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Integrated Management of Industrial and Municipal Wastewater in China - Demonstration Project in Jiaxing, Zhejiang Province

Main Report

Part 2 of Final Report

Norwegian Institute for Water Research

REPORT

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Abstract

The city of Jiaxing in Zhejiang Province is a medium-size, rapidly expanding Chinese city located in a flat landscape with numerous canals. These are used for navigation, fishing, aquaculture and as drinking and industrial water source, but also as recipients for domestic and industrial wastewater and runoff from agriculture, paved roads and solid waste landfills in the area. The canals are severely polluted. NIVA has been assisting Jiaxing Environmental Protection Bureau (JEPB) in finding solutions to the local wastewater problems. The industry in the area discharges substantial quantities of potentially toxic wastewater to the sewer systems. There are, however, good possibilities for cleaner production routines in various factories. Several measures facilitate the transport of sewage to the nearby Hangzhou Bay, and sewage treatment processes before final disposal have been identified. The project has identified current and future wastewater production and recipient status. Based on pilot-plant operation and computer models a complete system for sewage collection and treatment has been suggested. This is based on transport of untreated sewage to Hangzhou Bay where the construction of a sewage treatment plant is planned. The treatment methodology is based on a flexible chemically enhanced primary treatment (CEPT), followed by a biological step at a later stage. The project findings put emphasis on knowledge transfer and strengthening of JEPB resources to find solutions to the water-related problems in the city. In addition a detailed abatement plan should be developed, taking existing water quality, user interests and future water quality objectives into account.

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2.	Avløpsvannbehandling	2.	Wastewater management
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Preface

The city of Jiaxing in the Zhejiang Province is a medium-size rapidly expanding Chinese city located between Shanghai and Hangzhou. The city is situated on the lowlands South of Yangtze River, with numerous canals, which are influenced by tidal variations in the Hangzhou Bay to the Southwest. The canals are used for a multiple of functions, the main being drinking water, extensive barge traffic (transport), fishing and aquaculture.

The canals are also the recipients of untreated domestic as well as partly treated, but mostly untreated industrial wastewater. Runoff from agriculture, paved roads and solid waste landfills in the area also ends up in the canals. The canals are as a result of this multitude of activities, and are heavily polluted with a water quality far away from predetermined goals. Jiaxing is part of the Taihu lake influence area designated for special and highly prioritised clean-up activities by the government in Beijing.

During the last 3.5 years NIVA has had the pleasure to work with Jiaxing Environmental Protection Bureau (JEPB) on a NORAD-financed project, to assist JEPB in finding solutions to the wastewater treatment problems in the region. Special emphasis has been put on the potential and practical possibilities of integrating industrial and domestic effluents before treatment.

The project has identified several measures to help **transporting** the sewage to the nearby ocean, and has identified processes to **treat** the sewage before disposal into the Hangzhou Bay. We believe the project has been instrumental in changing the city's plans from local/de-centralised treatment to regional treatment. The project has also put emphasis on institutional strengthening and knowledge transfer, in addition to technical assistance and purchase of modern equipment to JEPB. We feel confident that the work carried out during these 3.5 years has been an important contribution to the plans for reducing the water-related pollution problems in the Jiaxing region. The project results are implemented and integrated in the city's overall plans for water-pollution abatement measures.

This project, which has been one of NIVA's first large involvement in the Peoples Republic of China, has given the Norwegian participants a unique insight in the rich and fascinating Chinese culture. I take this opportunity to thank all partners and contributors involved for their dedicated efforts, including SEPA, ZPSTC and The Norwegian Embassy and Consulate. A special thanks goes to the office staff at JEPB, which has always been outstandingly helpful, open for discussions, and enthusiastic in bringing the project forward. Last, but not least we – the Chinese and the Norwegians - appreciate the opportunity given us by Norad to carry out this, in many ways, pioneer-project.

Oslo, 23. June 2000

Finn Medbø

Foreword

After a 3.5 year long fruitful and successful cooperation between the JEPB and NIVA, we have attempted to present some of the most interesting and important findings and experiences briefly in this final report, which is organised in two volumes:

Part-1: Executive Summary, 19 pages.
Part-2: Main Report, 244 pages (this volume)

In addition to the information provided in the final report, there is a number of other reports and presentations providing detailed information on selected issues. The annual reports to NORAD, manuscripts of presentation at various conferences and workshops, reports prepared in various occasions and power point presentations are among them. A CD-ROM with a PowerPoint presentation of the project and the results is also produced. These additional information and material are available from NIVA and JEPB.

This final report and the presentation CD-ROM are prepared both in Chinese and English.

Henning Mohn

Editor

Contents

CHAPTER 1

Project activity 1:

Framework for a
Master Plan
for Wastewater
Management

With examples from the ongoing wastewater management project in City of Jiaxing, P. R. of China

1. Introduction

A modern city should have an efficient system for collection, treatment and final disposal of the wastewater produced in households, industry and institutions. A proper system for managing run-off from paved surfaces should also be provided. These systems should meet national and local effluent standards and should be managed by a set of pre-defined goals for system performance. Costs associated with construction, up grading and operation of these systems should also be carefully calculated and controlled.

To better achieve these goals various tools can be used. A Master plan is such a tool, and is developed in accordance with the City plan for the city officials in order to make the best decisions for a specific sector. Master plans and economical plans are examples of tools used early in the process to choose between alternatives, to illustrate differences between different solutions, to evaluate costs and for budgeting purposes. Other, more specific tools are being used to reduce the system complexity to achieve an overview over the different parts of the wastewater management system.

There are three main purposes of this report:

1. To provide information about how a Norwegian Master plan for wastewater management is developed, what it describes and how it is being used to decision-makers in the municipalities, local authorities and other people involved in wastewater management.
2. To provide information about the development of a Master Plan for wastewater management to parties without technical background.
3. To contribute to further developing Master plans for Chinese cities by using City of Jiaxing and its surrounding areas as a demonstration case together with a conceptual presentation of Norwegian methodology.

This chapter describes a *framework* for Master plan with specific examples of content in a master plan for The City of Jiaxing, not a complete Master plan for this city. The structure of this chapter is based on the current Norwegian Master plan guidelines for wastewater management. It is assumed that parts of the Norwegian planning methodology can be valuable for specific planning purposes in China.

The Master Plan methodology used in this report is based on the Norwegian guidelines, published in 1994 by SFT (Norwegian Pollution Control Authority). These guidelines are summarised in sections 3 to 9, and describes the theory behind planning methodology, frame conditions, current situation, goals, abatement strategy, action plan and annual report. Key issues of Norwegian planning are the concept of rolling integrated planning within a plan-hierarchy, and planning which is closely linked to the financial budgets.

This chapter is divided into two main sections. The first part (sections 1 to 9) is written for teaching purposes and describes the concept and theory behind Norwegian Master plans. Content, timeframe and links to other plans are presented in the first part, together with a description of how master plans are being used in Norway. The second part (sections 10 to 13) gives direct examples on how information about the current and future situation of the wastewater situation in Jiaxing can be presented within the framework of a Norwegian Master plan.

The second part of this report starts with a presentation of Chinese environmental law, local frame conditions and financial options. This is followed by a wide description of the current situation in Jiaxing with regard to water quality and quantity. The Chinese State authorities give pollution prevention and treatment of “Three rivers, three lakes and two zones” the highest priority within environmental protection issues, and Taihu Lake is among these. In the subsequent section the very important “Ninth five-year’ plan of Zhejiang provincial water pollution prevention and treatment” and “long-term objective for year 2010” is presented, together with a description of each of the main watersheds in the area and pollution sources. In this section a brief introduction of the new wastewater treatment plant and wastewater collection system is given. Finally, a presentation of how design data for the new treatment plant is collected by operating a pilot plant and by advanced computer modelling is presented.

2. **Purpose of a Master plan**

One of the main reasons for developing a Master plan for wastewater management in a city, county or region is to tie the wastewater issues to the general plan for the community, and give comprehensive evaluations of the elements that influence the wastewater management. Master plans also help to reveal information by defining what information that should be available before important decisions are being made. Another purpose of a Master plan is to standardise the planning process.

The main function of a Master plan for wastewater management is to be a tool for the city administration when implementing or up-grading the sewerage system in the city. In addition, the plan expresses interrelations and interactions between the use of water resources, water quality standards and quality goals, and presents costs and other economical aspects. Therefore, the plan acts as an important tool for decision-makers at the top city level, as well as for high-level politicians, in order to prioritise issues within environmental management.

For the regulatory authorities, the plan should be an essential tool for evaluating the progress made by the community in creating a cleaner environment, and to control that the water quality standards are met in time and at the decided cost-level.

In Master plans the importance of a comprehensive overview and thorough panning, which includes municipal (domestic) discharges as well as discharges from industry, rural areas and agriculture, are strongly pointed out.

A master plan is valid for a limited period of time. In Norway a Master plan is commonly valid for 4 years, and these plans are linked to the Municipal plans with a longer time perspective. The Master plan is the foundation for specific, highly detailed Action plans, which are updated annually. Results from each year's work should be summarised in Annual reports, which evaluates and verifies the impact and value of the Action plans and Mater plans.

It should be noted that the *planning-process* in many cases is almost as important as the resulting *plan itself*.

3. **Methodology**

3.1 Introduction: Trends in Wastewater Policy in Norway

<u>Co-ordinated work towards established objectives.</u>

The Master Plan methodology used in this report is based on the Norwegian guidelines, published in 1994 by SFT, the Norwegian Pollution Control Authority. This section summarises these guidelines.

The municipalities are facing large environmental challenges, both of regional and local character. To attain the environmental objectives, the politicians demand a cost-effective strategy.

In Norway it is recommended that each municipality develop a Master Plan in order to achieve an integrated approach to the wastewater sector, and to identify different elements influencing the water quality. For the environmental authorities the plan contributes to the municipalities by determining environmental goals for the water resources. This reflects the Norwegian policy with a frequent use of *environmental standards* instead of detailed *technical standards*. The local approach for wastewater management is based co-ordinated work towards established objectives together with frequent reporting to the regional authorities.

<u>Quality control by “environmental audits”</u>
Norwegian authorities prepare the framework for the processes in the municipalities by determining environmental *objectives* for the water resources. The municipalities are responsible for the quality control (called internal control) based on a monitoring programme established by the regional authorities.

Quality control by the authorities will be based on “environmental audits”. This means that officials from the regional environmental authorities visit the municipality to discover and discuss reported gaps between the environmental objectives and the current situation.

<u>Total costs recovering</u>

An adequate cost system should ensure that sufficient funds are available to enable the efficient operation of wastewater systems, including asset maintenance and replacement.

The Norwegian environmental authorities have envisaged that the municipalities charge their users for 100 % of the costs associated with the construction, operation and maintenance of the wastewater system. In poorer regions of the world certain extent of subsidising might be advisable.

3.2 Municipal plan and Master plan for waste water management

The *Municipal plan* is the top layer in the hierarchy of plans. The Municipal Plan is the most important tool to ensure co-ordination and control of all production and use of resources in the municipality. This plan describes long term goals for the municipal development and policy for the planning process in the various sectors. In Norway, the long-term section of the Municipal Plan usually has a 12-15 years perspective. The plan also includes an area management section, which describes utilisation and management of land and various nature resources.

Master plans constitute the second layer in the plan hierarchy. Each Master plan describes one specific sector in detail, for instance wastewater management of a region. Master plans for each sector of the municipality's area of responsibility (schools, health services, roads, agriculture, solid waste management, wastewater management, etc.) are generally upgraded every fourth years, following the frequency for election of members to the local government (although some municipalities keep their Master plans for 10 years). Master plans contain a short-term section, which should be upgraded annually.

The different layers of the Norwegian plan hierarchy are presented in Figure 1 below.

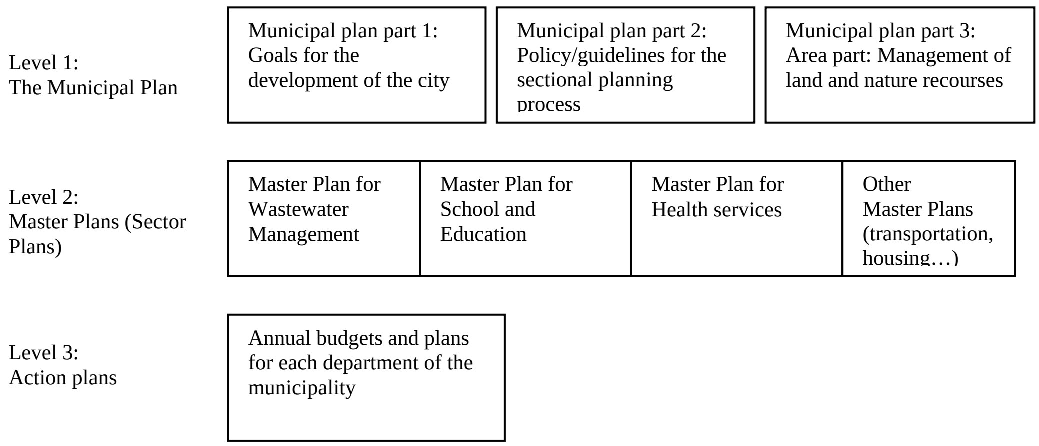


Figure 1.*:* The Norwegian plan hierarchy.

<u>Long -term budget</u>
Budgetary issues in the Master plan are included in the long-term budget ("Economic Plan") in the municipalities. The following elements should be included:

- Plan for investments, with milestones
- Operational and capital costs
- Plan for financing the costs
- Calculation of expected total fees for the wastewater sector.

<u>Annual planning and budgeting</u>
The Action Plan should be reflected in the annual budgets and plans for all departments of the municipality, which are somehow involved in wastewater management.

<u>Regional co-operation</u>
To obtain cost-effective solutions, the municipalities are encouraged to co-operate in establishing water quality objectives for the regional water resources, and assist in planning/implementing measures to reach these objectives.

Several municipalities in Norway co-operate with their water supply and wastewater management. The benefits from such co-operation are expected to increase as the tasks get more complicated and hence demand more resources.

A regional plan for a catchment area must identify and emphasise the consequences for each municipality. The plan may then be integrated in the Master Plans for the municipalities, with links to the local budgets.

The description above presents an ideal planning process. In this model the overall goals for development are established before the more detailed decisions about land use and technical solutions are made.

3.3 Concept of a Master plan for waste water management

Since the Master plan is promoting the connection between objectives, measures and costs, this plan is well adapted to be a document for political management. A Master plan defines the level of knowledge available before important decisions are made, and should therefor form the basis for all work within its specific sector.

The *concept* of a Master plan for wastewater management as presented in this section is recommended for all Norwegian municipalities, without regard to the size or complexity of the wastewater system. However, local actions will of course influence the content and comprehensiveness of each Master plan.

3.3.1 Plan document.

It is common for all Master plans to emphasise on objectives, measures and costs. This concept is presented in Figure 2 below.

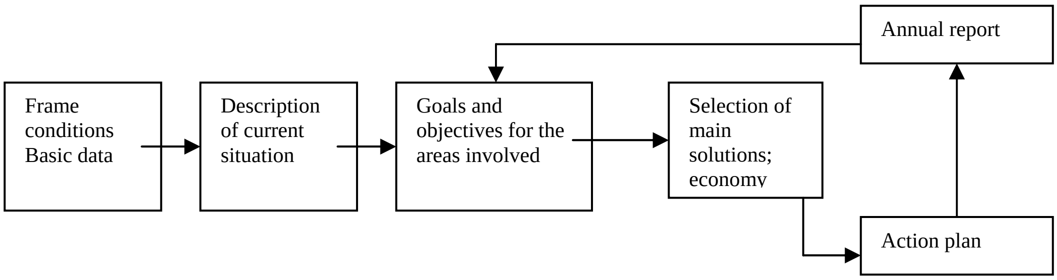


Figure 2. The relations between Objectives, Measures and Costs.

The Master Plan should be “user friendly”; both for elected officials/party members and administrators. Two versions of the plan are recommended:

1. Plan version 1, *for elected officials/party members*: The conclusions, main assumptions and evaluations should be emphasised.

2. Plan version 2, *for the administration*: This is a larger document and should present facts, assumptions, evaluations and measures in detail. Procedures for future control and documentation of achieved results should also be included in this version.

The Norwegian Pollution Control Authority (SFT) recommends that the political part of the Master Plan (plan version 1) should have the following content:

Preface
Summary
1 Frame conditions
2 Description of current situation
- 2.1 Water recourses related to user interests in the area
- 2.2 Pollution sources
- 2.3 Technical installations for water: Locations and technical condition
- 2.4 Management and institutional options
- 2.5 Economy

3 Goals and objectives
4 Abatement strategy and measures
- 4.1 The gap between status and objectives
- 4.2 Identification of potential measures and their cost-effectiveness
- 4.3 Strategy to meet the objectives
- 4.4 Selection of measures for the planning period
- 4.5 Costs and financial options

5 Action plan
6 Annual report

Version 2 of the plan for the administration contains, in addition to the sections above, sections with additional facts, assumptions, evaluations and measures.

A brief introduction of each section is given below. In the subsequent chapters each section is further described both in theory and for the Jiaxing case. It should be noticed that this report is meant to be a framework for Master plan with some examples from Jiaxing, not a complete Master plan.

Preface
The municipality should briefly describe the background for the Master Plan and its links to other relevant plans and political documents. A presentation of the municipality's visions for the environment and sustainable development should also be included in the preface.

Summary
The summary section should briefly describe the main objectives related to the water resources and wastewater management. Main measures and their consequences for the superior Municipal Plan, including the long-term budget, should also be briefly included. The summary should also indicate how the costs are implemented in the annual planning and budget process.

Frame conditions
The frame conditions restrict the planning process in the municipality and should be presented early in the Master Plan.

Description of current status
A summary of the current situation with regard to wastewater management should be presented in this section. Suggested main topics:

- The environmental conditions and user interests related to the water resources, preferably by using national standards for water quality.
- Pollution sources (point sources and diffuse sources) should be described. Possible sources: Municipal and industrial wastewater, surface run-off from agricultural fields, discharges from rural areas, aquaculture installations, tourist centres and natural background pollution.
- The technical condition on the existing wastewater treatment plants and sewers, including pumping stations and facilities for sludge treatment.
- Management and institutional options. Administrative structure and procedures for decisions, cross-sectional and regional co-operation, and capability of implementing the Action plan. All these elements are important factors for a successful implementing of a Master plan for the wastewater sector.
- The economy section should present the capital costs (for investments) in addition to annual costs for operation and maintenance of the wastewater treatment system. Further, administration and plan for finance should be included (fees, grants, loans).

Objectives
Current and future user interests of the water resources (i.e. water supply, bathing, and recreation) may lead to a higher extent of wastewater treatment than required by legislation. This may form a basis for a system where the objectives for water quality determine the discharge standards. These objectives can be integrated into environmental protection through integrated plans for the river catchment area, the river basin management and evaluations of the combined impact of all discharges. A wide water management policy is often useful.

When a decision for using water has been made, the municipality should decide goals for the quality of the water resources according to national water quality criteria. To meet these goals, objectives for the areas concerned (i.e. municipal and industrial wastewater, agricultural run-off and discharge from rural areas) should be established.

Abatement Strategy and Measures
The output of the Master Plan should be a strategy and a list of measures, which enables the municipality to meet its objectives at lowest possible costs. This section should also define which and how much information that should be revealed before the elected officials can make decisions related to the topic of the Master plan.

The planning procedure should include the following five steps:

- Identify the gap between the current situation and the objectives. The validity of the data used, and the influence of natural variations from one year to another should be considered.
- Identify potential measures and evaluate their cost-effectiveness.
- Strategy to meet the objectives, where applicable:
  - Further monitoring (water quality and quantity) and documentation of the environmental situation to improve the basis for decision on measures.
  - Evaluation of centralised or decentralised solutions.
  - Sludge treatment and disposal.
  - Should the organisation and operation of wastewater management systems be carried out by the municipality itself, through regional co-operation or by a private wastewater company?
  - Surveillance programme to evaluate effects of measures.
  - Information policy.
  - Financial strategy for cost recovery (capital and operational costs).
  - Strategy regarding industry and agriculture.
- Decision on measures (concepts) to be implemented, which will be presented in more detail in the Action plan
- Costs and financial options.

<u>Action plan</u>
The Action plan is based on the Master plan. The Action plan presents a yearly plan for actions to be carried out. The Action plan is a separate document. It is prepared for decision-makers and elected officials in the municipalities involved, and for financial institutions supporting the implementation of the plan.

The Action plan should be concise and exact. It should be easy to read and understand, have figures and overview over costs. Below is a list of recommended content of the Action plan:

- A list of prioritised measures and their costs
- Expected achievement of the objectives when implementing the measures
- Funding/cost recovery
- Milestones and co-ordination of cross-sectional measures.

<u>Annual Report</u>
The Annual Report to local politicians and regional environmental authorities should give a presentation of the results and investments from the previous year, within the wastewater sector.

The main purpose of the Annual report is to document the achieved results and relate these to the expectations and use of resources. This may lead to adjustments in the Action Plan for the following year. Evaluation of the implementation for the environmental effects should also be documented. By making a user-friendly document, the Annual Report might have a positive effect on the marketing of the wastewater sector.

3.4 Organising the development of a Master Plan

The administration should have the responsibility of taking the initiative, organise and run the planning process. This should, however, be performed in co-operation with and controlled by the elected officials. A close co-operation between elected officials and the administration from the start of the planning process is strongly recommended. This should result in a constructive, fruitful and efficient process.
A steering group should be appointed, with representatives from the head of the municipality (political and administrative leadership), municipal departments and other relevant organisations.

Employees in the technical department, eventually assisted by external consultants will usually carry out most of the work (fact-findings, calculations, evaluations and reporting).

An example of interaction between administrative and political involvement in elaboration of a Master Plan is presented in the figure below.

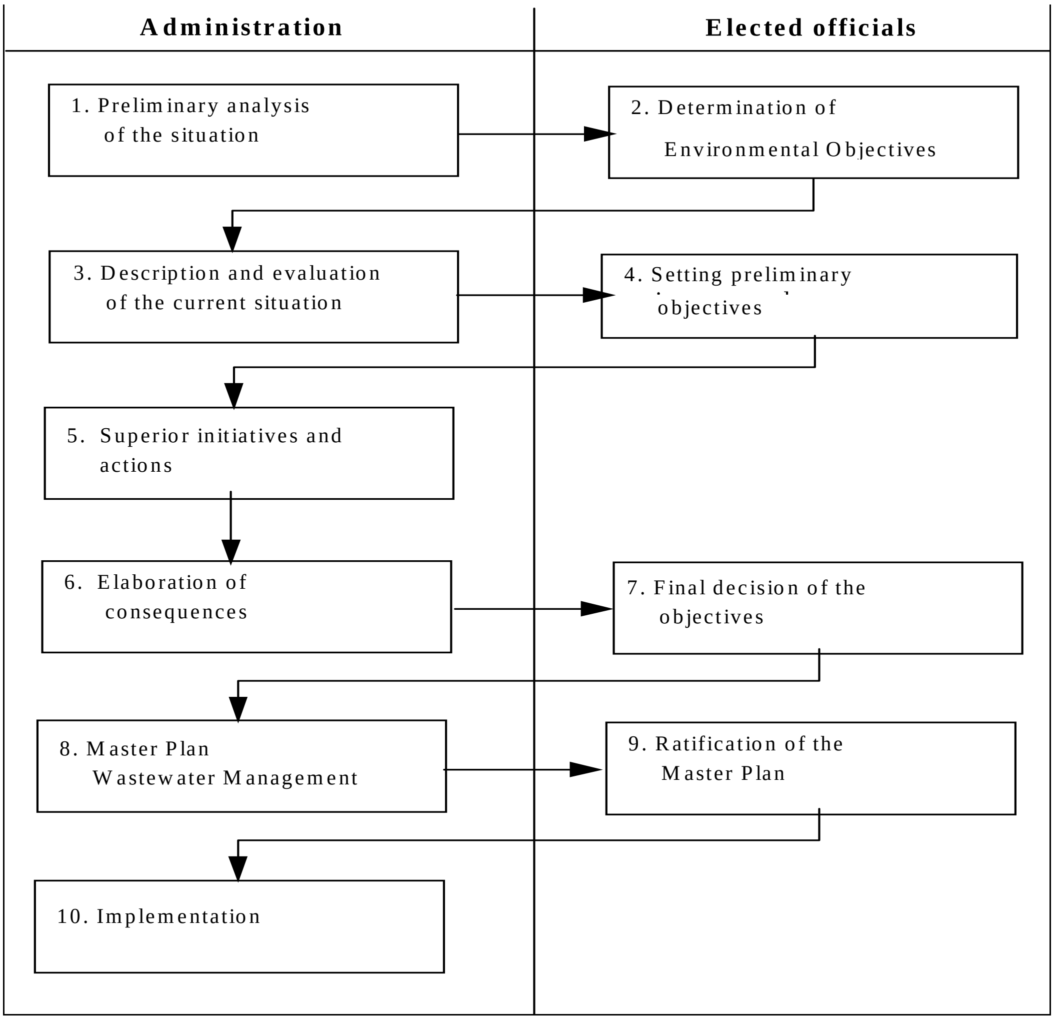


Figure 3. The interaction between administration and elected officials

4. Frame conditions

The frame conditions, which define the limits of the planning processes for the municipality, should be identified and described in the introduction of the Master plan. Many of the frame conditions are given in the Municipal plan, but other frame conditions should be identified from elsewhere.

Examples of such frame conditions are presented in the figure below (EEA, 1998).

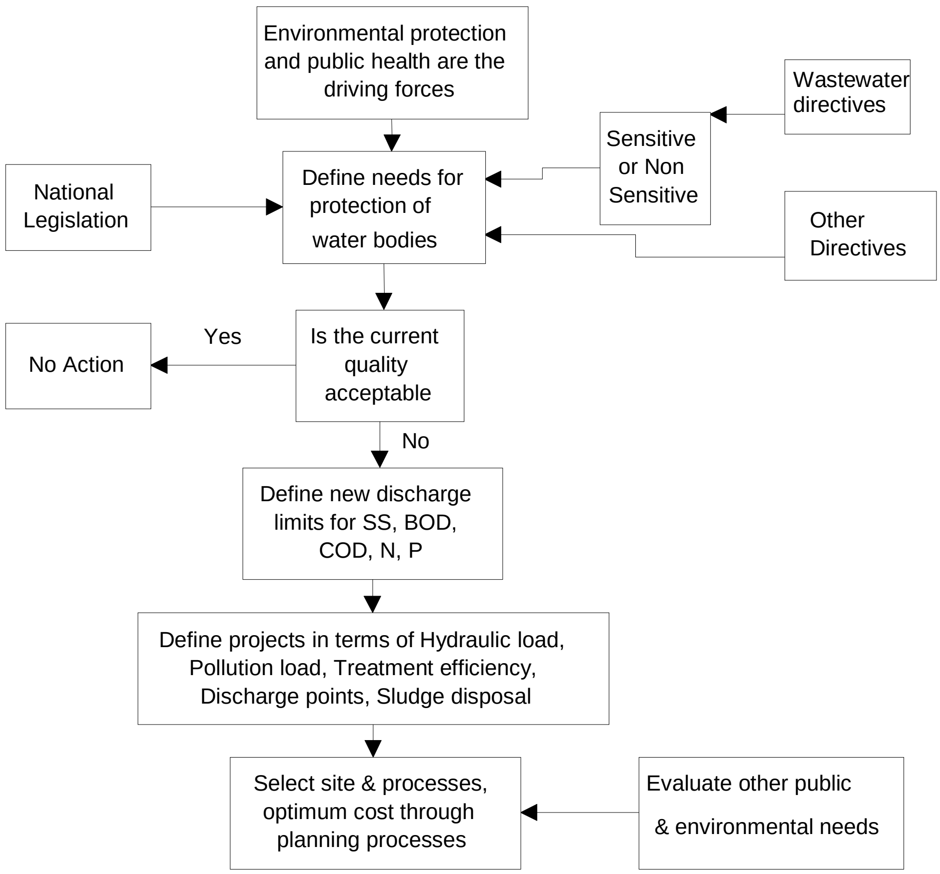


Figure 4. Systematic evaluation of frame conditions

4.1 Environmental protection law

An overview over the ruling national, regional and local environmental laws should here be given. The most important laws should be briefly introduced. In many cases a description of how the different laws can be applied may also be beneficial. Additionally, proposed laws that will affect the planning area should also be presented.

4.2 Strategy and objective of local drainage basins

In this section a general description of strategies and objectives of the local drainage basins should be given. These strategies and objectives form the framework for the Master plan.

4.3 Finance

Financial issues constitute a crucial part of the frame conditions. In this section the region or municipality should describe their financial situation, their expected future situation, measures to finance the planning, construction, maintenance and operation of wastewater management systems.

In this section the possibilities of receiving state, regional and foreign loans and grants should be evaluated and presented. A parallel presentation of payback plans and financial risk assessments should be presented.

In some cases foreign grants and loans can complement national funds. Some international sources are: Asian Development Bank, Bank of International Settlements (BIS), International Finance Corporation (IFC), International Monetary Fund (IMF), Multilateral Investment Guarantee Agency (MIGA) Organisation for Economic Co-operation and Development (OECD), World Bank (IBRD) and World Trade Organisation (WTO).

5. Current situation

In this section a summary of current situation should be presented, in areas which are relevant for the wastewater sector. Main topics may be:

- Present economical issues: Capital costs (from investments), annual costs for operation, maintenance and administration and how the costs are financed (fees, grants and loans).
- The current environmental conditions and user interests in the water resources, preferably by using national standards for water quality.
- Existing pollution sources (point sources and diffuse sources); municipal and industrial wastewater, surface run-off from agriculture, discharges from rural areas, aquaculture plants, tourist centres, background pollution, etc.
- The technical condition on the existing wastewater treatment plants and sewers, including pumping stations and facilities for sludge treatment
- Management and institutional options. Administrative structure and procedures for decisions, cross-sectional and regional co-operation, and capability of implementing the Action Plan.

5.1 Water resources with user interests

The water resources within the planning area should be carefully examined in order to be able to develop an exact and valuable Master plan for wastewater management. In this aspect water resources include surface water, rivers, canals, reservoirs, ocean coast, ground water and facts about precipitation and water transport. Further, the value of water resources should be evaluated according to their use Common categories: Drinking water sources, ground water reservoirs, fishing interests, seafood industry, water for irrigation and animals.

5.2 Pollution sources

In a Master plan for wastewater management the most significant pollutant sources should be identified. These sources are divided into diffuse sources (agricultural run-off, wastewater from individual households and industry which not are connected to a sewage collecting system, and leaks along the sewer network) and point sources (direct discharge of sewage from pipes, discharges of industrial effluent).

The pollution sources should be characterised by identification of contaminants present, distribution pattern and general water quality. A presentation of industry (heavy mechanical, chemical, pulp & paper, unregulated industry), disposal of solid waste into aquatic bodies and urban and agricultural run-off water is suitable in this chapter.

An evaluation of the expected future pollution situation should also be done. In this evaluation population expansion, industrial growth and the use of new technology should be examined.

5.3 Technical installations for water-infrastructure

In this section the current status of infrastructure related to drinking water supply, wastewater management and management of solid waste should be briefly presented. These descriptions should not be too extensive and detailed, but sufficient enough to give a picture of how these services are provided. One should be aware of that special Master plans for drinking water supply and solid waste management also should be developed. Future standard of the technical installations for transport and treatment of water within the planning area should be presented.

Key words for the sewer system: Extent of use, capacity and technical condition, recipients for wastewater, state of the sewer system, the state of WWTP (what, where, how), the extent of local pre-treatment in industry and management of storm water.

When of interest for the water quality, the system for solid waste and hazardous waste disposal should also be briefly described.

5.4 Management and institutional options

When establishing environmental goals for a catchment area an open-minded approach and broad co-operation between relevant partners is needed. To establish and operate sewerage systems and wastewater treatment plants require relevant knowledge and capacity in the municipalities involved. In this section an overview over the organisation of the city/region should be given, together with a description of how decisions are being made.

5.5 Economy

Information about the present and future economical situation of the planning region is crucial for the planning process. To develop realistic plans, precise budgets and analyses of future scenarios are required.

Issues which should be presented in this section:
- How is the economy today?
- Description of economic growth during the last 10-20 years
- How are the population growing, and the demography changing?
- How is the general economic development?
- Is there an improvement of living standards, and consequences of this?
- How are people paying for the different services?
- The possible use of foreign aid, loans
- Description of other factors that affects the economy in the region.

6. Goals and Objectives

6.1 Water quality of aquatic bodies

In this chapter aquatic bodies (i.e. lakes, rivers, streams, groundwater reservoirs, coastal areas) and watersheds within the planning area should be described. This presentation should state which water bodies that should be protected, which that need to be cleaned up, and which are potential recipients for wastewater.

Water quality standards should also be presented. Which standards are recommended to regulate issues related to the environment, health and safety? How should water quality be monitored?

6.2 Municipal waste water regions

The wastewater collection area is often divided into several regions within the municipality. In this section these regions should be presented together with an explanation of the division into regions.

6.3 Pollution sources - future situation

A presentation of probable new effluent standards from significant industry in the plan area (heavy industry, chemical, pulp & paper, other) should be made. How stringent rules will be possible? When will future changes take place? Further, plans and programs for extending pre-treatment of wastewater in the different factories/industrial plants should be presented here. What is the expected development of industry? Which types of industry are likely to grow, and what kind of factories is likely to go out of business? Do the authorities have any goals with regard to industrial development?

6.4 Transport system

Future goals of the systems for sewage collection, storm water management should be presented. Simplified descriptions of planned pipe up grading, development of separate collection systems etc. should be included.

6.5 Treatment, sludge handling and effluent

In this section the wastewater effluent standards should be presented together with an overview over the different discharge alternatives and receiving water bodies. This information forms the basis for choosing the appropriate wastewater treatment technology, which also should be briefly described. It might also be appropriate to present the timeframe of construction and/or stepwise up-grading of the wastewater management systems.

Treatment of wastewater results in improved water quality of the receiving waters and sludge production. The level of recipient improvements and sludge production should also be described, together with treatment and disposal routines for the sludge.

6.6 Efficiency and future development

When a new WW management system is established, it may often advisable to start with simple systems that performs adequately and treats the water only to a certain extent. These systems rely on later performance evaluation and up grading. By implementing this strategy, it may be easier to match population growth, operational/ management skills and keep the overall costs down, while still carrying out collection and treatment of wastewater.

Future effluent standards and removal efficiency for suspended particles, phosphorus, nitrogen, etc should be determined as early as possible, and established preferably together with the initial system performance indicators. The future effluent standards should be related to expansion of the WWTP and sewer network.

In this chapter plans for management of the WWTP and the whole sewerage collection system in the initial phase and future stages should be presented.

7. Abatement Strategy and Measures

7.1 The gap between the current situation and objectives

To judge the size of the challenges of the Master plan, it is important to evaluate the gap between the existing situation and the objectives of the plan. By doing this it may be possible to evaluate how realistic the plan is and how big resources that are necessary to implement the plan.

The main challenges associated with technical issues, economy, ecology, knowledge, equipment should be addressed. For instance, measured concentrations in rivers and canals today should be presented and compared to what is wanted for the future.

7.2 Identification of potential measures

A brief introduction to different strategies, means and methods to reach the desired goals should be presented. These measures should be characterised by their cost-efficiency, performance, reliability and environmental sustainability.

7.3 Costs and financial options

In this chapter, estimations of capital and management costs should be presented. Further, project finance should be addressed here. How much of the operating costs should be covered by the consumers? How will loans be established?

7.4 Strategy to meet the objectives

This section focuses on how to the objectives of the master plan. This chapters several strategic issues should be discussed, i.e.:

- Organisation and management of the WW facilities
- Monitoring data: What do we know today, and what do we want to know? Do we have enough monitoring data to establish a strategy?
- Planned progress: Which actions should be started first? Subsequently?
- Centralised or de-centralised solutions?
- How should management of the WW management system be organised?
- Water treatment creates sludge. What about sludge management?
- Monitoring and surveillance of receiving waters,
- Information policy
- Cost recovery
- Agriculture and industry

7.5 Selection of measures for the planning period

In this section the main actions of the planning period should be described. There should also be a ranking of the importance of the different actions. Examples of actions:

- Upgrading of sewer overflows within a certain area.
- Change of sewage pipelines within a certain area.
- Construct WWTP for treating sewage to a certain extent in a defined area.
- Develop a system for sludge treatment.

8. **Action plan**

A Norwegian Action plan for a certain topic is highly specified both with regard to system performance, operational issues and budget. An action plan that covers for instance upgrading of the sewage collection system in a part of the city describes the purpose of the job and goals for the upgrading and performance of the new system in detail. The budget for the job is also closely specified. The Action plan in Norway forms the basis for entrepreneurs' bidding for a job.

9. **Annual report**

Most annual reports refer directly to the yearly action plans, and indirectly to the Master plan. The annual report should be detailed enough to tell the readers what have been done the last year, and what issues that for various reasons not have been carried out as planned. The annual report is an important control tool for the city and regional administrations.

10. Frame conditions, case Jiaxing

The planning of wastewater system in Jiaxing

In Jiaxing it was decided to construct the Ocean Discharge wastewater treatment plant (OD-WWTP) with a long trunk sewer system before the Master Plan for wastewater management was completed. Hence, this process is somewhat different to what is described in this report as an ideal planning process. This makes the basis for the decision is less obvious and possible future conflicts of land use and/or resources may arise.

Even though some decisions about technical solutions have already been made in Jiaxing, JEPB and NIVA still believe our proposed idealised planning process can be quite useful for the city to conduct systematically planning of the future expansion of their wastewater system. All new planning processes should have a basis in the existing systems to be specific and realistic enough to be useful for the future. By doing good planning it should be possible to construct and maintain an efficient, reliable and cost-efficient wastewater system in Jiaxing.

10.1 Chinese environmental protection law

- "Constitution of Chinese People's Republic"
  Provision 26: Nation protects and improves the living environment and ecology, and prevents and treats pollution and other public nuisances.
- "Environmental Protection Act"
  Provision 16: Local governments at all levels should be responsible for the environmental quality under their jurisdiction and take measures to improve the environmental quality.
- "Water Pollution Protection Act of Chinese People's Republic"(amendment)
  Provision 3: Relevant departments in State Council and local governments at all levels must bring the environmental protection issues into planing, make the strategies and measures of water pollution protection and treatment.
  Provision 10: Local governments above county level should develop water pollution protection plans for their own administration areas according to the water pollution protection plan approved by law, and bring it into mid- and long term and annual plans of national economy and social development.
  Provision 19: Municipal WW should be treated centrally. Relevant departments of the State Council and local governments at all levels must bring the protection of water sources and control of water pollution into municipal construction plans, construct and optimise municipal drainage systems, build municipal central WW treatment facilities based on planing, and strengthen the integrated management of water environment.
- "Implementation bylaws of Water Pollution Protection Act of Chinese People's Republic"
  Provision 2: Relevant departments in State Council and local governments at all levels should bring water environmental protection issues into planing of national economy and social development. Economic construction departments of local governments at all levels should bring water pollution protection into their construction planing based on the requirements of water protection proposed by the same level government.

- "Implementation Methods of Water Pollution Prevention and Treatment of Zhejiang Province"
  Provision 6: Local governments at all levels should establish objectives and tasks to protect the environment and aquatic bodies, adjust of the layout of industries in a rational way and increase in investment of water pollution prevention and treatment.
  Provision 7: Local governments at all levels should formulate plans to prevent water pollution, protect surface water bodies such as rivers, lakes, reservoirs, ditches and ground water bodies under their jurisdiction, and implement the plan to let water bodies and run-off streams meet the desired quality criteria.
  Provision 11: Local governments at all levels should carry out integrated management of water pollution, and must bring water resource protection, water pollution prevention and water treatment into construction plans, construct and optimise the municipal drainage system, and build WWTP and other central WW treatment facilities according to plan.
- Document on "Notice on several issues of strengthening environmental protection" released by Zhejiang Provincial Government.
  "The Ninth five-year' plan of Zhejiang provincial environmental protection" and "long-term objective for year2010" state that pollutant discharge in each region should be within the limit of total discharge defined by the State by the end of year 2000. The tendency of increasing environmental pollution and ecological deterioration should be controlled as far as possible. Quality of water bodies in Hang-Jia-Hu water-catchment area, etc. should apparently be substantially improved.
- Strengthening the water pollution prevention and treatment within the drainage basin. Governments at all levels, both upstream and downstream drainage basins, should take measures to ensure that the qualities of water bodies and run-off streams under their jurisdiction meet the standards described in "Plan for environmental function zones of surface water in Zhejiang", which has been approved by Zhejiang provincial government.

10.2 Strategy and objective of local drainage basins

Strategy and objective of Taihu Lake drainage basin

To solve the significant environmental problems, the State gives pollution prevention and treatment of "three rivers, three lakes and two zones" the highest priority within environmental protection issues. Taihu Lake is one of these. Solving the water pollution problems and improve the ecological environment of Taihu drainage basin is an urgent desire of the people. This requires harmonious development of economy and society and the overall strategies related to sustainable development of Taihu drainage basin.

"The Ninth five-year' plan of Zhejiang provincial water pollution prevention and treatment" and "long-term objective for year 2010" presents the following objectives:
By the end of year 2000, the tendency of deteriorating water quality should be controlled significantly, and the quality of surface water should be improved to increase by one quality class. By the end of year 2010, the quality of surface water bodies in Zhejiang within Taihu drainage basin should meet class 2 and class 3 of the quality standard. Parameter used for rivers flowing to lakes and in plain water-catchment areas: CODmn, T-P, T-N.

Table 1. Goals for rivers flowing to Taihu Lake and leaving Jiaxing:

Name of river	Direction of flow	Intersection	Existing water quality	Goal:
Pinghu-Shanghai	Towards Shanghai	Qinyanghui	3	3
Hongqi	Towards Shanghai	Hongqi dam	4	3
Yuhui	Towards Shanghai	Sijiabang hydraulic station	3	3
Shandian-Jiashan-Fenjing	Towards Shanghai	Fennan bridge	4	3
Great canal	South of Shuzhou towards Jiaxing	Wangjiangjin	4-5	3

Strategies of treatment of Taihu drainage basin: Compared with Huihe drainage basin, the goal is higher, requirements are stricter and the enforcement is stronger.

The overall requirement for Hang-Jia-Hu water pollution prevention and treatment: Compared with other regions in Zhejiang province, goals are higher, requirements are stricter and enforcement is stronger and more efficient than general regions.

10.3 Finance (NORAD and WB involvement, Foreign loans and credits, other.)

A number of bilateral and multilateral institutions provide financial assistance in the infrastructure development projects in the wastewater management sector. The Norwegian financing is quite competitive, for which soft loans are usually available. In addition, a part or full interest payment and a part of the loan could be requested as a grant, which increases the attractively of these funds. Some times a specific part of the funds will then be required to have Norwegian suppliers. However, due to the high demand and the limited allocations, the possibility to obtain these loans may be limited. A number of WWTP projects in PR of China are at present financed through this scheme. Among the multilateral organisations, the World Bank, Asian Development Bank and the Nordic Development Bank are the most relevant institutions for financing.
See also section 4.3 of this chapter.

11. Current situation, case Jiaxing

11.1 Water resources with user interests

Hydrological characteristics

Hydrological characteristics of canals show the complicated water-network with flows and direction varying during the year. There are two main systems for waterway. One is through some key canals of Changshan canal, Haiyan canal and Yanguan canal to Hangzhou Bay, and the other through some key canals of great canal, Lanqi canal, Suzhou canal, Luxu canal, Hongqi canal, Sandian canal and Shanghai canal to Huangpu river. There is plenty of surface water from other regions passing through Jiaxing water-network. The water resources within Jiaxing water-net are showed in table. Amount of water resources is 1937 million cubic meters average for many years, of which 1584 million for surface water, 353million for ground water.

