WORKING PAPER 30

Wastewater Reuse in Agriculture in Vietnam: Water Management, Environment and Human Health Aspects

Proceedings of a Workshop held in Hanoi, Vietnam 14 March 2001

Liqa Raschid-Sally, Wim van der Hoek and Mala Ranawaka, editors

IWMI International Water Management Institute

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Cover photograph by Wim van der Hoek: Wastewater irrigated rice fields in Thanh Tri, Hanoi.

Contents

Acronyms

BOD	Biochemical oxygen demand
COD	Chemical oxygen demand
DHI	Danish Hydraulic Institute
DO	Dissolved oxygen
E. Coli	Escherichia coli
ha	Hectares
$HClO_4$	Perchloric acid
HF	Hydro Fluoric acid
HNO_3	Nitric acid
IWMI	International Water Management Institute
K_2O	Potassium oxide
KVL	Royal Veterinary and Agricultural University
MPN	Most Probable Number
N:P:K	Ratio of Nitrogen:Phosphorus:Potassium
NH_4^+	Ammonium ion
NIHE	National Institute of Hygiene and Epidemiology
P_2O_{5-}	Phosphorus pentoxide
pH	Hydrogen ion concentration
SS	Suspended solids
TK	Total potassium
TN	Total nitrogen
TP	Total phosphorus
VIWRR	Vietnam Institute for Water Resources Research
WAterSPS	Water Sector Program Support
WHO	World Health Organization

Map of Vietnam

Foreword

Wastewater reuse both for agriculture and aquaculture is a centuries old practice in Vietnam and needs no explanation. However, it was clear from preliminary discussions with our Vietnamese partners, that no attempt had so far been made to analyze the issues of wastewater reuse for these purposes in a systematic manner and to document these. In particular, though the potential health and environmental risks related to reuse are well known in general terms, and the economic costs and benefits acknowledged, no effort had been made to integrate these key aspects into an analytical framework which would provide useful information to policy makers in countries like Vietnam, faced with tough trade-off decisions. What level of treatment do we really need before using wastewater? What are the likely risks and how can these be offset?

To respond to these questions and as a first step, an inception workshop was organized on 14 March 2001 in Hanoi, gathering experts from the various disciplines such as health, environment, water resources management, irrigation, agriculture, soil sciences, water quality, etc. to discuss the findings of 16 papers on different aspects of wastewater reuse. The proceedings of this workshop are presented here in summary form, which we hope will provide a bird's-eye view of the current knowledge in Vietnam on this subject to a wide spectrum of interested persons.

Concrete results from this first situational analysis are a recommendation to carry out a nationwide survey on the current status of wastewater reuse for peri-urban agriculture and aquaculture in key cities in Vietnam, and three reviews on foodborne trematode infections, cysticercosis, and intestinal helminths in Vietnam. These reviews are now underway.

The editors wish to acknowledge the contributions of the various authors and the editorial board comprising persons from the different partner institutions who helped to edit the papers into their final format.

These proceedings are the first output of the DANIDA funded project on Wastewater Reuse for Agriculture in Vietnam. The partner organizations thank DANIDA for their support in funding the activities under this project.

Wastewater Reuse in Agriculture in Vietnam: Water Management, Environment and Human Health Aspects

Nguyen Tuan Anh, Director, Vietnam Institute for Water Resources Research

I am very happy for this opportunity to welcome you all at this workshop on *Wastewater reuse in agriculture in Vietnam: Water management, environment, and human health aspects.*

Rapid population growth, urbanization and the looming fresh water crisis have increased the need for wastewater reuse in agriculture in many countries.

In Vietnam, wastewater has been used for centuries by farmers as a cheap and reliable source of water and nutrients, for agriculture and aquaculture. Nowadays domestic and industrial wastewater is widely used, especially in the suburban areas. Products from this type of wastewater reuse are at low cost and contribute significantly to food production in Vietnam.

Despite the widespread reuse of wastewater, its significance has not received adequate attention. Being a low-income country, Vietnam is unlikely to be able to provide adequate wastewater treatment infrastructure. Little is known about the use of untreated wastewater in agriculture, its advantages and limitations, except that it is widespread and unregulated.

Encouraging wastewater reuse in agriculture has important economic and environmental benefits, such as conserving water and utilizing nutrients. However, using untreated wastewater also poses certain environmental and health risks, including environmental health risks to users and consumers of products utilizing wastewater.

To address this situation, with support from the Ministry of Agriculture and Rural Development, the International Water Management Institute (IWMI), the Royal Veterinary and Agricultural University (KVL), the Danish Hydraulic Institute (DHI), the National Institute of Hygiene and Epidemiology (NIHE), the Vietnam Institute for Water Resources Research (VIWRR) organized a Workshop on *Wastewater reuse in agriculture in Vietnam: Water management, environment, and human health aspects.*

Today's gathering of highly experienced and qualified experts, and researchers is mainly to share knowledge, information and experience on various issues of wastewater reuse in agriculture in Vietnam. Such an exchange and sharing of acquired knowledge and skill will help promote our understanding of issues related to infrastructure of wastewater disposal and treatment systems, wastewater reuse customs, water and soil quality as well as human health related to wastewater reuse. For the Vietnam Institute for Water Resources Research this is a unique chance to enhance its experiences and update its information and knowledge on this important aspect.

I am confident that the participants will make every effort to exchange their respective expertise. I do hope that the workshop will explore ideas and suggestions for developing research for wastewater reuse in agriculture in Vietnam effectively.

At this opening ceremony, I, on behalf of the Vietnam Institute for Water Resources Research, would like to extend a warm welcome to all the distinguished local and foreign delegates, guests, and participants in this workshop.

May I take the honor to declare open the conference on *Wastewater reuse in agriculture in Vietnam: Water management, environment, and human health aspects*.

I wish you all success at this workshop. Thank you.

Denmark-Vietnam Water Sector Program Support

Lars Skov Andersen, Sector Program Coordinator, Danida

Introduction

The Water Sector Program Support (WAterSPS) is the umbrella for Danish-Vietnamese Development Cooperation in the water sector and as such an important interface for the study on Reuse of Wastewater in Irrigated Agriculture.

Danish Development Assistance to Vietnam

The WAterSPS provides and administers grant assistance to capacity building and implementation of national sector programs that are given high priority by the Government of Vietnam, and which concur with the overall policies for Danish development assistance.

WAterSPS

The WAterSPS has four thematic components with a total of 15 Sub-Components defined at the beginning of program implementation (figure 1). The main objective of the WAterSPS is to support the implementation of the Law on Water Resources that came into force in 1999, and the National Rural Water Supply and Sanitation Strategy that was approved by the Government in 2000. These documents introduce far reaching reforms for the future management of Vietnam's water resources and for assistance to improved water and sanitation in rural areas. Components 1, 2 and 3 of WAterSPS have been designed to support these reforms and implement new procedures at national, river basin and provincial levels.

Interfaces

The WAterSPS supports the Institute for Water Resources Research, which is the main Vietnamese counterpart for the Wastewater Reuse Project, and Danida has, since 1993, supported a wide range of water projects in Dak Lak, which is one of the focus areas of the Wastewater Reuse project.

The WAterSPS support to VIWRR includes the introduction of the MIKE-suite of modeling software for water resources and environmental management. The modeling tools will enable VIWRR to assess the impact of wastewater discharges on water quality of receiving waters, and the potential for reuse in irrigation.

