VIETNAM – NETHERLANDS PARTNERSHIP
WATER FOR FOOD AND ECOSYSTEMS (WFE)

MAIN CASE STUDY #2

"Potential use of wastewater for irrigation to mitigate water pollution while assuring sustainable and safe agriculture in the Bac Duong Irrigation Scheme (Ha Noi & Bac Ninh)"

IMPLEMENTING INSTITUTION

Department of Water Resources (DWR)
Ministry of Agriculture and Rural Development (MARD)

DRAFT FINAL REPORT

Hanoi, November 2008

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ABBREVIATIONS

BDIS	Bac Duong Irrigation Scheme
Co-op	Cooperative
CPC/DPC	Commune People's Committee / District People's Committee
DARD	Department of Agriculture and Rural Development
DWR	Department of Water Resources
GOV	Government of Viet Nam
GSO	General Statistics Office
HHs	Households
IDMC	Irrigation and Drainage Management Company
IUCN	The World Conservation Union
IWRM	Integrated Water Resources Management
LNV	The Netherlands Ministry of Agriculture, Nature and Food Quality
MARD	Ministry of Agriculture and Rural Development
MB	Management Board
NIAPP	Natural Institute of Agriculture Planning and Projection
O&M	Operation and Maintenance
PC / PPC	People's Committee / Provincial People's Committee
PDS	Participatory Diagnostic Survey
PIM	Participatory Irrigation Management
PRA	Participatory Rural Appraisal
TOR	Terms of Reference
W/S	Workshop
WB	World Bank
WFE	Water partnership on water for Food and Ecosystem
WU	Water User
WUO	Water User Organization

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1. BACKGROUND

1.1 Introduction

This case study is designed to support the development of the Viet Nam – Netherlands Water Partnership on Water for Food and Ecosystems. The partnership is between Viet Nam's Ministry of Agriculture and Rural Development (MARD) and the Netherlands Ministry of Agriculture, Nature and Food Quality (LNV). IUCN has been asked to coordinate the Partnership development process, including through undertaking studies that will identify strategies for the management of water resources that balance agricultural production with the maintenance of the integrity of critical ecosystems depending on adequate water flows.

It will build on the overall strategy of the global Water for Food and Ecosystems Program, which seeks to promote an ecosystems approach to agricultural production and a productive services approach to ecosystems management. This will in turn provide a basis for ensuring more effective synergies between agriculture and ecosystems, the two largest water users, within an Integrated Water Resources Management (IWRM) framework.

The approach to the WFE Partnership will be to build a consensus on innovative approaches to balancing production and sustainability through developing the knowledge base and the involvement of key stakeholders in dialogue and discussion.
The case studies will be drawn from appropriate projects/programs that have been or are being implemented throughout the country. The purpose of the case studies is to identify mechanisms through which main areas of water management, which are traditionally approached as single purpose management regimes, can be enhanced to become more integrated, multi-stakeholder based management systems in which the original activity is maintained and improved and at the same time linked water-dependent activities are also taken into account in management decisions.

Water for Food and Ecosystems (WFE) form a specific sub-set of the broader IWRM approach. IWRM is concerned with a holistic integrated approach to water resources management, with a specific focus on coordinating and integrating the water demands and impacts (in and outflows) of the different sectors and stakeholders in a congruent IWRM management plan at the river basin scale. Special focus herein is given to match water demand of the multiple sectors and stakeholders with available supply at the river basin through integrated and multi-stakeholder coordination and management plans.
The specific aim of the WFE case-study is to identify and develop innovative practices in water use and management for the agriculture and environment sectors that can: a) mitigate the water demands and pressures in the river basin – especially for agriculture, while; b) securing an adequate level of (water) productivity. The focus is on how agricultural water use and productivity can become more environmental (and IWRM) friendly, while retaining required (economic) productivity; and co-exist and actively support ecological sustainability and/or rehabilitation. The explicit aim of the WFE approach is to develop alternatives to the traditional zero-sum trade-offs between agriculture, water supply, industry and environment that are typical for many IWRM scenarios, by fostering innovative approaches and practices

in which agriculture and environment can co-exist while maintaining agriculture and ecological productivity and value.

Recently, the water resources status in the Red-Thai Binh river basin changed unpredictable caused more difficulties for the exploitation and utilization of water resources. However, as result of muti-purpose reservoirs' operation such as Hoa Binh, Tuyen Quang and Thac Ba, the exploitation and utilization of water resources for agriculture development and domestic use become more difficulties.

One of the practical solutions for water shortage is the reuse of wastewater for irrigation. It is not doubt that the reuse of wastewater is a feasible solution, the wastewater may also contain organic matters that necessary for the development of crops. Apart from clear advantages, there also a number of clear risks associated to the use of wastewater in irrigation that need to be well contained and managed in order to assure a sustainable and safe (both for farmers and consumers) agriculture. That is reason of selecting Case Study #2 *"Potential use of wastewater for irrigation to mitigate water pollution while assuring sustainable and safe agriculture*". The Bac Duong irrigation scheme has been selected as the case study area.

1.2 Objectives of the Case Study

The case study aims to assist MARD with tools to protect the rice cultivation against possible negative impacts of irrigation with heavily polluted water from the NHK river by analyzing these impacts and formulating a strategy for addressing pollution problems farmers are facing.

Specific activities of the case study consist of:

- Assessing the status of pollution sources, wastewater quality in drains and canals of the Bac Duong Irrigation scheme and the trend of water quality in future;
- Assessing the potential impacts of reuse wastewater for agriculture production on agriculture productive and quality;
- Proposing recommendation to optimize the reuse of waste water for agriculture production in the scheme.
- Devising a specific and suitable strategy for the application of waste water in irrigation as an effective means to mitigate the problem of water pollution, while assuring sustainable and safe agriculture.

1.3 Approaches used in the case study

In order to reach the above said objective, the following approaches have been applied for the case study:

1.3.1 Participatory Diagnostic Survey (PDS)

Purposes:
The PDS is to give answers to the following questions:

- How is the scheme operated when reusing waste water for crop irrigation?
- What are areas using waste water for crop irrigation? What are affected and non-affected areas?
- What is decision making process for reuse of waste water for agriculture?
- What are locations of water quality sampling and rice product sampling?

PDS implementation steps
a) Desk study
b) Information/data collection
c) Information/Data Analysis
d) Field visit

- Field visit to headworks and main system:

A team of the main stakeholders jointly inspect the relevant headworks and main, secondary canals to:

- Confirm affected on non-affected areas;
- Identify the main issues related to reuse of waste water for crop irrigation;

- Field visit to on-farm systems:

- Identify cropping pattern within the scheme;
- Identify exact locations of water quality sampling and rice product sampling

e) Reporting: The case study team synthesized outputs of information/data collection, analysis, field visits to head works, main systems, on-farm system in to a report to meet PDS purposes said above.

In fact, the case study team organized several field surveys involved by staff of Bac Duong IDMC, DWR, local authorities, representatives of WUOs, agriculture cooperatives, and the case study team members to meet requirements of field visit said above.

1.3.2 Participatory Rural Appraisal (PRA):

Participatory rural appraisal (PRA) is a label given to a growing family of participatory approaches and methods that emphasize local knowledge and enable local people to make their own appraisal, analysis, and plans. PRA uses group animation and exercises to facilitate information sharing, analysis, and action among stakeholders. Although originally developed for use in rural areas, PRA has been employed successfully in a variety of settings. The purpose of PRA is to enable development practitioners, government officials, and local people to work together to plan context appropriate programs.

The case sudy team prepared a questionnaire form (see Appendix No 2) and distributed it to farmers of 3 communes named Khuc Xuyen, Xuan Vien and Phong Khe, where water pollution is serious. Around 30 representative of farmers in three communes filled in the questionnaires. The case study team organized a haft day meeting with these farmer representatives to interview them and got necessary information.

1.3.3 "With and Without Principle"

In this study, in order to quantify impacts by waste water reuse, the "With and Without Principle" is applied. It means that the impacts of wastewater irrigation can be measured as the differences between the scenarios with wastewater irrigation and without wastewater irrigation - the actual change in impacts. The aim here should be to separate out only the impacts that are clearly associated with wastewater irrigation and not include those impacts or changes that would have occurred even without wastewater irrigation. With and without is a useful tool when quantifying impacts of any intervention or policy. It is important to note that only incremental net impacts should be associated with the wastewater irrigation situation.

In order to apply this principle, the case study team collected water quality and rice product samples from wastewater affected and non-affected areas. Differences between water quality parameters and rice product parameters in these areas will help the team to have analysis, comments and recommendations. Agricultural production data of areas using wastewater and not using wastewater for irrigation also has been collected to support later analysis and assessment.

1.4 Implementation stakeholders

During implementing process, several stakeholders have been involved in the study as below:

(1). Bac Duong IDMC: 4 members of Bac Duong IDMC participated in the case study are:

- Mr. Ngo Chi Huong, Director of Bac Duong IDMC;
- Mr. Nguyen Anh Tuan, Head of Water Management Section;

- Mr.Nguyen Trang, Deputy Director of Trinh Xa Irrigation Enterprise;
- Ms. Nguyen Thi Dong, Deputy Director of Bac Ninh Irrigation Enterprise

Main tasks of 4 members of the Bac Duong IDMC are: (i) in close cooperation with the case study team to implement well all activities of data, information collection, sampling, surveys as requested by the case study team; (ii) to be involved other activities of the case study such as participation in workshops, meetings, and provide comments, contributions to the case study reports etc. All these members have actively participated in the case study.

(2) Bac Ninh Department of Agriculture & Rural Development. The Department provided necessary data, information related to the case study such as status of irrigation, drainage in Bac Duong scheme, crop cultivation data, operational regulations of Bac Duong IDMC, organizational arrangements, issues of wastewater reuse in the scheme. The Department (Deputy Director and 7 his staff) also had several meeting with the case study team to discuss about wastewater status, solutions, projections etc. The Department's contributions to the study are very signifinant.

(3) Bac Ninh Department of Natural Resources & Environment (DONRE). The Department provided data, information of waste sources, status of craft village and industry development in the scheme, status of wastewater discharging, operations of industrial zones and craft villages, environment status of the province. Deputy of the Department and his staff had two meetings with the study team to discuss about water pollution in the area, solutions and action plans for the future.

(4) Farmers of thee communes (Khuc Xuyen, Xuan Vien and Phong Khe) provided information about wastewater reuse in their communes, their comments and recommendations in the meeting with the study team.

(5) Institute of Water Resources Planning: The Director General and Head of Red river delta section of the Institute had a short meeting with the study team to inform about the revised irrigation drainage planning of the scheme which is being carried out by the Institute.

(6) National Institute of Water Resources Research provided data, information of water quality monitoring of Ngu Huyen Khe river, canals and drains of the scheme.

(7) Statistic Offices of Bac Ninh province and Tu Son, Yen Phong, Tien Du districts provided Year Books and other necessary informations.

All contributions, comments, advices from the stakeholders are very valuable to the study. Without their supports, the case study team can not fulfill its tasks given.

2. WASTEWATER REUSE OVERVIEW

With increasing global population, the gap between the supply and demand for water is widening and is reaching such alarming levels that in some parts of the world it is posing a threat to human existence. Scientists around the globe are working on new ways of conserving water. It is an opportune time, to refocus on one of the ways to recycle water—through the reuse of urban wastewater, for irrigation and other purposes. This could release clean water for use in other sectors that need fresh water and provide water to sectors that can utilize wastewater e.g., for irrigation and other ecosystem services. In general, wastewater comprises liquid wastes generated by households, industry, commercial sources, as a result of daily usage, production, and consumption activities. Municipal treatment facilities are designed to treat raw wastewater to produce a liquid effluent of suitable quality that can be disposed to the natural surface waters with minimum impact on human health or the environment. The disposal of wastewater is a major problem faced by municipalities, particularly in the case of large metropolitan areas, with limited space for landbased treatment and disposal. On the other hand, wastewater is also a resource that can be applied for productive uses since wastewater contains nutrients that have the potential for use in agriculture, aquaculture, and other activities.

In both developed and developing countries, the most prevalent reuse practice is the application of municipal wastewater (both treated and untreated) to land. In developed countries where environmental standards are applied, much of the wastewater is treated prior to use for irrigation of fodder, fiber, and seed crops and, to a limited extent, for the irrigation of orchards, vineyards, and other crops. Other important uses of wastewater include, recharge of groundwater, landscaping (golf courses, freeways, playgrounds, schoolyards, and parks), industry, construction, dust control, wildlife habitat improvement and aquaculture. In developing countries, though standards are set, these are not always strictly adhered to. Wastewater, in its untreated form, is widely used for agriculture and aquaculture and this has been the practice for centuries in countries such as China, India and Mexico.

Thus, wastewater can be considered as both a resource and a problem. Wastewater and its nutrient content can be used extensively for irrigation and other ecosystem services. Its reuse can deliver positive benefits to the farming community, society, and municipalities. However, wastewater reuse also exerts negative effects on humans and ecological systems, which need to be identified and assessed.

Before one can endorse wastewater irrigation as a means of increasing water supply for agriculture, a thorough analysis must be undertaken from an economic perspective as well. In this regard the comprehensive costs and benefits of such wastewater reuse should be evaluated. Conventional cost benefit analysis quite often fails to quantify and monetize externalities associated with wastewater reuse. Hence, environmental valuation techniques and other related tools should be employed to guide decision-making. Moreover, the economic effects of wastewater irrigation need to be evaluated not only from the social, economic, and ecological standpoint, but also from the sustainable development perspective.

In general, municipal wastewater is made up of domestic wastewater, industrial wastewater, storm water, and groundwater seepage entering the municipal sewage network. Domestic wastewater consists of effluent discharges from households, institutions, and commercial buildings. Industrial wastewater is the effluent discharged by manufacturing units and food processing plants.

In general, domestic wastewater entering municipal wastewater systems tend to follow a diurnal pattern. This flow is low during the early morning hours and a first peak generally occurs in the late morning followed by a second peak in the evening - after dinner hour. However, the ratio of peak flow loads to average flow is likely to vary inversely with the size of the community and the length of sewer system. Peak flows may also be generated during festive occasions, and at times of religious rituals, during business hours, tourist seasons, and in areas with large university campuses etc.

Industrial wastewater flows, closely follow the processing pattern of local industries, which depend on the processes involved, the number of shifts operated, and the water requirement of the industry. Variations from established patterns are minimal and occur during shift changes or stoppages. Flow variations may also occur due to processing of seasonal products. Therefore, seasonal fluctuations in the industrial wastewater discharges are more significant than in those of domestic wastewater. In cities where, industrial wastewater constitutes a major component of the total municipal wastewater flow, fluctuations in industrial wastewater discharges are likely to be of significant importance in water cycle management.

In developed economies, per capita wastewater generation is largely determined by economic factors, life-style and environmental policies. In some countries, the Netherlands for instance, water use in industry has greatly decreased after the introduction of the polluter pays principle for the discharge of industrial effluents. Companies started to look how they could reduce the flow of wastewater. However, in a developing country, where water supplies are rationed, availability is uncertain, and since water is not priced at its true opportunity cost, per capita wastewater generation may largely be a function of availability and minimum usage requirements.

Though the actual composition of wastewater may differ from community to community, all municipal wastewater contains the following broad groupings of constituents:

- Organic matter
- Nutrients (Nitrogen, Phosphorus, Potassium)
- Inorganic matter (dissolved minerals)
- Toxic chemicals
- Pathogens

Where diseases are present in a community its wastewater may contain high concentrations of excreted pathogens such as viruses, protozoa, bacteria and helminths eggs, At reuse of municipal wastewater intestinal nematodes pose the highest degree of risk of infection while bacteria pose a lower risk. Viruses exhibit the lowest risk. To minimize the potential risk of infection, the World Bank, World Health Organization and International Reference Centre for Waste Disposal convened a group of experts comprising of epidemiologists, social scientists and sanitary engineers at Engelberg, Switzerland in 1985, to review recent epidemiological evidence. This group made recommendations as summarized below.[4]

Reuse of wastewater could cause impacts on:

- Public health
- Crops
- Soil resources
- Groundwater resources
- Property values
- Ecological impacts
- Social impacts

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.

Generally speaking, wastewater (treated and untreated) is extensively used in agriculture, because it is a rich source of nutrients and provides all the moisture necessary for crop growth. Most crops give higher than potential yields with wastewater irrigation, reduce the need for chemical fertilizers, resulting in net cost savings to farmers. If the total nitrogen delivered to the crop via wastewater irrigation exceeds the recommended nitrogen dose for optimal yields, it may stimulate vegetative growth, but delay ripening and maturity, and in extreme circumstances, cause yield losses. Crop scientists have attempted to quantify the effects of treated and untreated wastewater on a number of quality and yield parameters under various agronomic scenarios. An overview of these studies suggests that treated wastewater can be used for producing better quality crops with higher yields than what would otherwise be possible.

The use of untreated municipal wastewater, as is the practice in many countries, pose a whole set of different problems. Nevertheless, the high concentration of plant nutrients becomes an incentive for the farmers to use untreated wastewater as it reduces fertilizer costs, even when the higher nutrient concentrations may not necessarily improve crop yields. Most crops, including those grown in peri-urban agriculture, need specific amounts of NPK for maximum yield. Once the recommended level of NPK is exceeded, crop growth and yield may negatively be affected.

For example, urea plant effluents are a rich source of liquid fertilizer but in concentrated forms they have adverse effects on rice and corn yields. The composition of municipal wastewater also has to be taken into account. Predominance of industrial waste brings in chemical pollutants, which may be toxic to plants at higher concentrations. Some elements may enter the food chain, but most studies indicate that such pollutants are found in concentrations permitted for human consumption. On the other hand, predominance of domestic wastewater may result in high salinity levels that may affect the yield of salt sensitive crops and could lead to serious soil degradation.

The economic impacts of wastewater on crops may differ widely depending upon the degree of treatment, types and nature of crops grown, and the overall farm level water management practices. Normally, as wastewater is a rich source of plant food nutrients, higher than average crop yields may be possible with wastewater irrigation. If crops are under supplied with essential plant food nutrients, wastewater irrigation will act as a supplemental source of fertilizer thus increasing crop yields. However, if plant food nutrients delivered through wastewater irrigation result in an oversupply of nutrients, yields may actually be negatively influenced. Also, since wastewater contains undesirable constituents such as trace elements and heavy metals, organic compounds and salts, crop yields may be negatively affected depending upon their concentrations in the wastewater and the sensitivity of crops to these elements. Thus from an economic standpoint, wastewater irrigation may have threefold impacts on crop production: (1) source of irrigation water; (2) influence on extent of irrigated areas, cropping intensity, crop mix, and on crop yields; and (3) fertilizer application. These aspects have implications for cost of production and overall profitability of crop production.

The above discussion shows that the economic impacts of wastewater on crops may differ widely depending upon the degree of treatment and nature of the crops. From an economic viewpoint, wastewater irrigation of crops under proper agronomic and water management practices may provide the following benefits: (1) higher yields, (2) additional water for irrigation, and (3) value of fertilizer saved. Alternatively, if plant food nutrients delivered through wastewater irrigation result in nutrient over supply, yields may negatively be affected.

BIG BENEFITS, BIG DANGERS

Use of wastewater for irrigation is considered as a saving cost by taking nutrient sources of wastewater. However, wastewater could make crop productivity reduce and bring a lot of diseases to farmers (Binh Minh, Buu Dien Viet Nam, No.42/2006)

In Vietnam, there have been several studies on wastewater reuse as following :

- The Institute of Agriculture Techniques (1994) carried out studies of impacts of urbanization on agriculture development in peri-urban areas.

- H.T.L Tra (2001) studied impacts of waste sludge use on soil environment and crop yields.

- Vu Thi Thanh Huong (Institute of Water Resources Research) (2001) did a study on wastewater reuse and recommended that for each type of crop it is necessary to select a reasonable ratio between wastewater and fresh water to get optimal crop yields.

- On 14 March 2001, under framework of the DANIDA funded project on Wastewater Reuse for Agriculture in Vietnam, the Institute of Water Resources Research organized a workshop on Wastewater Reuse in Agriculture in Vietnam: Water Management, Environment and Human Health Aspects. In this workshop, many papers related to wastewater reuse in Vietnam were presented. These papers mentioned about the existing status of wastewater reuse, treatment technologies, but no papers on impact assessments of wastewater reuse to rice production were presented.

- Dai Peters (CIP- Hanoi) and Do Duc Ngai (Institute of Ecologic Resources) did tests of using wastewater from food processing villages (Duong Lieu and Minh Khai communes, Ha Tay province) for rice irrigation.(2004)

- Viet Nam – Romania cooperation project on “Measures of Urban Treated Wastewater Reuse for Agricultural Purposes” (2005). The Project Implementing Agency is the Institute of Water Resources Research (Viet Nam).

- DANIDA project on Wastewater Reuse in Agriculture in Vietnam was implemented from 2002. The project was conducted in 2 phases over a period of 5 years. The first phase of study was to understand the extents, nature, and driving forces of wastewater agriculture and the background health risks from waterborne parasitic infection. On 4 May 2006 another workshop on Wastewater reuse in agriculture in Vietnam titledWater Management, Environment and Human Health Aspects was jointly organized by VIWRR, DANIDA, KVL, DHI, IWMI. In this workshop, 7 papers were presented to introduce results of various studies in the Red river delta, Nam Dinh province and other regions of Vietnam.

Generally speaking, according to results of studies in Vietnam, it can be seen that wastewater reuse for crop irrigation and fishery could have significant benefits such as taking advantages of water sources and nutrient source of wastewater, reducing production costs, increasing crop yields. However, if wastewater is not properly treated, negative impacts are dangerous, lasting for a long time and difficult to overcome bad consequences.

In this case study, impacts of wastewater reuse on crops will be assessed and analysed. Other aspects such as: public health, soil resources, groundwater resources, property values, ecological impacts, social impacts are out of the case study scope.

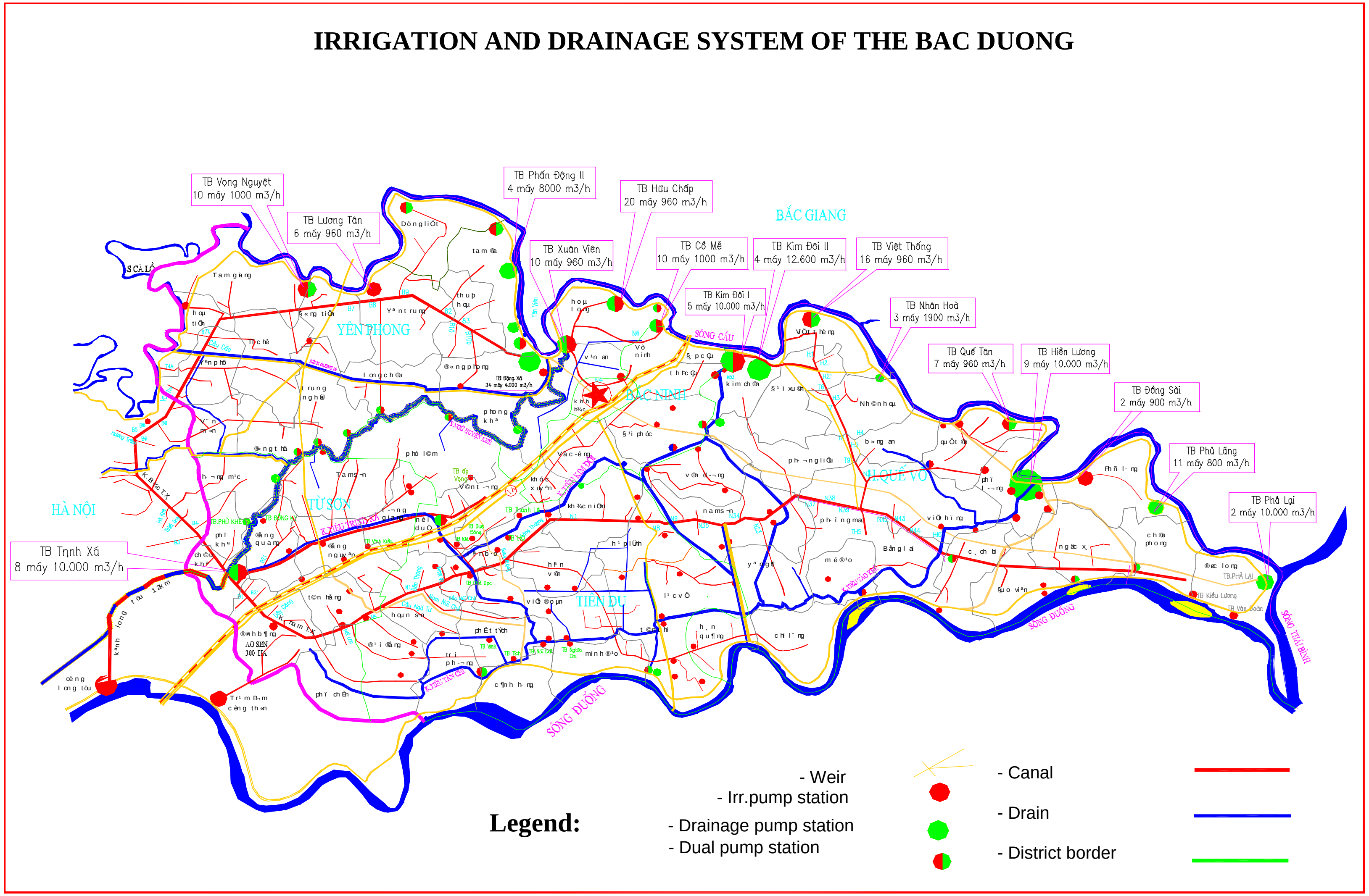


Figure 1. Bac Duong Irrigation Scheme layout

3. THE CASE STUDY AREA INTRODUCTION

3.1. NATURAL FEATURES

3.1.1. Geographic Location

The Bac Duong Irrigation Scheme (BDIS) is located in the Red River delta. It is located at 21^{o}10'27"– 21^{o}15'50" northern latitude, 105^{0}54'14" - 106^{0}10'20" eastern longitude in Bac Ninh province and it is a part of Ha Noi.

3.1.2. Topographic features

The case study area is rather flat. The decline direction is from north to south and from west to east. It is shown through flow direction to Duong and Thai Binh rivers.
Differences of land levels are not high. Normally, average land levels are 3.0-7.0 m above MSL. However, land level difference between hilly areas and plain areas is 300 – 400 m.
Hilly areas of Que Vo, Tien Du, Gia Binh and Bac Ninh town take account for 0.53% of the gross area.

3.1.3. Climatic features

The case study area is in tropical monsoon zone. There are two main seasons in a year: rainy and dry season. The rainy season lasts from May to September and the dry season is from October to April of next year.

Average air temperature varies from 23.5^{o}C to 25.1^{o}C. January is the month having the lowest monthly air temperature (15.7 ^{o}C – 18.4^{o}C), while July and August are the months having the highest monthly air temperature (28.8 ^{o}C – 30.7 ^{o}C).

Annual sun-shining hours varies from 1183 to 1429 hours/year. July and August have the highest sun-shining hours and January has the lowest sun-shining hours in a year.

Average annual rainfall is 1386 mm – 1598 mm. In the rainy season, the seasonal rainfall takes account for 80 – 90% of total annual rainfall. In the dry season, the seasonal rainfall is not significant. From August to October, typhoons often occur causing flooding and water logging in the area.

Average annual air moisture is rather high. It is around 70%. The maximum value of relative air moisture is 94-98% in January, February and March and the minimum value is in November and December.

Average annual evaporation is around 800 – 900 mm. The highest monthly evaporation is in months from May to August. From January to April, evaporation is rather small.

Table 1. Average monthly air temperature in the case study area and surrounding areas

Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Ha Noi	16.4	17.0	20.2	23.7	27.3	28.8	28.9	28.2	27.2	24.6	21.4	18.2
Bac Ninh	16.0	16.9	19.9	24.4	27.1	28.7	29.2	28.4	27.3	24.6	21.2	17.7
Bac Giang	15.9	16.8	19.7	23.5	27.1	28.5	28.8	28.3	27.2	24.4	20.9	17.4

Table 2: Average monthly rainfall at rain gauges in the case study area

(Unit: mm)

Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
Ha Noi	18.4	25.2	42.4	88.0	187.2	250.3	279.4	309.4	258.0	132.0	43.5	24.6	1658
BacNinh	18.8	21.8	38.2	94.2	173.5	227.2	246.7	268.5	194.2	132.3	46.0	15.8	1477
YenPhong	17.3	20.2	31.6	93.3	164.8	206.5	238.2	292.9	199.0	140.0	44.1	12.6	1460
Tu Son	12.7	17.4	25.2	91.7	158.2	210.6	240.7	301.2	196.1	127.0	41.0	15.2	1437
Tien Du	11.2	17.9	22.2	104.7	159.7	248.1	212.7	234.8	196.1	151.2	57.4	26.9	1443
Que Vo	11.3	13.3	18.2	93.3	134.2	226.2	218.6	296.3	184.1	144.6	40.7	13.8	1400

Two dominant wind directions in the area are northeast and southwest. The northeast wind is from November to April and the southwest wind is from May to October, in this time typhoons often happen with wind velocity is 34 – 35 m/s.