Table 2. The constitution of water resources.

Extent of dry or wet	Water level insurance(%)	Water resources(million cubic meter)		
		Runoff in canal	Evaporation	sum
Wet	20	20.75	4.09	2484
General	50	15.04	3.49	1853
General dry	75	11.40	3.03	1443
Special dry	95	7.28	2.4	975

Canals and lakes

There is 13802.31 km length of total canals with water area of 268.93 sq.km. Of which 57 canals are important, with the total length of 959 km and many tributaries. Lakes above 311.15 sq.km of water area are 80 numbers with an area of 42.22 sq.km. The total water area in Jiaxing is 311.15 sq.km, which is 7.89% of total area of Jiaxing.

The water quality of canals are different from class 4 to class 5, some even exceed class 5. Most of large lakes have better water quality, especially North-south Lake with class 2, which is a very beautiful scenic spot.

There are five main user interests related to Jiaxing canals and lakes and its tributaries:

1. Drinking water sources

The water works use water from canals as water source, with poor water quality worse than the standard requirement (class 3).

2. Transportation

Because of the high density of canals, traffic on water is developed very well with convenience. The navigation of boats and ships make canals with relative high concentration of dissolved oxygen.

3. Ocean coast

Jiaxing is located in west of Hangzhou Bay. The total coastline of Jiaxing is 121.1km long, in which 12 km of coastal line from Jingsiniang to Dushan in Pinghu, with the depth 12 m in the front and 25 km in Zapu, with the depth 10m in the front. Jiaxing is a convenient port for business of Hang-Jia-Hu plain.

4. Fishing

Fish cultivation area in 1997 was 18593 hectares, of which 132 hectares were marine-cultivating zone. Total aquatic products were 79324 tons per year, of which 4609 tons were marine products.

5. Water for agriculture

Jiaxing boasts abundant agricultural resources. It is an important area to produce grain, oil, silkworm cocoon and fish in Zhejiang province, which enjoys the fame of "town of fish and rice, and home of silk". It now has 208000-hectare farmlands. According to statistics from hydraulic construction, the water supply for agriculture was 2836 million cubic meters in 1997.

The water consumption of agriculture calculated by means of investigation-analysis fixed amount is showed in the two following tables.

Table 3. Allowable water consumption of rice

	Water level guarantee				unit
	20%	50%	75%	95%	
Annual allowable irrigation amount	6630	7920	9405	11805	M3/hec
Peak flowrate in busy season	750	21,45	24,6	29,25	M3/s.10000hec

Table 4. Allowable water consumption of other crops

crop	wheat	vegetable	unit
allowance	750	1500	M3/hec

The water consumption of agriculture is closely related to the precipitation. In Jiaxing, the relationship between the water consumption of agriculture and the precipitation is showed in the table below.

Table 5. Relationship between the water consumption of agriculture and precipitation

year	Precipitation rate	rice	wheat	vegetable	total
1997	20	14,45	1,03	1,18	16,66
	50	17,27	1,03	1,18	19,48
	75	20,50	1,03	1,18	20,50
	95	25,74	1,03	1,18	25,74

In Jiaxing, surface drinking water treatment plants take raw water directly from the canals, in which the water quality is between class 3 and 4. The main parameters that do not meet the standards for surface water are organic pollutants. The de-centralised strategy would have worsened the raw water quality, because it is common that the intakes for the drinking water works are located close to discharge sites of the wastewater treatment plants. At present the treatment processes for water plants are limited. This is one of the main reasons for Jiaxing to selecting the ocean discharge WWTP instead of several smaller plants within the city boundaries.

The quality of ground water can meet the standard for drinking water. However, water is drawn from the ground the ground sinks, and setting problems are likely to occur. Now the government are controlling the exploitation of ground water.

11.2 Pollution sources

11.2.1 Diffuse sources

Pollution from population
Based on the plan of water pollution prevention and treatment in Taihu Lake drainage basin, the indexes to calculating the yield of pollutant and the amount pollutants washed away are showed in table. Considering farmers 2589500 and residents 703400, with the integrated domestic WW of 60kg/p.a, the annual discharge of domestic WW was 72115000tons in 1997.

Table 6. Current specific pollutant load

Parameter	Yield of pollutant (kg/p.a.)		Pollutant Washed away (kg/pa)		
	farmer	Urban resident	farmer	Urban resident	Total (ton/a)
CODcr	21.9	21.9	2.65	21.9	8127.32
N	3.65	3.65	0.44	3.65	1352.98
P	0.49	0.62	0.17	0.62	319.86

Agricultural pollution
Jiaxing is one of the main grain production regions, with a long history of great extent of agricultural production in Zhejiang province. Therefore, agricultural pollution also contributes to significant environmental pollution in Jiaxing. Agricultural pollution comes from the use of fertilisers, and husbandry and fishery. Based on the plan of water pollution prevention and treatment in Taihu Lake drainage basin, amount of pollutants washed away is showed in the following table.

Table 7. Run-off from agriculture in 1997 (ton per year)

pollutant	**N (nitrogen)**	**P (phosphorous)**	**COD (chem. oxygen demand)**
Pig	2916.35	74.46	5894.35
Cattle	6.72	0.084	12.89
Poultry, rabbits	747.46	23.0	1307.48
Fresh-water fishery	3890.60	163.67	
N-fertiliser	13696.59		
P-fertiliser		119.36	
Sum	22257.72	380.57	7215.12

In Jiaxing City there are many buildings and large paved areas. The impermeable area is 19.6 sq.km, about 80% of total urban area. The green land is about 15% of total urban area. There is combined system in the city centre, collecting the run-off water from impermeable area then discharging to the canals directly. The annual precipitation is 1167mm.

11.2.2 Point sources

Population expansion

There are only incomplete combined systems in the old city areas for drainage. Separated systems are now being built in the new city area and development zones in different cities. But there is no central municipal WWTP existing, therefore almost all domestic WW discharges directly to canals through septic tanks, or through combined sewer or through rain pipeline. The amount of domestic WW to canals is 180675000 t/y based on a population of 3300000 with an average WW generation per capita of 150 l/day.

Of all the population involved in the catchment of Jiaxing WWT project, 97% are citizens from different cities and towns. The existing water consumption for each citizen is 300 l/p.d, 85% of this end up as WW. The domestic WW distribution in the catchment area is showed in the table below. The average concentration of COD is 420mg/l, BOD is 170mg/l and SS is 180mg/l. These values are based measurements from Cuiyuan district and Daguang district in Hangzhou, and Tuzaichang district in Jiaxing. Calculated concentrations of different pollutants are showed in the table below.

Table 8. Pollutant loads and concentrations

area	**Population (10000)**	**Domestic WW**			**Pollutants**		
		10000t/d	**10000 t/y**	**proportion (%)**	**COD (t/y)**	**BOD (t/y)**	**SS (t/y)**
Jiaxing city	20.65	5.16	1883.4	50.9	7910.3	3201.8	3390.1
Weitang town of Jiashan	5	1.25	456.3	12.3	1916.5	775.7	821.3
Chengguang town of Pinghu	6.03	1.50	547.5	14.8	2299.5	930.8	985.5
Wuyuan town of Haiyan	6.06	1.51	551.2	14.8	2315.0	937.0	992.2
Zapu	1.77	0.44	160.6	4.4	674.5	273.0	289.1
others	1.12	0.28	102.2	2.8	429.2	173.7	184.0
sum	40.63	10.14	3701.1	100	15545	6292.0	6662.0

The amount of domestic WW changes with the population expansion. This is shown in following table.

Table 9. Expected population expansion

	Year 2010		Year 2020	
	Population (10000)	Discharge (10000 t/d)	Population (10000)	Discharge (10000 t/d)
Jiaxing city	40	12	50	15
Weitang town of Jiashan	11	3.3	14	4.2
Chengguang town of Pinghu	9	2.7	14	4.2
Wuyuan town of Haiyan	9	2.7	14	4.2
Zapu	5	1.5	7	2.1
Other spread residents	3	0.9	4	1.2
Sum	77	23.1	103	31

<u>Industry</u>
According to a survey of Jiaxing Environmental Protection Bureau, of the more than 3000 enterprises in all of Jiaxing, 429 enterprises are key water polluters with 143626580 t/y of WW discharge and 81784.03 t/y of COD discharge. This corresponds to 86.45% and 91.67% of total discharges, respectively.

124 enterprises included in the catchment area will discharge their WW to the main pipeline. They produce 72226900t/y WW with 33611t/y COD totally. An overview over industrial WW from different areas is presented in the table below.

Table 10. Current pollution situation.

area	**Number of enterprises**	**Industrial WW**		**COD**	
		10000t/y	**proportion (%)**	**t/y**	**proportion (%)**
Jiaxing city	40	2979.20	41.25	14875	44.26
Weitang town of Jiashan	10	192.10	2.65	266	0.79
Chengguan town of Pinghu	19	633.93	8.78	2918	8.68
Wuyuan town of Haiyan	15	322.51	4.47	5892	17.53
Zapu	3	38.58	0.53	182	0.54
others	37	3056.37	42.32	9478	28.20
sum	124	7222.69	100.00	33611	100.00

Table 11. Estimated industrial WW

	Year 2010	Year 2020
	t/d	t/d
Jiaxing city	89784	97946
Weitang town of Jiashan	5789	6361
Chengguang town of Pinghu	19105	20842
Wuyuan town of Haiyan	9720	10603
Zapu	1163	1268
Other spread residents	92109	100438
Sum	217670	237458

WW discharge data organised for each type of industry is presented in table below.

Table 12. WW discharge per industry

Industry category	**Number of enterprises**	**Industrial WW**		**COD**	
		discharge (10000t/y)	**proportion (%)**	**discharge (t/y)**	**proportion (%)**
Paper and pulp	11	3786.86	52.43	19677	58.54
Food process	17	366.19	5.07	6389	19.01
Textile dying and printing	36	1132.52	15.68	4541	13.51
chemical	14	1102.18	15.26	2395	7.13
metallurgy	7	405.19	5.61	--	--
Mechanical electric	18	210.18	2.19	--	--
others	21	271.57	3.76	608	1.81
sum	124	7222.69	100.00	33611	100.00

In the table below total depositions of environmental contaminants to aquatic recipients from industry in the entire catchment area are presented.

Table 13. Deposition of environmental contaminants, entire catchment area

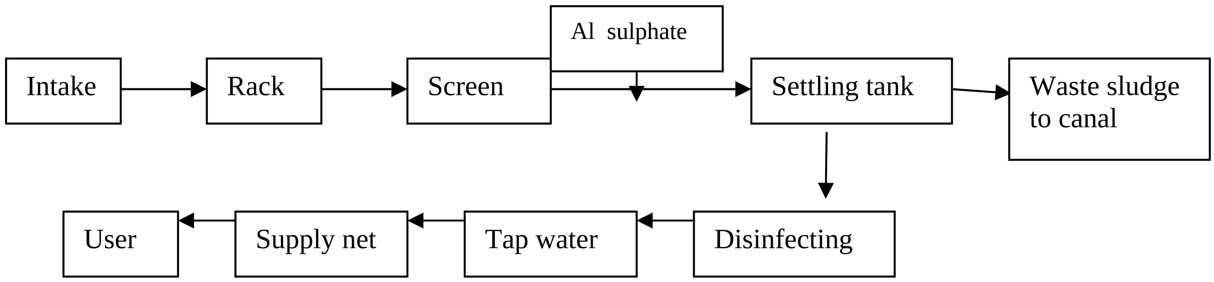
	Pollutant (Unit: **kg/y**)					Pollutant (Unit: **t/y**)			
	Cr6+	Pb	Volatile phenol	cyanide	petroleum	CODcr	SS	NH4-N	T-P
discharge (unit: see above)	2913	63	2987	2633	99117	33611	24948	1239	21.58

11.3 Technical installations for water-infrastructure

Drinking water supply

The waterworks infrastructure is developed very well and the water distribution network supplies most of the households. Only a minor number of the water works uses surface water as source; most water works use groundwater. Because of good quality, groundwater supply is direct, without treatment. Some old one-storied houses are installed taps outside, one tap for several houses. In the rural area, about 80-90% of inhabitants is served by groundwater supply net; others use groundwater from uncontrolled private wells. Some use surface water after alum sedimentation, but only occupy lower than 0.1%.

The treatment processes for surface water plant is as follows:



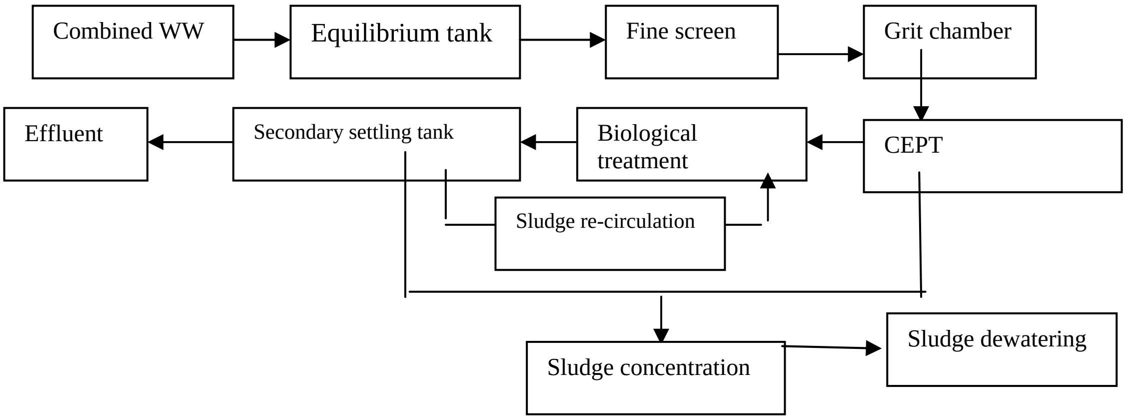
Groundwater is supplied for house usage and food processing industries.

Wastewater treatment plant

Jiaxing is located in the Hang-Jia-Hu Plain of Yangtze River Delta. It belongs to Taihu Lake drainage area. Jiaxing has very complicated water system with flow and its direction varying with time in the year. With the development of society and economy and the improvement of people's life, the water environment has been deteriorated. During the eighth 'five year', there was the most distinct decrease in water quality by one class. The CCP and State Council pay a lot of attention on prevention and treatment of water pollution in Taihu Lake drainage area. It is urgent to solve the problem of water environmental pollution. There is no central wastewater treatment plant in Jiaxing.

Jiaxing government has decided to build the Jiaxing sewage treatment project, which collect industrial and municipal wastewater from 34 towns and countryside towns and 124 industries. Catchment area is 860 sq.km, including urban area of city of Jiaxing, the capital town Chengguan town of Pinghu, Weitang town of Haiyan, and Zhapu, Daqiao, Xinfeng, Caoqiao, Xitang, Yuantong and part of Haining. The trunk line will be 37.98km long and sub-trunk 61.71km. The project will service for people 406300 in short-term and 1030000 in long-term. The designed capacity of WWTP is 300000m3/d in short-term and 550000m3/d in long-term, with an integrated changing coefficient 1.1. After the evaluation on environmental capacity of Hangzhou bay, location of discharge, and the environmental impact of effluent, the treatment plant with effluent to the ocean will be located near the area called Changqian, in Haitang countryside of Haiyan. The trunk will pass through 21 of big rivers over 50 meters and 66 of small rivers. The transportation system is pressure in combination with gravity flow, pressure flow when the line passes through rivers. The use of pressure flow can reduce the required pipe trench depth.

The recommended lay-out scheme of the new WW treatment plant:



Jiaxing City and region is developing integrated municipal and industrial wastewater treatment strategies. A highly recommended strategy is to develop treatment plants step-wise. The WWTP plant (or plants) to be build must therefore be designed in a way that allows for cost-effective upgrading to higher removal efficiencies at a later stage. Step-wise planning and construction also gives advantages with respect to flexibility in the future and provides valuable process information about the waste water and chosen first step configuration before choosing the further steps.

The suggested stepwise development of the OD-WWTP is presented in detail in chapter 8 in the back of this report. The design is based on 3 main construction steps:

Step 1 (In operation Year 2002)	Pre-treatment and Chemically Enhanced Primary Treatment
Step 2 (In operation Year 2004)	Extension with biological treatment
Step 3 (In operation Year 2011)	Possible extension of all sub-processes based on existing and estimated future loads

The design concentrations of influent and effluent are showed in the following table:

Table 14. Design concentrations

Flow / Parameter	COD	BOD5	SS	T-N	T-P
influent	400	161	147	36	5.5
effluent	120	30	30	25	1.0

Pre-treatment in industries

There are 72 industries that have WW treatment facilities within the catchment area of the planned Jiaxing WW treatment plant, with the total WW discharge of 72808100ton/a, 40548100ton/a after treatment, and 23996000 ton/a of treated WW meeting the emission standards. The total amount of WW matching standards is 30834900 ton/a. Of these 72 industries, 21 industries are textile dying and printing plants, 10 paper and pulp mills, 2 pesticide plants, and 7 common chemical factories. These industries have relative large amount of discharge. Data are showed in the table below. Other industries with small quantity of discharge are food processing works, tanneries, hospitals and other.

The following table presents pre-treatment in some industries (unit: 10000ton/a).

Table 15. Industrial pre-treatment

Category of industry	Annual WW discharge	Annual amount of treated WW	Annual amount of treated WW matching standards	Annual WW discharge matching standards
Paper and pulp	3522.47	2581.60	1517.16	1517.16
Common chemical	1034.23	695.83	346.54	595.99
Textile dying and printing	554.04	432.98	314.89	355.91
Pesticide	526.8	137.07	60.53	405.43
Sum	5510.7	3847.48	2239.12	2874.49

In China the control and treatment of solid waste is in the preliminary stage and there exists a lot of imperfect aspects related to classification, legislation, standards and estimation of amount of solid waste. A survey made in 1994 showed severe problems existing. The following two tables can give some idea about the treatment and disposal of solid waste and its consequent problems.

Table 16. Statistics of modes of waste discharge in 1994

Discharge mode	Amount of waste (t/y)	%
To canals	40764.67	63.66
Landfill without permit	10640.58	16.63
Dump at sea shore	5400.00	8.44
Dump at wasteland	679.37	1.06
Dump on-site	468.31	0.73
Dump along roads	400.83	0.63
Dump to ocean without permit	240.00	0.37
Dump to permeable well	91.69	0.14
Dump along the bank of canals	74.55	0.12
Dump to fresh water bodies	34.55	0.05
Mixed with domestic refuse	19.94	0.03
Others	5187.64	8.11
Sum	64002.13	100

Table 17. Statistics of amount of different kinds of waste in 1994

Serial No.	Name of waste	Amount of waste (t/y)	Serial No.	Name of waste	Amount of waste (t/y)
1	Sludge from organic WW treatment	16355.57	20	Waste from food processing	31.00
2	Waste containing phenol	3360.00	21	Asbestos waste	25.00
3	Spent pigments and dopes	2194.69	22	Residue of distillation and rectification	24.27
4	Waste containing PCB	1600.00	23	Waste emulsifying solutions	19.20
5	Spent acids or solid acids	963.66	24	Spent solution containing Cr	18.68
6	New chemicals	900.00	25	Organic solvent waste	10.86
7	Tannery waste	536.50	26	Waste containing Pb	6.35
8	Clinker from blast furnace	448.09	27	Hospital waste	5.98
9	Alkali solution and solid base	339.00	28	Petrolatum waste	5.59
10	Waste glass	265.00	29	Organic resin	4.00
11	Metal oxides	226.00	30	Coloured metals	2.50
12	Industrial dust	216.66	31	Sensitive material	0.87
13	Waste containing Zn	215.72	32	Waste containing Cu	0.87
14	Industrial garbage	208.00	33	Inorganic cyanide	0.65
15	Clinker from boiler	148.00	34	Waste containing Ca	0.60
16	Mineral waste	140.00	35	waste containing Ni	0.52
17	Waste from topdressing	54.29	36	Waste containing Hg	0.17
18	Animal residues	50.00	37	Black metals	0.07
19	Sludge from inorganic WW	35.53	38	others	35588.29
Total	64002.13				

11.4 Management and institutional options

The figure below is part of the organisation of Jiaxing government related to environmental issues. Jiaxing government is responsible for the decision making. Jiaxing Urban and Rural Construction Commission is responsible for making city plan after collecting different opinions from other authorities, and in charge of the implementation of the civil construction.

The figure on next page presents the different commissions and bureaus within the City of Jiaxing.

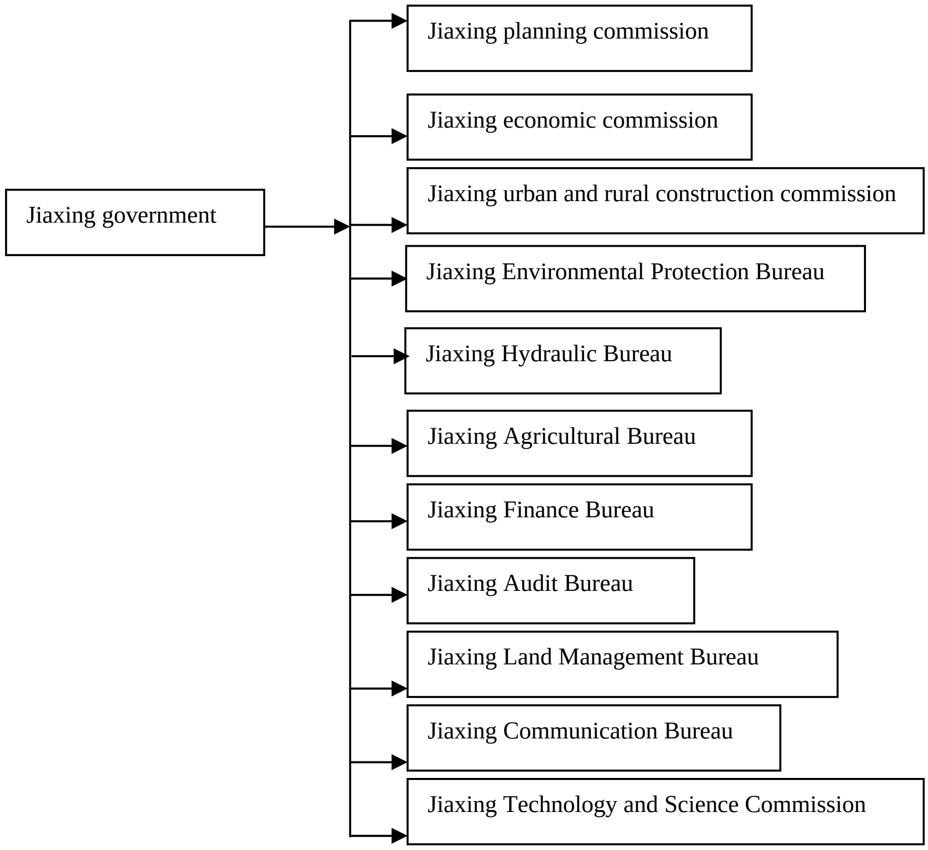


Figure 5. Commissions and bureaus in City of Jiaxing

11.5 Economy

GNP in 1997 in the entire city was RMB 41975million, in which GNP of first, second and tertiary industry was RMB 6345 million, 24817 million and 10812 million respectively, which were 15.12%, 59.12% and 25.76% respectively. GNP per capita was RMB 128 million. The total agricultural output value in 1997 was RMB 9441million, among which total agricultural output value of planting, forestry, husbandry and fishery were RMB 5605million, 31 million, 3137 million and 669 million respectively, which occupied 59.37%, 0.33%, 33.23% and 7.09% of the total respectively.

Total industrial output value in 1997 was RMB 94307 million, among which 47706 million were for enterprises at and above township level, which was about 50.39% of total. Total industrial values of light and heave industry were 66.78% and 33.22% respectively. Within light industries, with products based on agricultural products, was 76.91% of total value of light industry. Therefore the structure of industry in Jiaxing was mainly process industry based on agricultural products.
Investment of fixed assets in 1997 was RMB 14421million. Incomes within financial budget were RMB 2301 million, expenses 1112 million. Deposit surplus amount of residents was RMB 21746 million, loan surplus amount was RMB 26865 million. The average income for living expenditure of urban residents was RMB 6999. The per capita income of rural resident was RMB 4795.

There were 951500 families in 1997, with total population of 3291500. 78.64% of the total population is farmers. Fertility rate was 10.11% and mortality rate 6.93%. The natural population growth rate was 3.18‰.

The table below presents the situation of population growth, improving living conditions and economic growth.

Table 18. Population and economical growth in Jiaxing

year	Population growth		Economic growth GNP (RMB10000Yuan)					Income level(Yuan)	
	Total population (10000)	Natural growth rate(‰)	First kind of ind.	Second kind of ind.	Third kind of ind.	Sum	Average (Yuan/p)	Average income of urban residents	Average income of rural residents
1987	308	12.40	166588	298999	110322	575909	1811	1127	1012
1988	311	6.80	217279	363407	143531	724217	2339	1403	1273
1989	314	6.86	237053	397473	163144	797670	2554	1613	1552
1990	316	7.18	249722	405612	157966	813300	2582	1954	1648
1991	318	6.04	249308	475128	188158	912594	2877	2035	1653
1992	320	6.19	263042	622270	247855	1133167	3547	2439	1800
1993	323	5.90	308822	998958	380374	1688154	5249	3441	2162
1994	325	5.36	496698	1317107	571147	2384952	7372	5084	2919
1995	326	5.09	569497	1805971	797461	3172929	9750	6203	3366
1996	328	4.43	614333	2204505	998134	3816972	11665	6548	4088

11.5.1 Payment for water resources

Department of hydraulic decides the water resource charge standards are 5 fen/t for surface water used by industry, 1 fen/t for surface water used by residents and 8 fen/t for ground water. Based on the statistic, industries used 1904.6million cubic meters of water in 1997.

11.5.2 Effluent charges

Provision 18 of ‘Environmental Protection Act of Chinese People’s Republic’ states: “All of pollutants discharged exceeding the national standards should be charged according to their quantities and concentrations by the corresponding regulation”. Based on this, the effluent charge system was established. On 5th February 1982, the State Council issued the document of “Temporary method for collecting discharge fee”, which has been enforced since 1st July 1982. In this document, the discharge fee collection standards were also set for WW, exhaust and waste.

Accordingly, Zhejiang province established “the temporary regulation of discharge fee collection and pollution fine” to suit for its own effects. This regulation was authorised at the 15th session of the Standing Committee of the 5th National People’s Congress of Zhejiang, and enforced since 1st July 1982. (Revenue)

To make the effluent charge standards consistent with state-of the-art regulations and standards, authorised by State Council, SEPA, Price Bureau and Finance Bureau issued a notation on adjustment of standards for exceeding standard WW and noise discharge fee collection. This notation has been enforced since 1st July 1991.

11.5.3 Finance

Regarding the Jiaxing Wastewater Project, the estimated total investment in short-term is RMB933048100Yuan, consisting of 849554000Yuan investment for the project, 78494100Yuan interest during construction stage and basic floating capital. The financial situation is showed in the following table.

Table 19. Financial situation

Source	Amount (RMB10000Yuan)	Percent of total (%)	Remarks
Japanese loan	16600	17.78	US$2000, rate 8.3, annual interest: 1.3%, repayment period 30years, grace period:10years
Special fund from the central government	1000	1.07	
Special fund from local government	2500	2.68	Annual interest: 5.5%, repayment period: 6years
Special fund from city government	34704.81	37.21	capital
Loan from national commercial bank	38500	41.26	Annual interest: 7.6%, repayment period: 10years
Sum	93304.81	100	

12. Goals and Objectives, case Jiaxing

12.1 Water quality of canals, lakes and ocean coast

According to the analytical results of the routine measurements at each station of different water bodies/water sheds in 1996, and the state standard requirements for water quality for each water bodies/water sheds whose user interests has been defined in "The division of environmental protection zones for surface water, Jiaxing", the current status and objectives of related water bodies/water sheds are showed in the table below.

Table 20. The current status and objectives of related water bodies/water sheds

Water system	Name of water body	Length of river(km)	Section of river	Existing water quality	Objective quality	Function of water body
Flow to Hangzhou Bay	Changshan canal			IV-V	III	Multiple usage
	Haiyan canal			IV	III	Multiple usage
Flow to Huangpu River	Tongxiang section of the great canal	34.4	5km	III - IV	II	Source of water plant
			29.4km	IV - V	III	Industrial usage
	Jiaxing section of the great canal		10%	III - IV	II	Source of water plant
			67.5%	IV - V	III	Multiple usage
			22.5%	V or worse than V		Industrial usage
	Pinghu canal(including Shanghai canal)		85%	IV - V	III	Multiple usage
			15%	V or worse than V	IV	Industrial usage
	Hongqi canal	21.6		IV	III	Multiple usage
	Yuhui canal	13.5		III	III	Multiple usage
	Sandian canal	30.7		IV	III	Multiple usage
	Jiashan canal	21.8	5km	IV	IV	Multiple usage
			16.8km		IV	Industrial usage

Key water bodies protected are protected zones of sources of water plants, normal commercial fishery areas and important scenic pots and so on. Of which Xinchen canal, Changshui canal (including Shanghai canal), Changshen canal, Yanping canal, Zapu canal, the great canal, Jingniu canal, Majin canal, entry to Haining of Changshan canal, Dahongqiao canal, section of Suzhou canal and Haiyan canal in Jiaxing, Taishanqiao canal, section of Haiyan canal in Haiyan are sources reserved sources of water plants, which shall reach class 3 of the quality standard for surface water in short term and class2 in long term. While Hongqi canal, Yuhui canal and northern part of Suzhou canal are areas for fishery, The South Lake of Jiaxing, the North-south Lake of Haiyan, the Jiurongshan Shore of Pinghu and Qiantangjiang tide are places for tourism.

Hanzhou Bay has a total water area of 500 sq.km, with the upstream of Qiantang River and downstream of East Ocean, occupied by Zhejiang and Shanghai. Coastline of Hangzhou Bay in Jiaxing is 121.1km totally. According to the primary concept of the ninth five-year and the development plan of economic and society for year2010, the north bank of Hangzhou Bay will be developed considerably. Preparation will be done from year 2000 for the fast developing stage between year 2005 and year 2010. Many heavy chemical industries will be built there. The construction of three harbour areas of Zapu, economic development zone, zone of exported product manufactories and high-tech development zone started up. Recently, second stage of Jiaxing Power Station, second stage of Qinshan Nuclear Power Plant, second stage of Zapu harbour and the Shanghai petroleum chemical project of 650000 tons of ethylene have been approved to build.

Hangzhou Bay and Qiantang River are suitable for the cultivation of different kinds of aquatic lives because of their large water area. Fishery sources of Hangzhou Bay are 10000 tons with a density of 2.42 t/sq.km.

12.1.1 Relevant water quality standards

The requirement of the surface water body at scenic pot is to meet the class III of GB3838-88 and class II of GB3097-97 for the ocean water body. Emission standard GB8979-96 for integrated wastewater and some standards for special industries are existing.

12.1.2 Monitoring and assessment of the quality of water bodies and water sheds

There are some provincial controlled and local controlled monitoring stations at 24 different water bodies/water sheds. To identify the quality of water bodies or monitoring stations, samples are taken 3 times at each station annually at three seasons, i.e. average water level (in April), high water level (in July) and low water level in January). 19 parameters are measured for each sample. After compared measuring results to standard values in the quality standard for surface water, the worst parameter decides the water quality level at each station. The level is the class that the worst parameter surpasses.

12.2 Municipal waste water regions

In this project we have divided the City of Jiaxing into various wastewater regions, where each region acts like a catchment area. The picture below shows these areas and the basic design for the sewer system that we suggest in this project. Each of the new areas has separate sewer systems, which drain to a central collection point with a pumping station. In the old area (the island) there are combined systems, which drain to a ring pipe with a pumping station. All the pumping stations direct the water to the main trunk sewer. Please note the combined sewer overflow before the other branch-pipes are connected. Details of this design of the are pipes are discussed in section 12.4 of this report (transport system) and in the report for activity 6 (Planning of WW collection systems and design activities).

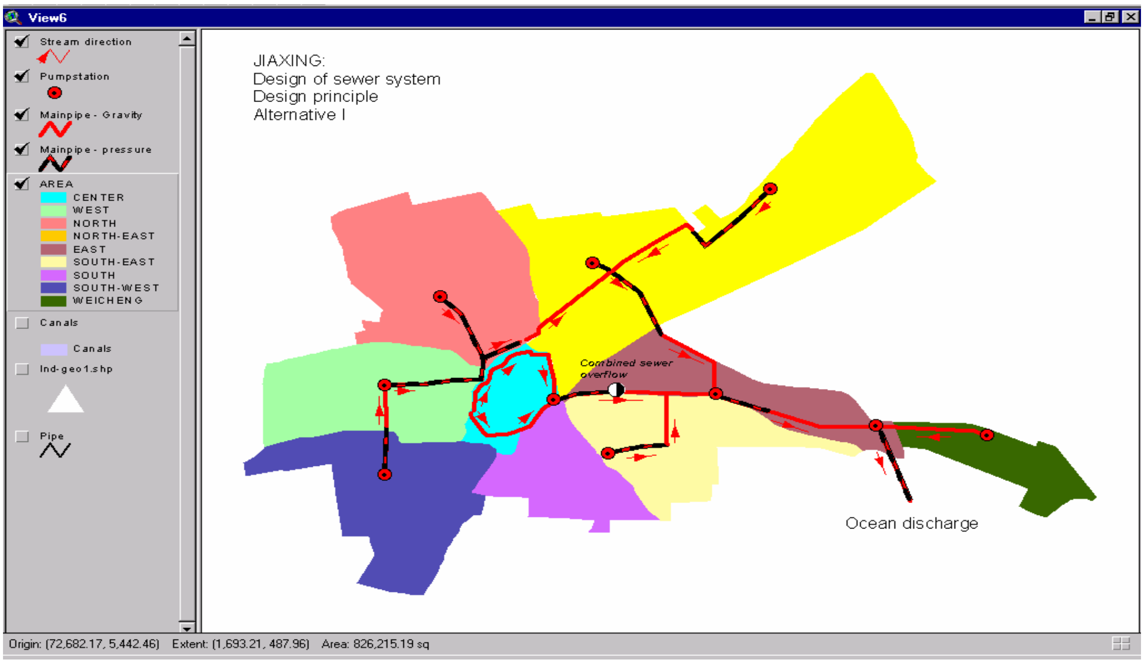


Figure 6. Municipal water regions

12.3 **Pollution sources - future situation**

12.3.1 New effluent standards

The new 'Integrated WW discharge standard', provided by the department of science and technology standard, SEPA, authorised by SEPA on 4^{th} October, 1996, started to be enforced on 1^{st} January, 1998. The principal of implementation of the standard is that it should be separated between 'Integrated WW discharge standard and special industrial discharge standards'. There are 12 individual standards for different kinds of industries, such as paper and pulp mill, shipping, ship industries, exploiting of ocean petroleum, textile dying and printing, meat process, synthetic ammonia, iron and steel, the application of space promoter, weapon manufactory, phosphorous fertiliser production, sodium sulphate production, and polyvinylchloride. Other institutions enforce these standards. This standard also includes 17 kinds of released industrial discharge standards. Compared with the old standard, the standard values for pollutants within the first duration (before 31^{s} December 1997) are almost same as what for new, expansion and innovation of plants in the old standard. 10 parameters are involved in the amended standard so as to control the characteristic, harmful and dangerous pollutants in 17 kinds of industries. The standard for industries built after 1^{st} January 1988 is increased in parameters by 40 pieces, the maximum discharge concentrations of COD and BOD5 and so on are stringent properly. Maximum allowed discharge concentrations for 69 kinds of pollutants and maximum allowed discharge amounts for a part of industries were set in accordance with the way of discharges.

12.3.2 Pre-treatment at the different factories

Standards described above are used for industries that discharge their WW to canals. Jiaxing government and relevant departments decided that standards for WW flowing into trunk sewer is class3 of 'integrated WW discharge standard' according to economic status, enterprise toleration and environmental capacity of recipient. Accordingly, most of industrial WW can flow to the trunk sewer directly, only such industries with very acidic or alkaline WW or heavy metal containing WW have to pre-treat their WW.

12.3.3 Prediction of WW amounts.

The amount of industrial WW being involved in the project is predicted on the basis of existing steady status of changes in recent years and "The 9th Five-Year implementation program of Jiaxing national economy and social development". Details are showed in the table below.

Table 21. Quantity of industrial wastewater included in the project

stage	unit	City centre	Weitang town	Chengguan town	Wuyuan town	Zapu town	Other Scanner sources	sum
Short term	10000t/y	2979.2	192.10	633.93	322.51	38.58	3056.37	7222.69
	10000t/d	8.1622	0.5263	1.7368	0.8836	0.1057	8.3736	19.7882
mid-term(2010)	10000t/y	3277.12	211.30	697.33	354.78	42.45	3361.91	7944.96
	10000t/d	8.9784	0.5789	1.9105	0.972	0.1163	9.2109	21.7670
Long term(2020)	10000t/y	3575.03	232.18	760.73	387.01	46.28	3665.99	8667.22
	10000t/d	9.7946	0.6361	2.0842	1.0603	0.1268	10.0438	23.7458

With the process of urbanisation and the upgrading of living standard, urban population and its water consumption are increasing. The water consumption is assumed for 350l/p.d for mid- and long-term, therefore domestic WW in mid- and long-term is showed in the table below.

Table 22. Water consumption

stage	unit	City centre	Weitang town	Chengguan town	Wuyuan town	Zapu town	Other Scanner sources	sum
Short term	Population(10000)	20.65	5.0	6.03	6.06	1.77	1.12	40.63
	WW(10000t/d)	5.16	1.25	1.50	1.51	0.44	0.28	10.14
mid-term(2010)	Population(10000)	40	11	9	9	5	3	77
	WW(10000t/d)	12	3.3	2.7	2.7	105	0.9	23.1
Long-term(2020)	Population(10000)	50	14	14	14	7	4	103
	WW(10000t/d)	15	4.2	4.2	4.2	2.1	1.2	31.0

12.3.4 Development of industry

Five kinds of industries are speeded up to develop in short term (year 2000), which are electric information, chemical (finery chemical), new model silk, mechanics and food processing. The annual growth for these industries is 11.5%, which is 2% higher than other industries.

12.3.5 Industries that will be closed

According to state council about "the decision of several problems of environmental protection", 15 kinds of small industries with heavy pollution are controlled continuously. The small paper mills which produce less than 5000 tons/y, the tanneries which annually produces less than 30000 pieces of cow-skin or less than 60000 pieces of sheepskin or less than 180000 pieces of pigskin, the dying manufactories which produce less than 500 tons/y, the small electroplate plants, the small dying and printing plants and small oil refineries should all be closed.

12.4 **Transport system**

12.4.1 Up-grading of sewer collection system

The sewer systems in old cities are combined systems, with the combined WW of different kinds of WW flowing to canals directly. Domestic WW from new residences is treated by septic to discharge to canals. Some industries have onsite WW treatment plants, where industrial WW discharge to canals after different extent of treatment. Other part of industrial WW discharge to canals directly. In the city plan of each city or county, within the expansion area of the city and new development zones, the sewer systems are planed to be separated systems. Considering the difficulties of reform sewer system in old cities, the only thing can be done is to change the combined system to separated system with the reform of old cities. With the progress of Jiaxing WW construction (OD), all of municipal WW is considered to be collected to the trunk sewer, which conveys WW to central WWTP to be treated, then discharge to Hangzhou Bay.

No matter what kind of design strategy is chosen, the sewer pipes should comply with some basic functionality regarding:

- Structural integrity
- Capacity
- Self cleansing
- Leakage

During the design and building of the sewer system the environmental aspects should be implemented with special attention to:

- Amount of combined sewer overflow (CSO) during rainfall
- Leakage from pipelines
- Connection ratio to the sewer system from industrial and domestic area
- Operational reliability of the pumping stations

Figure 7 show the mapping of existing and planned pipes and pumping station based on CAD drawings and paper maps from JEPB and City Engineering Department. These pipes feed the main transport pipes that were presented in section 11.2.

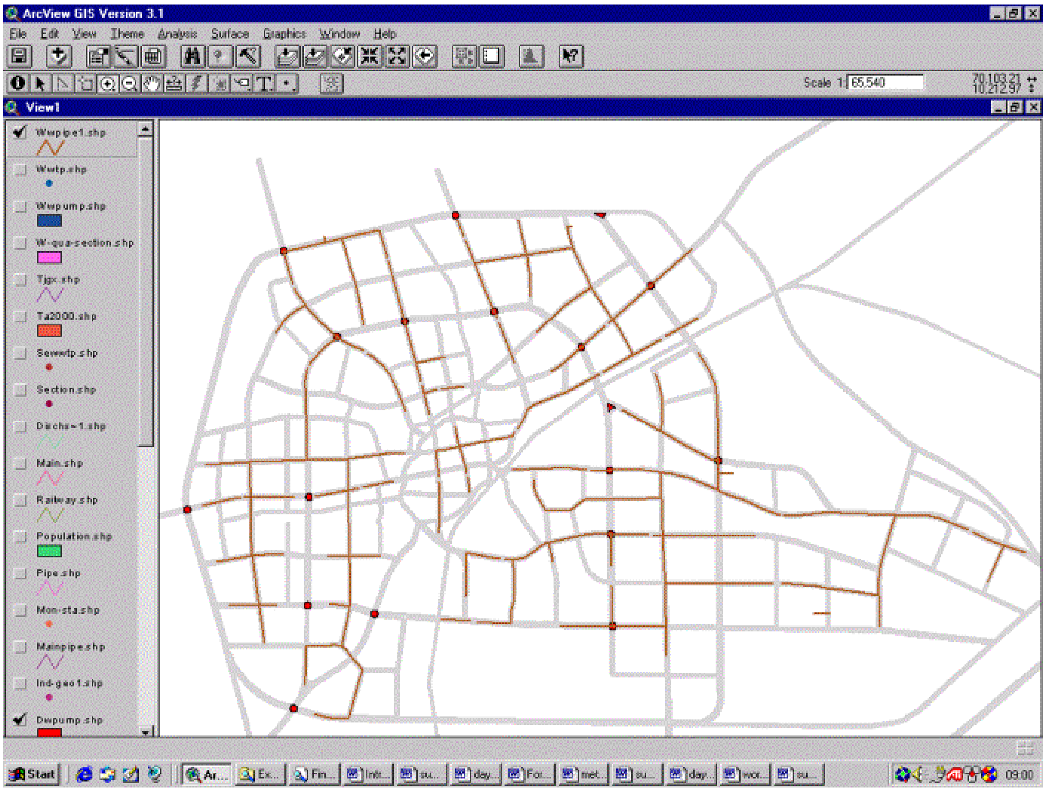


Figure 7. Existing and planned pipes and pumping station in Jiaxing

12.5 **WW treatment, sludge handling and effluent**

12.5.1 Trunk sewer

For the OD project, the trunk from Jiaxing to Hangzhou Bay is 38kms with a submain of 62kms. 13 pumping stations are provided as well as one pumping station to ocean. It will pass through 21 of big rivers over 50-meter width and 66 of small rivers. The transportation system is pressure in combination with gravity flow, pressure flow when the line passes through rivers. The use of pressure flow can reduce the pipe-buried depth and cost.

