Research article

Farmers and Wastewater Management - A Case Study of Integrated Urban Wastewater Management and Agriculture in Hanoi, Vietnam

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Abstract The amount of wastewater utilized by urban farmers worldwide is expected to increase due to the rising amount of wastewater generated from urban population. Despite the contribution of urban farmers to generate vast quantity of urban waste including solids and wastewater through agricultural practices, these activities are little recognized by municipal's management authorities or looked down by the communities, resulting in informal, unplanned and spontaneous practices. Twenty nine farmers from two communities in peri-urban area of Hanoi were involved in the participatory investigation of individual managerial capacity on farming related to wastewater irrigation, i.e., personal characteristics and skills. GIS application and water sampling technique were employed to study the physical environment; questionnaires, in-depth interviews and participatory observation were used to investigate the social, economic and institutional environment that was hypothesized to influence farmers' managerial capacity. From the assessment of water quality, it can be seen that wastewater irrigation has the potential to be reused for farmers in terms of nutrient recovery and income generation as well as brings high risk for human health relating to pathogens. The factors that influenced farmer's capacities of wastewater irrigation governance can be categorized into: *Internal factors:* (1) age of farmers, (2) experience in wastewater irrigation, (3) knowledge and skill, (4) motivation in wastewater agriculture; *External factors:* (1) institutional environment including regulation on agricultural wastewater use, decentralized/centralized wastewater management, spatial separation on governance responsibilities of different department, state of participatory in local cooperatives; (2) physical environment such as climate change, diseases outbreak, constituent in wastewater; (3) social environment consists of social linkage and norms; (4) economic environment: consumer buying behavior and income from wastewater agriculture. This research concludes that the farmers' managerial behavior were driven more by economical and physical factors, while institutional and social factors appeared to discourage farmers from high performance in wastewater farming.

Keywords farmer managerial capacity, wastewater irrigated agriculture, sustainability and urban wastewater management.

INTRODUCTION

Due to the improper management of wastewater in many cities in Vietnam, a large number of urban and peri-urban farmers are engaged in the practice of wastewater for irrigation and aquaculture. Especially in Hanoi, the total area irrigated with wastewater is 43,778 ha involving 658,300 farmers (Raschid-Sally and Jayakody, 2008). Despite the amount of wastewater utilized by urban farmers, it is expected to increase due to the rising amount of wastewater generated from urban population, and the contribution of urban farmers to generate vast quantity of urban waste including solids and wastewater through agriculture practices (Brody Lee et al, 2010), these activities neither received much recognition by municipal's management authorities (Do et al., 2006) nor looked down by the community. Hence, wastewater unitization by urban farmers remains as informal, unplanned and spontaneous practices.

The farmers' managerial capacity of wastewater irrigation was studied from both individual aspect of farmers' management capacities (i.e. personal characteristics and skills including drives and motivations, abilities and capabilities and biography) and farmers' performance in the environment that is influenced by various factors. Boehlje and Eidman (1984) distinguished four major dimensions: (1) the institutional environment; (2) the social environment; (3) the physical environment; and (4) the economic environment.

MATERIALS AND METHODOLOGY

Study area: Two communities in peri-urban, Thanh Liet and Dong Ba in Hanoi were selected due to their typical practices of wastewater irrigation and characteristics of participatory irrigation management (Fig. 1).

Thanh Liet is located about 9 km to the southwest of Hanoi along the 2 major drainage rivers of metropolitan areas of the city (To Lich River to the East and Nhue River to the Southwest). Domestic and industrial effluent from urban areas of Hanoi is diverted to the field with an area of approximately 194.51 ha through pumping stations along the Tolich River, which involved 201 Farmer Households. There were 105 ha of agriculture land used for cultivating rice; however, due to contamination of wastewater, those rice paddies were converted to integrated rice paddy, aquatic plant and fish ponds. Fish and aquatic plant cultivation generates main income for farmers in Thanh Liet.