3.1.4. Land and Soils

The case study area has a surface of 53 km^2 including various types of land: agricultural land, fishery land, forestry land, resident land. The agricultural land takes account for 63% of the gross land area.

In general, soil of the area is alluvial one concentrated in Tu Son, Yen Phong, Tien Du, Gia Binh districts. In low land areas (Luong Tai district), soil is Gley one. Fertile land is concentrated in Tu Son, Yen Phong, Tien Du and Gia Binh districts.
Hilly soils are concentrated in Chau Cau, Nam Son (Que Vo district), Phat Tich (Tien Du district), Bup Le (Bac Ninh town), Thien Thai (Gia Binh district). Acid soils are distributed in communes in west of Que Vo district.

3.1.5. Geologic features

The case study area is in zone having rocks formed from Cambrium to Quaternary period. In general, Kainozoi formation covers on ancient formations. This is dominant formation. The Trias formation is mostly distributed in hills of the areas. This formation mainly consists of sandstone, gravels.
Thickness of the Quaternary formation is increased from north to south. In Bac Ninh town area, the thickness is around 30-40 m only. The geologic structure shows a Mezozoic depression. Most of geologic formations is in the Red River quaternary alluvial.

3.2 SURFACE WATER SOURCES

The case study area has four main rivers named Duong river, Cau river, Thai Binh river and Ngu Huyen Khe river.

3.2.1. Duong river

It is a man-made river connecting the Red River and Thai Binh River. Its length is 42 km flowing in Bac Ninh province. Annual water volume is 31.6 biln. m^3. The Duong river has a lot of suspended loads in the rainy season. In average, in a cubic metre of water there are 2.8 kg of fertile sediment (concentration of suspended solids is 2.8 g/l), so that is a very good source to make lands of Tien Du, Tu Son, Que Vo, Gia Binh, Luong Tai, Thuan Thanh districts become fertile. The Duong river is a major water supply source for BDIS.

Table 3: Main rivers flowing within the case study area.

River name	Total length (km)	Length in the case study area (km)	From	To
Duong river	65	42	Dinh To (Thuan Thanh)	Cao Duc (Gia Binh)
Cau river	290	69	Tam Giang (Yen Phong)	Duc Long (Que Vo)
Thai Binh river	93	16	Duc Long (Que Vo)	Cao Duc (Gia Binh)
Ngu Huyen Khe river	-	24	Chau Khe (Tu Son)	Van An (Yen Phong)

3.2.2. Cau river

The Cau river originates from the mountains of Bac Can province. Main stream of the river flows through Thai Nguyen, Bac Ninh and Bac Giang province. At Pha Lai the Cau River joins the Thuong River, some 10 km downstream of the confluence of Luc Nam with the Thuong river. About 5 km downstream of Pha Lai the Duong River, which branched off from the Red River at Hanoi, meets the Thuong. The length of Cau river in Bac Ninh province is 69 km (from Yen Phong district to Que Vo district). There are two clear seasons: flood season and low flow season in a year. Flood season lasts from June to September, in which the seasonal water volume takes account for 70-80% of annual flow. The low flow season is from October to May next year. Differences between monthly discharges could be 10 times and differences of monthly water levels could be 5-6 m. In the flood season, river level could be 8 m (1-2 m higher field level), while in low flow season, the river level is only 0.5 – 0.8 m, so that gravity irrigation can not be carried out. The suspended solids load of Cau river is much lower than Duong river's one. However, the pH of the river water is rather high.

3.2.3. Thai Binh river

Thai Binh river is the confluence of Thuong river, Cau river and Luc Nam river. The Thai Binh river's length in the case study area is 16 km only (from Que Vo to Gia Binh district). The suspended solids load of Thai Binh river is very high. The river bottom slope is not steep, the velocity of the flow is low leading to strong sedimentation in the river bed. Annual water volume is around 53 biln. m^3.

3.2.4. Ngu Huyen Khe river

Ngu Huyen Khe river originates from Dam Thiep, then flows through 5 districts named Me Linh (Vinh Phuc province), Dong Anh (Ha Noi), Tu Son, Yen Phong and Bac Ninh town (Bac Ninh province). Presently, Ngu Huyen Khe is the major drain of these five districts in the rainy season as well as a main irrigation water source in the dry season. The river is seriously polluted by various sources (industries, trade villages, agriculture, domestic uses, etc.)

3.3. ECONOMIC AND SOCIAL FEATURES

3.3.1 Population and population distribution.

The case study area has rather high population density (1,217 people per km^2). According to the statistic data, up to 2005 the area population is over 1 milln. people. The highest population density is found in Bac Ninh town (3,065 people/km^2). The lowest population density is in Que Vo district (906 people/km^2). The average annual population growth is 1.02% (2005).

Most of the population is living in rural areas (taking account for 86%). However, the population distribution is changing because of a rapid growth of urbanization.

According to Bac Ninh Year Book 2007, the labour source of the area is rather abundant. There are 626,097 people at labour age. Around 54.97% of labourers is working in the agricultural sector, 17.67% of labourers is working in the service sector. The remaining 27.36% is working for other sectors.

Since the education system receives much attention from the provincial authority, the education level of people has increased. The poverty incidence in the area is about 7%.

Table 4: Gross areas and population of various districts in the case study area

No.	Province/District	Gross area (km^2)	Population	Population density(Head/km^2)
I	**Bac Ninh**	822.71	1,028,844	1,251
1	Tu Son	61.3	129,652	2,114
2	Tien Du	95.7	121,293	1,268
3	Que Vo	154.8	141,544	914
4	Bac Ninh town	82.6	151,549	1,835
5	Yen Phong	96.9	125,069	1,291
II	**Ha Noi**			
1	4 commune of Dong Anh district	30.35		

3.3.2 Economic Status

The economic growth rate of Bac Ninh province is rather high in comparison with surrounding areas. Annual GDP growth rate is 13.5% per year, in which increase of agriculture is 5.5%, increase of industries and construction is 19.5%, increase of services is 14.8%. In 2005, GDP per capita was 623 USD/head/year. At present, though the agricultural sector is still dominant, the contribution of industries to economic growth is increasing.

The case study area has a rather high economic growth rate as well. . In average, the annual economic growth rate in the period from 1997 to 2006 was 13.5%. GDP in recent years is shown in Table 5 below:

Table 5. GDP growth of Bac Ninh province in recent years

Year	2003	2004	2005	2006	2007
GDP	13,6%	13,8%	14%	15, 2%	15,7%

Source: Year Books of GSO (2007)

3.3.3 Contribution rate of various economic sectors

From 2002 – 2005, the industrial sector always kept an average growth rate of 26.64% per year. In 2005, value of the industrial production was 5,300 biln. VND of which local industries took account for 40%, the centrally and overseas financed industries took account for 60%.

From 2002 to 2005, the value of the agriculture, forestry andfishery sector had an annual growth rate of 5.22%. The weight percentage of the agriculture sector decreased from 38% in 2000 down to 25% in 2005. In agriculture, the weight percentage of cultivation decreased, while the weight percentage of animal husbandry and fishery increased.

Trading and services of the area have a good growth rate in both quantity and quality. Activities of tourism services, post and telecommunication services are increasing steadily. GDP of various sectors is shown in the below Table 6 and Figure 2.

Table 6: GDP of various sectors in the case study area

Year	**Gross GDP**	**GDP of various sector (mil. VND)**		
		Agriculture, fishery, forestry	**Industries and construction**	**Services**
2000	6,686.3	1,947.6	3,477.8	1,260.9
2001	8,042.8	2,115.2	4,407.8	1,519.8
2002	9,699.0	2,363.7	5,588.8	1,746.5
2003	13,635.4	2,562.6	8,988.2	2,084.6
2004	17,362.6	3,092.7	11,615.9	2,644.0
2005	22,563.6	3,572.7	15,642.5	3,318.4
2006	28,892.1	3,797.4	20,551.1	4,543.6
2007	37,561.8	4,364.5	27,313.1	5,884.2

Source: Bac Ninh Year Books 2007.

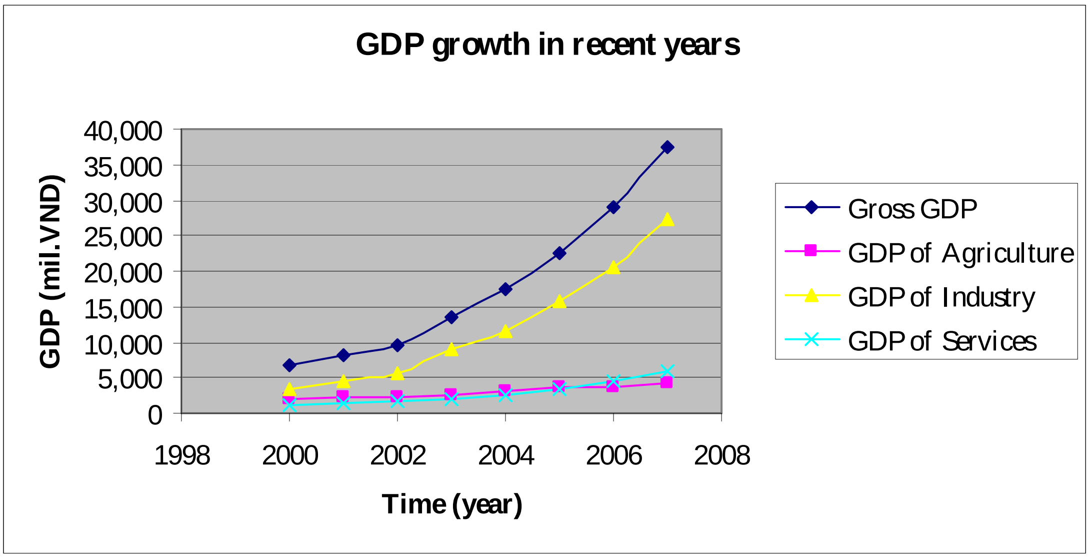


Figure 2. GDP growth of various sectors in recent years

According to the actual observations in Vietnam and study by Hyun-Hoon Lee [4], it can be seen that relationship between GDP growth and environment quality is inverse. It is not surprising when seeing that water quality in the case study area is deteriorating steadily.

3.4. STATUS OF THE PHYSICAL ENVIRONMENT

In recent years, the physical environment of the area has deteriorated. Degradation of the environmental quality occurs in urban and rural industrial areas, especially in and around the trade and handicraft villages.

3.4.1 Urban environment

The case study area consists of a provincial town, some district towns and many industrial zones. On the hand, these areas have contributed significantly to increasing economic development and living standards of the local people. On the other hand, they also have caused negative effects on the environment.

Air pollution comes from emission of the industries located in the urban areas, from vehicles and from construction material production bases. According to reports of the Department of Natural Resources and Environment (DONRE) of Bac Ninh, in Bac Ninh town dust is 1.8 - 2.2 times, NO_2 is 1.4 times, SO_2 is 1.35 times higher than permitted as per the National Standards of Vietnam.

Water pollution is caused by untreated wastewater from various sources. Values of BOD_5 are very high. Concentration of suspended solids, coliform and nutrient (N and P) are also high leading to eutrophication in ponds and lakes in the area. Concentration of dissolved oxygen (DO) in urban areas is low (4 mg/l). In some ponds, lakes pesticides have been identified (0.146 mg/l in average little bit lower than the National Standards- 0.150 mg/l), however in some places the pesticide residual value is over the National Standards.

Basically, ground water quality meets the National Standards. However, in some places, the concentration of iron (Fe) is 1.3 – 4.4 times higher, and manganese (Mn) is 1.2 – 2.0 times higher than the National Standards. If this ground water is used for domestic uses, water treatment is required.

Concentrations of TSS, COD, BOD_5, DO, N –P of wastewater in the area are much over the National Standards.

Daily volume of solid wastes from Bac Ninh town is 200 m^3/day. However, only 70% of this volume is collected, but its treatment is not appropriate.

3.4.2 Industrial Environment

The old industrial zones having uncompleted liquid, solid and air treatment facilities such as: factories of Dap Cau Glass, Bac Son Tobacco, Fload Glass, Dap Cau river ports, Paper Mill, Lime Production Bases are significant sources of pollution.

The new industrial zones such as Tien Son, Que Vo have proper waste treatment systems that meet the Standards. However, it is required to strictly monitor and manage their waste treatment systems during their operation process to ensure their continued compliance with the legal regulations.

Industrial zones of Chau Khe, Tan Hong – Hoan Son, Phong Khe with various forms of industries have poor waste treatment systems resulting in serious pollution.

3.4.3 Rural Environment

In the case study area there are around 62 trade and handicraft villages with diversified products. Major trade and handicraft villages are: Phong Khe paper production village, Tam Da alcohol processing, Da Hoi steel production, Van Mon lead and aluminum casting, Dai Bai copper casting, Dong Ky furniture production. Scope, labour and revenue of these villages are shown in the table below.

Table 7: Scale, labour and revenue of some main trade, handicraft villages in the area

Village	**Number of production bases/HH**	**Number of labour**	**Average monthly salary (1000 VND)**
Phong Khe paper production	64 bases	1200	400-500
Tam Da alcohol processing	800 HH	3 –4000	200-300
Da Hoi steel production	450 HH	10,000	400-500
Van Mon lead and aluminum casting	80-120 HH	500	300-500
Dai Bai copper casting	600-700 HH	2,000	300-500
Dong Ky furniture production	1000 HH	500-700	350-400

It can be seen that the handicraft bases are small, their technologies are old, backwards, their equipment and facilities are simple and poor, moreover, materials for production are recycled ones that lead to serious pollution. These bases are in the residential areas, therefore, they have had significant negative effects on health of the local people. Untreated solid and liquid wastes released into drains and canal systems are major causes of pollution in Ngu Huyen Khe river.

3.4.4 Environment of agricultural production

In agricultural production, critical issues are:

- In order to have high quality and valuable products, farmers have introduced changes of cropping pattern resulting in depletion of soil and water resources;

- Overuse of pesticides, fertilizers as well as other chemical inputs for crop cultivation makes soil of the area become infertile, polluted. Residuals of chemical inputs make aquatic life die. Residuals of the chemicals in crop products can be very dangerous for health of people. According to vegetable testing data reported by DONRE of Bac Ninh, chemical residuals in vegetables grown in Tu Son district are over WHO standards. Concentration of NO_3 is 867 mg/kg, 190 mg/kg and 180 mg/kg in samples of cabbage, carrot and onion respectively. (the permitted value is less than 500 mg/kg).

- Wastes from industries, handicraft villages such as heavy metals make water and soil polluted, causing negative effects on quality and quantity of crops and animal products.

- Drinking water supply is also affected by surface water pollution and ground water contamination. Some dangerous diseases such as cancer, pleurisy, diarrhoea, skin diseases have occurred in the area. However, no any study shows that cancer is caused by water pollution.

- Air pollution caused by the Pha Lai thermal factory is becoming a danger to health of the local people as well as crops grown in surrounding areas

Generally speaking, environment of the case study area is being polluted and deteriorated by activities of economic development. It is necessary to have urgent measures to control the present environment degradation.

4. SAMPLING LOCATION AND QUALITY PARAMETERS TESTED

4.1 Selection of water quality sampling location

The water quality sampling locations are identified and selected in close cooperation with Bac Duong irrigation scheme and Cooperatives, . Four paddy fields have been selected and each one meets the following assumptions:
The first paddy field is irrigated by Duong river water which is assumed as fresh water. The agricultural product does not have negative impacts caused by irrigation.
The second, third and fourth paddy fields are fields irrigated by waters that are contaminated by wastewater from pollution sources at upstream, midstream and downstream of the NKH river.
The quality of irrigation water in these fields is sampled independently, without notice to the farm owners. The field owners are asked to answer questionnaires regarding their farming activities. The water quality sampling is determined by the procedure of irrigation as issued and actual operation of the Bac Duong scheme, but at least five times per season. The drainage or leaching water from farms is also sampled.

According to discussions and agreements between Bac Duong IDMC director and staff as well as results of the first field trip carried out on 22 July 2008 by the case study team, specific sampling locations are identified as below:

Table 8: Sampling locations of the case study

No.	Location code	Location name	Latitude	Longitude
1	TH 2	Drain, Thai Hoa pumping station, Mo Dao commune, Que Vo district	21^{o}11.885	106^{o}15792
2	TH3	Canal, Thai Hoa pumping station, Mo Dao commune, Que Vo district	21^{o}11.901	106^{o}15773
3	XV2.1	Rice field, Thuong Dong village, Van An commune, Yen Phong district.	21^{o}19.759	106^{o}05409
4	XV2.2	Drain, Thuong Dong village, Van An commune, Yen Phong district.	21^{o}19.725	106^{o}05339
5	XV2.3	Canal, Thuong Dong village, Van An commune, Yen Phong district.	21^{o}19.648	106^{o}05395
6	PK 3.1	Rice field of Cham Khe village, Phong Khe commune, Bac Ninh town	21^{o}18.242	106^{o}03650
7	PK 3.2	Drain of Cham Khe village, Phong Khe commune, Bac Ninh town	21^{o}18.260	106^{o}03612
8	PK 3.3	Canal of Cham Khe village, Phong Khe commune, Bac Ninh town	21^{o}18.239	106^{o}03741
9	DQ 4.1	Rice field of Bich Ha village, Dong Quang commune, Tu Son district.	21^{o}11.634	105^{o}95412
10	DQ 4.2	Drain of Bich Ha village, Dong Quang commune, Tu Son district	21^{o}11.586	105^{o}95442
11	DQ 4.3	Canal of Bich Ha village, Dong Quang commune, Tu Son district	21^{o}11.664	105^{o}95406
12	VA 3	Canal of Dai Lam, Tam Da commune, Yen Phong district	21^{o}20.285	106^{o}02853
13	DX 3	Canal of Dong Xa, Dong Phong commune, Yen Phong district	21^{o}18.781	106^{o}02663
14	PL 3	Canal of Phu Lam commune, Tien Du district	21o17.464	106^{o}00703
15	HM 3	Canal of Huong Mac, Tu Son district (left bank)	21^{o}14.349	105^{o}94.157
16	DQ 3	Canal of Dong Ky commune, Tu Son district (right bank)	21^{o}14.310	105^{o}94.525

(More details please see the sampling location map below)

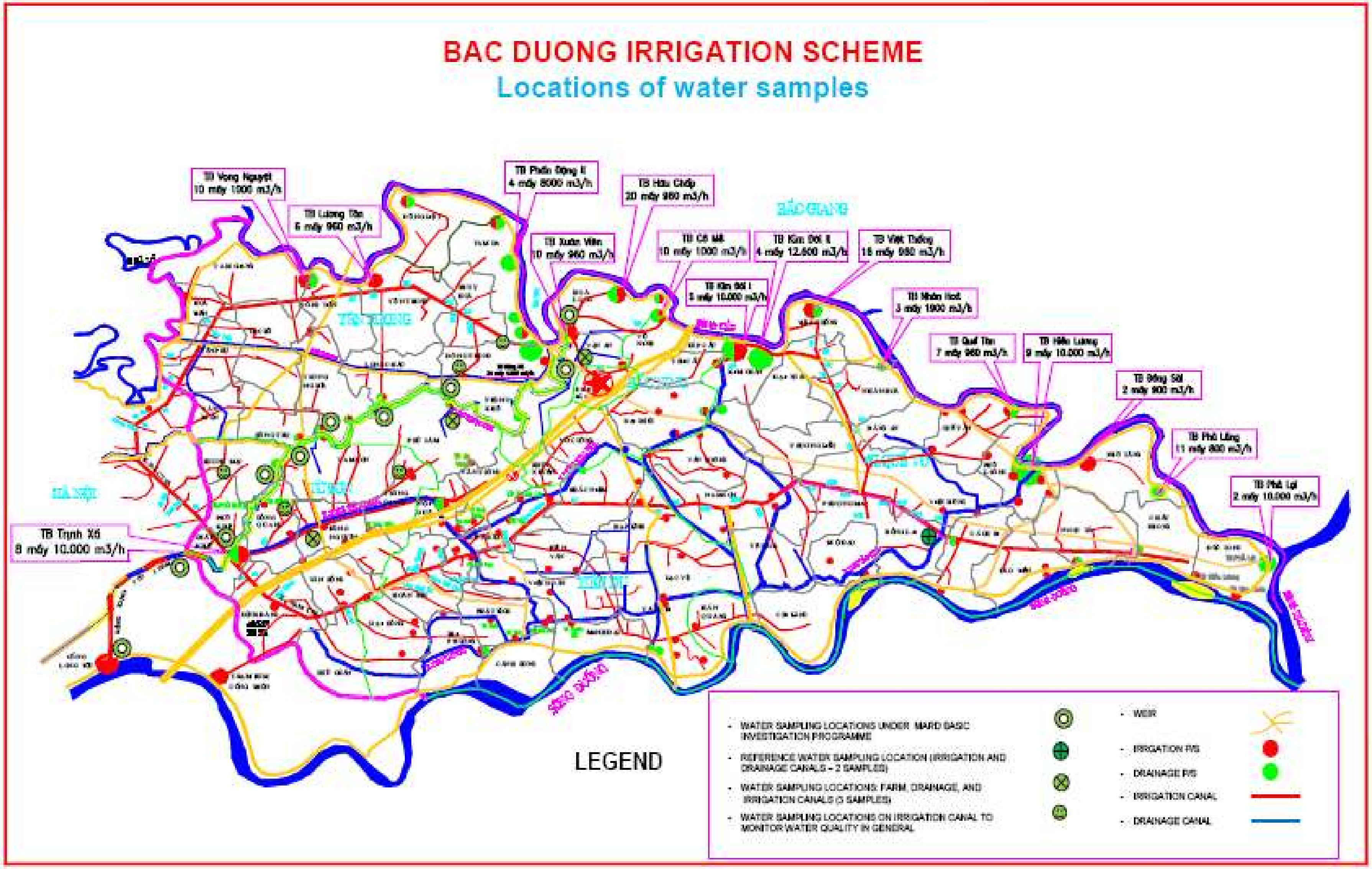


Figure 3: Map of case study sampling locations and MARD monitoring locations

4.2 Selection of rice product sampling location

Because of the limited budget for testing, only 6 rice product samples are required to be tested, therefore, rice product sampling locations have been selected to be:

- Thuong Dong village, Van An commune, Yen Phong district where pollution is serious (downstream);
- Cham Khe village, Phong Khe commune, Yen Phong district where pollution is serious (midstream);
- Thai Hoa pumping station, Mo Dao commune, Que Vo district where irrigation water is considered as unpolluted.

At each location, two rice samples of Spring and Summer rice crop have been taken.

(Please see the map above)

4.3 Selection of water quality parameters tested

There are many parameters that could describe water quality and rice product quality. Because time and budget of the case study are limited, only several necessary parameters of water quality and rice product quality will be selected on the basis of practical experiences, related references as well as consultations with experts in the field of environment and agriculture.

Wastewater is mainly comprised of water (99.9%) together with relatively small concentrations of suspended and dissolved organic and inorganic solids. Among the organic substances present in sewage are carbohydrates, lignin, fats, soaps, synthetic detergents, proteins and their decomposition products, as well as various natural and synthetic organic chemicals from the process industries. Wastewater also contains a variety of inorganic substances from domestic and industrial sources, including a number of potentially toxic elements such as arsenic, cadmium, chromium, copper, lead, mercury, zinc, etc. Even if toxic materials are not present in concentrations likely to affect humans, they might well be at phytotoxic levels, which would limit their agricultural use. However, from the point of view of health, a very important consideration in agricultural use of wastewater, the contaminants of greatest concern are the pathogenic micro organisms

Pathogenic viruses, bacteria, protozoa and helminths may be present in raw municipal wastewater at various levels and will survive in the environment for long periods. Pathogenic bacteria will be present in wastewater at much lower levels than the coliform group of bacteria, which are much easier to identify and enumerate (as total coliforms/100ml). Thermotolerant *Escherichia coli* are the most widely adopted indicator of faecal pollution and they can also be isolated and identified fairly simply, with their numbers usually being given in the form of faecal coliforms (FC)/100 ml of wastewater.

The quality of irrigation water is of particular importance. The physical and mechanical properties of the soil, such as dispersion of particles, stability of aggregates, soil structure and permeability, are very sensitive to the type of exchangeable ions present in irrigation water. Thus, when effluent use is being planned, several factors related to soil properties must be taken into consideration.

Another aspect of agricultural concern is the effect of total dissolved solids (TDS) in the irrigation water on the growth of plants. Dissolved salts increase the osmotic potential of soil water and an increase in osmotic pressure of the soil solution increases the amount of energy which plants must expend to take up water from the soil. As a result, respiration is increased and the growth and yield of most plants decline progressively as osmotic pressure increases. Although most plants respond to salinity as a function of the total osmotic potential of soil water, some plants are susceptible to specific ion toxicity.

Many of the ions which are harmless or even beneficial at relatively low concentrations may become toxic to plants at high concentration, either through direct interference with metabolic processes or through indirect effects on other nutrients, which might be rendered inaccessible. Morishita (1985) has reported that irrigation with nitrogen-enriched polluted water can supply a considerable excess of nutrient nitrogen to growing rice plants and can result in a significant yield loss of rice through lodging, failure to ripen and increased susceptibility to pests and diseases as a result of over-luxuriant growth. He further reported that non-polluted soil, having around 0.4 and 0.5 ppm cadmium, may produce about 0.08 ppm Cd in brown rice, while only a little increase up to 0.82, 1.25 or 2.1 ppm of soil Cd has the potential to produce heavily polluted brown rice with 1.0 ppm Cd.

Important agricultural water quality parameters include a number of specific properties of water that are relevant in relation to the yield and quality crops, maintenance of soil productivity and protection of the environment. These parameters mainly consist of certain physical and chemical characteristics of the water. Table 9 below presents a list of some of the important physical and chemical characteristics that are used in the evaluation of agricultural water quality. The primary wastewater quality parameters of importance from an agricultural viewpoint recommended by FAO are:

Table 9: PARAMETERS USED IN THE EVALUATION OF AGRICULTURAL WATER QUALITY

Parameters	Symbol	Unit
Physical		
Total dissolved solids	TDS	mg/l
Electrical conductivity	Ec_w	dS/m[1]
Temperature	T	°C
Colour/Turbidity		NTU/JTU[2]
Hardness		mg equiv. $CaCO_3$/l
Sediments	TSS	g/l
Chemical		
Acidity/Basicity	pH	
Type and concentration of anions and cations:		
Calcium	Ca^{++}	me/l[3]
Magnesium	Mg^{++}	me/l
Sodium	Na^{+}	me/l
Carbonate	CO_3^{--}	me/l
Bicarbonate	HCO_3^{-}	me/l
Chloride	Cl^{-}	me/l
Sulphate	SO_4^{--}	me/l
Sodium adsorption ratio	SAR	
Boron	B	mg/l[4]
Trace metals		mg/l
Heavy metals		mg/l
Nitrate-Nitrogen	NO_3-N	mg/l
Phosphate Phosphorus	PO_4-P	mg/l
Potassium	K	mg/l

According to the Water quality standard for irrigation TCVN-6773:2000, parameters of irrigation water quality regulated are:

Table 10: Water quality parameters regulated by TCVN – 6773:2000 (Irrigation water)

No	Parameters	Unit
1	Total dissolved solids	mg/l
2	Sodium adsorption ratio	
3	Boron (B)	mg/l
4	Dissolved Oxygen (DO)	mg/l
5	Acidity/Basicity (pH)	
6	Chloride (Cl^-)	mg/l
7	Pesticides	mg/l
8	Mercury (Hg)	mg/l
9	Cadmium (Cd)	mg/l
10	Arsenic (As)	mg/l
11	Lead (Pb)	mg/l
12	Chromium (Cr)	mg/l
13	Zinc (Zn)	mg/l
14	Feacal coliforms	MPN/100 ml

Based on Water quality standard for irrigation TCVN-6773:2000, 13 parameters of Standard TCVN – 6773:2000 are tested except pesticides . Four additional parameters of BOD_5, COD, total N and total P are also tested as requested by IUCN and DWR (MARD).

4.4 Selection of rice product parameters tested

Based on FAO guidelines on Threshold levels of trace elements for crop production, for rice product quality, the following parameters are tested:

1. Lead (Pb)
2. Chromium (Cr)
3. Arsenic (As)
4. Sulfate (S)
5. Mercury (Hg)
6. Manganese (Mn)
7. Zinc (Zn)
8. Cadmium (Cd)

5. POLLUTION SOURCES IN THE SCHEME

5.1 Existing status

5.1. 1 Causes of water quality deterioration

Activities of economic social development are main causes to water quality deterioration in the area, including:

- Activities of the trade, handicraft villages;
- Activities of the industrial zones;
- Activities of agricultural production;
- Activities of waste disposals from resident areas.

Another objective cause is climate change which makes drought longer and more serious in the area.

5.1.2. Main pollution sources

5.1.2.1. Main pollution sources from trade and handicraft villages

According to the statistic data, in the case study area there are 62 trade, handicraft villages, of which 30 villages are traditional ones and rest of 32 villages are new ones. Most of the trade, handicraft villages is concentrated in Tien Son district (27 villages). One third of the villages is distributed over 4 communes along National Road No.1A.

