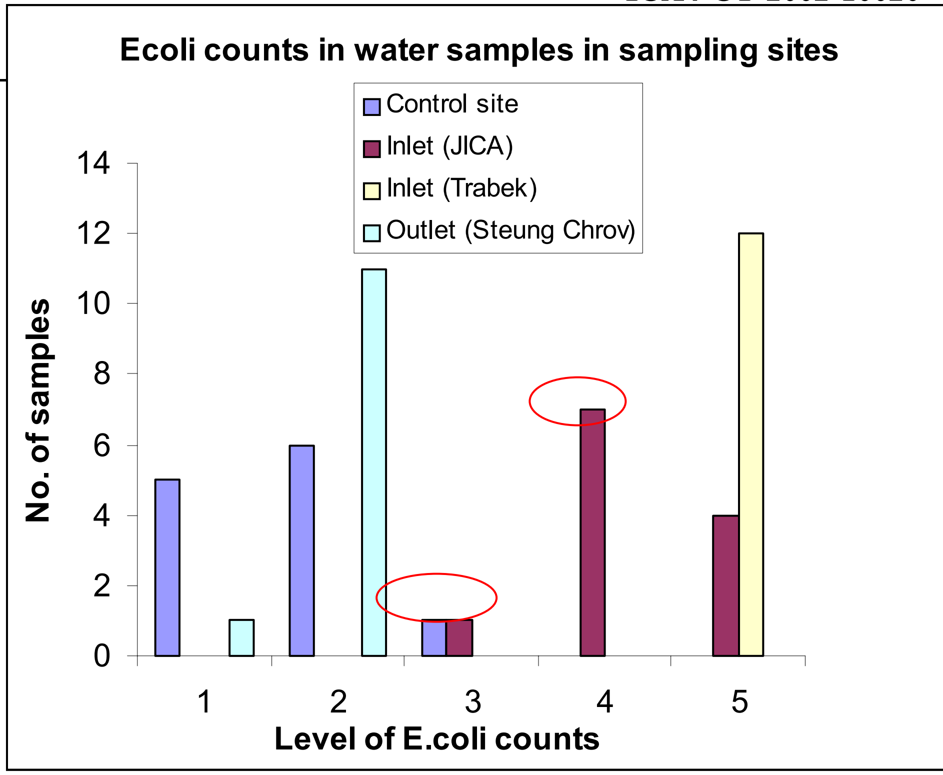

Figure 1.10 *E. coli* counts in 100ml-water samples collected in sampling sites

1.4 Conclusion

- Relative high TC numbers (10^3-10^6 CFU/100 ml) were found in the wastewater pumped into the six fields in Bang Be village. This indicates that wastewater with high faecal pollution levels were used for irrigation. Helminth eggs were not detected in any samples suggested sedimentation of eggs took place upstream.
- A reduction in numbers of thermotolerant coliforms was observed when quality of inlet, including supplying brick canal, and outlet water was compared. In general, thermotolerant numbers were reduced from around 10^4-10^6 CFU/100ml to around 10^3 -10^4 CFU/100 ml. However, some variation was seen.
- Water in storage containers used for splashing/refreshing vegetables at the local market in Hang Be village were faecal contaminated and did contain protozoan parasites indicating that refreshing vegetables with such waters constitute a food safety risk.
- The Boeng Cheung Ek Lake in Phnom Penh did significantly reduce faecal contamination levels typically with 2-3 log reductions in numbers of thermotolerant coliforms and *E. coli*. Outlet water from the lake typically contained less than 10^3 *E. coli* per 100 ml which is the acceptable level for recreational waters in Europe. Only few samples contained helminth eggs with no clear differences between inlet, outlet and control sites.

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2. WATER QUALITY FOR HANOI AND PHNOM PENH – TOXIC METALS

Authors:
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2.1 Introduction

Wastewater discharged into Boeng Cheung Ek Lake in Phnom Penh and used for irrigation of aquatic vegetables and as water source for fish cultivation in Thanh Tri district is of both domestic and industrial origin. The industries located in Hanoi and Phnom Penh include battery fabrics and repair, paint manufacture, zinc and metal products, pulp, leather and textile industries which are known to be pollution sources of toxic metals. In both cities there has been a concern that the use of wastewater in aquatic food production would result in accumulation of toxic metals in vegetables and fish produced. Further there is a risk that toxic metals may build up in sediment over time, making the systems unfit for food production in the future. The objective of this study was therefore to assess the concentrations of toxic metals in water, water spinach, fish and sediment. Only water and sediment results are presented in the present report. Toxic metal analyses of aquatic plants and fish will be presented in the report on food safety.

2.2 Methodology

2.2.1 Sampling sites

2.2.1.1 Hanoi

Three water spinach production sites and two fish ponds were chosen for investigation of toxic metal accumulation in Hanoi (Table 2.1). Samples from water spinach production systems were collected from 22nd to 28th September 2004 and samples from fish production sites were collected April 2005. Samples from fish ponds were collected at the wastewater inlet, the middle of the fish pond and at the outlet.

Table 2.1 Sampling sites in Hanoi

No.	District / Commune	Production	Wastewater exposure	River Water supply
1.1	Thanh Tri / Hoang Liet	Water spinach	High; flooded with about 25 cm wastewater once or twice a week	To Lich
1.2	Thanh Tri / Hoang Liet	Water spinach	High; flooded with about 25 cm wastewater once or twice a week	To Lich
1.3	Thanh Tri / Hoang Liet	Fish poly culture	Wastewater is pumped into the lake about two days every week	To Lich
2.1	Thanh Tri / Tran Phu	Water spinach	Low; mainly irrigated with rain water, wastewater which has passed through find ponds and only to low degree directly with wastewater	Kim Nguu
2.2	Thanh Tri / Tran Phu	Water spinach	Low; mainly irrigated with rain water, wastewater which has passed through find ponds and only to low degree directly with wastewater	Kim Nguu

2.3	Thanh Tri / Yen So	Fish poly culture	Wastewater is pumped into to the lake for 24 hours for 3 days every week	Kim Nguu
3.1	Dong Anh / Duc Tu	Water spinach	Non; irrigated with water from Red River	Red river

2.2.1.2 Phnom Penh

Water and sediment samples were collected at Trabek and Tumpun pumping stations and in the lake at a distance of 100, 200, 400, 600, 800, 1000m from the pumping stations. In the Boeung Tumpun inlet canal transporting drain and wastewater to the Tumpun pumping station samples were collected from the beginning of the canal towards the pumping station. Control samples from a system not exposed to wastewater were collected in Cheung Ek village. Water samples were collected from 26th Nov. to 4th Dec. 2004 and from 6th to 12th Feb. 2005. Sediment samples were collected from 6th to 12th Feb. 2005 (not all results are presented in this report).

2.3 Results and discussion

Screening carried out for the 39 elements aluminium (Al), silver (Ag), arsenic (As), Barium (Ba), beryllium (Be), cadmium (Cd), cerium (Ce), cobalt (Co), chromium (Cr), caesium (Cs), copper (Cu), dysprosium (Dy), europium (Eu), erbium (Er), iron (Fe), gadolinium (Gd), holmium (Ho), potassium (K), lanthanum (La), lithium (Li), lutetium (Lu), magnesium (Mg), manganese (Mn), neodymium (Nd), nickel (Ni), lead (Pb), praseodymium (Pr), tin (Sb), scandium (Sc), samarium (Sm), strontium (Sr), terbium (Tb), thorium (Th), thallium (Tl), thulium (Tm), uranium (U), Yttrium (Y), ytterbium (Yb) and zinc (Zn) in sediment and water spinach samples showed that samples generally had low concentrations of the analyzed elements and there seemed to be no major risk to food safety. However arsenic, cadmium and lead are toxic at low concentrations therefore a more detailed study was carried out for these elements.

2.3.1 Water samples

Concentrations of As, Cd and Pb in all water samples were below the detection limit of 0.09, 0.02 and 0.2 µg/L, respectively. The fact that these metals could not be detected in the water samples does not necessarily indicate that metals are not transported to the production systems with the wastewater. pH in all water samples were between 6 and 8. Thus, at such pH values the availability of toxic metal is very limited as metals will be absorbed to the surface suspended particulate matter or sediment. Water samples were filtrated before acidification and analyses which means that only dissolved metals were determined. So only metals absorbed to the particulate matter will be transported to the production system.

2.3.2 Sediment samples

2.3.2.1 Hanoi

Water spinach production

Concentrations of arsenic, cadmium and lead are presented in Table 2.2. All sediment samples had cadmium concentrations below the Vietnamese limit values for agricultural soils of 2 mg/kg d.w. Pb concentrations were below the Vietnamese limit value of 70 mg/kg d.w. but samples no. 2.1 and especially no. 3.1 had soil concentrations close to the limit value. Only sample 3.1 did not have As concentrations above the Vietnamese limit value of 12 mg/kg d.w. High concentrations of Pb and As was observed, however concentrations were not elevated in the exposed samples 1.1 to 2.2 compared to the non-exposed sample 3.1 and no clear indication of pollution with toxic metals as result of wastewater use can be found.

