WASTEWATER-FED AQUACULTURE IN THE WETLANDS OF HANOI, STATUS AND PROBLEMS

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Introduction

In Hanoi, as other developing countries facing a rapid increase in population, urbanization and industrialization, the volume of domestic wastewater, and urban wastes, industrial effluents is steadily increasing.

Wastes, rich in organic matter (sewage, human feces, animal wastes, etc) are in some instances, valuable resources that can be recycled or reused. The utilization of both liquid and solid wastes as fertilizers in Asia was well reviewed in the papers of Chongrak Polprasert and Peter Edward (1981). In the course of the last decades, both natural and artificial wetlands are increasingly being identified as efficient ecosystems for improving wastewater quality and recovering its nutrients (Dhrubajyoti Ghosh, 1990). It is in this context that the traditional practice of using sewage for aquaculture in the wetlands to the south of Hanoi assumes significance.

Sewage-fed fish farming in the wetlands of Hanoi

Thanh Tri is a suburb-district of Hanoi, which is in the south of the city. As it is lying in the lowest part of Hanoi, the wetlands here form the main part of the district with about 70% of the total area. Wetlands in Thanh Tri are semi-natural lakes, ponds and bogs of some hundreds square meter to nearly one hundred hectare, canals and rice-fields. The wetlands to the south of Hanoi are important part of the city ecosystem.

Hanoi produces about 130-140 million cubic meter of wastewater a year, in which 70-75% are domestic and 30-25% are industrial. Sewage from Hanoi is rich in nutrients, contaminated by fecal coliforms and toxic chemicals. BOD content ranges from 50 mg/l to 100 mg/l, COD values in rivers are rather high; nitrogen content ranges from 10 to 12.7 mg/l which mainly is NH_4-N. SS content ranges from 120mg/l to 150 mg/l. Fecal coliform in river ranges from 700/100ml to 7,000/100 ml. The canals water is also polluted by toxic heavy metals like Ni, Cu, As, Pb (Figure 1).

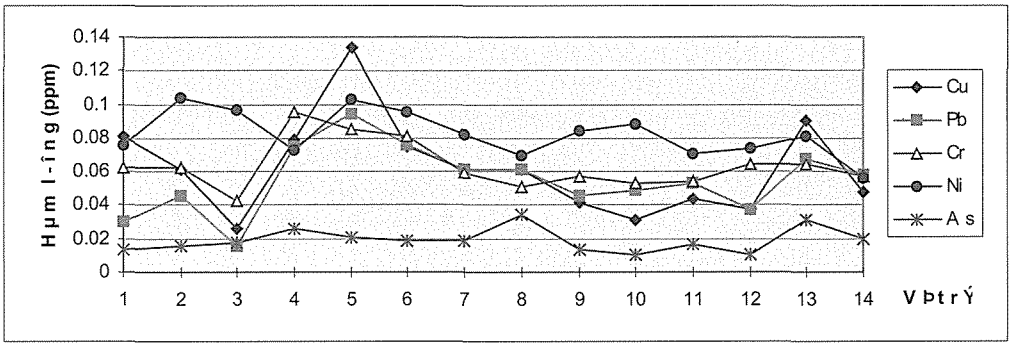

Fig. 1: Heavy metals in the drainage rivers of Hanoi (Thang, V.Q., 1997)

Wastewater from the city, through its drainage rivers flows through Thanh Tri. Here, it will be recycled by pumping to the fish culture systems and effluents will flow into the local rice-fields. Hanoi is the largest place in Vietnam, where wastewater has been used widely for irrigation and fish farming.

Several wastewater reuse systems have been developed in Hanoi which were generally described and presented (Tuan, P.A. et all; 1990 and Sy, D.T., 1995)). The most efficient wastewater reuse systems are (1) fish culture only systems, (2) rice-fish rotation systems and (3) wastewater paddy fields.