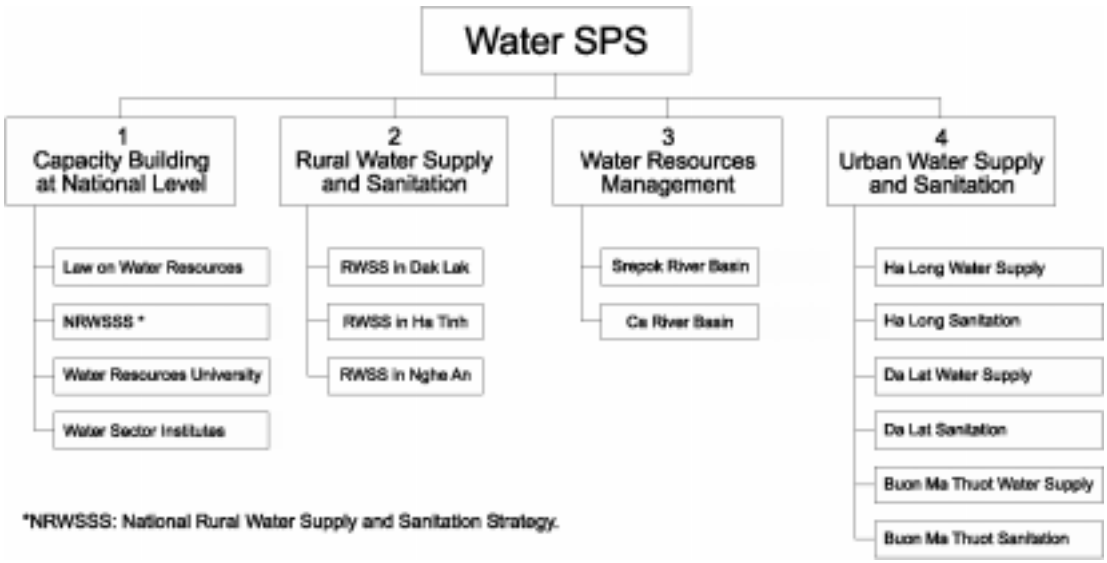
In Dak Lak, the main issue in water resources management is the competition for water between domestic uses and irrigation of coffee and rice, especially in the plateau surrounding Buôn Ma Thuôt City. A rapid increase of coffee cultivation since 1992 and extensive abstraction of groundwater for its irrigation has had a negative impact on domestic water supply for both rural and urban areas, as well as irrigation of rice, downstream of the coffee areas. In 1994 and

1995 Buôn Ma Thuôt City suffered critical water shortages, with daily supply falling to 2,000 m^3 or 10 liters per capita per day !

Buôn Ma Thuôt Urban Water Supply project (figure 1) will increase the abstraction of ground water for the city to 50,000 m^3/day by 2010. This will restrict cultivation of coffee in the source areas upstream of Buôn Ma Thuôt, but a systematic reuse of the urban wastewater may provide new opportunities for increased cultivation of coffee and other crops downstream of the city.

Buôn Ma Thuôt Sanitation project (figure 1) will improve the collection of wastewater from the city and construct a wastewater treatment plant to ensure an environmentally sustainable discharge of the wastewater. One of the criteria that has been set for discharge of the treated wastewater is that it can be reused for irrigation. Establishing realistic criteria for reuse in irrigation of different crops will thus be a valuable contribution to the sanitation project.

Figure 1. Components and subcomponents of the Water Sector Program Support.



Reuse of Wastewater, a Global Perspective

Wim van der Hoek, Theme Leader Water, Health and Environment, IWMI

Many cities in the developing world face a myriad of problems in providing water supply, solid and liquid waste management, and food security to their growing populations. Two-thirds of the urban wastewater generated in the world receives no treatment at all. In most cases, the wastewater is dumped in the most convenient surface water source, be it a river, canal, lake, or ocean. The costs involved in providing wastewater treatment facilities for all cities are astronomical. And even if the resources are available there is no guarantee that the situation improves. Many of the wastewater treatment plants are not functioning properly. This can partly be explained by the tendency of local authorities to request the 'best' and 'most modern' available technologies, rather than low-cost alternatives that might be more appropriate.

An alternative to the disposal of untreated urban wastewater in surface water is to reuse the water for agriculture. In this way wastewater may be seen as a resource, which provides an opportunity for increasing food security in rapidly growing urban areas. Advantages of reuse of wastewater in agriculture are that it:

- conserves water (by recycling and groundwater recharge);
- is a low-cost method for sanitary disposal of municipal wastewater;
- reduces pollution of rivers and other surface water;
- conserves nutrients, thereby reducing the need for artificial fertilizer;
- increases crop yields; and
- provides a reliable water supply to farmers.

However, there are a number of important disadvantages:

- health risks for the irrigators and communities who are in prolonged contact with untreated wastewater and the consumers of vegetables irrigated with wastewater;
- contamination of groundwater, especially with nitrates;
- buildup of chemical pollutants in the soil, especially heavy metals; and the
- creation of habitats for disease vectors such as mosquitoes in peri-urban areas.

The potential negative impacts on human health have always been the main concern in relation to wastewater reuse. However, there are many misunderstandings around this issue and it is helpful to review the history of wastewater reuse.

In the second half of the 19th century, when cities were growing there was a lot of public and official support for wastewater farming which was seen as a method to prevent pollution of

rivers and to retain nutrients. In the 20th century we became aware of bacteria and other microorganisms and people started to question the safety of wastewater irrigation. As a result water quality standards were set and included in new legislation to restrict wastewater irrigation. The standards had no scientific basis but were very strict and reached a level of authority, first in the USA and later in many other countries. Standards were very strict and could only be achieved with expensive treatment. Therefore most public health engineers in developing countries decided that it was better to do nothing than to get involved in something that was unable to meet the government quality standards. It was not until 1986 that a World Bank commissioned study (Shuval et al. 1986) reviewed all epidemiological evidence. The main conclusion was that standards had been overly restrictive because there was a difference between a potential risk when there are pathogens in the water and an actual risk of people falling ill, which depends on several other factors. They suggested a standard of < 1000 fecal coliforms per 100 ml for unrestricted irrigation, much more lenient than the previous guidelines. On the other hand, there was increasing evidence that worm infections were the major problem and the standard was set that wastewater used for unrestricted irrigation should contain no more than 1 worm egg per liter of water.

We seem to be back to the situation of a century ago. There is now increasing awareness that we have to prevent pollution of surface water and that we should recycle valuable nutrients. And the world now faces new problems: water scarcity, population increase, and mega-cities with sanitation problems that nobody can solve. For all these reasons it is quite likely that many towns in developing countries will expand irrigation with untreated wastewater. Governments may wish to regulate reuse but are unable to offer practical solutions to the users. Developing a framework for evaluating the different options and tradeoffs, for informed decision making is therefore an urgent matter.

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Wastewater and its Treatment System in the Southern Part of Vietnam

Trinh Thi Long, Southern Institute of Water Resources Research

Objective

The objective of the study was to describe in brief:

- the wastewater sources, characteristics, and the existing wastewater treatment work in the southern part of Vietnam;
- their advantages, disadvantages and problems being faced; and
- present some examples of systems commonly used in Vietnam for wastewater treatment before reuse in agriculture.

Methods

Published reports and the authors' personal knowledge and experience were the sources of information for this paper. The author analyzed and interpreted the existing information and summarized it under the various topics outlined in the objective.

Results

Characteristics of Wastewater from Cities of Southern Vietnam

The four main sources of wastewater are domestic, industrial, rainwater run off, and agricultural activities. Rapidly growing cities like Ho Chi Minh City and other industrialized cities are facing environmental pollution problems, especially water pollution, due to discharge of untreated wastewater. In Ho Chi Minh City alone there are more than 800 central and local industries, and more than 30,000 varied service enterprises both large and small. With the current rate of economic development in Vietnam, many industrial and processing zones have been established, such as: Long Binh, Vung Tau, Tan Thuan, Linh Trungthat. Very few of the factories have, as yet, local wastewater treatment systems, and all wastewater is discharged to the sewage system or directly discharged into the canals or rivers. Every day HCM City discharges about 938,000 m^3 of wastewater to the receiving water bodies. The total waste load is about 450,000 kg Biochemical Oxygen Demand (BOD) per day. Some analytical results of wastewater at main discharge sewers of the city show that the wastewater Dissolved Oxygen (DO) is very low 0–1.2 mg/l, and that Chemical Oxygen Demand (COD) fluctuated from 40–200 mg/l, Suspended Solids (SS) was 30–400 mg/l, BOD varied between 20–140 mg/l, organic nitrogen was 0.5–8.3 mg/l, and Ammonia was 10–90 mg/l.

In rural areas with agricultural activities, pesticides, fertilizers and livestock breeding are also sources of pollution. Pesticides are soluble in water, and they therefore, concentrate in some of the sites that receive drainage water from the fields. Rough estimates show that the concentration

of these chemicals is high in the soils and water and exceed the standards for surface water, especially during spraying, and could provoke the death of shrimp and fish. It is estimated that every year in the Mekong Delta about 2000–3000 tons of chemicals are used for plant protection. Increasing livestock populations pollute both soils and surface waters (pools and rivers) and even shallow groundwater.