Table 2.2 Mean and standard deviation (SD) (n=4) for elemental concentration (μg/g dry weight) in sediment samples from water spinach production sites in Hanoi.

Site		1.1	1.2	2.1	2.2	3.1
As**	Mean ± SD	12.6 ± 0.8^{c}	15.4 ± 3.3^{ab}	16.3 ± 0.8^{bc}	9.11 ± 0.75^{c}	18.7 ± 4.6^{a}
Cd^{ns}	Mean ± SD	0.433 ± 0.206	0.333 ± 0.009	0.667 ± 0.129	0.485 ± 0.083	0.418 ± 0.128
Pb**	Mean ± SD	37.0 ± 1.8^{c}	34.4 ± 2.0^{bc}	59.9 ± 6.65^{ab}	32.5 ± 3.3^{bc}	67.4 ± 11.5^{a}

^{ns} non-significant; *, **, *** significant at 95, 99 and 99.9 % confidence level, respectively.
There is no significant difference between mean concentrations followed the same letter.

Fish production

Concentrations of arsenic, cadmium and lead in fish ponds in Hanoi are presented in Table 2.3. In the fish pond in Yen So As, Cd and Pb concentrations decreased significantly from the inlet to the middle and from the middle to the outlet indicating that the pond is gradually polluted with all three elements. The pond in Hoang Liet has lower concentrations of all three elements and the concentrations are at the same level at all three points indicating that no major pollution with arsenic, cadmium and lead is taking place.

Table 2.3 Mean and standard deviation (SD) (n=4) for elemental concentration (μg/g dry weight) in sediment samples from fish ponds in Hanoi.

Site	Yen So -1.3			Hoang Liet - 2.3		
	Inlet	Middle	Outlet	Inlet	Middle	Outlet
As	22.8 ± 2.2^{a}	15.0 ± 1.9^{b}	10.3 ± 3.1^{c}	19.0 ± 2.6^{a}	17.9 ± 1.9^{a}	16.8 ± 3.1^{a}
Cd	1.25 ± 0.33	0.41 ± 0.21	<0.40	<0.40	<0.40	<0.40
Pb	55.3 ± 3.7^{a}	34.2 ± 7.6^{b}	25.7 ± 4.5^{c}	35.9 ± 4.2^{a}	37.4 ± 6.1^{a}	34.3 ± 2.1^{a}

There is no significant difference between mean concentrations followed the same letter.

2.3.2.2 Phnom Penh

Concentrations of arsenic, cadmium and lead are presented in Table 2.4. Arsenic concentrations are relatively high but evenly distributed in the lake indicating a natural high occurrence of arsenic. Cadmium concentrations were below the detection limit for most samples, however slight pollution is indicated since low concentration are measured at Trabek pumping station and in the first part of the Tumpun inlet canal. The Tumpun inlet canal and Boeng Cheung Ek Lake near the pumping stations have been polluted with lead, but concentrations are not highly elevated and in the lake only the site the Trabek pumping station should not be used for production according to the Vietnamese limit value for agricultural soils.

Table 2.4 Mean elemental concentration (µg/g dry weight) in sediment samples from Phnom Penh.

Site	As	Cd	Pb
Sediment collected in Tumpun inlet canal			
1.4 km from pumping station	13	0.53	120
1.0 km from pumping station	12	0.62	111
0.6 km from pumping station	10	<0.40	50
0.1 km from pumping station	9	<0.40	46
Sediment collected in Boeng Cheung Ek Lake			
Tumpun pumping station	10	<0.40	49
200 m from Tumpun pumping station	10	<0.40	45
400 m from Tumpun pumping station	8	<0.40	38
Trabek pumping station	13	0.83	99
200 m from Trabek pumping station	13	<0.40	42
400 m from Trabek pumping station	8	<0.40	44
Lake outlet	14	<0.40	30
Cheung Ek village – control	<0.81	<0.40	18

2.4 Conclusion

- Toxic metal concentrations in water and sediment were low and suggest that limited food safety risks with regards to toxic metals are associated with production and consumption of wastewater irrigated products.
- Concentrations of arsenic are at a natural high level in the production systems investigated
- Some pollution with cadmium and lead occurs however the production systems are still not polluted to a degree which makes them unsuitable for production.

3. PAPUSSA UAF PARTNER

WATER QUALITY ANALYSIS REPORT

3.1 Introduction

Since water quality is a very important factor for aquaculture systems, it is always paid the most attention. Water quality and treatment capacity of aquaculture systems in and around city, where wastewater is used as the main water supply, often receive more concerns. This is understandable because aquaculture systems can be good medium for water treatment if wastewater and other inputs are managed appropriately. Otherwise, wastewater could become the constraint for aquaculture systems or aquaculture systems could conversely cause more impacts to the natural environment.

In peri-urban areas of Ho Chi Minh city (HCMC), wastewater was previously used as the main and effective nutrient source for many aquaculture systems. However, as the city expands and its population grows, wastewater has become more polluted. As a result, aquaculture farmers have had to find ways to avoid negative impacts of wastewater to their systems. Limiting the supply of wastewater to the aquaculture pond is the most common method, by which farmers only exchange pond water at high tide period when wastewater is least dense. With the current practice, wastewater is no longer the main source of input and thus farmers often supply nutrients to their system through feeding and fertilization. Hence, aquaculture systems are not currently the effective medium for water treatment. Moreover, with the supply of nutrient inputs, aquaculture may become an additional source of pollution to the water bodies around the city.

Though the clear impacts of technical changes in wastewater aquaculture systems have not been studied, it is a potential risk for the environment as treatment capacity of these systems are more and more limited. Therefore, in order to create a clear understanding of treatment capacity of wastewater, a study on nutrient fluxes of some wastewater-fed aquaculture systems surrounding HCMC was conducted by PAPUSSA project with the following objectives to:

- Analyze the nutrient fluxes of studied aquaculture systems
- Evaluate the actual treatment capacity of the systems with the current farmers’ practice
- Announce of the potential impacts if any

3.2 Methodology

Three wastewater-fed aquatic production systems were selected for the current investigation, including tilapia seed production in wastewater, morning glory in wastewater, and water mimosa in wastewater, which were previously involved in PAPUSSA studies. After careful analysis of farmers’ water exchange methods, the water sampling protocol was produced as depicted in Table 3.1. The actual dates of water sampling for different systems are indicated in Table 3.2

Three ponds of each production system were chosen to take water samples. From each pond, three water samples were also collected separately for analysis as three replicates. Five water sampling times were defined on a weekly basis with the whole period of one month production cycle. Out of the 5 sampling times, the 1st, 3rd and 5th points are the core sampling times as these are the water exchange periods. These are always the high tide periods, often at the middle and the end of the moon cycle. The 2nd and the 4th sampling points are just for monitoring the water quality between any two main sampling times.

Table 3.1 Water sampling protocol

Category	**Sampling times**				
	1st	**2nd**	**3rd**	**4th**	**5th**
Time definition	When farmers exchange water from their systems. High tide period.	One week after the 1st sampling	Two weeks after the 1st sampling. The following water exchange	One week after the 3rd sampling, three weeks from the 1st sampling	The last water exchange during sampling period. Four weeks from the 1st sampling. Final sampling point.
Water samples	- Pond water: three samples from each pond. Pond water samples both before and after water exchange. -Samples of inlet water	-Only samples from pond water, three samples from each pond	- Pond water: three samples from each pond. Pond water samples both before and after water exchange. -Samples of inlet water	-Only samples from pond water, three samples from each pond	- Pond water: three samples from each pond. Pond water samples both before and after water exchange. -Samples of inlet water
Other parameters	- Volume of water discharge and supply	Any irregular water discharge during the period	- Volume of water discharge and supply	Any irregular water discharge during the period	- Volume of water discharge and supply
Overall parameters	- Volume of water from sampled ponds (area and water depth)				

Total nitrogen and phosphate concentration of water samples were used to calculate the treatment capacity of the studied systems.

Table 3.2 The actual dates of water sampling for different systems

Systems	Sampling times				
	1st	2nd	3rd	4th	5th
Tilapia seed	24 February	3 March	10 March	17 March	24 March
Morning glory	27 February	6 March	13 March	20 March	27 March
Water mimosa	28 February	7 March	14 March	21 March	28 March

3.3 Results

3.3.1 The change of nitrogen and phosphate concentrations of pond water during a month

3.3.1.1 Water mimosa

Variation of nutrient concentrations in pond water could be a good indication of nutrient flows in the system. With weekly sampling schedule and 14 days duration for each water exchange cycle, three points of water sampling were done for each water exchange cycle. Tables 3.3 and 3.4 describe the change in nitrogen and phosphate concentrations of water mimosa pond water samples.