The application of sewage to aquaculture in Thanh Tri has been lasted for nearly 40 years. With a total of 1,200ha fish pond, of which 682 ha are all round year fish farming area, 527 ha are one-crop fish farming area in flooded season and the other 4500 ha are rice fields. Among that, About 750 ha of fish ponds of both kind and 3500 ha of paddy fields are fed with wastewater of some different extent (Thang, V.Q. et all, 1996).

The productivity of natural fish pond (no waste) is only less than 1 ton/ha/year. Sewage / waste -fed intensive fish ponds have much higher production, from 3.6 - 9.2 t/ha/y and net profit was investigated from 4,160,000 - 15,700,000 VND/ha/year. In the rice-fish rotation ponds / fields fish yield is 1.16-5.0 ton/ha/y, and net profit is 7,607,300 – 12,300,000 VND/ha/y. In the rotation fields, besides fish, one can have an additional 5 ton rice/ha/y, thus the total profit in some instances is very high.

Annual fish production of Thanh Tri is about 3000–3500 ton, which supply 86% of city consuming. (Sy, D.T, 1995)

The fish culture only model

The lakes / ponds are used only for fish culture in the whole year; the average annual gross yield is 4 ton fish/ha with an 11 months growing season. Total 682ha. Typical systems are illustrated below:
The fish pond in Yen Duyen commune: The fish pond's area is 18 ha, with average depth from 1.2 to 1.5m. This pond was completely fed with wastewater. The fish pond takes condensed sewage in from Kim Nguu river through Thanh Mai pumping station. This station has two pumps with the power of 1000 m^3 per hour for each. Pumping time depends on quality of Kim Nguu river's wastewater. The longest pumping time is 20 hours/d. The distance from the station to the fish pond is 350 m.

The fish pond in Hoang Liet commune: The fish pond's area is 1.082 ha. The average depth is from 1.0 to 1.2m. The fish pond recharges water from To Lich river through 300 m-long channel.

The fish pond in Tu Hiep commune: The fish pond's area is 0.43 ha. The average depth is 1.5m. The pond mainly feeds on fresh night soil, and dilute sewage, bran as supplement source. The night-soil quantity used in the fish pond is 4 baskets (about 30 kg per basket) a day in two times, in early morning and in late afternoon. Feeding method: pouring each scoop of night soil along the fish pond shore.

The fish pond in Tu Hiep commune: area is 19.44 ha, average depth is from 1.3 to 1.5 m. The pond reused diluted wastewater from Kim Nguu river. . When the sewage becomes rich in nutrient (exhibited by the sewage color), the fish pond owner will pump the sewage into the pond continuously, sometimes up to 4 - 5 days. In dry season, the river's flow is limited hence beside sewage, supplement source of foods (spoiled fruits, market wastes, vegetables) should be supplied. Waste quantity applied in this pond is from 3.5 to 4 tons per day. In addition to this waste, residue from beer brewing is also given to this pond for once or twice a week in amount of 4 - 5 tons each time.

The fish pond in Tu Hiep commune: The area of this fish pond is 1.66 ha. The average depth ranges from 1.5 to 1.7 ha. This fish pond loads diluted sewage from Kim Nguu river. In the dry season, the river's wastewater flow is scarce so that it is not main source but supplement source of foods. However, when the wastewater becomes rich in nutrient (shown by the water's color) it will be pumped into the fish pond, sometimes up to 4 - 5 days. Another food source is from cattle manure cassava root and sugar cane residue with different quantity.

The nursery fish pond in Thinh Liet commune: The fish pond's area is 8.64 ha. The average depth is from 1.4 to 1.6 m. The shore is 0.5 m high. The water level is from 1.2 to 1.5 m high. This fish pond is located close to Yen So's fish pond. The wastewater inlet to the fish pond flows through the recharge channel of

Yen So's fish pond. The pump's power applied in this pond is 1000 m^3 per hour. Water is pumped into the fish pond for 15 hours a day to feed fishes.