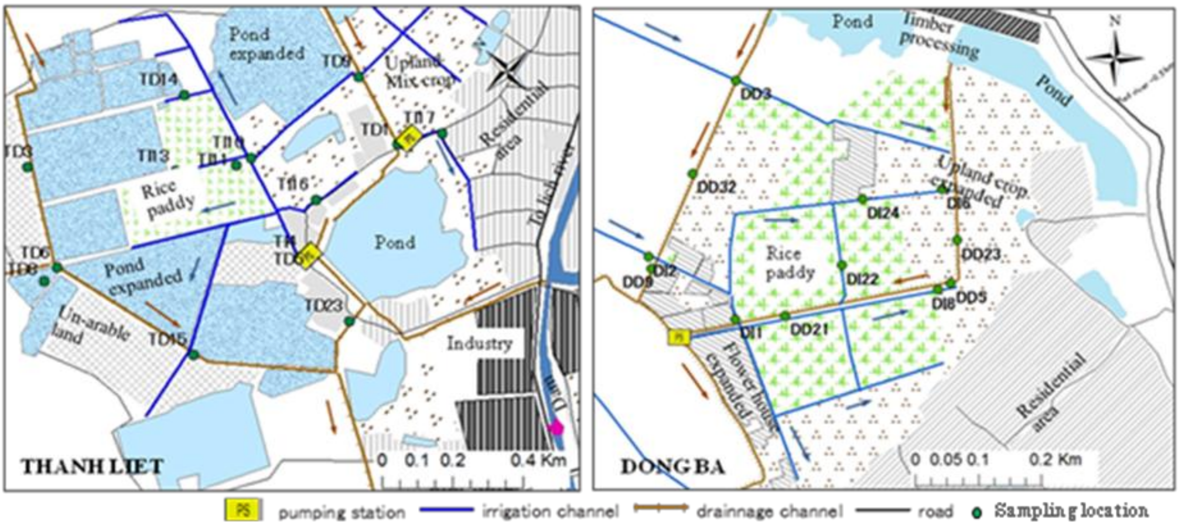

Fig. 1 Agricultural land use map of study areas: Thanh Liet (left) and Dong Ba (right)

Dong Ba is located about 15 km from the centre of Hanoi. In dry season due to water shortage, 24 ha of agricultural area are irrigated with diluted wastewater which is the mixture of rainwater and wastewater generated by the village's daily activities. The dominant crop is rice with a yield of 5.15 ton/ha. 525 farmer households in Dong Ba only produce rice for family consumption. Compared to Thanh Liet, agriculture production in Dong Ba does not have much economical value.

Site survey and water sampling: GIS device was used to map the study area, irrigation systems, water sampling points and cropping pattern. Physical characteristics of irrigation water (temperature, pH, conductivity) were measured onsite using Hanna Instruments, portable measurement instrument. Chemical characteristics were measured onsite using test kits from Kyoritsu Chemical Check Lab. Corp, Japan. Samples were stored in plastic bottles (PET) to examine Coliform and E.coli in laboratory using bacteria detection paper from SUNCOLI, Japan. The samples were then diluted and incubated in 35-37 °C for 24 hours.

Data from water sampling (Table 1) showed that many water quality parameters in both areas neither meet the National technical regulation on surface water quality - QCVN 08: 2008/BTNMT nor National Standard -Water quality guidelines for irrigation - TCVN 6773:2000, especially showing very high value of detected E.coli and total coliforms. However, when distributing into the plots, the quality of water showed some improvement from flowing through long distance of channels and undergone natural treatment (Fig. 2).