The part of ocean outfall consists of one ocean discharge pumping station which is located in the treatment plant, high level pressure-adjusting well, ocean discharge pipe (including pressing pipe, diffusing pipe) and emergency discharge pipe. The length of pressing pipe is about 1700m defined temporarily with the diameter of d2100. The diffusing pipe includes horizontal pipe, up-flow pipe and jet mouth. The horizontal pipe is temporarily defined 300m long, with 16 up-flow pipes of 400mm in diameter. Each up-flow pipe has 6 jet mouths.

12.5.2 Pilotplant studies

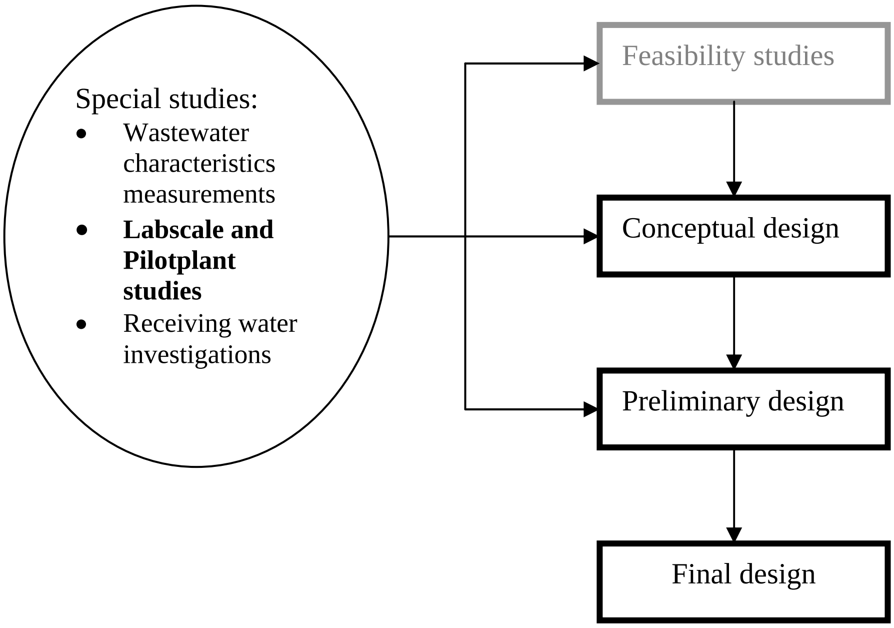


Figure 8. The analytical way of planning and designing wastewater treatment plant(s).

Objectives for pilotplant studies:

- To test treatment processes to determine its performance and feasibility for a particular application
- To compare alternate process configuration to determine the most cost-effective and reliable system for final design
- To determine what effluent quality can be achieved by a particular process and if supplemental sub-processes/chemicals are needed to meet discharge standards
- To observe long-term performance of a process as a function of site-specific wastewater characteristics and variations in wastewater flow and strength.
- To provide operator training and experience with the process operational needs.
- To obtain specific design factors for suggested treatment processes to establish a more optimal and cost-effective design and to identify specific safety factors for such design

Labscale tests and pilotplant experiments have been carried out in Jiaxing City for a period of one year. The project group's view is that these test results and gained experiences have been of vital importance in order to reduce the uncertainty in design of the planned Ocean Discharge Waste Water Treatment plant.

The main motivations for carrying out the experiments have been:

- Obtain design and dimension criteria for OD-WWTP
- Document and give confidence concerning the waste waters suitability for chosen treatment processes
- Examine alternative pre-treatment, secondary treatment and design alternatives
- Clarify waste waters possible toxic/inhibited effects over time
- Optimise chosen WW treatment processes
- Training of JEPB personnel in mechanical, chemical and biological WW treatment
- Re-use possibilities of pilotplant (ODWWTP, pre treatment of industrial WW etc.)

Specific objectives for pilotplant studies in Jiaxing:

a) To evaluate the robustness of chemical and biological WW treatment processes to combined WW (domestic and pre-treated industry WW) by pilot plant tests. Test how the mixed domestic and industry WW contribution from Jiaxing will effect treatment at the planned Ocean WWTP, using a model WW.
b) Evaluate if pre-treatment of selected industries are recommendable
c) Find the critical organic load that enables sufficient organic matter removal and/or inhibition of micro-organisms by other materials in industry WW
d) Find the fraction of soluble inert and soluble slowly biodegradable organic matter, measured as COD, at different loads and process configurations.
e) To evaluate sludge-production at different loads, and study sludge characteristics
f) To get basic data about treatment efficiencies with different configurations and loads
g) To obtain dimension criteria for a full-scale plant, and basic information for a rough calibration of a dynamic chemical and biological model (STOAT)

Our conclusions, based on the results from labscale and pilotplant experiences, were:

- Test results and gained experiences from experiences have been of vital importance in order to reduce the uncertainty in design of the planned ODWWTP
- Chemical treatment alone will not meet effluent requirements but have been a relatively robust and stabile process. Organic removal was only about 45% measured as COD, because of high fraction of soluble COD
- Biological treatment alone will not meet effluent requirements and caused severe operational problems in the pilotplant. Biological treatment alone is not recommended for the new OD-WWTP
- A combination of chemical and biological treatment showed to be the best process configuration. A likely explanation is that chemical pre-treatment removes some of the soluble and colloidal toxic/hampering/interfering substances in the mixed wastewater that caused problems for the biological tests without pre-treatment.
- Because of high degree of industrial waste water, normal design practise for municipal waste water can not be used for the planned OD-WWTP
- High fractions of soluble slowly biodegradable organic matter (from industries) in mixed wastewater demands low load in the biological treatment stage. In periods with high load in the pilotplant operating as chemical/biological process, effluent requirements were not met. A detention time of about 6.8 hours in the activated sludge process were necessary to achieve stable effluent quality (equals an organic load in the activated sludge system of about 0,12 g BOD_5/g MLSS*d and 0,2 g COD/g MLSS*d).
- Poor sludge settling properties must be expected in the planned OD-WWTP. Even with pre-precipitation, measured sludge-volume (SV) and sludge volume index (SVI) in the pilot plants activated sludge system were high (typically SV=600 and SVI=200). Design of planned ODWWTP secondary sedimentation tank must therefor allow for poor sludge settling properties.

12.5.3 Sludge management

The more extensively wastewater is treated, the more sludge is produced. The city should develop a plan for treating, storage, transport and final disposal of sludge.

There are three goals for sludge treatment:

- To make is hygienic safe (i.e. removal of parasites, parasite eggs and viruses)
- To stabilise the sludge by degrading the easily degradable organic matter
- To reduce odours and the aesthetic problems associated with sludge

In general, biological wastewater processes produces less waste sludge than chemical precipitation processes do. A step-wise treatment plant based on the CEPT concept is assumed to produce intermediate low sludge volumes.

Sludge stabilisation can be done by either anaerobic, aerobic or chemically by lime-addition. Large WWTPs often finds it beneficial to treat the sludge anaerobically in large digesters, in order to utilise some of the chemically bound energy as biogas for electricity and heating.

After stabilisation, the sludge should be de-watered (in centrifuges or filter presses) to reduce the water content and the total volume. This makes the final product easier to handle and transport, and reduces the volumes needed for temporary storage.

Ideally, the final stabilised sludge should be brought back to the farmlands to provide valuable nutrients and organic support matter. In order to use sludge as fertiliser its content of environmental contaminants (i.e. heavy metals and organic micro-pollutants) should be low, in addition to the three criteria mentioned above.

Alternatively, the dry sludge can be incinerated with re-use of the excess energy, but these plants are expensive to build and operate, have the possibility to cause major air pollution, and they destroys the nutrient value of the sludge.

Whichever process that is selected for sludge treatment, one should keep in mind that the major goal for sludge handling is to have a system that is cost-efficient, reliable, hygienic safe and that not pollutes lakes, rivers, marine waters and dry land.

12.5.4 Expected improvement of local canals etc in Jiaxing

When the wastewater treatment plant (WWTP) is finished, the load of nutrients, organic matter and chemicals to the canals in Jiaxing will be considerably reduced. This will most probably lead to significantly better water quality in the local canals, with better conditions for fish and a lower extent of undesirable algae growth. It is very likely that the population of Jiaxing will appreciate the improvement of the canal water, and the environment will be saved for harmful pollutant loads. It is likely that the construction of the WWTP will improve the conditions for everybody that depends on the canals as a source for fish, water chestnuts and other natural freshwater resources.

Based on the initial situation with three WWTPs within the city borders we have modelled the future nutrient load to the canals, and compared the results to the current situation and to a hypothetical future situation without any treatment. The results are presented in the table below. For the selected OD-WWTP situation with close to zero load to the canals, the situation in 2020 will be even better than the table indicates.

Table 23. Estimated pollution load to canals with and without wastewater treatment.

	totP tonnes			totN tonnes			BOD tonnes		
	indu.	popul.	total	indu.	popul.	total	indu.	popul.	total
1995 no WWTP	50	115	165	578	843	1431	4985	3449	8434
2000 no WWTP	55	164	220	636	1204	1840	5483	4928	10411
2020 no WWTP	55	380	435	636	2464	3100	5483	10439	15922
2000, WWTP in city	28	82	110	318	602	920	2741	2464	7947
2020, WWTP in city	4	30	35	51	197	248	439	835	1274

12.6 **Efficiency and future development**

12.6.1 Expansion of sewer system

The Yuxin-Fengqiao-Xinhuang sewer system: Three towns of Yuxin, Fengqiao and Xinhuang located in the Southeast of Xiuzhou district will be developed focused. The development focuses on residence and infrastructure in three towns, plastic, art craft and ironware production in Yuxin, paper, feed and agricultural products in Fengqiao, agricultural products and mechanic process in Xinhuang.

Table 24. Population and GDP in three towns

	Population			Per capita GDP (Yuan)		
	1998	2010	2020	1998	2010	2020
Yuxin	6600	10000	20000	7471	22000	40000
Fengqiao	3200	5000	8000	5556	22000	40000
Xinhuang	3200	5000	8000	6343	22000	40000

The expanded pipeline is 18.8 km long from west of Yuxin town to east of Yongnin village. Quantity of wastewater is 5000 t/d in short-term and 10000 t/d in mid-term (year 2010).

Ganyao-Huiming sewer system: Ganyao is a key large town planned to develop with wood process and electronic industries in Jiashan. Huiming, located in the east of Weitang town, is a modern agriculture town with certain food process industries.

Table 25. Population and GDP

	Population			Per capita GDP (Yuan)		
	1998	2010	2020	1998	2010	2020
Ganyao	6600	10000	12000	14819	33000	60000
Huiming	3000	5000	7000	——	——	——

4-km long pipeline for Ganyao starts from north of Ganyao to south of Weitang, with the wastewater 2000 t/y in 2000 and 5000 t/d in 2010.
3-km long pipeline for Huiming starts from east of Huiming to west of Weitang, with the wastewater 2000 t/d in 2000 and 3500 t/d in 2010.

The organisation of the WWTP and the whole sewerage collection system is presented in the figure below.

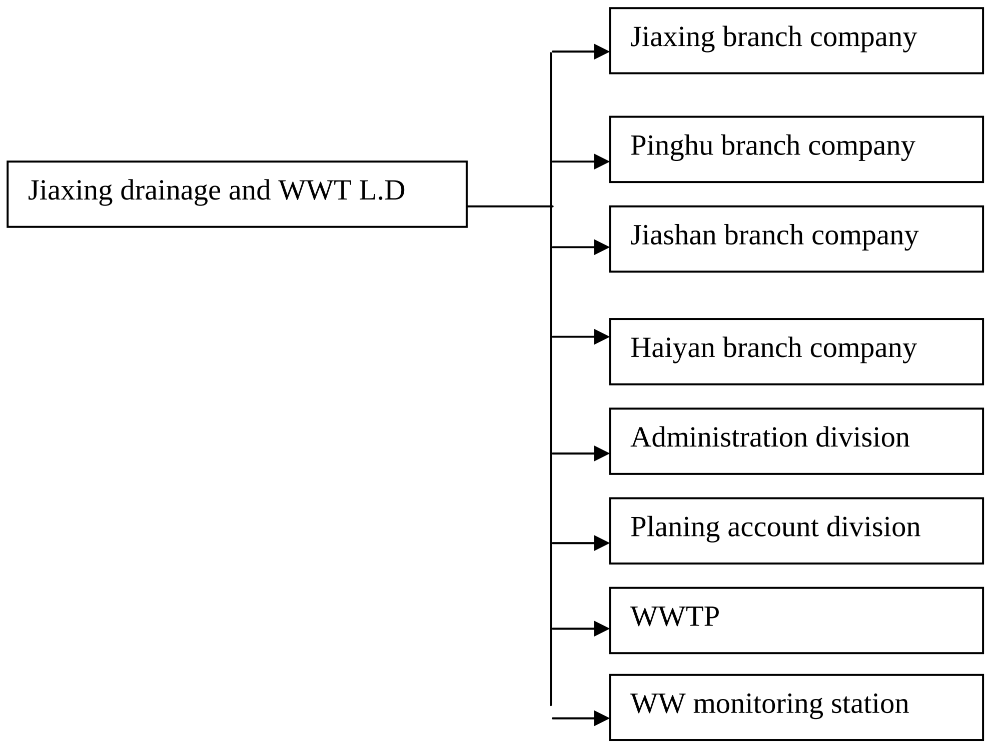


Figure 9. Organisation plan for the WWTP collection system.

13. Abatement Strategy and Measures, case Jiaxing

This section is beyond the scope of this project and is therefore not written for the City of Jiaxing. The wastewater management systems in Jiaxing need to be discussed thoroughly before they can be planned in detail.

The following issues should be included in this chapter:

The gap between the current situation and objectives:

- What are the main challenges? (technical, economical, ecological, knowledge, equipment)
- Measured concentrations in rivers and canals today, compared to what we want for tomorrow

Identification of potential measures:

- Alternative strategies/technologies to react the goals

Costs and financial options

- Cost-effectiveness
- Other tools to measure costs
- Should operating costs be covered by the consumers?

Strategy to meet the objectives:

- Organisation, management
- Monitoring data: What do we know, and what do we want to know? Conclusions?
- Which actions first?
- Centralised or de-centralised solutions
- WW management
- Sludge management
- Monitoring and surveillance
- Information policy
- Cost recovery
- Agriculture and industry

Selection of measures for the planning period

- Selection of main goals and sets of sub-goals
- When should the different goals be met?
- Which actions should be undertaken if unexpected delays occur?
- Other

CHAPTER 2

Project activity 2:

Water Quality Status and Resource Management

14. Introduction

14.1 General

This activity has covered data compilation, abatement strategy related principles and simple model running. Furthermore, it suggests future work on water quality related issues. The activity documents that the nutrient and organic loads into the canals are too high, and that the canals do not have natural capacity to manage the loads from sources such as sewage and industry. It is necessary to develop a comprehensive Abatement Plan, taking account of the existing water quality, user interests and future water quality goals for the canal system.

The objectives of this activity were changed several times during the running of the project, subsequently to changes of the number and/or location of the planned wastewater treatment plants. Considerable activity time was spent on data compilation.

14.2 Data compilation

In the early days of the project, the impact of the wastewater from the planned WWTP on the alternative recipients, both with regard to physical impact i.e. water flow, overflow, and the chemical impact i.e. water quality of the recipients, and possible adverse effect on a drinking water recipient, were said to be the issue of interest. At that time there were two alternative discharge points for the wastewater from the planned WWTP, one in the Beijiao Canal, and one in the Ping Hu Canal.

As an example, the following comprises the originally suggested alternatives for this particular activity at the outset of the project, viz.:
A:
- to examine the results of the hydraulic modelling which had been carried out by Chinese authorities and which would provide answers to the concerns about the physical impact of the waste water on the two recipients;
- on the basis of the hydraulic modelling results and the existing monitoring data on total phosphorus, dissolved oxygen, COD_{Mn}/COD_{Cr}/BOD_5 and suspended solids from all three sampling periods viz. April, July and December at the alternative discharge points, to assess the impact of the wastewater on the two alternative recipients.

B: in case there were no data available on hydraulic model running:

- to assemble data on the two recipients as regards:
- the shortest distance between the water surface and the street level in July, when the water level is at its highest- data from 1988-1996 required, if available;
- the narrowest and the broadest part of the canal on a stretch 1 km downstream the alternative discharge points;
- the water flow at the alternative discharge points- data from 1988-1996- with, if possible, an indication of how many days per year there is no flow (standstill);
- the water flow in the Zhopu-Jiaxing-Sushou canal and in the Beijiao Canal close to the planned discharge point of the WWTP;
- to assess the impact of the waste water on the two primary recipients as well any impact on the water flow in the Zhopu-Jiaxing-Sushou canal and in the Beijiao Canal;
- on the basis of the data assembled and the existing monitoring data on total phosphorus, dissolved oxygen, COD_{Mn}/COD_{Cr}/BOD_5 and suspended solids from all three sampling periods viz. April, July and December at the alternative discharge points, to assess the impact of the wastewater on the two alternative recipients.

The changing of plans, also changed the objectives of this activity, but the data collection and compilation activities were pursued. Considerable project time was spent on the data collection part, see Activity 1 (Chapter 1). Much of the data collected within the Activity 2 are listed under Activity 1 of this project, such as data related to agricultural activities and land-use

14.3 Modelling activities

With the almost ‘continuous’ change of wastewater treatment strategy, and also with the change of model used by NIVA, see section 3 on model running (QUAL-2E to WASP), the objectives of the activity were also altered. The final activity report includes results of running the WASP model under various scenarios with or without discharges from wastewater treatments plants, with or without the ‘round the city’ canal. It could be advocated that such scenarios are meaningless now that the discharges from the wastewater treatment plants will be channelled to the sea. However, the purpose of the activity and modelling running was no longer to endeavour to find the ‘close to truth’ situation in e.g. the year 2020, but to show the principles of using such a model as a management tool for authorities in Jiaxing in conjunction with abatement considerations in the canals.

The canal system within the city of Jiaxing and in the vicinity of the city is complex and difficult to handle. The total length of the canals is 13802.31 km, with a ‘water area’ of 268.93 km^2. There are more important 57 canals, with a total length of 959 km. The total water area in Jiaxing is 311.15 km^2, which represent about 8 % of total area of Jiaxing.

The main canals in Jiaxing, used in the model running, are:

1. Zhopu-Jiaxing-Sushou
2. Beijiao Canal- ‘round-the city’
2’ Hanhzhou Canal
3. Ping Hu Canal
4. Jiashan Canal
5. Changshue Canal
6. Haiyan Canal
7. Xinshoug Canal
8. Sandian Canal

The canal sections used in the final model running, are shown in **Figure 10**.

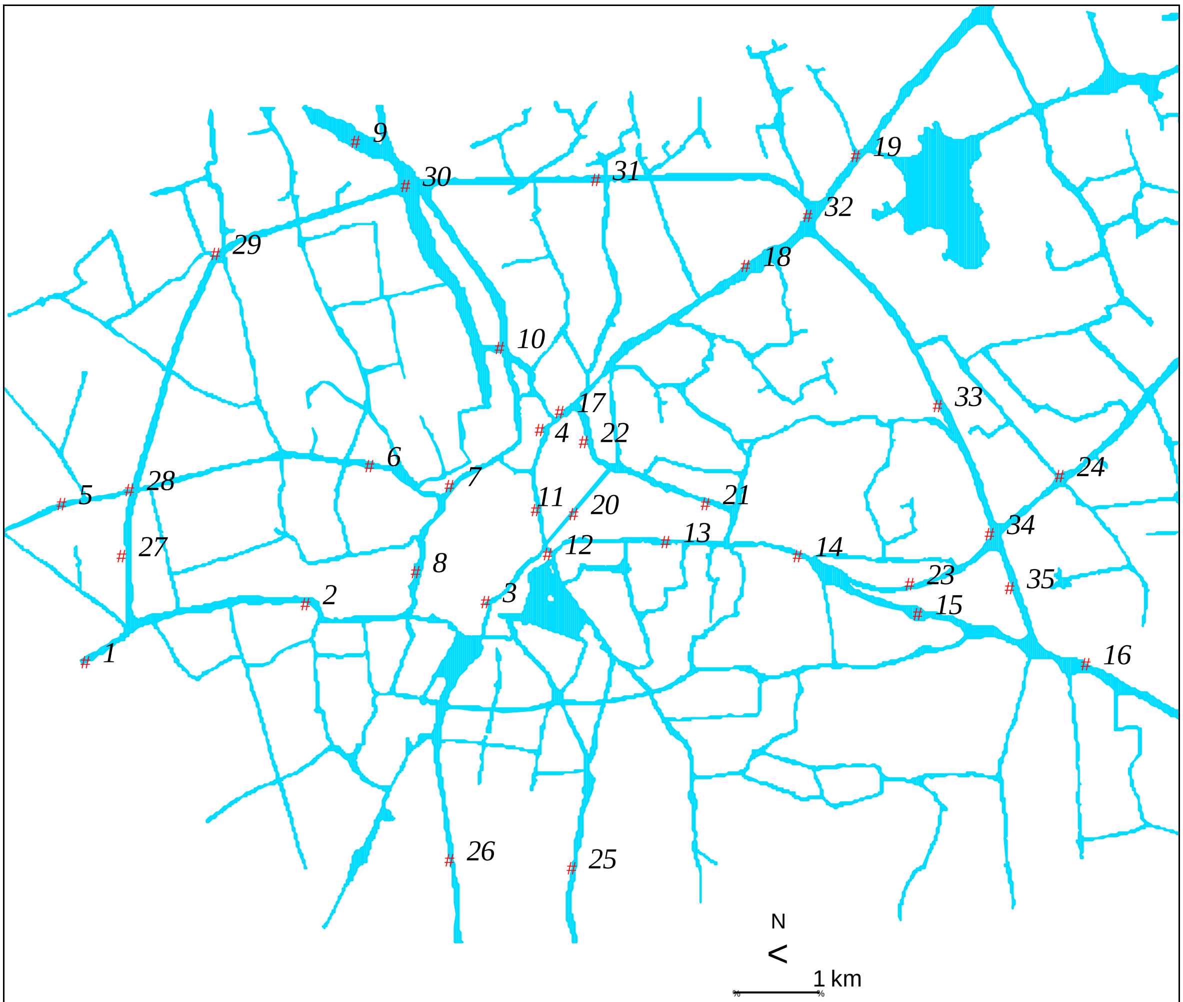


Figure 10: Canal segments as referred to and used in the model

14.4 Abatement strategy

The methods and procedures for an abatement strategy should also be encompassed within Activity 2 (see Section 17 of this chapter). Parts of this are also covered under Activity 1.

This includes elements such as:

- user interests
- definition of water quality goals
- prioritisation of user interests with regard to polluting substances
- dose/response models
- calculation of reductions required in order to reach the goals set
- criteria for prioritisation of measures
- evaluation of necessary means to implement the measures chosen

The sources to be taken account of are briefly described in the following, with the main activities per source.

Industry:

- Prioritisation of industrial sectors with regard to abatement, taking current water quality and user interests into account.
- Assess existing technology/processes
- Suggest new technology (BAT)/processes
- Cost/effectiveness analysis

Waste Water Treatment:

- Develop an overall Master Plan for WWT in the whole catchment area
- Sites
- Connection
- Sewerage
- Type of treatment
- Evaluate the necessary degree of treatment needed at WWTPs, taking user interests into account, with the aim of improving the existing water quality to achieve set goals.
- Cost/effectiveness analysis

Agriculture:

- Develop a complete picture of agricultural activities in the catchment
- Develop a comprehensive list of measures
- Cost/effectiveness analysis

Waste Deposits:

- Develop an overview of existing waste deposit sites
- Develop a plan for new waste deposit sites in the catchment

Atmospheric Deposition:

- Estimate the atmospheric deposition of identified, main pollutants
- Develop a monitoring network for atmospheric deposition

15. Data compilation

15.1 General

In view of the fact that integrated catchment management (in this case integrated canal system management) has not reached an advanced stage in this region to date, the data compilation, with indications of which data to compile, took a considerable part of the activities of this part of the project. It is, however, of importance to apply a holistic view when considering the specific parameters and their concentrations in water, the water flow, population densities, discharges of specific parameters from industrial plants, barge traffic, information about agricultural practices and land-use. The thought and implementation of a holistic approach to data compilation for canal system management (catchment management) is one important input (and output) to this project from Activity 2.

One main achievement in this activity has therefore been the first general compilation exercise successfully performed by JEPB in order to understand this holistic approach, and the common understanding of data sources necessary for water quality related work, as well as the procedures for categorising data gathered. The holistic view concerning data collection for water management purposes has been practised in Europe for some years, but the idea of a catchment-orientated approach is much more recent and has had its ‘final break-through’ with the adoption of the Water framework Directive within the European Union (EU).

15.2 Starting point

NIVA considered that it was necessary to assemble data on the following items:

- the water flow in the 8 canals in Jiaxing city in the period 1988-1996 with, as a minimum, flow data on the Shan Dian Canal;
- the concentration prioritised substances at all sampling points within Jiaxing city in the period 1988-1996 with, as a minimum, the concentrations of total phosphorus, dissolved oxygen, COD_{Cr} , suspended solids, cadmium, mercury, iron and manganese;
- the concentrations of all substances analysed for in precipitation in Jiaxing city in the period 1988-1996 with, as a minimum, the concentration of nitrate, ammonia, phosphate, cadmium, mercury, iron and manganese as well as the quantity of precipitation;
- all chemical and biological data available on the bottom sediment in the 8 canals in Jiaxing city in the period 1988-1996 with, as a minimum, all bottom sediment data on the Shan Dian Canal;

Additional data requirements were data such as data on population density and agricultural activities.

15.3 Results

Although the data collection and compilation took time, it is important to note the considerable efforts were made by JEPB to comply with the data requirements of NIVA, and also the achievements of JEPB in collecting data. The data compiled is mainly listed under Activities 1 and 2.

One further result of the data compilation exercise, was the measurements and generation of data on oxygen concentration in the water column that was launched during the project period. Furthermore, Jiaxing Monitoring Station has now also taken part, together with agencies involved in other NORAD projects in China, in an intercomparison exercise run by NIVA. It is hoped that laboratories providing monitoring data for the canals in Jiaxing will participate in any future exercise.

It was important to get access to time series (monitoring over several years) as time series of water quality data are often strongly dependent on climatic factors such as precipitation and runoff. Thus, the inter-annual variations in load can vary substantially and cause spurious trends and lead to misinterpretation.

16. Model running

16.1 Background

QUAL-2E is probably the most commonly used water quality model today. The original version of QUAL2E, which is shareware on Internet, could not handle the conditions in Jiaxing. The QUAL-2E model has been adapted for NIVA purposes. The Jiaxing situation was used by running this model in the first half period of the project time with some preliminary simulations. The model is originally made for river systems and needed special coding to handle the canal network in Jiaxing.

At a later stage, NIVA was asked, not only to produce simulation results, but also deliver the model for later use in Jiaxing. As the NIVA version of QUAL-2E would be difficult to use without continuous support from NIVA in the future, it was decided to use the WASP model. The WASP model includes user manuals that can be downloaded freely from Internet. An adapted description of the model has been produced and delivered to JEPB. The model is probably the most flexible water quality model in use. However, the input of data is complicated and time-consuming (DOS-based model).

The eutrophication part of the model was used in this project. That included possibilities to handle nutrients, oxygen and algae. Focus was on phosphorus, nitrogen and biological oxygen demand (BOD). The situation in 1995 was simulated, with mostly observed data to represent the situation today. Thereafter the simulations were related to the situations in 2000 and 2020 with data that should represent the suggested population and industry developments. The simulations were made to study the effect of the planned wastewater treatment plant. Furthermore, simulations were made that took account of the effects of the ”circular canal” around the city. Each of these alternative scenarios was studied for low-, mean- and high water flow.

The yearly input values for the model running were provided by JEPB. The data extrapolations were based on Chinese personal experiences with the local conditions. In order to simplify the work, the same values for water flow and input concentrations of relevant parameters in the waters flowing into Jiaxing have been used for the various scenarios. This to show the effects of changes (e.g. changes in discharges/losses) within the city area, independently of changes outside this area (e.g. changes in inflow). Future simulations would benefit from taking account of different inflow concentrations and water flows.

16.2 Principles

Dynamic models are based on detailed mathematical descriptions of hydro-physiological, chemical and biological processes in the water body. The models require, in general, a considerable amount of data of the area of concern. Compared to empirical and simple average considerations, the dynamic model has the advantage of providing the possibility to describe single processes and how environmental conditions influence these processes. The dynamic models enable also a good description of trends.

QUAL-2E is a river model (here used on canals) which simulates water quality (concentrations of various substances) as a function of input (kg) and water flow. The model is one-dimensional, i.e. it uses only one water quality value for the entire river stretch. The river (canal) system is divided into river stretches of equal length. The water flow (profile) for each river stretch is known. Dissolved oxygen, BOD, organically bound nitrogen, ammonia, nitrite, nitrate, organically bound phosphorus, phosphate, bacteria, phytoplankton, three groups of benthic algae, may be modelled.

16.3 Model running

The following input concentrations were used in all simulations::

BOD = 3 mg/l
NH_3 = 1 3 mg/l
NO_3=0.150 3 mg/l
PO_4=0.1 3 mg/l
DO=7 3 mg/l
OrgN=0.1 3 mg/l
OrgP=0.01 3 mg/l

The background values are shown on maps and in tables as the first elements of the inflowing canals into the city. The following shows the results of the model simulations, as illustrative examples are given the simulations of BOD, as well as some figures on general background information, structured as:

- Background information used in the running of the water quality model, such as info on discharges from industrial plants, population, canal segments
- Point sources of nutrients and organic matter
- Simulation results

They should provide the necessary input for JEPB in the future to use model simulations as a practical tool for canal management purposes.

Table 26 lists the figures shown in this chapter (a complete set of all simulations of all parameters will be submitted to JEPB), together with the background data used as input to the model simulations.

Table 26: List of figures related to model simulations

Number	Concerns	Remarks
Figure 11	Population in the years 2000 and 2020	2000 same as 1995 Ex.: 2000: P= 1,5 g/p and day; N= 11 g/p and day
Figure 12	Effluents from industry in 1995	
Figure 13	Phosphorus from industry	
Figure 14	Ammonia from industry	
Figure 15	COD from industry	BOD= COD ’ 0,3)
Figure 16	Low, mean and high water flow	The figures provided for input Q ’without canal’ are slightly higher than those ’with canal’. The result is that the dilution with canal is too high compared to without canal
Figure 17	Effects of constructing the canal on the P-concentrations	Increased water flow (Q) results in reduced concentrations due to dilution. The concentrations in the canals within the city are higher than in the ’input canals’. The concentrations with the new canal are higher than without the canal (within central Jiaxing) for most of the ’check-points’). This is due to the fact that the new canal reduces the effects of diluting water flow. Because ∑Q with canal is higher than ∑ without canal, the real effect of the canal is higher than shown on the map.
Figure 18	Simulated BOD values (1995, 2000 and 2020), low water flow, with and without new canal	
Figure 19	Simulated BOD values (1995, 2000 and 2020), mean water flow, with and without new canal	
Figure 20	Simulated BOD values (1995, 2000 and 2020), high water flow, with and without new canal	
Figure 21	Increase in BOD above background, year 2020, median Q, no treatment plant	

Sources not taken account of within the city are as follows:

Drainage
Storm water overflow
Leakage
Releases from sediments
Atmospheric deposition (N)