Table 3.3 Nitrogen concentration (mg/L) of water samples in water mimosa ponds over two water exchange cycles

Value of	First water exchange cycle			Second water exchange cycle		
	1st week	2nd week	3rd week	3rd week	4th week	5th week
WM 1	8.630	2.320	8.610	7.883	8.910	6.170
WM 2	7.243	2.237	4.440	7.473	5.777	3.690
WM 3	10.380	2.143	3.490	6.390	4.747	4.210
Average	8.571	2.233	5.513	7.249	6.478	4.690

A series of abnormal figures were gained from 2nd week samples which made these figures unusable leading to the wastage of whole data set for the first water exchange cycle. In the second cycle, nitrogen concentration of pond water tent to decrease over time within the cycle. In fact, the average concentrations of water samples decreased from 7.249 mg/L in the third week to 6.478 mg/L in the fourth and then down to 4.690 mg/L in the last week of the water exchange cycle. This indicates that nutrient has been taken away from the water intake. A completely similiar trend can seen with phosphate concentration in pond water, which dropped to 2.241 mg/L in the fourth week from 2.508 mg/L in the 3rd week and then down to 1.623 mg/L in the last week of water exchange cycle. This trend allows raising a hypothesis that water mimosa still remains a means of water treatment.

Table 3.4 Phosphate concentration (mg/L) of water samples in water mimosa ponds over two water exchange cycles

Value of	First water exchange cycle			Second water exchange cycle		
	1st week	2nd week	3rd week	3rd week	4th week	5th week
WM 1	2.986	0.803	2.979	2.728	3.083	2.135
WM 2	2.506	0.774	1.536	2.586	1.999	1.277
WM 3	3.591	0.742	1.208	2.211	1.642	1.457
Average	3.028	0.773	1.098	2.508	2.241	1.623

3.3.1.2 Morning glory

Nutrient concentration in the study morning glory pond during the first water exchange cycle was increased (Tables 3.5 and 3.6). This could be due to the evaporation lost of pond water which is normal in dry season. In the second exchange cycle, nitrogen and phosphate concentration of pond water varied without any rule and it seemed to be affected by the fertilization practice of farmers.

Table 3.5 Nitrogen concentration of water samples in morning glory ponds over two water exchange cycles

Value of	Nitrogen concentration (mg/L)					
	First water exchange cycle			Second water exchange cycle		
	1st week	2nd week	3rd week	3rd week	4th week	5th week
MG 1	3.130	4.347	7.417	5.020	3.030	4.677
MG 2	2.347	2.900	6.563	4.273	2.293	4.787
MG 3	2.913	2.683	7.407	4.577	3.053	4.080
Average	2.797	3.310	7.129	4.623	2.792	4.514

Table 3.6 Phosphate concentration of water samples in morning glory ponds over two water exchange cycles

Value of	Phosphate concentration (mg/L)					
	First water exchange cycle			Second water exchange cycle		
	1st week	2nd week	3rd week	3rd week	4th week	5th week
MG 1	1.083	1.504	2.566	1.737	1.048	1.618
MG 2	0.812	1.140	2.400	1.633	0.793	1.656
MG 3	1.008	1.031	2.214	1.579	1.056	1.412
Average	0.968	1.225	2.393	1.650	0.966	1.562

3.3.1.3 Fish seed production

Although water samples were collected, nutrient analysis for fish seed production system was almost impossible to be conducted as water exchange in this system is uncontrollable. Despite the fact the farmer tried himself to schedule the water exchange, water flows in and out the system nearly freely by daily tides. Therefore, the following Tables 4.7 and 4.8 are just to provide ideas of how nutrient concentrations vary during a breeding cycle as the data is not interpreted.

Table 3.7 Nitrogen concentration of water samples in fish seed production ponds over two water exchange cycles

Value of	Nitrogen concentration (mg/L)					
	First water exchange cycle			Second water exchange cycle		
	1st week	2nd week	3rd week	3rd week	4th week	5th week
FS 1	4.41	6.83	5.52	Missing	3.59	3.73
FS 2	2.36	5.68	4.31	Missing	4.61	4.10
FS 3	4.10	5.22	4.24	Missing	4.78	4.65
Average	3.62	5.91	4.69	Missing	4.33	4.16

Table 3.8 Phosphate concentration of water samples in fish seed production ponds over two water exchange cycles

Value of	Phosphate concentration (mg/L)					
	First water exchange cycle			Second water exchange cycle		
	1st week	2nd week	3rd week	3rd week	4th week	5th week
FS 1	1.53	2.36	1.91	Missing	1.24	1.29
FS 2	0.82	1.97	1.49	Missing	1.60	1.42
FS 3	1.42	1.80	1.47	Missing	1.66	1.61
Average	1.25	2.05	1.62	Missing	1.50	1.44

3.3.2 Nutrient fluxes of the studied systems

3.3.2.1 Water mimosa

According to Tables 3.9 and 3.10, nutrients (nitrogen and phosphate) concentrations of pond water are always higher after water exchange in comparison to that before water exchange. This indicates that the systems are taking up nutrients from the water source and utilize it as a means of water treatment. Indeed, from 8.751 mg/L after 1st exchange, nitrogen concentration of pond water dropped down to 5.513 mg/L before the next water exchange. Completely the same trend can be easily seen at the second and third water exchange, 7.249 mg N /L down to 4.690 mg N /L before next water exchange. Phosphate is also taken from the system in similar trend. This illustrated that water mimosa cultivation system has removed significant amount of nitrogen and phosphate supplied from inlet water.

Table 3.9 Nitrogen concentration of pond water samples before and after water exchanges

Value of	Nitrogen concentration (mg/L)					
	1st water exchange		2nd water exchange		3rd water exchange	
	Before	After	Before	After	Before	After
WM 1	8.363	8.630	8.610	7.883	6.170	6.907
WM 2	5.327	7.243	4.440	7.473	3.690	5.670
WM 3	6.690	10.380	3.490	6.390	4.210	4.223
Average	6.793	8.751	5.513	7.249	4.690	5.600

Table 3.10 Phosphate concentration of pond water samples before and after water exchanges

Value of	Phosphate concentration (mg/L)					
	1st water exchange		2nd water exchange		3rd water exchange	
	Before	After	Before	After	Before	After
WM 1	2.894	2.986	2.979	2.728	2.135	2.390
WM 2	1.843	2.506	1.536	2.586	1.277	1.962
WM 3	2.315	3.591	1.208	2.211	1.457	1.461
Average	2.350	3.028	1.908	2.508	1.623	1.938

The treatment capacity is studied quite simply in this study. By monitoring the nitrogen and phosphate concentration of water samples, volume water exchange and the total volume of the sampled ponds, the treatment capacity is evaluated as the ability of the systems in removing these nutrients. However, the details of nutrient budget of the systems are not analyzed. Therefore, how much nutrient taken up to the products and how much nutrient accumulated in the sediments are unknown.

The parameter used to assess treatment capacity of aquatic production pond is the amount of nutrient (nitrogen and phosphate) inflow and outflow during water exchange. Based on these figures, whether or not a system uptook or discharged nutrient could be determined.

According to Table 3.11, in the first water exchange, the amount of nitrogen discharged to the environment is 12.19kg/ha while the nitrogen supplied to the system is only 9.88 kg/ha. The same trend is observed for phosphate as phosphate outflow is 4.22 kg/ha while the inflow is only 3.42 kg/ha. The data imply that water mimosa system is discharging nutrient into the environment rather than treating nutrient rich water supply as it is previously assumed. However, in the second and third water exchanges, the converse trend occurs. In the second water exchange, only 5.51kg nitrogen was drained to the environment from every 1 hectare of water mimosa system while the nitrogen inflow of the system was 15.32 kg/ha. In the third water exchange, only 5.72 kg nitrogen/ha outflowed from the system whilst 14.41 kg N/ha inflowed to the pond. A similar trend is applied for the amount of phosphate inflow and outflow. With this pattern, it is quite clear that nutrient is removed from water by the water mimosa system.

Table 3.11 Treatment capacity of the water mimosa system

Pond	Amount of nutrient (mg/ha)			
	Nitrogen out	**Nitrogen in**	**Phosphate out**	**Phosphate in**
1st water exchange				
WM 1	12,545,000	8,085,000	4,340,570	2,797,410
WM 2	10,653,333	10,780,000	3,686,053	3,729,880
WM 3	13,380,000	10,780,000	4,629,480	3,729,880
Average	**12,192,778**	**9,881,667**	**4,218,701**	**3,419,057**
Kg	**12.19**	**9.88**	**4.22**	**3.42**
2nd water exchange				
WM 1	8,610,000	15,320,000	2,979,060	5,300,720
WM 2	4,440,000	15,320,000	1,536,240	5,300,720
WM 3	3,490,000	15,320,000	1,207,540	5,300,720
Average	**5,513,333**	**15,320,000**	**1,907,613**	**5,300,720**
Kg	**5.51**	**15.32**	**1.91**	**5.30**
3rd water exchange				
WM 1	9,255,000	16,625,000	3,202,230	6,250,000
WM 2	3,690,000	13,300,000	1,276,740	5,000,000
WM 3	4,210,000	13,300,000	1,456,660	5,000,000
Average	**5,718,333**	**14,408,333**	**1,978,543**	**5,416,667**
	Amount of nutrient (kg/ha)			
Average	**5.72**	**14.41**	**1.98**	**5.42**

Indeed, between the first and the second water exchange, 3.37 kg N and 1.51 kg P was removed from 1 hectare of water mimosa system. Similarly, 9.6 kg N/ha and 3.32 kg P/ha were taken by the system between the second and the third water exchanges. This can be considered as treatment capacity of water mimosa system in each water exchange cycle of 15 days.