Table 1 Irrigation water quality in the study area at different points in March 2011

Parameter	QCVN	TCVN	Dong Ba		Thanh Liet			
Sample ID			DI31	DD9	TD22	TD24	TD31	TD32
pH	5.5 - 9	5.5 - 8.5	8.56	7.52	7.37	7.42	7.46	7.46
Conductivity (mS/cm)	-	-	0.27	0.32	0.67	0.65	0.89	0.99
Dissolved oxygen (mg/l)	≥4	-	>9	6	4	<1	<1	<1
Total Dissolved Solid (mg/l)	-	$\leq 10^{+3(1)}$	130	150	345	342	460	500
Chemical oxygen demand (mg/l)	≤30	-	5	20	20	45	120	120
Ammonia Nitrogen(mg/l)	≤0.5	-	1	5	>10	>10	>10	>10
Nitrate-Nitrogen (mg/l)	≤10	-	2	2	2.2	0.1	0	0
Phosphate –Phosphorus (mg/l)	≤0.3	-		0.2	1.5	1.1	2	2
Total Iron Fe^{3+}+Fe^{2+} (mg/l)	≤1.5	-	<0.3	<0.3	0.4	0.8	0.5	0.5
Copper Cu(mg/l)	≤0.5	-	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Zinc Zn (mg/l)	≤1.5	$\leq 1^{(2)}$ $\leq 5^{(3)}$	0.2	0	0.5	0.5	0.5	0.2
Lead Pb (mg/l)	≤0.05	≤0.1	-	-	0.2	0.5	0.5	0.5
E.coli (MPN/100ml)	≤100	$200^{(4)}$	200	-	233	1400	-	-
Total coliforms (MPN/100ml)	≤7500	-	38×10^4	-	26×10^4	23×10^5	-	-

Note:
DI31: sample taken at the inlet of Dan Phuong water gate.
DD9: sample taken at the drainage canal to the pump station in Dong Ba
TD24: sample taken at the Tolich river
TD22, TD31, TD32: samples taken at the Ba Xa drainage canals

(1) applied for agriculture land with irrigation system
(2) applied for agriculture soil with pH≤6.5
(3) applied for agriculture soil with pH>6.5
(4) applied for restricted crops (vegetables and crops that eaten raw)

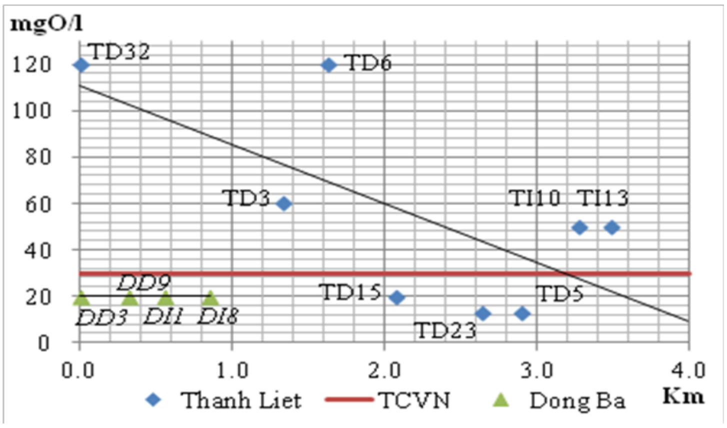

Fig. 2 Chemical Oxygen Demand (COD) variation along main channels, March 2011

The risk of diarrheal disease from consumption of vegetables irrigated with wastewater were estimated of 2×10^{-3} (WHO, 2006). Wastewater irrigation in the studied areas has some potential to be reused by farmers in terms of nutrient recovery (e.g. rich content of Nitrogen and Phosphorus) and income generation. However, it brings about high risk for human health relating to pathogen and other hazardous substances.

Interview and participatory observations: General information of the communities and agriculture activities of the farmers were obtained from key informants. Combined informal interviews and participatory observation were conducted to farmers either at the field when working or at their homes.

A total of 29 farmers were interviewed from both areas (Thanh Liet 13/Dong Ba 16). The number of female participants outnumbered men (18 female /11 male farmers). Most farmers interviewed were between age 40 and 60 (72.4%); all were literate with primary and upper education and most were involved in rice cultivation. Farmers in Thanh Liet were more exposed to wastewater than Dong Ba farmers in terms of exposure time and concentration of wastewater because they spend more time on the field for vegetable farming. Most farmer households have access to hygienic latrines with septic tank while fewer farmer households have access to tap water.