Actual Situation of Wastewater Treatment Work in the South

In spite of Vietnam having an Environmental Protection Law for the last five years, the real problem is that environmental technology in Vietnam is still very weak and needs investment. Presently, most of the wastewater treatment systems are not designed for industrial conditions. In general, in the southern province, wastewater treatment is more prevalent. But this is true mostly for industries that are either joint-venture companies or have 100 percent capital from abroad, or for a few state-managed industries. Private and local small industries like handicraft show almost no progress. Various commonly used treatment technologies are applied but there are still limitations to their proper functioning. Some of the common reasons are over loading, complex composition of wastewater, insufficient operational budgets, lack of experience and technical skills for design, construction, operation and maintenance.

Wastewater Treatment for Recycling in Agriculture

Wastewater reuse has not received much attention in Vietnam, although it has been used widely in agriculture and fishery because it is cheap and contains many nutrients. Wastewater from livestock breeding, and some agro-industries is also recycled for biogas production. The BIOGAS model and the VAC model (pig sty– fish; pond–garden) are both popular in Vietnam, for treating and recycling wastewater for fishery and planting. However, these models have only been applied on a small or moderate scale. They can be applied on a large scale as examples from Thailand and the Philippines show. In some countries, constructed wetlands are used to treat wastewater before reuse. This type of system consists of a series of plots filled with crushed brick, sand, and gravel. The plots are lined with plastic to prevent waste from leaching into groundwater, and are planted with native wetland plants to aid in wastewater treatment. These constructed wetlands mimic nature by mechanically filtering, chemically transforming, and biologically consuming potential pollutants in the wastewater stream.

Conclusion

- Some limitations exist concerning environmental management and control in Vietnam. These are: insufficient attention paid to environmental pollution issues at all levels; poor policy and minimal investment in treatment measures; limited knowledge, skills and experience in environmental issues; lack of awareness, and resistance towards investing in treatment plants by polluters.

- Anaerobic digester technology has not been applied in Vietnam for treating waste in spite of its applicability for Vietnam’s climatic conditions, and characteristics of waste.

- Vietnam should apply international approaches to wastewater management, such as "prevention is better than abatement;" "choose cleaner technologies," and "reduce pollution at its source," and establish legislation and standards.

- Conventional solutions to wastewater treatment are expensive, and use of low-cost options must be encouraged. Viable systems utilized on a small scale are available, and these should be extended for use on a wider scale.

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Impacts of Hoa Khanh Industrial Zone on Bau Tram Reservoir

Chu Phuong Chi and Nguyen Hoang Thao, Center for Water Resources of Central and Highland

Objective

The Bau Tram reservoir, about 10 km northwest from Danang city, has a water surface area of 61 ha with a capacity of 1.2 million cubic meters. The reservoir was constructed in 1961 to irrigate 120 ha of alternate rice and dry crops. Thanks to the reservoir, the number of crops increased from one to three per year and the rice yield increased to around 6 tons per ha per season. In addition, aquaculture was developed and was a large benefit to the local people with an annual fish production of 100 tons. However, after the establishment of the Hoa Khanh industrial zone in the 1990s, wastewater released from this industrial zone was flowing to the Bau Tram reservoir at 436 cubic meters per day.

This study assesses the content of wastewater released from the industrial zone into the reservoir. Also, the study aims at evaluating the impact of wastewater released into the reservoir on the major sectors using water from the reservoir.

Methods

- Water ssamples (12 samples) were collected from the wastewater released into the reservoir and from the reservoir itself. The water samples were analyzed in the laboratory for physical and chemical characteristics to assess the pollution.

- A field survey was undertaken in the study area: Interviews were conducted among water users, scientists representing various sectors and managers in the system to identify the benefit from the reservoir and the damage caused by wastewater released into the reservoir. The before-after method was used for evaluation of the impacts of wastewater inflow into the reservoir on selected sectors.

Results

The water quality of samples from the reservoir shows values higher than that permitted by the Vietnam Standard 1995; with measured levels of COD exceeding the standards by 1.9-3.2 times, and BOD_5 and heavy metals also exceeding the standards permitted.

Pollution of the reservoir causes losses of rice output (155.6 tons of rice annually) to the community using water from the reservoir. At an early stage rice grew normally but when the rice was in ear, its roots decayed. In the autumn crop, rice died after planting. It has been clarified that the damage, which is not caused by any insect, affects all areas irrigated with water from the reservoir.

Because water in the reservoir was severely polluted, the cultivation of fish was prohibited in the Bau Tram reservoir in order to protect the consumers' health.

Conclusion

Since the Hoa Khanh industrial zone was established and its wastewater released into the Bau Tram reservoir, it has resulted in severe pollution because wastewater either has not been treated or has been treated insufficiently. The pollution of the Bau Tram reservoir has caused a number of direct and indirect impacts:

- Direct damages to agricultural production to the north of the reservoir with hundreds of tons of rice being lost due to reduced productivity, and aquaculture production coming to an end.
- Contamination of drinking water sources.
- Damage to the natural ecology in the region.

In order to protect the water sources of the Bau Tram reservoir, and prevent increasing pollution sources, it is recommended that:

- Factories and production units be encouraged to construct new wastewater treatment systems, and repair old systems that are not effectively operated so that treatment standards are met.
- Future projects must include environmental impact assessments under the instructions of the Department of Science, Technology and Environment of Da Nang city.

However, it would be very difficult and impossible, in the short term, to address this issue. This industrial zone is very important for the development of the country in general and the region in particular, thus any measures selected should be carefully examined and considered. We think that this problem can only be solved with technological solutions.

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Treatment of Domestic Wastewater and its Reuse in Farm Irrigation in the Red River Delta

Vu Thi Thanh Huong, Center for Irrigation and Water Supply, Vietnam Institute for Water Resources Research

Objective

Though domestic wastewater is a good source of fertilizer for plants, it is also a source of environmental pollution and a medium where different microroganisms of importance to human health can exist. Therefore, it is important to study the reuse of wastewater by considering both farming practices and hygienic conditions of the farmers. The study assesses a model for wastewater treatment and reuse in the Red River Delta (RRD). The model is based on wastewater treatment through biological ponds combined with its reuse as a source of irrigation in rice fields.

Methods

- Selection of two typical communes in the RRD to study the wastewater treatment approach using a biological pond system. The two communes include the Van Phu commune in Thuong Tin district, Hatay province and the Binh Duong commune in Vinh Tuong district, Vinh Phuc province.

- Assessment of wastewater characteristic (50 samples), effectiveness of the treatment (96 samples of treated wastewater), improvement of water environment (40 samples were taken in villages before and after construction of village wastewater treatment systems). Methods for assessment and analysis were based on Vietnam Standards for the following major parameters: pH, Suspended solids (SS), COD, BOD_5, ammonia (NH_4^+), coliform bacteria, nitrogen, phosphorus, and potassium.

Results

Domestic Wastewater Characteristics

Domestic wastewater in rural areas includes waste from humans, food processing, washing, and animal wastes that often accumulate in small and stagnant sewage ponds or even along hamlet pathways. The suspended sediment in the wastewater was 271.4mg/l; COD was 367.8mg/l; BOD_5 364.2mg/l; NH_4^+ 17.6mg/l and coliform bacteria-$32x10^5$MPN/100ml. Pollution concentration was about 10-100 times higher than the acceptable level for use in agriculture. The ratio of BOD_5/ COD was about 0.69 indicating that the biological treatment method would be highly effective.

The total nitrogen (TN) varied from 81.6mg/l to 94.6mg/l, total phosphorus (TP) was between 16.7 and 20.1mg/l and total potassium (TK) between 36.7 and 41.6mg/l. The average ratio of N:P:K was 4.7:1:2.1. The analysis of the wastewater indicates that a combination of biological treatment processes and a subsequent reuse in agriculture would be the best combination.

Effectiveness of the Treatment in a Biological Lake

After 20 days of treatment, BOD_5 was reduced between 76.4 percent and 93.8percent, COD decreased by 61.1percent-85.4percent, NH_4^+ was reduced by 36.6 percent-45.6percent and suspended matter was reduced by 58.7 percent-75.6 percent. Likewise, total nitrogen was reduced by 16.9 percent-37.2 percent, phosphorus by 9.9 percent-26.8 percent, potassium by 8.8 percent-22.8 percent, coliform bacteria by 79.0 percent-96.5 percent and E. coli by 79.5 percent-98.2 percent. These improvements fall within wastewater standards for agriculture reuse (TCVN-5945 -1995).