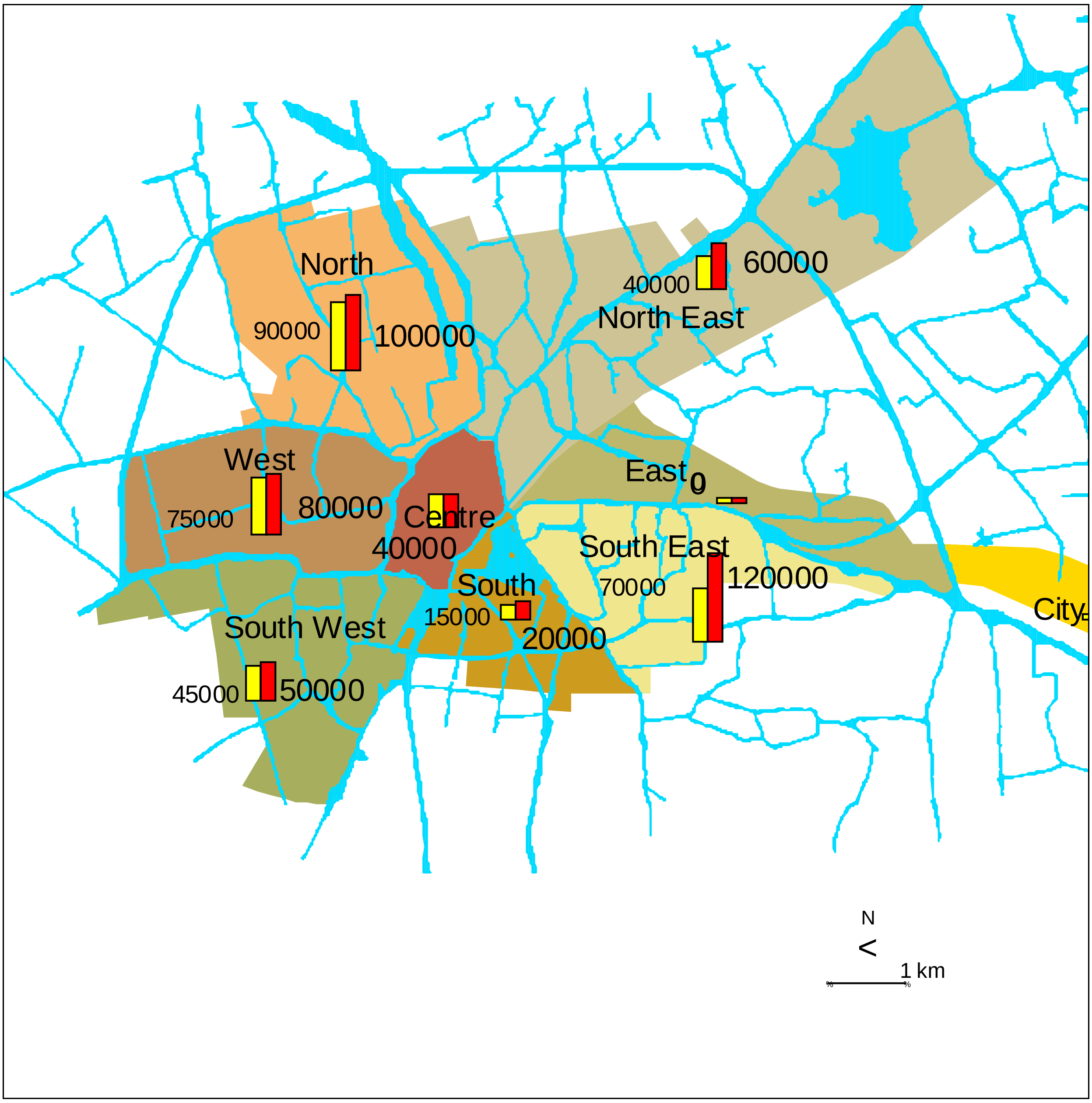


Figure 11: Population in the years 2000 and 2020

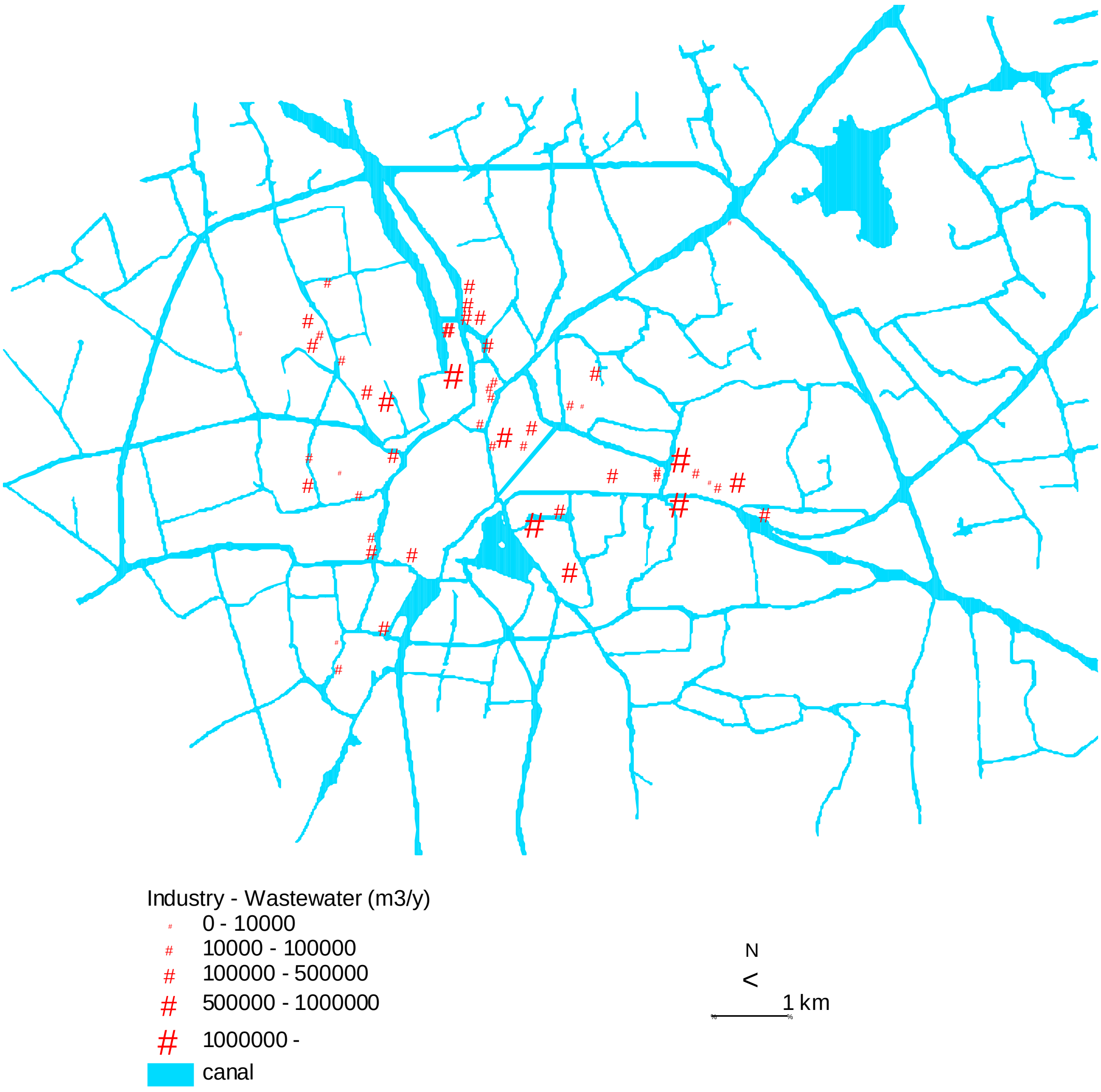


Figure 12: Effluents from industry in 1995

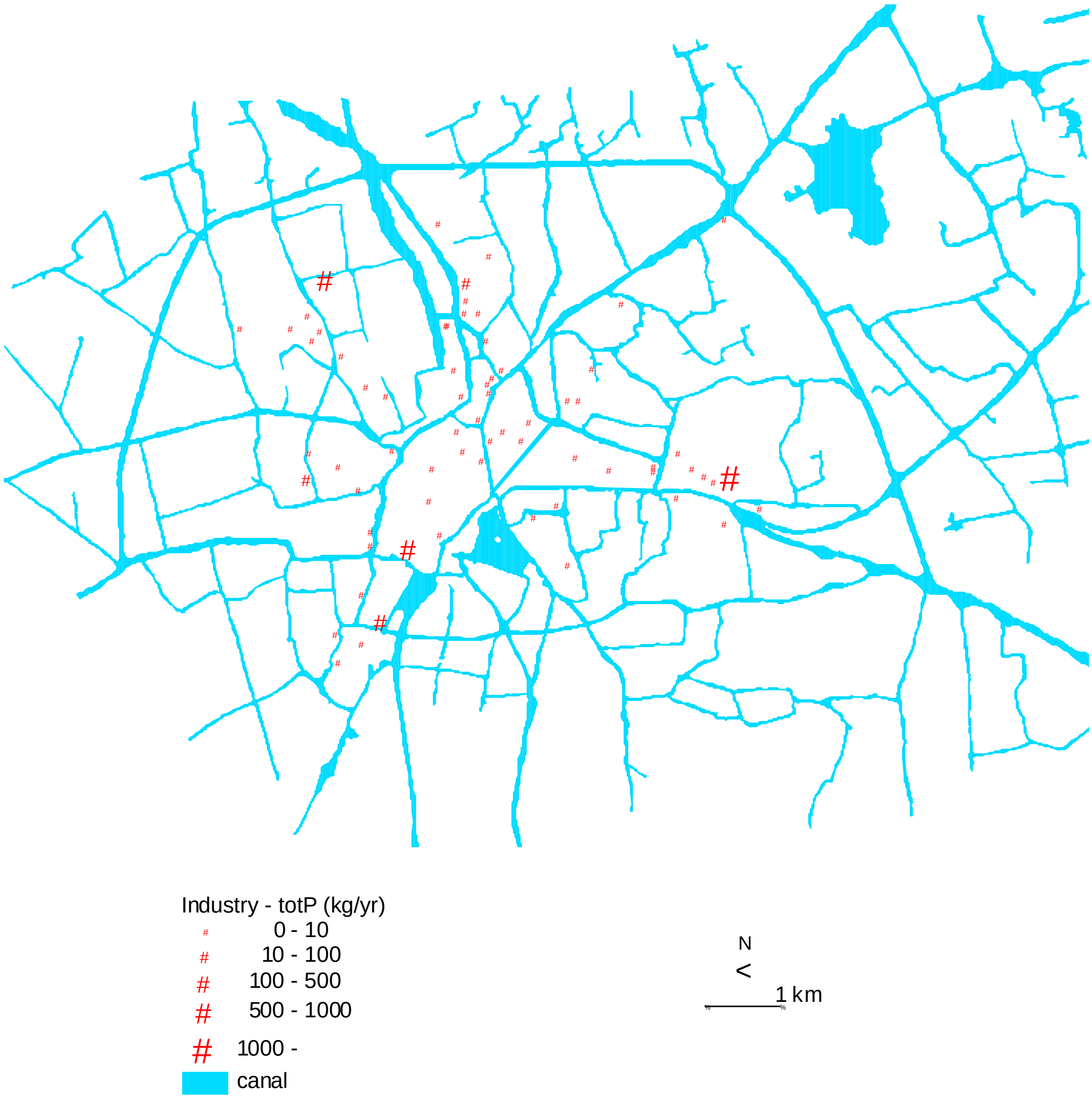


Figure 13: Phosphorus from industry

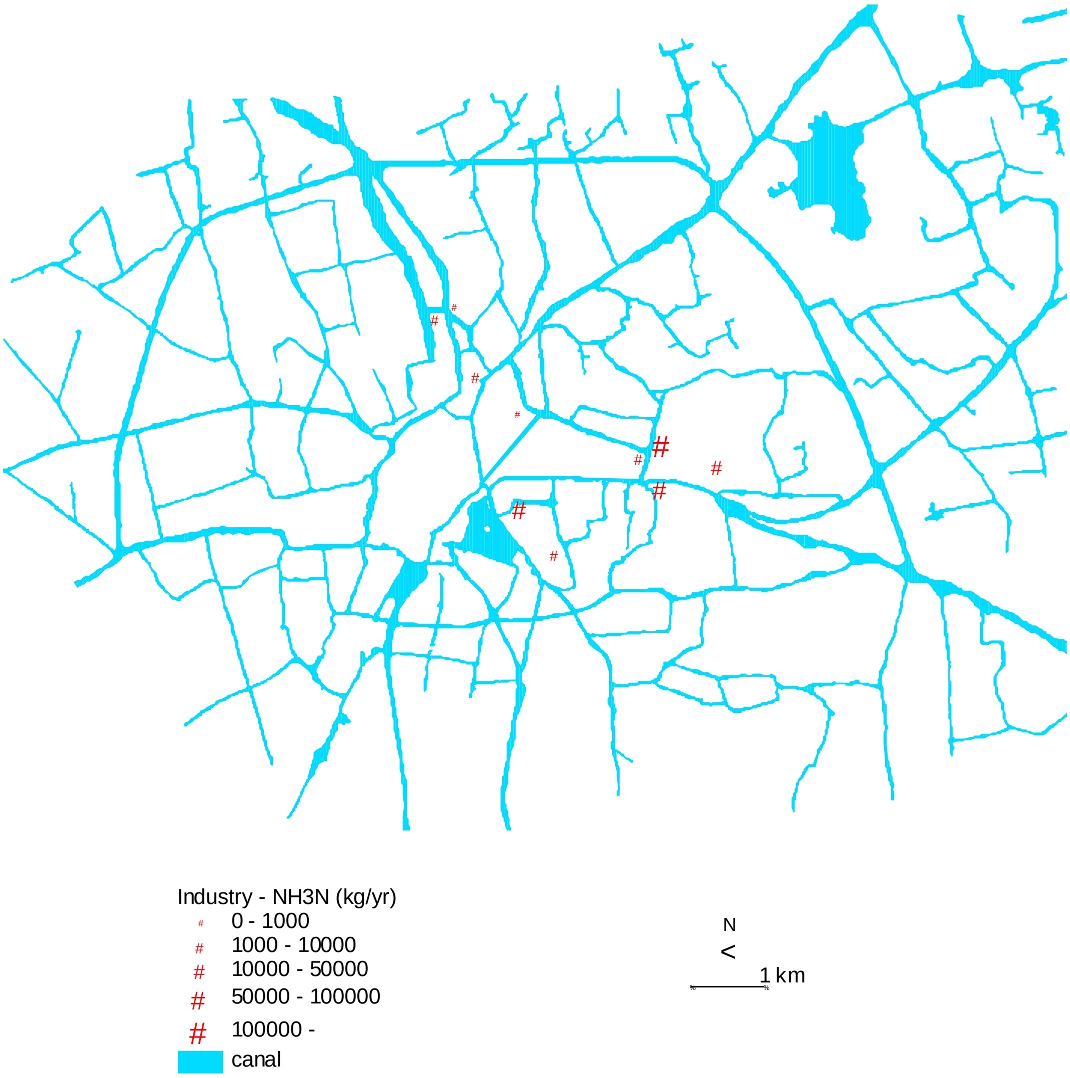


Figure 14: Ammonia from industry

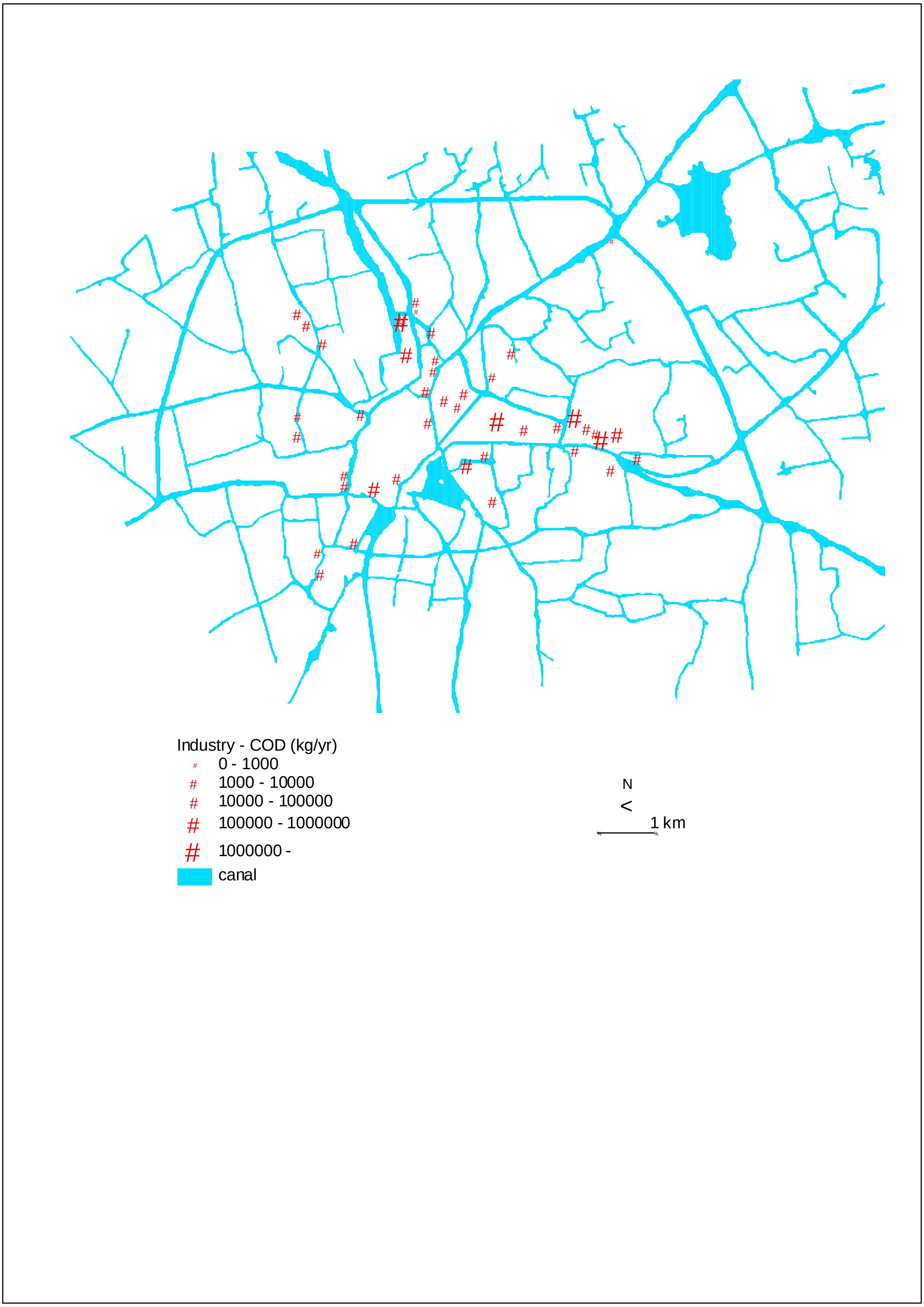


Figure 15: COD from industry

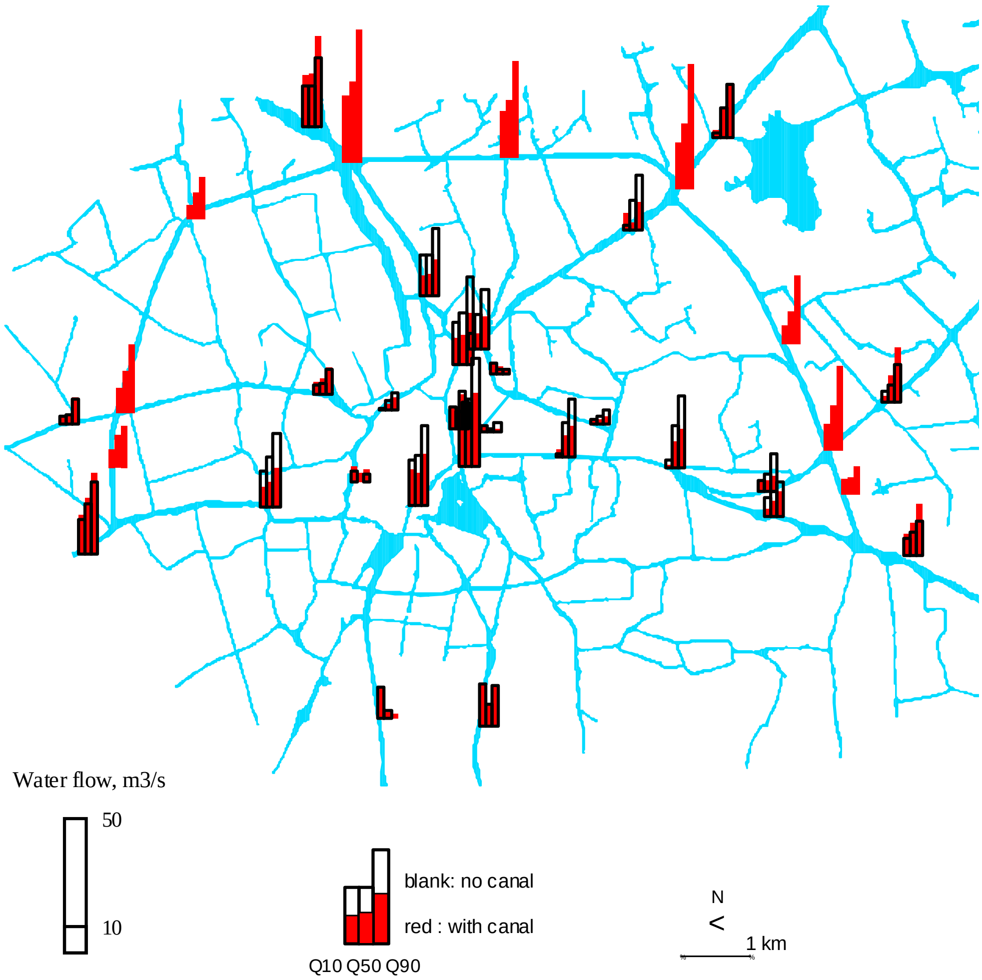


Figure 16: Low, mean and high water flow, with and without the ‘round-the city’canal

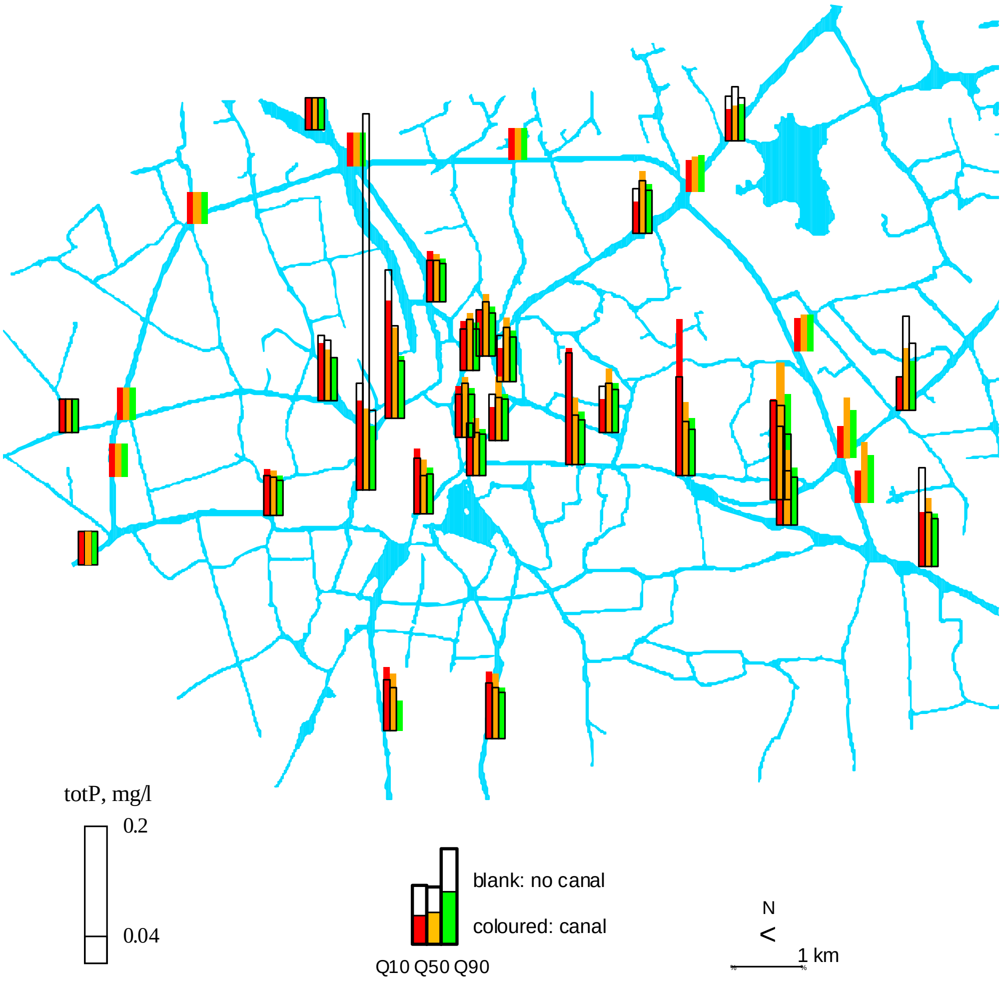


Figure 17: Effects of water flow and the ‘round-the city’ canal on phosphorus concentrations for 2000

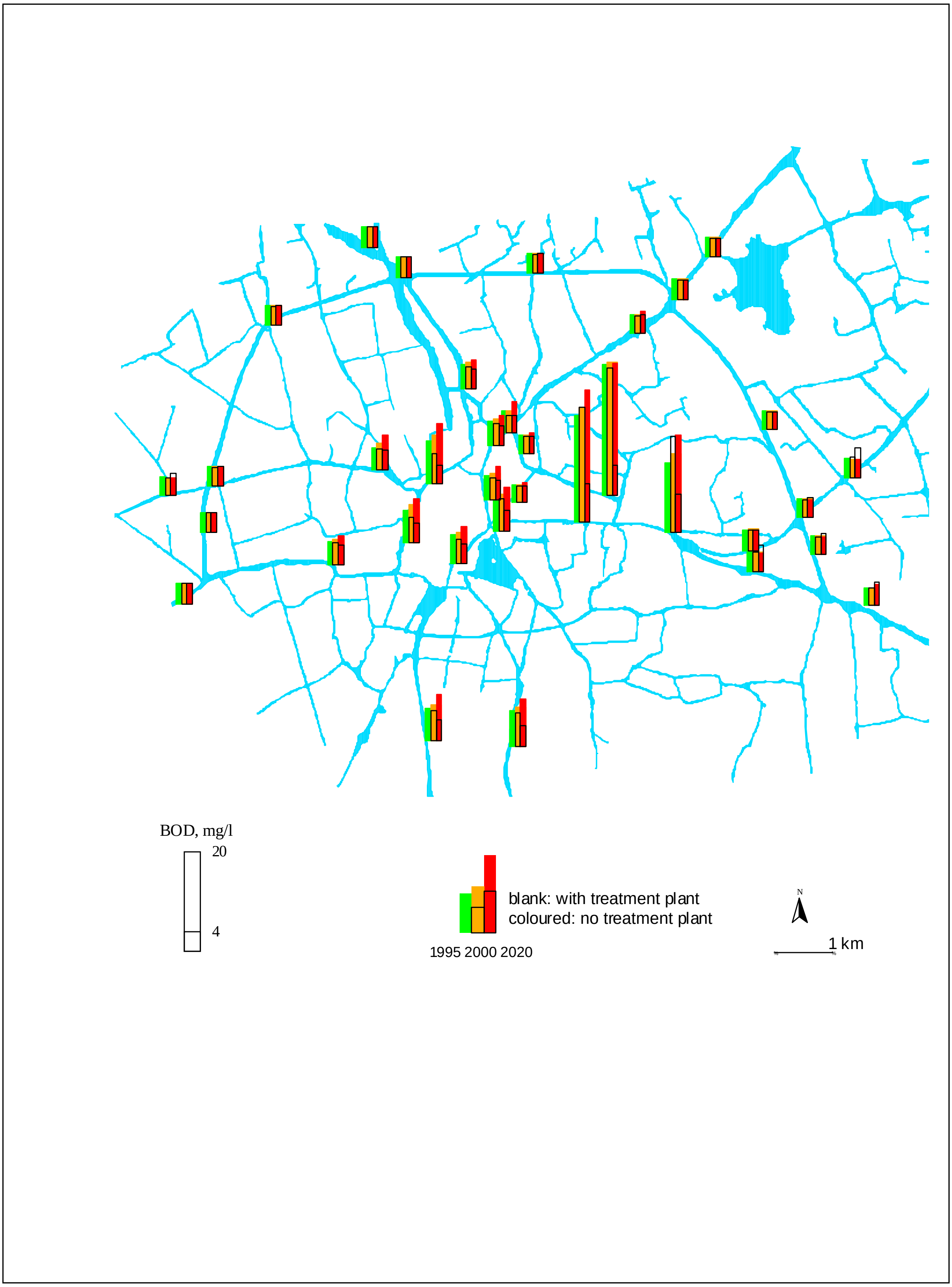


Figure 18: Simulated BOD concentrations 1995, 2000 and 2020 with and without treatment plant at low water flow

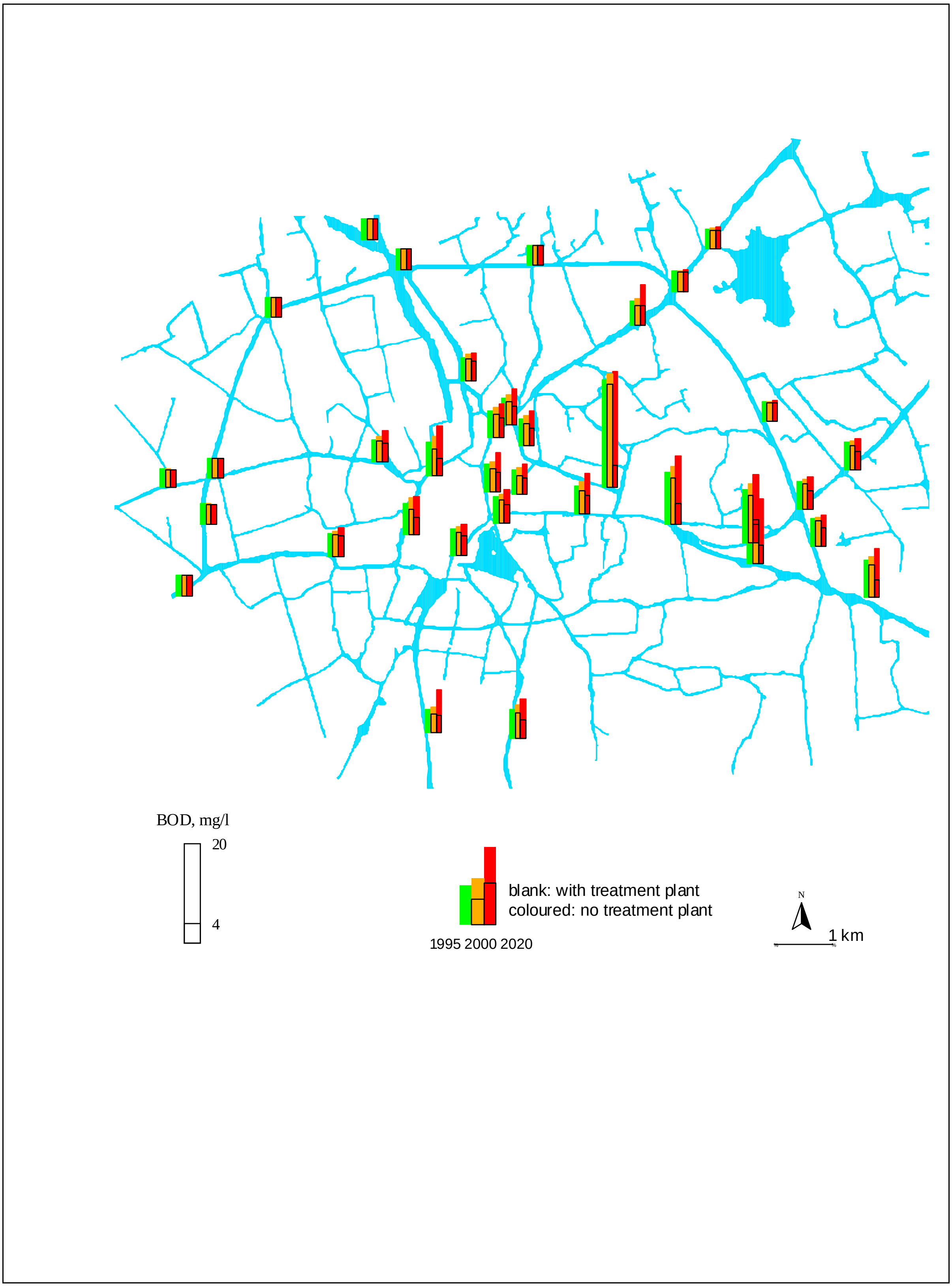


Figure 19: Simulated BOD concentrations 1995, 2000 and 2020 with and without treatment plant at mean water flow.

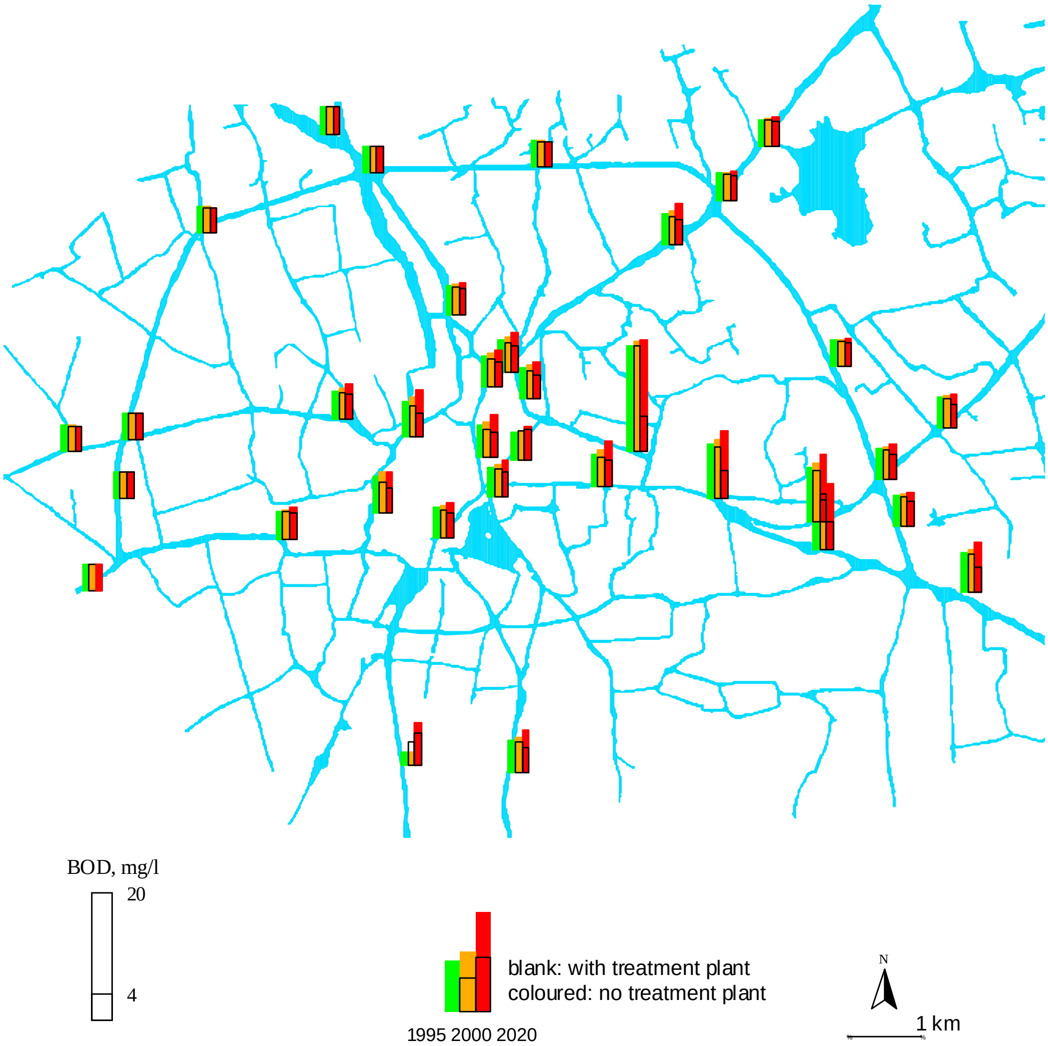


Figure 20: Simulated BOD concentrations 1995, 2000 and 2020 with and without treatment plant at high water flow

Figure 21: Increase in biological oxygen demand, BOD, above background concentration for the year 2020 at median water flow, no treatment plant.

17. Abatement Strategy

17.1 General

Water resources development and management are planned in an integrated manner, incorporating environmental, economic and social considerations. An Abatement strategy is a comprehensive methodology to use in the management of rivers and lakes to reach a better water-quality.

This project has resulted in a preliminary rough screening of easily available monitoring data and industrial sources lists, to identify the most important water quality problems (e.g. eutrophication/organic load, hazardous substances). Such a screening facilitates the data collection process by focusing on parameters qualifying the identified problems. This has been carried out during the project both for the purpose of wastewater treatment facilities and for the quantification of the pollution load to the canals.

The classification of quality status should be based on measured concentrations that have two components; a natural component, which stems from natural processes in the catchment area, and a component, which stems from human influence, *e.g.* effluents from industry and sewage, and agricultural runoff. The latter is defined as 'pollution'. The information provided about the natural component has been scarce.

The next step is to set water-quality goals. These should be set on the basis of user interests such as drinking, fishing and irrigation, and the goals related to aquatic life. The more detailed mapping of existing user interests has been carried out by JEPB.

The basis of a sound Abatement strategy is the catchment area. Discharges/losses of pollutants located upstream Jiaxing have effects and influence the situation in Jiaxing City. On a larger scale, it is therefore not sufficient only to consider pollution sources within the city, but also upstream.

17.2 Achievements

The project has managed to provide an outline of an abatement strategy for use in a future more specific detailed goal orientated strategy. The existing Chinese water quality classification systems and relevant sections of the Norwegian system, are annexed for information and comparison purposes (see Annex 1). Further work to adapt the monitoring programme (relevant parameters for the specific Jiaxing related pollution problems) to the classification system and user interests, is necessary.

17.2.1 Outline

An Abatement strategy is a comprehensive methodology used in the management of water bodies to reach a better water quality.

Some basic elements are considered when developing an abatement strategy:

1. Water-quality goals are to be set. These should be set on the basis of user interests, such as drinking, fishing, irrigation, and the goals related to aquatic life.

2. Discharge of pollutants upstream will have effects downstream. It is therefor not sufficient only to consider at pollution sources within ones own administrative area, but also upstream and downstream ones municipality or county. Of this follows that the basis of a sound Abatement strategy is the catchment area.

3. When trying to reduce the concentration/quantity of a polluting substance in a river/canal/lake, for instance COD, the source could be industrial (e.g. pulp and paper or brewery), municipal wastewater from households or fertiliser from agriculture. In that respect, a wise strategy would be to take all sources of a given pollutant into consideration. That means that possible/potential sources need to be identified.

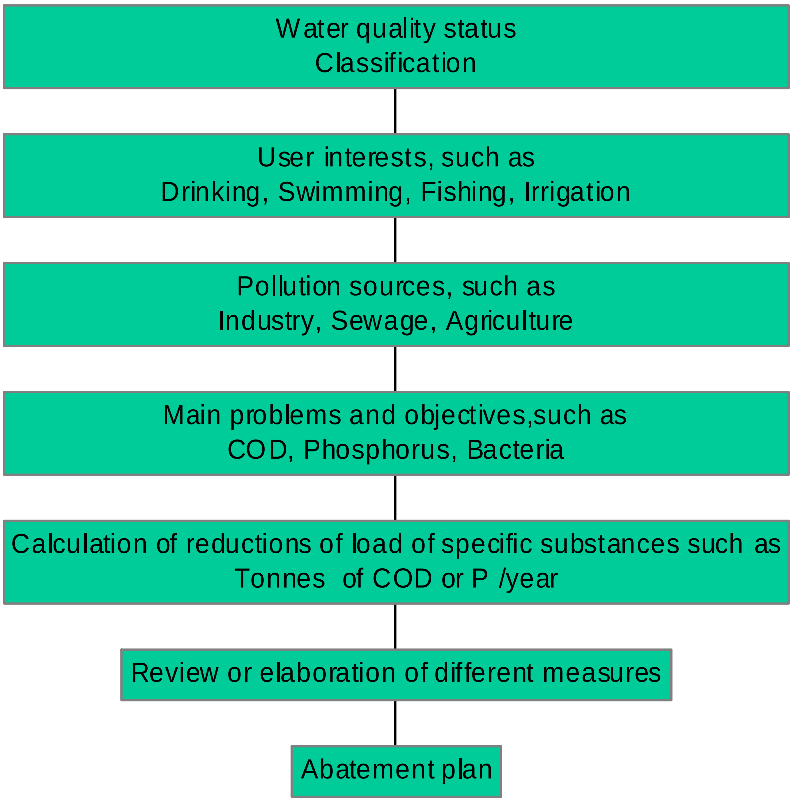


Figure 22. Elements or working tasks a possible abatement strategy could consist of.

17.2.2 Sources

Industrial plants

It is necessary to identify those sectors that may discharge significant quantities of polluting substances (possible linked to preliminary screening). For example if eutrophication is an environmental problem in water study area, the below listed industrial sectors may discharge phosphorus and/or nitrogen directly to surface waters:

- Fertiliser industry;
- Food and drink related industry, incl. dairy industry, soft drinks, wine production and brewing industry; meat and fish processing, alcoholic beverages manufacture and bottling, manufacture of fruit and vegetable products, manufacture of gelatine, production of yeast;
- Organic chemical and biochemical industry, incl. pharmaceutics, detergents industry, manufacture of glue, production of industrial alcohol, manufacture or removal of ink;
- Waste processing industry, including manure processing industry;
- Pulp and paper industry;
- Cokeries and refineries; and
- Other sectors, such as non-ferrous metal industries that are considered to be of catchment related or national importance.

Wastewater

It is necessary to take account of:

- Discharges by combined sewer systems;
- Discharges by separate sewer systems;
- Discharges by sewer systems that are not connected to a waste water treatment plants
- Losses from households not connected to sewerage into aquatic systems.

Urban wastewater means domestic wastewater or the mixture of domestic wastewater with industrial wastewater and/or run-off rain water. Domestic wastewater means wastewater from residential settlements and services, which originate predominately from the human metabolism and from household activities

Diffuse sources

Any source that is not accounted for as a point source, is a diffuse source. Small, dispersed point discharges (e.g. from scattered dwellings or from point sources in agriculture, e.g. farmyards) should be dealt with as diffuse sources. Based on this definition, losses from scattered dwellings are diffuse sources.

- Agricultural land;
- Other land categories;
- Direct atmospheric deposition on inland water surfaces; and
- Natural background losses.

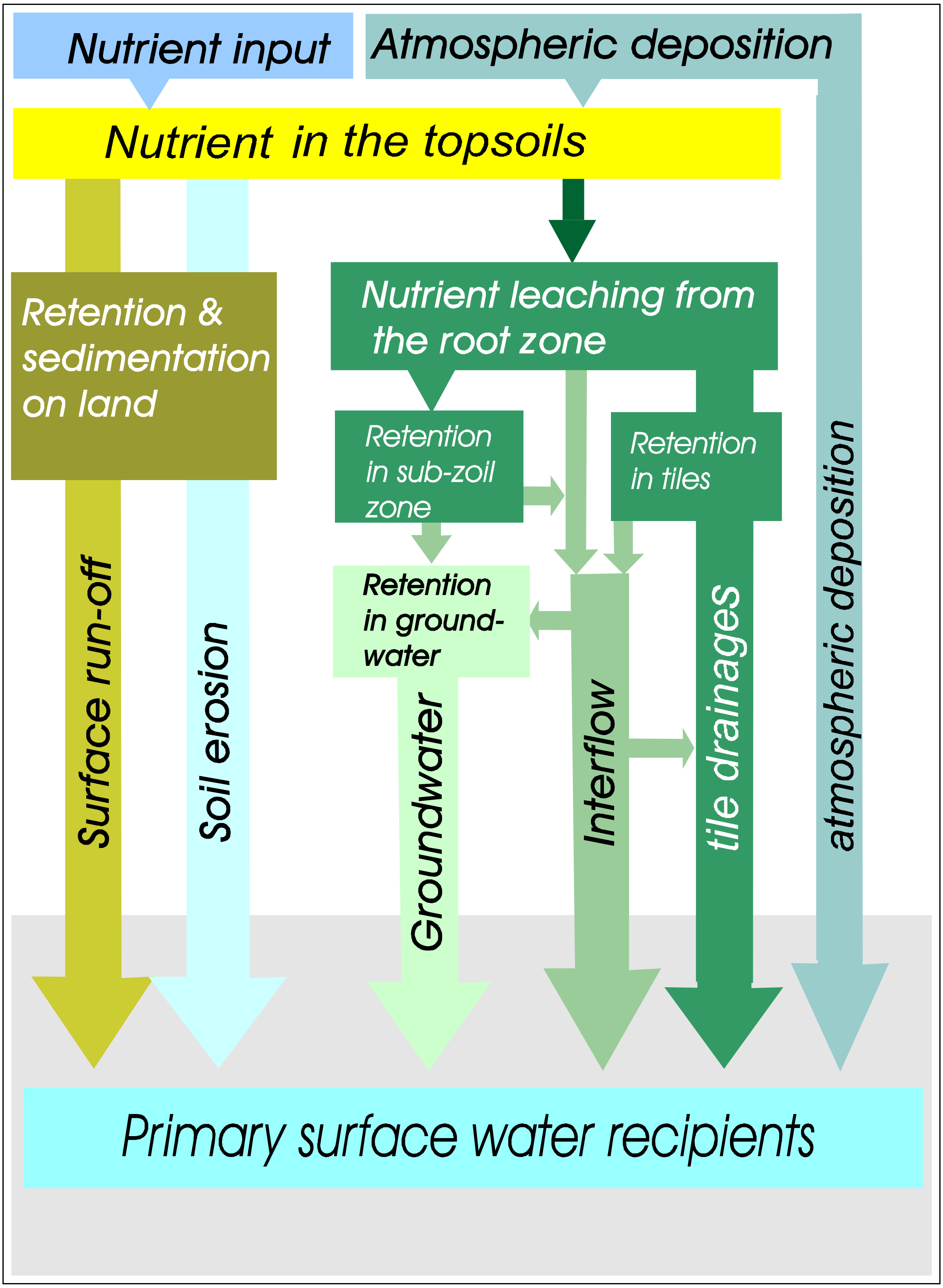


Figure 23: Pathways of nitrogen and phosphorus losses from diffuse sources to primary surface water recipients (HARP Guideline 6)

Natural background losses are losses that would occur from unpaved areas if they were unaffected by human activities (except anthropogenic atmospheric deposition) and if they were in the state of natural pristine land.

Natural background losses are part of the total estimated inputs to primary surface water recipients and include:

- Losses from unmanaged land; and
- That part of the losses from managed land that would occur irrespectively of anthropogenic activities.

Direct deposition of anthropogenic origin of substances from the atmosphere onto inland waters. Direct atmospheric deposition of specific substances on inland waters may represent an important input for some substances and should be quantified where it is considered as a major source of the total inputs to inland surface waters. The atmospheric deposition on land is accounted for within the quantification of specific substances reaching the primary surface water recipients via the soil-related pathways.

The potential inputs to primary surface water recipients are transferred via a number of pathways. A large number of removal, storage or transformation processes may influence the final quantities of specific substances entering primary surface water recipients. The loss pathways to surface waters include:

- Losses by surface runoff (transport of dissolved substances);
- Losses by soil erosion(transport of particular, adsorbed substances)
- Bank and riverbed erosion;
- Losses by artificial drainage flow (through drainage pipes/tile drainage);
- Losses by leaching (net mineralisation, percolating waters i.e. interflow, tile drain flow, spring water and groundwater); and
- Direct atmospheric deposition on inland waters

Agriculture

Pollution from agriculture is often divided into two categories, diffuse pollution from runoff from the areas, and direct (point) sources from manure tanks etc.

The latter can be quantified on the background of the number of animals, which kind of animals, how many month a year they are inside the barn, and the type of manure tanks in use.

The diffuse sources from the crop areas are more difficult to estimate. Soil losses are often calculated using a version of USLE (Universal Soil Loss Equation) calibrated for the conditions in the country or region in question. The equation takes into account the soil erodibility the slope length, the slope steepness and the cultivation system (crop type, fertiliser use)

The load from the agricultural areas can also be estimated on the basis of empirical data (monitoring data from different fields).

Whatever method is used for quantifying the losses, the result is a loss coefficient, for example 80 kgP/km^2*year.

Households not connected
The quantification should be made on the basis of national statistics. The national statistics should be as up to date as possible. It is possible that the national register will provide information on:

- The number of households not connected to sewerage systems; and of
- The number of people living in the households, taking account the ’part of the year inhabitants’ (e.g. offices, shops, hotels, tourist accommodations and secondary houses).

General statistics should provide information about:

- The waste-water treatment methods and water consuming devices in the households; and
- Location of the households in relation to watercourses (if available) and soil conditions (the part of the load actually reaches the surface waters).

17.2.3 Retention

Retention is, *inter alia*, a function of temperature, physical characteristics of rivers, lakes and canals, such as residence time (lakes) and specific runoff, hydraulic load and bottom characteristics (rivers). Many of these parameters are difficult to measure, and therefore difficult to implement in calculation procedures. In general, nitrogen retention is more influenced by biological processes than the phosphorus retention, whereas the phosphorus retention is more influenced by sedimentation processes than the nitrogen retention.

Parameters influencing nitrogen and phosphorus retention are, *inter alia*, renewal time in lakes, input of nitrogen and phosphorus to freshwater systems, trophic level, oxygen condition, volumes of lakes, temperature, nitrogen fixation, general water chemistry, water vegetation and human activity in the catchment.

In most cases, nitrogen and phosphorus retention is quantified on the basis of the mass balance of investigated canals, lakes and rivers. The different methods may be divided into the following categories:

- Models of nitrogen and phosphorus retention based, on the mass balances of river systems (including both rivers, canals and lakes)
- Models of nitrogen and phosphorus retention based on mass balances of lakes and transformation of these findings related to the whole river system,
- In-situ measurements or other types of measurements that provide retention coefficients for nitrogen removal in streams and rivers.

The following factors are considered to be important when quantifying the retention of nitrogen and phosphorus in a catchment:

- The portion of lakes, canals, river stretches and wetland in each catchment;
- The hydrological and morphological conditions within the river system; and
- The development of retention coefficients or methods f6r both nitrogen and phosphorus should be based on national and/or international research on retention in different freshwater systems.

The canals in Jiaxing will have many mechanisms closely linked to lakes, as the water is running very slowly. The releases of e.g. nutrients from the sediments to the water column may be very important (see also Figure 24, possible reactions and releases). The construction of the ‘round- the city) canal, that forces the boat traffic out of the city may, paradoxically, entail a degradation of the water quality as the turbulence caused by the heavy loaded boats contributed to a surprisingly high oxygen level in the entire water column (3-4 mg/l), taking into account the heavy organic load and the almost stagnant water in the canals.

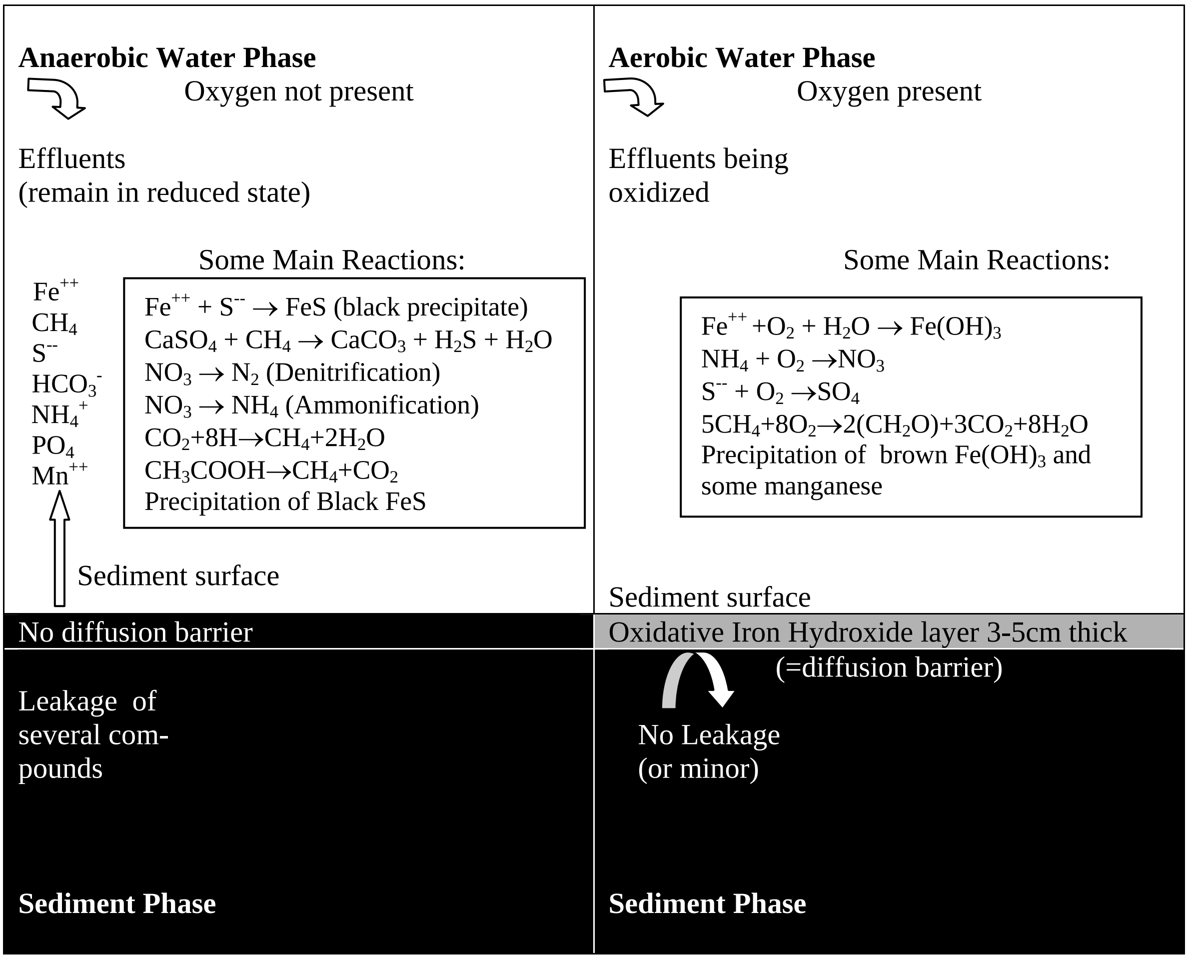


Figure 24: Outline of some important possible reactions at a sediment water interface (Anaerobic Phase – Left Panel) and after the water has been aerobic for some months (Aerobic Phase – Right Panel) (Dag Berge, NIVA- pers.com.)

18. Recommendations

Due to a lack of data for many of the main aspects of the Abatement Strategy, it is necessary to carry out further work on data collection. This concerns both the collection of background data (e.g. from agriculture) and monitoring data (industry and river/lake monitoring) in order to establish a sufficiently complete pollution load for the catchment and the sub-catchments. On the basis of this pollution load quantification and the local/regional/national water quality goals (that take user interest into account), it will be possible to quantify more accurately the reductions necessary to reach the goals.