RESULTS AND DISCUSSION

Perceptions on wastewater irrigation: Farmers in Thanh Liet have more experience in wastewater agriculture compared to farmers in Dong Ba. They have more knowledge about the contaminants and risk posed by wastewater, mainly from physical symptoms and experience of diseases. Dong Ba farmers on the other hand are more concerned about invisible risks since they were informed by various channels such as the media or relatives or neighbors, but they insisted that the irrigation water in Dong Ba is from Red river, and therefore it is clean.

Regarding willingness of farmers to adopt measures in 2 study areas, 59% farmers agreed to wear protective clothes; and 76% consider that keeping food and drinks hygienic are effective to keep their physical health.

Behavioral outcome: It is observed that many farmers in Thanh Liet wear protective clothes, especially rubber gloves and rubber boots to protect the skin from contacting the wastewater. This practice can be seen on both women and men. In contrast, very few farmers in Dong Ba answered that they wear gloves and boots, and many of them said it is not necessary and uncomfortable.

Endogenous environment: Managerial capacity can be reflected from age and experience of farmers. Most farmers interviewed were aged above 40. Hence, they gained more experience in managing the farm including irrigation to increase productivity compared to younger farmers. Through practicing wastewater agriculture they receive more knowledge and develop management skill to minimize wastewater risks on crops and health. But on the other hand, old farmers were more hesitating to new technology adoption or carry out new experiments on crops; they prefer their own way of farming that resulted from many years of experience or learnt from parents.

Motivation in farming also affects farmer's managerial behavior by encouraging them to develop knowledge and skills, invest labor and money in wastewater irrigation techniques to increase productivity. Income from fish and flower farming in 2009 ranges from about 150 mil to 700 mil VND (7,500- 35,000 USD) per ha a year, therefore farmers have more motivation to invest money and labor to improve irrigation condition, i.e. making settling ponds or pumping oxygen to boost wastewater treatment processing in the pond and extracting groundwater.

Exogenous environment: The quality of water seems to affect the crop pattern. Thanh Liet farmers show more adaptation than Dong Ba farmers, they shift from rice to other aquatic vegetables. For over the past 10 years, it is estimated that rice paddies were converted to more than 60 ha of fish pond area of a total of 85 ha in Thanh Liet. While in Dong Ba, 9 ha area of rice paddy were converted to flower field (Fig. 1).

Sewage and drainage systems in Thanh Liet and Dong Ba were not served by Hanoi Sewage and Drainage Company (SADCO) but were provided by local irrigation, drainage and sewerage sectors under the Commune's PCs. Wastewater discharged from the communes' everyday activities were collected through combined covered sewage ditches. These ditches transport wastewater to open drains or nearby ponds, being the water area in the commune without any treatment of effluent. Some ditches are connected directly to irrigation channel or drain channel in the agriculture areas. Wastewater irrigation management by farmers in these areas were recognized as informal, short-term and self-interested due to the separation of farmers from urban wastewater management, ignorance of wastewater irrigation agriculture in the urban food supply chain and lack of regulation relating wastewater reuse and food safety for wastewater irrigated crops. In addition, centralized urban wastewater system in Hanoi makes barriers for farmers in utilizing nutrients in wastewater without bearing the risks of hazardous constituents.

Participation in wastewater irrigation is a fundamental concern for wastewater governance at local level. However, farmers are less motivated to participate and are more dependent on LCs management scheme (normally 2 or 3 times a week), or by the state if the water is taken from Red River through Dan Phuong water gate (about 1.5 km away from Dong Ba). They only need to pay for irrigation service fee and leave the rest to the LCs' responsibilities.