Regarding the negative sign in the first water exchange, the reason may be that the first water exchange was the fully drained time of the system. Therefore all of the nutrient in the pond was removed and new water was supplied.

3.3.2.2 Morning glory

Since the pond fully drained at the 2nd water exchange, nutrient concentration of pond water after water exchange was lower than that before the exchange (Table 3.12). However, in the third water supply, the differences between nutrient concentrations after and before water supply were observed the same as that in water mimosa. This trend showed that morning glory is still playing the same roll of water treatment as water mimosa system. The same outcomes of nutrient variations can be applied for phosphate concentration of morning glory ponds (Table 3.13).

Table 3.12 Nitrogen concentration of pond water samples before and after water exchanges

Value of	Nitrogen concentration (mg/L)					
	1st water exchange		2nd water exchange		3rd water exchange	
	Before	After	Before	After	Before	After
MG 1	-	-	7.417	5.020	4.677	5.720
MG 2	-	-	6.563	4.273	4.787	5.893
MG 3	-	-	7.407	4.577	4.080	5.580
Average			7.129	4.623	4.514	5.731

Table 3.13 Phosphate concentration of pond water samples before and after water exchanges

Value of	Phosphate concentration (mg/L)					
	1st water exchange		2nd water exchange		3rd water exchange	
	Before	After	Before	After	Before	After
MG 1	-	-	2.566	1.737	1.618	1.979
MG 2	-	-	2.400	1.633	1.656	2.039
MG 3	-	-	2.214	1.579	1.412	1.931
Average			2.393	1.650	1.562	1.983

Similar to the analysis of nutrient budget was applied for morning glory system. Although water supply seems to dissolve pond water in the 2nd water exchange, the same trend of nutrient removal was seen in morning glory system. As water was lost through evaporation, volume of water inflow is more than water outflow to compensate the lost.

Table 3.14 Treatment capacity of morning glory system

Pond	Amount of nutrient (mg/ha)			
	Nitrogen out	Nitrogen in	Phosphate out	Phosphate in
2nd water exchange				
MG 1	22,250,000	20,400,000	7,698,500	7,058,400
MG 2	24,612,500	25,500,000	8,998,883	8,823,000
MG 3	27,775,000	25,500,000	8,301,117	8,823,000
Average	**24,879,167**	**23,800,000**	**8,332,833**	**8,234,800**
Kg	**24.88**	**23.80**	**8.33**	**8.23**
3rd water exchange				
MG 1	4,676,667	10,720,000	1,618,127	3,709,120
MG 2	5,983,333	13,400,000	2,070,233	4,636,400
MG 3	5,100,000	13,400,000	1,764,600	4,636,400
Average	**5,253,333**	**12,506,667**	**1,817,653**	**4,327,307**
	Amount of nutrient in kg/ha			
Average	**5.25**	**12.51**	**1.82**	**4.33**

According to Table 3.14, during 2 weeks (one water exchange cycle), 18.55 kg N and 6.41 kg P were removed from 1 hectare of morning glory cultivation. Amount of nutrients inflowing into the system is always higher than that outflowing from it. Therefore, the system still remains a means of biological water treatment. From these figures, if one has the data on larger total areas of morning glory (assuming similar management practices), it is quite possible to calculate the amount of nutrient that could be removed and thus the environmental significance could be estimated.

Results from the nutrient budget analysis have convincingly proved that water mimosa and morning glory cultivation systems are still playing n roles in biological wastewater treatment in and surrounding Ho Chi Minh City.

3.4 Conclusions

- Water analysis for fish seed production system was unable to be conducted due to the complexity of water exchange nature.
- Nitrogen and phosphate concentrations of pond water in the water mimosa system tend to decrease over time within one water exchange cycle
- Nutrient concentrations of morning glory varied without any rule due to farmers' fertilization practices.
- With the current water exchange practice of farmers, morning glory and water mimosa cultivation systems are still playing important role in water treatment as a biological treatment means
- Morning glory appears to have higher treatment capacity than water mimosa system as we calculated one hectare could remove 18.55 kg Nitrogen and 6.41 kg phosphate while one hectare water mimosa could remove only 9.6 kg nitrogen and 3.32 kg phosphate from the system.
- It is highly recommended that water mimosa and morning glory cultivation systems should be encouraged as a means of environmental protection since a complete wastewater treatment system has not been established in Ho Chi Minh City.

3.5 APPENDIXES

Data and calculations for morning glory system

	1st sampling series (mg/L)				**2nd sampling**		**3rd sampling**				**4th sampling**		**5th sampling**			
	efore water exchan		**fter water exchang**				**Before water exchange**		**After water exchange**				**Before water exchang**		**After water exchange**	
Inlet	∑N	∑P	∑N	∑P	∑N	∑P	∑N	∑P	∑N	∑P	∑N	∑P	∑N	∑P	∑N	∑P
water			4.5	1.56					6.8	2.35					5.36	1.85
1	Data missing		3.130	1.083	4.347	1.504	7.417	2.566	5.020	1.737	3.030	1.048	4.677	1.618	5.720	1.979
2			2.347	0.812	2.900	1.140	6.563	2.400	4.273	1.633	2.293	0.793	4.787	1.656	5.893	2.039
3			2.913	1.008	2.683	1.031	7.407	2.214	4.577	1.579	3.053	1.056	4.080	1.412	5.580	1.931
			2.797	0.968	3.310	1.225	7.129	2.393	4.623	1.650	2.792	0.966	4.514	1.562	5.731	1.983
						Pond	V discharge		V intake			Pond	V discharge		V intake	
							300	300	300	300			100	100	200	200
							300	300	300	300			100	100	200	200
							300	300	300	300			100	100	200	200
						mg	N out	P out	N in	P in		mg	N out	P out	N in	P in
						1	2,225,000	769,850	2,040,000	705,840		1	467,667	161,813	1,072,000	370,912
						2	1,969,000	719,911	2,040,000	705,840		2	478,667	165,619	1,072,000	370,912
						3	2,222,000	664,089	2,040,000	705,840		3	408,000	141,168	1,072,000	370,912
							S ao						S ao			
							1,000	1,000	1,000	1,000			1,000	1,000	1,000	1,000
							800	800	800	800			800	800	800	800
							800	800	800	800			800	800	800	800
						mg	N out per ha	P out per h	N in per ha	P out per ha		mg	N out per ha	P out per h	N in per ha	P out per ha
							22,250,000	7,698,500	20,400,000	7,058,400			4,676,667	1,618,127	10,720,000	3,709,120
							24,612,500	8,998,883	25,500,000	8,823,000			5,983,333	2,070,233	13,400,000	4,636,400
							27,775,000	8,301,117	25,500,000	8,823,000			5,100,000	1,764,600	13,400,000	4,636,400
						Aveara	24,879,167	8,332,833	23,800,000	8,234,800		**Aveara**	5,253,333	1,817,653	12,506,667	4,327,307
						Kg	24.88	8.33	23.80	8.23		**Kg**	5.25	1.82	12.51	4.33