The villages having significant impacts on environment of the area are:

- Village group of recycling black and coloured metals (for instances, iron, copper, zinc etc). This village group including Da Hoi, Chau Khe, Van Mon, Dai Bai villages causes air, water and soil pollution.

- Village group of furniture producing (11 villages), bamboo handicraft (6 villages) is concentrated in Dong Ky (Dong Quang commune), Phu Khe, Huong Mac (Tu Son district), Khu Xuyen commune (Yen Phong district).

- Village group of paper mill and recycling is located in Phong Khe commune (Yen Phong district), Phu Lam (Tien Du district.

- Village group of alcohol processing, food processing includes Dai Lam village, Tam Da commune (Yen Phong district), Van Mon commune (Yen Phong district), My Xuyen, My Huong (Luong Tai district), Lang Cam, Dong Nguyen commune (Tu Son district), Tam Giang commune (Yen Phong district).

- Village group of dyeing, silk production includes villages of Tuong Giang commune (Tu Son district).

Besides the above said village groups, there are other villages of construction material production, agricultural tool producing etc.

Products and production procedures of the village groups are different from one to the other. Hence, wastewater features are also different. All untreated wastewater of the villages is discharged directly into Ngu Huyen Khe river, drain system of BDIS or ponds and lakes.

Common production features of the trade, handicraft villages are: small scale, old and backward facilities and technologies. These production bases have not any treatment system for air emission, wastewater, and solid waste. No any planning for production bases of these villages but spontaneous Normally, the production bases are close to or within the local households causing direct impacts on the households and neighbors. The trade, handicraft villages often use the recycled materials, cheap materials, therefore much waste matters are disposed into environment, mainly to Ngu Huyen Khe river. It means Ngu Huyen Khe river is considered as a dumping place in the area. At present time, the trade, handicraft villages are under very heavy pressure of environmental pollution.

5.1.2.2 Main pollution sources from the industrial villages

In order move the trade, handicraft villages out the residential areas, some industrial village zones such as: Phong Khe Paper, Chau Khe Steel, Van Mon Lead &

Aluminium Casting, Dong Quang Furniture, Dai Bai Copper Casting have been formed.

Table 11: List of the industrial villages and their impacts on environment

Village name	Raw materials used	Waste matters		
		Air emission	Liquid waste	Solid waste
Phong khe - Yen Phong (Paper recycling)	Recycled paper, water, chemicals (NaOH, Detergent, Na_2CO_3)	Air emission (CO_2,SO_2,NO_2Cl, dust etc.)	Wastewater consisting detergent residuals, chemicals domestic wastewater	Coal residues, domestic waste solids, paper, plastic bags etc.
Chau Khe- Tu Son (Recycled iron, steel)	Lubricants, Zinc, H_2SO_4,NaOH, HCl, HNO_3, NaCl, water...	Dust, CO, CO_2, SO_2, NO_2, O_3, HC, Pb gas, Zn, Cd, HCl...	Wastewater consisting acid, Fe, Zn, Cl, domestic wastes	Coal residues, iron dust, domestic waste
Van Mon – Yen Phong (Lead, Aluminum casting)	Recycled lead, aluminum	Dust of aluminum, Pb gas, Cd, As, Zn, CO, CO_2, SO_2, O_3, NO_2, HC...	Wastewater	Coal residues, lead dust, domestic solid waste
Dong Quang – Chau Khe – Tu Son (Furniture producing)	Woods of various kinds	Dust, gas	Domestic wastewater	Wood dust, pieces of woods, domestic solid waste
Dai Bai – Gia Binh (Copper casting)	Copper, aluminum	CO, CO_2,SO_2, NO_2, dust.	Domestic wastewater	Coal residues, domestic solid waste

5.1.2.3 Main pollution sources from the industrial zones

In recent years, many investors have invested in industrial bases in the case study area to form industrial zones, for instance:, Tien Son, Que Vo industrial zones. These industrial zones have various production fields:

- Food processing;
- Drug (pharmaceutical herbs) processing for exporting;
- Tobacco preliminary processing for exporting;
- Cosmetic production;
- Electronic equipment assemblages

These industrial zones discharge wastewater into drain systems of the Bac Duong scheme and cause water pollution. In dry season, because of lack of water avaibility, farmers have to take water from the drains for irrigation.

Below are more detailed descriptions about these industrial zones.

Tien Son Industrial Zone.
This is one of industrial zones, which was established in the area early. The Tien Son industrial zone's fields are: food processing and animal food processing. This zone is

located near Ha Noi – Lang Son road (National Road No.1A). When the Tien Son industrial zone was put into operation, evidence of environment pollution has been identified. The surrounding communes have been affected by water wasted from the zone. Because no ponds and lakes are available in the zone, all wastewater is discharged into drains of 6 communes belonging to Nam Trinh Xa drain system. In the dry season (from November to March), bad smell is dispersed everywhere in the surrounding communes. Though the pollution level is not very serious, potential pollution is clear. It is required that Tien Son industrial zone should implement regulations on wastewater treatment as regulated in the Environment Protection Law.

The electronic and telecommunication industries of Dai Dong – Hoan Son are under construction and initial operation. No evidence of environment pollution has been identified. However, it is required that the local authority and authorized agencies should manage and monitor strictly waste matter treatment of the Dai Dong – Hoan Son industries.

Que Vo Industrial Zone

The Que Vo industrial zone is established in Phuong Lieu commune, Que Vo district. Its gross area is 153 ha located close to Noi Bai – Ha Long highway. Irrigation canals of Nam Trinh Xa and drain system of Tao Khe are within this area. Though there have been no any specific study, many evidences of environment pollution caused by wasted matters from the zone have been identified.

Dap Cau Industrial and Handicraft Zone.

This zone is located in east of Bac Ninh town. The zone has several big central factories such as Dap Cau Glass Factory, Bac Son Tobacco Factory, Float Grass Factory, and Dap Cau Port, Hoang Long Ltd. In the zone there are also 45 lime production bases having old facilities and technologies that result in negative impacts on the environment. In general, none of thel factories in the zone have facilities for the treatment of waste gases and wastewater. Daily, the Dap Cau zone uses 2000 liters of FO oil with high sulfur concentration (3.2%) for its operation. However, the factory has no air filter or SO_2 gas treatment facility, so that it causes air pollution in the zone. On the other hand, during operation, the oil leaks into the cooling system and then moves into canal system resulting in pollution to crops.

This industrial zone has Dap Cau port which also causes dust pollution by vehicles. It should be noted that the pollution level of the Dap Cau industrial zone has increasing trend, while no any measure for pollution mitigation has been taken.

5.1.2.4 Other pollution sources

Besides pollution sources of the industrial villages and the industrial zones mentioned above, other pollution sources are from urbanization, and overuse of chemical inputs in agricultural production. However, data and information of pesticide content in water of canals, drain systems and agricultural products are not available. Study of impacts caused by chemical inputs is out of scope of this case study.

Figure 4 Liquid and solid waste matters of Ngu Huyen Khe river

Table 12: List of industrial zones and their waste discharge

No.	Industrial zone	Area (ha)	Waste discharge (m3/day)	Note
1	Tien Son	600	20000	
2	Que Vo	636	10665	
3	Que Vo II	570	20000	
4	Que Vo III	300	11000	2020 plan
5	Yen Phong	840.7	NA	
6	Yen Phong II	1200	NA	
7	Dai Dong - Hoan Son	600	NA	
8	Nam Son - Hap Linh	1000	NA	
9	Dai Kim - Bac Ninh	1200	NA	
10	VSIP	700	NA	
11	Tien Du	300	NA	
12	Tu Son	300	NA	
13	Hanaka	74	NA	
14	Ma Ong (Dinh Bang)	5	1000	
15	Nhan Hoa - Phuong Lieu	4.5	2050	
16	Tan Chi	70	4500	
17	26 Trade Villages	661	NA	
	Total	9061		

5.2 Expected pollution sources in the future.

Bac Ninh province has been planned to become an industrial province in 2020 with 3 projection scenarios. Economical sector structure of each projection is given in Table 13 bellow.

Table 13 : Economic structure of Bac Ninh province to 2020

Economic structure/Year	**2005**	**2010**	**2015**	**2020**
Projection 1	**100**	**100**	**100**	**100**
- Industry	*47*	*51*	*53*	*56*
- Agriculture	*25*	*15*	*11*	*7*
- Service	*28*	*34*	*37*	*37*
Projection 2	**100**	**100**	**100**	**100**
- Industry	*47*	*53*	*56*	*57*
- Agriculture	*25*	*15*	*9*	*6*
- Service	*28*	*32*	*35*	*37*
Projection 3	**100**	**100**	**100**	**100**
- Industry	*47*	*49*	*51*	*52*
- Agriculture	*25*	*14*	*9*	*5*
- Service	*28*	*36*	*40*	*43*

Data of the above table shows that rate of industry and service will be increased and incomes from these sectors will be main sources of the province in 2020. This requests increase of industrial production in both quantity of industrial production and its value. Therefore, it is required to build more industrial zones for new factories leading to increase of waste matters into environment. As previously mentioned besides existing industrial zones, planning of new industrial zones has been developed and it has been approved by Prime Minister in accordance with Decision No.1107/2006/QĐ-TTg dated on 21 Aug. 2006.
Bac Ninh province has had a decision of changing land use purpose of 7,483 ha, of which 3,484 ha in Bac Duong irrigation system area are used for the industrial and urban areas. Some of these areas have finished settlements and ready for construction. On other hand, according to the development plan to year 2020, Bac Ninh province also has a plan of reallocating craft villages to concentrate in craft village areas or in small and moderate scale industry groups.

List of industrial, craft village and urban areas in Bac Duong area up to year 2020 in Bac Duong scheme is shown in Table 14 bellow.

Table 14 : Industrial and urban zones in Bac Duong area

No	**Industrial zone**	**Total planned area for industrial and Urban zone (ha)**	**Detail**	
			Industrial zone (ha)	**Urban zone (ha)**
1	Tien Son extend (including Tan Hong – Hoan Son)	410	380	30
2	Que Vo 2	270	270	0
3	VSIP Bac Ninh	700	500	200
4	Nam Son - Hap Linh	1.000	800	200
5	Yen Phong 2	1.200	1.000	200
6	Tu Son extend	300	300	0
7	KCN Hanaka	74	74	0
	Total	3,484	3,324	630

Table 15: List of land use areas for the planned craft villages

Trade village zone **Industrial small and average size group**	**Land use area (ha)**	**District**
Chau Khe	13.5	Tu Son
Dong Quang	12.7	Tu Son
Phong Khe	12.7	Yen Phong
Dinh Bang I	9.7	Tu Son
Dinh Bang II	5	Tu Son
Tan Hong – Dong Quang	16.3	Tien Du
Hap Linh	NA	Tien Du
Pho Moi	15.2	Que Vo
Phu Lam	18	Yen Phong
Noi Due	13	Tu Son
Yen Phong	57	Yen Phong
Total	173	

In direction of industrial development, Bac Ninh province gives priorities to high level technological branches, subsidiary branch, mechanical manufactory, at the same time promotes branches that will use more raw materials produced in province including food processing, construction material production, textile, leather and shoes production and traditional craft .

This directional plan shows that waste matters will be increased year to year. List of factories to be located in the industrial zones is presented in Table 15, meanwhile craft villages are to be reallocated in these areas.

This directional plan shows that production of industry sector and craft villages is not so much changed in comparison with the existing industry sector.

At present, detailed information of what factories, what scope, what production technologies and what waste matters disposed are not available. Wastewater from the future industrial zones can be quantitatively estimated in accordance with available data of existing industrial zone, including (i) amount of wastewater, (ii) land use area, (iii) fill up rate, (iv) wastewater treatment means and some relevant factors.

Unfortunately, Bac Ninh DONRE has had a monitoring of wastewater quality at some locations of industrial zones and from craft villages only. Volume data of wastewater discharged from industries and craft villages is not available. The investigation on waste status carried out by IWRR also focused on quality of wastewater only, not quantity.

It is impossible to estimate exactly amount of wastewater in year 2020. Trend of wastewater quantity could be forecasted on the basis of following assumptions:

- Economic Development of Bac Ninh province will follow various seniors presented in Table 13;
- Population growth rate of the province estimated in accordance with the development plan to 2020;
- Craft villages concentrated in planned zones;
- Industrial zones constructed in 100% of the planned areas;
- Legal regulations of the State and province on environmental protection strictly implemented.

Some data of wastewater discharge in several existing industrial zones has been gathered by Bac Duong IDMC given in Table 12 above. This shows that with the existing industrial zone areas of 1,344 ha (accounting for 59% of the planned industrial zone areas) the present wastewater discharge is 41,865 m^3 per day or 15,280,725 m^3 per year.

If it is roughly estimated that one hectare of industrial zone discharges about 32 m^3 of wastewater per day, then in 2020 with 6,263 ha of the industrial planned zones amount of 200,416 m^3 of wastewater will be discharged per day (or 73,151,840 m^3 per year).

Besides these industrial zone areas, 173 ha of craft villages will be a considerable source of wastewater. According to of actual information, a unit area of trade village discharges 1.2 times higher than a unit area of industrial zones. It is estimated that wastewater from craft village area will be 6,643 m^3 per day or 2,424,695 m^3 per year.

Urbanisation growth in Bac Ninh province in general as well as in the Bac Duong area in particular also leads strongly increase of wastewater amount from domestic uses. It could be roughly estimated that: standard water consumption for domestic use in urban areas is 150 lit/person/day, urban population in 2010 is about 300,000 people, and to 2020, urban population will be 350,000 people. If wastewater amount is estimated to be equal 85% of water amount used, wastewater amount form urban area is to be 52,500 m^3 per day or 19,162,500 m^3 per year.

Thus, total amount of wastewater to 2020 in the study area is 259,559 m^3 per day or 94,739,035 m^3 per year.

In 2020, wastewater in study area could be forecasted that:

- Total amount of wastewater is to be up to 95 mil m^3 per year, 1.3 times higher than the present wastewater quantity.
- Quality of wastewater will be controlled as permits licensed by the authorized agencies, if the legal regulations is strictly implemented by all stakeholders, especially industrial zones and craft villages.

6. ASSESSMENT OF WATER QUALITY IN THE CASE STUDY AREA

6.1 Assessment of Water Quality in Ngu Huyen Khe river

In order to have data of water quality in Ngu Huyen Khe river, 10 monitoring points were established under MARD's program (from 2005 to 2007) to be sampled as indicated below.

Point No.1 (K1): At Long Tuu sluice. This sluice takes water from Duong river into Ngu Huyen Khe river during the winter crop. During the summer crop, the Long Tuu sluice is always closed and Ngu Huyen Khe plays a role of a drain. At this location, population is not dense and there are no any activities of trade villages or industries. Water quality of the location is considered as water quality of Duong river. This monitoring point can be considered as an ambient water quality monitoring point.

Point No.2 (K2): At Da Hoi bridge. This is a trade village of iron and steel processing with high population density. A lot of solid waste matters is disposed along the Ngu Huyen Khe river banks. The river bed is narrowed. Flow velocity is rather high when the Long Tuu sluice is opened or Trinh Xa pumping station is operated.
Point No.3 (K3): At Trinh Xa pumping station. This station has both functions of irrigation and drainage. In this area, water pollution is caused by waste matters of villages and beverage production bases.

Point No.4 (K4): At Minh Duc pumping station. This is a irrigation pumping station. Water quality of this place is much affected by waste sources from upstream.

Point No.5 (K5): At Dong Tho pumping station. Population density of this location is not high. Waste matters in this place are not so much as in Da Hoi.

Point No.6 (K6): At Bat Dan pumping station. Water quality of this place is affected by both upstream (Da Hoi village) and downstream (Phu Lam village, Phong Khe commune). Here, the river water has a dark colour and bad smell.

Point No.7 (K7): At Phu Lam pumping station. This location is within paper recycling villages with high population density. Many waste matters (both solid and liquid waste) are disposed into the river. Water is much polluted.

Point No.8 (K8): At Phuc Xuyen bridge. Here is downstream and water pollution can be seen by normal eyes.

Point No.9 (K9): At Dang Xa sluice. This is the end of Ngu Huyen Khe river before discharging into Cau river. In this place, the river water is much polluted.

Point No.10 (K10): At Xuan Vien pumping station. Water of this place is mixture of Ngu Huyen Khe river's water and Cau river's water.

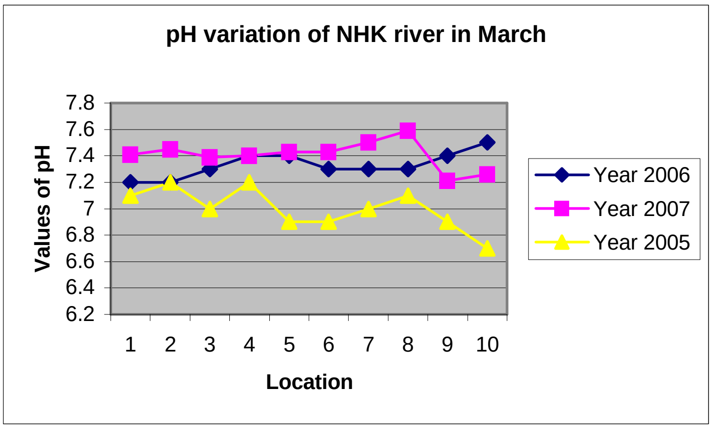
Figure 5. Ngu Huyen Khe river in dry season

A RIVER HAS PASSED AWAY
"According to the local people of Phong Khe commune, Ngu Huyen Khe romantic river has been killed by themselves. Process of paper recycling has discharged a great wastewater load consisting much toxic matters, chemicals. Day by day, solid and liquid wastes are freely disposed into the river". *(TuoiTr e Online, 13 May 2008)*

PEOPLE HAVE TO WEAR COMFORTERS WHEN SLEEPING
"In Phong Khe (Bac Ninh province), all people are racing in paper recycling that made Ngu Huyen Khe river seriously polluted. Living close to the river with heavy bad smells, the local people always have to wear comforters even when sleeping". *(Van Nguyen, Cong An Nhan Dan news paper, 9 October 2008)*

6.1.1 Variation of pH

According to the tested data, in general, the pH of Ngu Huyen Khe river water varies from 6.2 to 7.9. It has a light alkaline characteristic. pH variation is uneven. It has an increasing trend from upstream to downstream. Especially, at places receiving big wastewater flows such as Phu Lam, Phuc Xuyen, Xuan Vien, the pH variation depends on chemicals included in the wasted water. However, values of pH are within the range of the National Standards TCVN 6773:2000.



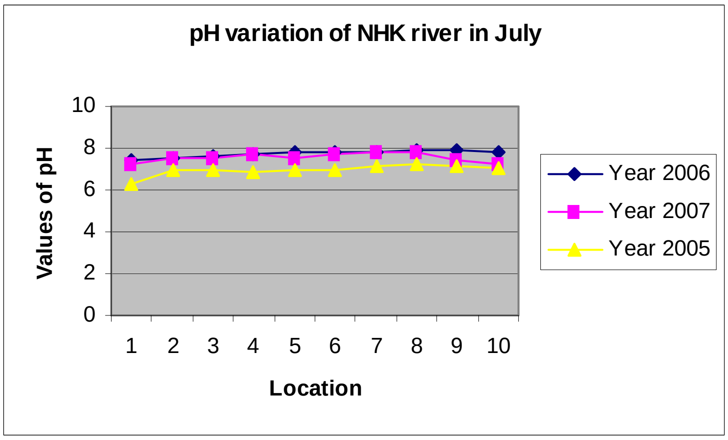


Figure 6. pH variation of Ngu Huyen Khe in dry and rainy season

Note: Location No.1: Long Tuu sluice; 2:. Da Hoi bridge; 3: Trinh Xa station; 4 Minh Duc station; 5: Dong Tho station; 6: Bat Dan station; 7: Phu Lam station; 8: Phuc Xuyen bridge; 9: Dang Xa sluice; 10: Xuan Vien station

6.1.2 Mineralization level

Mineralization level of the river water is evaluated via Electric Conductivity (EC). In Ngu Huyen Khe river, EC value normally is high in dry season (From January to May) and low in rainy season. If comparing EC values of March (dry season) and July (rainy season), it can be seen that EC values in March are much higher than in July and EC values increase from upstream to downstream. (Please see Table 13 below)

Table 16. Values of EC in dry and rainy season of Ngu Huyen Khe river

Year	Location	Value of EC (ms/cm)	
		In March	In July
2005	Long Tuu sluice	287	234
	Da Hoi bridge	244	302
	Trinh Xa station	254	311
	Minh Duc station	278	313
	Dong Tho station	299	320
	Bat Dan station	324	378
	Phu Lam station	563	337
	Phuc Xuyen bridge	414	323
	Dang Xa sluice	434	387
	Xuan Vien station	433	410
2006			
	Long Tuu sluice	984	232
	Da Hoi bridge	389	468
	Trinh Xa station	504	490
	Minh Duc station	449	492
	Dong Tho station	501	391
	Bat Dan station	494	396
	Phu Lam station	732	416
	Phuc Xuyen bridge	1315	414
	Dang Xa sluice	1247	378
	Xuan Vien station	758	520
2007			
	Long Tuu sluice	283	348
	Da Hoi bridge	339	354
	Trinh Xa station	390	435
	Minh Duc station	420	367
	Dong Tho station	457	425
	Bat Dan station	546	350
	Phu Lam station	838	406
	Phuc Xuyen bridge	1005	320
	Dang Xa sluice	796	322
	Xuan Vien station	868	326

The EC variation of Ngu Huyen Khe river water shows that a lot of metal ions of iron, copper and other chemicals (like NaOH, HCl, H_2SO_4) are wasted from the trade villages along Ngu Huyen Khe river.

6.1.3 Dissolved Oxygen (DO)

Dissolved Oxygen (DO) is considered as an important parameter of water quality. It is an indicator of self-purification of a natural stream. It is also a crucial value to indicate the possibility of healthy life to aquatic organisms. Low DO simply means that organisms like fish and their food die and the river is given to lower microorganisms. Values of DO tend to decrease from upstream to downstream. They much depend on the river flow rates and wastewater loads. According to the observed data, in the sections from Long Tuu sluice to Trinh Xa pumping station the river flow rate is rather high. From Minh Duc pumping station to downstream the river

flow rate is river flow rate is much decreased, due to irrigation water intake, and pollution in these locations is serious because of wastewater from the industries andtrade villages. On the other hand, because of sedimentation and solid waste matter disposal, the river flow is obstructed. The DO concentration downstream of Bat Dan station (point 6) is often lower than the critical value of 3.0 mg/l, especially in the dry season (March). Water smell in the downstream locations is very bad.
In Ngu Huyen Khe river, values of dissolved oxygen vary from time to time and from place to place (please see Table 17 below). Upstream, DO is rather stable, however, at Phu Lam, Phuc Xuyen, Dang Xa, Xuan Vien, values of DO are much lower in comparing with upstream values. In June and July, DO is higher than 2 mg/l. In dry season, DO is lower especially at downstream. From Phu Lam to Xuan Vien places, DO is very low and does not meet the National Standards. (greater or equal 5 mg/l and 2 mg/l for water of Class A and Class B respectively).The sellf purifying capacity of the river has been seriously exceeded

Table 17: Values of Dissolved Oxygen in Ngu Huyen Khe river

Year	Location	Value of DO (mg/l)	
		In March	In July
2005	Long Tuu sluice	4.05	5.67
	Da Hoi bridge	5.86	3.43
	Trinh Xa station	3.48	4.04
	Minh Duc station	5.15	4.03
	Dong Tho station	3.21	3.97
	Bat Dan station	1.45	4.00
	Phu Lam station	0.18	2.73
	Phuc Xuyen bridge	1.16	2.90
	Dang Xa sluice	0.67	2.05
	Xuan Vien station	1.22	4.11
2006			
	Long Tuu sluice	4.28	12.16
	Da Hoi bridge	5.96	9.92
	Trinh Xa station	6.60	9.28
	Minh Duc station	6.44	9.00
	Dong Tho station	4.28	9.12
	Bat Dan station	5.60	11.52
	Phu Lam station	2.67	7.12
	Phuc Xuyen bridge	0.10	6.72
	Dang Xa sluice	0.25	9.28
	Xuan Vien station	0.30	7.52
2007			
	Long Tuu sluice	8.25	7.28
	Da Hoi bridge	7.95	8.25
	Trinh Xa station	7.65	7.82
	Minh Duc station	7.01	8.20
	Dong Tho station	8.20	8.05
	Bat Dan station	4.65	7.26
	Phu Lam station	1.03	3.58
	Phuc Xuyen bridge	0.00	5.35
	Dang Xa sluice	0.00	4.86
	Xuan Vien station	0.00	5.66

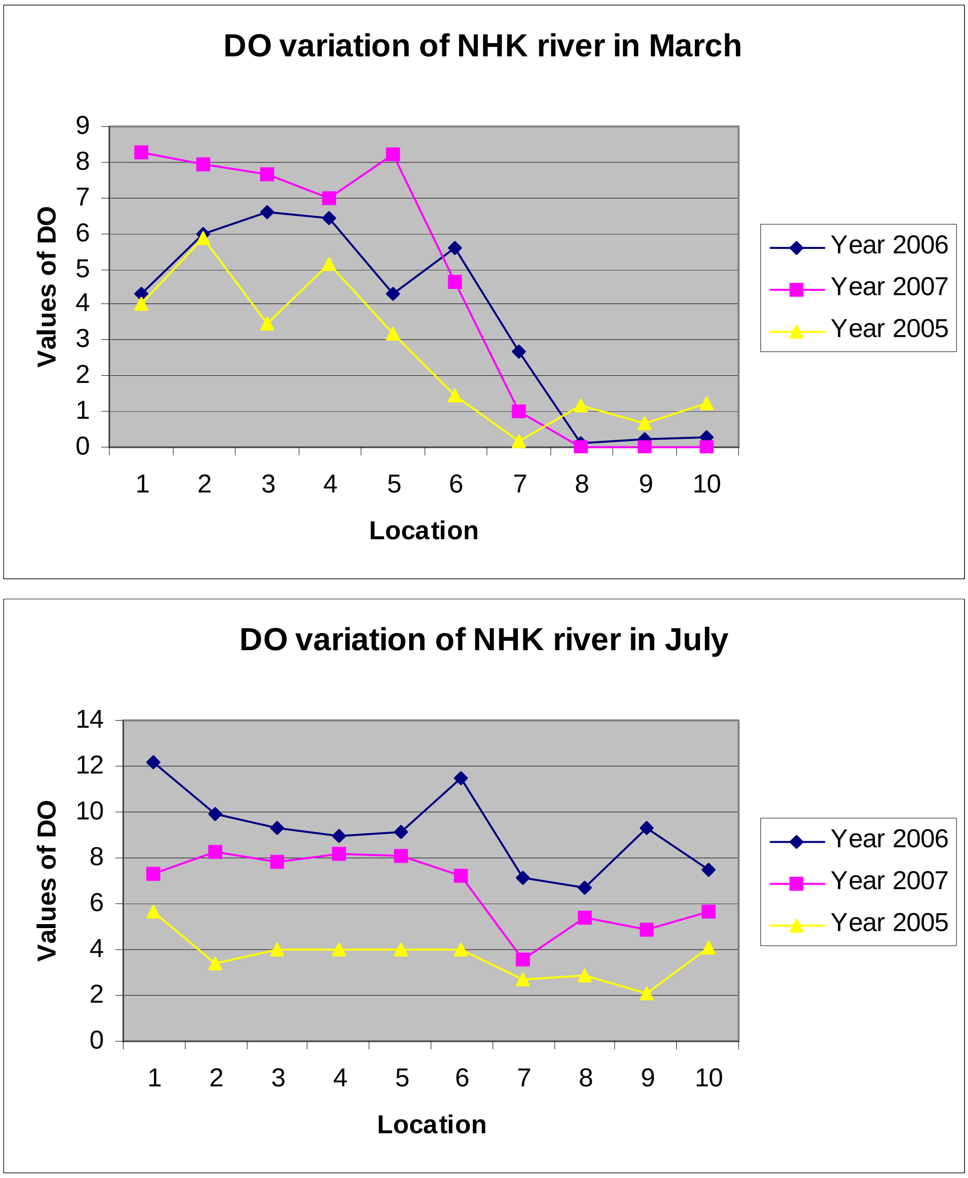


Figure 7. Dissolved Oxygen variation of Ngu Huyen Khe in dry and rainy season

Note: Location No.1: Long Tuu sluice; 2:. Da Hoi bridge; 3: Trinh Xa station; 4 Minh Duc station; 5: Dong Tho station; 6: Bat Dan station; 7: Phu Lam station; 8: Phuc Xuyen bridge; 9: Dang Xa sluice; 10: Xuan Vien station

6.1.4 Chemical Oxygen Demand (COD)

COD of Ngu Huyen Khe river varies very much time to time and place to place (Please see Fig…….. At Long Tuu sluice, value of COD normally is the lowest. At various places, in the dry season, COD concentrations are higher in comparison with the rainy season, because COD much depends on the river seasonal flow. (according to the Vietnam Standards, COD permitted values are <10 and < 35 mg/l for Class A and Class B of surface water, and < 50 and 80 mg/l for waste water – please see Annex 1)

Table 18: Values of Chemical Oxygen Demand in Ngu Huyen Khe river

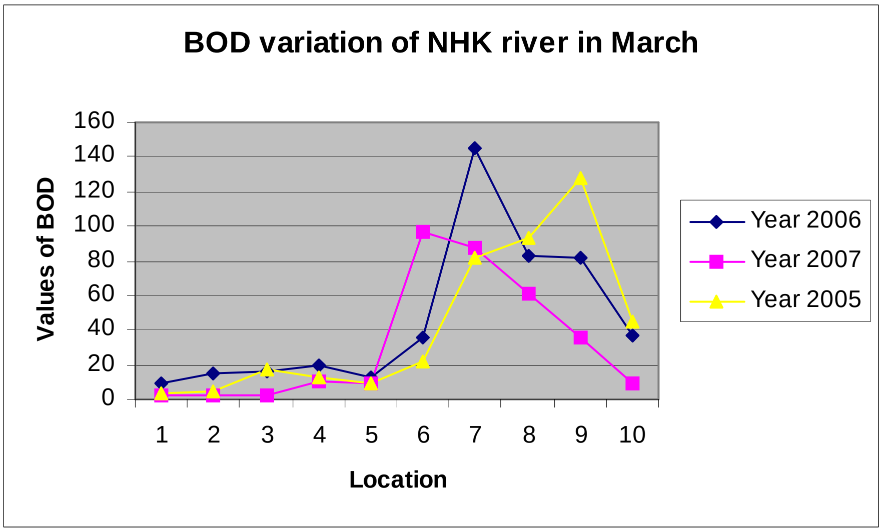
Year	Location	Value of COD (mg/l)	
		In March	In July
2005	Long Tuu sluice	3.00	3.73
	Da Hoi bridge	4.18	5.71
	Trinh Xa station	17.69	7.86
	Minh Duc station	12.17	7.38
	Dong Tho station	9.28	9.00
	Bat Dan station	22.11	7.11
	Phu Lam station	81.92	6.22
	Phuc Xuyen bridge	92.67	27.63
	Dang Xa sluice	128.17	36.17
	Xuan Vien station	77.16	21.16
2006			
	Long Tuu sluice	15.6	19.2
	Da Hoi bridge	17.2	27.2
	Trinh Xa station	36.4	27.0
	Minh Duc station	24.4	31.5
	Dong Tho station	28.4	36.0
	Bat Dan station	84.8	22.4
	Phu Lam station	187.7	38.3
	Phuc Xuyen bridge	216.8	38.4
	Dang Xa sluice	220	35.7
	Xuan Vien station	103.6	19.7
2007			
	Long Tuu sluice	6.4	7.2
	Da Hoi bridge	5.6	6.4
	Trinh Xa station	6.72	8.0
	Minh Duc station	13.15	9.6
	Dong Tho station	15.2	8.0
	Bat Dan station	394.5	14.4
	Phu Lam station	122.6	19.2
	Phuc Xuyen bridge	261.6	16.0
	Dang Xa sluice	141.6	20.8
	Xuan Vien station	15.2	5.6

6.1.5 Biochemical Oxygen Demand (BOD_5)

Biochemical Oxygen Demand has a variation similar to the COD concentration. In spatial scale, BOD_5 has an increasing trend from upstream to downstream. From upstream to midstream, the observed values of BOD_5 are lower than the Standard B (TCVN 5942-1995) (smaller than 25 mg/l). However from midstream (Bat Dan Station) to downstream, BOD increases fast and is over the allowable values of the Standards -TCVN 5942-1995 and Standards of industrial wastewater discharge TCVN 5945-2005. From midstream to downstream, BOD values in March are always higher than BOD values in July, as at these places, in the dry season, water quality in Ngu Huyen Khe river much depends on wastewater from various sources.