Wastewater Reuse in Rice Field Irrigation

Each 1000m^3 of treated wastewater may contain an average of 52.9kg of N, 13.9 kg of P_2O_5, and 28.0 kg of K_2O. This is a good source of fertilizer for plants. Based on this information the optimum use of wastewater can be determined for each crop. The seasonal wastewater requirement for irrigation was determined based on results of field studies assessing best irrigation regime and defining irrigation guidelines for rice and other plants carried out by the Vietnam Institute for Water Resources Research (QT-NN.TL-9-78). The optimal use of wastewater also depends on plant fertilizer requirements, geological, hydrological, climatological, and pedological conditions and local farming practices.

As determined, wastewater reused for spring rice irrigation was 2,563.6m^3/ha (accounting for 47.6 percent of total water demand of the whole season); for maize it was 1000m^3/ha (accounting for 35.7%); and for potato 902.2 m^3/ha (accounting for 34.2%). Wastewater reuse and fertilizer utilization should be combined to ensure adequate nutrition requirement for plants. With regard to using wastewater for irrigation of ploughed soils, the concentration of suspended solids, after 5 days of irrigating on 50 m^2 testing slots (three sets were tested), decreased by 23.7 percent, BOD_5 decreased by 74.6 percent, COD reduced by 63.8 percent, nutrition matters decreased by 73.3-79.3 percent, total coliform fell by 97.2 percent, and E. coli was reduced by 98.6 percent.

When using wastewater for irrigation of spring rice in the branch growth phase, the concentration of suspended solids, after 5 days of irrigating, decreased by 33.5 percent, BOD_5 was reduced 85.6 percent, COD by 71.3 percent, coliform by 99.3 percent and E. coli was reduced by 99.0 percent. Nutrients fell between 68.3 percent and 82.8 percent.

Conclusion

Treatment of wastewater using biological reservoirs is a simple but effective and appropriate method for the prevalent economic conditions and management level of the people in the Red River Delta. The process results in:

- improvement of the environment, and water quality;
- effective use of the water resources and increase in the community's interest in environmental protection activities.

Domestic wastewater treatment combined with the use of treated wastewater does not only save water and fertilizer for the farmers but is also significant in decreasing the scale of the treatment facilities and the level of investment.

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Wastewater Problems and its Potential to Contaminate Clean Water Sources in Hanoi

Vu Kim Tuyen and Nguyen Xuan Tang, National Centre of Natural Science and Technology

Objective

Wastewater of Hanoi City is discharged untreated, which has resulted in contamination of the city's clean water sources. It is essential to find a solution to protect the water source. This study was aimed at assessing the present status of water pollution caused by wastewater in Hanoi.

Methods

Data on chemical, physical, and bacterial quality of surface and groundwater were collected. The hydraulic relationship between surface water and groundwater, and influence of the exploitation of water sources in the Hanoi area were investigated to assess the pollution of water sources by wastewater in Hanoi.

Results

At present, the surface water system of the city is very polluted. Approximately 500,000 m^3 of wastewater is produced a day in Hanoi City, which is neither managed nor collected nor treated properly. This, in turn, pollutes the surface water system causing a bad odor in the city.

Contaminated water from the surface water system infiltrates into the soil and pollutes the groundwater sources of the city. Groundwater from some wells being exploited as potable water source in the south of the city is also polluted.

In the Nhue River System, the contaminated water flowing from the small rivers caused a bad odor in the surroundings. In addition, this river water is used to irrigate vegetables and runs into fishponds causing contamination of the soil.

Conclusion

It is very important to recognize the existence of pollution in the environment, especially the water sources in Hanoi City. An investigation to protect the environment and water sources of the city is imperative. The following measures are suggested:

- Better management, exploitation and sensible use of clear water sources in Hanoi.
- Consolidate and enhance management and treatment systems of wastewater in Hanoi.
- Community education about environmental and water sources protection.

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Urbanization and Wastewater Reuse in Peri-Urban Areas: A Case Study in Thanh Tri District, Hanoi City

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Objective

The aim of this study was to better understand the impact of urbanization on agriculture in peri-urban areas. The following research questions were addressed:

1. What is the impact of loss of cultivable land on flooding?
2. How does urbanization affect the transformation of the agricultural system?
3. What role does wastewater reuse play in these developments?

Methods

The study was carried out in Thanh Tri, a lowland area on the outskirts of Hanoi, which has undergone rapid urbanization. Most of the wastewater of the capital flows via natural rivers to Thanh Tri district, where it is reused for agriculture and aquaculture. Secondary data were collected on population and cultivable land over the period 1960–1993. Water samples were taken at 6 locations along the rivers that convey the wastewater and from three wastewater-fed fishponds. Additional information was collected through interviews with experienced agronomists and through rapid assessments of the situation in communes in the area.

Results

1. *Loss of cultivable land and flooding*
   - Over the period 1960–1993, the area of cultivable land per inhabitant decreased by 2.8 percent per year.
   - Flooding events and duration have increased between 1984 and 1994.

2. *Transformation of the agricultural system*
   Urbanization causes the loss of cultivable land and increases flooding. However, it also creates a larger consumer market, which stimulates the development and diversification of the agricultural systems. Important is the change to crops such as vegetables that are more profitable than rice and expansion of aquaculture.

3. *Urbanization and wastewater reuse*
   3.1 Characteristics of wastewater from Hanoi to Thanh Tri district
   Upstream river water samples contained elevated levels of copper and lead. Levels of cadmium, mercury, chromium, nickel, and arsenic were all below permissible standards. Suspended solids, pH, BOD, COD, and hydrogen sulphide concentration in the fishponds were below permissible standards.

3.2 *Wastewater reuse for fishery*

Over the last 30 years farmers have gained a lot of experience in wastewater-fed aquaculture. Different fish species are cultured and the yield is increasing. Compared with non-wastewater-fed fishponds, the fishing under wastewater gives yields that are 2-2.5 times higher with financial benefits that are 2-3 times higher.

3.3 *Wastewater reuse for rice and vegetable cultivation*

Compared with non-wastewater fields, the yield of rice under wastewater gives 10-15 percent higher yields and 10-20 percent higher financial benefits. Farmers have found that vegetables grow better when wastewater is diluted with fresh water or when the effluent from fishponds is used, instead of the raw wastewater.

3.4 *Pollution and human health*

The survey and data from hospitals show very high incidence and prevalence of eye and skin diseases in Thanh Tri.

Conclusion

Thanh Tri receives most of its wastewater from Hanoi. It is an area undergoing urbanization and this leads to a loss of cultivable land and increase in flooding. The agricultural system is changing with reuse of the wastewater for high value crops such as vegetables and aquaculture. Wastewater reuse for rice and vegetable cultivation and aquaculture leads to increased yields and financial benefits. However, the quality of the products is uncertain. Of concern is the high burden of disease among the population, which could, to some extent, be related to the reuse of wastewater in agriculture and aquaculture.

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Impact of Wastewater on Water Quality in Irrigation System and Treatment Measures to Reduce Pollution: A Case Study in Nhue Irrigation System

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Objective

The Nhue River Irrigation System covers areas of the two provinces of Ha Tay and Nam Ha as well as Hanoi City. Of the total area of 107,530 ha, the system command area is 49,247 ha and the population of this area is 2,954,089.

The objective of the study was to evaluate impacts of wastewater from Hanoi city on water quality in the Nhue irrigation system and identify treatment methods to reduce water pollution, preserve the environment, crop production and human health.

Methods

The approach adopted was to test different dilution ratios in order to identify appropriate dilution levels for intake operations in the irrigation system. Experiments were carried out by mixing water samples taken from the Hong River (at Lien Mac sluice) and from the Nhue river at the To bridge with fresh water. These samples were diluted in different proportions ie., 5 percent, 10 percent, 15 percent, and 20 percent. A mathematical model was used to identify hydraulic parameters such as flow, water level, and substance transmission to identify appropriate alternatives.

Results and Conclusion

Waste Sources

At present, the total wastewater discharged from the city is 335,000 m^3/day. Of this, 115,000 m^3/day comes from industries, accounting for 27–30 percent of the total wastewater. The domestic wastewater released from Hanoi accounts for 70–73 percent of the total wastewater. The wastewater volume from the hospitals is 5,321 m^3/day along with more than 26 tonnes/day of solid waste. Although this source of wastewater accounts for only 1.4 percent of the total municipal wastewater it is a serious threat to the environment.

The results of the water analyses along the Nhue River carried out in 1996 and 1997 show that water quality changes from location to location. At the Lien Mac sluice, water quality was still good with dissolved oxygen (DO) at 7.5 to 8 mg/l, the five-day biological oxygen demand (BOD_5) at 2 mg/l, and the chemical oxygen demand at 4 mg/l. At the Cau Dien section, where sewage from dense residential areas and wastewater from factories are released directly to the river, the river water was lightly polluted with higher BOD_5 and COD, and a reduced DO of 5.5 mg/l. Downstream of the To section, at the junction of the To Lich river, the river water was seriously

polluted with DO at 4–4.5 mg/l, BOD_5 at 18.5–19 mg/l and COD at 29.5 mg/l. The water was black in color and had a very bad odor.