Data and calculations for water mimosa system

	1st sampling series (mg/L)				2nd sampling		3rd sampling				4th sampling		5th sampling			
	Before exchange		After exchange				Before exchange		After exchange				Before exchange		After exchange	
	∑ N	∑ P	∑ N	∑ P	∑ N	∑ P	∑ N	∑ P	∑ N	∑ P	∑ N	∑ P	∑ N	∑ P	∑ N	∑ P
0			**5.39**	**1.86**					**7.66**	**2.65**					**6.65**	**2.50**
1	8.363	2.894	8.630	2.986	2.320	0.803	8.610	2.979	7.883	2.728	8.910	3.083	6.170	2.135	6.907	2.390
2	5.327	1.843	7.243	2.506	2.237	0.774	4.440	1.536	7.473	2.586	5.777	1.999	3.690	1.277	5.670	1.962
3	6.690	2.315	10.380	3.591	2.143	0.742	3.490	1.208	6.390	2.211	4.747	1.642	4.210	1.457	4.223	1.461
	6.793	2.350	8.751	3.028	2.233	0.773	5.513	1.908	7.249	2.508	6.478	2.241	4.690	1.623	5.600	1.938
Ao	V discharge		V intake			Ao	V discharge		V intake			Pond	V discharge		V intake	
	60	60	60	60			40	40	80	80			60	60	100	100
	200	200	200	200			100	100	200	200			100	100	200	200
	160	160	160	160			80	80	160	160			80	80	160	160
mg	N out	P out	N in	P in		mg	N out	P out	N in	P in		mg	N out	P out	N in	P in
1	501,800	173,623	323,400	111,896		1	344,400	119,162	612,800	212,029		1	370,200	128,089	665,000	250,000
2	1,065,333	368,605	1,078,000	372,988		2	444,000	153,624	1,532,000	530,072		2	369,000	127,674	1,330,000	500,000
3	1,070,400	370,358	862,400	298,390		3	279,200	96,603	1,225,600	424,058		3	336,800	116,533	1,064,000	400,000
	S ao						S ao						S ao			
	400	400	400	400			400	400	400	400			400	400	400	400
	1,000	1,000	1,000	1,000			1,000	1,000	1,000	1,000			1,000	1,000	1,000	1,000
	800	800	800	800			800	800	800	800			800	800	800	800
mg	N out per ha	P out per h	N in per ha	P out per ha		mg	N out per h	P out per h	N in per ha	P out per ha		mg	N out per ha	P out per h	N in per ha	P out per ha
	12,545,000	4,340,570	8,085,000	2,797,410			8,610,000	2,979,060	15,320,000	5,300,720			9,255,000	3,202,230	16,625,000	6,250,000
	10,653,333	3,686,053	10,780,000	3,729,880			4,440,000	1,536,240	15,320,000	5,300,720			3,690,000	1,276,740	13,300,000	5,000,000
	13,380,000	4,629,480	10,780,000	3,729,880			3,490,000	1,207,540	15,320,000	5,300,720			4,210,000	1,456,660	13,300,000	5,000,000
Avearage	12,192,778	4,218,701	9,881,667	3,419,057		**Avearage**	5,513,333	1,907,613	15,320,000	5,300,720		**Avearag**	5,718,333	1,978,543	14,408,333	5,416,667
Kg	12.19	4.22	9.88	3.42		**Kg**	5.51	1.91	15.32	5.30		**Kg**	5.72	1.98	14.41	5.42

Data for fish seed production system

	1st sampling				2nd sampling		3rd sampling				4th sampling		5th sampling			
	Before exchange		After exchange				Before exchange		After exchange				Before exchange		After exchange	
Ao	∑N	∑P	∑N	∑P	∑N	∑P	∑N	∑P	∑N	∑P	∑N	∑P	∑N	∑P	∑N	∑P
0	3.450	1.194														
1	1036.000	358.456	2822.400	976.550	3826.667	1324.027	3089.333	1068.909	0.000	0.000	2008.533	694.953	2088.800	722.725	0.000	0.000
2	1803.200	623.907	1510.400	522.598	3182.667	1101.203	2411.733	834.460	0.000	0.000	2581.600	893.234	4.100	1.419	0.000	0.000
3	2129.867	736.934	2624.000	907.904	2921.333	1010.781	2374.400	821.542	0.000	0.000	2678.667	926.819	2604.000	900.984	0.000	0.000

4. WATER QUALITY MONITORING AT PERI-URBAN AQUATIC FOOD PRODUCTION SYSTEMS SURROUNDING BANGKOK OF THE THREE COMMUNITIES: LUMSAI, SUANPRIXTHAI AND NONGPRAONGAI VILLAGES

4.1 Introduction

Aquatic food production including fish and aquatic vegetables have been taking place intensively around Bangkok's peri-urban areas as a result of the rapid growth and development of the city during the last decades. In the northern part of Bangkok in particular, hybrid catfish farms produce more than 70 percent of the country's total production (around 80,000 tons). Meanwhile, water mimosa is farmed in public canals in Pathumtani province and morning glory is produced intensively in vast areas in Nontaburi province, 40 kilometres west of Bangkok. However, recent changes in water and land uses in peri-urban areas to accommodate rapid expansions of housing projects and industrial factories have seriously impacted on aquatic production systems, especially on the deterioration of the aquatic environment. On the other hand, the aquatic food production systems have also degraded water quality of public waterways in peri-urban areas resulting from discharging pond effluents which contain high concentrations of solids, organic matters, nutrients and pesticides.

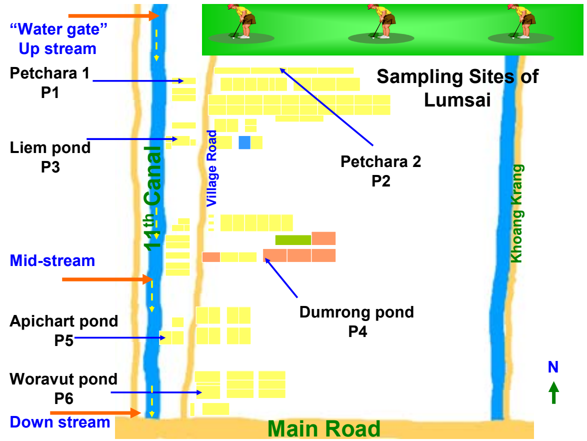
Therefore, the objective of this study was to monitor the state of water quality in terms of physical, chemical and biological parameters from selected peri-urban aquatic production systems and surrounding canals. The study areas include three PAPUSSA project communities - Lumsai, Suanprixthai and Nongpraongai villages. .

For the nutrient budget study, we selected large-scale and small-scale catfish farms at Lumsai area during dry and raining grow-out cycles. Nutrient contents (nitrogen and phosphorus) were analyzed in input water during stocking time and wastewater drained from the ponds during fish harvests.

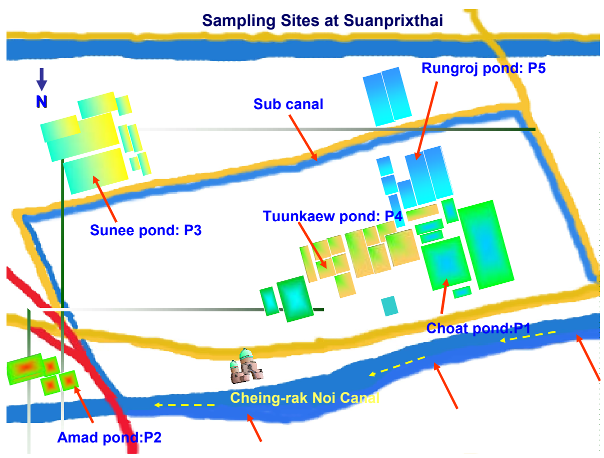
4.2 Methodology

Water quality in physical, chemical and biological parameters was monitored for peri-urban aquatic food production systems in three project communities in October, 2004. All water quality parameters were measured both in a natural water canal and representative culture ponds/plots. The farm layout and water sampling locations in three communities are shown in Figures 4.1A, 4.1B and 4.1C. Water samples for water quality analysis were taken from up, mid and down stream of each canal along selected farms in each community. The ponds studied included six practicing catfish culture, five mixed fish culture and five morning glory plots. These ponds were randomly selected in Lumsai, Suanprixthai and Nongproangai villages. The DO, temperature and pH were measured in situ twice daily in the morning (06.00-07.00 hours) and afternoon (16.00-17.00 hours) (Table 4.1). Water samples for other parameters were generally collected at 9 a.m. with an integrated column sampler at the inlet and outlet of each fish pond/aquatic vegetable plot. All water samples were kept in plastic bottles in chest coolers containing ice during transportation to the laboratory for analysis. All parameters and analytical methods were also presented in Table 4.1. The information on farming activities were also collected by interviewing the farm owners.

A



B



C

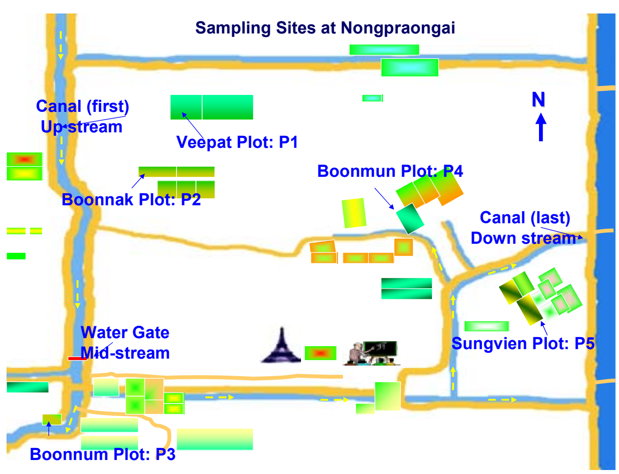


Figure 4.1 Map showing locations of water sample collection for water quality measurement in A: Lumsai village, Lumlukka district, Pathumtani province,

B: Suanprixthai village, Muang district, Pathumtani and C: Nongpraongai village, Sai-noi district, Nontaburi province.