Table 19: Values of Biochemical Oxygen Demand (BOD_5) in Ngu Huyen Khe river

Year	Location	Value of BOD_5 (mgO_2/l)	
		In March	In July
2006	Long Tuu sluice	3.00	3.73
	Da Hoi bridge	4.18	5.71
	Trinh Xa station	17.69	7.86
	Minh Duc station	12.17	7.38
	Dong Tho station	9.28	9.00
	Bat Dan station	22.11	7.11
	Phu Lam station	81.92	6.22
	Phuc Xuyen bridge	92.67	27.63
	Dang Xa sluice	128.17	36.17
	Xuan Vien station	44.77	21.16
2006			
	Long Tuu sluice	8.90	13.69
	Da Hoi bridge	14.68	15.73
	Trinh Xa station	16.45	18.50
	Minh Duc station	19.36	18.70
	Dong Tho station	12.33	20.88
	Bat Dan station	35.87	13.44
	Phu Lam station	144.50	25.70
	Phuc Xuyen bridge	82.93	21.12
	Dang Xa sluice	81.60	20.33
	Xuan Vien station	36.29	12.79
2007			
	Long Tuu sluice	2.56	4.85
	Da Hoi bridge	1.86	4.20
	Trinh Xa station	2.05	5.45
	Minh Duc station	10.60	6.21
	Dong Tho station	9.12	5.32
	Bat Dan station	96.15	8.95
	Phu Lam station	87.30	12.02
	Phuc Xuyen bridge	60.48	10.63
	Dang Xa sluice	35.70	13.87
	Xuan Vien station	8.96	3.56



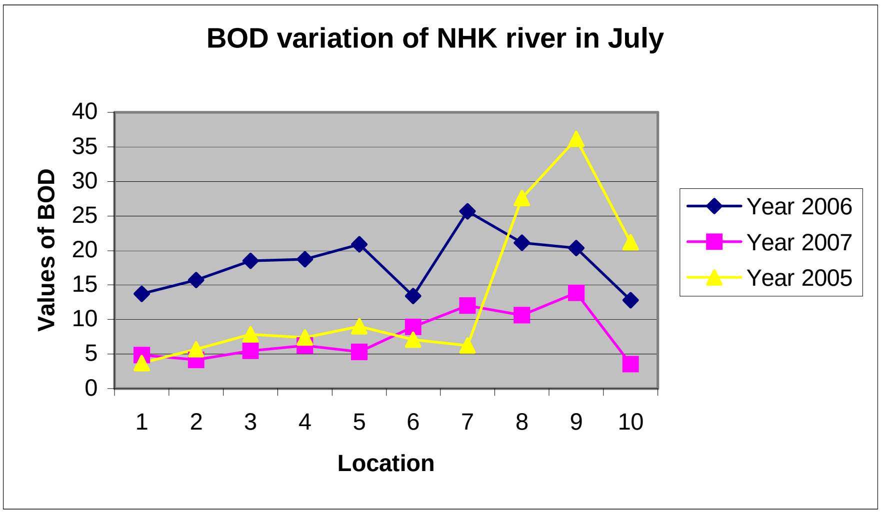


Figure 8. BOD_5 variation of Ngu Huyen Khe in dry and rainy season

Note: Location No.1: Long Tuu sluice; 2:. Da Hoi bridge; 3: Trinh Xa station; 4 Minh Duc station; 5: Dong Tho station; 6: Bat Dan station; 7: Phu Lam station; 8: Phuc Xuyen bridge; 9: Dang Xa sluice; 10: Xuan Vien station

6.1.6 Nitrogen compounds *(NH_4+, NO_2-, NO_3-)*

Variation of NH_4^+ in Ngu Huyen Khe river is rather complicated. It can be seen that at midstream, values of NH_4^+ are relatively high, while at upstream and downstream these values are smaller, but in general still higher than the standards (1 mg/l)

Table 20: Values of NH_4^+ in Ngu Huyen Khe river

Year	Location	Value of NH_4^+ (mg N/l)	
		In March	In July
2005	Long Tuu sluice	0.42	0.60
	Da Hoi bridge	0.39	1.79
	Trinh Xa station	1.07	1.34
	Minh Duc station	0.58	1.97
	Dong Tho station	0.67	1.64
	Bat Dan station	1.03	1.74
	Phu Lam station	1.14	0.83
	Phuc Xuyen bridge	1.17	0.47
	Dang Xa sluice	0.37	0.36
	Xuan Vien station	0.83	0.23
2006			
	Long Tuu sluice	0.28	1.40
	Da Hoi bridge	1.12	0.56
	Trinh Xa station	6.58	4.20
	Minh Duc station	2.52	2.10
	Dong Tho station	2.38	0.84
	Bat Dan station	2.55	1.06
	Phu Lam station	1.86	1.33
	Phuc Xuyen bridge	1.26	1.12
	Dang Xa sluice	0.10	1.68
	Xuan Vien station	1.28	1.01
2007			
	Long Tuu sluice	0.11	0.01
	Da Hoi bridge	0.17	0.01
	Trinh Xa station	0.28	0.01
	Minh Duc station	0.38	0.01
	Dong Tho station	0.50	0.01

Year	Location	Value of NH_4^+ (mg N/l)	
		In March	In July
	Bat Dan station	3.28	0.01
	Phu Lam station	2.77	0.01
	Phuc Xuyen bridge	0.67	0.01
	Dang Xa sluice	1.18	0.01
	Xuan Vien station	0.01	0.01

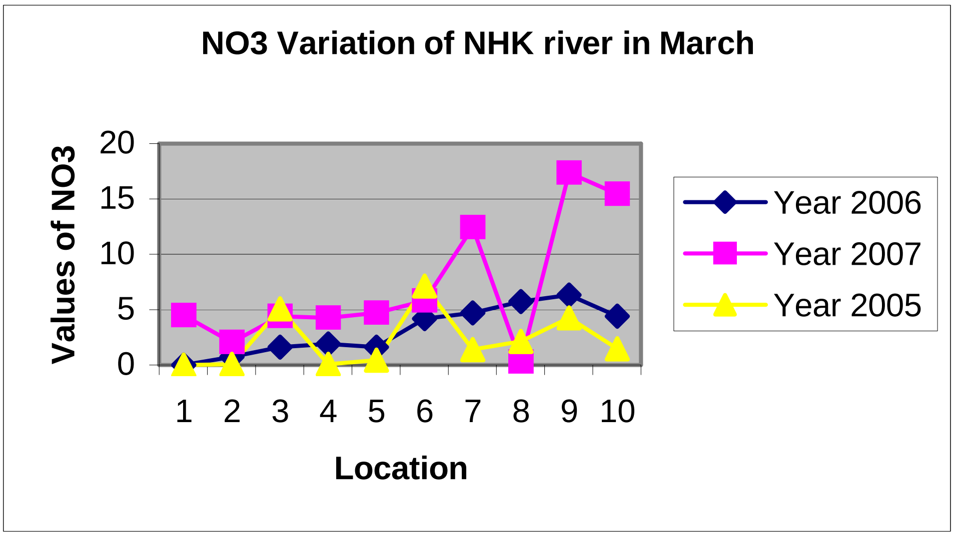
According to the observed data, variation of ammonia is not the same trend as variation of Nitrite and Nitrate. Values of NO_2 increase from upstream to downstream in various months and they are higher at places from Phu Lam to Xuan Vien. downstream, when Dang Xa sluice is closed, all wastewater is blocked, water colour becomes black, DO decreases resulting in serious water pollution. Variation of NO_3 is something the same as NO_2. In general, values of NO_3 are within the Standards (15 mg/l) (see Table 18 below). However, values of NO_2 downstream of Ngu Huyen Khe are higher than the Standards (0.01 -0.05 mg/l) (see Table 19 below)

Table 21: Values of NO_3^- in Ngu Huyen Khe river

Year	Location	Value of NO_3^+ (mgN/l)	
		In March	In July
2005	Long Tuu sluice	0.02	0.75
	Da Hoi bridge	0.07	0.67
	Trinh Xa station	5.05	1.25
	Minh Duc station	0.07	0.90
	Dong Tho station	0.43	1.00
	Bat Dan station	7.11	0.87
	Phu Lam station	1.43	1.32
	Phuc Xuyen bridge	2.14	1.21
	Dang Xa sluice	4.23	0.01
	Xuan Vien station	1.50	0.87
2006			
	Long Tuu sluice	0.01	6.48
	Da Hoi bridge	0.76	5.90
	Trinh Xa station	1.64	8.38
	Minh Duc station	1.93	7.70
	Dong Tho station	1.64	6.96
	Bat Dan station	4.22	6.72
	Phu Lam station	4.73	6.10
	Phuc Xuyen bridge	5.70	5.68
	Dang Xa sluice	6.30	3.90
	Xuan Vien station	4.44	13.36
2007	Long Tuu sluice	4.46	2.15
	Da Hoi bridge	2.07	0.48
	Trinh Xa station	4.42	0.64
	Minh Duc station	4.25	0.29
	Dong Tho station	4.74	0.85
	Bat Dan station	5.80	0.32
	Phu Lam station	12.42	0.61
	Phuc Xuyen bridge	0.32	0.01
	Dang Xa sluice	17.32	0.15
	Xuan Vien station	15.45	0.48

Table 22: Values of NO_2 in Ngu Huyen Khe river

Year	Location	Value of NO_2 (mgN/l)	
		In March	In July
2005	Long Tuu sluice	0.01	0.02
	Da Hoi bridge	0.02	0.01
	Trinh Xa station	0.01	0.1
	Minh Duc station	0.01	0.16
	Dong Tho station	0.18	1.23
	Bat Dan station	0.07	0.37
	Phu Lam station	0.83	1.28
	Phuc Xuyen bridge	1.02	1.56
	Dang Xa sluice	0.68	1.03
	Xuan Vien station	0.19	1.03
2006			
	Long Tuu sluice	0.16	0.01
	Da Hoi bridge	0.4	0.01
	Trinh Xa station	0.66	0.6
	Minh Duc station	1.05	0.6
	Dong Tho station	1.46	0.01
	Bat Dan station	1.18	0.01
	Phu Lam station	0.89	1.1
	Phuc Xuyen bridge	0.04	0.76
	Dang Xa sluice	0.01	1.02
	Xuan Vien station	0.01	3.48
2007	Long Tuu sluice	0.01	0.15
	Da Hoi bridge	0.14	0.30
	Trinh Xa station	0.24	0.52
	Minh Duc station	0.22	0.28
	Dong Tho station	0.24	0.25
	Bat Dan station	0.54	0.18
	Phu Lam station	0.01	0.01
	Phuc Xuyen bridge	0.01	0.08
	Dang Xa sluice	0.01	0.06
	Xuan Vien station	0.01	0.12



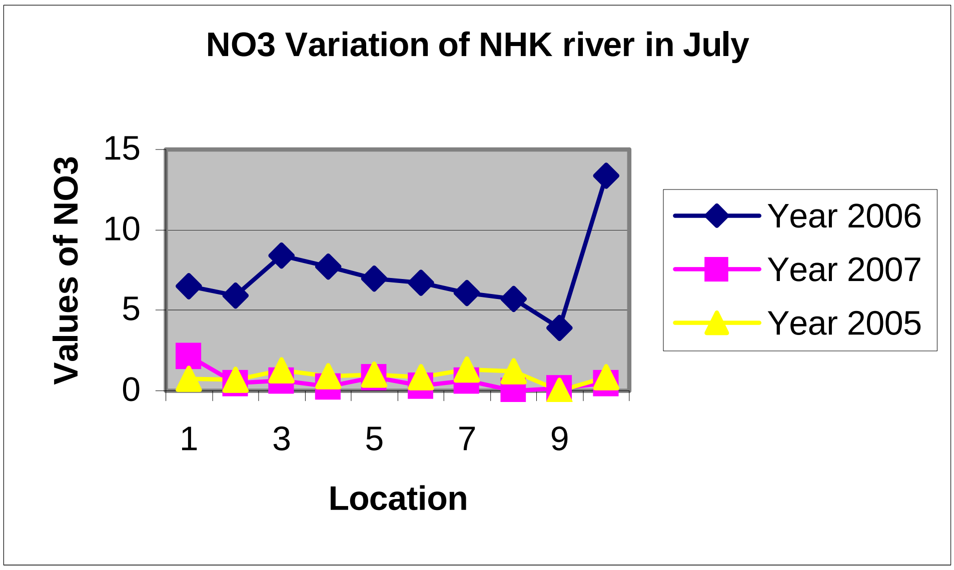


Figure 9. NO_3 variation of Ngu Huyen Khe in dry and rainy season

Note: Location No.1: Long Tuu sluice; 2:. Da Hoi bridge; 3: Trinh Xa station; 4 Minh Duc station; 5: Dong Tho station; 6: Bat Dan station; 7: Phu Lam station; 8: Phuc Xuyen bridge; 9: Dang Xa sluice; 10: Xuan Vien station

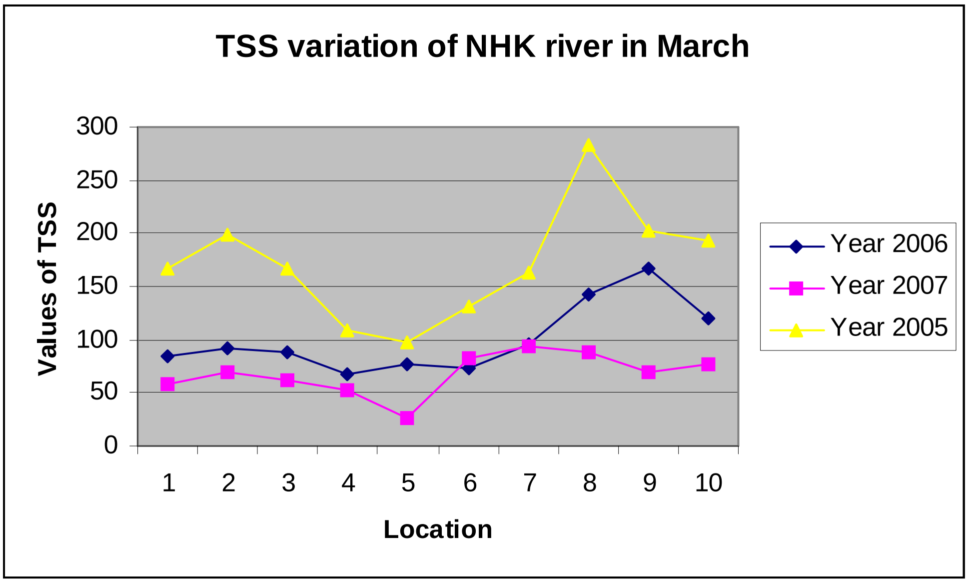
6.1.7 TSS and PO_4

In Ngu Huyen Khe river, spatial variation of Total Suspended Solid (TSS) is rather complicated. It has a decreasing trend from upstream to midstream and a increasing trend from midstream to Dang Xa sluice. However, in general, according to the tested samples, values of TSS are over the Standards TCVN 5942-1995 for Class B (1.1 to 4.0 times higher) and Standards of industrial wastewater discharge TCVN 5945-2005.

Table 23: Values of TSS in Ngu Huyen Khe river

		In March	In July
2006	Long Tuu sluice	167	196
	Da Hoi bridge	198	138.9
	Trinh Xa station	167	110
	Minh Duc station	108	89.63
	Dong Tho station	98	103.73
	Bat Dan station	132	99.6
	Phu Lam station	163	173.7
	Phuc Xuyen bridge	284	198.8
	Dang Xa sluice	203	180
	Xuan Vien station	192.2	186.4
2006			
	Long Tuu sluice	83.70	138.80
	Da Hoi bridge	92.10	108.30
	Trinh Xa station	87.60	87.50
	Minh Duc station	66.70	93.00
	Dong Tho station	76.80	80.40
	Bat Dan station	73.11	73.60
	Phu Lam station	95.12	83.70
	Phuc Xuyen bridge	141.60	86.60
	Dang Xa sluice	166.80	72.68
	Xuan Vien station	120.10	82.40
2007			
	Long Tuu sluice	57.95	60.20

	Da Hoi bridge	68.71	54.10
	Trinh Xa station	62.66	171.20
	Minh Duc station	53.21	75.90
	Dong Tho station	27.03	89.23
	Bat Dan station	83.20	61.80
	Phu Lam station	93.91	48.46
	Phuc Xuyen bridge	88.08	50.50
	Dang Xa sluice	69.71	37.46
	Xuan Vien station	76.08	35.20



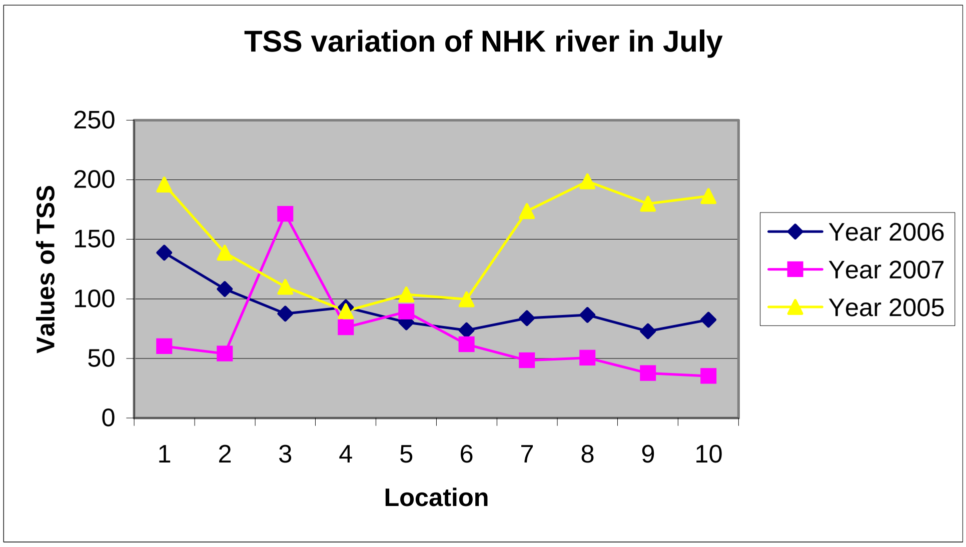


Figure 10. TSS variation of Ngu Huyen Khe in dry and rainy season

Note: Location No.1: Long Tuu sluice; 2:. Da Hoi bridge; 3: Trinh Xa station; 4 Minh Duc station; 5: Dong Tho station; 6: Bat Dan station; 7: Phu Lam station; 8: Phuc Xuyen bridge; 9: Dang Xa sluice; 10: Xuan Vien station

Values of PO4 are 1.0 – 1.7 times higher the Standards (permitted values are 0.2 - 1.0 mg/l). However, variation of PO4 is locally only. At Long Tuu sluice, values of PO4 are not high (< 0.1 mg/l in the dry season) and rather stable in various months. At midstream and downstream, values of PO4 vary rather strong. Their values are high at Trinh Xa, Minh Duc, Phu Lam, Phuc Xuyen, Dang Xa and Xuan Vien where water is much polluted by other parameters.

Table 24: Values of PO_4 in Ngu Huyen Khe river

Year	Location	Value of PO_4 (mg/l)	
		In March	In July
2005?	Long Tuu sluice	0.06	0.73
	Da Hoi bridge	0.34	0.64
	Trinh Xa station	0.18	1.07
	Minh Duc station	0.26	1.28
	Dong Tho station	0.06	0.67
	Bat Dan station	0.07	0.55
	Phu Lam station	1.03	1.47
	Phuc Xuyen bridge	1.17	1.36
	Dang Xa sluice	1.83	1.11
	Xuan Vien station	1.07	1.20
2006			
	Long Tuu sluice	0.02	0.06
	Da Hoi bridge	0.04	0.18
	Trinh Xa station	0.10	0.30
	Minh Duc station	0.06	0.40
	Dong Tho station	0.06	0.34
	Bat Dan station	0.74	0.24
	Phu Lam station	0.11	0.47
	Phuc Xuyen bridge	0.08	0.16
	Dang Xa sluice	0.08	0.10
	Xuan Vien station	0.14	0.26
2007			
	Long Tuu sluice	0.01	0.01
	Da Hoi bridge	0.01	0.02
	Trinh Xa station	0.01	0.12
	Minh Duc station	0.01	0.06
	Dong Tho station	0.01	0.04
	Bat Dan station	0.04	0.01
	Phu Lam station	0.03	0.04
	Phuc Xuyen bridge	0.03	0.04
	Dang Xa sluice	0.20	0.04
	Xuan Vien station	0.01	0.04

6.1.8 Coliform and Faecal coliforms

Comparing with Standards TCVN 6773:2000 nearly all values of Coliform and Faecal coliforms are over the allowable values, especially at Trinh Xa, Bat Dan, Phu Lam, Phuc Xuyen, Dang Xa, Xuan Vien in dry season or when Trinh Xa sluice is closed.
Maximum value of Coliform is 1,400,000 MPN/100ml (Dang Xa sluice) and its minimum value is 170 MPN/100ml (Long Tuu sluice). Maximum value of Faecal coliforms is 11,000 MPN/100 ml (Phu Lam station) and its minimum value is 36 Faecal coliforms (Long Tuu sluice).

Table 25: Values of Coliform in Ngu Huyen Khe river

Year	Location	Value of Coliforms (MPN/100ml)	
		In March	In July
2005?	Long Tuu sluice	1000	0
	Da Hoi bridge	120	120
	Trinh Xa station	54	12000
	Minh Duc station		
	Dong Tho station		
	Bat Dan station	3500	170
	Phu Lam station	16000	3200
	Phuc Xuyen bridge	4000	0

Year	Location	Value of Coliforms (MPN/100ml)	
		In March	In July
	Dang Xa sluice	140000	1420
	Xuan Vien station	11700	0
2006			
	Long Tuu sluice	18	3300
	Da Hoi bridge		
	Trinh Xa station	17000	7900
	Minh Duc station		
	Dong Tho station		
	Bat Dan station		
	Phu Lam station	170000	120000
	Phuc Xuyen bridge	520000	27000
	Dang Xa sluice	1400000	13000
	Xuan Vien station	180000	180000
2007			
	Long Tuu sluice	170	17000
	Da Hoi bridge	1300	92000
	Trinh Xa station	2400	54000
	Minh Duc station	32000	22000
	Dong Tho station	3500	17000
	Bat Dan station	2200	100000
	Phu Lam station	160000	100000
	Phuc Xuyen bridge	130000	12000
	Dang Xa sluice	93000	18000
	Xuan Vien station	810000	54000

6.1.9 Heavy metals

Concentration of heavy metals such as Pb, Cu, Mn, and Zn in the river water is not high and still within the allowable limits as regulated by the Standards TCVN 6773:2000, TCVN 5942-1995 and Standards of industrial wastewater discharge TCVN 5945-2005. Variation of Mn and Pb is not high.

6.2. Assessment of Water Quality in Canal and Drain Systems

6.2.1. Water quality in canal system

6.2.1.1 Bac Trinh Xa canal

Irrigation water of the Bac Trinh Xa canal is taken from Ngu Huyen Khe river through Trinh Xa pumping station to irrigate areas (adjacent to?) of North National Road 1A. Therefore, water quality of the Bac Trinh Xa canal fully depends on water quality at Trinh Xa pumping station (location K3) and Duong Xa pumping station. According to the observed data (presented in Table 22) values of DO, COD, BOD_5, NH_4, NO_2, TSS are higher than the Standards (see Annex 1).

Values of pH in the Bac Trinh Xa canal vary from 6.5 to 7.9. These are under allowable value of the National Standard.

Concentrations of dissolved oxygen (DO) in the dry season are quite different in comparison with the rainy season. It is around 3-5 mg/l and 7-9 mg/l in March and July respectively.

Values of COD and BOD_5 are within limits of the Standards. From head down to tail of the canal, COD and BOD_5 do not vary very much and have an increasing trend because irrigation water in the canal tail is supplemented by pumping from Duong Xa station (intake water from Ngu Huyen Khe river where water is much more polluted in comparison with upstream). In March values of COD and BOD_5 are around 20 mg/l and 10 mg/l respectively. However, in July these values are 12 mg/l and 5 mg/l respectively.

Concentrations of TSS, NH_4, NO_2, in general, are 1.2 - 3 times higher than the Standards, but lower than TSS, NH_4, NO_2 of Ngu Huyen Khe river. NH_4 varies from 0.01 mg/l (July) to 4.2 mg/l (March). NO_2 is 1.84 mg/l (March) and 0.01 mg/l (July). TSS changes from 50 mg/l (March) to 89 mg/l (July).

According to the tested results in 2006 and 2007, concentrations of As, Cu, Pb, Mn and Zn are low and under the allowable limits.

Table 26: Values of several parameters of water quality in Bac Trinh Xa canal

Location	pH		COD (mg/l)		BOD_5 (mg/l)		NH_4 (mg/l)	
	March	July	March	July	March	July	March	July
2006								
Head	7.32	7.70	20.10	16.32	13.07	8.16	4.200	1.000
Mid	7.31	7.80	10.38	12.17	6.85	7.10	1.200	1.030
Tail	7.20	7.84	15.17	15.26	10.30	10.68	0.830	1.960
2007								
Head	7.39	7.27	12.00	8.80	6.23	5.23	0.010	0.010
Mid	7.42	7.25	21.10	8.00	15.60	5.53	0.010	0.010
Tail	7.45	7.13	22.40	9.02	13.25	6.21	0.010	0.010

6.2.1.2. Nam Trinh Xa canal

Nam Trinh Xa canal is one of two main canals of the Bac Duong irrigation scheme (BDIS). The canal is from Trinh Xa canal. It irrigates area located south of National Road 1A. The canal flows across many new industrial zones. Water quality of the canal very much depends on following factors:

- Wastewater from industrial zones of Tien Son and Que Vo;
- Water source of Trinh Xa pumping station (wastewater from trade villages, domestic uses, industries);
- Solid waste landfill and sewer system of Bac Ninh town.