Proposal for Pollution Treatment

Results of this research show that:

1. Wastewater from industries and sewage from Hanoi City's densely populated areas and trade villages are released to Nhue River, which affected its water quality. All of the water quality indices between the reach of the Dien bridge section and downstream were higher than the water quality standard used for surface water type A, especially at the To junction, as the concentration of both BOD_5 and COD was 5-7 times higher than the criteria used for water type A. Therefore, this has large negative impacts on the health of the population and production in the region.

2. The research shows that the quality of the Nhue River had improved significantly from river flow dilution. The dilution rate of (15-20%) of the river basic flow gave the highest efficiency. This is shown clearly from the analyzed data, using the most popular index for determining water pollution, BOD_5, which reduced by 11.2-16.4 percent.

3. The application of the water quality simulation model, WASP5 in hydraulic computing and substance transmission for the Nhue River shows that at the To junction that receives wastewater from the To Lich river, the value of BOD_5 was 34.7 mg/l, and DO was less than 4 mg/l. Depending on the different dilutions used, BOD_5 values were reduced rapidly in the downstream reaches. With a dilution rate of 20 percent it was reduced to 24 percent after 10 Km, 32 percent after 20 km, and 59 percent at the downstream end. This proves that the dilution measures could reduce the pollution level and improve the self-purification ability of the river considerably. The dilution application could also be considered as an efficient means for reduction of pollution in irrigation systems.

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Wastewater Reuse through Aquaculture in Hanoi: Status and Prospects

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Objective

At present, there are only preliminary and/or incomplete descriptions on the development and potential of wastewater reuse through aquaculture which has been practiced in Hanoi since the early 1960s. A field study was carried out to describe its historical development and to evaluate the current status and prospects of wastewater-fed aquaculture production in the Thanh Tri District, the main wastewater reuse area of Hanoi city.

The specific objectives were to:

- describe the historical development and the different farming systems;
- determine the main constraints and the potential of the system in the context of high economic growth rate and rapid urbanization; and
- offer recommendations for further research and development of the system.

Methods

This study was of an exploratory nature and the survey followed the methodology recommended by Weber and Tiwari (1992). For data collection and information gathering, methods of rapid appraisal and a combination of personal observations and standardized questionnaire surveys were used.

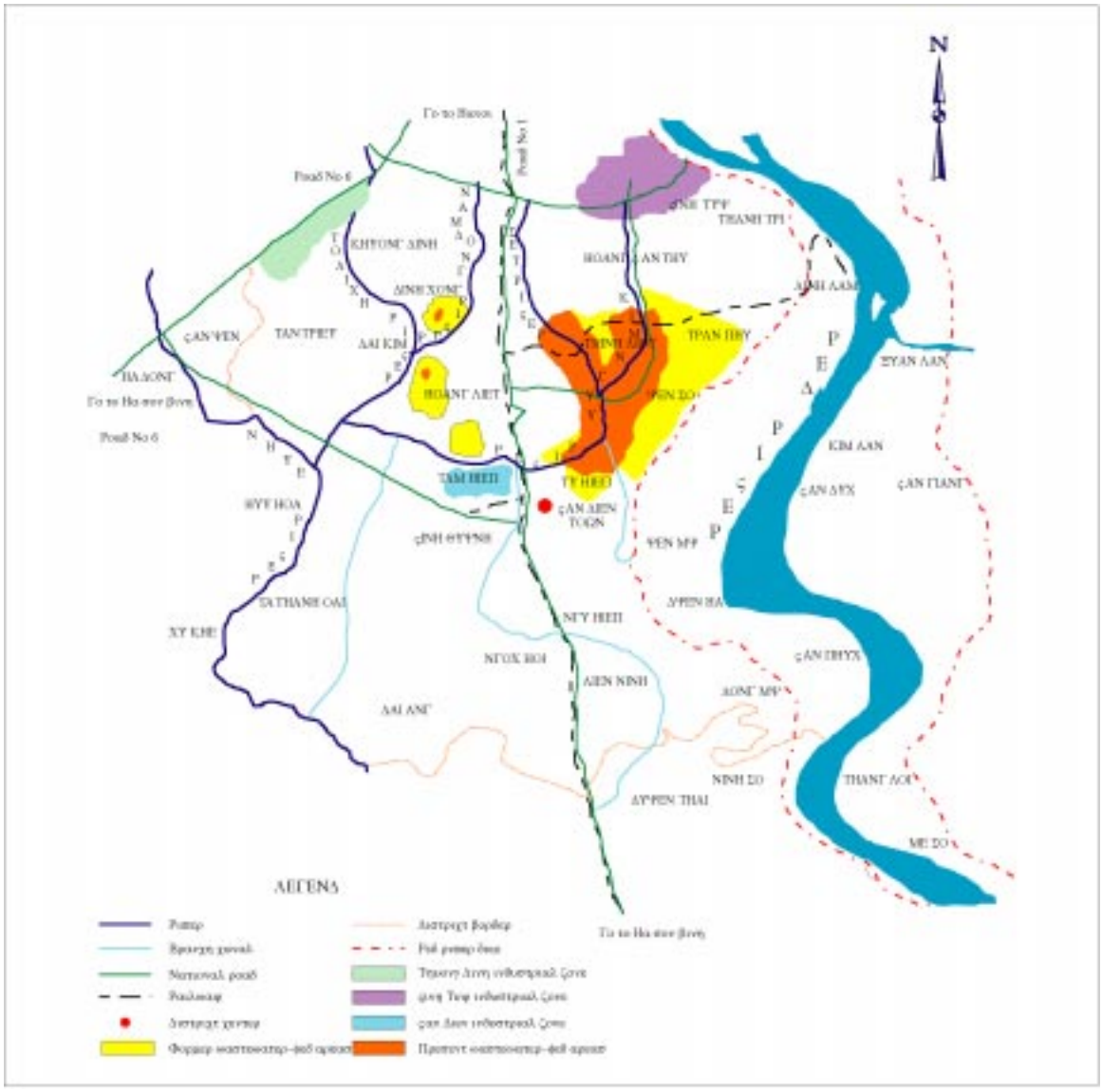
Almost all farms with wastewater reuse were interviewed to obtain primary data. A stratified random sampling technique (Miah 1993) was used to increase representativity and precision. A total of 92 farms from these four production systems (24, 19, 30 and 19 from Production Systems I, II, III and IV, respectively) which were fed either with or without wastewater were interviewed using standardized questionnaires.

Data collected from the farm household survey were entered in a Dbase computer package. For statistical and economic analysis SPSS was used.

Results

In Thanh Tri district (figure 2) the total aquaculture area was 1121 ha or 19 percent of total farmed area (as at 1995). This figure shows a 120 percent increase from 1985. From this area more than 3,000 tonnes/year of fish (10% of the total fish supply for Hanoi city) are produced. Aquaculture should be retained in the Thanh Tri district for improving and extending to new

Figure 2. Wastewater disposal and reuse in Thanh Tri District.



farming areas (as recognised by the Hanoi authorities in the Master Plan for City Development 1993). All interviewed farmers displayed a strong willingness for obtaining wastewater and improving their present system of production.

Four farming systems: fish-only, rice-fish culture, fish seed and vegetables were practiced in the wastewater-fed production area. In the fish "grow-out" system, a polyculture of Mozambique tilapia (*Oreochromis mossambicus*) and Nile tilapia (*O. niloticus*), two Indian major carps (Rohu, *Labio rohita* and mrigal, *Cirrhinus mrigala*), and Chinese silver carp (*Hypophthalmichthys molitrix*), was practiced in wastewater-fed earthen ponds. While tilapia had precocious, uncontrollable breeding, slow growth rates and were small in size at harvest, rohu and mrigal were the most popular species in farmed areas both with and without wastewater supply. In wastewater-fed fishponds, fish yields ranged from 4.7 tonnes/ha in rice-fish culture to 5.6 tonnes/ha in fish-only culture during the 10-month growing season.

Privatization of land use rights has made it difficult to supply wastewater to fish ponds resulting in a decrease in the area of wastewater-fed aquaculture. The systems were highly efficient economically and had a positive sociological impact because of higher gross margins and job opportunities than the rice-only production system.