Table 4.1 Methods, date and parameters for water quality analysis

Parameters	Equipments and analytical methods	Time of water samples collection and *in situ* measurement
DO* (mg/L)	YSI model 95	06.00-07.00 hrs and 15.00-16.00 hrs
PH*	YSI model 63	06.00-07.00 hrs and 15.00-16.00 hrs
Temperature* (^oC)	YSI model 63	06.00-07.00 hrs and 15.00-16.00 hrs
Conductivity* (µs/cm)	YSI model 63	06.00-07.00 hrs and 15.00-16.00 hrs
Total hardness ($mgCaCO_3/L$)	Titration with EDTA solution using Eriochrome Black-T indicator (APHA, 1989)	09.00 hrs
Total alkalinity ($mgCaCO_3/L$)	Titration with 0.02 N sulphuric acid using methyl orange indicator (APHA, 1989)	09.00 hrs
Total ammonia-N (mg/L)	Phenate method with spectrophotometer (APHA, 1989)	09.00 hrs
Nitrite-nitrogen (mg/L)	Diazotization with spectrophotometer (APHA, 1989)	09.00 hrs
Nitrate-nitrogen (mg/L)	Cadmium Reduction with spectrophotometer (APHA, 1989)	09.00 hrs
Transparency* (cm.)	Secchi-disc	14.00 hrs
Turbidity* (NTU)	2100 P Turbidity meter (HACH)	09.00 hrs
Total phosphorus (mg/L)	Ascorbic acid method (Persulfate digestion) (APHA, 1989)	09.00 hrs
Soluble reactive phosphorus (mg/L)	Ascorbic acid method (APHA, 1989)	09.00 hrs
BOD_5 (mg/L)	5 Days BOD Test (Azide modification Winkler Method)	09.00 hrs
Total coliform bacteria (MPN/100 mL)	Department of Microbiology	09.00 hrs

Note: * *in situ* measurement

4.3 Results

4.3.1 Water quality monitored in Lumsai village

Intensive monoculture of hybrid catfish in the earthen pond was the major aquatic food production system in this village. The canal and sub-canal served for both water supply and discharge of ponds.

Mean values of water quality parameters in canals and catfish ponds in Lumsai village are presented in Figure 4.2.

- The dissolved oxygen concentration in canal water in the morning and afternoon ranged from 2.24 to 6.52 mg/L. While most fish ponds contained dissolved oxygen lower than 3 mg/L in the morning, but saturated in the afternoon (3.64-23.25 mg/L).
- The pH in canal was in a normal range both in the morning (7.09-7.39) and afternoon (7.23-7.79). In comparison, the pH in fish ponds ranged wider between 6.82 and 8.33 with some ponds over 8.5 in the afternoon.
- Water temperature was similar in canal and fish ponds ranging from 29.5 to 32.9^oC and 29.6-34.4^oC, respectively.
- Total alkalinity ranged from 136 to 254 $mgCaCO_3/L$ in fish ponds and 100-120 $mgCaCO_3/L$ for the canal water.

- Turbidity was found highly variable among fish ponds (132-601 NTU) but it was relatively low in the canal (46-76 NTU).
- Fish ponds also showed high variation in total ammonia-nitrogen (0.51-15.49 mg/L) but they were relatively stable and similar at 1.00 -1.95 mg/L. in the canal water among three sampling locations.
- Concentrations of nitrite and nitrate-nitrogen were found relatively low in both the canal (0.033-0.058 mg/L) and fish ponds (0.011-0.046 mg/L).
- Total phosphorus was 0.209-0.311 mg/L in canal water and 1.290-4.672 mg/L in fish ponds while soluble reactive phosphorus ranged from 0.056-0.084 mg/L in canal water and 0.063-1.250 mg/L in fish ponds.
- The BOD was highly variable in canal and fish ponds at 3-34.5 mg/L and 3.7-96.0 mg/L, respectively.
- High variations in total coliform bacteria were also found among fish ponds (490-92,000 MPN/100 mL) and in the canal ranged from 3,500-5,400 MPN/100 mL.

4.3.2 Water quality monitoring at Suanprixthai village

Two types of aquatic food production systems existing in the Suanprixthai village were fish culture in ponds and water mimosa farming in a natural water canal. The most typical fish culture was polyculture of hybrid catfish and striped silver catfish. Some farms also added herbivorous fish such as tilapia, rout and silver barb However, an integrated pig-fish culture system was also present. A natural water canal, *klong Chiengrak-Noi*, located along fish pond areas was the main water supply to fish ponds whilst some got water from sub-canals. Water mimosa was grown densely at the down stream end of this canal. Farming activity details of an individual fish pond during the water quality monitoring were provided by farmers.

Mean values of important water quality parameters in the natural water canal and fish ponds in Suanprixthai village were presented in the Figure 4.3.

- Dissolved oxygen was relatively poor in the natural water canal both in the morning (1.53-3.77 mg/L) and the afternoon (1.53-3.73 mg/L). Similarly, fish ponds had low dissolved oxygen in the morning (0.81-3.74 mg/L), but it increased with large variation among ponds in the afternoon (2.60-13.65 mg/L).
- pH in the natural water canal was in an optimal range of both in the morning (6.93-7.13) and the afternoon (6.85-7.13). Fish ponds also had pH at 6.67-7.60 in the morning and 6.73-8.83 in the afternoon.
- The daily water temperatures in fish ponds ranged from 28.9 to 32.8^{o}C, whereas the natural water canal was 28.5-29.1^{o}C. The total alkalinity in fish culture ponds exhibited higher variation (77-390 mg/L as $CaCO_3$) than those of the natural water canal (79-114 mg/L as $CaCO_3$).
- High variations in water turbidity (27-254 NTU) were also found among fish ponds. In the natural water canal, turbidity ranged from 31-64 NTU and the highest turbidity was recorded at 351 NTU in sub-canal.
- The total ammonia-nitrogen concentration ranged widely from 0.250 to 10.765 mg/L among fish ponds, while in the natural water canal its range was 0.104-1.052 mg/L.
- Nitrite and nitrate-nitrogen were relatively low in both fish ponds and the natural water canal with value ranged from 0.006 to 0.196 mg/L and 0.011-0.65 mg/L, respectively.
- There were relatively similar in total phosphorus and soluble reactive phosphorus between fish ponds and the natural water canal. Total phosphorus was 0.110-0.853 mg/L in fish

ponds and 0.109-0.317 mg/L in the natural water canal; while the soluble reactive phosphorus was 0.018-0.051 mg/L in fish ponds and 0.047-0.054 mg/L in the natural water canal, respectively.

- BOD were present with large variation among fish ponds (8.2-42.0 mg/L), but relatively low in a natural water canal (1.0-10.2 mg/L).
- Fish ponds were contaminated with total coliform bacteria in highly variable numbers (330-16,000 MPN/100 mL). However, the contamination of coliform bacteria in the natural water canal was between 480 to 2,800 MPN/100 mL.

4.3.3 Water quality monitoring at Nongpraongai village

Intensive cultivation of morning glory in plots or paddy fields was the main peri-urban aquatic food production system in Nongpraongai village. Chemical fertilizers and pesticides were intensively used for the crop. A natural water irrigation canal and sub-canals were the main water supplies to the areas. Details of farming activities were obtained from representative farmers during the water quality monitoring period.

Mean values of important water quality parameters in the irrigation canal and cultivation plots at Nongpraongai village were presented in the Figure 4.4.

- Dissolved oxygen in the canal exhibited similar concentration both in the morning and the afternoon ranging from 1.63 to 4.08 mg/L and 1.03-4.00 mg/L, respectively. Large variations in dissolved oxygen existed among plots both in the morning (0.98 to 9.17 mg/L) and the afternoon (1.04-20.00 mg/L).
- pH in the canal was between 6.98 to 7.27 during the morning and afternoon. In the aquatic vegetable plots the pH was 6.71-7.57 and 7.17-9.56 in the morning and the afternoon, respectively.
- Water temperature ranged from 25.2 to 29.3^{o}C in the plots and 29.2-29.8^{o}C in the canal in the morning. In the afternoon it was 27.6-34.9^{o}C in plots and 29.6-30.9^{o}C in the canal.
- The total alkalinity ranged between 20 and 184 mg $CaCO_3$/L among plots, while in the canal it was 90-122 mg $CaCO_3$/L.
- Turbidity was similar in plots (7-34 NTU) and the canal water at 10-35 NTU.
- Total ammonia-nitrogen had high variation among plots (0.129-7.045 mg/L) but less variable in the canal at 0.302-0.763 mg/L.
- Nitrite and nitrate-nitrogen concentrations were similar in both plots and the canal ranging from 0.012 to 0.453 mg/L and 0.030-0.298 mg/L, respectively.
- Total phosphorus had a range of 0.111-0.517 mg/L among plots and 0.239-0.324 mg/L in the canal, while the soluble reactive phosphorus ranged 0.025-0.335 mg/L and 0.088-0.175 mg/L in plots and the canal, respectively.
- BOD of both canal and plots were lower than 20 mg/L. It was 4.2-6.6 mg/L and 5.4-10 mg/L in the canal and plots, respectively.
- Total coliform bacteria count varied among plots (330-9,200 MPN/100 mL) and was 3,500-9,200 MPN/100 mL in the canal.