According to the observed data, it can be seen that values of COD and BOD_5 are lower than Standard TCVN 5942-1995 (Class B: <35 mg/l and < 25 mg/l respectively)) at Lien Van, Viet Hung, Nhan Hoa, while at Vu Ninh pumping station these parameters have very high values. COD and BOD5 are high in January, February and March. Under the effect of rains, in July COD and BOD5 are lowest. At Vu Ninh pumping station, parameters of DO, COD, BOD_5, NH_4, PO_4, NO_2, TSS do not meet the Standard Class B. Concentration of Ammonia at Vu Ninh is greater than 1.0 mg/l in January, February, March, April, June and July. At Kim Doi and Lien Van, Ammonia concentration is high in some months, but still lower than Vu Ninh. In some sections of Nam Trinh Xa canal, concentration of NO_2 is rather high in comparing with the Standard Class B, typically at Lien Van, Vu Ninh, Viet Hung and Nhan Hoa. At these places, most of NO_2 concentration is 1.1 – 34 times higher than the Standard Class B. It can be said that, in Nam Trinh Xa canal, water is seriously polluted by NO_2. In July, the pollution is much decreased.

Some values of water quality parameters are presented below:

Table 27: Values of several parameters of water quality in Nam Trinh Xa canal

Location	COD (mg/l)		BOD_5 (mg/l)		NH_4 (mg/l)		NO_2 (mg/l)	
	March	July	March	July	March	July	March	July
2006								
Lien Van	38.82	15.68	15.70	10.47	0.12	1.57	0.67	0.01
Vu Ninh	48.40	17.28	14.59	11.75	22.68	8.68	0.9	5.46
Viet Hung	20.16	2.88	7.33	1.73	1.11	0.33	0.22	0.01
Kim Doi	23.20	17.28	14.85	12.09	1.15	1.62	1.14	1.58
Nhan Hoa	16.20	6.08	7.85	3.71	0.42	0.56	0.82	0.01
Tan Chi	19.20	16.38	10.7	11.45	0.67	1.34	0.22	1.84
2007								
Lien Van	20.80	13.60	11.97	8.55	2.52	0.01	0.98	0.06
Vu Ninh	22.40	24.00	13.21	15.51	17.92	0.14	0.42	0.48
Viet Hung	10.40	19.20	4.97	13.68	1.26	0.01	0.36	1.10
Kim Doi	12.80	8.80	6.91	5.67	0.42	0.01	0.52	0.10
Nhan Hoa	10.40	10.40	5.11	7.21	0.98	0.01	0.36	1.20
Tan Chi	15.20	10.50	8.04	6.25	0.25	0.01	0.42	0.80

Similar as the Bac Trinh Xa canal, in the Nam Trinh Xa canal, pollutions by Cu, Pb, Mn, As, Zn have not been identified, because these parameter concentrations are within the allowable limits of the Standard Class B. However, at Vu Ninh, concentration of Coliform is very high.

6.2.2. Water quality in drain system

6.2.2.1 Road No.16 drain

The Road No.16 drain is a big drain of Yen Phong district where there are many trade villages. Though it is a drain, in the dry season Duong Xa pumping station has to pump water from this drain for irrigation purpose when water source of Trinh Xa pumping station is insufficient.
Located in a zone having many trade villages, industrial bases of paper, alcohol processing etc. the drain always receives various types of wastewater.
At Duong Xa, Dissolved Oxygen (DO) is very low from January to April. In May and July, under effects of rain water, value of DO is little higher but still around only 2.0 – 2.8 mg/l. The highest DO value observed is 9.60 mg/l in July 2006 when rain occurred.

COD and BOD5 are decreased in June and July at Duong Xa and Van An. Comparing with the Standard Class B, most of samples has NO2 concentration >0.05 mg/l at Duong Xa and Van An. The highest value of NO2 at Duong Xa is 1.14 mg/l (23 times higher than the Standard). TSS of the drain is rather high (1.2 – 4.0 times higher than the Standard).

Coliform and Faecal Coliform are very high in comparison with other drains of the Bac Duong irrigation scheme and over the allowable limits of the Standard.
In general, the Road No.16 drain is suffering from rather serious pollution, especially in dry season (from January to May).

6.2.2.2 Tao Khe drain

The Tao Khe drain is an important drain of the southern zone of the scheme. The Tao Khe drain has a concentration of TSS higher than the allowable values of the Standard Class B, while other water quality parameters are within the allowable limits. Values of some water quality parameters of Tao Khe drain are presented in Table 23 below. The Tao Khe drain is not much polluted because it is in an area where industries and craft villages have not been much developed. Irrigation water is taken from Duong river.

Table 28: Water quality parameter at Dung Quyet bridge (Tao Khe drain)

Time	DO (mgO_2/l)	COD (mgO_2/l)	BOD_5 (mgO_2/l)	$NH_4(+)$ (mgN/l)	$NO_3(-)$ (mgN/l)	$NO_2(-)$ (mgN/l)
Mar 06	8.32	14.4	10.37	1.54	1.74	1.56
Apr 06	7.84	17.2	8.68	1.42	1.95	0.56
Jun 06	7.84	18.56	11.67	1.57	6.9	0.62
Jan 07	7.68	14.4	8.63	0.01	2.29	0.01
Mar 07	7.89	12	6.14	0.01	6.64	0.2
Apr 07	7.5	7.66	4.59	0.67	1.06	0.02
May 07	8.32	9.92	5.95	0.56	0.44	0.18
Jul 07	8.21	12	8.41	0.01	1.05	0.84

According to the tested data of Bac Trinh Xa canal and Tao Khe drain, no any evidence of pesticide residuals has been identified, even in March and April when pesticides are much used. It can be said that water in the canal and drain has not been polluted by pesticides and organic phosphate.

Table 29: Some water quality parameters at Duong Xa pumping station

Month	DO (mg/l)			COD (mg/l)			BOD_5 (mg/l)			NH_4 (mg/l)			TSS (mg/l)		
	2005	2006	2007	2005	2006	2007	2005	2006	2007	2005	2006	2007	2005	2006	2007
Jan	1.76		4.89	49.80		13.6	25.34		8.84	1.18		0.01	286		54.41
Feb	1.07			37.17			25.04			1.05			245		
Mar	1.00	2.83	3.01	33.17	195.60	20.0	21.50	57.40	12.1	0.97	4.68	0.01	287	140	54.99
Apr	1.18	2.70	5.40	31.16	189.30	26.24	26.53	163.70	15.74	0.83	3.83	0.91	187	138	25.2
May	2.16		7.52	16.00		24.32	10.51		15.80	0.41		0.98	320		80.8
Jun	1.18			11.90			8.00			0.42			148		
Jul	3.07	9.60	6.88	10.30	14.08	30.4	6.30	8.72	20.54	1.11	1.70	0.01	194	92	61.6

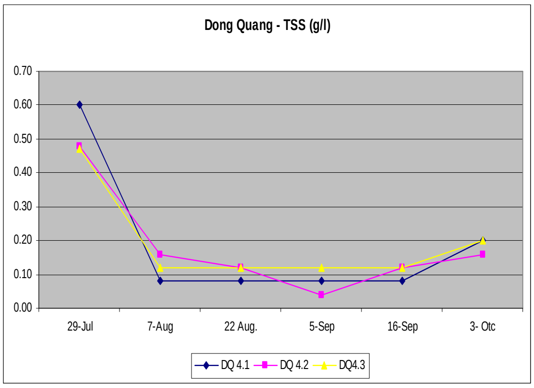
6.3 Assessment of water quality in rice fields, secondary/ tertiary canals drains in the scheme

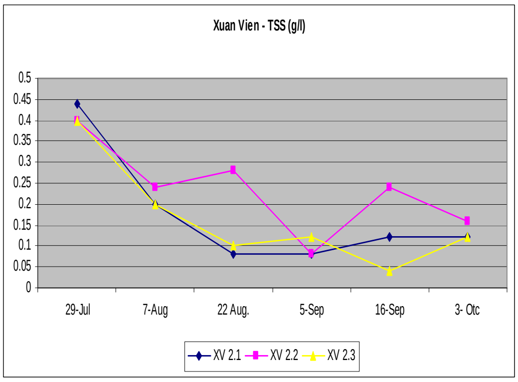
6.3.1. Assessment of water quality in rice fields, canals and drains

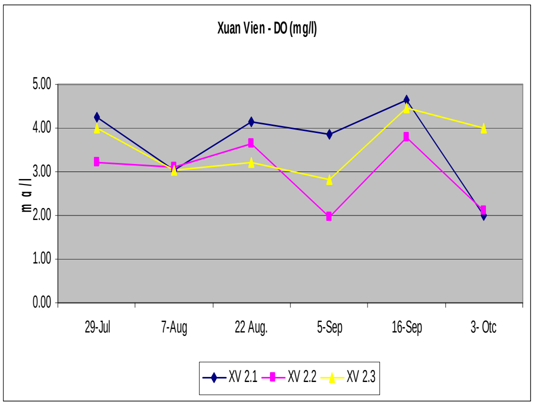
Comparing the testing results of 17 water quality parameters in rice fields, canals and drains, some following assessments could be drawn:

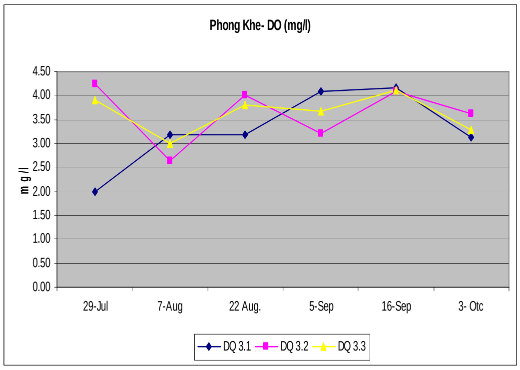
Temporal variations of the water quality parameters in rice fields, canals and drains are something the same. The differences between rice fields, canals and drains are not significant. These variations are the same phase.

In general, water quality in rice fields is better than in canals and drains. It could be explained by impacts caused by chemical reactions between soils and water in the rice fields.









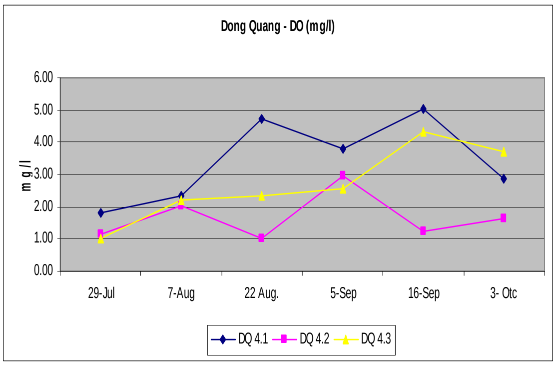


Figure 11. Variation of some parameters at rice fields, drains and canals

Table 30 Water quality parameters of rice fields at various locations

No.	Parameter	Unit	TCVN	Dong Quang			Phong Khe			Xuan Vien		
			6773:2000	Max	Min	Average	Max	Min	Average	Max	Min	Average
1	TSS	g/l	0.4-1.0-2.0	0.60	0.08	0.19	0.48	0.08	0.26	0.44	0.08	0.17
2	SAR	mg/l	10-18	1.98	0.72	1.25	2.61	0.92	1.60	2.23	0.72	1.39
3	B	mg/l	1	0.0113	0.0045	0.0068	0.0150	0.0034	0.0076	0.0108	0.0048	0.0071
4	DO	"	≥ 2.0	5.02	1.80	3.42	4.16	1.99	3.29	4.65	2.00	3.65
5	pH		5.5-8.5	7.33	6.79	7.00	7.49	6.78	7.04	7.61	6.61	7.07
6	Cl-	mg/l	≤ 350	53.96	24.14	32.86	68.00	28.40	44.70	53.96	25.56	40.69
7	Hg	"	≤ 0.001	0.00038	0.00016	0.0003	0.00041	0.00018	0.0003	0.00046	0.00019	0.0003
8	Cd	"	<0.01	0.003	0.002	0.0025	0.004	0.002	0.0025	0.004	0.002	0.0030
9	As	"	< 0.1	0.00512	0.00161	0.0028	0.00370	0.00172	0.0025	0.00574	0.00136	0.0028
10	Pb	"	≤ 0.1	0.00614	0.00253	0.0043	0.00595	0.00237	0.0038	0.00818	0.00318	0.0050
11	Cr	"	≤ 0.1	0.00417	0.00281	0.0034	0.00448	0.00235	0.0034	0.00416	0.00260	0.0034
12	Zn	"	1 - 5	0.04	0.002	0.0320	0.25	0.008	0.0872	0.24	0.005	0.0587
13	Feacal Coli	MPN/100ml	< 200	1400	0	370	1300	0	497	1400	0	308
14	COD	mg/l		54.3	21.2	37.03	34.6	23.0	28.34	39.4	25.7	30.93
15	BOD5	"		49	23	23.25	35	23	18.00	39	29	20.00
16	N ts	"		5.04	2.24	3.36	14.01	1.68	5.32	4.30	1.12	3.32
17	P ts	"		2.66	0.47	1.30	1.51	0.25	0.71	1.35	0.44	0.98

Table 31 Water quality parameters of secondary drains at various locations

No.	Parameter	Unit	TCVN	Dong Quang			Phong Khe			Xuan Vien		
			6773:2000	Max	Min	Average	Max	Min	Average	Max	Min	Average
1	TSS	g/l	0.4-1.0-2.0	0.48	0.04	0.18	0.52	0.08	0.25	0.40	0.08	0.23
2	SAR	mg/l	10-18	5.69	1.34	3.00	2.53	1.84	2.17	3.00	1.51	1.97
3	B	mg/l	1	0.0122	0.0049	0.0072	0.0095	0.0045	0.0068	0.0152	0.0038	0.0082
4	DO	"	≥ 2.0	2.96	1.02	1.67	4.23	2.63	3.63	3.80	1.95	2.97
5	pH		5.5-8.5	7.18	6.87	7.03	7.58	6.86	7.22	7.67	6.84	7.16
6	Cl-	mg/l	≤ 350	71.00	26.98	51.12	63.90	29.82	44.97	56.80	35.50	45.20
7	Hg	"	≤ 0.001	0.00046	0.00019	0.0003	0.00037	0.00019	0.0003	0.00029	0.00018	0.0003
8	Cd	"	<0.01	0.003	0.002	0.0023	0.005	0.002	0.0030	0.004	0.003	0.0028
9	As	"	< 0.1	0.00497	0.00201	0.0032	0.00303	0.00172	0.0033	0.00312	0.00149	0.0031
10	Pb	"	≤ 0.1	0.00633	0.00178	0.0385	0.00916	0.00107	0.0768	0.00629	0.00126	0.0417
11	Cr	"	≤ 0.1	0.00391	0.00171	0.0028	0.00394	0.00284	0.0033	0.00387	0.00197	0.0031
12	Zn	"	1 - 5	0.11	0.004	0.0385	0.20	0.011	0.0768	0.12	0.004	0.0417
13	Feacal Coli	MPN/100ml	< 200	5900	0	3118	9500	0	4167	5200	0	1689
14	COD	mg/l		66.5	27.7	53.63	51.4	26.2	34.84	67.9	23.8	47.18
15	BOD5	"		44	18	34.25	30	17	21.75	41	16	29.25
16	N ts	"		12.32	1.68	5.88	4.48	1.68	3.08	7.28	1.12	4.06
17	Pts	"		4.67	0.25	1.86	2.23	0.26	0.94	2.90	0.13	1.69

Table 32: Water quality parameters of secondary canals at various locations

No.	Parameter	Unit	TCVN	Dong Quang			Phong Khe			Xuan Vien		
			6773:2000	Max	Min	Average	Max	Min	Average	Max	Min	Average
1	TSS	g/l	0.4-1.0-2.0	0.47	0.12	0.19	0.45	0.08	0.20	0.40	0.04	0.16
2	SAR	mg/l	10-18	2.75	0.85	1.75	2.61	1.55	2.03	1.18	0.63	0.86
3	B	mg/l	1	0.0120	0.0042	0.0065	0.0100	0.0031	0.0057	0.0150	0.0044	0.0076
4	DO	"	≥ 2.0	4.33	1.00	2.70	4.10	3.00	3.62	4.48	2.82	3.59
5	pH		5.5-8.5	6.96	6.81	6.89	7.53	6.83	7.04	7.22	6.49	6.94
6	Cl-	mg/l	≤ 350	62.20	28.40	43.85	61.20	41.62	42.30	51.00	28.40	38.92
7	Hg	"	≤ 0.001	0.00030	0.00019	0.0002	0.00029	0.00018	0.0003	0.00027	0.00018	0.0002
8	Cd	"	<0.01	0.003	0.002	0.0022	0.004	0.002	0.0032	0.003	0.002	0.0023
9	As	"	< 0.1	0.00328	0.00200	0.0031	0.00681	0.00143	0.0032	0.00452	0.00210	0.0026
10	Pb	"	≤ 0.1	0.00567	0.00159	0.0039	0.00363	0.00208	0.0027	0.00296	0.00120	0.0020
11	Cr	"	≤ 0.1	0.00457	0.00198	0.0031	0.00407	0.00271	0.0032	0.00427	0.00183	0.0026
12	Zn	"	1 - 5	0.10	0.002	0.0440	0.05	0.006	0.0308	0.11	0.007	0.0390
13	Feacal Coli	MPN/100ml	< 200	9200	0	2148	790	0	368	490	0	107
14	COD	mg/l		52.8	21.8	43.05	54.8	26.2	38.24	42.2	31.1	35.60
15	BOD5	"		33	15	26.50	34	16	23.00	25	17	21.25
16	N ts	"		5.60	2.24	3.22	4.48	2.24	3.36	3.36	2.24	2.38
17	Pts	"		2.05	0.25	0.93	2.66	0.47	0.56	0.80	0.25	0.56

Comparing with the Standards of Viet Nam- TCVN 6773:2000, water quality of the rice fields, canals and drains meets the Standards of Vietnam, except Feacal Coliforms. This could be explained that the sampling period is in rainy season. Pollution sources are much diluted by rain water.

6.3.2. Comparing water quality of the rice fields in various locations

Temporal variations of water quality in rice fields of three locations: Dong Quang, Phong Khe and Xuan Vien are the same phase. Values of TSS are reduced from early rainy season to later rainy season. Under impacts of rain water, differences of other water quality parameters in three locations are not big. In Section 5.1, spatial variation of water quality parameters in Ngu Huyen Khe river is clearly identified from upstream to downstream. However, in the rice fields these differences are not significant.

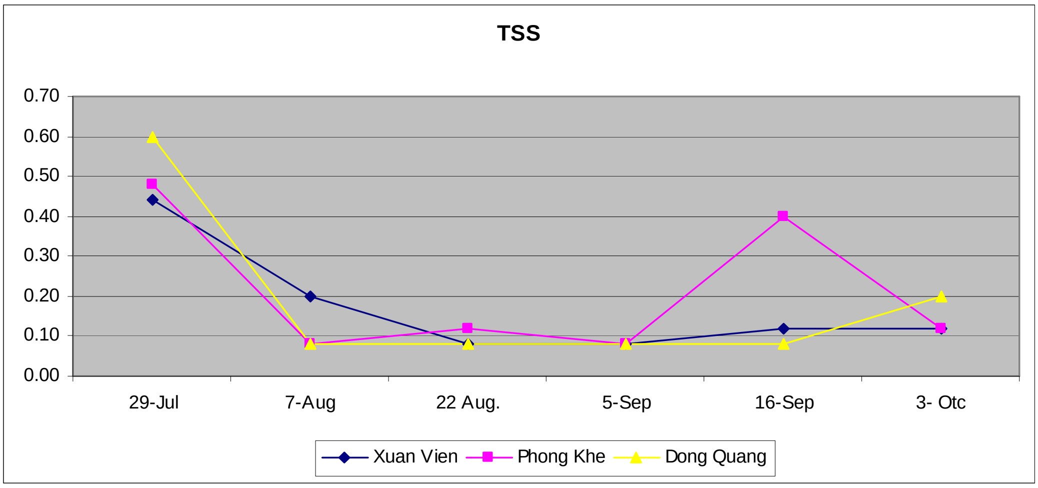


Figure 12 Temporal variation of TSS in the rice fields of Xuan Vien, Phong Khe and Dong Quang

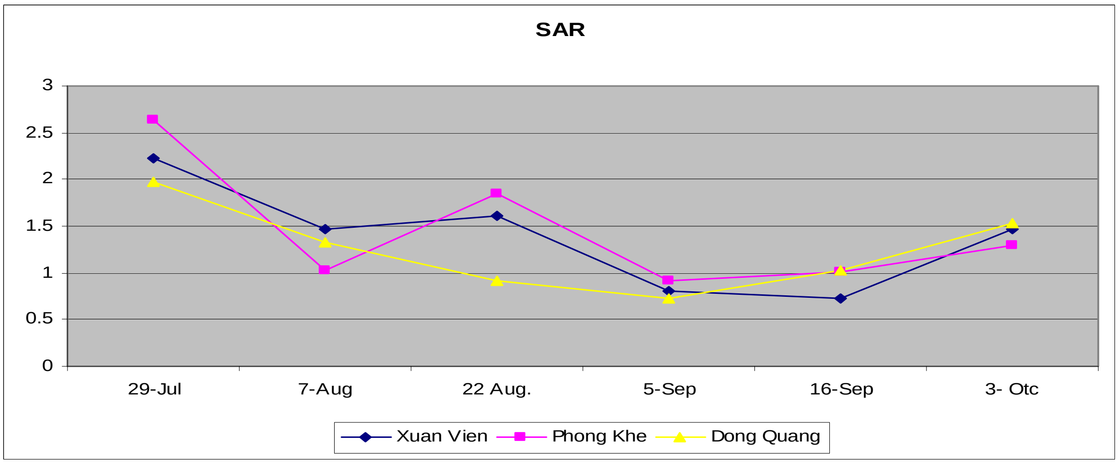


Figure 13. Temporal variation of SAR in the rice fields of Xuan Vien, Phong Khe and Dong Quang

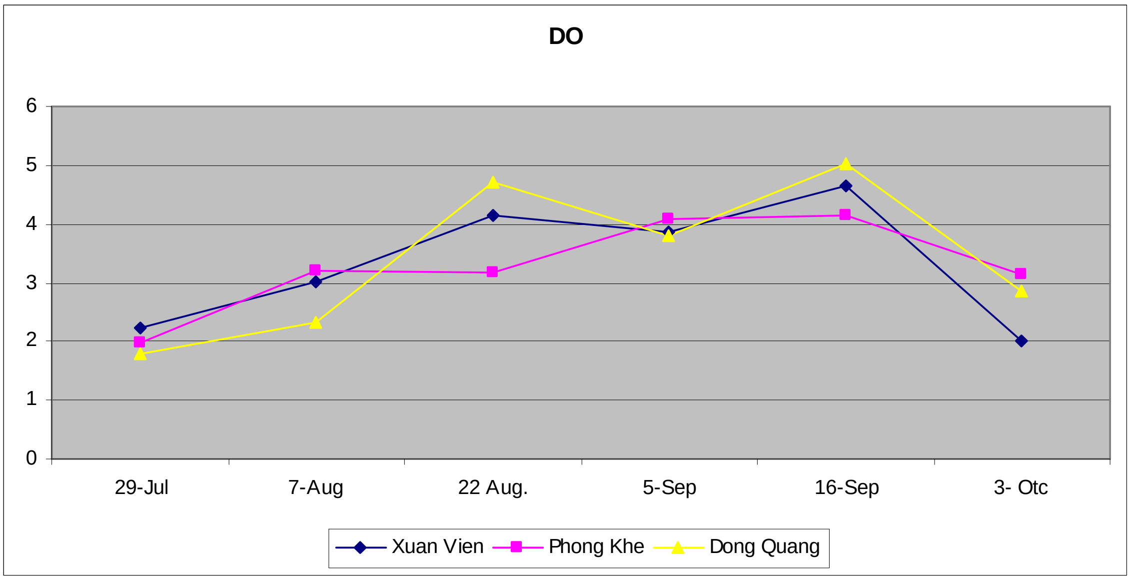


Figure 14. Temporal variation of DO in the rice fields of Xuan Vien, Phong Khe and Dong Quang

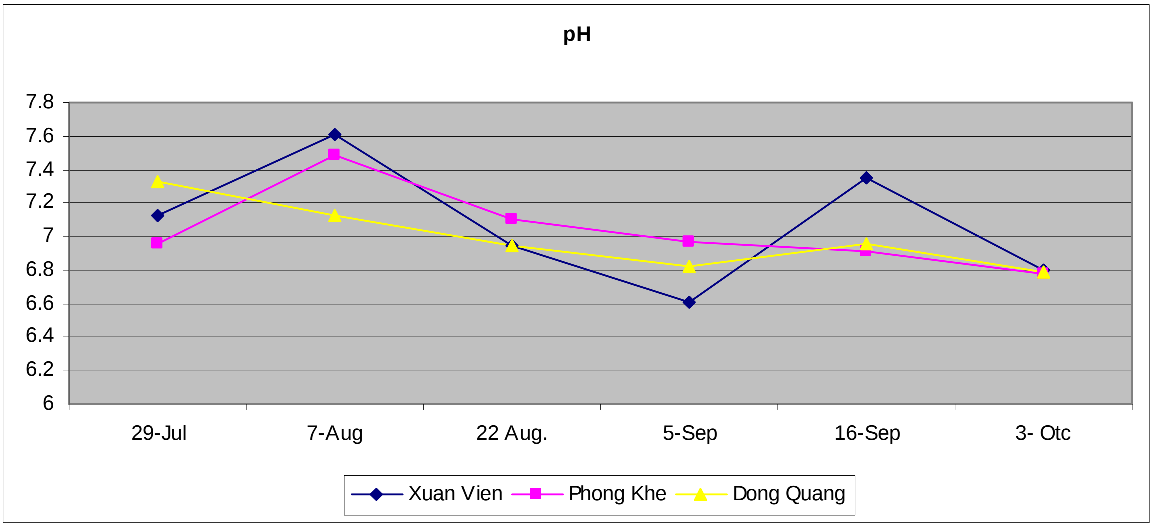


Figure 15. Temporal variation of pH in the rice fields of Xuan Vien, Phong Khe and Dong Quang

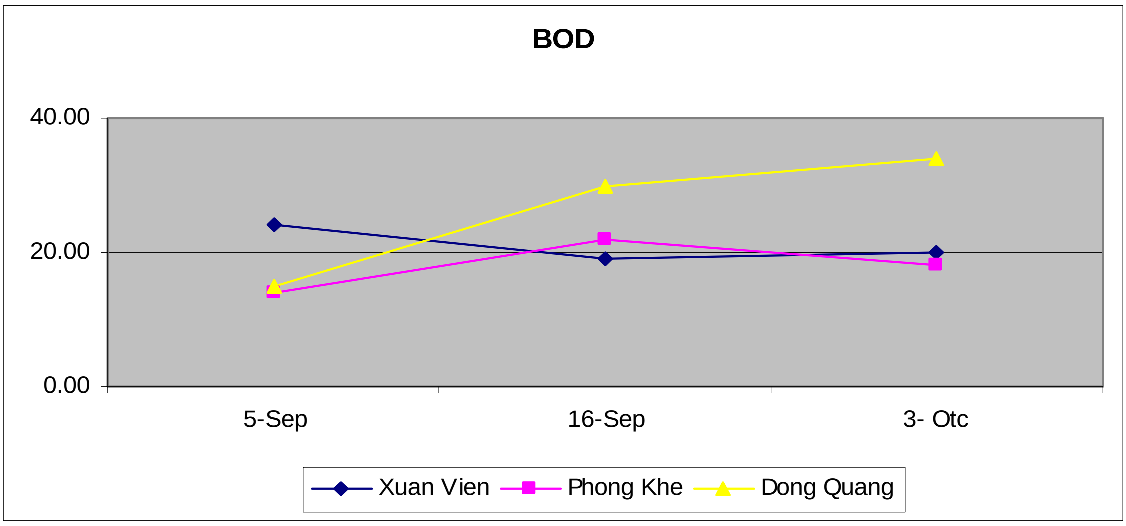


Figure 16. Temporal variation of BOD in the rice fields of Xuan Vien, Phong Khe and Dong Quang

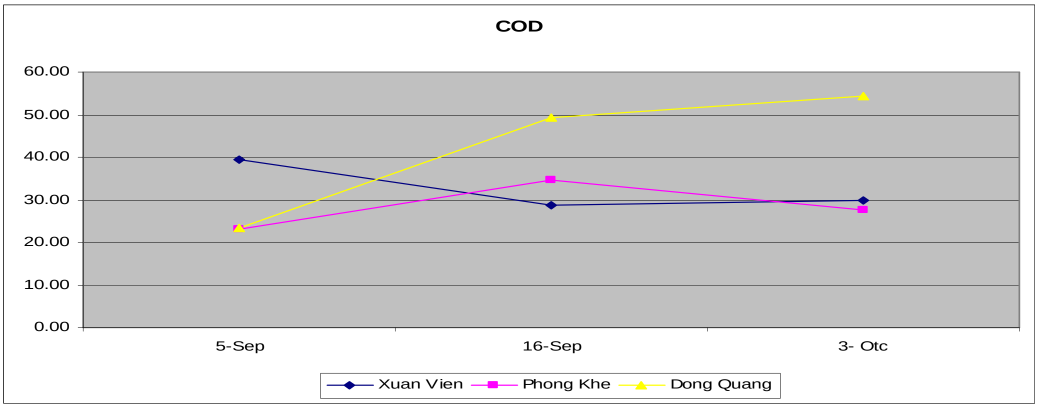


Figure 17. Temporal variation of COD in the rice fields of Xuan Vien, Phong Khe and Dong Quang

6.4 Sub-chapter conclusions

- In Ngu Huyen Khe river, the water is much polluted. Values of DO, COD, BOD_5, Ammonia, Nitrate, Nitrite, PO_4^{3-}, TSS, Coliform and Faecal Coliform vary considerably from season to season and also there were found significant differences between the years. All these parameters are much over the allowable values as regulated in the Standards TCVN 6773:2000 and TCVN 5942-1995, especially at downstream such as Phu Lam, Phuc Xuyen, Dang Xa and Xuan Vien.