1. The point sources, i.e. the individual main discharges (or a number of discharges in close proximity) into the canals, such as the effluents discharged from a sewage collecting system via an outfall pipe or channel and the industrial sources, have been mapped to a certain extent. The mapping of sources outside the city (influencing the incoming water) should be pursued. This is particularly important for diffuse sources, i.e. losses from scattered dwellings, agricultural land other land categories, direct atmospheric deposition on water surfaces; and natural background losses.

2. The quantification of retention in the load quantification procedures is, *inter alia*, a function of temperature, physical characteristics of water bodies, such as residence time (lakes) and specific runoff, hydraulic load and bottom characteristics (rivers). Many of these parameters are difficult to measure, and therefore difficult to implement in calculation procedures. It is necessary to increase knowledge about the hydrological and morphological conditions within the canal system;

3. The organic load and the eutrophication (nutrients) are perceived as the main canal related water quality problems. In order to get an improved picture of the organic matter problem in the canals, a revised monitoring scheme should be applied:

- Biological Monitoring
  - Proposal for 'low level biological monitoring programme
- Sediments
  - Current status sediment survey
  - Routine sediment monitoring programme

- Revision of the existing Chemical Monitoring Programme
  - Assess the existing monitoring programme, taking account in particular industrial activities
  - Revised chemical monitoring programme

The data should be assessed with regard to reliability- Quality Assurance Procedures.

4. It is recommended that the classification in water quality criteria take account of the suitability of the water for different uses, such as swimming, fishing, irrigation and drinking. In areas or situations where unsatisfactory conditions have been identified, an action plan for mitigation should be suggested.

5. Upgrading of laboratory performances to international standards of analytical quality and sensitivity should be carried out, wherever necessary; possibly on the basis of results of intercomparison exercises.

6. Ideally, all industrial plants that discharge polluting substances should have a monitoring programme. Practically it is necessary to ensure that at least the most important industrial plants as regards the substances of concern have an adequate monitoring

programme. Practical difficulties will arise when there are small plants with small discharges. It will therefore, in many cases, be necessary to agree on a ‘discharge limit figure’ for the purpose of distinguishing between significant and less significant annual discharges.

7. Spatially accurate land cover and/or land use data is a prerequisite for assessing diffuse losses of nitrogen and phosphorus to surface waters. Land use data should provide a more detailed classification of the nature of agricultural practices (e.g. stocking density, areas of different arable crops). This level of detail can be important as for example diffuse N and P losses may vary with arable crop type.

8. It is necessary to further develop a more complete user interest map” (swimming, fishing, irrigation, others) for the entire canal system. It is also necessary to develop a list of possible measures, the cost of their implementation and the effects of implementing the measures.

CHAPTER 3

Project activity 3:

Preliminary Evaluation of an Alternative Location for the WWTP-1

19. Background

The starting point for this activity is that there are two alternatives for location of the WWTP-1 - serving the Northwest section of Jiaxing city -see maps. This chapter presents the discussions from the early stage of the project, before the ocean discharge alternative was introduced.

The Construction and Planning Commission (CPC) - which represents the municipality of Jiaxing recommends to stay with the original decision of location - at the outskirts of the city near the newly -or to be- constructed canal Bei Jiao surrounding the city. The plan for this location (which we call alt. A) has existed for some 15 years, and CPC has a vast amount of sewer-pipe plans with this site as the end station.

JEPB on the other hand wants to consider an alternative site location (called alt. B) some 5 km to the south east of the alt. A - for two reasons:

- The site is closer to the city centre - thus can be serving the majority of the city at a quicker pace than Alt. A.
- Alt. B is closer to the sea (Hangzhou bay) which on the long term is the goal for sewage treatment not only for Jiaxing but also for the surrounding 5 counties.

The Norwegian project (NP) learned about this dilemma on the last mission (96-01) in November 1996, and at that time worked out a check-list to help JEPB to put weight on as many arguments and reasons as possible. The NP emphasised that the final choice had to be made by the relevant authority, while NIVA could only point to a more systematic approach in reaching a decision. This activity can only point to a general knowledge concerning site selection. The local background and a know-how must be decisive when choosing between alternatives A and B.

Most of the criteria for choice of site are the same for both alternatives. Probably the most significant difference is the quality of the recipient to where the treated effluent is being led.

The JEPB representatives explained that the treated water from site A has to be pumped through a pipe 3 km along the new Bei Jiao canal from where it follows natural waterways Jia Shan in to Huang Pu river. The quality of this receiving water is high and Mr Song is worried that the river will be impacted negatively - due to the discharge from WWTP-1.

On the other hand the discharging point from site B is 4-5 km due west to the Bei Jiao canal at a stretch with considerably lower flow, which also ends up in the river Ping Hu. Ping Hu is downstream from the future WWTP-2 in the industrial area - where the water is of considerably lower quality (class IV) and will probably remain of low quality in the future.

There is no difference between the two alternatives concerning choice of treatment-process, size/dimensioning, size of site, construction steps etc. In other words the effluent quality from the WWTP-1 will be the same in both alternatives. It is logical that the remaining polluting material in the effluent from Alt. A will lower the quality relatively more in a cleaner river than the same effluent into a river with lower quality.

20. Discussions

The group discussed the work that our water resources specialist has caried out during this project. This work may shed some light and some approximate figures on the ability of the two alternative recipients to dilute the effluent from A or B. The following input data is assumed needed for this exercise:

- Water flow: amount, variation during the year, direction.
- Water quality in the discharging points (and quality 2-3 km after): annual average, variation during the year, any estimation available.
- Existing (and any future) pollution discharge points from industries close to the discharge point and 2-3 km after.
- Estimated wastewater loads to the discharge points (volume, concentration/loads, variation during the year).
- Estimated reductions of pollution loading to the river due to the new sewerage collection (which will be sent to the WWTP-1 and be treated) and the impact of this on the water quality of recipients at discharging points.
- Goals for water quality criteria at the discharge points now, and in the foreseeable future.

The following answers are expected from this exercise:

- Systematic presentation (and verification using general rules of thumb) of the above information supplied by JEPB.
- Modelling of the impact of wastewater discharges on the recipient quality, with annual variations.
- Need for improvement of the treatment processes based on the required water quality goals for 2000, 2010, 2020.

The group then discussed the costs concerning collection of raw sewage from various points in the existing, serviced part of Jiaxing. It is a valid argument that a site located close to the majority of the existing sewers and sewage should have merit compared to a site further away from the existing sewage. On the little information available it seems, however, that the costs of collecting numerous waste streams in the canals and rivers surrounding the city centre of Jiaxing is the major expenditure and will be the same in both alternatives. Transporting the collected waste is somewhat longer for Alt. A than for Alt. B, but this extra cost is small relative to the cost of rehabilitation and tying the sewers together around the city centre.

Early 1998 it was suggested to lead all sewage in the greater Jiaxing area towards the ocean shore at nearby Hangzhou Bay. A large treatment plant should be constructed at Hangzhou Bay, which would then substitute the smaller WWTPs that were planned within Jiaxing City. The argument of bringing the sewage out in Hangzhou Bay is an important one - for the site selection - if these larger schemes are considered realistic for the foreseeable future. The plans from CPC to bring sewage from the south to the north will be contrary to this scheme - and will in the least postpone the possibility of bringing the sewage to the sea.

A possible thought, which may have some merit - is to look at the WWTP-1 and WWTP-2 in the heavily polluted industrial area at the same time. If site B is chosen the effluent could be brought Southeast in the vicinity of the location for the WWTP-2. The master plan activity will look into this possibility to some extent. The group concluded that the most likely choice would be site A, mainly because of the time factor involved, since CPC already have plans ready for this alternative, and the need to get started is of importance.

After all these discussions, the ocean-discharge alternative was re-introduced after having been supported by NIVA. Finally, it was decided to transport all sewage from the region to the ocean, and construct a large WWTP by Hangzhou Bay.

CHAPTER 4

Project activities 4, 5 (part 1), 7, and 10:

Impact Assessment of Combined Wastewater

(Domestic wastewater combined with industrial wastewater)

21. Introduction

Wastewater treatment processes are usually sensitive to industrial wastewater (WW). The presence of some industrial WW in the influent to the WWTP may result in a non-optimal treatment process or may even completely destroy the process causing serious environmental and economical problems. It has been estimated that the WW in Jiaxing consists of 50-70% of industrial WW, a fact that clearly indicates the seriousness of the problem.

Since beginning of this activity there have been several decision-making stages, which have motivated the project group to gradually move focus from local wastewater transport and treatment strategy to a regional solution called the Ocean Discharge alternative. During the first part of the project, evaluations and documentation about Jiaxing city has been put forward. However, in this report focus will be on the Ocean discharge alternative. Because the final decision about choosing the Ocean discharge alternative came at a relatively late state of the project, the detailed examinations were limited to the Jiaxing City. For the rest of the sub catchments which will drain to the Ocean Discharge Waste Water Treatment Plant (OD-WWTP), only preliminary analysis have been carried out. In future planning and detailed design of the OD-WWTP, it is strongly advised to evaluate other sub catchments in the same way as we have done in Jiaxing, in order to have sufficient and reliable design data for the future stepwise construction of the OD-WWTP.

22. Objective

The main objectives for this activity was:

- To establish basic documentation and knowledge for impact assessments of industrial WW to the planned Ocean WWTP in general and in Jiaxing City especially.
- To evaluate the robustness of WW treatment processes to combined WW by pilotplant experiments and labscale tests (chemical and biological), together with modelling and simulation work

23. Work description

In order to achieve the main objectives, several activities have been carried out by JEPB and NIVA. The work started up in February 1997 and was finalised in October 1999.

Following activities have been carried out:

- General evaluation and recommendations regarding pre-treatment of industrial waste water Collection and editing (computerised) of existing and measured WW quality data. Adaptation and preparation of all WW data and results in a database for presentation in ArcView (a Geograpiphcal Information System, GIS for regular computers). Evaluations, calculations and modelling/simulation of future loads to the planned Ocean Waste Water Treatment Plant (OD-WWTP).
- Pilot plant experiments and labscale tests: Design, construction and operation of a mechanical, chemical and biological pilot plant, experimental scheme for pilotplant and labscale tests, follow-up s activities during testing, evaluation of results.
- Evaluation, design, modelling and simulation of suggested OD-WWTP process configurations. Design and modelling were among other factors based on calibration data from pilot plant experiments and labscale tests.

In the following results and conclusions from all activities are presented.

24. Strategies for management and pre-treatment of industry wastewater

Waste Water Treatment Plants (WWTPs) collect wastewater from homes, commercial buildings, and industrial facilities and transport it via a collection system to the treatment plant. The selected regional concept for Jiaxing will include several cities and large industries, where evaluation and decision of transport and treatment strategies will be of vital importance for future environmental (and economical) conditions in the planned collection system, the Ocean waste water treatment plant and recipient.

Generally, WWTPs are designed to treat typical household wastes and biodegradable commercial and biodegradable industrial wastes. The contaminants from these sources are often called conventional pollutants and include nutrients (organic matter as BOD, nitrogen and phosphorus), suspended solids, faecal coliform and oil/grease. Commercial and industrial facilities may, however, discharge toxic pollutants that the treatment plant is neither designed for nor able to remove. In fact they can cause serious environmental problems. Volatile organic substances discharge to sewers can accumulate in the headspace of sewers, increasing the likelihood of explosions that can cause significant damage. Furthermore, discharge of toxic organic compounds can also result in the release of poisonous gas. This occurs most often when acidic wastes react with other wastes in the discharge. These gases can be highly dangerous to WWTPs collection system operators exposed to such conditions in the performance of their duties. Other problems associated with toxic discharges include air pollution, corrosion of collection system and treatment plant, and groundwater pollution.

The undesirable outcome of these discharges can be prevented using treatment techniques or management practices to reduce or eliminate the discharge of these contaminants. The act of treating wastewater prior to discharge to a WWTP is commonly referred to as "pre-treatment".

The objectives of a pre-treatment program should be:

a) Prevent the introduction of pollutants into WWTPs that will interfere[1] with the operation of a POTW, including collection system, treatment plant and interference with its use or disposal of municipal sludge.
b) Prevent the introduction of pollutants into WWTPs which will pass through[2] the treatment works or otherwise be incompatible with such work
c) Improve opportunities to recycle and reclaim municipal and industrial wastewaters and sludges.

In the US, specific prohibitions forbid eight categories of pollutant discharge as follows:

1) Discharge containing pollutants that create a fire or explosion hazard in the WWTP, including wastestreams with a closed cup flashpoint of less than 60 ^{o}C.
2) Discharge containing pollutants causing corrosive structural damage to the WWTP, but in no case discharges with a pH lower than 5.0, unless the WWTP is specifically designed to accommodate such discharges
3) Discharges containing pollutants in amounts causing obstruction to the flow in the WWTP resulting interference

[1] Interference: A discharge which inhibits or disrupt the MWWTW, its treatment processes or operation, or its sludge processes, use or disposal.
[2] Pass through: A discharge that exits the MWWTW into waters in quantities or concentrations that is a cause of a violation of any permit requirement.

4) Discharge of any pollutants released at a flow rate and/or concentration which will cause interference with the WWTP
5) Discharges of heat in amounts which will inhibit biological activity in the WWTP resulting in interference, but in no case heat in such quantities that the temperature at the WWTP treatment plant exceeds 40 ^{o}C unless specially approved alternative temperature limits
6) Discharge of petroleum oil, non-degradable cutting oil, or products of mineral oil origin in amounts that will cause interference or pass through
7) Discharges which will result in the presence of toxic gases, vapours, or fumes within the WWTP in a quantity that may cause acute worker health and safety problems
8) Discharge of trucked or hauled pollutants, except at discharge points designed by the WWTP

These prohibited discharge standards are intended to provide general protection for WWTP. To follow up these intentions categorical pre-treatment standards and local limits are set. PRC also has standards for discharge limits to WWTP. Examples of "State Standards" discharge limits in PRC are presented in the Master plan sketch, activity 1.

The choice of pre-treatment strategy/level of one specific industry strongly depends on the wastewater characteristics and amounts. This means that individual evaluation and possible pre-treatment claims must be performed at each industry that will discharge to the future Ocean WWTP (or local recipients). Individual evaluation of all industries has not been a part of this project. However, we strongly advise that such a study should be carried out in the whole catchment area that will drain to the planned OD-WWTP.

For Jiaxing City, our general opinion is that for the time being, present discharge limits for industries to local recipients should be maintained also for the future discharge to collection system. Possibilities for reduced or omission of existing pre-treatment at industries should be based on individual analysis and evaluation of discharges from each industry, in accordance with discharge limits in PRC's State Standards.

Since wastewater streams characteristics will vary a lot within a single industry and from industry to industry, many pre-treatment strategies exist. Figure 25 on next page shows a simple overview over main strategies for industry wastewater handling and treatment, integrated with a "cleaner technology" concept.

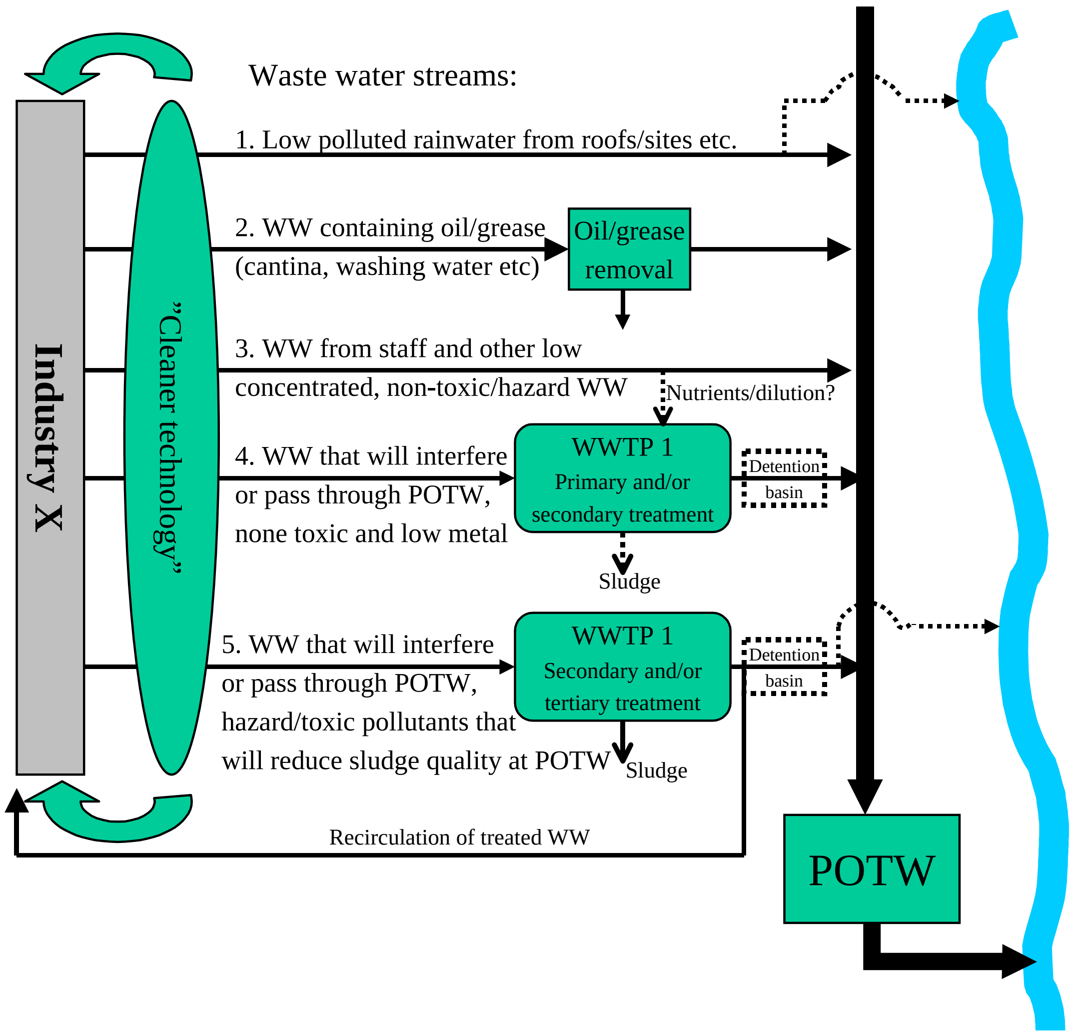


Figure 25. Strategies for industry waste water management and pre-treatment.

25. Waste Water quantity and composition, existing and estimated future

25.1 Introduction

Collection and adaptation of wastewater data has been done in the following steps:

- Editing of existing industries in Jiaxing City into ArcView as a point-theme (with geographical location, name and reference numbering).
- Existing discharge data from industries in Jiaxing City (discharges to canals). JEPBs database from 1996 was used as basis and adapted in a spreadsheet. Other requested information about industries were edited and finally included in an ArcView table as attributes to industry theme.
- Estimation of future industry discharge to main sewer system in year 2000 and 2020.
- Editing of sub-catchment areas, exiting and planned future population (year 2000 and 2020), and planned catchment areas with combined sewer system in Jiaxing City. All information is edited in ArcView GIS programme.
- Summary calculation of estimated WW quantity and composition from industries and domestic discharge from Jiaxing city to main sewer in year 2000 and 2020.
- Preliminary estimates of population, industry discharge and drainage areas/impermeable surface in other sub areas outside Jiaxing city which are planned to drain to main sewer, for year 2000 and 2020. Suggestion of design influent load to OD-WWTP.

25.2 Summary of collected and calculated discharge loads from Jiaxing city

Industrial wastewater

It has been estimated that the produced wastewater in Jiaxing City consists of 50-70% of industrial WW. It was therefor important to collect and evaluate data from all major industries in the city. The figure below illustrates what kind of industries that are dominating concerning wastewater production.

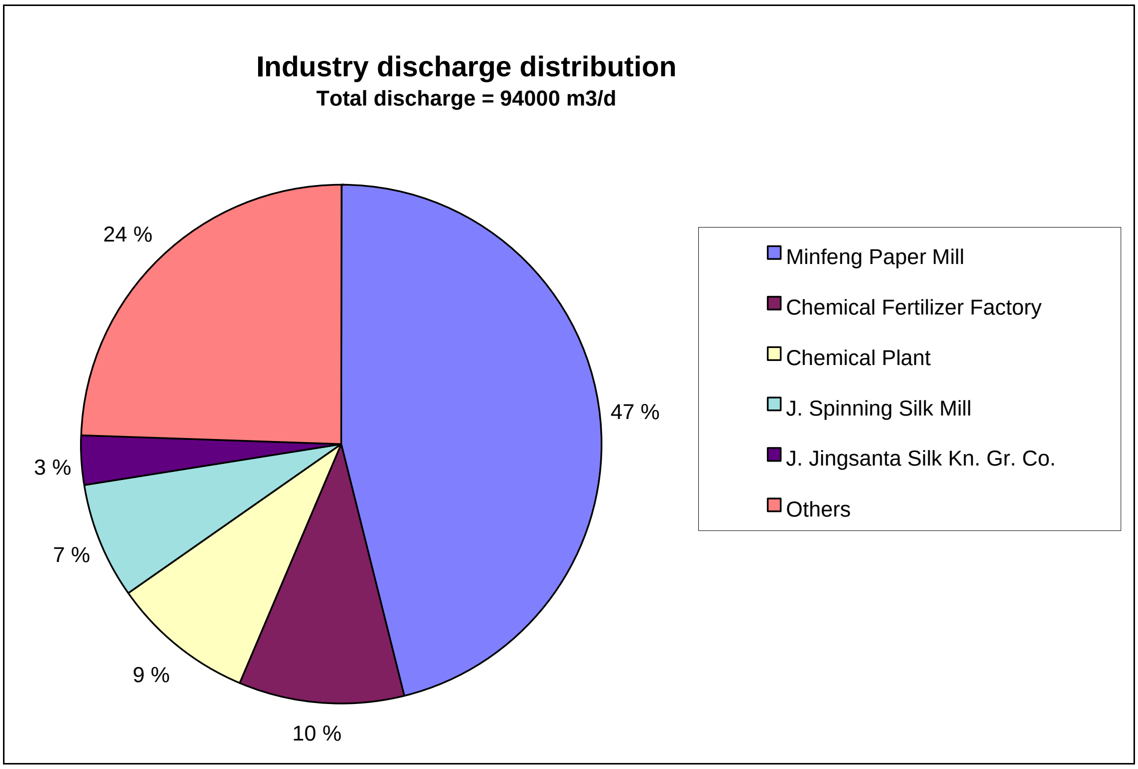


Figure 26. Existing (1995) industry discharge in Jiaxing City.

A database was established for all major industries and edited in Arc-View. Parameters such as placement, existing wastewater discharge site, type of industry, major toxic components used in production, number of employees, measurement and analyses of discharge wastewater (including toxic parameters) etc. were edited into ArvView. Table 27 shows a screenshot example form the database and a corresponding map-view from Arc-view (Figure 27).

Estimates of future discharge from industries are summarised in Table 28. All estimates assumes that future pre-treatment of industry wastewater will be at the same level as existing pre-treatment. Most of the data describing the existing situation were taken from JEPBs existing industry database. The project group made the estimates for future situation on the basis of input from Jiaxing Construction Bureau.

Table 27. Estimated future industrial discharges.

Enterprise	Ref_no_	Number of employees	Discharge to canal (m3	Cod
J. Jingsanta Silk Kn. Gr	8	2541	1047107	
J. Silk Dying and Printi	9	432	273475	
J. Dying and Printing Pl	21	98	13200	
Chemical Pant No. 3/4	53	372	113400	
J. Heat and Power Plant	1	454	374400	
Minfeng Paper Mill	2	5022	15825903	
J. Woolan Textile Factor	3	4769	761200	
Tanghui Cement Factory	4			
J. Spinning Silk Mill	6	3193	2495247	
No. 2 Woolen Textile Fac	7	1849	256000	
J. Iron and Steel Plant	10	1794	166000	
Chemical Fertilizer Fact	11	1345	3447600	
Winery	12	302	103334	
Oil Refinery	14	200	4050	
Plastic Rubber Factory	15	7612	303269	
Pesticide Plant	16		664051	
Nanhu Cloth-making Facto	17	1280	770610	
No. 5 Woolan Textile Fac	18	760	232866	
No. 6 Woolan Textile Fac	19	70	34400	
Bicycle Factory	20	1057	311313	
Dairy Products Factory	23	359	73200	
Art Paper Factory	24	155	24000	
Pharmaceutical Factory	26	351	210660	
Light Textile Auxiliary	27		87450	
5318 Factory	28	1067	198750	
Brewery	29		17225	
Cereal Products Factory	30	164	267438	
No. 2 Metallurgy Machine	31		530000	
Meat Products Plant	32	1500	238820	
Wenfu Sauced Duck Factor	33		19800	
Metallurgy Machinery Pla	35	3053	365095	
Sweets and Drinks Factor	36			
Artificial Leather Facto	37	257	11760	
Cotton Textile Mill	39	911	348000	
J. Brewery Factory	40		33660	
No. 36 Research Institut	41	1130	1800	
Aviation Cases Factory	42	1029	82550	

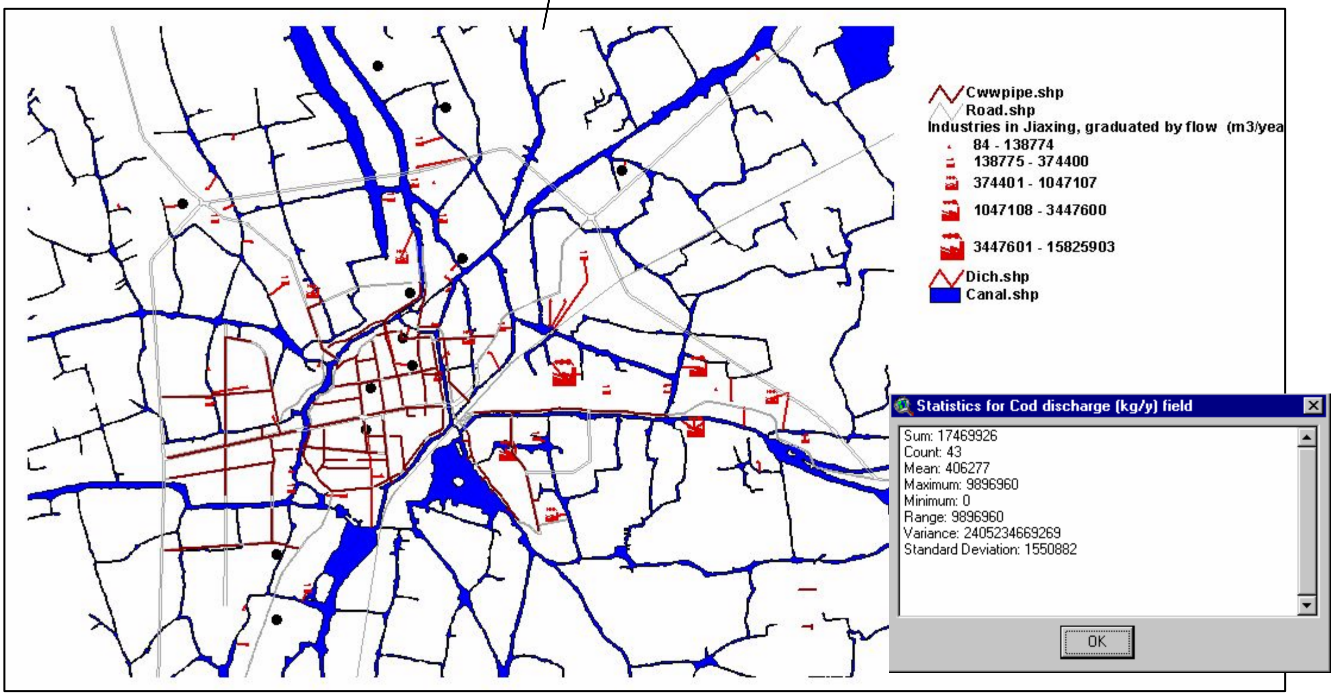


Figure 27. Industries in Jiaxing, graduated by flow (m3/year). The top layer shows a selection of the industry database while the bottom layer shows an example map from ArcView GIS. Existing discharge sites into canals are also shown (discharge to sewer system in future).

Table 28. Summary of estimated discharge from industries in Jiaxing City, year 2000 and year 2020

Discharge data from all industries in Jiaxing:					
			Industry + part of commercial WW		
			Year 1994	**Y 2000 (1994 + 10% unknown)**	**Y 2020 (30 % flow increase, 0% load increase)**
Parameter	**No. of data**	**Unit**	**Amount**		
Industries in database	65	no.	65		
Flowrates					
Q average	56	m3/year	34231263	37654389	48950706
Q average	56	m3/d	93784	103163	134112
Population equivalent		pe	468921	515814	670558
Q "max" average	52	m3/h	5568	6125	7963
Population equivalent		pe	668198	735018	955524
Q dim (1.2*Q max ave)		m3/h	6682	7350	9555
Q max dim		m3/h			
Organic load					
COD average	42	kg/year	17469925	19216917	19216917
COD average	42	kg/day	47863	52649	52649
Population equivalent		pe	354539	389993	389993
Concentraton		mg COD/l	510	510	393
COD "max" average	38	kg/h	3081	3389	3389
Population equivalent		pe	547694	602464	602464
Concentraton		mg COD/l	553	553	426
COD dim. (2* max ave)		kg/h	6162	6778	6778
COD max dim		kg/h			
BOD			"=0.3*COD"	"=0.3*COD"	"=0.3*COD"

(table, continued)

SS load					
SS average	34	kg/year	9628571	10591429	10591429
SS average	34	kg/day	26380	29018	29018
Population equivalent		pe	329746	362720	362720
Concentration		mg SS/l	281	281	216
SS "max" average	32	kg/h	1382	1521	1521
Population equivalent		pe	414719	456191	456191
Concentration		mg SS/l	248	248	191
SS dim (2* max ave)		kg/h	2765	3041	3041
TP load					
Concentration	assumption	mg TP/l		1	0.77
TP average	assumption	kg/d		103	103
TN load					
Concentration	assumption	mg TN/l		5	3.8
	assumption	kg/d		516	516

Domestic waste water

Figure 28 and Figure 29 show existing and estimated future population in Jiaxing City. Estimates and calculations of wastewater production from population are given below (Table 29 and Table 30).

A study of future transport system in Jiaxing City concluded that it was advantageous to choose a combined sewer system in the centre area because of expected high pollution in the run-off water. In the following analyses we have first made an analysis of pollution production excluded discharge and run-off from centre area. Thereafter a study of estimated total discharge from Jiaxing centre was carried out using a simplified run-off model (see next sub-section).

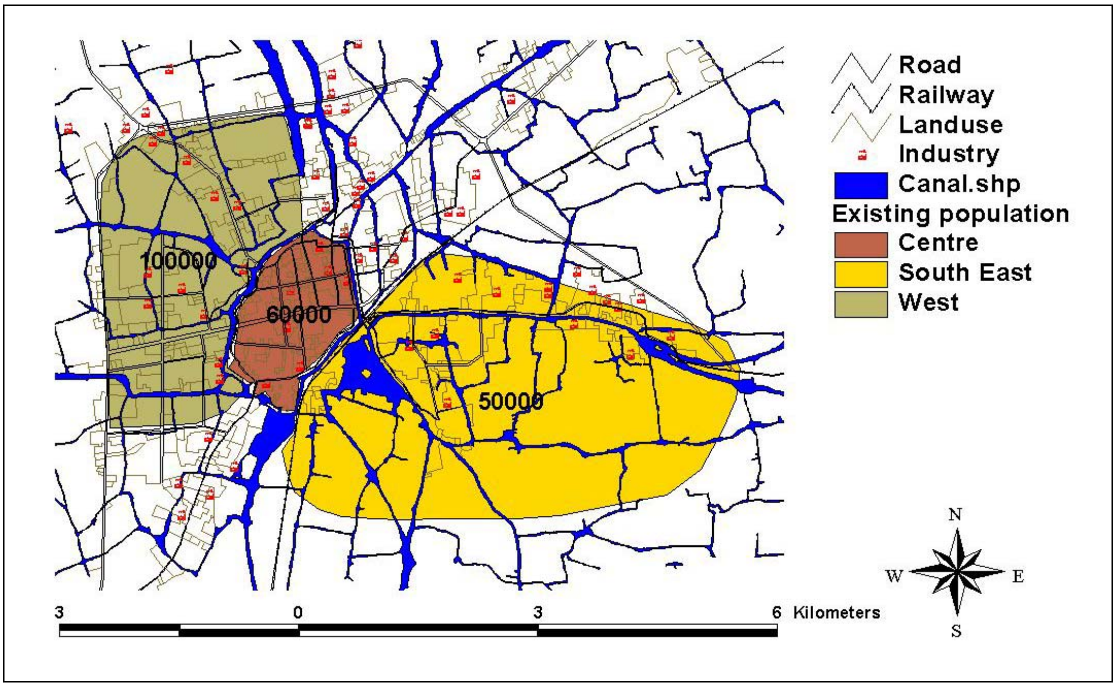


Figure 28. Population in Year 1996 (total population of 210.000)

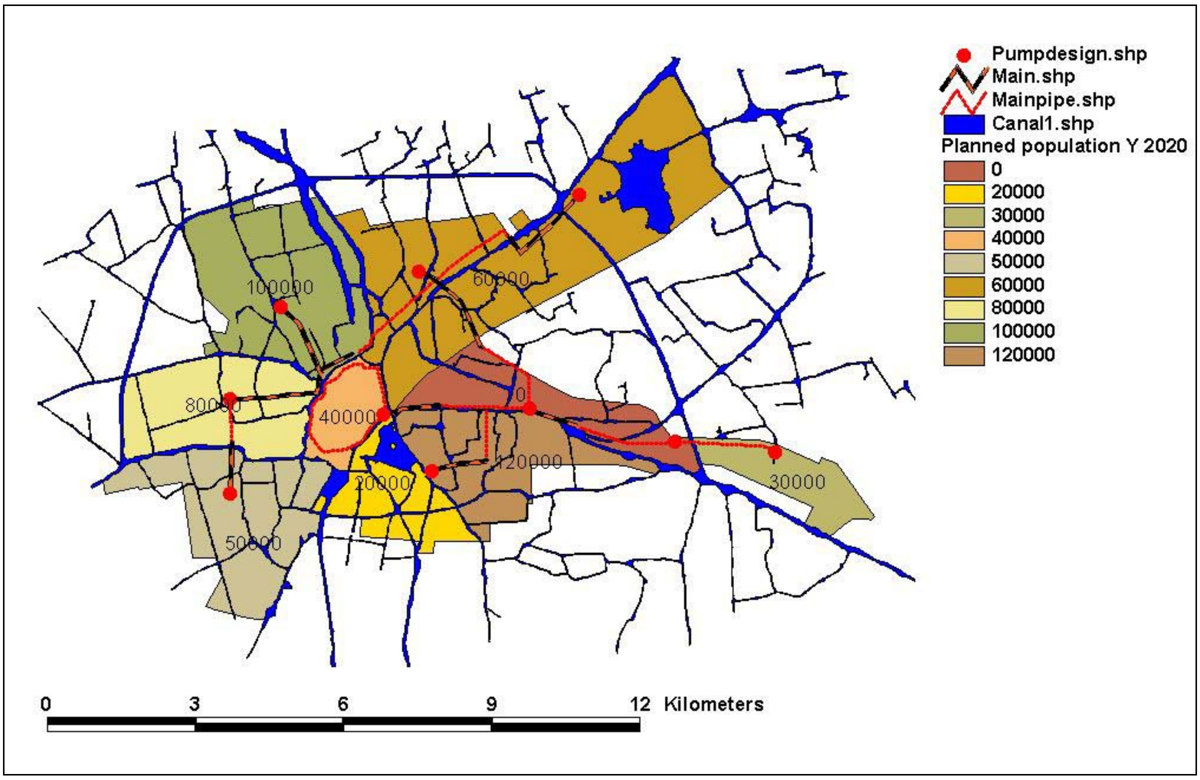


Figure 29. Estimated population in Year 2020 divided in sub-areas (total population of 500.000) Data received from Jiaxing Construction Bureau.

Municipal wastewater (sum of industrial, domestic and commercial wastewater)
The total estimated wastewater discharge from Jiaxing City excluding discharge and run-off from centre area is presented in Figure 30.

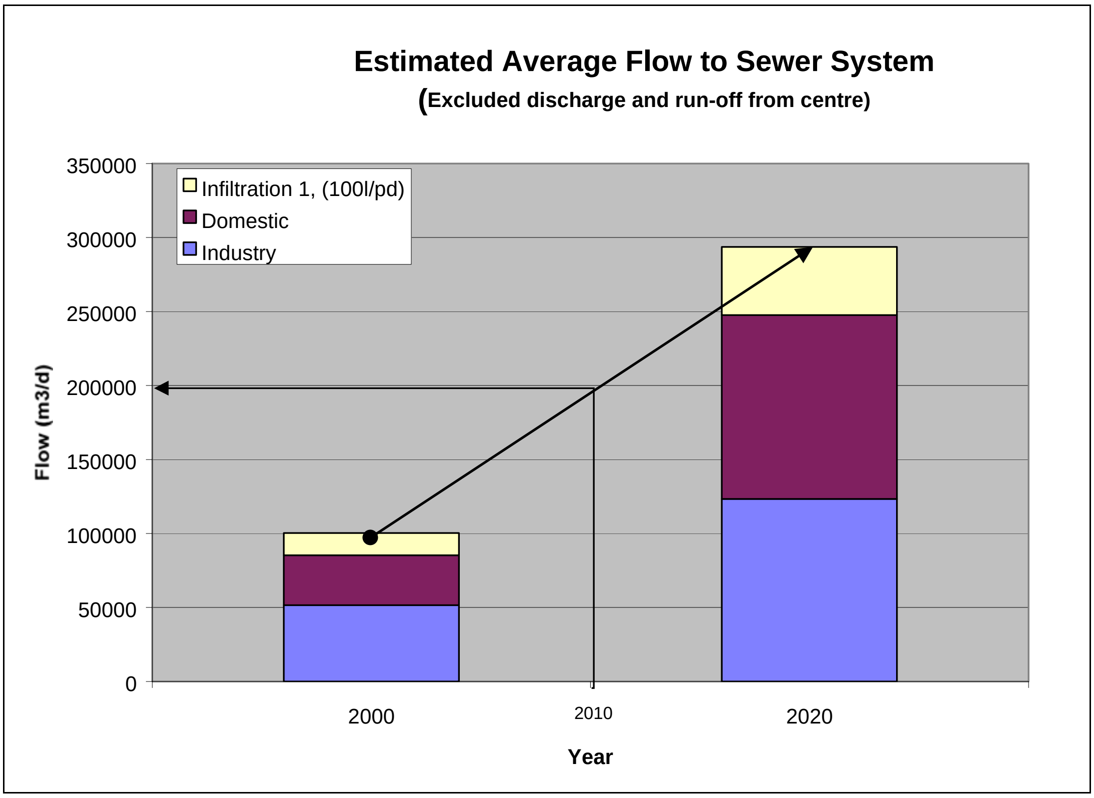


Figure 30. Estimated flow from Jiaxing City Year 2000 and 2020, *excluding discharge and run-off form centre area.* (See next sub-section for run-off calculations).

Table 29 shows a more detailed classification and the assumptions used for calculations of domestic and commercial wastewater production. Table 30 summarises the estimated total discharge from industry, domestic and commercial wastewater (excluding centre area).

Table 29. Summary of estimated domestic wastewater discharge in Jiaxing City, year 2000 and year 2020. (Centre area with combined system is not included.)

Design data based on estimated population			
All areas except centre:			
Parameter	**Unit**	**Amount**	
		Year 2000	**Year 2020**
Population	no.	240000	460000
Flowrates			
Q average	m3/year	28470000	62123000
Q average	m3/d	78000	170200
Q dim (=1.2*Qav.)	m3/d	93600	204240
Organic load			
COD average	kg/year	8322000	19644300
COD average	kg/day	22800	53820
Concentration	mg COD/l	292	316
COD dim	kg/day	27360	64584
BOD5 average	kg/year	3942000	9234500
BOD5 average	kg/day	10800	25300
Concentration	mg BOD5/l	138	149
BOD5 dim	kg/day	12960	30360
SS load			
SS average	kg/year	3942000	8395000
SS average	kg/day	10800	23000
Concentration	mg SS/l	138	135
SS dim	kg/day	12960	27600
TN load			
TN average	kg/year	963600	2182700
TN average	kg/day	2640	5980
Concentration	mg SS/l	34	35
TN dim	kg/h	3168	7176
NH4-N load			
NH4-N average	kg/year	604440	1359990
NH4-N average	kg/day	1656	3726
Concentration	mg NH4-N/l	21	22
NH4-N dim	kg/h	1987.2	4471.2
TP load			
TP average	kg/year	131400	335800
TP average	kg/day	360	920
Concentration	mg TP/l	4.6	5.4
TP dim	kg/h	432	1104

The above calculations are based on the following assumptions:

Table 30. Assumptions for calculations of domestic wastewater production.

Parameter	Specific load	
	Y 2000	Y 2020
Flowrate (l/p*d) 1)	225	270
Flowrate incl. Infiltr. from ground water 2)	325	370
BOD5 (g BOD5/p*d)	45	55
COD (g COD/p*d)	95	117
SS (g SS/p*d)	45	50
TN (g TN/p*d)	11	13
NH4-N (g NH4-N/p*d)	6.9	8.1
TP	1.5	2

1) Specific flowrate includes part of commercial wastewater, rest is included in industry discharge
2) Estimated infiltration from groundwater is based on new sewer pipelines but with areas with high groundwater level

Discharge from centre area with combined system is estimated and calculated in a simplified model. This is described in the next sub-section.

Table 31 Summary of estimated wastewater discharge from Jiaxing City year 2000 and year 2020, excluding run-off and discharge from centre area with combined system.

Parameter	**Unit**	Amount, total		**Discharge amount**	
		Year 2000	Year 2020	**Y 2000**	**Y 2020**
Connection degree				**50 %**	**92 %**
Flowrates					
Q average	m3/year	66124389	111073706	33062195	102187810
Q average	m3/d	181163	304312	90581	279967
Q dim	m3/d	270004	433566	135002	398880
Organic load					
COD average	kg/year	27538917	38861217	13769459	35752320
COD average	kg/day	75449	106469	37725	97952
Concentration	mg COD/l	416	350		
COD dim	kg/day	190025	227249	95013	209069
BOD5 average	kg/year	9707075	14999575	4853538	13799609
BOD5 average	kg/day	26595	41095	13297	37807
Concentration	mg BOD5/l	147	135		
BOD5 dim	kg/day	14993	32393	7497	29802
SS load					
SS average	kg/year	14533429	18986429	7266714	17467514
SS average	kg/day	39818	52018	19909	47856
Concentration	mg SS/l	220	171		
SS dim	kg/day	85950	100590	42975	92543
TN load					
TN average	kg/year				
TN average	kg/day	3156	6496	1578	5976
Concentration	mg TN/l	17.4	21.3		
TP load					
TP average	kg/year				
TP average	kg/day	463	1023	232	941
Concentration	mg TP/l	2.6	3.4	2.6	3.4

25.3 Simulations of existing and estimated future waste water quantity and composition in Jiaxing City

The computer program STOAT was used to make a simplified study of estimated run-off from the centre area of Jiaxing City. Figure 31 shows a screenshot from STOAT of the structure of the model.