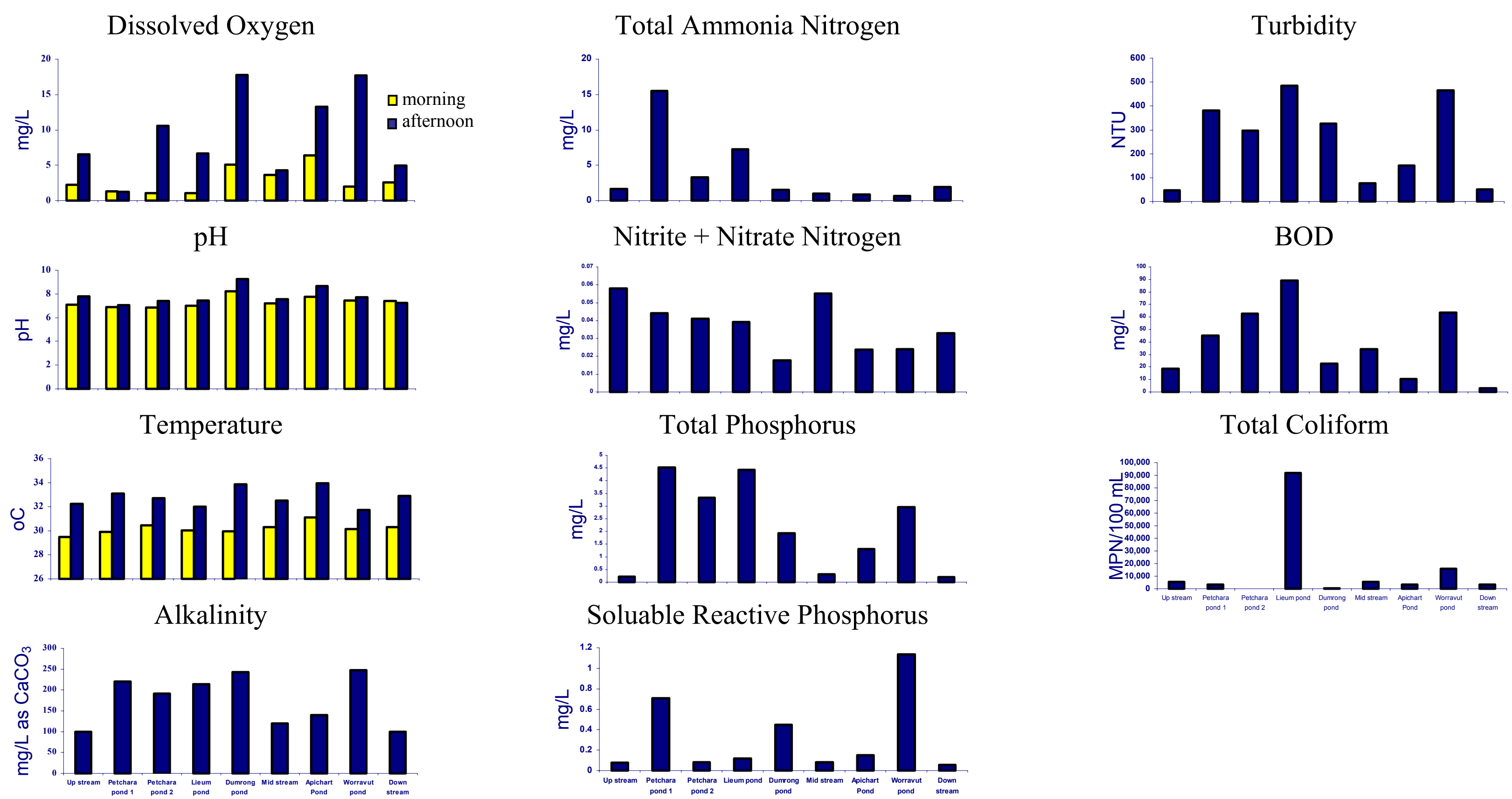


Figure 4.2 Mean values of important water quality parameters in monoculture of hybrid catfish ponds and a natural water irrigation canal at Lumsai village, Lumlukka district, Pathumtani province.

Dissolved Oxygen Total Ammonia Nitrogen Turbidity

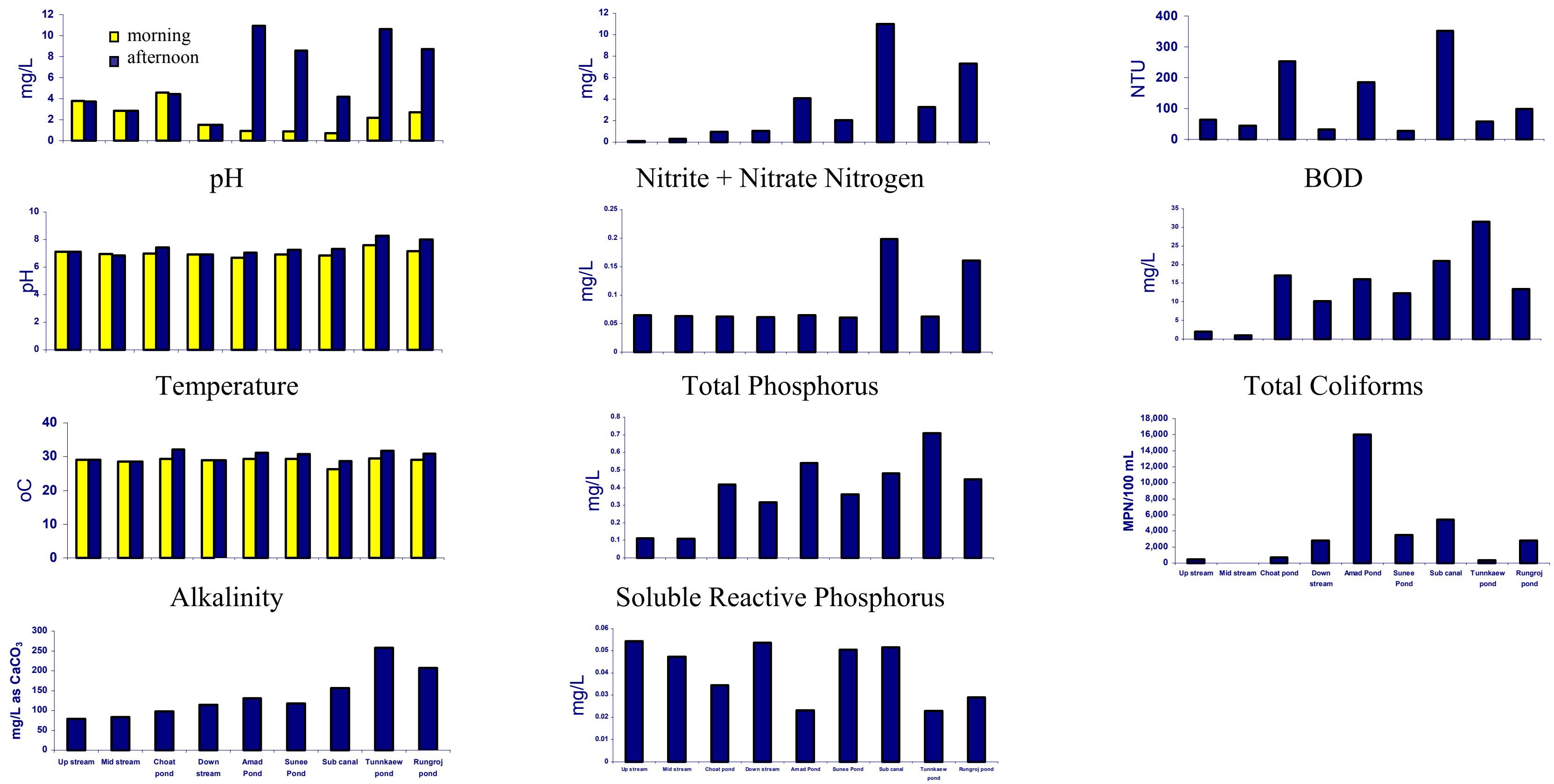


Figure 4.3 Mean values of important water quality parameters in fish ponds and a natural water canal at Suanprixthai village, Muang district, Pathumtani province.