- In 2005, because the Red river delta suffered a very serious drought in dry season, therefore, concentrations of the water quality parameters said above are more serious in comparing with other years (2006, 2007).

- Under effects of rainwater, in rainy season, the pollution level of Ngu Huyen Khe river is clearly reduced by virtue of dilution. Temporarily improved water quality will not be able to restore the damage done to the aquatic ecosystem and self-purifying capacity during periods of DO concentrations less than 2 mg/l in the dry season. If no proper measures are soon undertaken, Ngu Huyen Khe river will become a dead river. Negative effects caused by pollution of the river are becoming a big challenge to Bac Ninh province as well as the central government.
- Water quality of main drains and canals does not meet the Standards of Vietnam, especially in dry season.
- Spatial variation of water quality parameters in Ngu Huyen Khe river is clearly identified from upstream to downstream. However, in the rice fields these differences are not significant in rainy season.
- In rainy season, variations of the water quality parameters in rice fields, canals and drains are something the same. The differences between rice fields, canals and drains are not significant. These variations are the same phase.
- In rainy season, water quality of the rice fields, secondary canals and drains meets the Standards, except Feacal Coliforms.

7. POTENTIAL IMPACTS OF WASTEWATER REUSE ON AGRICULTURAL PRODUCTION IN BAC DUONG IRRIGATION SCHEME

7.1 Overview agricultural production status in the scheme

The cultivable land area in the scheme is 33,905.62 ha, taking account for 65.6 % of gross area. Annually cropped area is 30,718.76 ha, taking account for 59.4% of gross area.

Table 33: Actual land use for agriculture in districts of Bac Ninh Province

Landuse types	Area	Ratio (%)	Districts					
			Bac Ninh	Yen Phong	Que Vo	Tien Du	Tu Son	Dong Anh
Agricultural land	***33,905.62***	***65.6***	***1,364.58***	***7651.08***	***10,670.85***	***7,108.86***	***4,074.98***	***3,035.27***
1. Annual crop	30,718.76	59.4	1,266.36	7,244.96	9,697.44	6,565.37	3881.93	2062.7
a. Rice and up-land cropsl	29,769.5	57.6	1,191.42	7,137.64	9,438.09	6,209.46	3,878.38	1,914.51
b. Others	805.77	1.6	74.94	107.32	259.35	355.91	3.55	*4.7*
2. Mixed orchard	854.78	1.7	2.46	30.52	555.43	256.12	10.25	0
3. Perennial crops land	90.81	0.2		13.37	14.69	52.14		10.61
4. Grass land	2.09	0				2.09		0
5. Aquacultural land	1392.1	2.7	95.76	362.23	403.29	233.14	182.80	114.88

Cultivation

Rice cultivation takes account for 96.7% of cultivable area of Bac Ninh Province and rice is main crop in the scheme. Recently, Bac Ninh province has issued policies on price and variety subsidies to facilitate farmer to adapt new varieties and to change variety and cropping pattern . Widely cultivated short-term varieties with potential of high yield and quality and effectively applied advanced technologies have made average yield increase from 52 quintal/ha in 2000 to 5.30 T/ha in 2007. Thus, food production is quickly increasing. At present, Bac Ninh not only meets its food demand but also supplies for its outsider demand with about 130 ton/year.

Production of rice in 2007 achieved 257,298.9 tons, increased by 14,185 tons in comparison with 2004 (when rice cultivated area was reduced by strong urbanization and industry development and rather stable in recent years). Annual rice yield is 5.30 T/ha; spring and summer rice yields are 5.33 T/ha, 5.25 T/ha respectively.

Table 34: Area - Yield- Production of rice in Bac Ninh province

Description	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**
	Annual Rice							
Area (ha)	52,449	52,306.7	52,380.6	51,935.5	44,681.4	49,301.8	48,653	48,118.1
Yield (T/ha)	5.20	5.07	5.25	5.28	5.34	5.39	5.35	5.30
Production (Ton)	27,3942	269,390	277,658	276,922	243,113	271,425	260,172	257,298
	Spring rice							
Area (ha)	26,002	26,163	26,158	25,998	22,452	35,732	24,317	24,078
Yield (T/ha)	5.40	5.17	5.33	5.52	5.59	5.77	5.76	5.33
Production (Ton)	141,361	136,768.	140,524	145,368.	128,066.	145,713.	140,114	128,432
	Summer rice							
Area (ha)	26,447	26,344	26,223	25,938	22,229	24,570	24,336	23,939
Yield (T/ha))	4.99	4.96	5.17	5.05	5.09	5.01	4.93	5.25
Production (Ton)	132,581	132,618	137,134	131,554	115,048	125,712	120,091	126,540

Together with the main crop of rice, subsidy crops as maize, sweet potato are also cultivated in the area. The planted sweet potato area is much reduced from 2000 to 2007. However, its yields are much fluctuated year to year

Table 35 Area - Yield- Production of sweet potato

Description	2000	2001	2002	2003	2004	2005	2006	2007
Area (ha)	2,217.8	1,424.7	1,437.5	1,557	1,365	1,630	713.4	868.5
Yield (T/ha)	6.48	6.52	6.80	6.61	8.71	8.97	5.22	7.33
Production (Ton)	14,729	8,636	11,043	10,912	13,819	16,587	2,943	4,259

Up-land crop planted area is 854.8 ha accounting 2.8% of annual crop area. Other crops are vegetables, bean, and potato. In the year 2007, the yield of vegetables was 15.6 Tl/ha; potato: 15.72 T/ha, bean: 9.10 T/ha.

Table 36: Area - Yield- Production of Vegetables and Soya Bean

No.	Description	2000	2001	2002	2003	2004	2005	2006	2007
	Total of area	2,991	3,010	2,819	3,053	2,128	3,218	2,830	2,870
I	**Vegetables**								
	Area (ha)	1,024	920	783	774	739	1,205	1,461	1,585
	Yield (T/ha)	8.40	8.40	8.30	8.00	8.00	10.10	15.40	15.60
	Production (ton)	9,091.9	9,316	6,971	6,645	4,372	11,417	23,191	23,350
II	**Beans**								
	Area (ha)	1,967	2,090	2,036	2,279	1,389	2,013	1,369	1,285
	Yield (T/ha)	9.50	10.10	10.10	10.10	5.90	11.40	7.50	9.10
	Production (ton)	33,201	35,849	33,838	34,168	10,315	39,623	26,912	22,677

Annual industrial crops

Main industrial crops are: groundnut cultivated on 806 ha, production of groundnut was 1,540 tons; soybean cultivated area : 580 ha, production of soybean : 930 tons. In recent years, (from 2005 to 2007) area of other industrial crops such as : jute, sugarcane, tobacco has been reduced due to limited consumption market.

Fruit trees

The main fruit trees planted in Bac Ninh province are orange, mandarin, pomelo, longan, litchi, and banana with total area about 1,859 ha. However, in the recent years the area of some fruit trees such as : orange, pomelo tree, longan, litchi has reduced.

7. 2 Agriculture Water Demands in the Bac Duong Irrigation Scheme

According to MARD's standards, irrigation water requirements of various crops in the Red river delta are below:

Table 37. Water demand standards of various crops

No.	Crop type	Water requirement (m^3/ha)
1	Early Spring Rice	6,000 – 7,000
2	Spring Rice	5,500 – 6,500
3	Summer Rice	4,500 – 5,500
4	Maize	1,200 – 1500
5	Ground nut	1,000 – 1,200
6	Potato	1,200 – 2,000
7	Soya Bean	1,200 – 2,000
8	Sweet Potato	1,200 – 1,400
9	Vegetables	1,500 – 2,500

According to agricultural production statistic data of recent 5 years (2003 – 2007), approximately, annual water requirements of the Bac Duong scheme are below:

Table 38. Water demands of the Bac Duong scheme

Description	Cropped area (ha)	Water requirement standard (m^3/ha)	Gross annual water demand (m^3)
Spring Rice	24826	6500	161,371,600
Summer Rice	24727	5000	123,635,000
Maize	784	1250	980,250
Sweet Potato	1504	1300	1,955,720
Soya Bean	1253	1600	2,004,096
Ground nut	1021	1100	1,123,188
Total			291,069,854

Water demands for agriculture of the scheme are around 300 mil m^3/year. Comparing with surface water availability of Bac Ninh (Thai Binh river (at Pha Lai) 8.83 bil. m3/year; Cau river: 4.85 bil. m^3/year and Duong river 27 bil. m^3/year), this water requirement could be met. However, 80% of annual run-off is concentrated in rainy season, and water of the rivers has to be used for other provinces and purposes. Irrigation water supply still is a pressure to the Bac Duong scheme in dry season, especially at current time under global climatic change status, serious droughts frequently happen in the Red river delta.

Comparing monthly rainfall and evaporation distributions presented below, it can be seen that in December, January when much irrigation water is required for land preparation, however, rainfall is less, while evaporation is high. Crop cultivation has to be fully based on irrigation water supply by the Bac Duong IDMC.

Table 39: Monthly rainfall data of Bac Ninh station

Description	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Mean	18.8	21.8	38.2	94.2	173.5	227.2	246.7	268.5	194.2	132.3	46.0	15.8	1477
Minimum	0.0	0.0	4.1	6.4	65.9	71.8	58.4	54.3	38.5	0.0	0.0	0.0	1029
Maximum	106.7	71.9	152.0	262.9	421.3	446.7	581.1	626.7	522.5	292.4	163.3	76.8	1978

Table 40: Monthly potential evaporation data of Bac Ninh station

Description	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Mean	66.4	54.3	54.5	59.8	86.8	91.9	92.4	79.0	76.7	82.4	81.0	77.7	902.9
Minimum	28.8	26.3	24	32.2	64.1	53.5	41.1	46.6	46.4	47.4	48.7	41.3	270
Maximum	155.9	99.1	81	90.5	140.1	148.7	136.3	109.4	136.2	142.2	131.5	132.4	1503

(Source: Hydro-meteorologic data from 1960 to 2000)

7. 3. Orientation of agricultural development:

Due to cropping pattern change, urbanization growth rate, and industrial development as well as agricultural area conversion for for other purposes, more 5,100.68 ha will be used for industrial zones, infrastructure that reduces agricultural land area .

Cultivation: From now to 2010, it is cultivated about 2,500-3,000 ha of food crop, annual industrial crop: 2000ha, vegetable: 7000ha. It is planned to set up intensive cultivation and increase land use factor from 2.17 times in the year 2000 to 2.5 times in the year 2010. Expanding area of early summer rice, intensively develop winter crops. Cultivate rice with high yield in Yen Phong 2,500 - 4,000 ha, Que Vo: 3,000-3,500 ha, Tien Du: 1,000-1,500 ha, Tu Son 1,000-1,500.

Aquaculture: Land area planned for fishery in the year 2010 is 2000ha.

According to the above information, it can be seen that though rice cultivation area will be reduced; quantity of water demands for industries, domestic uses are less than quantity of water demands for agriculture; pressure of water supply is still very heavy. Because, in the future, water quality demands are much more higher. When applying new high yield crop varieties, requirements of water quality and quantity will be changed. Irrigation services should be also changed to meet the actual requirements.

According to the development plan to year 2020 of Bac Ninh province, the province's viewpoint to agriculture development is to consider agricultural production to be an important sector to ensure food security and material supplies to industrial sector. The province's agricultural development direction is to develop an agricultural sector with sustainable ecology and development to protect the living environment.

As the province's development forecast, in 2020, number of farmers in the province is to be 470,000 people and land area per capita will be 387 m^2/head. The cultivated land area will be reduced. The agricultural production has to be follow direction of modernization, intensive farming, crop diversification, high quality products.

Rice is considered as a main food crop of Bac Ninh province. However, areas which are often suffering water logging or having poor fertility will be used for fishery raising or vegetable cultivation. In year 2020, rice cultivation areas in the case study area will be much reduced as below:

Table 41: The present and future cultivation areas in the Bac Duong scheme

Cropped area (ha)	Tu Son	Yen Phong	Tien Du	Que Vo
2007	3217	5542	3217	7596
2020	1000-1500	2500-4000	1000-1500	3000-3500

However, it should be noted that land areas to be used for non-agriculture purposes are along Road No.18. Cultivation land areas along both banks of Ngu Huyen Khe are not much changed. Therefore, amount of water demands for agriculture in these areas could not be changed very much. Irrigation water can not divert from Duong and Cau river, because inverse canal slope. The areas have to extract irrigation water from Ngu Huyen Khe river, where water availability is sufficient, but water quality becomes more serious. Moreover, new varieties are to be applied, high quality of irrigation water has to be met. Pollution of water sources such as Ngu Huyen Khe river or other drains in the scheme has to be solved.

7.4 Reuse of wastewater for irrigation in the scheme

Normally, rice cultivation calendar in the Bac Duong scheme is below:

Table 42: Rice cultivation calendar in the Bac Duong scheme

Seasonal crop	Land preparation	Seeding	Transplanting	Harvesting
Spring rice	Later Nov.	December	Jan. to Feb.	Apr.- May
Summer rice	Later May	May – Jun.	Jun. Jul.	Oct.

In fact, irrigation coefficient for land preparation is 1.1 l/s/ha on-farm or 1.6 l/s/ha at head works. It means that for areas along Ngu Huyen Khe river it is required to pump with rate of 3,3 m^3/s (for 2033 ha of areas taking wastewater from Ngu Huyen Khe). The total designed capacity of pumping stations extracting irrigation water from Ngu Huyen Khe river is 5.15 m^3/s. If pumping efficiency coefficient is 0.7, the present pumping stations could meet the rice production requirement. A problem is that whether irrigation water sources are sufficient or not. Peak of irrigation water demands falls in period of land preparation (irrigation for land aeration). This time is in dry season and all rice fields need irrigation water for a very short time. This causes a very heavy pressure on the pumping stations of the Bac Duong scheme. Because river water levels go down, electricity sources are not stable, irrigation water demands are high, irrigation time is short. Therefore, all water sources in the scheme have to be fully extracted. Wastewater of Ngu Huyen Khe river is a compulsory choice for areas along both banks of the river.

According to information of interviews to farmers of three communes named Cham Khe, Khuc Xuyen and Xuan Vien (Yen Phong district), wastewater for irrigation is very dangerous for nursery rice (just after transplanting). Direct use of wastewater from Ngu

Huyen Khe river could makes nursery rice trees die in this period. Wastewater of Ngu Huyen Khe river also makes potato product quality significantly reduce. Poor quality of potato products could be recognized by normal eyes. Gourds can not be planted if using wastewater irrigation. Sometimes, when water pollution of Ngu Huyen Khe river is too high, farmers did not want to take irrigation water for their fields, even their crops need water very much. Farmers have experience of storing wastewater in channels, ponds for 7 or 10 days, then taking this wastewater for their crops. They also identified that rice leaves of fields at canal heads often are too verdant but rice yield is low. That could be explained that nutrient contents of wastewater is very high. Adverse impacts of wastewater reuse for irrigation on farmers' health are very learly recognized. All interviewees said that they often have to suffer skin and breathing diseases caused by wastewater. According to statistic data of Phong Khe commune (2006) (where water pollution is serious), percentages of people having skin and breathing diseases are 36% and 29% respectively. *(source: Report of Environment Status 2006, DONRE, Bac Ninh province).*

In the case study area, farmers often use fertilizers for rice cultivation with input dozes as following: Urea: 5-7 kg/sao; Phosphate: 15 – 20 kg/sao; Potassium: 4-5 kg/sao; manure: 250 – 300 kg/sao. These used dozes are the same in both areas that are using and not using wastewater for irrigation. As presented above, nutrient contents of wastewater in Ngu Huyen Khe river are very high. Farmers in areas of using wastewater for irrigation should adjust their urea inputs to save money and to avoid affects from too much nutrient for rice trees.

7.5. Impacts of wastewater reuse on rice production quantity and quality

7.5.1. Impacts of wastewater reuse on rice production quantity

In order to identify impacts of wastewater reuse on rice production quantity, 8 year data, including cultivated land areas, rice yields and rice production at commune level have been collected.

According to areas irrigated by pumping stations, and irrigation water sources, areas reusing wastewater for irrigation are identified as below:

Table 43: Pumping stations, irrigation areas and their waste water sources

No.	Pumping station	Commune name	Area (ha)	No. of pump sets	Pumping rate (m^3/h)	Water source
1	Dong Tho 1	Dong Tho	230	4	1000	NHK river
2	Dong Tho 2	Trung Nghia	30	1	540	NHK river
3	Bat Dan		290	4	1000	NHK river
		Long Chau	260			
		Trung Nghia	30			

No.	Pumping station	Commune name	Area (ha)	No. of pump sets	Pumping rate (m^3/h)	Water source
4	Trung Nghia	Trung Nghia	104	2	1000	NHK river
5	Duong Xa		557	4	1000	NHK river
		Van An	29			
		Thuy Hoa	303			
		Dong Phong	225			
6	Dong Cho	Huong Mac	19	1	1000	NHK river
7	Cau To	Huong Mac	136	2	1000	NHK river
		Kinh bắc	49			
		Van An				
		Hoa Long				
		Phong khe				
		Khuc Xuyen				
8	Huu Chap	Hoa Long	61	1	1000	NHK river
9	Noi Due	Noi Due	323	4	1000	Trinh Xa drain
10	Phu Lam	Phu Lam	759	6	1000	NHK river
11	Tri Phuong	Tri Phuong	402	4	1000	Tao Khe drain
12	Tan Chi 1		601	6	1000	Tao Khe drain
		Tan Chi	228			
		Minh Dao	202			
		Han Quang	171			
13	Do Phuong	Phuong Lieu	60	1	1000	Kim Doi
14	Chi Lang	Chi Lang	331	4	1000	Tao Khe drain
15	Cach Bi		552	4	1000	Tao Khe drain
		Dao Vien	154			
		Cach Bi	398			
16	Cau Tien	Que Tan	135	2	1000	Tao Khe drain
17	Phu Lang	Phu Lang	160	2	1000	Tao Khe drain
18	Yen Dinh	Phu Lang	88	1	1000	Tao Khe drain
19	N5- Bo Gao	Phu Lang	114	2	1000	Tao Khe drain

After identifying the areas using and not using wastewater for irrigation, weighted average seasonal rice yields of three districts named Tu Son, Yen Phong and Tien Du

are calculated. Variations of average seasonal rice yields in three districts are described in the following charts (see also annex 3):
The way of identifying areas using and not using wastewater for irrigation is carried out as below:

- Based on the Table 43 above, what communes taking wastewater for irrigation are known;
- Based Year Book of the districts, rice yields of the communes taking wastewater for 8 years are known;
- Based Year Book of the districts, rice yields of the communes not taking wastewater for 8 years are known;
- Calculating weighted average rice yields of communes taking and not taking wastewater for irrigation;
- Comparing the weighted average seasonal rice yields of areas taking and not taking wastewater for irrigation.

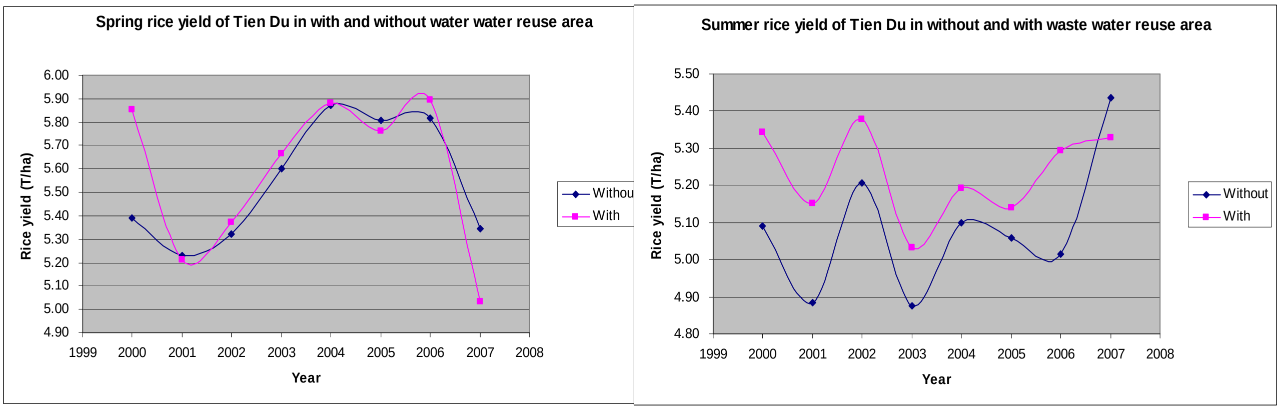


Figure 17: Spring and summer rice yield variation in areas using and not using waste water

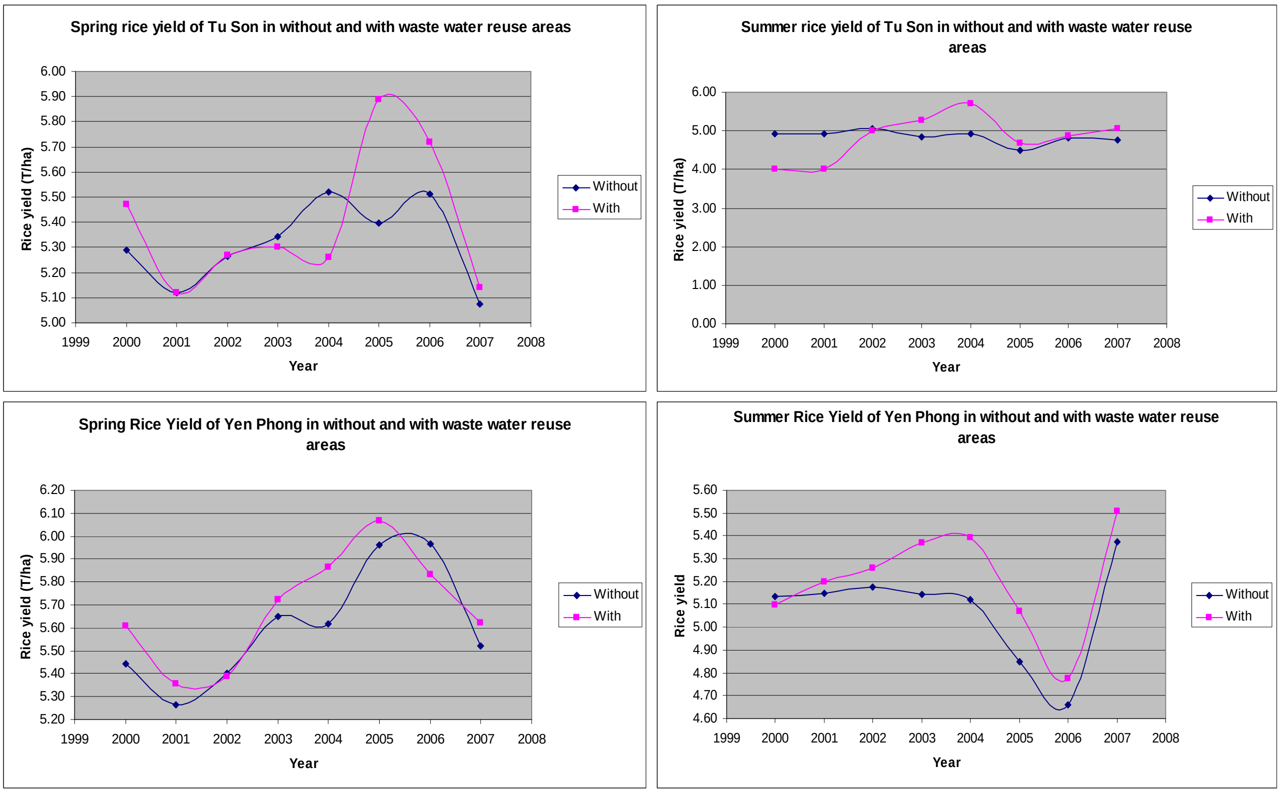


Figure 17 (Continued): Spring and summer rice yield variation in areas using and not using waste water

Based on the above analysis it can be seen that rice yields of areas using polluted water are higher than rice yields of areas using unpolluted water. The differences between these two types of areas are clearer in the summer (rainy) season. It may be explained that use of diluted wastewater for irrigation could make rice have higher yields in comparison with case of using undiluted wastewater. This issue should be studied in more details in next phases of the case study.

According to the Viet Nam – Romania cooperation project on “Measures of Urban Treated Waste Water Reuse for Agricultural Purposes” (2005), in Lim (Bac Ninh province) impacts of treated waste water reuse on rice are identified as below:

Description		Control rice field (untreated waste water)	Tested rice field (treated waste water)
Number of nursery rice plants when transplanting		3-5	3-5
Height of rice plant when harvesting		0,95-0,98	0,97-1,0
Number of rice plants in a rice clump when harvesting		8-10	10-12
Number of rice ears in a clump when harvesting		8-9	10
Number of sub-ear in a rice ear when harvesting		10	10-11
Average yield (T/ha)	Fresh	8,8	9,7
	Dry	7,1	7,8

7.5.2. Impacts of wastewater reuse on rice production quality

In order to assess impacts of wastewater reuse on rice production quality, three unhusked rice samples of 2007 winter crop have been taken at Xuan Vien, Phong Khe where wastewater is more serious, and at Thai Hoa where irrigation water is considered as fresh (irrigation water source is Duong river). The testing results are presented in below table:

Table 44 Rice product quality in water unpolluted and pollued areas
(Rice product samples of 07-08 Spring crop)

No.	Parameter	Unit	Allowable limit	Xuan Vien (Polluted)	Phong Khe (Polluted)	Thai Hoa (Unpolluted)
1	Hg	ppm	0.5	0.10	0.11	0.09
2	Cd	"	0.2	0.06	0.06	0.08
3	As	"	1.0	0.15	0.22	0.18
4	Pb	"	0.2	0.58	2.33	0.25
5	Cr	"	NA	0.35	0.41	0.27
6	Zn	"	40	1.87	1.77	3.59
7	SO_4	"	NA	0.07	0.04	0.06
8	Mn	"	NA	4.55	2.73	6.57

Table 45: Rice product quality in water unpolluted and pollued areas
(Rice product samples of 2008 Summer crop)

No.	Parameter	Unit	Allowable limit	Xuan Vien 1 (Polluted)	Xuan Vien 2 (Polluted	Phong Khe (Polluted)	Thai Hoa (Unpolluted)
1	Hg	ppm	0.5	0.10	0.09		0.08
2	Cd	"	0.2	0.14	0.12		0.09
3	As	"	1.0	0.65	0.29		0.53
4	Pb	"	0.2	2.38	1.63		0.58
5	Cr	"	NA	0.62	0.61		0.25
6	Zn	"	40	1.45	2.62		2.38
7	SO_4	"	NA	3.18	2.42		3.47
8	Mn	"	NA	0.057	0.050		0.049

According to the Occupational Health & Safety Information Service, the products covered by the provisions of this standard shall be free from heavy metals in amounts which may represent a hazard to human health (CODEX STANDARD FOR RICE CODEX STAN 198-1995). However, Pb and Cr concentrations of all rice samples in both polluted and unpolluted areas are very high in comparing with the Vietnamese Standards. These concentrations are also higher Pb concentrations in water of the rice fields, canals and drains tested. (maximum Pb and Cr concentrations in these locations is 0.009 mg/l and 0.0039 mg/l respectively). This can be explained as following: in water, Pb and Cr are in dissolved form. When this water is taken into a rice field, Pb and Cr are accumulated in soil time to time leading to increase of Pb and Cr contents in the soil. Rice trees uptake these metals from the soil resulting to high concentrations of Pb and Cr in rice products. However, based on few rice product samples said above, correct conclusions can not be affirmed. More samples and more testing should be carried out.

In general, concentrations of heavy metals in polluted areas is higher than ones in unpolluted area, except concentration of Zn and Mn. This issue could be caused by errors of testing or complicated chemical reactions between soil and water or Zn and Mn concentrations of Duong river water is high. However, most of above parameters are lower than the allowable limits as defined in the Food Standards attached with Decision 46/2007/QD-BYT dated 19 December 2007 issued by Minister, Ministry of Health, except Pb. It is required to continue the rice product, soil sampling and testing in order to have a proper conclusion of Pb and Cr concentrations.