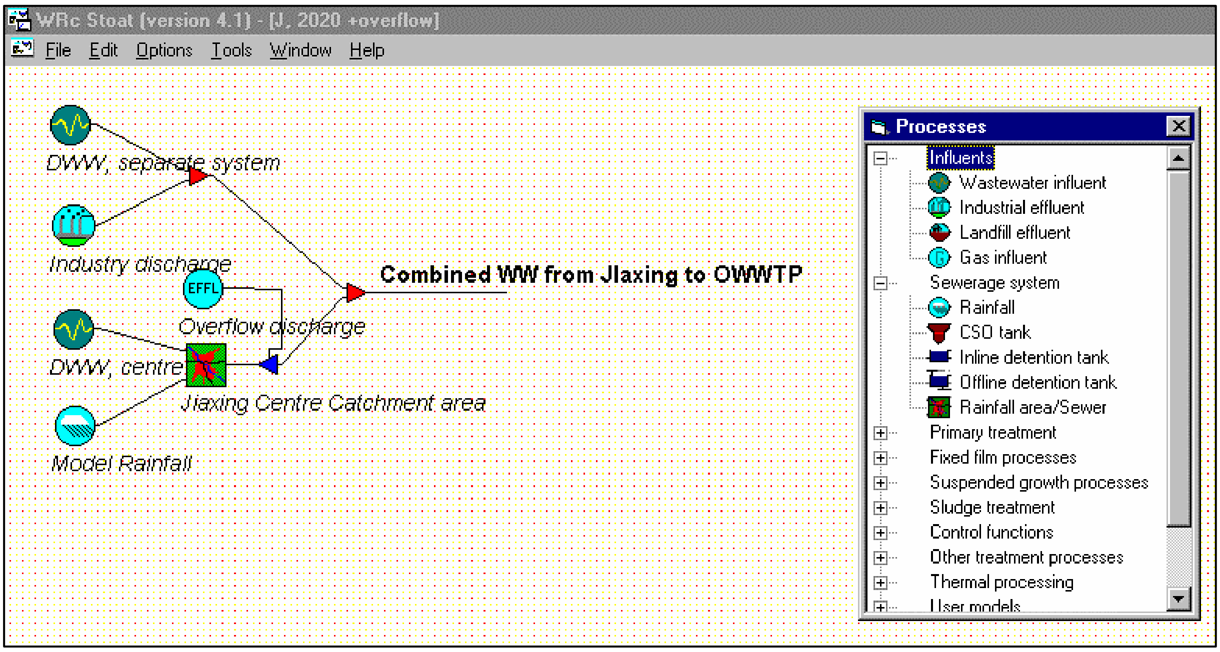


Figure 31. Modelling of wastewater quantity and composition from Jiaxing City by using STOAT, including a simplified run-off model for combined system in centre of Jiaxing.

A one-year simulation of estimated discharge loads from Jiaxing City were done for year 2000 and 2020. Hourly rainfall data from year 1997 was constructed based on received average daily data and selected days with maximum and minimum values. Other input parameters for the catchment area model was taken from literature based on experience from similar urban catchment areas. However, input parameters vary a lot from place to place and the model must be calibrated at each catchment area in order to be able to predict simulated results in accordance with measured results. This means that calculated results in this study are coarse estimates of future run-off.

Other inputs are taken from the results examined elsewhere in this section. Table 32 and Figure 32 show a summary of estimated wastewater discharge from Jiaxing City in 2000.

Table 32. Estimated existing wastewater discharge from Jiaxing City, included run-off from centre (Year 2000).

	Flow (m^3/h)	Total SS (mg/l)	Total COD (mg/l)	Ammonia (mg/l)	Total P (mg/l)	Total N (mg/l)
Mean	4467	219.7	365.6	11.6	2.7	18.9
Minimum	2369.7	75.2	108.7	4.5	1.6	7.8
Maximum	12512.6	393.3	651.8	13.3	3.3	21.6
Standard deviation	1483.7	112.5	181.8	1.2	0.3	1.9
Total mass (kg/year)		9960569	16391051	458024	110278	745445
Peak load (g/s)		1248	1375	23	7.3	39
Total flow (m3/year):	39126453					

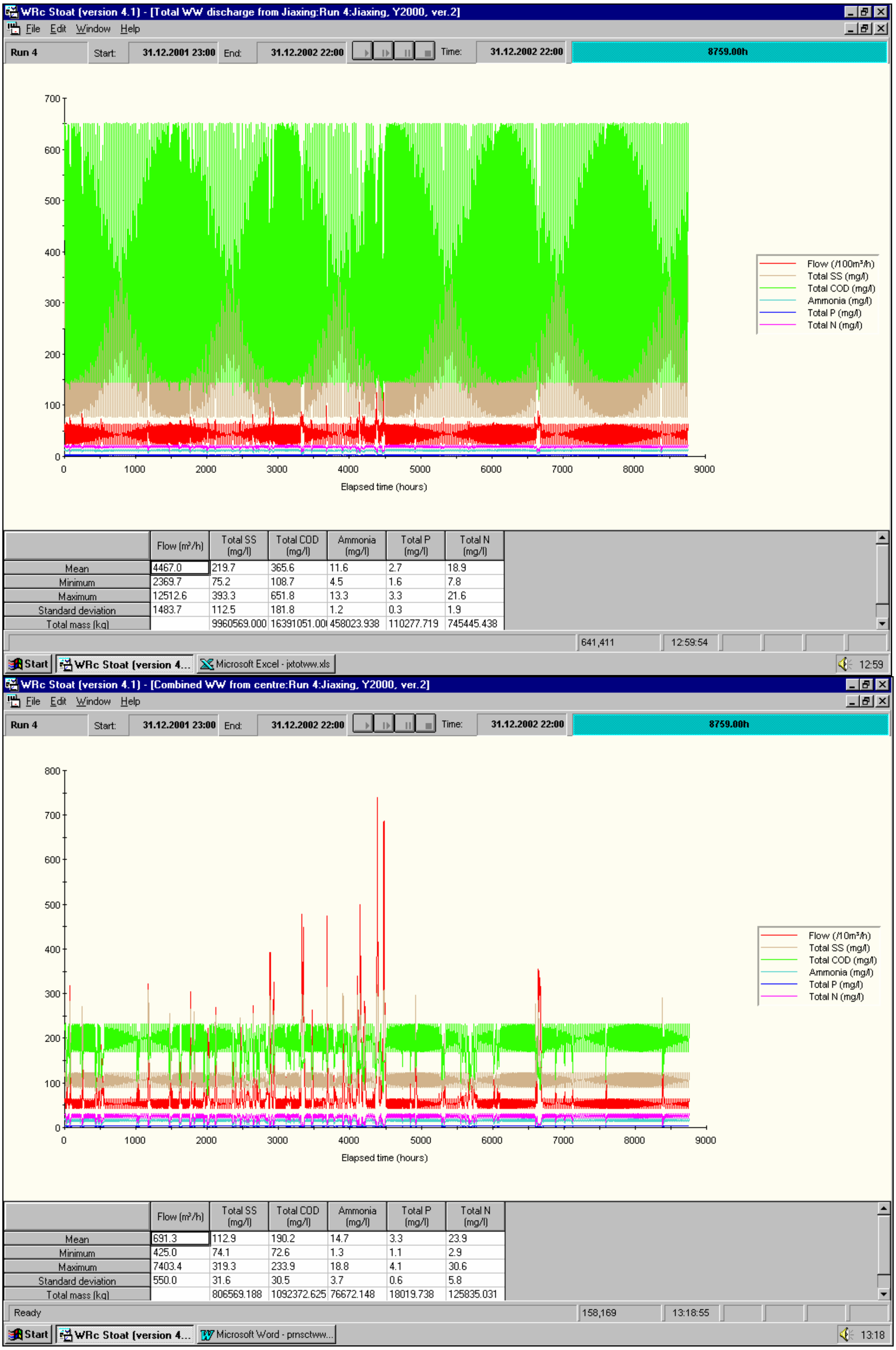


Figure 32. Example of simulation results from Jiaxing city included run-off from centre area, year 2000 (top: total discharge from Jiaxing city, bottom: discharge from centre area).

Table 33 and Figure 33 shows a summary of estimated wastewater discharge from Jiaxing City in year 2020.

Table 33. Estimated future waste water discharge from Jiaxing City, included run-off from centre (Year 2020).

	Flow (m^3/h)	Total SS (mg/l)	Total COD (mg/l)	Ammonia (mg/l)	Total P (mg/l)	Total N (mg/l)
Mean	12586	178.3	322	13.8	3.5	22
Minimum	7338.3	80.8	136.4	7.7	2.3	12.6
Maximum	23472.9	308.8	514.8	15.1	3.9	24.2
Standard deviation	3675.4	76.3	123.1	0.9	0.3	1.5
Total mass (kg/year)		22057260	39277436	1533043	391131.9	2449382
Peak load (g/s)		2013	2732	74.1	20.5	119.8
Total overflow from centre (m3/year)	164000					
Total flow (m3/year):	110240774					

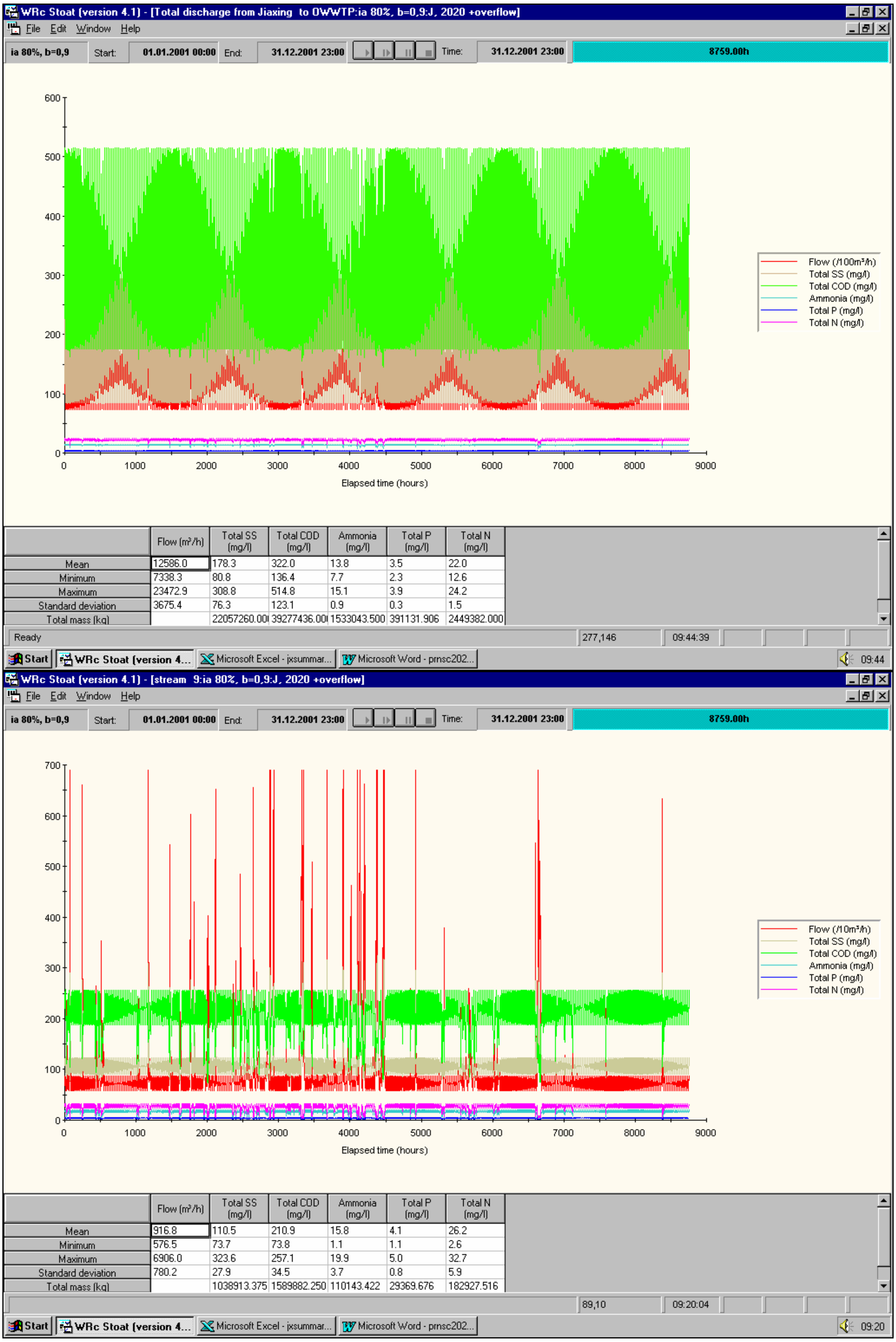


Figure 33. Example of simulation results from Jiaxing city included run-off from centre area, year 2020 (top: total discharge from Jiaxing city, bottom: discharge from centre area).

25.4 Estimates of future waste water quantity and composition in Jiaxing region planned to drain to OD-WWTP

As shown above, a rather detailed study of estimated discharge loads from Jiaxing City has been accomplished. At a later stage in the planning process (and project work), a regional strategy was found to be the best overall solution. Below we have worked out a detailed estimate of future loads to the planned Ocean WWTP, based on received data from other sub-areas which also will discharge.

Estimates of population and industry quantities are found from an updated study (Summer 1999) done by a recently established institute called Jiaxing Institute of Ocean Discharge. These new estimates of population and industry discharge in year 2000 from Jiaxing City is a bit smaller than earlier estimates used in the detailed study of Jiaxing City in this report.

Other estimates such as connection degree, combined system areas, specific pollution load (see previous sub-section) etc. is done by this studies project group. Among other factors, the expected total pollution load from industries has been increased based on less stringent discharge requirements for some industries that discharge to the sewer system.

Figure 34 shows the planned Ocean discharge system included catchment areas, trunk sewer, industries and wastewater treatment plant.

Table 34 summarises estimated loads, daily variation factors, and combined systems total area/ impermeable area to the planned Ocean WWTP.

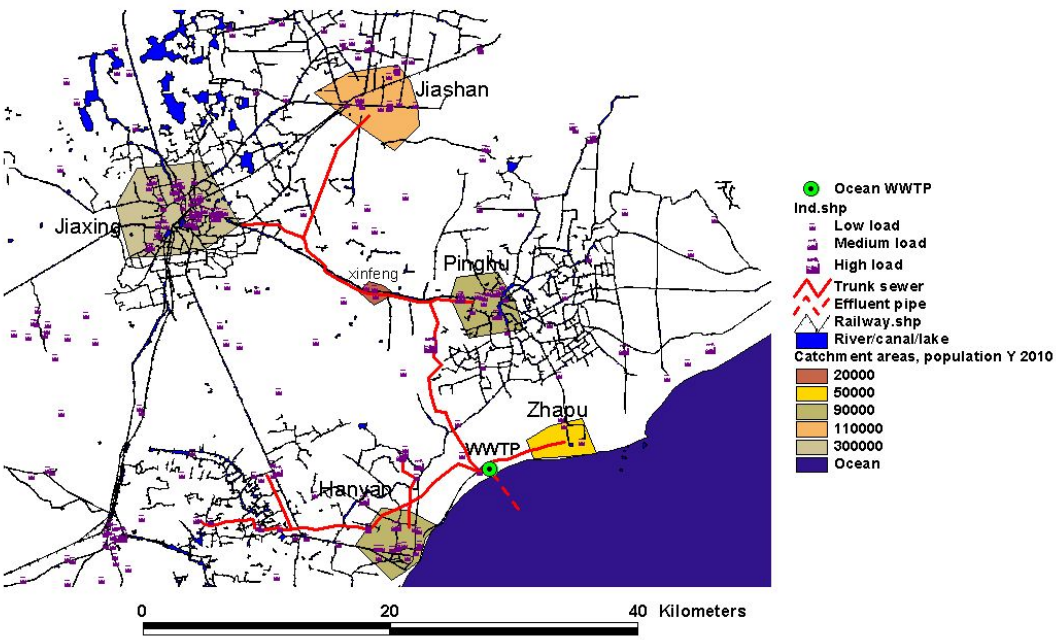


Figure 34. Planned Ocean discharge system with catchment areas, trunk sewer, industries and wastewater treatment plant.

Table 34. Estimated loads, daily variation factors, combined systems total area/ impermeable area to the planned Ocean WWTP.

Parameter	**Unit**	Amount, total				**Discharge amount**	
		Year 2000		Year 2020		**Y 2000**	**Y 2020**
Connection degree						**50 %**	**92 %**
		Domestic	Industry	Domestic	Industry		
Population	Inhabitant/1000						
Jiaxing centre		206.5		500			
Weitang town		50		140			
Chengguan town		60.3		140			
Wuyuan town		60.6		140			
Zapu town		17.7		70			
Other Scanner sources		11.2		40			
SUM		406.3		1030			
Specific load	l/p*d	325		370			
Combined system (Centre of towns):							
Drainage area	% of total	10		10			
	km2	4.8		4.8			
	% impermeable	60		80			
Flowrate	(m3/d)/1000						
Jiaxing centre		67.1	81.6	185.0	97.9	74.4	260.3
Weitang town		16.3	5.3	52.5	6.4	10.8	54.2
Chengguan town		19.6	17.4	52.5	20.8	18.5	67.4
Wuyuan town		19.7	8.8	52.5	10.6	14.3	58.1
Zapu town		5.8	1.1	26.3	1.3	3.5	25.4
Other Scanner sources		3.6	83.7	15.0	100.4	43.7	106.2
SUM		**132.1**	**197.9**	**383.8**	**237.4**	**165.2**	**571.6**
Estimated daily variations to ODWWTP:							
Flow	% of average	1.2	1.3	1.2	1.3		
Substrates	% of average	1.2	1.3	1.2	1.3		

Figure 35 below shows a summary of estimated discharge to ODWWTP from population and industries in year 2000 and 2020.

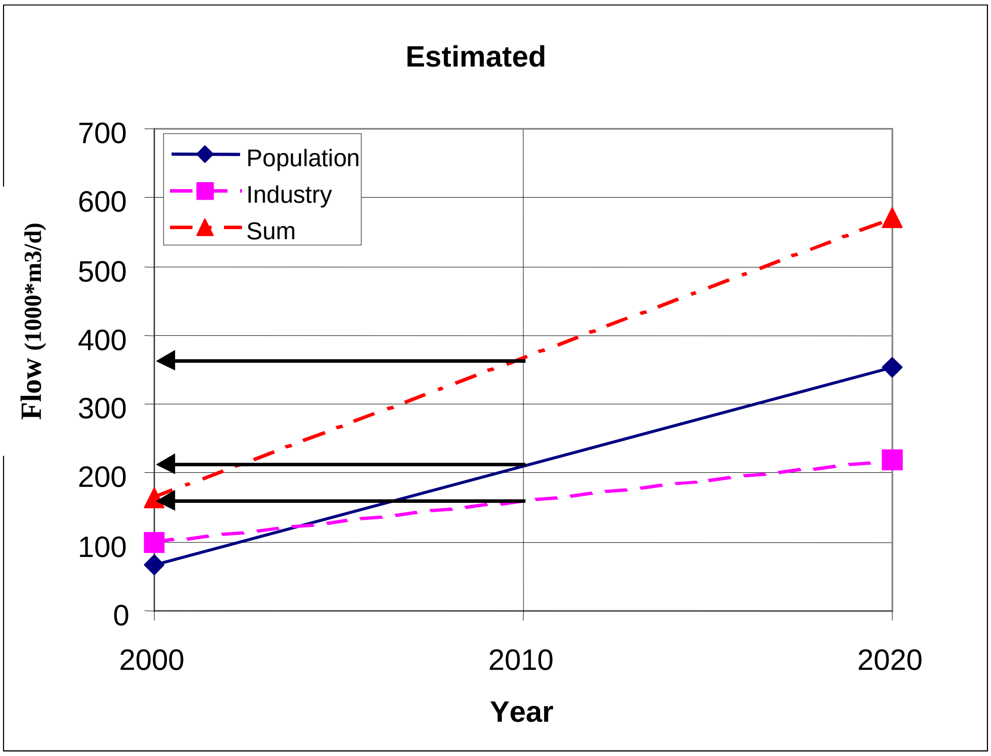


Figure 35. Estimated discharge loads from industries and population to Ocean WWTP, excluding run-off from combined system areas.

Based on these calculations and the fact that these estimates are highly uncertain, suggested design year is 2010 for construction of the first stage of the OD-WWTP. Because of the uncertainty in discharge estimates, we will also suggest that the OD-WWTP should be designed in accordance with a stepwise strategy. We will discuss this further in next main section of this chapter.

Suggested average design loads from industry and population for year 2010 excluded run-off from combined system areas:

Domestic waste water	= 210 000 m^3/d
Industrial waste water	= 159 000 m^3/d
SUM	= 369 000 m^3/d

A rough estimate of future run-off and total discharge to OD-WWTP is shown in Figure 36. Total wastewater discharge to future Ocean WWTP is divided in **a**) Domestic WW from separate system, **b**) Industry WW (connected to separate system) **c**) Domestic WW from combined system and **d**) Run-off from combined system areas. Rainfall data from 1997 is used in the simulations, and the same percentage of total area from Jiaxing city is used as drainage area (10 % of all sub-catchment areas are estimated as future combined system/drainage area). Because of the expected high degree of equalisation in the OD trunk sewer, daily rainfall data has been used (not hourly data as for the calculations for Jiaxing City in previous sub-section).

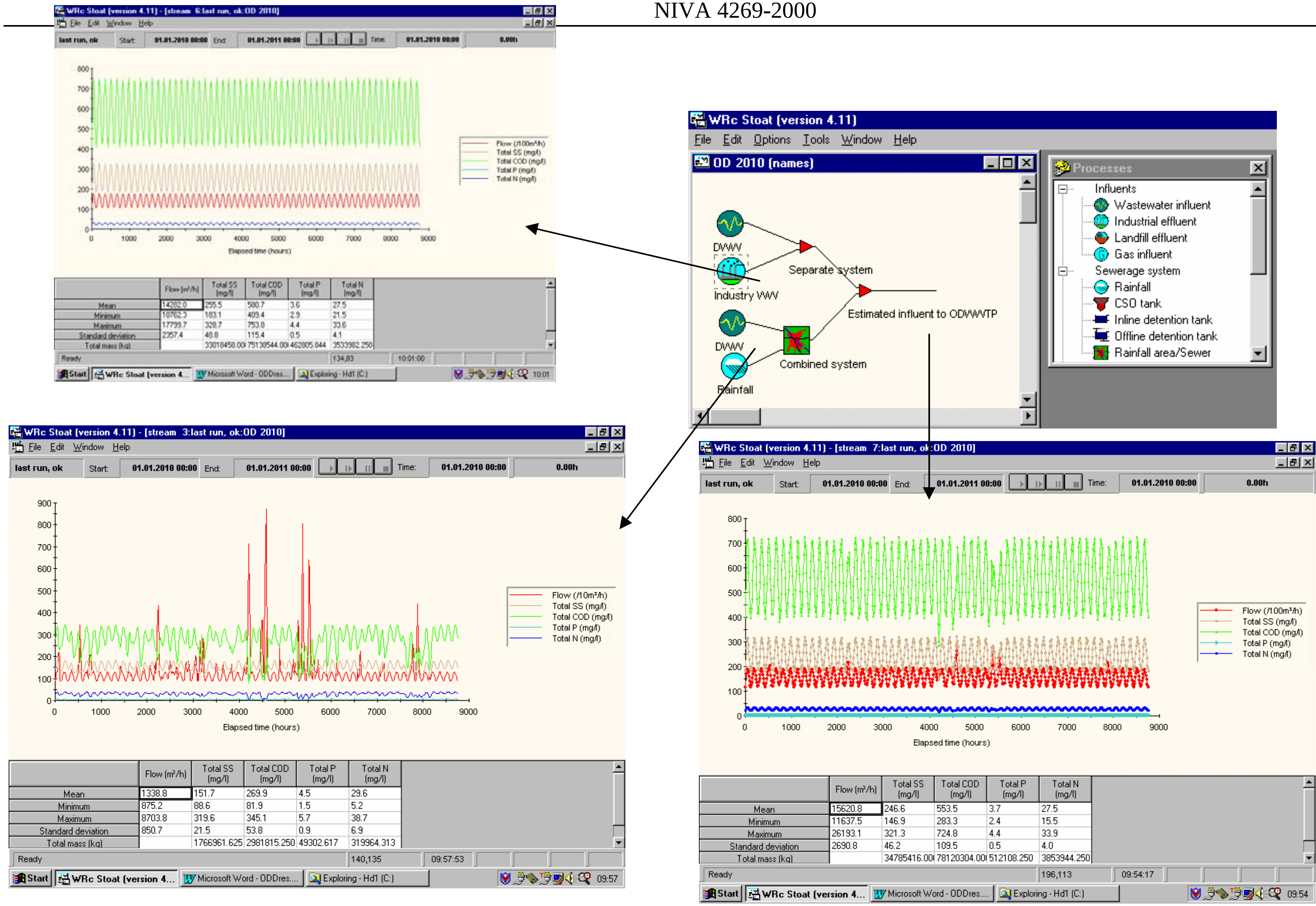


Figure 36. Estimated total influent to OD-WWTP, Year 2010 (right). Contributions from the separate system (upper-left) and the combined system (left) are also shown.

Based on above calculations the estimated and chosen design parameters for Ocean WWTP are as follows:

Table 35. Estimated and chosen design loads for ODWWTP year 2010.

Design parameter	Unit	Quantity
Flowrates:		
Q average	m3/d	374900
Q average	m3/h	15620
Q max	m3/h	26200
Q design pre-treatment	m3/h	26200
Q design biological treatment	m3/h	17700
Organic matter (influent):		
COD average	mg/l	554
COD average	tons/d	208
Nutrients (influent):		
N average	mg/l	27.5
N average	tons/d	10.6
P average	mg/l	3.7
P average	kg/d	1.4

Design and simulations of two different design alternatives for ODWWTP are presented later in this chapter.

26. Pilot plant experiments and labscale tests

Labscale tests and pilotplant experiments have been carried out in Jiaxing City for a period of one year. The project group's view is that these test results and gained experiences have been of vital importance in order to reduce the uncertainty in design of the planned Ocean Discharge Waste Water Treatment plant.

The main motivations for carrying out the experiments have been:
- To obtain design and dimension criteria for OD-WWTP.
- To document and to provide confidence to that the chosen treatment processes is the most appropriate for the present and future wastewater qualities.
- To examine alternative pre-treatment, secondary treatment and design alternatives.
- To reveal possible toxic/inhibitory effects of different wastewater qualities over time.
- To optimise chosen WW treatment processes.
- To train JEPB personnel in mechanical, chemical and biological WW treatment.
- To explore possibilities for re-use of pilotplant (used at the ODWWTP, for pre treatment of industrial WW etc.)

26.1 Pilotplant and labscale equipment

The pilotplant was designed by NIVA and constructed by JEPB. The pilotplant consisted of:
- 3 primary settling tanks for sedimentation of primary and chemically sludge
- Chemical flocculation unit using flexible tubes
- Mixing unit for coagulants
- Flexible aerated activated sludge tank with adjustable volume and number of compartments
- Secondary settling tank
- Dosing pumps for chemicals/polymer and storage tanks

JEPB was responsible for operation of the pilotplant, with process advise from NIVA. Figure 37 shows a simplified flowsheet of the pilotplant, and Figure 38 shows pictures of the pilot-plant, located at the Mingfeng Papermill.

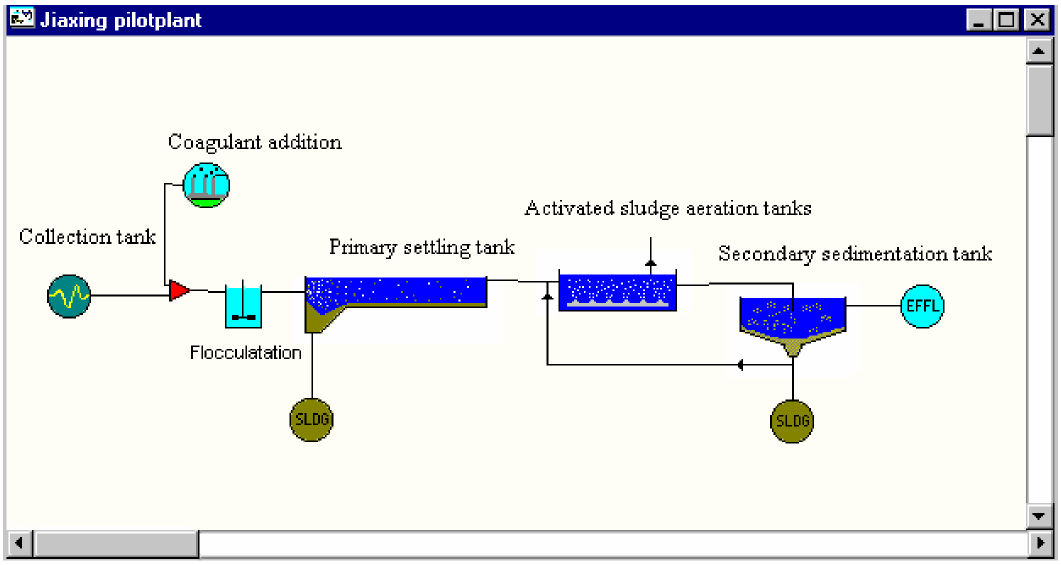


Figure 37. Flowsheet of the pilotplant, operating with pre-precipitation followed by 3 aerated activated sludge reactors and a secondary sedimentation tank.

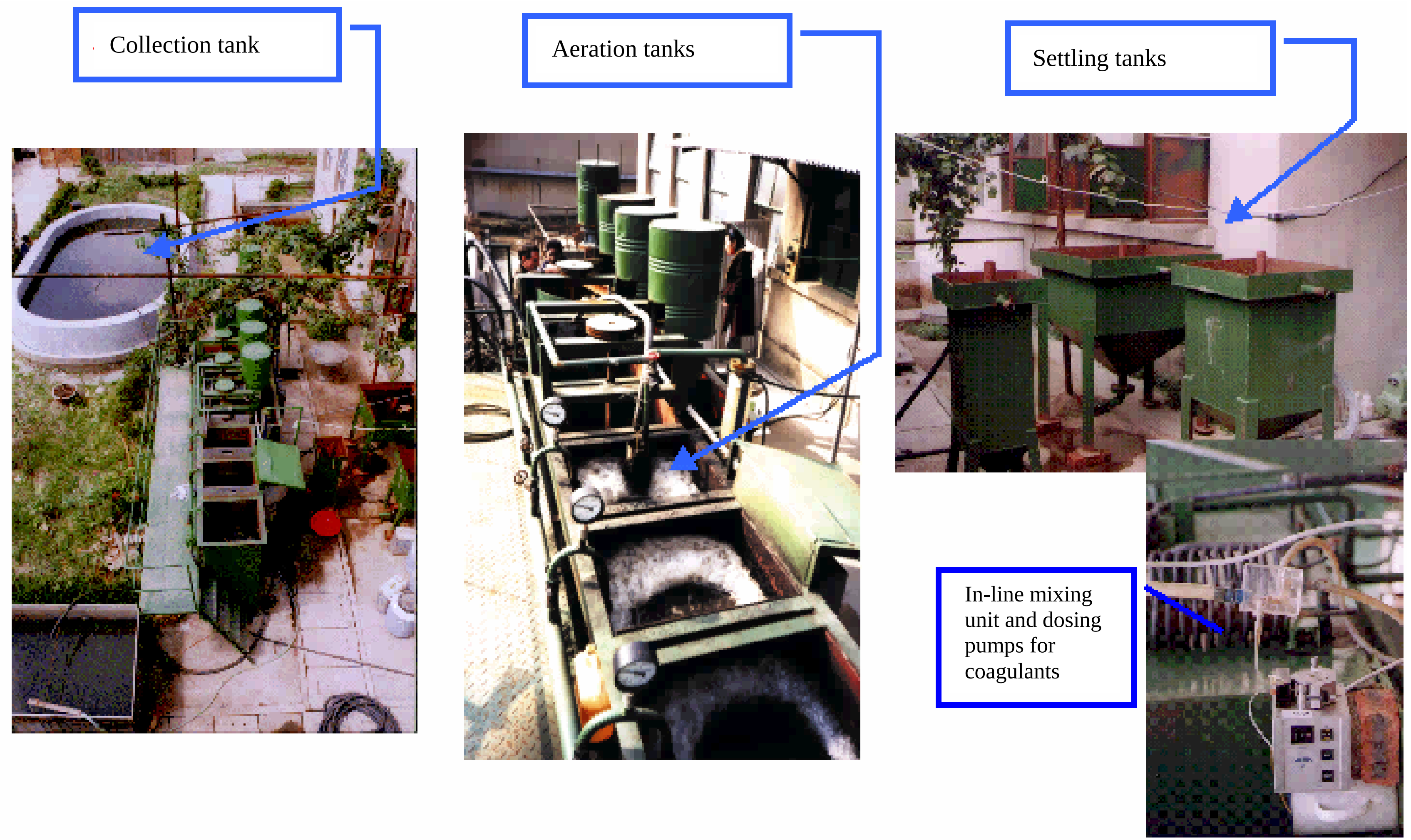


Figure 38. Pictures from the pilotplant site.

Labscale tests were performed before and during the pilotplant experiments. Mechanical, chemical and biological tests were carried out in order to achieve detailed process knowledge of selected sub-processes.

Figure 39 shows pictures of the Jar-test apparatus used for chemical treatment tests (coagulation and settling), and jars after sedimentation.

Figure 39. Automatic Jar-tests equipment, and jars after sedimentation.

Biological Oxygen Uptake Rate (OUR) test were carried out among other reasons to examine possible toxic or hampering material in industry waste water. Figure 40 shows pictures from OUR test carried out at Mingfeng Paper mills laboratory, sited nearby the pilotplant.

Figure 40. Biological Oxygen Uptake Rate tests of domestic waste water and industry waste water. Picture shows oxygen measurements in a test-bottle (left) and parallel aeration of test bottles (right).

26.2 Experimental scheme

26.2.1 Pilotplant experiments

Objective

The objectives for the tests were:

1. To evaluate the robustness of chemical and biological WW treatment processes to combined WW (domestic and pre-treated industry WW) by pilot plant tests. By using a model WW these tests describe how the mixed domestic and industry WW from Jiaxing are going to affect the treatment process at the planned Ocean WWTP,
2. To evaluate if pre-treatment of selected industries are recommendable
3. To find the critical organic load that enables sufficient organic matter removal and/or inhibition of micro-organisms by other materials in industry WW
4. To find the fraction of soluble inert and soluble slowly biodegradable organic matter, measured as COD, at different loads and process configurations.
5. To evaluate sludge-production at different loads, and study sludge characteristics
6. To get basic data about treatment efficiencies with different configurations and loads
7. To obtain dimension criteria for a full-scale plant, and basic information for a rough calibration of a dynamic chemical and biological model (STOAT)

Test programme

During one year of pilotplant experiments the following test program has been carried out:

Process	**Period (weeks)**	**Load**
Biological (no pre-treatment)	23	Low/medium
Chemical	2 (intensive tests)	Low/medium/high
Chemical/biological	15	Low/medium

Influent waste water (model waste water)

The proposed wastewater management plan for Jiaxing assumes to have an influent mixed with both treated and untreated industrial wastewater combined with domestic wastewater. Although it is difficult to predict the composition of this influent, JEPB together with NIVA has estimated a mixture of wastewaters most likely to imitate the composition in future.

The pilotplant influent (model WW) was a mixture of wastewater from the Jiaxing's main industries and domestic wastewater from Jiaxing City centre. JEPB choose the extent of pre-treatment at the selected industries in accordance with expected future discharge permits.

The influent was composed according to the following ratios (volume basis):

WW type	**% of total**	**Volume if total V=18 m3**
Domestic	50	9
Mingfeng	25	4.5
Textile	16.7	3
Chemical	6.7	1.2
Pesticide	1.6	0.3
SUM	**100 %**	**18 m3**

The chosen percentage of each wastewater component was done after estimates of future wastewater composition at the ODWWTP.
Waste water sampling and collection was carried out weekly as follows:

Table 36. Water sample collection and analyses.

Period	**Monday**	**Tuesday**	**Wednesday**	**Thursday**	**Friday**
Start-up		**Gr3**	**Di/De and Gr3**		**Gr3**
Sample collection:					
G		**x**	**x**		**x**
D		←	→		
Test period		**Di/De and Gr3**	**Di/De and Gr3**		**Di/De and Gr3**
Sample collection:					
G		**x**	**x**		**x**
D	←→	←	→	←	→

D = 24 hours composite sample (sample every 15. Min. Mix all 24 bottles)
i = Influent
e = Effluent
G = Grab-sample
r3 = Biological reactor no. 3
Sample collection: D- samples from 08-08 next day. (Tuesday D-sample: From Monday 08:00 to Tuesday 08:00) Grab-sample: At 08:00.

Table 37. Measurements and analyses:

Parameter	**Grab/composite samples**	**In situ**
TCOD (mg/l)	X	
FCOD (mg/l)	X	
TBOD5 (mg/l)	X	
SBOD5 (mg/l)	X	
TP (mg/l)	X	
PO4-P (mg/l)	X	
TN (mg/l)	X	
NH4-N (mg/l)	X	X
NO3-N (mg/l)	X	X
NO2-N (mg/l)	X	
SS (mg/l)	X	
VSS (mg/l)	X	
MLSS (mg/l)	X	
MLVSS (mg/l)	X	
Temperature		X
pH		X
Oxygen		X
WW flowrates		X
Air flow		X
Sludge removal		X
Sludge volume		X

All data were edited and reported in Excel-spreadsheets. A "day-to-day" log report was also created with detailed information about running conditions, in situ measurement etc. Activated sludge properties such as floc-structure, composition of microorganisms, colour were periodically studied in microscope.

26.2.2 Laboratory scale tests

Biological Oxygen Uptake Rate tests
The main objective for the biological tests was to examine possible toxic or hampering material in industry wastewater.

Several intensive tests were carried out with different fractions of industry wastewater and domestic wastewater. Industry wastewater was tested separately and with a standardised synthetic wastewater as reference. Mixed wastewater with the same composition as the pilotplant influent was also studied.

Chemical treatment tests
Jar-tests have been used for the purpose of preliminary evaluation of coagulation efficiency in laboratory scale for many decades by researchers and WWTP-personnel, and are an established way to predict the coagulation properties. It is fast and a simple way of scaling down the costly and lengthy pilot-scale tests to a minimum. We have used an advanced semi-automated jar-test unit for these experiments.

The experiment takes place in one-litre jars equipped with a programmable mixer with variable speed and a timer. The colloidal destabilisation and chemical reactions occur during the rapid mix stage (1 min at 400 rpm) which starts immediately after the addition of coagulant. The slow mixing stage (10 min at 30 rpm) follows to build up microflocks to large and dense flocs. A sedimentation stage follows and samples are then taken for water quality analysis.

The main objectives of the labscale chemical treatment tests were to study whether it was possible to coagulate the proposed wastewater type, and to find out the optimum coagulant dosage and pH-range for the process. While only the results from the tests on the mixed wastewater are reported in this chapter, a range of other tests were carried out, and are reported with Project Activity 9, chapter 8.

26.3 Results

26.3.1 Labscale test

Biological Oxygen Uptake Rate (OUR) test
Several intensive OUR tests were carried out with activated sludge from the pilotplant and sludge from a full-scale plant in Hangzhou. The motivation for these tests was mainly the assumption that some of the industrial wastewater consists of toxic or hampering substances, and also large fractions of slowly biodegradable/inert organic matter.

An international standard method for OUR-tests were used to describe possible inhibition/hampering effects by activated sludge (ISO 8192). This standard specifies a method for assessing the potential toxicity of wastewater to the activated sludge microbial cultures.

Figure 41 shows results from one OUR-test of the mixed wastewater using activated sludge from the pilotplant.

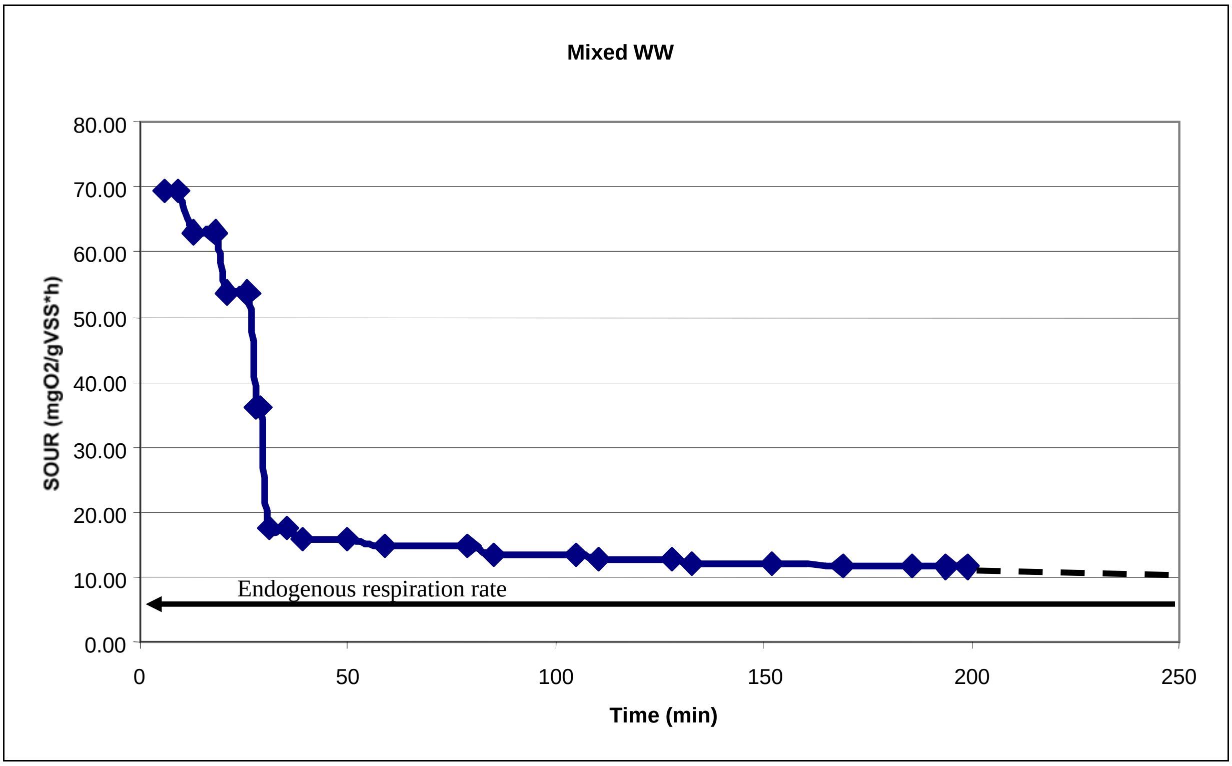


Figure 41. Oxygen uptake during a Specific Oxygen Uptake Rate (SOUR) test with mixed wastewater.

The results showed high activity during the first 20 minutes, which represents the biodegradation of the easily biodegradable organic matter fraction in the mixed wastewater. After approximately 30 minutes the SOUR drops down to about 15 gO2/g VSS*h and then slowly (and stable) reduces until the test was stopped after 200 minutes. The result indicated that the mixed wastewater consisted of a relatively high fraction of slowly hydrolysable organic matter in the mixed wastewater. Endogenous respiration rate is also shown in the figure to illustrate that there still was a rest of slowly hydrolysable biodegradable organic matter left when the test was stopped.