Conclusions

Wastewater-fed aquaculture is a well understood and well established production system and has been developed mainly through farmer experience accumulated over the past 30 years. Production systems have gained importance for local people and the Hanoi authority in terms of socioeconomy, environmental improvement and resource recovery. As such, it has received much attention in the city and district development plans.

Techniques and skills developed are still far from sustainable and optimal in achieving the dual objectives of aquaculture production and treatment of the wastewater.

Further studies and development of the systems should focus on the improvement of the effectiveness of wastewater-fed fishpond systems in terms of wastewater treatment and reuse through aquaculture, rice and vegetable culture and their potential health risks.

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Sewage Water Aquaculture in Hanoi: Current Status and Further Development

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Objective

The objective of the paper is to provide an overview of the current status of development of sewage water aquaculture in Hanoi and its peri-urban districts and to present the master plan developed by the aquaculture authorities for future development of fish culture.

Methods

The methodology of research adopted was a literature survey covering sources of information like published and unpublished reports based on surveys conducted by the Research Institute for Aquaculture, and journal articles and the author's personal knowledge and communications. A key source of information was the master-plan report produced for the aquaculture authority.

Results

Aquaculture in Hanoi

The city has more than 2,430 ha deep-water rice fields, in which rice is cultivated once a year. Between 1994-1998, a total of 300 ha of rice fields were converted into mixed rice cum fish farming systems. The total fish production of Hanoi has increased by 27.6 percent, from 5,094 tons in 1991 to 6,500 tons in 1998-1999. This represents 40 percent of the demand for fresh fish in the city. The average production of fish has increased by 12.3 percent, i.e., 1.86 tons/ha to 2.09 ton/ha respectively in the same period. The percentage of high quality fish produced increased from only 25 percent in 1991 to more than 40 percent in 1998. Many new varieties of cultured and economical fish species, such as hybrid common carp, monosex tilapia have been introduced and now there are many fish culture intensive modules with a productivity of 5-10 tons/ha/crop.

Aquaculture in Thanh Tri

Eighty one percent of the total freshwater fish production of Hanoi city is produced in Thanh Tri, one of Hanoi's peri-urban districts situated to its south, which has 1,000 ha of flooded areas for fish culture. The annual production is about 5,280 tons of market fish/year. The fish production table of Thanh Tri is almost fully concentrated in the wastewater fish culture area (nearly 74%), where the productivity is 5 tons/ha. A comparatively smaller area of 404 ha is devoted to non-wastewater fish culture but production is low (1 ton/ha). The main popular fish species in Thanh Tri are silver carp, big head carp, grass carp, common carp, rohu, tilapia. Since 1995, Nile tilapia *O. niloticus* has been introduced and has become popular with farmers. Actually, tilapia is one of

the most interesting fish species for culture here. Some concerns have been raised by consumers about pollution risks to fish from the increasing toxics found in wastewater from urban areas.

Conclusions

- Hanoi is the second largest city in Vietnam with a resident population of more than 2 million and a transient population that exceeds 1 million. As such, the demand for high quality aquatic products is high.

- With over 5000 ha of surface area, Hanoi has the potential for aquaculture development and tourism-entertainment services. There are still more than 2,000 ha of deep water rice fields with no aquaculture.

- The orientation of the aquaculture authorities now is towards integrated and sustainable fish production exploiting all potential to a maximum. This involves using modern technology, more intensive systems, stocking with high value fish species and introducing better marketing policies. There are, however, a few questions to be resolved related to the species used for stocking, the impact of toxic wastewater use on the quality of the fish, the degraded condition of hatcheries and breed stocks, and the lack of measures for successful and timely prevention and treatment of fish diseases.

- The aquaculture industry still lacks policy measures dealing with production, financing, support and extension services, and skilled technical staff in areas like environment protection, fish disease etc.

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Health Aspects of the Reuse of Wastewater in Agriculture and Aquaculture in Vietnam

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The objective of this presentation is to provide an introduction to the epidemiological aspects and guidelines for the safe use of wastewater and excreta in agriculture and aquaculture as recommended by the World Health Organization (WHO).

Any guidelines on the safe use of wastewater and excreta in agriculture and aquaculture should protect the health of the workers involved and the public at large. Here "wastewater" refers to domestic sewage and municipal wastewaters that do not contain substantial quantities of industrial effluent. According to the WHO and the World Bank, hygiene standards applied to wastewater reuse in the past, based solely on the presence and survival of pathogens, have been stricter than necessary. Today, most international institutions agree on a more realistic approach to the use of wastewater based on epidemiological evidence on health risks.

Excreta-related diseases are very common in Vietnam, and wastewater contains correspondingly high concentrations of excreted pathogens—bacteria, viruses, protozoa and helminths. About 30 such diseases are of public health importance, and many of these are of specific importance in wastewater reuse schemes. However, the agricultural or aquacultural use of wastewater can result in an actual risk to public health only if all of the following occur:

a) if an infective dose of an excreted pathogen reaches a field or pond or the pathogen multiplies in the field or pond to form an infective dose;

b) the infective dose reaches a human host;

c) the host becomes infected; and

d) the infection causes disease or further transmission.

If (d) does not occur, then (a), (b) and (c) can pose only potential risks to public health. Further, if this sequence of events is broken at any point, the potential risks cannot combine to constitute an actual (measurable) risk.

An understanding of the epidemiology of infections is needed to design and implement schemes for wastewater reuse that pose minimal risks to human health. In this way, appropriate and adequate standards for the microbiological quality of excreta and wastewater intended for reuse can be established and public health properly protected.

In general, there are few well-designed epidemiological studies on reuse of wastewater; more evidence is available about wastewater irrigation than about the aquacultural use. Based on a review of available epidemiological studies on wastewater irrigation, a report published by the World Bank concluded that:

a) Crop irrigation with untreated wastewater causes significant excess intestinal nematode infection in crop consumers and field workers. Field workers, especially those who work barefoot, are likely to have more intense infections, particularly with hook-worms, than those not working in wastewater-irrigated fields;

b) Irrigation with adequately treated wastewater does not lead to excess intestinal nematode infection in field workers or crop consumers;

c) Cholera, and also typhoid, can be effectively transmitted by irrigation of vegetable crops with untreated wastewater;

d) Cattle grazing on pasture irrigated with raw wastewater may become infected with beef tapeworm, but there is little evidence of actual risks to humans;

e) There is little evidence that the health of people living near fields irrigated with raw wastewater is negatively affected, either directly by contact with the soil or indirectly by contact with farm workers.

Thus, when untreated wastewater is used to irrigate crops, there is a high actual health risk from intestinal nematodes and bacteria, but little or no risk from viruses. However, as wastewater treatment may also reduce the content of nutrients substantially, treated wastewater is less attractive to the Vietnamese farmer as he/she often irrigates with wastewater as a cheap fertilizer because of its high nutrient contents. Further, minimal and acceptable health risks may be associated with raw wastewater irrigation of a number of crops, including coffee, fruit and other trees, ornamental plants, and industrial crops.

Although very few epidemiological studies are available about health risks associated with the aquacultural use of wastewater, the following risks have been identified:

a) Passive transmission of fecal pathogens by fish and cultured aquatic plants;

b) Transmission of trematodes whose life cycles involve fish and plants (principally *Clonorchis sinensis* and *Fasciolopsis buski*); and

c) Occupational health risks to fish pond workers. With respect to trematode infections, incidental fecal pollution of other local water bodies and ponds not purposefully fertilized with wastewater may also be important in disease transmission.

There seem to be very few studies, if any, on health risks associated with the use of treated and raw wastewater in Vietnam. Wastewater irrigated agriculture and wastewater-fed aquaculture are widespread in Vietnam yielding a range of benefits, including production of food and low-cost treatment of wastewater. Studies of health risks and ways of reducing such risks are therefore urgently needed if sustainable benefits are to be obtained from future wastewater reuse in Vietnam.