The rice-fish rotation model:

Fish culture (6-7 months) is rotated with rice cultivation (5 months) in the same pond / fields, average gross yield of 2.5-3.5 t fish/ha and 5 tonnes rice / ha. Total 527 ha. Examples of this model are:
The alternative fish pond in Yen So commune: The fish pond's area is 5.3 ha. The average depth is from 1.2 to 1.7 m. The fish pond is only fed by condensed wastewater from Kim Nguu river. The pump's power used in this pond is of 1000m3 per hour. Pumping time changes from 4 to 12 hours depending on season and color of the water. Early six months in a year, entire area of the fish pond is cultivated with rice. In this period, the water level in the fish pond is only about from 0.2 to 0.3 m high. Late six months in a year, the fish pond is pumped full of water.

The alternative fish pond (rice-fish rotation model) in Tu Hiep commune: The fish pond's area is 6.84 ha. The average depth is 1.2m. Early six months in a year, the total area of the fish pond is used for rice cultivating. In this period, the water level is only from 0.2 to 0.3 m high. Late six months in a year, the fish pond is pumped full of water. The average water level is 1.2m high. The pump's power applied in this pond is 270 m^3 per hour. In a fish growing period, the pump operates twice to three times a week and for 10 hours each time. Besides, the fish pond also is added more foods from cattle manure, night soil and agricultural residue.

Ecology of sewage-fed fish ponds in Thanh Tri

Fish stock
There are 20 species of fish in sewage-fed fish ponds, in which 8 species are identified as culture species (*Hypophthalmichthys molitrix, H. harmandi*, cyprinus *carpio, Aristichthys nobilis, Cirrhina molitorella, Squaliofarbus, Genopharyngodon idellus, Tylapia mossambica, labeo rohita*) and 12 are natural species. Silver carp is a phytophagous species and Tilapias is an omnivorous species. They are most common species, which supply about 30-50% of total productivity. Rohu (*Labeo rohita*), introduced to Vietnam from Indian in 1986, feeds on organic residuals.

Water quality
In general, the water quality of sewage/wastes – fed fish ponds in Hanoi are properly controlled to maintain a suitable environment for fish growing: pH fluctuations is 7.0 -8.0, Dissolved oxygen (DO) in fish pond's water ranges from 4 mg/l to 6.4 mg/l.

Table 1. Sewage-fed Fish ponds water quality (Thang, V.Q. et al, 2000)

Commune			Mean Concentration (mg/l)							
	(n)	pH	DO	BOD 5	NH_4^+	NH_3	PO_4^{-3}	CO 2	H_2S	Cl
28TC, MOFA		6.5-8.5	>4	<12	1.0-1.5	<1	0.5-1.0		<1	<200
THINH LIET	12	7.3	4.0	11.5	1.3	0.6	0.8	13.9	1.2	66
YEN SO	24	7.6	4.2	10.9	5.7	0.5	0.8	13.3	1.1	54
TU HIEP	48	7.5	5.3	7.4	0.9	0.4	0.6	11.3	0.3	71
HOANG LIET	24	7.9	6.4	10.5	0.7	0.3	0.8	8.9	0.4	39

BOD_5 from 7.4 mg/l to 11.5 mg; NH_4^+ from 0.7 mg/l to 1.3 mg/l (averaged 0.9 mg/l), the fluctuation of NH_4^+ directly relates to the type and the quantity of the feeding matters applied in a pond; PO_4 ranged from 0.6-0.8 mg/l. In fish ponds which feed on night soil, the TP concentration is normally high. Toxicants

like NH_3 and H_2S in the studied fish pond ranged from 0.1 to 0.9 mg/l and 0 mg/l - 1.2 mg/l respectively, which was well below the standards except in some cases with a short time.