Figure 42 shows results from a comparable test using wastewater from all major industries, domestic wastewater and mixed wastewater, and a synthetic wastewater as reference. The same amount of synthetic wastewater (imitate domestic wastewater) was added to all test bottles. Relative amounts of industry wastewater and domestic wastewater compared to total water volume in the testbottles were the same as in the mixed wastewater composition. All test bottles were filled up with deionized water so that the total water volume was the same for all tests. Sludge was taken from the activated sludge pilotplant's recycle stream.

The aim was then to study if some of the industrial wastewater could result in inhibition/ hampering of sludge activity.

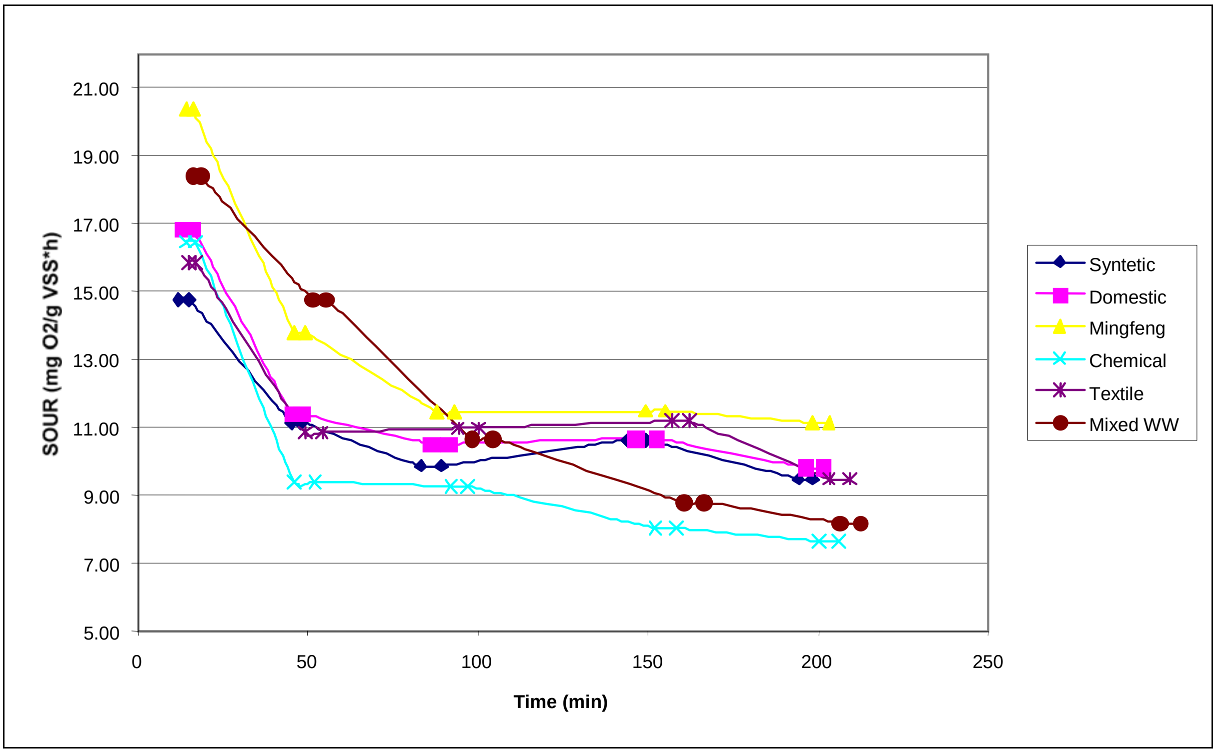


Figure 42. Specific Oxygen Uptake Rate test comparing different industry waste water, domestic waste water, synthetic waste water and mixed waste water. Synthetic wastewater was added in the same amount to all test bottles.

The results in Figure 41 and Figure 42 together with other OUR-tests showed:

1. Mixed waste water had a high fraction of slowly hydolysable/biodegradable organic matter
2. Mixed wastewater had a considerable and variable fraction of easily biodegradable organic matter. None of the industrial waste water seemed to hamper the OUR of the easily biodegradable fraction of organic matter
3. Wastewater from Chemical industry significantly hampered the OUR of slowly biodegradable organic matter, but it seemed as if it did not hamper the biodegradation of easily biodegradable organic matter (readily biodegradable). Figure 42 confirms this conclusion were SOUR results for chemical WW (and mixed WW) is lower than synthetic waste water after the biodegradation of readily biodegradable fraction of COD
4. Other industrial WW did not hamper the OUR of synthetic waste water but resulted in the same or higher OUR.

5. Ammonia nitrogen Uptake Rates tests (AUR) showed a considerable production of nitrite-nitrogen. This finding indicated that industrial wastewater interfered and hampered the nitrification tests.

The results from the labscale tests showed that it is important to consider other pre-treatment processes at the Chemical industry. Discharge of wastewater from chemical industry without proper pre-treatment could interfere with the operation and reduce treatment efficiencies at the Ocean WWTP.

Small-scale chemical precipitation tests

A range of jar-tests was conducted on various fractions and types of wastewater and is reported in chapter 8. The few tests conducted on the mixed wastewater indicated that it is possible to achieve significant removals of pollution, as shown in Figure 43. Results presented in Figure 43 confirm that at dosages of 40 mg-Fe/l, it is possible to achieve >90% of Tot-P removal, together with up to 70% removal of SS. T-COD removal remained around 30%. The efficiencies at lower dosages should be tested under better process conditions, such as with increased sedimentation times.

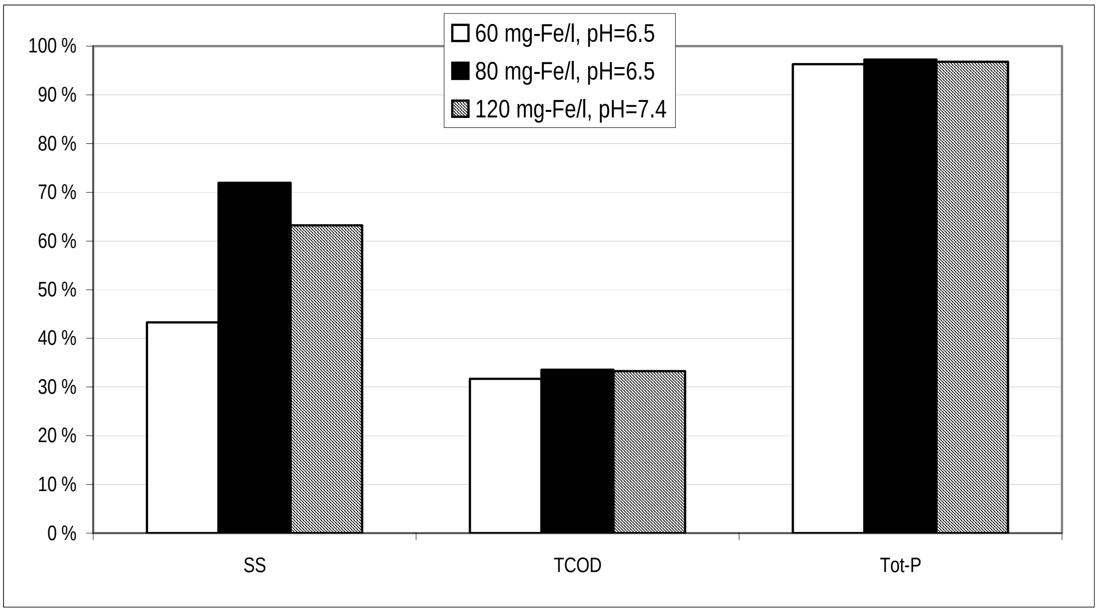


Figure 43. Lab-scale chemical treatment tests on mixed wastewater with iron (Fe^{3+}) coagulant in jar-tests.

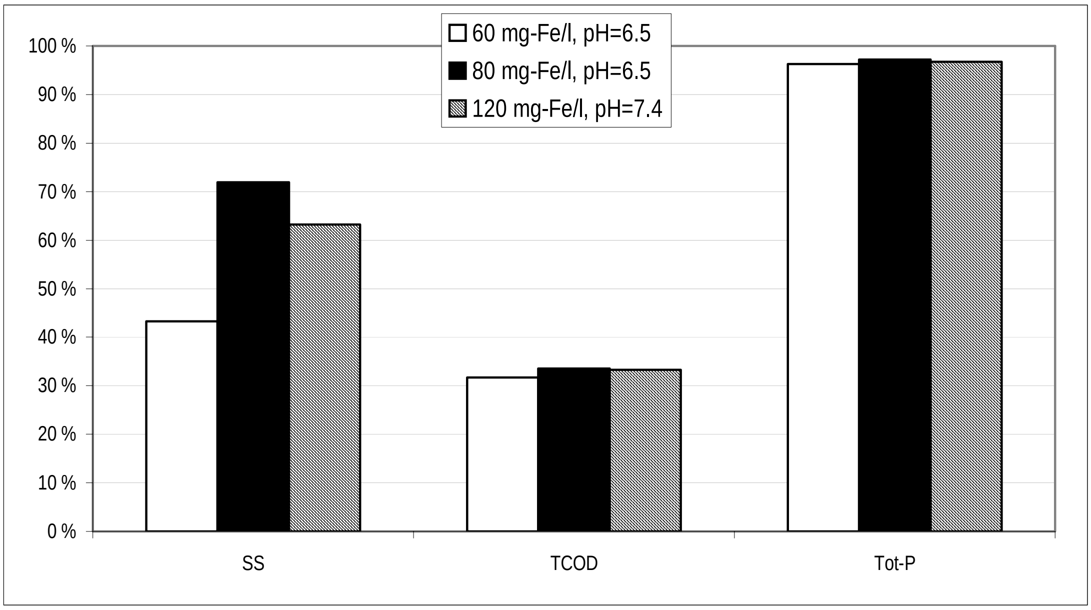


Figure 44. Lab-scale chemical treatment tests on mixed wastewater with iron (Fe^{3+}) coagulant in jar-tests.

Figure 44 shows the coagulation efficiencies of domestic wastewater with the same kind of coagulant. The amount of coagulant needed to achieve similar or better removals are much lower, compared with the mixed wastewater.

By comparing Figure 43 to Figure 44 one can see how seriously the industrial wastewater affect the chemical treatment process. For the same reason, it will be very important to run similar tests when one knows the exact composition of the influent quality of the ODWWTP. On the other hand, it also emphasises the need for pre-treatment of industrial wastewater.

26.3.2 Pilotplant test

In this sub-section, results from the various pilotplant tests (chemical, biological and chemical/biological) are reported individually. Thereafter follows a summary with conclusions.

Chemical treatment

Figure 45 shows a typical result from intensive pilotplant tests with iron coagulant.

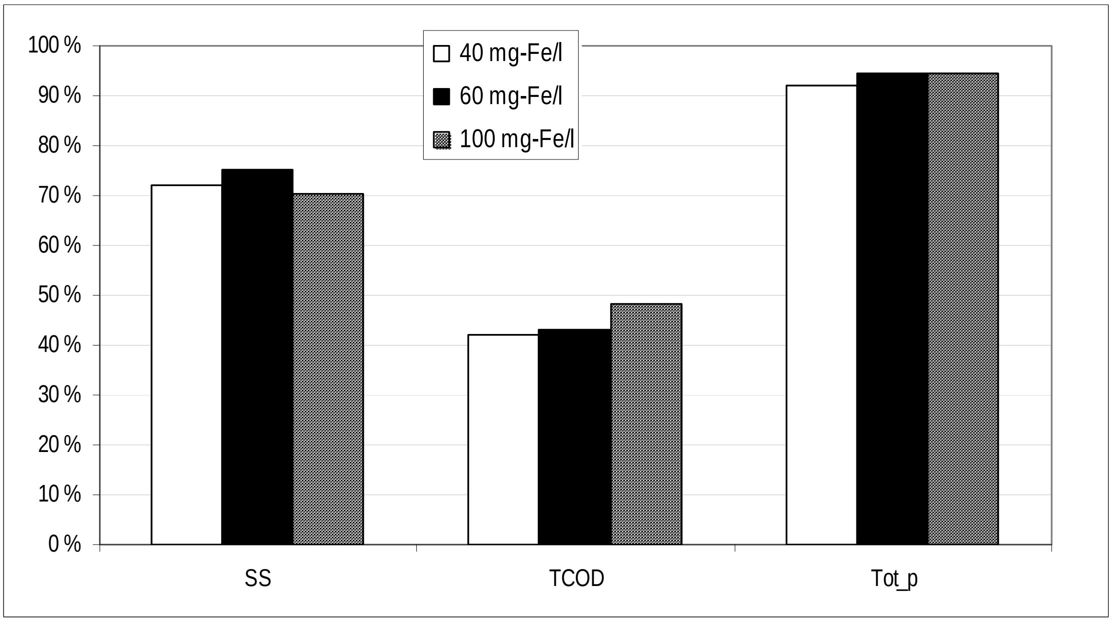
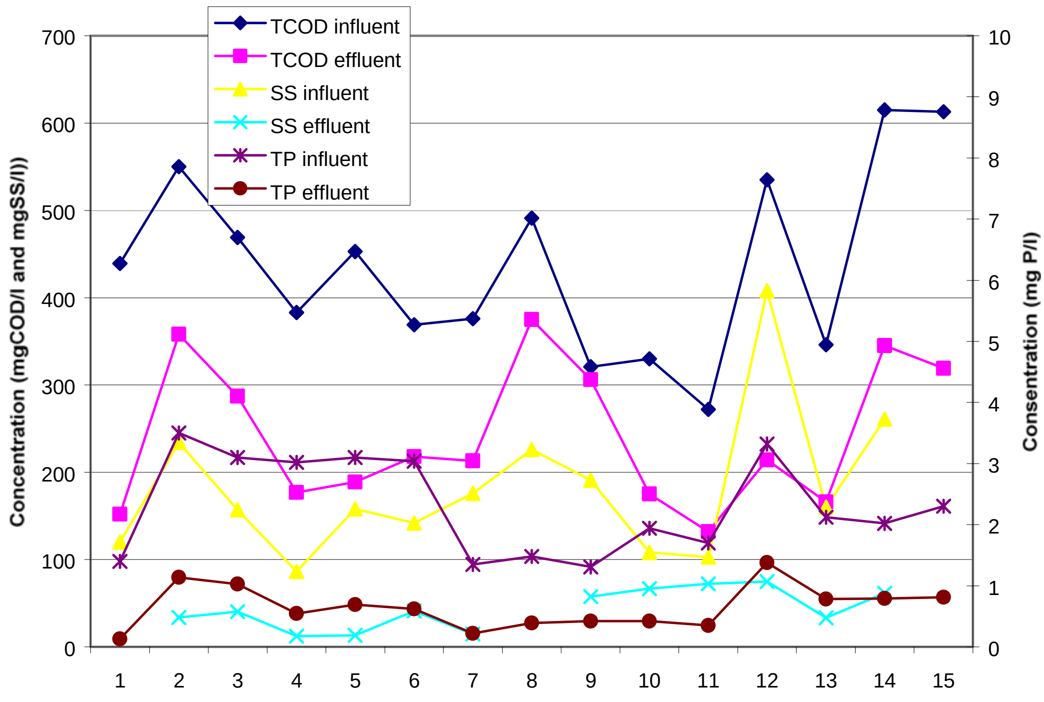


Figure 45. Chemical treatment of mixed wastewater with iron coagulants. (Figure shows removal of pollutant in % with different doses.)

The results shown in Figure 45 confirms that at dosages of 40 mg-Fe/l, it is possible to achieve >90% of Tot-P removal together with up to 70% removal of SS. At this level T-COD removal is around 40-45 %. A relatively low reduction of COD was achieved because most of the organic matter was soluble which is only partly removed in a coagulation process (typically 20 % removal of soluble COD).

Figure 46 shows results from long-term tests with chemical enhanced primary treatment (CEPT) with a low dosage of aluminium coagulant prior to biological treatment (pre-precipitation).



Parameter	Influent (mg/l)	Effluent (mg/l)	% Removal
SS	181	43	73
TCOD	437	242	44
SCOD	254	200	21
TP	2.3	0.65	73

Figure 46. Results from CEPT treatment with aluminium coagulant. Results shown in the table are average values.

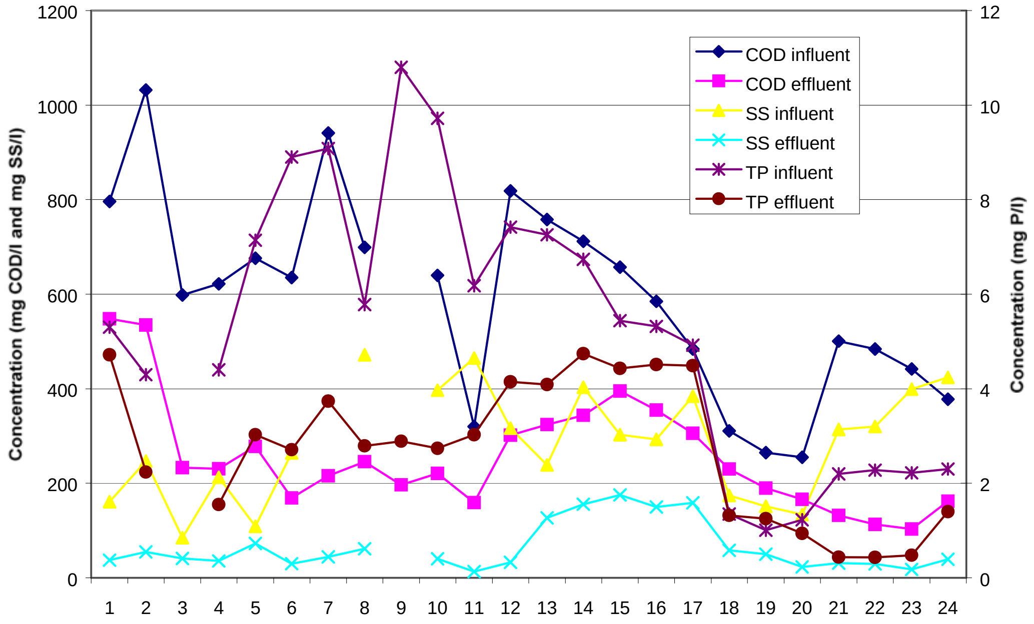
The results in Figure 46 confirm that it is possible to achieve about 75 % removal of suspended solids (SS), 45 % COD removal and 75 % total phosphorus removal with a low coagulant dosing.

Biological treatment (no pre-treatment)

The pilotplant tests started up with biological treatment to evaluate if it was possible to treat the mixed wastewater without pre-treatment.

Detention time in the activated sludge tanks varied between 7 and 15 hours (medium and low load).

Figure 47 shows selected results from the biological test period.



Parameter	Influent (mg/l)	Effluent (mg/l)	% Removal
SS	290	66	73
TCOD	560	230	56
SCOD	330	140	55
TP	5.3	2.6	45

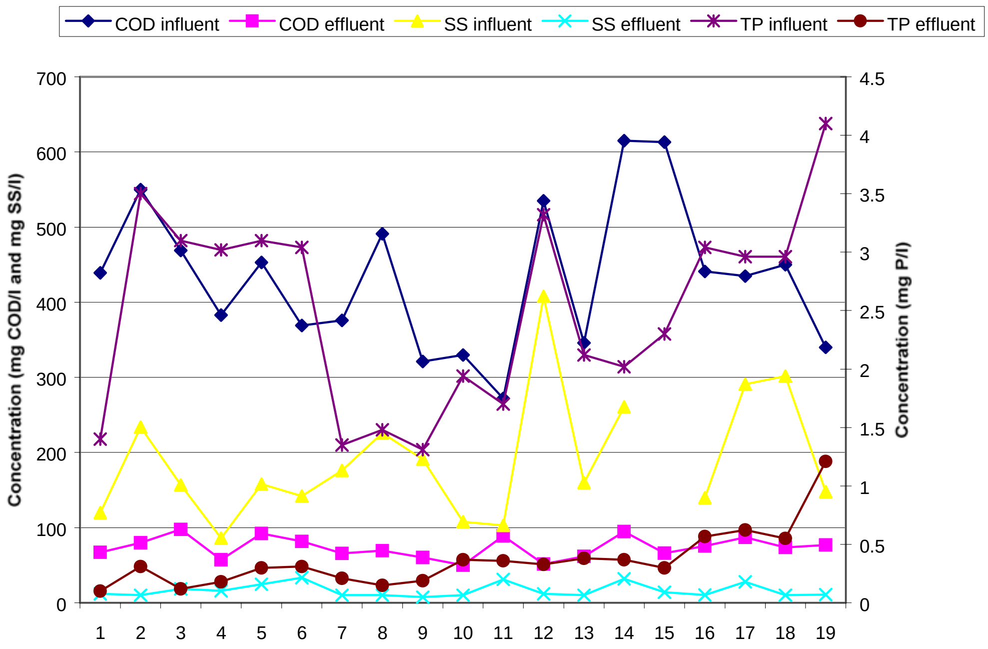
Figure 47. Results from biological treatment of mixed wastewater. Results shown in the table are average values.

The results showed poor treatment efficiencies and severe operational difficulties due to poor sludge settling properties. Even at low loads and favourable temperature, nitrification was partly hampered and disturbed (high effluent nitrite-nitrogen concentrations were observed).

The results clearly showed that biological treatment alone were not a suitable treatment process for the mixed wastewater. The reason was the high degree of industrial wastewater that interferes and hampers the biological process and the settling process. After these results and conclusions based on 23 weeks of operation, the project group decided to continue the pilotplant operation with a combination of chemical and biological treatment. Biological treatment alone was rejected as an alternative process for the ODWWTP.

Chemical and biological treatment

Chemically Enhanced Primary Treatment (CEPT) followed by aerated biological treatment were tested with different loading. Detention time in the aerated activated sludge tanks varied between 6 and 11 hours. Most of the test period a detention time of 6.8 hours was chosen.



Parameter	Influent (mg/l)	Effluent (mg/l)	% Removal
SS	190	16	90
TCOD	433	74	82
SCOD	246	54	78
TP	2.5	0.36	86
NH4-N+Nox-N	22	15	30

Figure 48. Selected results from chemical and biological treatment of mixed wastewater. Results shown in the table are average values.

During combined chemical and bilogical treatment satisfactory removal of all wastewater components was acheived. This is demonstrated in Figure 48.

Sludge settling characteristic improved compared to the tests with biological treatment only, but were still poor compared to experience with treatment of domestic wastewater only. However, effluent suspended solids were quit low due to low load in the pilotplant's secondary sedimentation tank. Poor sludge settling is normal to observe when the contribution from industrial wastewater is high. It is therefor important to design the future OD-WWTP secondary sedimentation tank using design data for poor sludge settling.

Summary and conclusions

Table 38 shows a summary of achieved results from pilotplant testing with different process configurations.

Table 38. Summary of results from pilotplant experiments with mixed wastewater from Jiaxing and future effluent requirement for OD-WWTP.

Parameter	**Chemical treatment (CEPT)**	**Biological**	**Chemical/ Biological**
Removal efficiencies(%):			
COD	44	56	82
SS	73	73	90
TP	73	45	86
Effluent Concentrations (mg/l):			
COD, measured	242	230	74
COD, required	120	120	120
SS, measured	43	66	16
SS, required	30	30	30
TP, measured	0.65	2.6	0.36
TP, required	-	-	-
NH4-N + NOx-N, measured	-	27.5	15
TN, required	25	25	25
Sludge settling properties	-	Poor	Improved but poor
Nitrification[1)]	-	Hampered	Complete
Effluent meet requirements	No	No	Yes

[1)] Complete nitrification is not required for OD-WWTP but during low load situation it is a good indirect parameter to evaluate mixed wastewaters suitability for biological treatment.

Based on these results our conclusions with respect to the planned OD-WWTP are:

1. Chemical treatment alone will not meet effluent requirements but have been a relatively robust and stabile process. Organic removal was only about 45% measured as COD, because of high fraction of soluble COD.
2. Biological treatment alone will not meet effluent requirements and caused severe operational problems in the pilotplant. Biological treatment alone is not recommended for the new OD-WWTP.
3. A combination of chemical and biological treatment showed to be the best process configuration. A likely explanation is that chemical pre-treatment removes some of the soluble and colloidal toxic/hampering/interfering substances in the mixed wastewater that caused problems for the biological tests without pre-treatment.
4. Because of high degree of industrial wastewater, normal design practise for municipal wastewater can not be used for the planned OD-WWTP.

cont.

5. High fractions of soluble slowly biodegradable organic matter (from industries) in mixed wastewater demands low load in the biological treatment stage. In periods with high load in the pilotplant operating as chemical/biological process, effluent requirements were not met. A detention time of about 6.8 hours in the activated sludge process were necessary to achieve stable effluent quality (equals an organic load in the activated sludge system of approx. 0,12 g BOD_5/g MLSS*d and 0,2 g COD/g MLSS*d).
6. Poor sludge settling properties must be expected in the planned OD-WWTP. Even with pre-precipitation, measured sludge-volume (SV) and sludge volume index (SVI) in the pilot plants activated sludge system were high (typically SV=600 and SVI=200). Design of planned ODWWTP secondary sedimentation tank must therefor allow for poor sludge settling properties.

27. Design, modelling and simulation of planned OD-WWTP

27.1 Selection of design strategy and design loads

Design strategy
The planned drainage area to the OD-WWTP is a fast growing region both related to population, service and industry establishment. The industries also have to face new environmental and economical challenges and requirement, which will enforce restructuring of parts of the industry.

Estimates of future wastewater amounts and composition is therefor attended with high uncertainties; factors which are of vital importance for the design and operation of the planned OD-WWTP. Pilotplant and labscale tests with an imitated mixed waste water (estimated future OD-WWTPs influent waste water) has showed that conventional design methods based on municipal waste water can not be used, mainly because of the high fraction of unfavourable industry waste water. The consequence for the OD-WWTP is that larger tank volumes (biological stage and settling tank) and more advanced process solutions (CEPT) should be chosen.

In this case both the future wastewater load to the OD-WWTP and WW composition are difficult to estimate. Due to this uncertainty we highly recommend a stepwise to development of the treatment plant. The WWTP plant to be built should be designed in a way that allows cost-efficient upgrading to higher removal efficiencies at a later stage. In general, step-wise planning and construction give advantages with respect to future flexibility, and it provides valuable process information about the wastewater amount and composition. Further, the configuration of the first step will be the core in the future plant with some special treatment steps added. This suggested strategy should ensure a high cost/benefit value with regard to the OD-WWTP development.

The suggested stepwise development of the OD-WWTP is shown in Table 39. Construction is based on 3 main construction steps:

Step 1 (In operation Year 2002)	Pre-treatment and Chemically Enhanced Primary Treatment
Step 2 (In operation Year 2004)	Extension with biological treatment
Step 3 (In operation Year 2011)	Possible extension of all sub-processes based on the existing and estimated future loads

The intermediate step between step 1 and step 2 should be used to optimise the CEPT process and obtain final design parameters for the extension with biological treatment.

Furthermore, design load for first and second step is chosen to estimated load in year 2010. Normal design period is usually 20 years, but because of uncertainties described above we suggest to use 10 years for step 1 and 2. If todays estimated growth in population and industry for year 2010 (and 2020) shows to be correct, then further extension of all sub-processes should be done in year 2011. Plot plan for year 2010 must ensure that future extensions are arranged for (prepare for duplicates of sub-processes and land access).

Design loads

In this study we have chosen Year 2010 as design year for step 1 and 2. Detailed description of design loads is stated in a previous sub-section of this chapter, Table 35.

Table 39. Suggested step-wise development of OD-WWTP.

Step	**Year**	**Plant design and construction**	**Operation, Research & Development activities**	**Laws and regulations: Effluent requirements and % removal** [1]
1	**2002**	Pre-treatment & CEPT (coarse + fine screen bars, grit chambers, settling tanks with precipitation)		COD: 245 mg/l, 40 %. SS: 45 mg/l, 70%. Total-P: 0.7 mg/l, 70% [2]
Inter-mediate step	2002-2004		1. Measurements and characterisation of influent WW 2. Optimisation of the existing plant. 3. Biological Pilot-plant tests of influent WW	
2	**2004**	Extension with biological treatment to improve BOD-removal		COD: 120mg/l, 70%. SS 30 mg/l, 85% [3] Total-P: 0,4 mg/l 84 %
Inter-mediate step			Optimisation of the plant, recipient evaluation	
3	**2010**	Re-examine future loads, possible extension of all sub-processes based on increased load		(Same as step 2)

1) Provided following estimated average influent composition: COD= 430 mg/l, SS=190 mg/l and TP=2,5mg/l.
2) Suggested preliminary effluent requirement. Requires agreement with authorities for short-term deviate from the existing State Standards effluent requirements.
3) According to PRC's State Standard for OD-WWTP

27.2 Sketch design of OD-WWTP

Table 40 shows design load, design criteria and chosen dimensions for CEPT and biological treatment.

Table 40. Process, design load, design criteria and chosen dimensions for the OD-WWTP.

STEP	Process	Qdim m3/h	Qmaxdim m3/h	qf dim m/h	Area/ depth m2 / m	CODdim t/d	F/Mdim gCOD/g MLSS*d	V m3
1	CEPT: 1)							
	Settling tank	17708	26200	2.5	7085/3	(235)		21255
2	Activated sludge system:2)							
	Basins3)	17708	17708			100.3	0.2	124000
	Settling tank4)	17708	17708	0.5	35416/3.5			

1) Chemically Enhanced Primary Treatment (CEPT). Low coagulant dosage, app. 10 g Fe/m3. Average reduction of COD is estimated to approximately 57 % in CEPT with a corresponding effluent concentration of 236 mg COD/l. Estimated removal is higher that observed in the pilotplant due to higher estimated influent concentration of particulate COD. Estimated effluent concentration of total COD from CEPT is comparable with pilotplant results
2) Oxidation ditch system is suggested in this study in order to generate for a small reduction of nitrogen and reduce pumping costs, and because it is a well known process in the region.
3) Design MLSS = 4 g/l
4) Secondary settling tanks are designed to allow for poor sludge settling properties.

Pre-treatment system (prior to CEPT) should be chosen based on local conditions (supplier, costs, maintenance etc.). Normally we would suggest coarse bar screens, fine bar screen followed by an aerated grit chamber. Design criteria could be found in the sub-report called "Stepwise development of treatment plant".

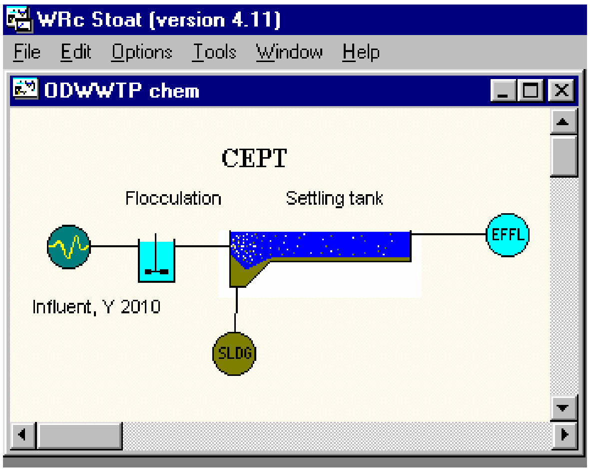
27.3 Modelling and simulations of designed OD-WWTP, Year 2010.

We have carried out modelling and simulations of the planned OD-WWTP based on the estimated influent composition in year 2010, design as shown in Table 40, and a rough model calibration based on pilotplant results. Chosen model parameters and assumptions are based on critical evaluations of test results in Jiaxing and general experiences from similar case studies. However, estimates of an unknown future wastewater composition are attended with high uncertainties. Results should be regarded as best estimates at present time, with a relatively low degree of safety.

A computer program called STOAT was frequently used in this project, including training and case studies done by JEPB. The computer program is used for the design and simulation of sewage work including a simple sewerage model. The program could simulate the performance of an entire sewerage works, including sludge treatment processes, septic tank imports and recycle streams. The results of STOAT simulations can be used to optimise both the design of new works and the performance of existing works. Substantial capital and operational cost savings can be achieved.

Simulations have been carried out in two steps, according to suggested step-wise design.

Simulations of CEPT (Step 1)



Results from one-year simulations of the CEPT process are shown in Figure 49. The model is simplified by using only one line (one sedimentation tank) that represents the future total plant. Parallel lines will of course be constructed.

Results showed average removal of 57 % COD (effluent concentration = 236 mg/l) and 83 % suspended solids (effluent concentration = 42 mg/l). Total sludge production is calculated to be approximately 34,570 ton suspended solids. A coagulant dosage of 10 mg Fe/l was used.

During start-up of the OD-WWTP the operational hydraulic load in the primary settling tank will be considerable lower than design load for year 2010 (estimated average hydraulic load is 1 m/h and 2.2 m/h for year 2002 and 2010 respectively). Consequently a higher removal degree could be expected between step 1 and 2. Coagulant dosage and method must be optimised after start-up of the OD-WWTP.

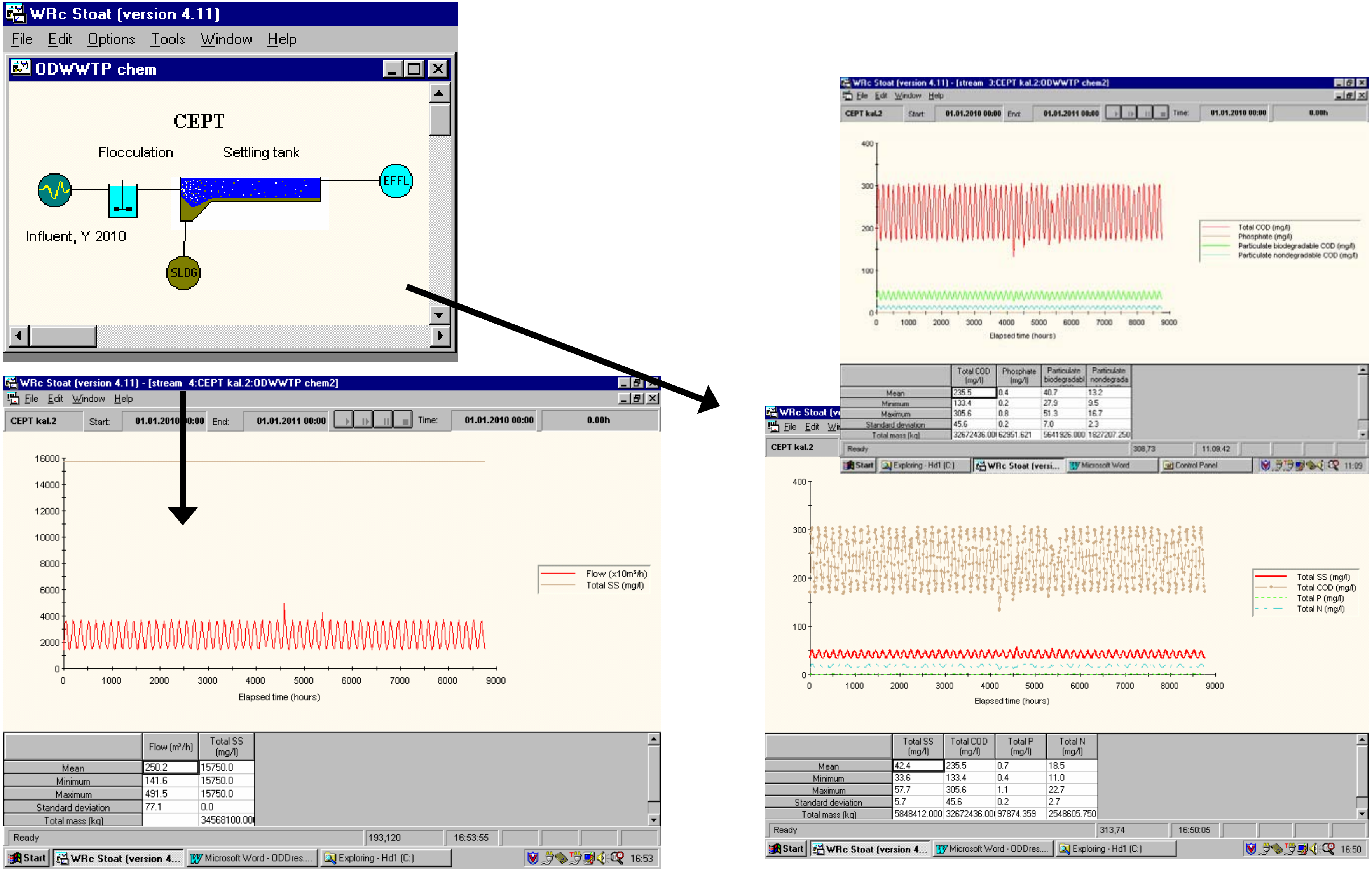
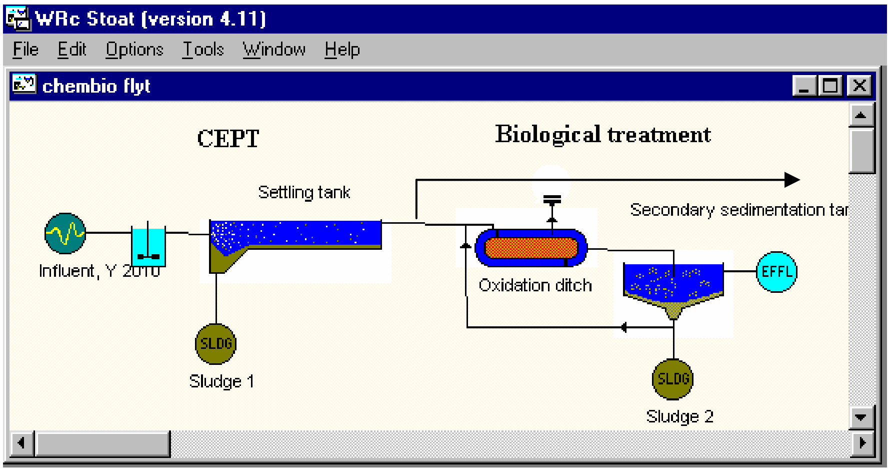


Figure 49. Estimated effluent quality and quantity after Chemical Enhanced Primary Treatment (CEPT)

Simulations of CEPT and biological treatment (Step 2)



Results form one-year simulation with CEPT concept followed by biological treatment are shown in Figure 50. The model is simplified by using one line that represents the future total plant. Parallel lines will of course be constructed.

Results showed average removal of 86 % COD (effluent concentration = 78 mg/l), 93 % suspended solids (effluent concentration = 16 mg/l), and 89 % total phosphorus (effluent concentration = 0.4 mg/l). Removal of total nitrogen is calculated to 64 % but recycle of nitrogen from sludge treatment is not included. Included recycle streams a reduction of approximately 50-60 % is estimated (effluent concentration = 13 mg TN/l). Sludge production is calculated to be approximately 4,030 ton suspended solids in the biological stage (secondary sedimentation tank).

If future wastewater shows to have less hampering/toxic materials than what we experienced in the pilotplant (long-term development of industry production methods), then CEPT load could be increased and/or coagulant addition reduced in order to treat more of the organic matter in the biological step. This will reduce the total sludge production and operational costs. If unfavourable wastewater contribution from industry reduces considerably during the planning period, then the primary tank could be operated as a conventional pre-settling tank without coagulation.

An overflow after CEPT treatment is included in suggested design (Maximum flow to biological stage = 17700 m3/h)., The total estimated overflow however, which not will be biological treated, is estimated to only 2% of total influent flow.

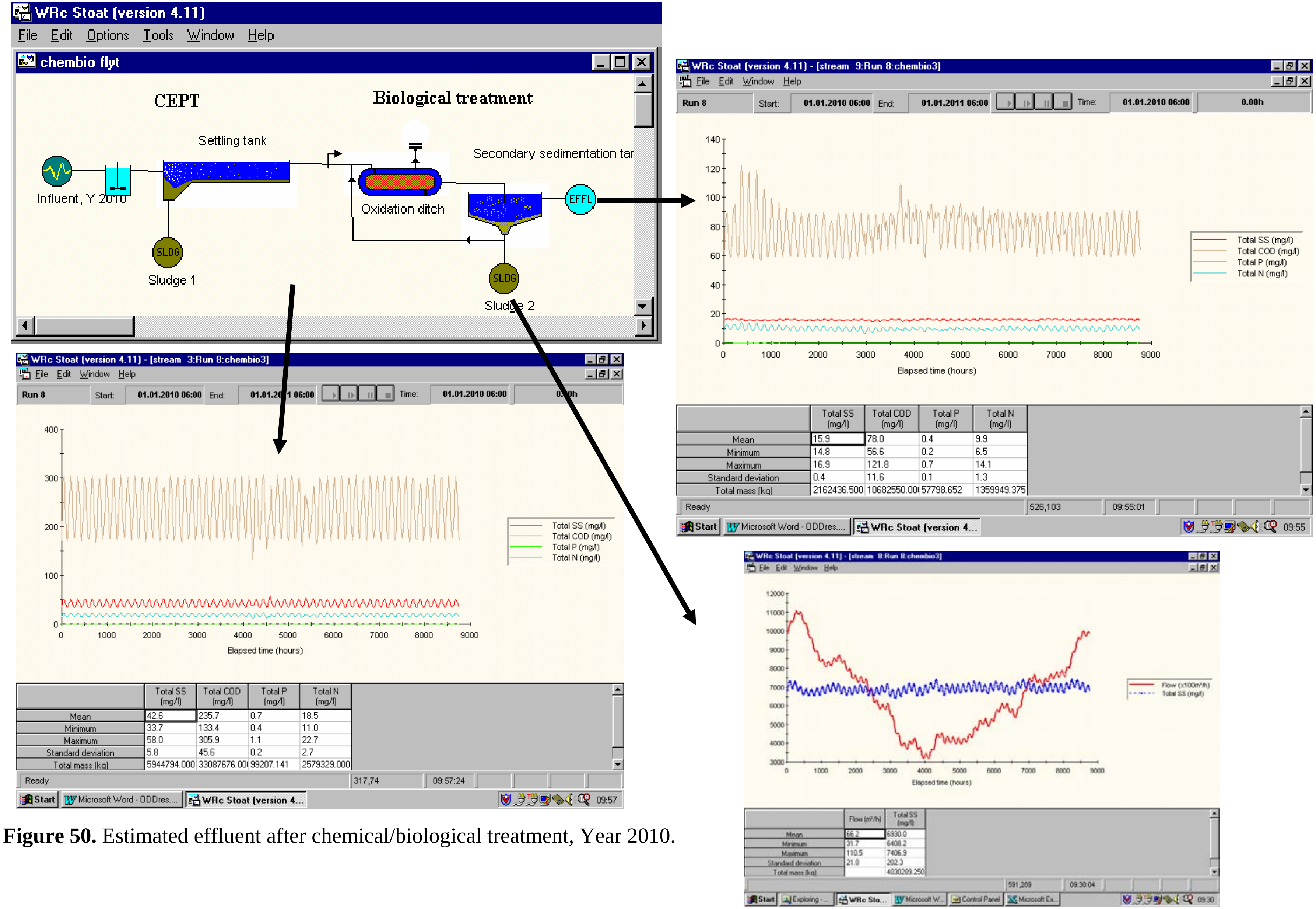


Figure 50. Estimated effluent after chemical/biological treatment, Year 2010.