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Epidemiology of Clonorchiasis in Northern Vietnam

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Objective

Clonorchiasis is caused by infection with *Clonorchis sinensis*. This disease is endemic in several Asian countries, including China, Japan, Korea and Vietnam with an estimated 50 million people infected worldwide with this liver fluke. In Vietnam, distribution of *C. sinensis* appears to be located mainly in the Red River Delta among people having a habit of eating raw fish. Epidemiological surveys on *Clonorchis* were therefore needed to describe its occurrence and health importance. In July 1998, a survey was carried out in the Nghia Phu commune with the following objectives:

- To identify the infection rate by mass-population examination and to assess the efficacy of treatment.
- To identify the snail and fish intermediate hosts of *Clonorchis.*

Methods

The Nghia Phu commune in the Nghia Hung district, Nam Dinh province was selected as the study site. The commune had 10,270 inhabitants. The total area of the commune was 1,081 ha of which 779 ha were used for agriculture and 65 ha were covered with fishponds. The habit of eating raw fish or inadequately cooked fish products was widespread. Wastewater management was poor with most wastewater being untreated. Stool samples were examined with the Kato-Katz technique for identification of *C. sinensis*. Fish were examined for metacercarial cysts with an artificial digestion technique using an acidic pepsin solution.

Results

Among the stool samples examined of 992 people, 308 people (31%) were infected with *C. sinensis*. Infection rate was higher in males (267/579 men; 45%) than in females (45/413 women; 11%) ($p < 0.001$). The habit of eating raw fish was common in the commune with 60-70 percent of the men eating raw fish regularly.

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Following treatment of patients with a praziquantel dose of 25 mg/kg-body weight/day for 3 successive days, adult flukes were collected from 7 patients after termination of the administration of praziquantel. The number of flukes collected varied from 1 to 24 per patient.

Snails that are intermediate hosts for *C. sinensis* were identified and their infection rate determined. A total of 2 of 13 snail species identified were found to be the first intermediate host of *C. sinensis.* The infection rate of the snail Melanoides tuberculatus varied from 3.3-5.7 percent, while the infection rate of the snail Bithynia fuschiaria varied from 2.0-5.0 percent. Of 11 fish species examined, 8 fish species were found to contain the parasite and act as the second intermediate host. The number of metacercarial cysts found in the fish flesh varied from 1 to 603 with an average of 75 metacercarial cysts per fish and 85 cysts per 100 g fish. Silver carp, *Hypohthalmichtys molitrix*, was found to be the fish species with the highest infection rate (38/56 fish analyzed (68%)). Silver carp was commonly used to prepare raw fish dishes.

Conclusion

The study showed that clonorchiasis is a major problem in the Nghia Phu commune and most likely in other Red River Delta provinces that are in the habit of eating raw fish. Infection is likely to cause significant complications, including cholangiocarcinoma and obstructive jaundice. Clonorchiasis is further likely to cause significant economic losses due to treatment costs, lost working days, etc. However, clonorchiasis can be effectively treated with a 3-day treatment of praziquantel at a dosage of 25 mg/kg body weight. Efforts should be strengthened to prevent the disease by health education and information about the risk of disease from the habit of eating raw fish. In addition, all water reservoirs must be properly managed to avoid fecal contamination that may cause infection of the intermediate snail and fish hosts with *C. sinensis*. Further studies on the presence and parasite numbers in different fish species, snails and different mammal reservoir hosts, like cats, pigs and dogs, are urgently needed.

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The Microbial Water Quality of the West Lake, Hanoi—Bacterial Indicators

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Objective

West Lake is located in the northwest of Hanoi. The lake is the largest in the city and receives untreated wastewater from the city of Hanoi. The West Lake area is a famous tourist resort with several hotels and restaurants. The objective of the study was to monitor the microbial water quality of the West Lake in the period 1997-1999.

Methods

The lake was divided into 3 subareas for sample collection and analysis. Subarea I was located in the southern part of the lake from Thuy Khue to Tran Quoc Pagoda. This area received wastewater through two large sewage inlets from the city and was densely populated. Subarea II was also located in the southern parts of the lake from Yen Phu to Nghi Tam areas with several hotels and popular tourist areas. Subarea III was located in the northern part of the lake and was less densely populated. Vegetables are grown around this part of the lake, which seems a less polluted area. Five water samples were collected from each subarea, including one site 10 m from the sewage ports and another site 50 m away from sewage ports (subarea I). Water samples were collected twice a year in the dry and rainy seasons, yielding a total of 25 samples analyzed from each subarea. The Most Probable Number (MPN) technique was used for the analysis of total coliforms and fecal coliforms (thermotolerant coliforms) as recommended by the WHO using the National reference TCVN-1995 method.

Results

According to the Vietnam Standard TCVN 5942-1995, surface water should contain <10,000 total coliforms per 100 ml if used for recreational and other purposes. Also, wastewater containing >10,000 total coliforms per 100 ml cannot be released into recipient lakes. No national guidelines are available for fecal coliforms but they were nevertheless tested. In subarea I, only 3/25 (12%) samples met the guideline value for total coliforms; in subarea II, 7/25 (28%) samples met the guideline value; and in subarea III 21/25 (85%) samples met the guideline value for total coliforms. The results for fecal coliforms were similar. In subarea I, 5/25 (20%) samples contained <10,000 fecal coliforms per 100 ml; in subarea II, 14/25 (56%) samples contained <10,000 fecal coliforms per 100 ml; and in subarea III 23/25 (92%) samples contained <10,000 fecal coliforms per 100 ml. Little differences in results were found between dry and rainy seasons, although the number of total coliforms were somewhat lower in the rainy season probably due to a dilution effect.

Conclusion

Although West Lake still has the capacity to treat and reduce the bacterial indicators in the received wastewater as indicated by the findings in subareas II and III, the high levels of fecal pollution in subarea I is disturbing. Thus, it is necessary to seek urgent measures to treat the wastewater, in particular from subarea I, before it is discharged into the lake.

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Water Quality in Drilled Wells in Hanoi

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Objective

Drilled well water is increasingly used as drinking water in Hanoi. The objective of the study was to survey the water quality of drilled wells in the Hanoi area by enumerating bacterial indicators and chemical parameters between 1989 and 2000.

Methods

The Most Probable Number (MPN) method was used as recommended by WHO for enumerating total and fecal coliforms. Chemical analysis for dissolved oxygen, iron, ammonia, nitrate and phosphate was done according to WHO standards. Samples were collected between 1989 and 2000 and included more than 400 water samples from wells in Hanoi and approximately 350 samples from wells in a number of different provinces.

Results

According to Vietnamese decision 505BYT/QD 13/4/1992 drinking water must be free of fecal coliforms and the standard for total coliforms is <10 per 100 ml.

Fecal Coliforms

Results from Hanoi showed that 342/461 (74%) samples did not contain any fecal coliforms. A mean number of 50 fecal coliforms was found in the 119 samples that contained fecal coliforms. Similar findings were seen in seven provinces in 1991, where 259/362 (72%) well water samples were free of fecal coliforms. In 1989, 290 wells with hand pumps located in three provinces and built with support by UNICEF were studied for fecal coliforms. Results showed that 76/85 (89%) of samples in Thanh Hoa; 16/30 (53%) samples in Hanoi; and 36/68 (52%) samples in Ha Nam Ninh were free of fecal coliforms. Of more than 400 samples collected from drilled wells in five provinces in 1991, between 70-89 percent in four of the provinces were free of fecal coliforms, while only 24/50 (48%) samples from Hai Hung did not contain fecal coliforms.

Total Coliforms

In Hanoi between 1989 and 2000, 222/324 (69%) samples contained <10 total coliforms per 100 ml. However, variations were found in the samples as only about 56-57% of samples analyzed between 1992 and 1997 contained <10 total coliforms per 100 ml. Similar findings were seen

among samples from 4 suburban districts of Hanoi between 1992 and 2000. It was noted that 20 (85%) samples in the Thanh Tri district, which is a major sewage-reuse area, met the standard for total coliforms.

Chemical Parameters

Analysis of 729 drilled water samples in Hanoi showed that only 112 (15%) met the standards for all the parameters studied. Samples often contained too high concentrations of iron and nitrate. In the Thanh Tri district, about 77 percent of samples contained high iron concentrations with an average of 10-18 mg/L, while values of 30 mg/L were found for some wells.

Conclusions

Generally, drilled well water is hardly fecally polluted and is of a reasonable microbial quality as indicated by the findings. About 75 percent of samples were free from fecal coliforms. However, measures to improve the microbial drinking water quality can and should still be introduced. As for the chemical parameters, drinking water most often contained too high concentrations of iron, nitrate and other parameters indicating organic pollution of the groundwater sources. In particular, the groundwater and drilled well water quality in the Thanh Tri district should be further investigated, including the impact on water quality of the discharge of sewage into the Kim Nhue river and the sewage-irrigated agriculture and aquaculture practices in the district.