7.6 Chapter Conclusions

Assessments by Farmers:

- Wastewater reuse much impacts on farmer's health;
- Wasterwater reuse for irrigation much negatively affects on rice in nursary periods and up-land crops. But it could be good for rice in later periods;
- Rice fields at canal heads are much affected (too much Nitrogen, rice leaves are too verdant but poor yield);
- Wasterwater should be stored for a time (7-10 days) before taking for irrigation (However, it is difficult to have a space for wastewater storage);

- Much sedimentation in canal beds caused by waste matters (leading to soil pollution when dredging and filling)

Initial assessments by the consultants:

- Rice yields of areas using polluted water are higher than rice yields of areas using unpolluted water. This is clearly recognized in Summer crop.
- Rice product tests are few. It is not sufficient to have a proper assessment. No specific rice quality standards (only for foods in general). Concentrations of Pb and Cr are rather high in rice product samples. It is required to have more tests to affirm a conclusion.

8. INSTITUTIONAL ARRANGEMENTS RELATED TO BAC DUONG IRRIGATION SCHEME

8.1. General introduction

Bac Duong Irrigation System is one of the most important scheme in the Red River Delta. The scheme was constructed in 1962 to irrigate for 32,821 ha and drain for 51,711 ha, which are mainly located in Tu Son, Tien Du, Que Vo, Yen Phong districts and Bac Ninh City of Bac Ninh Province and a part of Dong Anh and Gia Lam Districts of the Hanoi Capital City. The scheme borders with Cau River on the North and Northeast, Duong River on the South and Southeast, and Ca Lo River on the West.

Topography of the system area slopes from Northwest to Southeast. The area consists of mountains, hills, and delta that locate alternatively creating a various topographical area. In dry season, water levels in rivers are general lower than average elevations of cultivated land. On the contrary, in wet season, water levels in rivers are from 2 – 5 m higher than elevations of cultivated land. Therefore, irrigation and drainage in the area of Bac Duong System are mainly carried out by using pumps.

In general, irrigation and drainage canals include main and primary canals (163 km), secondary and tertiary irrigation canals (818 km), and secondary and tertiary drainage canals (878 km). The scheme has 642 pumps in 59 P/Ss, of which only 17 P/Ss are for irrigation, 26 P/Ss are for dual purposes (irrigation and drainage), and 16 P/Ss for drainage. Most of the pumps were installed in end of 1960s and early of 1970s and therefore, capacities of these pumps have been reduced significantly.

The two main irrigation canals namely as North Trinh Xa and South Trinh Xa with length of 35 km and 25 km, respectively. Water is taken from Duong River through Long Tuu Sluice and Trinh Xa P/S to irrigate for about 75 percent of command area while the rest is irrigated by water taken from the Cau River through Kim Doi P/S and some smaller P/Ss locating along the Cau River. The main North and South Trinh Xa irrigation canals are made by earth. The system is divided into 39 sub-irrigation areas managed by 39 P/Ss. The largest sub-irrigation area is Trinh Xa (10,006 ha), following by Kim Doi (1,520 ha), Thai Hoa (1,109 ha), Phu Lam (759 ha), Tan Chi 1 (601 ha), Duong Xa (557 ha), Xuan Vien (532 ha), and Chau Cau (500 ha). The remaining sub-areas are small with serviced areas ranging from several tens hectares to approximately 300 ha. Irrigation structures are deteriorated over years of operation reducing efficiency of not only canal system but also headwork and P/Ss. Water losses in both discharge and water head occur commonly over the system. In addition, due to the rapid socio-economic development in the area, the capacity of power transmission line and transformers cannot meet requirements of loads causing overload and sometimes interrupted the operation of P/Ss.

Main drainage system includes Ngu Huyen Khe River, Tao Khe stream, road No 16 drainage canal, and Kim Doi and Trinh Xa canals. Flood water is drained to Cau River mainly by Dang Xa and Van An P/Ss and to Duong River by small P/Ss. Drainage canals, such as Ngu Huyen Khe, Tao Khe, Trinh Xa, Kim Doi, Dang Xa, are eroded and silted. Lot of raw waste from craft villages dump directly into the scheme without treatment causing pollution and blocking flow. The system is divided into 38 sub-drainage areas. The largest sub-drainage area is Kim Doi (7,491 ha), following by Trinh Xa (5,724 ha), Thai Hoa (4,766 ha), Hien Luong (4,699 ha), Dang Xa (2,479 ha), Tri Phuong (1,494 ha), Pha Lai (2,200 ha), Tan Chi (5,104 ha), Huu Chap (1,020ha), Vong Nguyet (1,941 ha), and Xuan Vien (503 ha). The remaining sub-drainage areas are small. Even though the system has high density of drainage P/Ss, flooding frequently occurs in lot of areas in system's districts causing difficulties for lives of people and agricultural production. According to statistics, approximately 4,000 ha of paddy in Yen Phong, Tien Du, and Tu Son Districts are inundated annually and it is estimated that one-third of this is totally lost and the yield of the remaining area is reduced 25 – 30%.

The IDMC is operated following the regime of a SOE providing public services. Annually, PPC assign irrigation and drainage targets together with budget. As a result of the Decree 154/2007/ND-CP, 100% of the IDMC's financial source is provided from government budget.

8.2. Organisational arrangement of Bac Duong IDMC

Organisational structure of the Bac Duong IDMC consists of the followings:

- Head office: Management board includes Director and 3 deputy directors. Five office departments, including Administration and Personnel Department, Electrical and Mechanical Department, Hydraulic Works and Water Management Department, Technical and Planning Department, and Financial and Accounting Department. Besides that, the IDMC also has Project Management Unit, Design and Investigation Unit, and Civil Works Unit.
- Six irrigation management enterprises (IMEs). Each IME consists of administration office, Irrigation Management Groups (IMGs), and civil works units. The system has 53 IMGs and units, including 4 IMGs of Tu Son IME, 6 IMGs of Tien Du IME, 11 IMGs of Que Vo IME, 10 IMGs of Yen Phong IME, 8 IMGs of Bac Ninh City IME, and 4 IMGs of Trinh Xa IME.

Organisational chart of the Bac Duong IDMC is presented in Figure 1.

In 2008, Bac Duong IDMC has 490 staffs, including 70 staffs holding bachelor degrees (14%), 5 staffs holding higher high school degrees (1%), 29 staffs holding intermediate degrees (6%), 360 workers over 3rd grade (74%), and supporting staffs. Female staffs consisted of 142 persons making up approximately 30% of the total staffs.

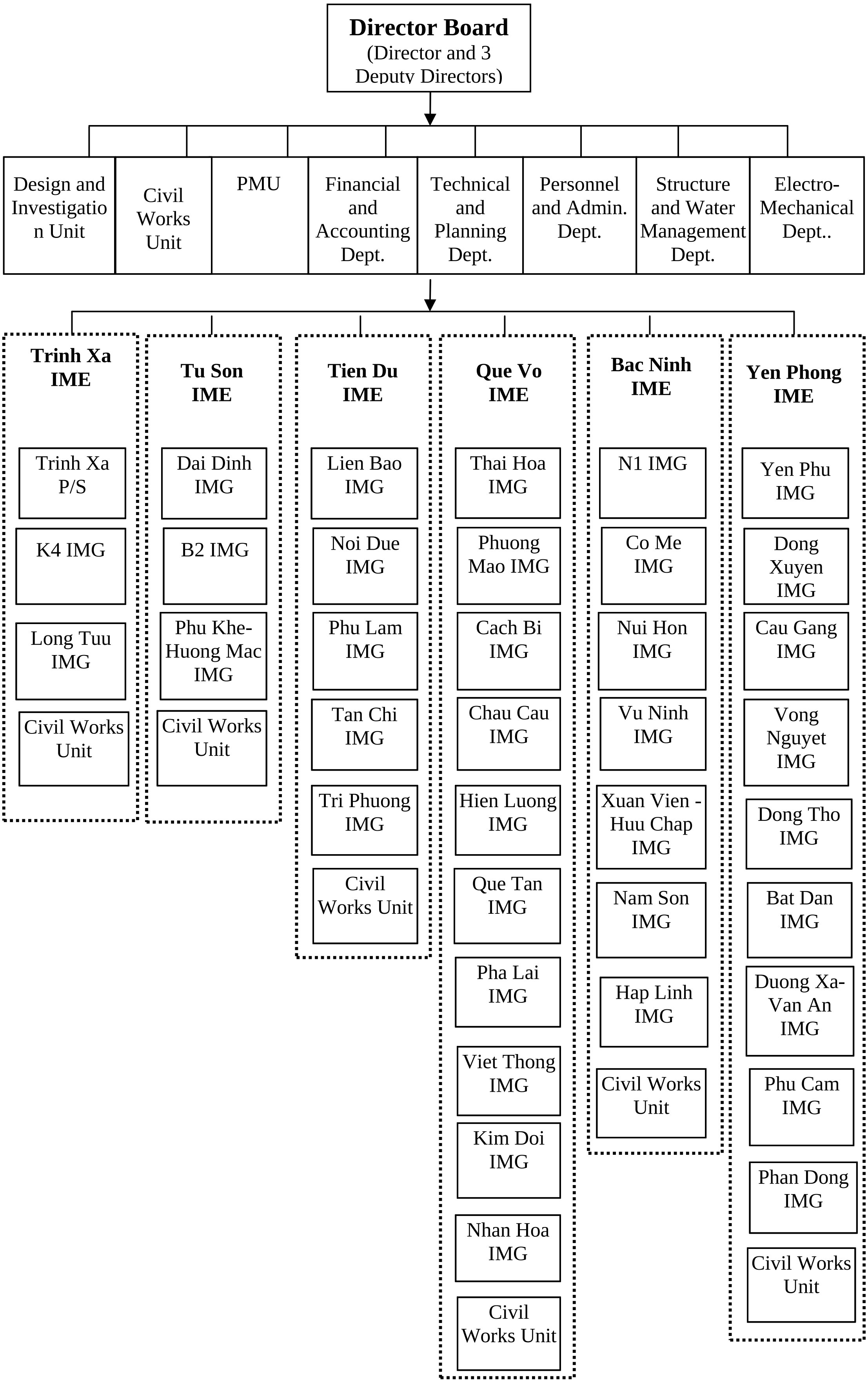


Figure 18 .Organisational Chart of Bac Duong IDMC

Operational procedures of Bac Duong IDMC

The operation of the Bac Duong IDMC is complied with following major legal documents and regulations:

- Water Law (08/1998/QH10) dated 20/5/1998 of the National Assembly;
- Dyke Law (79/2006/QH11) date 29/11/2006 of the National Assembly;
- Ordinance 32/2001/PL-UBTVQH dated 04/04/2001 of National Assembly on Exploitation and Protection of Hydraulic Works;
- Decree 140/2005/ND-CP dated 11/11/2005 of the Government stipulates administrative fines for violations in exploitation and protection of hydraulic works;
- Decree 143/2003/ND-CP dated 28/11/2003 of the Government on Exploitation and Protection of Hydraulic Works;
- Decree 154/2007/ND-CP dated 15/10/2007 provide amendments to the Decree 143/2003/ND-CP dated 28/11/2003 of the Government on Exploitation and Protection of Hydraulic Works;
- Circular 06/1998/TT- BNN – TCCB dated 03/09/1998 of MARD on Organisation and Operation of IDMCs (hereinafter called Circular 06/1998/TT- BNN – TCCB);
- Inter-Circular 90/1997/TTLT-TC-NN dated 19/12/1997 of MARD and MOF on Instruction for Financial Management for state enterprises operating in exploitation and protection hydraulic works (hereinafter called Circular 90/1997/TTLT-TC-NN);
- Circular 26/2008/TT-BTC dated 28/3/2008 provided implementation guidance for some of articles of Decree 154/2007/ND-CP dated 15/10/2007 amending some articles of Decree 143/2003/ND-CP dated 28/11/2003 of the Government on Exploitation and Protection of Hydraulic Works;
- Decision 131/2008/QD-UBND dated 11/9/2008 issued cost norms for management and uses of appraisal fees for wastewater discharge into irrigation system in Bac Ninh Province.
- Decision 55/2004/QD-BNN dated 1/11/2004 stipulated permission provision for activities in protection of hydraulic works and Decision 62/2007/QD-BNN dated 28/6/2007 amending some articles of Decision 55/2004/QD-BNN;
- Decision 56/2004/QD-BNN dated 1/11/2004 stipulated regulations on competence, permission procedures for wastewater discharge into irrigation system;
- Decision 211/1998/QD-BNN-QLN dated 19/12/1998 of MARD issues Regulations on Regime to Finance Routine Maintenance of Fixed Assets of IDMCs (hereinafter called Decision 211/1998/QD-BNN-QLN);
- Bac Duong system operation process - Decision No.143/QLN/QD dated 3 July 1996 of DWR of MARD.

The system is operated based on hydraulic boundary and is not divided by administrative borders. The Bac Duong IDMC operates main irrigation and drainage structures if (i) water levels in rivers are lower than the permitted water levels; and (ii) structures are under normal operational conditions and will not cause break-downs or unsafety.

During the period of summer-fall season (from 15 June to 15 October), if the Bac Duong IDMC wants to open sluices to take water against drought, it needs to get permissions from Bac Ninh DARD and reports to DWR. However, if water level in the Duong River is lower than the first alert water level, Bac Duong IDMC can open Thai Hoa and Thon Sluices to take water for irrigation by gravity. During this season, water in buffer zones is drained as needed to protect against floods.

In rainy season, water is drained to Ngu Huyen Khe River and then drained to Cau River through the Dang Sluice by gravity when water level in the Cau River is low and Dang Xa P/S when water level in Cau River is high. When water level in discharge basin of Dang Xa P/S reaches +7.5 m, the Dang Xa P/S and other P/Ss that drain water into the Ngu Huyen Khe River have to stop operation.

In following operational conditions, the Bac Duong IDMC has to get permissions from the Provincial Flood and Storm Control and Protection Board:

- Open sluices to take water against drought when water level in river is higher than the designed water level for sluices' opening.
- Operate drainage P/Ss when water levels in discharge basins are higher than the P/Ss' operational permissions.

8.3. Water User Organisations in the Scheme

In the system area, the common form of WUO is agricultural cooperative at commune or hamlet level. Cooperatives contract with IMEs for irrigation services. Staffs of cooperatives take water from tertiary canals to farms and drain water from farms to drainage canals. Most of cooperatives' irrigation teams are not trained on irrigation and on-farm water management skills. The quantity and quality of irrigation teams are changeable. Cooperatives are paid from fees collected from water users.

Table 46 Agricultural cooperatives in Bac Duong Irrigation system's area

No.	IME	Cooperatives	Serviced area
1	Bac Ninh	60	2,505
2	Tien Du	60	4,506
3	Yen Phong	100	4,516
4	Tu Son	29	2,815
5	Trinh Xa	10	1,084
	Total	***354***	***21,348***

As can be seen from the above table, the Yen Phong holds one-third of the cooperatives in the area. Following by Bac Ninh City and Tien Du. A typical structure of irrigation management at lower level in Bac Duong Irrigation System is presented in the chart below:

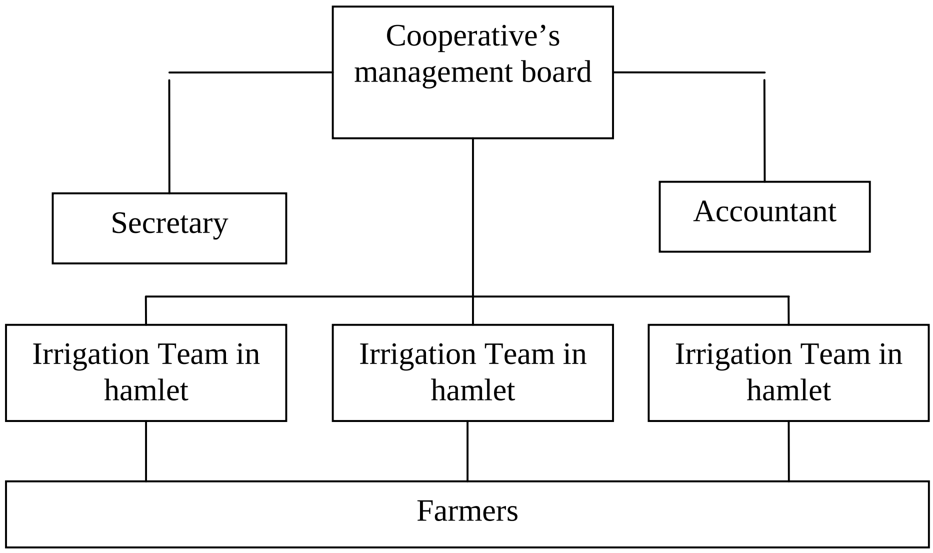


Figure 19. A typical organizational structure of irrigation management at cooperative level in Bac Duong system

Irrigation teams, under the leadership of cooperatives, are responsible for the delivery of irrigation water from IDMC off-take(s) to the farmer's fields, minor maintenance and repair, and guarding the irrigation infrastructure. Irrigation teams are employees of cooperatives and are paid from cooperative fees imposed on the farmers.

Within Hamlet irrigation deliveries are managed by the Irrigation Team (IT). In general, this often involves opening the off-take gates along the IDMC main canal or secondary canal or closing off upstream gates supplying water upstream to other Hamlets; monitoring gates of Hamlet WUGs above them, managing water deliveries to farmer's along the tertiary channels, clearing debris from canals, plugging canal breaches, investigating illegal water taking and guarding the irrigation infrastructure.

8.4. Irrigation decision making process

Irrigation policy/decision making organs of the Province are the Peoples Provincial Committee (PPC) and the Department of Agriculture and Rural Development – Sub-department of Water Resources (SDWR). DARD develops O&M policy and assists the PPC to supervise the Irrigation and Drainage Management Companies (IDMC).

Irrigation management structure in Bac Ninh Province is presented in the figure below:

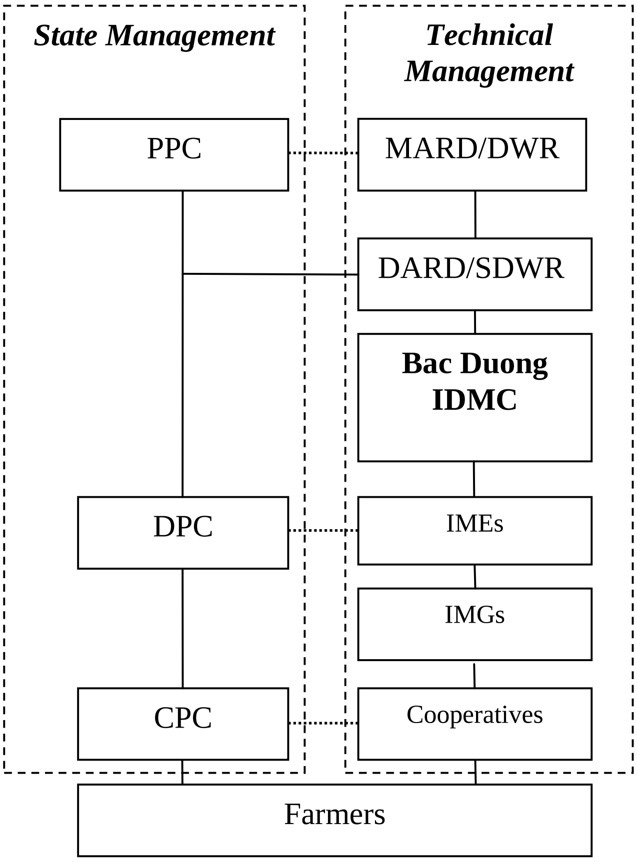


Figure 20. The irrigation management structure in Bac Ninh Province.

Irrigation and drainage in the system is managed by Bac Duong IDMC under the direction of SDWR of Bac Ninh DARD. DPCs and CPCs are responsible for frequent inspections and oversee the management and of the system in order to ensure the normal operation of the system during flood seasons.

The Bac Duong IDMC manages large P/Ss, inter-provincial and inter-district primary canals and on-canal structures. IMEs manage P/Ss, secondary canals and on-canal structures or inter-commune tertiary canals. IMGs manage P/Ss, tertiary canals and on-canal structures locate within a commune. Specific lists are prepared by IDMC and informed to IMEs. Cooperatives manage on-farm canals and related intakes.

General irrigation and drainage management principles are as follows:

- Irrigation and drainage plans consist of plan for the whole season and plans for each irrigation interval of 10 days. Irrigation and drainage activities are based on the prepared irrigation and drainage plans and enforceable decision making.
- Irrigation and drainage plans are prepared based on irrigation and drainage demands, irrigation and drainage norms, and experiences.
- The preparation and implementation of irrigation and drainage plans should be unified and suitable with actual conditions.

- IMEs approve irrigation and drainage plans prepared by IMGs and the IDMC approves irrigation and drainage plans prepared by IMEs.
- In order to provide irrigation services timely while ensuring legal status of plans, for each irrigation and drainage interval, IMEs and IMGs can implement, feedback, and submit plans for approval simultaneously.

In actuality, irrigation plan only defines land preparation period, the crops to be grown, area to be planted to each crop and the period of planting/transplanting. The plan does not specify a water delivery schedule for the farmers; rather it appears to be used to encourage farmers to plant/transplant within the same period. During the land preparation period the pumping stations operate at full capacity and may use irrigation rotations to increase delivery rates during this period of heavy demand. After land preparation and throughout the crop growing period, the IDMC operates the pumping stations on a demand basis and are said to supplement this procedure with occasional field visits to the field to observe water levels. During the cropping season, when irrigation water is required the Hamlet Head requests the IDMC pumping station for water.

As previously mentioned, the IDMC delivers water on a rotational basis during the land preparation period, in order to meet the heavy water duty at that time. During the cropping season water is delivered to cooperatives by requests from chairmen of cooperatives. Farmers are notified of a pending irrigation water delivery.

8.5. Chapter Conclusions

The Bac Duong Irrigation System was constructed in 1960s to provide irrigation services for Tu Son, Tien Du, Que Vo, and Phong Khe Districts and Bac Ninh City of Bac Ninh Province. Due to topographical conditions of the system, irrigation and drainage in and out of the system are mainly by pumps. The system, including P/Ss, canal, and on-canal structures, are deteriorated generally due to long time of operation. The Ngu Huyen Khe River takes water from the Duong River for irrigation and drains flood water to the Cau River. The river is heavily polluted due to commercial and production activities in riverine craft villages. Due to the lack of water sources for irrigation, wastewater in Ngu Huyen Khe River is reused for agricultural production.

The Bac Duong IDMC is a SOE and fully supported by government budget. The IDMC is under direction of Bac Ninh DARD/SDWR. Organisation of the Bac Duong IDMC consists of management board, office departments, and six IMEs. The IDMC operates the Bac Duong System based on existing legal documents. Specific system operation procedures are mainly followed Decision No.143/QLN/QD dated 3 July 1996 of DWR of MARD.

The system has 354 WUOs under the form of agricultural cooperatives that provide irrigation services for 21,348 ha (on-farm level). Each cooperative has irrigation teams at hamlet level and they are responsible for taking water from IDMC's off-takes to farms.

Irrigation decision making process is carried out jointly by MARD/DWR, PPC, and DARD/SDWR. The management of the Bac Duong Irrigation System is divided into higher and lower parts where IDMC/IMEs manage higher part of the system and cooperatives manage lower part of the system. Irrigation and drainage plans are prepared for the whole season and for each irrigation and drainage intervals.

9. STRATEGY OF WASTEWATER REUSE IN THE SCHEME

Strategy of wastewater reuse in the scheme should be developed on foundations of reuse sustainability and below principles/themes:

Figure 21. Foundations of reuse sustainability

It should be noted that specific actions have to be developed in order to fulfil each of the strategy's principles/themes and to demonstrate progress toward sustainability.

Ensure Safe Irrigation Water

- Coordinate with the stakeholders in Bac Duong scheme to ensure the provision/delivery of safe and acceptable irrigation water.
- Monitor and report on the quality of the irrigation water in accordance with applicable regulations.
- Ensure the protection of the irrigation water supply through the development of source protection strategies for intake zone protection strategies for surface water supplies.

- Optimize water treatment facilities to minimize chemical use and process waste residuals.

Healthy Irrigation Area

- Develop comprehensive irrigation area strategies addressing all aspects of water quality and quantity. This activity should address all surface and groundwater taking activities, wastewater discharges and stormwater discharges. The strategies should define baseline conditions; address restoration needs; set specific irrigation area goals and objectives; examine the impact of future development; and, propose appropriate mitigation policies, programs and measures. Planning will need to be done in partnership with the stakeholders.

- Develop specific monitoring strategies and reporting re-quirements for each wastewater treatment facility. These should address performance measures supporting Bac Duong scheme's goals and objectives as well as any regulatory requirements. Reporting on wastewater liquid effluents, air effluents and biosolids residues.

Wise Use of Wastewater

- Finalize the wastewater efficiency plan update and implement further wastewater efficiency measures.

- Develop and implement adverse impact reduction measurements.

- Explore the potential for wastewater effluent reuse

- Identify further opportunities for wastewater product recycle.

Community Well Being

- Develop level of service targets for wastewater system continuous operation.

- Develop level of service targets for water supply pressure and for pressure related complaints.

Full and Equitable Funding

- Developing full cost life cycle funding requirements for wastewater services over period of Master Plan

Timely and Integrated Service Delivery

- Develop master implementation schedules through the Master Plan process.

- Prepare risk analyses for major stages of major projects so that timely mitigation strategies may be implemented.

- Develop a public communication program regarding the importance of maintaining the schedule and the role that Bac Duong IDMC, agencies and the public play in the process.

Climate Change and Energy Efficiency

- Benchmark energy usage in wastewater facilities.

- Develop and implement an energy efficiency strategy for wastewater facilities.

- Benchmark greenhouse gas emissions from wastewater facility operations. If the emissions are significant develop a greenhouse gas emission reduction strategy.

- Incorporate climate change impacts into the design of linear wastewater infrastructure and wastewater treatment facilities.

- Prepare an analysis of climate effects on water resources including water supply availability and assimilative capacity. Depending on the outcome of this analysis develop mitigation strategies.

Communications and Consultation

- Develop and implement a communications strategy for wastewater sustainability that reaches out to people of all ages, cultural backgrounds and all walks of life.

- Provide a point of public access on up to date information available on water and wastewater issues, ideas and trends.

- Establish interest-based sustainable wastewater committees to provide input into wastewater planning.

- Engage citizens as volunteers in support of wastewater planning and project implementation, for example, by seeking volunteers for water conservation programs, Children's Water Festivals, and the like.

- Track public comments and provide a considered response to the comments.

- Develop social marketing programs promoting wise use of water and water conservation.

- Utilize a broad variety of methods to communicate water and wastewater sustainability

Monitoring, Performance Measurement and Adaptive Management

- Develop a wastewater sustainability report and prepare a first year report. The report should integrate all the items, be refined over time, and published annually.

- Establish communications networks on wastewater sustainability within the scheme.

- On an annual basis, through customer service surveys, learn whether wastewater services are measuring up to customer expectations.

• Construct internal and external monitoring and reporting mechanisms involving: surveys, focus groups, brochures, web based customer input, and the like.

• Implement a monitoring, performance measurement, and adaptive management system that will evaluate the effectiveness of Bac Duong IDMC's performance.

Performance indicators determined for each principle of the wastewater sustainability strategy could be presented as below:

No.	Principle/Theme	Performance Indicators
1	Safe Irrigation Water	Number of customer complaints concerning "dirty water" .
2	Healthy irrigation area	Total annual wastewater volume treated as well as per capita and unit area wastewater volumes; Number of complaints
3	Community Well-being	Hours per year of continuous wastewater service operation Number of complaints resulting from events less than service target
4	Full and Equitable Funding	Financial indicators of funding capacity in relation to funding need
5	Climate Change and Energy Efficiency	Wastewater energy reduction targets; Greenhouse gas emission reduction targets
6	Communications, Consultation	Measures of change in water efficiency habits due to social marketing campaigns; Change in public attitudes toward wastewater sustainability, measured through surveys

Based on the above chapter analysis, it can be seen that in areas along Ngu Huyen Khe river, quantity of irrigation water is not a big problem, but quality is. Ngu Huyen Khe river is a sole irrigation source for cultivable lands along two river banks. Farmers have no another choice of irrigation sources. Now, Institute of Water Resources Planning, MARD is carrying out a revised irrigation planning of Bac Duong scheme. However, no any idea of replacing Ngu Huyen Khe irrigation source is proposed. Wastewater reuse is compulsory for the areas. Therefore, in order to improve the situation of this river, with a long term objective it is necessary to make the river revive.

According to the environment protection plans of Bac Ninh province, in 2010, targets for Ngu Huyen Khe river protection are redution of pollution, overcoming water quality depletion. In 2020 it is expected that basically water pollution is well controlled and the river will revive.

The case study has been implemented for a short time, initial available data and information do not allow to produce absolute correct conclusions on impacts of wastewater reuse on various aspects. However, it can be very clearly seen that wastewater reuse causes negative impacts on farmers' health and their living. The present wastewater reuse should be improved. At least, preliminary treatments such as temporary storage before irrigating or pumping water from Cau river to dilute pollution should be carried out. Measures of protecting farmers from adverse impacts of wastewater on their health such as: using boots, gloves, glasses etc. should be applied.