Phytoplanktons

In wastewater/waste - fed fish ponds, there were seven phylums of algae, among which only five phylums that played important roles in the ecosystem, including 177 species belong to *Chorophyta (84 sp.), Euglenophyta (31 species), Bacillaiophyta (24sp), Cryophyta (4sp)* and *Cyanobacteriophyta (19sp).* The rest containing *Xanthophyta (10sp), Crysophyta (1sp)* and *Dinophyta (4sp)* didn't have rich species composition and they were not high density population.

Species composition was found rich in March, April, May, June and July, became poor from August to January and begin to increase in February through April of next year. The species become the richest in July. The *Chlorophyta* phylum had a rich species composition in April, May, June, and July 1994; *Bacillaiophyta* in November and December, 1994 and January 1995; Cya*nobacteriophyta* in June and July; *Euglenophyta* in November and December, 1994, however just in several ponds. *Xanthophyta, Cryophyta,* and *Dinophyta* had poor species composition and their composition didn't change apparently.

The plankton biomass is changing all the time during the year. In Yen So, for example, the biomass fluctuation ranged from 120 g/m^3 in August to 1981 g/m^3 in April. Due to fertilizers applied to the pond. The garbish fish ponds in Tu Hiep had the lowest biomass compared with other ponds, ranged from 152 to 887g/m^3.

Comparisons made among algae species biomass showed that the *Chlorophyta* biomass is the highest. *Chlorophyta* serves as a main source of food for invertebrates and also plays an important role in an increase in dissolved oxygen in fish ponds. In night soil fish ponds, algae blooming occurs all the time, as the *Cyanobacteriophyta* biomass is always high, especially in June and July. In rice-fish ponds, algae blooming doesn't occur very often as the *Cyanobacteriophyta* biomass is low.

Invertebrates

Composition. Invertebrates living in fish ponds are very abundant. There are 52 species. Zooplankton makes up for 38 species which belong to four groups, including R*otatoria, Cladocera, Copepoda and Ostracoda.* Among them, rotatoria is dominant, which make up for 68% of the entire zooplankton. There existed 14 species of zoobenthos, which belong to three groups, such as *Ologochaeta, Gastropoda* and *Decapoda.* Zoobenthos made up for 27% of invertebrates.

Numbers of invertebrates. There were great fluctuations in species composition and number of zooplankton in sewage/waste fed fish ponds. The number of zooplankton fluctuates from 88,000 individuals/m^3 to 187,000/m^3. Among the zooplankton, *Oligochaeta* is dominant. The number of zoobenthos varies from 200 individuals/m^3 to 240 individuals/m^3. In terms of biomass of invertebrates, the keystone species is zoobenthos.

Environmental & public health problems

Utilization of untreated wastewater in Hanoi has caused adverse effects to the environment and community health. Some research results on these problems will be presented in the following paragraphs.

Heavy metals in sewage-fed fish ponds and reared fish

Heavy metals accumulated in water environment and in the food chains can have bad effects to the workers and fish consumers. A study on the existing of heavy metals in the fish ponds and the sewage – reared fish was conducted.

Concentration of As, Hg, Cd, Cr and Pb in the fish pond water are below the permissible standards of MOFA (1983), except the case of Cu and Ni, that are higher than permissible standards in all studied fish ponds. Ni concentration is exceeding 4-6 times. It was also recognised that the accumulation of heavy metals in pond sludge are very high, even hundreds time more than that in the water.

Table 2. Heavy metals in wastewater – fed fish ponds (V.Q. Thang, et al, 2000)