Physical environment includes weather, diseases on crops and state of wastewater influence on productivity, cropping pattern and agricultural land use. These physical factors could either encourage or discourage farmers' motivation to improve the irrigation condition.

Weak social linkage among farmers, between farmers and local authorities, and between farmers and consumers influence the information sharing, which prevent them from applying innovation in farming. Moreover, the contamination of irrigation water seems invisible and is not considered important compared to the normal understanding of dirt. These results are not enough motivation to improve irrigation quality, while more efforts are put on making products look fresh and clean.

Economic environment plays an important role in controlling farmers' behavior toward economic benefits and consumer buying habits. Most of wastewater crops and fish were supplied to urban or nearby markets. However, consumers are not aware of the irrigation aspect but only care about appearance and price. This further induces farmers to produce cheaper products with nice appearance, while, according to farmers, investment in better irrigation conditions does not bring much benefit compared to selling wastewater irrigated products.

SIGNIFICANCE OF THE STUDY

Wastewater irrigation system in Hanoi peri-urban agriculture and urban wastewater management system were found as an integrated system. Despite being linked together regarding urban wastewater and urban food chain, waste-water farmers behaved independently and self interested among peers and others, which results in some short terms measures such as to generate income from wastewater fed fish ponds, aquatic plants or non-food crops, to reduce occupational health risks or to keep food and drinks clean to improve health.

Factors that influence farmer's capacities of wastewater irrigation governance are determined as: internal factors: (1) age of farmers, (2) experience, (3) knowledge and skill, and (4) motivation in waste-water agriculture; external factors: (1) institutional environment including regulation on wastewater use in agriculture, decentralized/centralized wastewater management, spatial separation on governance responsibilities of different departments, state of participatory in local cooperatives; (2) physical environment such as climate change, diseases outbreak, constituent in wastewater; (3) social environment consisting of social linkage and norms; and (4) economic environment: consumer buying behavior and income from wastewater agriculture.

Farmers' behavior was more driven by economical and physical factors while institutional and social factors appeared to discourage farmers from high performance of farming.

Findings from this research were more focused on personal characteristics of farmers and the external factors that influence management capacity of farmers on wastewater irrigated agriculture. However, it is suggested that farmer's managerial capacity should involve decision making process to try to optimize, or at least influence the technical and biological process at farms and to include the assessment of farm results. Nevertheless, a farmer who has favorable characteristics is more likely to have good results in management practices even if there might have some faults in his decision making process.

RECOMMENDATIONS

From the dynamics of internal and external driving factors, the authors suggest that more efforts should be made in institutional and social aspects of urban wastewater management relating to reuse of wastewater taken by farmers. The resilience transition of the system could be enhanced by empowering farmers' managerial capacity toward institutional and social environment. Two mechanisms for strengthening farmers' managerial capacity on wastewater governance via wastewater irrigation are proposed, i.e. strengthening social participation and institutional involvement of farmers.

Farmers should be more involved in the management of wastewater irrigation practice. There is a need for a farmer organization, which acts as a wastewater user association. This organization should be given full authority including planning, design, operation, maintenance, re-habilitation, resource mobilization and conflict resolution.

Cooperation of different governmental bodies and stakeholders along the urban wastewater chain and food chain are vital for supporting and strengthening farmers' managerial capacity. Each stakeholder has to recognize the common goal of safe wastewater irrigated products. Farmers should be recognized as the stakeholder in the management of urban wastewater systems. In this manner, farmers could have access to information to get control over risks and to optimize benefits from wastewater reuse and at the same time, have responsibility over their products. This could therefore prevent farmers from behaving like self-interested or *spot-market,* and could lead to more sustainable and long-term management.

Projects relating farmer capacity building for wastewater irrigation in particularly, NGOs and donors should consider managerial capacity of farmers within the wastewater farming. Farmers are more likely to participate in irrigation management if they have more motivation in wastewater agriculture and they could count on wastewater irrigation as the provision of their livelihood.

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