Dissolved Oxygen

Total Ammonia Nitrogen

Turbidity

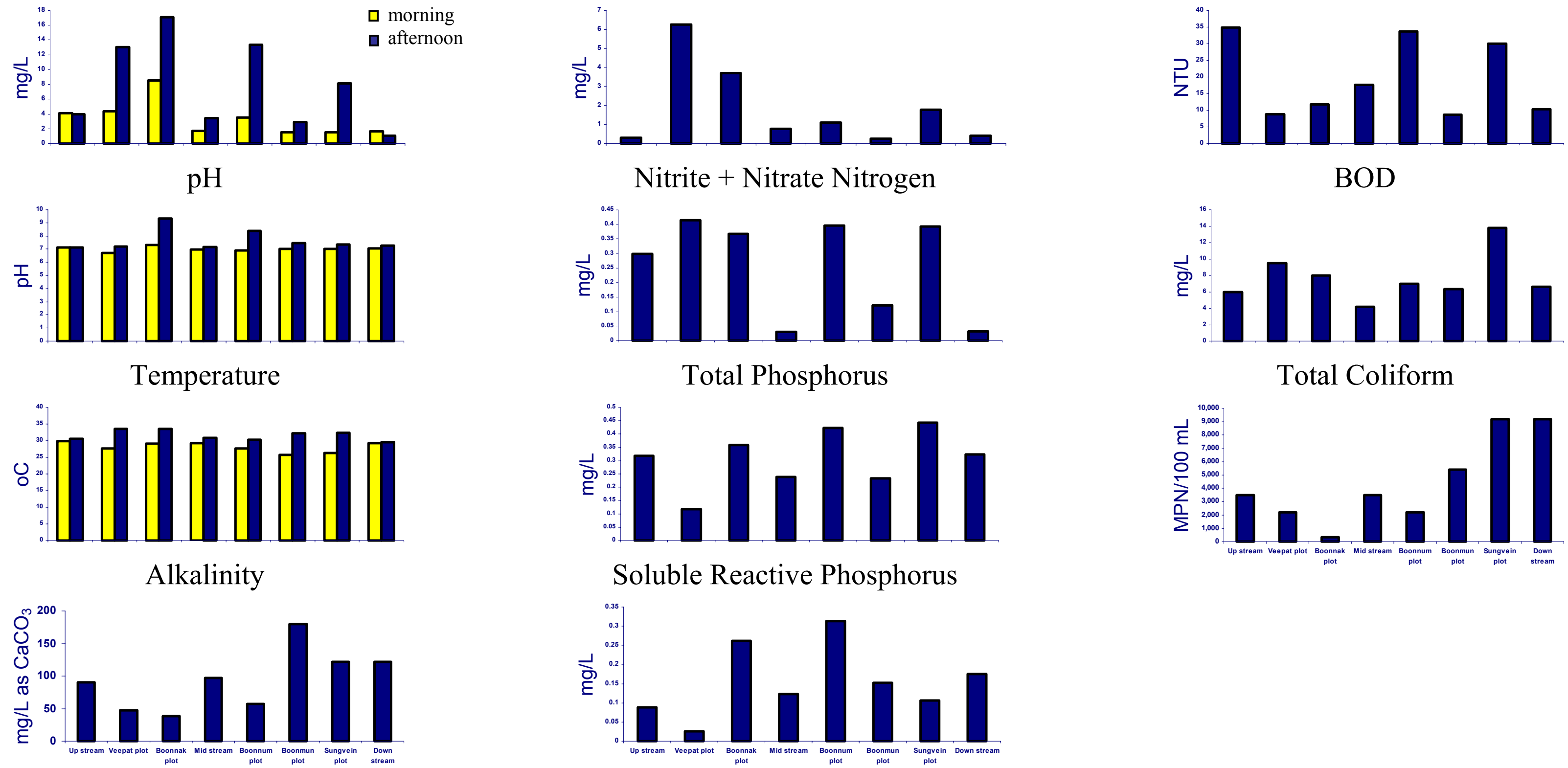


Figure 4.4 Mean values of important water quality parameters in intensive morning glory cultivation plots and a natural water irrigation canal at Nongpraongai village, Sai-noi district, Nontaburi province.

4.3.4 Nutrient budget

The amount of nutrients contributed to environment from fish ponds was estimated by nutrient budget analysis which includes inputs and losses of nutrients in a pond system. The major sources of nutrient input in catfish pond originate from feed, filling water and stocked fish. The outputs (losses) are harvested fish, drained water and others such as seepage, and nutrients recycled from pond mud. The nitrogen can also be lost to air through volatilization of ammonia and denitrification. The nutrient budgets in hybrid catfish pond vary between dry and rainy seasons, especially for P (Table 4.2).

Table 4.2 Inputs, outputs and balance of total nitrogen and total phosphorus (kg/ha) in various components of catfish culture between dry and rainy seasons

Nutrient	Total Nitrogen (kg/ha)		Total Phosphorus (kg/ha)	
	Dry	Rainy	Dry	Rainy
Inputs				
Feed	2252.3	2345.1	453.2	230.0
Catfish fingerlings	186.68	168.01	6.20	5.58
Water inflow	43.2042	39.4545	2.81905	8.12
Total input	**2482.17**	**2552.52**	**462.19**	**243.67**
Output				
Catfish production	1966.78	1864.80	77.46	73.44
Water outflow	304.37	239.89	51.96	25.57
Total loss	**2271.15**	**2104.69**	**129.41**	**99.01**

4.4 Overall discussion

Results showed that dissolved oxygen was relatively low in natural water irrigation canals at the three communities, especially in the morning it was below than 1.0 mg/L. Similarly, low levels of dissolved oxygen also existed in the morning among aquatic production systems in all three communities, but it reached saturation level in the afternoon, especially in the fish ponds in Lumsai and Suanprixthai villages. This probably resulted from the intensive monoculture of hybrid catfish at Lumsai village where farmers stocked fish at high density and fed with waste by-products such as chicken bones and visceral organs from slaughter houses; whereas canteen waste-food composed mainly of the vegetable by-products was used as fish feed in Suanprixthai village. These kinds of fresh feed could be easily lost as uneaten forms and decomposed in ponds, consuming large amount of dissolved oxygen and released high dose of total ammonia nitrogen which often exceeded 1.1 mg/L in fish ponds.

While in intensive cultivation of morning glory, various types of chemical fertilizer were heavily used at weekly intervals resulting in high concentration of total ammonia nitrogen in vegetable plots. However, both nitrite and nitrate nitrogen were present below than 0.5 mg/L in both natural water irrigation canals and aquatic production systems in three communities. This probably indicates that the active anaerobic decomposition of organic matter occurred in fish culture systems.

However, most aquatic production systems had the concentration of total phosphorus over 0.4 mg/L, especially in hybrid catfish culture. These nutrients probably cause the phytoplankton bloom in the afternoon resulting in pH increase to exceed 8.5 in some ponds/plots. More turbid water existed in fish culture systems than the morning glory cultivation system and natural water canals. In contrast, water transparency was low in fish ponds, while the water transparency reached pond bottom in morning glory plots. One important factor contributing to turbidity and lowering water transparency in fish ponds was the constant vertical movement of catfish which stirred the pond bottom. In addition, the high turbidity also caused in part by the dense phytoplankton bloom due to rich of nutrients in the systems

In terms of BOD, relatively low concentrations (<20 mg/L) were found only in the morning glory cultivation system while the value was high in fish ponds, especially in ponds for monoculture of hybrid catfish with BOD exceeding 20 mg/L. This probably resulted from using wastes by-products from slaughter house and canteen, whereas the cultivation of morning glory used only inorganic fertilizers. Contamination of total coliform bacteria was found variable among aquatic production systems. However, there was a trend of greater risk in coliform contamination in fish culture systems higher than that of morning glory cultivation. It is to be of some concern that the high number of total coliform bacteria at 92,000 MPN/100 mL in some catfish ponds was found. Some sampling stations of the natural water irrigation canals in the three communities had contamination of total coliform bacteria over 5,000 MPN/100 mL.

The nutrient wastes from peri-urban aquatic food production systems constitute a significant factor in eutrophication of waterways. It was estimated that discharges of nitrogen and phosphorus from catfish ponds contain 13.82-20.09 g/ton (179.66-261.17 kg/ha) of TN and 1.2-3.78 g/ton (17.4-54.81 kg/ha) of TP. The apparent impact of nutrient enrichment is the profuse growth of aquatic weeds in the canal around Lumsia area where water quality has been badly deteriorated for human activity including water supply to fish ponds.

Overall, it could be concluded that there is a large variation in water quality among aquatic production systems and canals in the three communities. Factors affecting the variations might come from the different locations with various surrounding environments, history of pond/plots uses, the state of farming activities and farm management. Apparently, some of those aquatic production systems are causing adverse environmental impact due to their water quality being below the required standard of discharged water set by the Ministry of Science Technology and Environment in 1992. The standard guideline concentrations for important parameters are as follow: pH 6.5-9.0, BOD < 20 mg/L, total ammonia nitrogen < 1.1 mg/L, total phosphorus 0.4 mg/L, total nitrogen < 4.0 mg/L and hydrogen sulphide < 0.01 mg/L. Improvement in quality of discharged water from those production systems is needed.