Heavy metals	Perm. StD	Sewage / wastes – fed fish ponds								
		A1	A2	A3	A4	A5	A6	A7	A8	TB
		In fishpond's Water (mg/l)								
As	(0.05)	**0.068**	0.026	0.039	0.041	0.023	0.053	0.049	0.012	0.039
Cu	(0.01)	**0.029**	**0.031**	**0.032**	**0.044**	**0.043**	**0.015**	**0.037**	**0.024**	**0.032**
Pb	(0.10)	**0.103**	0.043	0.053	0.089	0.067	0.025	**0.100**	0.027	0.063
Cr	(0.05)	0.037	0.042	0.032	0.032	0.038	0.037	0.022	0.030	0.034
Ni	(0.01)	**0.060**	**0.051**	**0.056**	**0.056**	**0.046**	**0.054**	**0.058**	**0.038**	**0.052**
Cd	(0.005)	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Hg		<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
		Fish Pond's bottom sludge (ppm)								
As		75	25	98	50	80	5	25	15	
Cu		50	47	35	52	32	30	18	26	
Pb		14	7	7	13	10	12	12	10	
Cr		13.1	11	9.8	10.9	6.6	8.8	8.0	6.0	
Ni		43	22	42	37	27	32	17	35	

Accumulation of heavy metals in fish

The content of heavy metals in the culture fish meat is somewhat higher than in the water. It is supposed that fish has accumulated heavy metal but the concentration of heavy metals in the fish meat are still below the permissible standards.

Table 3. Heavy metals in sewage reared fish meat (Thang, V.Q. et al, 2000)

	Fish pond	Fe	Pb	Cu	Cr	Ni
Wet Fish meat *(mg/kg)*	Duong Sat (n=11)	21.1	0.163	0.201	0.30	0.182
	Dinh Cong (n=8)	17.3	0.202	0.70	0.26	0.05
	Tran Phu (n=5)	16.4	0.212	0.17	0.19	0.258
Per.Standards (MOH)	Wet product		2.0	20		
	Dried product		2	10	1	

Health impacts

The risk for the local people in the community, who lives and working in the polluted environment is high. A survey with 3,400 local people showed that Farmers with direct exposure to waste water in working at typical communes is 38.50% in Hoang Liet, 40.29% in Lien Ninh, 55.50% in Tu Hiep, and 63.28% in Yen So, while this rate is very low in Yen My (0.6%).

A detail study on community health, conducted by the Center (CRES) in cooperation with the Hanoi Medical College (V.Q.Thang et al, 1995) showed a remarkable difference between Yen So, Tu Hiep, Hoang Liet (exposed) and Yen My (control) in wastewater related diseases such as:

- Clinical digestive diseases, trachoma and skin diseases at Yen So is markedly higher than at Yen My (Table 5).
- Respiratory diseases, sore throat, cough, fever for example, in adults at Yen So (24.08 - 37.74 percent) are significantly higher than at Yen My (17.41 - 30.35 percent);

Table 4. Some typical diseases (%)

	Commune	Patient Number (n)	Digestive diseases	Skin diseases	Trachoma T1,T2,T3,T4
1	Hoang Liet	305	7.54	3.60	54.09 +++21.71
2	Lien Ninh	148	4.72	1.35	30.40
3	Tu Hiep	103	6.79	4.85	55.33 +++13.66
4	Yen So	175	18.28 +++13.17	18.28 +++15.77	33.71
5	Yen My	228	6.57	5.70	33.77

- Detailed study of digestive diseases showed that digestive diseases as adult diarrhea at Yen So (13.04%), Tu Hiep (11.56%), Lien Ninh (15.45%) is all statistically higher than in Yen My (7.12%); Digestive diseases in children of under 5 years old such as diarrhea, frequent stool, vomiting at Lien Ninh (3.01 - 16.48%), Tu Hiep (3.36 - 13.03%), Yen So (4.73 - 13.79%) are statistically higher than in Yen My (1.05 - 8.74%), Genecologic diseases at Hoang Liet (52.81%), Lien Ninh (54.59%), Tu Hiep (80.00%), Yen So (57.95%) are statistically higher than at Yen My (43.04%).