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Status of Heavy Metal Pollution of Agricultural Soils and River-Sediments in Central Hanoi

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Objective

The objective of the study was to evaluate heavy metal pollution of the agricultural soil and river-sediment in central Hanoi City.

Methods

Nine soil and one river-sediment samples were collected from agricultural soils in Tuliem and Thanh Tri districts and from the Kimnguu River in July 1997 (table 1). Furthermore, eleven river-sediment samples were collected from three rivers flowing through the center of Hanoi City and Tuliem and Thanh Tri districts in July 1998 (table 2). Agricultural soil samples were taken from the surface 15-cm layer. Sediment was sampled at a position of 150-200 m away from a main wastewater discharge point of factories. Samples were taken to Japan after air-drying, 1 g of air-dry soil and sediment was digested with the HF-HNO_3-$HClO_4$ acid treatment to determine concentration of total heavy metals (Committee of Soil Standard Methods for Analyses and Measurements 1986). The solution was analyzed for cadmium, chromium, copper, nickel, lead and zinc by Atomic Absorption Spectrophotometry. Determination was made in duplicate and the relative deviation of the duplicate values was usually less than 5 percent.

Results

Agricultural Soil

Nine soil samples, which were collected to cover the whole area with different land uses, were evaluated for heavy metal pollution (table 1). However, they did not show any artificial contamination or pollution by heavy metals, since the total heavy metal concentrations were below the Vietnam standard for heavy metal concentrations in soils and within the common range and around the selected averages for soils. The highest concentration of heavy metals was observed for sample No 6, except for cadmium and copper. The highest concentration of cadmium was observed for sample No 7 taken from a paddy field cultivated with spinach. In the case of copper, the highest concentration was obtained in sample No 1 taken from an upland field for vegetables, while the concentrations of the other eight samples were in a narrow range of 40-50 mg kg^{-1}. In the vegetable field, farmers applied considerable amounts of pesticide. Total copper concentration of the vegetable field was below the critical level but would increase over that level in the near future if the heavy application of pesticide continued.

River Sediment

Severe pollution by various heavy metals was shown in a river-sediment sample collected from the Kimnguu River in 1997 with concentrations (mg/kg) of 2.48 for cadmium, 376 for chromium, 258 for copper, 146 for nickel, 158 for lead and 1040 for zinc. The heavy metal pollution of the river sediment from three rivers (Nhue, Tolich and Kimnguu) is shown in table 2. Comparison with the maximum permissible levels for crop growth (Steve 1994) showed a more or less severe heavy metal pollution of the river-sediment in central prefectures and Tuliem and Thanh Tri districts. Considerable accumulation of all six heavy metals examined was found in the sediment. Among the six heavy metals, zinc was the highest in concentration. Pollution of cadmium, chromium and nickel was not as severe as that of zinc. Industrial discharge is probably the most important source of the pollution for these four heavy metals. Only in one of the river sediment concentrations lead fell within the range observed for agricultural soils.

Conclusions

The Tuliem and Thanh Tri districts have been rapidly industrialized and populated in Hanoi City, but pollution of agricultural soils by heavy metals is limited and very low at present. Sediments from the rivers flowing through the central prefectures and Tuliem and Thanh Tri districts are polluted with various heavy metals to various degrees. The pollution is most severe in sediments

Table 1. Location and concentrations of total heavy metals of agricultural soil samples.*

Sample No	Location	Crop	Concentrations of total heavy metals (mg/kg)					
			Cd	Cr	Cu	Ni	Pb	Zn
1	Taytuu, Tuliem	Vegetables	0.16	62	73	34	32	114
2	Phudien, Tuliem	Rice-rice	0.22	72	41	35	44	106
3	Xuanphuong, Tuliem	Rice-rice-vegetables	0.16	79	44	42	43	106
4	Yenhoa, Caugiay	Rice-rices	0.23	82	50	46	45	117
5	Mydinh, Thanh Tri	Rice-rice	0.16	66	40	37	37	98
6	Thanhliet, Thanhxuan	Rice-rice	0.19	113	43	66	45	137
7	Tuhiep, Thanh Tri	Spinach	0.36	76	43	41	39	100
8	Lienninh, Thanh Tri	Rice-rice-vegetables	0.19	69	40	37	36	106
9	Daiang, Thanh Tri	Rice-rice	0.26	69	42	38	36	103

*Ho Thi Lam Tra and Kazuhiko Egashira (1999). Heavy metal status of agricultural soils in Tuliem and Than Tri Districts of Hanoi City, Vietnam. *J. Fac. Agr., Kyushu Univ* 43 (3-4): 489-497.

Table 2. The factories near the sampling site and concentrations of total heavy metals in river-sediments.*

River	Sample No.	Factories near the sampling site	Concentrations of total heavy metals (mg/kg)					
			Cd	Cr	Cu	Ni	Pb	Zn
Nhue	11	None	0.28	81	65	38	76	93
	12	None	0.27	95	64	46	76	109
	13	None	0.36	100	67	47	159	163
Tolich	14	Thuykhue leather, Hanoi beer, Trangan food and candy	1.44	217	112	100	96	612
	15	None	0.34	78	37	37	67	105
	16	Hanoi mechanical engineering, Saovang rubber, Hanoi soap, Thanglong tobacco	4.50	337	55	44	70	877
	17	Hanoi paint	3.46	131	57	62	60	240
Kimnguu	18	Haichau candy, Dongnama beer, Huunghi food, Maidong mechanical engineering, Hanoi leather	2.94	517	309	174	213	1423
	19	None	2.52	415	236	171	157	1062
	20	Vandien phosphate factory, Vandien battery, Vandien engineering	2.93	110	77	59	361	4950
	21	None	0.63	96	44	46	43	103

* Thi Lam Tra Ho and Kazuhiko Egashira (2000). Heavy metal characterization of river sediment in Hanoi, Vietnam. *Commun. Soil Sci. Plant* Anal. 31(17&18): 2901-2916.

at and near the industrial zones. Heavy metals were accumulated or deposited around the sites and did not move away to be redistributed in the whole area. Cadmium, chromium, copper, nickel, lead and zinc are all pollutants found in the area. Among them, zinc is most hazardous to crops, when the sediment is applied to agricultural fields, due to its high total concentration.

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Annexes

Annex A: Agenda for Workshop on Wastewater Reuse in Agriculture in Vietnam: Water Management, Environment and Health Aspects, Hanoi, Vietnam, 14th March 2001.

8:00-8:30	Registration	
8:30-8:45	Dr. Le Minh Dr. N.T. Anh	Introduction Opening Speech
Section I – Chairs : Prof. Anders Dalsgaard and Prof. T.D. Hoi		
8:45-9:15	Las Skov Andersen	Water Support Program: Vietnam-Denmark Joined Program for Water Resource Development
9:15-9:45	Wim van der Hoek	
9:45-10:15	T.T. Long	Wastewater & its Treatment Work System in the Southern Part of Vietnam
10:15-10:45	Coffee Break	
Section II – Chairs: Dr. Liqa Raschid and Dr. N.T. Quang		
10:45-11:15	C.P Chi	Impact of Hoa Khanh Industrial Zone to Bau Tram Reservoir
11:15-11:45	V.T. Huong	Treatment of Domestic Wastewater & Utilization of Treated Domestic Wastewater for Irrigation in Red River Delta
11:45-12:15	V.K. Tuyen	Wastewater Issues & Risk of Polluting Water Source of Hanoi City
12:15-1:30	Lunch	
Section III – Chairs: Dr. Wim van der Hoek and Dr. D.D. Tuan		
1:30-2:00	N.N. Thu	Urbanization & Wastewater Reuse in Pre-urban Area – Case Study in Thanh Tri District, Hanoi City
2:00-2:30	N.Q. Trung	Impact of Wastewater on Quality of Water in Irrigation System & Treatment Measures to Reduce Water Pollution – A Case Study in Nhue Irrigation System
2:30-3:00	V.Q. Hoan	Wastewater Reuse Through Aquaculture in Hanoi : Status & Prospects
3:00-3:30	Coffee Break	
Section IV – Chairs: Prof. Jorn Rasmussen and Prof. P.D. Cam		
3:30-4:00	Anders Dalsgaard	Public Health Aspects of the Reuse of Wastewater in Agriculture and Aquaculture
4:00-4:30	L.V. Chau	Epidemiology of Clonorchis in North Vietnam
4:30-5:00	H.T. Nghia	Hygienic Quality of West Lake's Water – Hygienic Index
	N.N. Nga	Water Quality of Drill-Wells in Hanoi During the Period of 10 Years (1989-2000)

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