In order to gain the above targets, specific measures for environment protection should be carried out in Bac Ninh province as below:

- Legal aspects: Development and improvement of legal documents including Laws, Decrees, Circulars, Decisions related to environment protection;
- Licensing: All polluters must be licensed by the authorized agency; Wastewater must be treated before discharging into the river;
- Institutional arrangements: Bac Ninh province should have close cooperation with relevant agencies, universities to develop and implement a project “Assessment of existing environment status and recommendations of solutions for Ngu Huyen Khe river environment protection”;
- Monitoring: Implementing periodical monitoring activities at discharging points, canals, drains to control water pollution;
- Environment inspections and sanctions have to be seriously carried out to all industries, craft villages etc. to prevent timely any violation to environment protection;
- Education and awareness improvement: Implementing effectively activities of education, awareness improvement to the local people to facilitate their participations in the environment protection;
- Polluter reallocation: polluters of villages have to be reallocated in groups to create good conditions for wastewater treatment.

10. CONCLUSIONS AND RECOMMENDATIONS

10.1. Main Conclusions

The final report of TA 4903 – VIE Water Sector Review Project has indicated that many of the river basins in Viet Nam have low water availability by international standards, and many are moderately or highly stressed because of current and planned extractions of water from rivers in the long dry season. The report shows that including the projected future dry season water uses to 2020 and assuming that all reservoirs in the basin are full at the start of the dry season and that the water is available for use in the dry season, and dry season inter-basin diversions, meaning that the projected water use would well exceed the total water available in the basin during the dry season.

At present, climate change is expected to alter the current runoff and rainfall regimes. MONRE has estimated increased mean annual temperature for Viet Nam from climate model simulations under a range of emissions scenarios. Most of the increase in average annual rainfall predicted is expected to occur in the already wet months of the year, with only a minor increase over the dry season. The result would be that the seasonal variation in river flows would increase, with a greater variation in runoff at the seasonal scale. The frequency of dry season water shortages may also increase, because of higher dry season evaporation rates. The higher temperatures will increase plant water requirements, increasing the dry season crop water demands.

Therefore, it can be said that saving water and wastewater reuse is considered as good options for irrigation.

In Bac Duong irrigation scheme, Ngu Huyen Khe river is a natural drain. However, in fact, it is an irrigation water source for areas along both river banks. In dry season, the river water mainly is wastewater from industries, craft villages, domestic uses, agriculture etc. The study of "**Potential use of waste water for irrigation to mitigate water pollution while assuring sustainable and safe agriculture in the Bac Duong Irrigation Scheme**" has a great significance in both theory and practice.

This study has gained following results:

1. Identification of sampling location for water quality and rice product quality study;
2. Identification of parameters tested for water quality and rice product quality;
3. Assessment of pollution sources in the Bac Duong irrigation scheme;
4. Assessment of water quality in the Bac Duong scheme;
5. Potential impacts of wastewater reuse on agricultural production in the Bac Duong scheme;
6. Institutional arrangements related to the Bac Duong scheme.

Based on the gained results, the study has also proposed a strategy of wastewater reuse in the Bac Duong scheme.

Issues of wastewater reuse are complecated and difficult ones. For 5 months of studying, the study team wishes to show a general picture of wastewater and wastewater reuse status in the Bac Duong scheme. Assessments of impacts of wastewater reuse for irrigation on agricultural production are considered as initial ones. The study has been implemented in rainy season, therefore, water pollution of Ngu Huyen Khe river are much lower in comparing with dry season. However, it is clearly seen that:

- Water pollution in Ngu Huyen Khe river is too serious, especially in dry season;
- Ngu Huyen Khe river is a sole irrigation water source for areas along the river banks in dry season. Wastewater reuse is a compulsory choice for these areas;
- Wastewater reuse has clear direct impacts on farmer's health. It's impacts on agricultural production are initially identified. However, in the first phase, proper assessments have not been affirmed yet. It is required to continue the study in Phase 2.
- In the future, because of high growth rate of economic and social development, water pollution in the scheme will be increased, if no any urgent measures are taken from now. The above proposed strategy should be considered and implemented by the relevant agencies at various levels and communities.

10.2. Recommendations for Application of Wastewater in Irrigation

Based on the above sections, it can be seen that wastewater reuse in the Bac Duong irrigation scheme has clear negative impacts on farmers' health, irrigation area health. It is necessary to have preliminary treatment before using the wastewater for irrigation at least. When water pollution level of the Ngu Huyen Khe is high, wastewater should be stored temporary for 7-10 days in canals, drains or ponds before taking it to crop fields. In case wastewater of the Ngu Huyen Khe is too serious, it is required to pump water from Cau river to dilute water pollution before pumping to the canals. However, this measure is considered as a compulsory situation solution. It should not be considered as a positive measure for wastewater reuse.

In order to control water pollution of the Ngu Huyen Khe river, it is required to implement necessary measures to manage the waste sources. Craft villages, industries should be reallocated to collect waste matters into planned places where waste matter treatment could be effectively, efficiently carried out. Polluters must have responsibilities for treatment before discharging into the water source and paying for their waste matters into environment. Awareness improvement on wastewater reuse for the communities and agencies should be well implemented. Water of the Ngu Huyen Khe river should be improved soon.

10.3. Recommendations for Further Research

Because main study #2 was carried out for 5 months of a rainy season, the collected data, information are still insufficient. The above conclusions and recommendations are initial ones. It is necessary to continue the study with the following aspects:

(i) Surveying wastewater sources: re-identifying main waste sources in the scheme. Measuring wastewater discharges of the wastewater sources;
(ii) Continuing water quality monitoring at crop fields, canals and drains (as phase 1) for 2 more years (in both dry and rainy seasons). However, some more water quality parameters should be tested (for instance, pesticide residuals);
(iii) Continuing rice product, soil sampling and testing in areas selected in phase 1;
(iv) Studying impacts of wastewater on other up-land crops (such as potato, vegetables etc.);
(v) Studying feasible and simple wastewater treatment technologies for the area;
(vi) Continuing study and having specific recommendations to legal framework, decision making process, organizational arrangements to wastewater reuse in the area;
(vii) Supporting DARD and DONRE in wastewater licensing;
(viii) Supporting DARD and DONRE to develop wastewater treatment proposals to craft villages, industries;
(ix) Developing action plans for awareness improvement and capacity building for communities and agencies.

ANNEXES

ANNEX 1.

Irrigation Water Quality Standards of Viet Nam- TCVN 6773:2000

Parameter	Unit	Allowable limits
1. Total suspended solid	mg/l	Less than 400, in poor irrigation, drainage areas, salt intrusion soil. (Water having EC $\leq$ 0,75 µS/cm, 25°C) Less than 1000, in good irrigation, drainage areas (EC $\leq$ 0,75 µS/cm, 25°C)
2. Sodium Absorption Ratio (SAR)	mg/l	Less than 10, in poor irrigation, drainage areas Less than or equal 18, in good irrigation, drainage areas Higher 18, in poor fertile, nutrient soil areas
3. Bo (B)	mg/l	Less than or equal 1 to areas of cultivating Bo sensitive trees. Less than or equal 2 to areas of cultivating Bo moderate sensitive trees. Less than or equal 4 to areas of cultivating other trees.
4. Dissolved Oxygen	mg/l	Equal or greater than 2
5. pH	mg/l	5,5 – 8,5
6. Chloride (Cl)	mg/l	Less than or equal 350
7. Pesticides	mg/l	Less than or equal 0,001
8. Mercury (Hg)	mg/l	Less than or equal 0,001
9. Cadmi (Cd)	mg/l	0,005 – 0,01
10. Arsenic (As)	mg/l	0,05 – 0,1
11. Lead (Pb)	mg/l	Less than or equal 0,1
12. Chromium (Cr)	mg/l	Less than or equal 1
13. Zinc (Zn)	mg/l	Not higher 1, if pH of soil less than or equal 6.4 Not higher 5, if pH of soil higher 6.5
14. Fecal coliform	MPN/ 100ml	Not higher 200 (to vegetable soils) Not required for other trees.

Industrial Waste Water Discharge Standards - TCVN 5945 - 2005

No.	**Parameter**	**Unit**	**Allowable value**	
			A	**B**
1	pH	-	6 to 9	5,5 to 9
2	BOD5 (20oC)	mg/l	30	50
3	COD	mg/l	50	80
4	Dissolved Oxygen	mg/l	≥ 6	≥ 2
5	Total suspended solid	mg/l	50	100
6	Arsenic	mg/l	0,05	0,1
7	Bari	mg/l	1	4
8	Cadmium	mg/l	0,005	0,01
9	Lead	mg/l	0,1	0,5
10	Chromium (VI)	mg/l	0,05	0,01
11	Chromium (III)	mg/l	0,2	1
12	Copper	mg/l	2	2
13	Zinc	mg/l	3	3
14	Manganese	mg/l	0,5	1.0
15	Nickel	mg/l	0,1	1
16	Iron	mg/l	1	5
17	Mercury	mg/l	0,005	0,001
18	Tin	mg/l	0.2	1
19	Ammonia	mg/l	0,05	1
20	Fluoride	mg/l	5	10
21	Nitrate	mg/l	10	15
22	Nitrite	mg/l	0,01	0,05
23	Cyanide	mg/l	0,07	0,1
24	Phenol (total)	mg/l	0,1	0,5
25	Lubricants, greases	mg/l	5	5
26	Detergents	mg/l	0,5	0,5
27	Coliform	MPN/100ml	3000	5000
28	Total pesticides (excluding DDT)	mg/l	0,1	0,1
29	DDT	mg/l	0,01	0,01
30	Total alpha unit of activity (α)	Bq/l	0,1	0,1
31	Total beta unit of activity β	Bq/l	1,0	1,0

Note: Column A is used for discharging into water sources used for domestic uses
Column B is used for other water sources

Surface Water Quality Standards of Viet Nam- TCVN 5942 - 1995

No.	Parameter	Unit	Allowable value	
			Class A	Class B
1	pH	-	6 to 8,5	5,5 to 9
2	BOD5 (20oC)	mg/l	< 4	< 25
3	COD	mg/l	<10	<35
4	Dissolved Oxygen	mg/l	$\geq$ 6	$\geq$ 2
5	Total suspended solid	mg/l	20	80
6	Arsenic	mg/l	0,05	0,1
7	Bari	mg/l	1	4
8	Cadmium	mg/l	0,01	0,02
9	Lead	mg/l	0,05	0,1
10	Chromium (VI)	mg/l	0,05	0,05
11	Chromium (III)	mg/l	0,1	1
12	Copper	mg/l	0,1	1
13	Zinc	mg/l	1	2
14	Manganese	mg/l	0,1	0,8
15	Nickel	mg/l	0,1	1
16	Iron	mg/l	1	2
17	Mercury	mg/l	0,001	0,002
18	Tin	mg/l	1	2
19	Ammonia	mg/l	0,05	1
20	Fluoride	mg/l	1	1,5
21	Nitrate	mg/l	10	15
22	Nitrite	mg/l	0,01	0,05
23	Cyanide	mg/l	0,01	0,05
24	Phenol (total)	mg/l	0,001	0,02
25	Lubricants, greases	mg/l	no	0,3
26	Detergents	mg/l	0,5	0,5
27	Coliform	MPN/100ml	5000	10000
28	Total pesticides (excluding DDT)	mg/l	0,15	0,15
29	DDT	mg/l	0,01	0,01
30	Total alpha unit of activity (α)	Bq/l	0,1	0,1
31	Total beta unit of activity β	Bq/l	1,0	1,0

Note: Class A is used for domestic water uses after having a treatment as regulated
Class B is used for other purposes

ANNEX 2

QUESTIONNAIRE TEMPLATE FOR INVESTIGATION OF AGRICULTURAL PRODUCTION AND ENVIRONMENTAL POLLUTION

INTERVIEW FARMER HOUSEHOLD

PART I. MAIN INFORMATION OF THE HOUSEHOLD

Name of head of the household:

.....................Village.......................commune.............district ....

1.1. Sex: 1. ☐ Male 2. ☐ Female

1.2. Age: ....

1.3 Household's water source

1. ☐ clean water supply system 3. ☐ drilled well 5. ☐ rainfall 7. ☐ other. . .

2. ☐ digged well 4. ☐ lake 6. ☐ stream

1.4 Household's water quality 1. ☐ safe 2. ☐ polluted 3. ☐ unsafe

1.5 Does household have toilets? 1. ☐ Yes 2. ☐ No

Where is waste water draigned 1. ☐ sluice 2. ☐ hole 3. ☐ garden

4. ☐ pond, lake, river

1.6 Does household involve in production, trading activities? 1. ☐ Yes 2. ☐ No

What type of production. . . . .

Was waste water treated before draigned ? 1. ☐ Yes 2. ☐ No

Draigned to 1. ☐ canal 2. ☐ sluice 3. ☐ pond, lake, river 4. ☐ other

Waste water volume : …………..m^3/day

Was solid waste treated? 1. ☐ Yes 2. ☐ No

How to be treated 1. ☐ burn 2. ☐ burried 3. ☐ collected by company

4. ☐ throw

Waste volume : …………..m^3/day

1.7 Any ill person in the household get:

1. ☐ Fever 2. ☐ diarrhea 3. ☐ Skin 4. ☐ Other

Why . . . .

PART II. AGRICULTURAL PRODUCTION ACTIVITIES

A. Cultivation

2.1 How large your (household's) cultivation area ?

Forest land____________ sao; Rice land ___________sao;

Up-land crop:__________sao; Fruit land ____________sao

2.2 Cultivated area

Crop	Cultivated area (sao)	Irrigated area (sao)*	Yield (kg/sao)	Yield of irrigated area (kg/sao)
1. Spring crop 2008				
Rice				
Subsidy crops				
Other				
2. Summer crop				
Rice				
Subsidy crops				
Other				
3. Winter crop				
4. Forestry				
5. Fruit tree				
Total				

(*) Area with irrigation water directly pumped from Ngu Huyen Khe river or through canal which takes water from Ngu Huyen Khe river.

.. . .

2.3 Where is irrigation water source 1. ☐ canal 2. ☐ pond, lake river 3. ☐ rainfall

4. ☐ waste water

2.4 Do you have any comment about water sources?

1. ☐ Turbid 2. ☐ Smell 3. ☐ Black 4. ☐ ….

2.5 How about product quality? (appearance, smell, taste or recognizable characters…..)

. . . .

. . . .

2.6 Has your family taken these products for meals?

1. ☐ Yes 2. ☐ No

2.7 With this water source for irrigation, were fertilizer and chemical input doze applied lower than that without this water source?

1. ☐ Yes 2. ☐ No

2.8 If low yield gained, what reasons? 1. ☐ lack of water 2. ☐ Inundated

3. ☐ poor quality of soil 4. ☐ pests & diseases 5. ☐ lack of fertilizer

6. ☐ poor quality of irrigation water 7. ☐ others ….

2.9 Do you want to improve status of irrigation water source ?

1. ☐ Yes 2. ☐ No

2.10 Was irrigation water supplied in time? 1. ☐ Yes 2. ☐ No

If not why? ……………………………………………….

2.11 Was irrigated water enough ? 1. ☐ Yes 2. ☐ No

If not, why? ……………………………………... . . . .

. . . .

2.12 Water source for livestock production:

1. ☐ clean water supply system 3. ☐ drilled well 5. ☐ lake, pond

2. ☐ digged well 4. ☐ river 6. ☐ others

2.13 Water source for cleaning breeding facilities:

1. ☐ clean water supply system 3. ☐ drilled well 5. ☐ lake, pond

2. ☐ digged well 4. ☐ river 6. ☐ others

2.14 Were your livestock in disease?

1. ☐ Yes 2. ☐ No

Why .. . .

2.15 Have you bred shrimp and fish? 1. ☐ Yes 2. ☐ No

Areas : . . . . Yield . . . .

With water sourced from 1. ☐ canal 2. ☐ lake, pond

Were shrimp and fish in diseases ? 1. ☐ Yes 2. ☐ No

Why .. . .

Have you eaten these products ?

1. ☐ Yes 2. ☐ No

2.16 Do you think your irrigation water was polluted ? 1. ☐ Yes 2. ☐ No

2.17 What reasons cause pollution to your irrigation water?

1. ☐ Indutrial wastes released in to canal, river 2. ☐ Living wastes

3. ☐ Flow containing pesticide and animal wastes

4. ☐ Other (specific). . . . .

2.18 Diseases caused by polluted water sources:

1. ☐ death and illness of poultry and cattle 2. ☐ death of fish

3. ☐ reduced yield cops

4. ☐ Bad smell 5. ☐ Health problems (specific)...................

2.19 Have you have any experience of using wast water for irrigation?
……………………………………………………………………………………………………
…………………………………………………………………………………………….
2.20 According to you, how to improve quality of irrigation water/solve the abover mentioned shortcomings? (propose, please)
……………………………………………………………………………………………………
……………………………………………………………………………………………………
……………………………………………………………………………………………………

ANNEX 3.

Average rice yield data in Yen Phong district

Year	Using wastewater		Not using wastewater	
	Spring crop	Summer crop	Spring crop	Summer crop
2000	5.61	5.10	5.44	5.14
2001	5.35	5.20	5.26	5.15
2002	5.39	5.26	5.40	5.18
2003	5.72	5.37	5.65	5.14
2004	5.86	5.39	5.62	5.12
2005	6.07	5.07	5.96	4.85
2006	5.83	4.78	5.97	4.66
2007	5.62	5.51	5.52	5.37

Average rice yield data in Tien Du district

Year	Using wastewater		Not using wastewater	
	Spring crop	Summer crop	Spring crop	Summer crop
2000	5.85	5.34	5.39	5.09
2001	5.21	5.15	5.23	4.88
2002	5.37	5.38	5.32	5.21
2003	5.66	5.03	5.60	4.88
2004	5.88	5.19	5.87	5.10
2005	5.76	5.14	5.81	5.06
2006	5.89	5.29	5.82	5.02
2007	5.03	5.33	5.35	5.44

Average rice yield data in Tu Son district

Year	Using wastewater		Not using wastewater	
	Spring crop	Summer crop	Spring crop	Summer crop
2000	5.47	4.00	5.29	4.92
2001	5.12	4.00	5.12	4.92
2002	5.27	5.00	5.26	5.06
2003	5.30	5.27	5.34	4.85
2004	5.26	5.71	5.52	4.92
2005	5.89	4.68	5.40	4.48
2006	5.72	4.87	5.51	4.81
2007	5.14	5.05	5.07	4.78

Annex 4.

Water Quality Sampling Diary (upto 16 Sep.08)

Date	No.	Code	Location	Time	Weather
29/7/2008	1	TH 1	Water in paddy field at Thai Hoa pumping station – Vu Duong village – Bong Lai commune- Que Vo	9:00 AM	It's sunny,
	2	XV2.1	Rice field ofThuong Dong village, Van An commune, Bac Ninh	10:15 AM	to : 35-37oC
	3	XV2.2	Drain of Thuong Dong village, Van An commune, Bac Ninh	10:15 AM	
	4	PK 3.1	Rice field of Cham Khe village, Phong Khe commune, Bac Ninh	11:35 AM	
	5	PK 3.2	Drain of Cham Khe village, Phong Khe commune, Bac Ninh	11:35 AM	
	6	ND 1	Rice field of Dinh Ca village, Noi Due commune, Tu Son	12:30 PM	
	7	ND 2	Drain of Dinh Ca village, Noi Due commune, Tu Son	12:30 PM	
	8	DQ 4. 1	Rice field of Bich Ha village, Dong Quang commune, Tu Son	14:35 PM	
	9	DQ 4. 2	Drain of Bich Ha village, Dong Quang commune, Tu Son	14:35 PM	
7/8/2008	1	XV2.1	Rice field of Thuong Dong village, Van An commune, Bac Ninh	9:30 AM	
	2	XV2.2	Drain of Thuong Dong village, Van An commune, Bac Ninh	9:35 AM	Rainy on 7 Aug.
	3	PK 3.1	Rice field of Cham Khe village, Phong Khe commune, Bac Ninh	10:45 AM	to : 28-30oC
	4	PK 3.2	Drain of Cham Khe village, Phong Khe commune, Bac Ninh	10:42 AM	
	5	ND 1	Rice field of Dinh Ca village, Noi Due commune, Tu Son	11:05 AM	
	6	ND 2	Drain of Dinh Ca village, Noi Due commune, Tu Son	11:08 PM	
	7	DQ 4. 1	Rice field of Bich Ha village, Dong Quang commune, Tu Son	11:30 PM	
	8	DQ 4. 2	Drain of Bich Ha village, Dong Quang commune, Tu Son	11:35 PM	
25/8/2008	1	TH 1	Rice field of Thai Hoa pumping station – Vu Duong village – Bong Lai commune- Que Vo district	8:35 AM	It's sunny,
	2	XV2.1	Rice field of Thuong Dong village, Van An commune, Bac Ninh	9:15 AM	Rainy on 24 Aug.
	3	XV2.2	Drain of Thuong Dong village, Van An commune, Bac Ninh	9:16 AM	to : 35-37oC
	4	PK 3.1	Rice field of Cham Khe village, Phong Khe commune, Bac Ninh	10:35 AM	
	5	PK 3.2	Drain of Cham Khe village, Phong Khe commune, Bac Ninh	10:36 AM	
	6	ND 1	Rice field of Dinh Ca village, Noi Due commune, Tu Son	11:30 PM	
	7	ND 2	Drain of Dinh Ca village, Noi Due commune, Tu Son	11:32 PM	
	8	DQ 4. 1	Rice field of Bich Ha village, Dong Quang commune, Tu Son	13:45 PM	
	9	DQ 4. 2	Drain of Bich Ha village, Dong Quang commune, Tu Son	13:47 PM	
9/5/2008	1	TH2	Drain, Thai Hoa pumping station of Mo Dao commune, Que Vo district	8:55 AM	It's sunny,
	2	TH3	Canal, Thai Hoa pumping station of Mo Dao commune, Que Vo district	8:57 AM	Rainy on 4 Sep.
	3	XV2.1	Rice field ofThuong Dong village, Van An commune, Bac Ninh	9:25 AM	to : 28-30oC
	4	XV2.2	Drain of Thuong Dong village, Van An commune, Bac Ninh	9:26 AM	
	5	XV2.3	Canal of Thuong Dong village, Van An commune, Bac Ninh	9:32 AM	
	6	VA3	Canal of Van An commune, Bac Ninh	9:55 AM	
	7	PK 3.1	Rice field of Cham Khe village, Phong Khe commune, Bac Ninh	10:42 AM	
	8	PK 3.2	Drain of Cham Khe village, Phong Khe commune, Bac Ninh	10:43 AM	
	9	PK 3.3	Canal of Cham Khe village, Phong Khe commune, Bac Ninh	10:38 AM	
	10	PL3	Canal of Phu Lam commune, Tien Du district	14:20 PM	
	11	HM3	Canal of Huong Mac commune, Tu Son district (left bank)	14:21 PM	
	12	DQ3	Canal of Dong Quang commune, Tu Son district (right bank)	15:25 PM	
	13	DQ 4. 1	Rice field of Bich Ha village, Dong Quang commune, Tu Son	15:35 PM	
	14	DQ 4. 2	Drain of Bich Ha village, Dong Quang commune, Tu Son	15:35 PM	
	15	DQ 4. 3	Canal of Bich Ha village, Dong Quang commune, Tu Son	15:35 PM	
	16	DP 3	Canal of Dong Xa, Dong Phong commune, Yen Phong district	10:14 AM	
16/9/2008	1	TH2	Drain, Thai Hoa pumping station of Mo Dao commune, Que Vo district	9:05 AM	It's sunny,
	2	TH3	Canal, Thai Hoa pumping station of Mo Dao commune, Que Vo district	9:07 AM	to : 32-34oC
	3	XV2.1	Rice field of Thuong Dong village, Van An commune, Bac Ninh	10:25 AM	
	4	XV2.2	Drain of Thuong Dong village, Van An commune, Bac Ninh	10:27 AM	
	5	XV2.3	Canal of Thuong Dong village, Van An commune, Bac Ninh	10:30 AM	
	6	VA3	Canal of Van An commune, Bac Ninh	10:50 AM	
	7	PK 3.1	Rice field of Cham Khe village, Phong Khe commune, Bac Ninh	11:40 AM	
	8	PK 3.2	Drain of Cham Khe village, Phong Khe commune, Bac Ninh	11:42 AM	
	9	PK 3.3	Canal of Cham Khe village, Phong Khe commune, Bac Ninh	11:38 AM	
	10	PL3	Canal of Phu Lam commune, Tien Du district	14:28 PM	
	11	HM3	Canal of Huong Mac commune, Tu Son district (left bank)	14:55 PM	
	12	DQ3	Canal of Dong Quang commune, Tu Son district (right bank)	15:05 PM	
	13	DQ 4. 1	Rice field of Bich Ha village, Dong Quang commune, Tu Son	15:30 PM	
	14	DQ 4. 2	Drain of Bich Ha village, Dong Quang commune, Tu Son	15:30 PM	
	15	DQ 4. 3	Canal of Bich Ha village, Dong Quang commune, Tu Son	15:30 PM	
	16	DP 3	Canal of Dong Xa, Dong Phong commune, Yen Phong district	10:04 AM	

3/10/2008	1	TH2	Drain, Thai Hoa pumping station of Mo Dao commune, Que Vo district	8: 50 AM	It's sunny,
	2	TH3	Canal, Thai Hoa pumping station of Mo Dao commune, Que Vo district	8:55 AM	to : 30-33oC
	3	XV2.1	Rice field ofThuong Dong village, Van An commune, Bac Ninh	10:30 AM	
	4	XV2.2	Drain of Thuong Dong village, Van An commune, Bac Ninh	10:30 AM	
	5	XV2.3	Canal of Thuong Dong village, Van An commune, Bac Ninh	10:35 AM	
	6	VA3	Canal of Van An commune, Bac Ninh	11:00 AM	
	7	PK 3.1	Rice field of Cham Khe village, Phong Khe commune, Bac Ninh	11:45 AM	
	8	PK 3.2	Drain of Cham Khe village, Phong Khe commune, Bac Ninh	11:50 AM	
	9	PK 3.3	Canal of Cham Khe village, Phong Khe commune, Bac Ninh	11:57 AM	
	10	PL3	Canal of Phu Lam commune, Tien Du district	14:00 PM	
	11	HM3	Canal of Huong Mac commune, Tu Son district (left bank)	14:30 PM	
	12	DQ3	Canal of Dong Quang commune, Tu Son district (right bank)	14:45 PM	
	13	DQ 4. 1	Rice field of Bich Ha village, Dong Quang commune, Tu Son	15:15 PM	
	14	DQ 4. 2	Drain of Bich Ha village, Dong Quang commune, Tu Son	15:20 PM	
	15	DQ 4. 3	Canal of Bich Ha village, Dong Quang commune, Tu Son	15:25 PM	
	16	DP 3	Canal of Dong Xa, Dong Phong commune, Yen Phong district	10:05 AM	

Annex 5.

Information of Sampling and Testing

70 samples were taken by 6 times in summer season from 29/7-3/10/2008. Sampling method and sample preservation were observed under TCVN 5993-1995, TCVN 6663 – 2002.

Each water sample was divided into 2 PET bottles and put 1 PET bottle in ice box and kept at 2^o -5^oC to minimize the change in biological character. Based on the other required parameters to deciding preservation measures (whether preserved in ice box or not). This measure was implemented on site and the samples were brought to laboratory within the day. Together with sampling, data was collected on site such as information on natural condition, weather, operation regulations of scheme and other related documents Water sample testing.

Physical chemistry elements : pH, Cl-, TSS, DO, COD, SAR, BOD5, Total N, Total P; Microorganism elements : Fecal coliform; Heavy metals elements : As, Pb, Cr, Zn, Cd, Hg

Analysis methods:

No.	Elements	Unit	TCVN 6773:2000	Method
1	TSS	g/l	0.4-1.0-2.0	Gravity
	Ca			Atomic Absorption Spectrophotometer
	Mg			Atomic Absorption Spectrophotometer
	Na			Flame photometer
2	SAR	mg/l	10-18	Calculate by TCVN 6773 - 2000
3	B	"	1	Spectrophotometer
4	DO	"	≥ 2.0	DO-meter
5	pH		5.5-8.5	pH - meter
6	Cl-	mg/l	≤ 350	AgNO3
7	Hg	"	≤ 0.001	Atomic Absorption Spectrophotometer
8	Cd	"	< 0.01	Atomic Absorption Spectrophotometer
9	As	"	< 0.1	Atomic Absorption Spectrophotometer
10	Pb	"	≤ 0.1	Atomic Absorption Spectrophotometer
11	Cr	"	≤ 0.1	Atomic Absorption Spectrophotometer
12	Zn	"	1 - 5	Atomic Absorption Spectrophotometer
13	Feacal Coli	MPN/100ml	< 200	Culture and counter
14	COD	mg/l		K2Cr2O7
15	BOD5	mg/l		BOD-set
16	Total N			Kjeldahl
17	Total P			Spectrophotometer

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