- The present study to examine the risk of cervical intraepithelial neoplasia (CIN) among female farmers working and living in wastewater communities shows: a specific visible trend was found for CIN (CIN 1, CIN 2, and CIN 3 combined) positive rate: 2.9%, 3.8%, 3.2%, 9.3% and 12.0% in control, low, medium, high and very high exposure areas, respectively. A slight increased risk of CIN for female farmers in very high exposure areas was found: crude OR=4.6, 95% CI = 0.9-22.9, adjusted OR = 8.8, 95% CI = 0.8-100.9 when compared to that in very low exposure areas. The risk of CIN for female farmers in high and very high exposure areas combined was also slightly increased (Adjusted OR=2.4, 95% CI = 0.9-6.7) when compared to that in low and medium exposure areas combined. However, that was significantly increased when compared to that in very low, low, and medium exposure areas combined (Adjusted OR = 3.0, 95% CI=1.2-7.8). The present results indicated a positive association between the high exposure to municipal wastewater and the risk of CIN.

Conclusions

Reuse of wastewater for fish farming in the wetlands of Hanoi can not only reclaim the "waste nutrients" into valuable fish products, but also improve local employment and sanitation. These wastewater-fed agro-aqua-culture ecosystems function as biological units in treatment of wastewater from the city. Concentration of BOD_5, nitrogen and phosphorous at the outlet of the sewage-fed fishponds has been reduced apparently in compare with the inlet. It has been shown that integrated resource recovery and institutionalization of urban solid and liquid waste management can reduce their cost to municipalities by 30-90% (Gunnerson 1984). Therefore, integrated resource recovery systems and waste recycling regions in peripheral wetlands are important planning concepts for cities. The Hanoi wetlands demonstrate the viability of such a system. Those planners should take into account as a strategy in conserving local wetlands.

Besides, the reuse of untreated wastewater in the wetlands can cause adverse effects to the environment: accumulation of heavy metals and toxic chemicals in the environment and food chains, groundwater pollution, eutrophication, community health, and risks to the consumers, etc. Therefore, in order to prevent environmental pollution and reduce the risks to the people, these informal systems need effective maintenance, monitoring, and upgrading.

References

1. Chongrak, P. and Edwards, P. *Low cost waste recycling in the tropics. Biocycle*, J. Waste recycling, 20, 30-5, (1981)
2. Dhrubajyoti, Ghosh, *Wastewater-fed Aquaculture in the wetlands of Calcutta – an Overview, in "Wastewater –fed Aquaculture"*, AIT, (1990)
3. Gunnerson, C.G. *Research and Development in integrated resource recovery (an interim technical assessment)*. UNDP Project GLO/80/004.
4. Sy, D.T. *Aquatic ecosystems and the role of fish pond/lakes in decreasing water pollution in Hanoi, in the book "Some problems on Human Ecology in Vietnam"*, Agriculture Publisher, (1995)
5. Thang, V.Q. *Heavy Metals in Hanoi wastewater drainage rivers*. Journal of scientific Activities, 12/1997.
6. Thang, V.Q.; Yen, M.D. *Ecological-based Environmental Planning of Thanh Tri District; National workshop on "Ecological Sustainability for Vietnam"*, Ecology Association of Vietnam, Hanoi 10-11/10/2000.
7. Thang, V.Q.; Thanh, T. T.; Quynh, N.X.; Sy, §.T. *Ecological Characteristics of sewage-fed fishponds in Thanh Tri District*; Bulletin of Universities, Ministry of Training and Education, (2000)
8. Thang V.Q. et al. *Effects of Sewage Utilization for Fish Farming and Irrigation in Vietnam.* Final Technical Research Report to IDRC, Center for Natural Resources and Environmental Studies (CRES), VNU, Hanoi -1996.
9. Thang, V.Q., Phong, D.N.; Ngoan, L.T. *Some public Health Aspects of Sewage Utilization for Fish Farming and Irrigation in Hanoi, Vietnam.* International Workshop on Urban Agriculture & Sustainable Environment, Calcutta, India, December 8 -10, (1995)
10. Tuan, P.A. and Trac, V.V.; *Reuse of wastewater for fish culture in Hanoi, Vietnam; in "wastewater-fed Aquaculture"*, Edit. By P.Edwards and R.S.V. Pullin; AIT, (1990)