28. Summary and Conclusions

The main conclusions from this chapter are:

1. Various evaluations and decision-making processes carried out during the project period by the city authorities have motivated the project group to gradually move the focus from the originally local waste water management in Jiaxing city, to a regional solution in Jiaxing called the Ocean Discharge alternative.
2. Management, pre-treatment and control/follow-ups of discharge standards requirements for industry wastewater and commercial wastewater must be a priority task. Commercial and industrial facilities may discharge toxic pollutants that can cause serious environmental problems to the Waste Water Treatment Plants (WWTP). The undesirable outcome of these discharges can be prevented using treatment techniques or management practices to reduce or eliminate the discharge of these contaminants. The objectives of a pre-treatment program should be to prevent the introduction of pollutants into WWTPs, which will interfere with the operation or pass through the treatment works. It is also important to improve opportunities to recycle and reclaim municipal and industrial wastewaters and sludges. Examples of general strategies for industry wastewater handling and pre-treatment are given in the chapter.
3. Collection and adaptation of data concerning infrastructure, industries, population, recipients has been edited into a Geographical Information system (GIS). The project group has used a GIS as an effective tool for identification and evaluation of different management strategies. Selected strategies and summary of detailed evaluations and calculations has been edited in the same GIS. JEPB has been trained in the use of Arc-View GIS (a commercial computer program), and has lately done independent planning analyses in Jiaxing. Arc-View GIS is now implemented in JEPBs planning procedures. All Arc-View projects made during the project are transferred to JEPBs computers.
4. A study of existing and estimated future wastewater discharge loads from population, commercial and industry has been carried out. A rather detailed study of Jiaxing City and a somewhat less comprehensive study of estimated future loads to the planned Ocean Discharge based Wastewater Treatment plant (ODWWTP) has been accomplished.
5. Labscale and pilotplant experiments have been carried out in Jiaxing City for a period of one year. The project groups view is that these test results and gained experiences have been of vital importance in order to reduce the uncertainty in design of the planned ODWWTP. A combination of chemically enhanced primary treatment (CEPT) and biological treatment showed to be the best process configuration, and was the only configuration that met future ODWWTPs effluent requirements. Because of high degree of industrial wastewater, normal design practise for municipal wastewater can not be used for the planned ODWWTP. Design of the planned ODWWTP must therefor allow for influent substances which with no pre-treatment will interfere with biological treatment, relatively high fractions of slowly biodegradable organic matter and poor sludge settling properties in secondary sedimentation basins.
6. Selection of design strategy and design loads, sketch design and modelling and simulations of the planned ODWWTP have been carried out.
7. The planned drainage area to the future ODWWTP is a fast growing region related to population, commercial and industry establishment. Estimates of future wastewater loads and wastewater composition are therefor attended with high uncertainties. The project group therefor suggests a step-wise development of the OD-WWTP. A concrete 3-step development plan with suggested process configurations and effluent requirements has been worked out. First and short-term process configuration is suggested to be the CEPT

(year 2020), followed by the second step which include biological treatment (year 2004). Step 1 and 2 is designed based on year 2010 as design year. The intermediate step between step 1 and step 2 should be used to optimise the CEPT process and obtain design parameters for the extension with biological treatment. Step 3 will consist of a re-examine of influent wastewater load with possible extensions of all processes.

8. A sketch design of the CEPT process and the suggested extension with biological treatment has been accomplish.

9. A wastewater treatment plant computer program called STOAT was frequently used in this project, including training and case studies done by JEPB. The computer program was used for the design and simulation of the OD-WWTP including a simple sewerage model. Simulations have been carried out in two steps, according to suggested step-wise design.

10. One-year simulations with year 2010 as design year have been accomplished. The results indicated that suggested design with CEPT and biological treatment will meet future effluent requirements for the OD-WWTP

11. If future waste water shows to have less hampering/toxic materials than what we experienced in the pilotplant (long-term development of industry production methods), then CEPT load could be increased and/or coagulant addition reduced in order to treat more of the organic matter in the biological step. This will reduce the total sludge production and operational costs. If unfavourable wastewater contribution from industry reduces considerably during the planning period, then the primary tank could be operated as a conventional pre-settling tank without coagulation.

CHAPTER 5

Project activity 5 (part 2):

Cleaner Production Study in Selected Industries

29. Objective

The Jiaxing City Plan contains a Cleaner Production policy statement:

> Use «Cleaner Production Technology», restrict and treat key pollution resources, reduce pollutant discharge, improve environmental quality. Require enterprises to strengthen scientific management before production and put pollution prevention into the whole line of production, reduce energy consumption and treatment at the end of pipeline. Reform old production process, use advanced technical equipment to lift the usage rate of resource and energy and reach pollutant minimisation. Do multiple use of resources well and actively, dispose harmful and toxic industrial refuse.

One of the objectives of activity 5 is to promote this policy by introducing Cleaner Production as a method to reduce pollution loads from industry in Jiaxing city.

The methodology is demonstrated by making an assessment in two industrial companies in Jiaxing city; one pulp and paper mill and one textile factory, in order to point out the possibilities for improving the environmental performance, regulatory compliance and competitiveness through cost-effective preventive measures.

30. Cleaner production methodology

30.1 Principles

Cleaner production is a preventive environmental strategy. The purpose is to prevent or reduce pollution and waste generation by implementing measures that are both environmentally sound and economically profitable.

In the past, pollution problems were mainly managed by «end of pipe»- solutions, a strategy that put considerable financial strain on the companies. Furthermore, «end of pipe»-measures don’t really solve the pollution problem, because the waste is merely turned into another form, for instance from water pollution to solid waste. Nor does this strategy solve the problem concerning scarcity of natural resources such as water and non-renewable energy sources.

By employing techniques that emphasis reduced consumption of water, energy and raw materials, reduction of pollution and waste generation can be achieved in an economically favourable way. Such techniques may involve in-house cleaning of polluted water streams with subsequent recycling of water, energy recovery, replacement of old production equipment with new water and energy efficient production equipment, recovery of raw materials and products from waste streams, as well as improved management and house-keeping procedures and worker training.

30.2 Methodology

A Cleaner Production project comprise of the following phases:

- Planning and Organisation
- Assessment Phase
- Feasibility Analysis
- Implementation

Activities within these phases may be modified to fit local conditions and practice. However, some techniques and activities are essential to achieve the desired results and should not be omitted.

In the **planning and organisation phase**, management commitment, acceptable and achievable goals and clear assignment of responsibilities are important factors to promote a successful result. Task forces should be set up to fit the size and organisation of the plant and the overall goals and priorities of the project.

The **assessment phase** should include the following activities:

- Collect process and facility data
- Prioritise and select assessment targets
- Review data and inspect site
- Generate options
- Screen and select options

A mass balance is a useful basis for the selection of assessment targets, as it demonstrates clearly where the major losses and waste streams can be found. The mass balance should include water, energy and raw materials as well as products, by-products and waste streams.

Options should be generated for all the selected assessment targets. There are several categories of options for cleaner production, such as product reformulation, raw material changes, technology changes, changes in operating procedures, recycling and reclamation. Options should be prioritised according to their preventive capability, as shown by this priority hierarchy:

- Source prevention
- Source reduction
- Recycling
- Waste separation and concentration
- Waste exchange
- Energy/material recovery
- Incineration/waste treatment
- Ultimate disposal

Low or non-cost options, as for example measures for improved «housekeeping», should be implemented immediately. Other prioritised options should be subject to further feasibility analyses.

The **feasibility analyses** involves environmental, technical and economic evaluations of the selected options. The options that are environmentally favourable and technically and economically acceptable should be selected for implementation. If all the selected options can not be implemented at the same time, an implementation plan should be prepared. This plan should be reviewed regularly to check if the assumptions and prioritising are still valid.

An important aspect of a cleaner production project is to ensure a continuous work in the company, preferably by the establishment of a Cleaner Production Management System that constitute a part of the company’s overall management system.

31. Project work

31.1 Workshop

A workshop was arranged on March 20 1998 at the JEPB main office in Jiaxing. This workshop marked the start of the clean production study, and gave the opportunity to introduce the concept of clean production to the participating companies and other industrial companies in Jiaxing.

Present at the workshop were:
- Representatives of the Jiaxing Environmental Protection Bureau
- Representatives of Minfeng Group Corporation
- Representatives of Zhejiang Lanbao International Woollen Textile Corporation
- Representatives of fertiliser plant in Jiaxing
- Representatives of chemical factory in Jiaxing

Mrs. Astri Huse gave the lectures on clean production, with the assistance of Mr. Finn Medboe.

The first part of the workshop concentrated on explaining the concept of clean production and the working methods involved. In the second part, examples were given form companies in Europe and North America, showing results that have been achieved with regard to environmental and economic benefits. A forthcoming project in the Chinese pulp and paper industry was briefly presented. The workshop was concluded with a short discussion among the participants.

31.2 Visits to the plants

The participating companies were visited twice. In advance, the factories had presented their view on what they considered to be their most pressing environmental problems.

The Minfeng Pulp and Paper Mill was visited on March 23 and 26 1998. On March 23 parts of the pulp and paper production facilities were reviewed, with emphasis on the bleaching plant, facilities for alkali recovery, and facilities for cigarette paper production. The alcohol and rice wine production site was also reviewed. This production site is located outside the Pulp and Paper factory, in another part of Jiaxing City. After the site visits, there were discussions regarding the main problems.

The Zhejiang Lanbao International Woollen Textile Corporation was visited on March 24 and 27. As with the Minfeng Pulp and Paper Mill, the first day was dedicated to site review, with emphasis on wool scouring, textile dying and wastewater treatment plant. After the review, the problems were discussed in more detail.

32. Cleaner production in pulp and paper industry

32.1 Environmental impacts

Manufacturing of pulp and paper implies use of considerable amounts of chemicals and natural resources such as fibrous raw materials (wood, straw), water and energy, and produces large waste streams. Areas of particular concern are:

- Extensive use of water
- Extensive use of non-renewable energy sources (coal, oil)
- Effluents with high concentrations of organic materials, resulting in oxygen depletion in the water recipient
- Effluents with high concentrations of suspended solids, coating the bottom of the water recipient and smothering aquatic plants and animals
- Effluents containing toxic substances, in particular persistent chlorinated organic compounds from bleaching effluents, and effluents with high pH
- Effluents causing colouring, foaming and unpleasant odour, impairing the aesthetic value of the recipient
- Emissions of dust, CO_2 and toxic substances from coal or oil fired power plant

On an international level, the pulp and paper industry has undergone a development towards larger and more efficient units and closing down of old and out of date mills. This modernisation of the industry has also brought about substantial improvements in the environmental performance and reduced the industry's environmental impact. The principles of cleaner production have been an important basis for the innovation in the field of process technology and production equipment.

32.2 Minfeng Pulp and Paper Mill

Minfeng Pulp and Paper Mill was established about 1930, and is a medium size paper mill by Chinese standards. In 1996 the production rate was 45.684 tons of paper. The Minfeng Group Corporation also administers a cement production plant and a factory for alcohol and wine production. The latter is located outside the paper mill area, in another part of Jiaxing City. Total workforce is 4900. Some key figures for the production are shown in the tables below.

Table 41. Key figures for production, Mingfeng.

Raw materials consumption	**1996, tons/year**	**1995, tons/year**	**Note**
Wheat straw	20 636	27 552	
Rice straw	10 947	13 941	
Flax straw	1 681	714	Closed down
Waste paper	10 329	11 540	
Waste cloth/cotton	510	559	
NaOH (solid)	5 506	6 005	
Chlorine (liquid)	1 245	1 467	
Coal	134 143	133 212	
Heavy oil	864	784	

Water	**1997, tons/day**	**1996, tons/day**	
Water (incl. Cooling water)	56 785*	60 023	

* During January - August

Minfeng produces straw pulp from wheat and rice straw. They also utilise waste paper and cotton cloth. In addition, commercial wood pulp is used in the production of some paper qualities. The sulphite process was used to produce flax straw pulp, but this production has been closed down. Today, no sulphur compounds are used in pulp production. The black liquor is partly recovered.

The pulp is bleached with $CaClO_2$, which is produced in-house from commercial chlorine gas. Parts of the effluents from the bleaching plant are treated in the wastewater treatment plant. The rest is discharged directly to the canal without treatment.

The mill produces 16 different paper qualities, i.a. writing paper, capacitor paper and cigarette paper. At five of the paper machines white water is cleaned by flocculation and reused. White water from the other paper machines, i.a. the cigarette paper line, is discharged directly to the canal.

The black liquid from the pulping, with a solids content of ca. 12%, is evaporated to a solids content of 40 - 45% and burned in a furnace at 800 - 900^oC. The resulting ashes, containing Na_2CO_3, is treated with hydrated lime to form NaOH, which is reused in the pulp production. The furnace can treat ca. 80% of the produced black liquid.

Waste water is treated in two lamella sedimentation tanks with a capacity of 10 000 tons/day each and an active sludge treatment unit with capacity 10 000 tons/day. The total treatment capacity is not sufficient to treat all the waste water. The discharge limit, set by JEPB, is 3 000 tons/year for COD by 2000. In 1996, the discharge of COD was ca. 10 000 tons/year. If the plant is not able to meet the discharge limitations, they will have to reduce their production rate in accordance with limitations set by JEPB.

32.3 Cleaner Production Options at Minfeng

To be able to maintain their production rate, the Minfeng Pulp and Paper Mill is forced to reduce discharges of polluted waste water to meet the national and local environmental standards. There are several options within the framework of cleaner production that can contribute to reach this goal. The limited site review and subsequent brief discussions with Minfeng staff during this study revealed some of the most obvious options.

The options described below are examples of clean technologies and pollution prevention techniques. Most likely, there are numerous options in those parts of the plant that were not selected for reviews, both analogous to those described, and others.

Options for water saving will also contribute to energy saving, as the water in the pulp and bleaching processes is heated. It will also contribute to reduce the load in the wastewater treatment plant.

1. Housekeeping and maintenance
The production equipment in the pulp and bleaching plants is fairly old and require extensive maintenance. During the site review, leaks from valves and pipelines were observed. Even though each leak may be of minor significance, the sum of all such leaks adds to a considerable amount that contributes significantly to the extensive water consumption. They can be dealt with through intensified surveillance and maintenance. This is a simple and inexpensive measure that should be implemented immediately.

2. *Process optimising*
The pulp and bleaching processes are not automated and have no control and regulation equipment. The production managers are aware that the processes are not optimised, and that the water consumption is probably too large. According to the management, there are

technical obstacles to introducing automatic control and regulation. As an alternative, inputs of water, chemicals and raw materials should be carefully monitored and controlled with methods available and fit for the existing process equipment, and the process parameters set within as strict limits as possible. This measure requires only minor investments and should be implemented before long.

3. Recovery of black liquid
Today, only 80 -90% of the black liquid is treated, and the yield of the recovery is considered to be too low. According to the production management, the furnace capacity is insufficient. The furnace was built more than 25 years ago, and the possibilities for increasing the capacity are limited.

Increasing the treatment capacity and the rate of recovery requires reconstruction of the existing furnace or new process equipment, a measure that is likely to necessitate major investments. The option should be subject to a feasibility study to evaluate both the environmental, technical and economic aspects.

4. *Reuse of white water*
The white water from several of the paper making machines is treated by flocculation and reused. The white water from the cigarette paper machine contains emulsified $CaCO_3$, which obstructs water reuse.

An option for cleaning and reusing the white water is treatment by nano-filtration. The technique is well-known and in regular use for cleaning of several types of waste water in the pulp and paper industry, including white water. The option requires investments in filters and supplementary equipment, and should be subject to a feasibility study.

5. *Bleaching*
A chlorine compound ($CaClO_2$) is used for bleaching. Chlorine compounds are considered to be environmentally unfavourable due to the possible formation of persistent, toxic chlorinated organic compounds in the effluent. There is no monitoring of chlorinated organic compounds in the wastewater at present.

Changeover to chlorine free bleaching chemicals should be evaluated. If technical and/or quality problems make a complete changeover difficult, a partial changeover should be considered. At present, the most commonly used non-chlorine bleaching chemicals are oxygen and hydrogen peroxide. Changes in the bleaching process necessitate new process equipment. A technical, environmental and economic evaluation must be performed.

6. Bottle washing (wine bottling plant)
The rice wine production factory contains two automated bottling lines. At present, the washing water is discharged continuously to the sewer. The possibility for re-circulating the washing water for a period of 2 - 3 months should be investigated. This is common practice in Norwegian breweries and soft drink bottling plants. The chemicals and detergents used in Norway are much the same as in the Minfeng wine bottling plant. Norwegian bottling plants have not experienced hygienic or quality problems.

32.4 International trends

Description of cleaner production options for the pulp and paper industry can be found in textbooks and professional journals, in databases and on Internet. Some examples are given below.

Bleaching
Chlorine compounds, and in particular elemental chlorine, is regarded as an unfavourable bleaching chemical due to the formation of persistent, toxic chlorinated organic compounds in the waste water. There is a continuous search for new bleaching chemicals with reduced environmental impact. Oxygen and hydrogen peroxide are in regular use in pulp and paper mills in Europe and North-America. Ozone, activated oxygen and enzymes are options that are investigated at the moment.

Closed-cycle technology
«Closed cycle» means processes with practically no effluents, with recycling of water and reclaiming of energy, raw materials and products. Special attention has to be paid to product quality and the quality of the recycled water, and the closed-cycle technology always implies advanced water treatment methods like ultra and nano-filtration. In addition to reducing pollution loads, the technology contributes to large reductions in water and energy consumption.

Energy saving
Focus on greenhouse gases and high prices on energy have encouraged energy saving in the industry. Excellent results have been achieved by:

- Change-over to more energy-efficient equipment, e.g. motors, lighting
- Change-over to more energy-efficient processes
- Recovery of waste heat
- Use of co-generation facilities for heat production
- Increasing energy awareness among employees through training and information

Improved management and housekeeping
Remarkable results can be achieved by improved process control and housekeeping. Losses from leaks, inaccurate process control, high fault rates, negligence etc. can add up to considerable amounts. Such losses can be prevented by increasing awareness among employees through training and information, and written guidelines for operations that are crucial with respect to the environment.

Chinese Cleaner Production initiative in pulp and paper industry
China is the world’s leading producer of straw pulp, and the industry possesses much knowledge of the special technology and problems related to this production. Under the National Agenda 21 programme, China has launched a Cleaner Production project dealing with the environmental challenges in the straw pulp and paper industry, in particular the discharges of organic matter and suspended solids, the bleaching process and the alkali recovery. The 5-year project will contain two main activities:
- Establishing an expert group on university level
- Building a demonstration plant based on Cleaner Production principles

Pulp and paper industry throughout China will in time benefit from this project.

33. Cleaner production in textile industry

33.1 Environmental impacts

Textile manufacturing produces aqueous, air and solid waste streams that have to be managed, recovered, treated and disposed of.

Aqueous effluents are considered to be the primary pollution problem for the industry. Effluent includes discharges from fibre preparation, fabric preparation, dyeing, finishing and other operations. Pollutants of particular concern are:

- High concentrations of organic materials, resulting in oxygen depletion in the water recipient
- High concentrations of suspended solids, coating the bottom of the water recipient and smothering aquatic plants and animals
- Toxic substances in dyes, surfactants and other chemicals
- Effluents causing colouring, foaming and unpleasant odour, impairing the aesthetic value of the recipient

Further, textile manufacturing is a water-intensive industry, and uses energy for heating of process water and drying in several stages of the production process. Air emissions from fossil fuelled power plants is the industry's second greatest pollution problem.

33.2 Zhejiang Lanbao International Woollen Textile Corporation

The textile plant in Jiaxing was established in 1958. The plant produces knitting wool, fabrics and garments from wool and mixtures of wool and synthetic fibres. The production plant contains facilities for wool scouring, spinning, weaving, wet treatment (washing, dying, shrinking), finishing and sewing. The plant also treats its effluent in a wastewater treatment plant. Some key figures for the production are shown in the tables below.

Table 42. Key figures, Textile corporation.

Product	**Amount, Jan. - Nov. 1997**
Woollen fabric	1 163 000 m
Yarn	519 tons
Thread	2 288 tons
Sweaters	275 000 pieces

Raw material	**Annual Amount, tons**
Wool	2 285
Synthetic fibre	1 128
Dyes	50
Glacial acetic acid	65
Sulphuric acid	37
Sodium sulphate	131
Other additives	217
Water	3 653 317
Coal	28 683

Process water is drawn from the canal and is cleaned by precipitation and lamella sedimentation. According to the environmental manager, pollution of the canal water causes problems in the dying process, in particular with regard to reuse of water.

Waste water from dying is treated in the waste water treatment plant. The treatment plant consists of coarse and fine screen, retention basin, anaerobic and aerobic treatment. The design capacity is 3000 tons/day. At present, 1700 tons/day of dying waste water is treated. The quality of the treated waste water complies with the national standards for waste water. Other waste waters (i.a. from power plant, cooling water and domestic waste water), a total of 6 840 tons/day, is discharged directly to the canal without treatment.

33.3 Cleaner production options at Zhejiang Lanbao Textile Plant

There are several options within the framework of cleaner production that could contribute to reduce the pollution load from the textile production. The limited site review and subsequent brief discussions with the environmental manager during this study revealed some of the most obvious options.

The options described below are examples. Next section describes other clean technologies and pollution prevention techniques that are used by the textile industry word-wide.

1. Wool scouring
Raw wool is washed in the wool scouring plant. The washing is carried out stepwise with water and alkali (NaOH or soda). Water from washing step 2 is reused in washing step 1. All other waste water, which is heavily polluted with grease and dirt, is discharged directly to the canal without treatment.

By applying more counter current washing and in-house cleaning of the waste water to remove the dirt and grease (centrifuging, ultra-filtration), the pollution load in the waste water can be significantly reduced, and water can be reused in the scouring process. The grease is a valuable by-product (lanolin) that may be sold. A process based on these principles have been designed for the plant by JPPB.

2. Dying
Hanks of yarn are dyed in hot dying baths. The yarn is dyed batch-by-batch, and the colour bath is changed between each batch. Colouring and rinsing is carried out in the same equipment.

The dying baths are heated with steam. Temperature varies with colour. For instance, black colour bath is heated to 85^{o}C. The waste water from the dying process holds a temperature of approximately 50^{o}C when discharged to the waste water treatment plant.

If the amount of colour used pr. meter of yarn can be reduced, this will reduce the pollution load and at the same time reduce the production costs. There are at least two options to reduce colour consumption:

- Use more efficient colours which are absorbed better in the yarn. This reduces the necessary amount of colour pr. meter of yarn, and leaves less colour in the waste water

- Use muffs instead of hanks in the colour bath. This allows the yarn to be compressed, and more yarn can be dipped in the colour bath in each batch. Change of method requires new equipment for yarn winding.

3. *Energy saving in the dying process*
Heat is lost through evaporation from the warm dying baths and with the warm wastewater that is discharged to the treatment plant. By applying heat exchanger technique, this energy could be conserved and reused in the process, for example to preheat the water in the dying baths.
Such measures requires investments in new equipment and should be subject to an economic evaluation before implementation.

33.4 International trends

Description of clean technologies and pollution prevention techniques for the textile industry can be found in textbooks and professional journals, in databases and on Internet. Some examples are given below.

Low bath ratio dying
Typical values for weight of dye liquid per weight of material dyed is 12:1. New types of jet and package dying machines offer low bath ratio dying in the range of 3:1 to 5:1. Ultra low liquor ratio (ULLR) machines offer the lowest ratios.

Dye bath reuse
Used hot dye baths can be analysed for residual colour content, replenished as necessary and reused for new batches of yarn or fabric. Dye baths can be reused from 5 to 25 times if the process is properly controlled. Acid, basic, direct and disperse dyes are best suited for reuse.

Continuous dying for knits
Several equipment manufacturers now offer lower-than-standard tension or tensionless continuous dying machines that do not pull or stretch the fabric out of shape. This allows for continuous dying of knitted as well as non-knitted fabrics.

Automated colour mix
By using computer-controlled mixing and batching of colours, it is possible to improve the accuracy and speed in colour matching while mixing. This reduces overuse of colours and waste due to errors.

Automated chemical dosing
Automated dosing improves the accuracy and allows for continual adjustments to fit product standards, fabric quality etc. This reduces spills, overuse of chemicals and waste due to errors.

Counter-current washing
In multi-stage washing operations, the waste water from the final washing stage can be used in the early stages where the fabric is «most dirty». This can reduce the water consumption and the waste water discharge significantly.

A variant of this principle is the horizontal or inclined washer, where fabric enters the bottom of the machine and exits through the top. Clean water is introduced at the top of the machine, causing a water flow within the machine that is inherently counter-current.

34. Summary and conclusions

This limited study in two factories in Jiaxing has shown that there is a considerable potential for pollution reduction through cleaner technology.

In the study, the emphasis was put on options for water saving and reduced discharge of waste water. Such options have been described for both the participating factories. I addition, options for reduced consumption of chemicals and energy savings are described.

Some of the options require no or low-investments and could be implemented within a short time. Others require funds for modification of equipment or new production and treatment equipment and must be subject to more thorough feasibility studies.

The described options are examples based on a relatively superficial survey of the factories. Before implementation, the measures should be analysed with regard to environmental, technical and economical aspects. The analysis must be based on the situation in the factory and its surroundings.

It must be emphasised that this study is limited and do not bring to light all possibilities for employing cleaner production in the participating industries. Moreover, the study was not conducted as a «real» Cleaner Production project, as the staff and employees in the factories did not play as active a role as could be desired. Utilising the expertise of the company’s employees is one of the basic principles of cleaner production. Hence, the work should be continued to fully explore the potential for improvement through cleaner production techniques.

CHAPTER 6

Project activity 6:

Planning of Wastewater Collection Systems and Design Alternatives

35. Introduction

A transportation system for wastewater is an important part of a city and its infrastructure. The concept of a WW collection system is usually a pipe with an inclination angle for areas with slope and a pipe connected to a pumping station in flat areas. Although this sounds like an easy concept, almost every city experiences the same common problems with its sewage pipe network: The problems are typically but not limited to:

- Lacks of capacity of pipes during heavy rainfall that causes discharge of combined sewage and rainwater to the city's recipients and occasionally overflow of streets and basements.
- To small inclination angle for some of the pipes leading to sewage stoppage and odours.
- Pipe material with lack of resistance to corrosion and deterioration gives need for expensive repair and maintenance operations.

The task of the design engineer is actually complicated. Variables like pipe dimension, inclination angle, material type, trench depth, number of pumping stations and CSO's should be optimised regarding self-cleansing, capacity and the need for structural integrity. Compromises due to economical and practical restraints have to be made. Furthermore the pipe network is a static system in a city in dynamic change and with large meteorological variations in rainfall intensity and depth over the years.

Certainly a lot of the most common problems can be predicted and avoided by using advanced computerised planning tools in the design of the WW collection system. This chapter describes an example of a design using advanced planning tools, for the sewer network in Jiaxing. The design is based on an alternative with ocean discharge.

It should be emphasised that this activity only suggests some basic principles for the design of the sewer system. To find the optimal design we suggest that more alternative designs should be calculated and compared based on discussions and co-operation between, Construction Commission, JEPB, Design Institute and Consultants.

36. Objectives

The main objectives for this activity were:

- To suggest some basic principles for the design of the sewer system in Jiaxing

- Train technical personnel on simulation models

37. Work description

The following activities have been carried out:

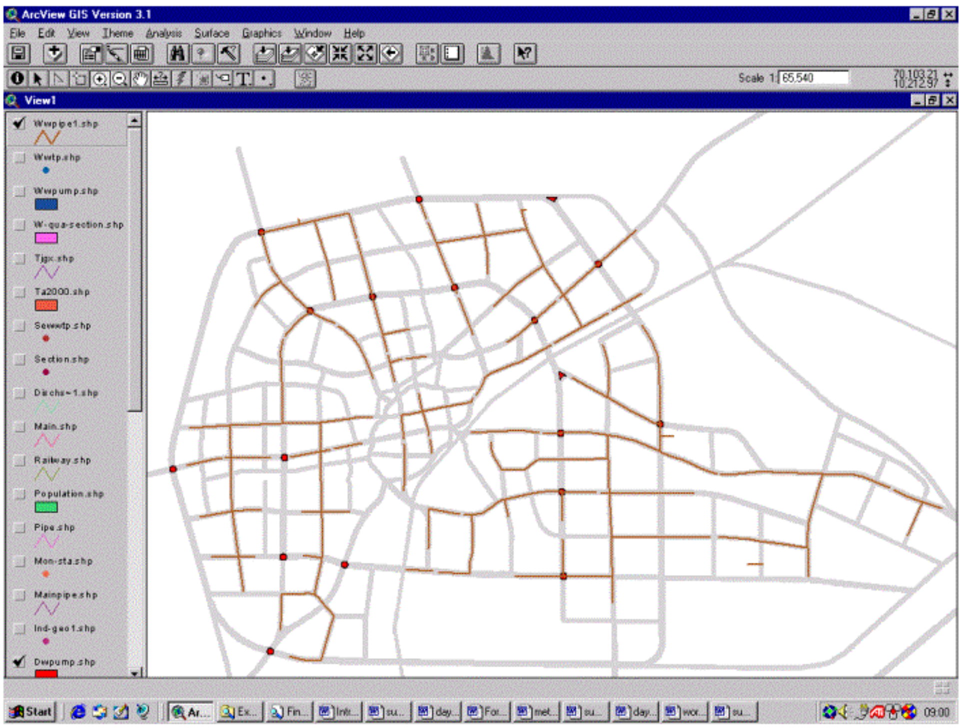
- Collection and adaptation of required design data, including computerised mapping of existing and planned main pipelines, main industries, main population density and main canals
- A basic design has been performed for the WW collection system
- Technical personnel at the Jiaxing EPB has been trained on simulation models

38. Collection and adaptation of design data

- Mapping of the existing and planned pipes and pumping stations
- Estimate of future population
- Mapping of the industry discharges in the area

The estimates of future population and mapping of the industry discharges in the area is described in project activity 4 (Chapter 4), impact assessment of combined WW.

The figure show the mapping of existing and planned pipes and pumping station based on CAD drawings and paper maps from JEPB and City Engineering Department.



39. Design for the WW collection system

39.1 Some basic principles

39.1.1 Operation and maintenance aspects

No matter what kind of design strategy is chosen the sewer pipes should comply with some basic functionality regarding:

- Structural integrity
- Capacity
- Self cleansing
- Leakage

39.1.2 Structural integrity

The structural integrity of the sewer pipes will decrease with time and the speed of this process for each pipe will usually depend on:

- Pipe material quality
- Method of trench digging, back-filling and pipe work
- Amount of aggressive waste water
- Total load of soil, buildings and traffic

It is important to perform regularly control of the pipe material quality and to set some standards for the fabrication regarding amount of cement versus rock and soil for the pipe material.

39.1.3 Capacity

The capacity of the sewer pipe is depending on:

- Pipe dimension
- Slope

The pipe dimension and slope should be chosen so that each pipe obtain the capacity to transport the total future flow from:

- Infiltration
- Industrial discharge
- Domestic discharge
- Storm water runoff

39.1.4 Self cleansing

The sewer pipes ability to perform self-cleansing will mainly depend on:

- Pipe diameter
- Slope
- Daily peak flow of waste water

Self-cleansing will in most cases be obtained by using some simple rules:

- Minimum diameter to avoid blocking by large objects typically 300 – 400 mm.
- And a minimum slope for the pipeline typically (1/1000):

-Pipe from house to main pipe branch	10 - 20
-Pipe at the end of a smaller branch	4 - 5
-Other pipelines	2 - 3

39.1.5 Leakage

If the pipe is not leakage proof it will result in infiltration of clean water into the pipe during high ground water level and leakage of waste water to the ground during low ground water level.

Whether the sewer pipeline is leakage proof or not will depend on:

- Method and quality of each pipe connection
- Structural integrity of pipeline

39.2 Environmental aspects

During the design and building of the sewer system the environmental aspects should be implemented with special attention to:

- Amount of combined sewer overflow (CSO) during rainfall
- Leakage from pipelines
- Connection ratio to the sewer system from industrial and domestic area
- Operational reliability of the pumping stations

39.3 Economical aspects

The economical aspects regarding the sewer system can be divided into:

- Economical aspects regarding future operational and maintenance
- Economical aspects regarding construction of the sewer system.

In general, a low cost/low quality strategy for the construction of the sewer system will give high future operational and maintenance cost.

Generally a strategy for the pipe design regarding the economical aspect should emphasise a to minimise the following:

- Number of canal crossings
- Total length of pipeline
- Maximum trench depth
- Number of pumping stations

39.4 Stepwise design of a sewer system

The final choice of design for the sewer system should be based on an evaluation of a number of alternatives regarding:

- Operational and maintenance aspects
- Economic aspects
- Environmental aspects

The steps in the example design and a general approach for the design could be:

1. Make a basic design in Arc View for the main sewer system following the general rules discussed under environmental and economical aspects.
2. Decide for maximum trench depth, minimum slope, minimum diameters.
3. Make a more detailed design in Arc View implementing the steps 1 and 2.
4. Decide for the discharge coefficients for the flows mentioned under capacity.
5. Make a design and calculation in HYDRONET and/or MOUSE implementing the steps 3 and 4
6. Present and evaluate the results in ArcView

39.5 Example design

39.5.1 Step 1 – Basic design in ArcView

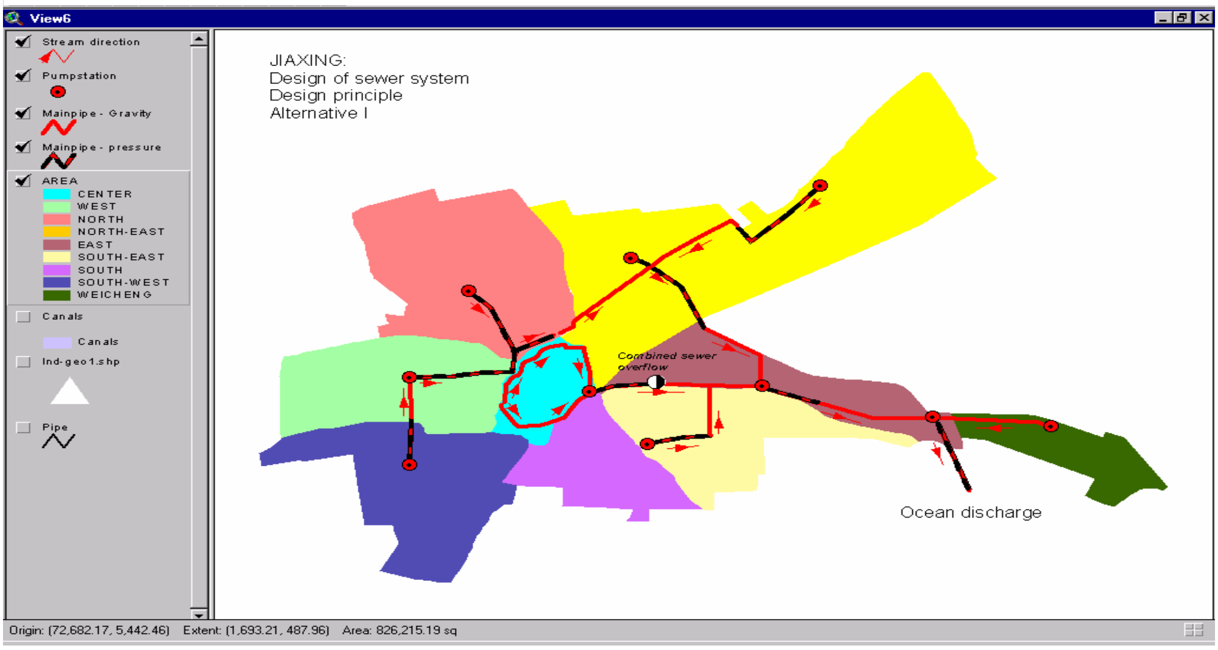


Figure 51. Basic design, sewer network

The figure above shows the basic design for the sewer system following the general rules discussed under environmental and economical aspects:

Environmental aspect:

- The separate system areas discharge to a main collector.

  The alternative would have been to route some of the separate systems through the main Centre ring pipe. This would however give increased discharge of sewage to the ring canal during rainfall.

- The combined storm water and waste water from the Centre area is pumped to a combined sewer overflow (CSO) a distance from the ring canal.

  A main CSO for the Centre area will ensure the sewage from the separated areas priority to the treatment plant during rainfall. The positioning of the CSO gives the smallest amount of sewage discharge to the ring canal.

The solutions described will give a minimum overall CSO to the canal system and will minimise the CSO to the ring canal and is therefore recommended as the best environmental solution.

Economical aspect:

The sewage system is designed with pumping stations as the Centre drainage point in the areas. The wastewater is pumped with a pressure pipe to a main collector.

The solution described reduces the needed amount of pumping stations and or makes it possible to reduce the trench depth. This will in most cases be the most economical solution in flat areas.

39.5.2 Step 2 and 3 – A more detailed design in ArcView

The figure below shows the more detailed design in ArcView for each area.

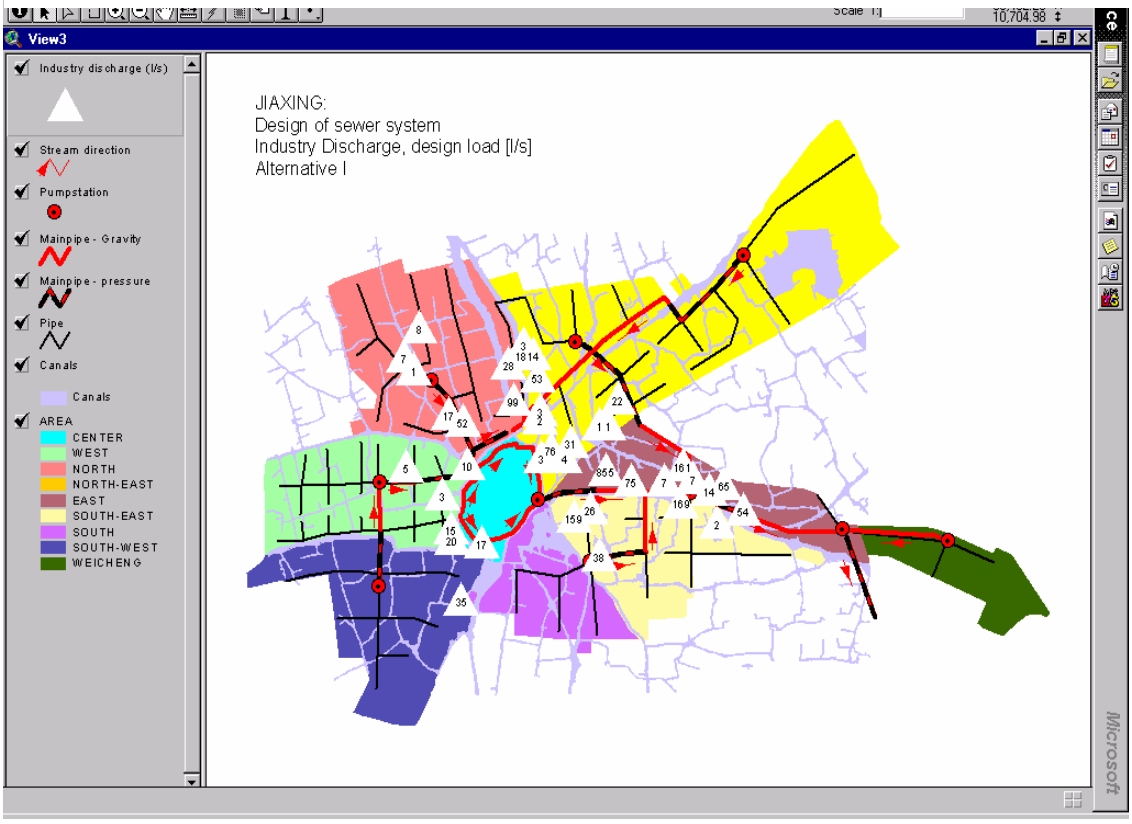


Figure 52. More detailed design of sewer network

39.5.3 Step 4 – Decision of the discharge coefficients

Calculation of peak hour design flow – Industry discharge

The following table presents examples of calculation of peak hour design flow for three of 76 calculated industry discharges in Jiaxing. See also the figure above for the discharge distribution.

Table 43. Peak hour design flow, industry

	Calculation of Peak hour design flow / Industry discharge							
Code		B-1	B-3		B-4	B-5		
	Industry name	number of discharge days	number of discharge hours + amount		average discharge WW flow	peak hour discharge flow	peak hour discharge coefficient	peak hour design flow
Ref. No.*		days	hours/day	t/day	t/y	m3/hour		l/s
1	J. Heat and Power Plant	365,0	24,0	42,7	374400	42,7	1,5	17,8
2	Minfeng Paper Mill	321,5	24,0	49225,0	15825903	2051,1	1,5	854,6
3	J. Woollen Textile Factory (3+69)	346,0	24,0	2200,0	761200	91,7	1,5	38,2

Calculation of peak hour design flow – Domestic wastewater

The figure below shows the estimated population for each sub-catchment in the year 2020.

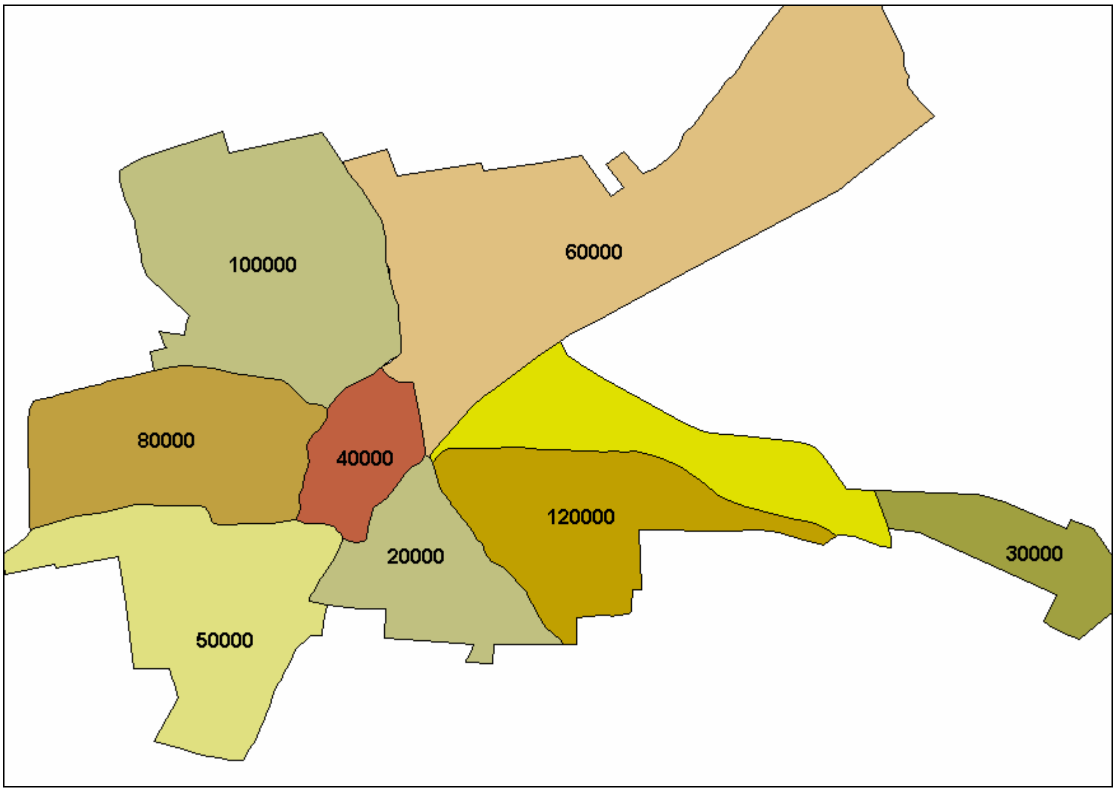


Figure 53. Estimated population in Jiaxing's different areas.

Table 44 shows the calculation of the peak hour design flow for domestic wastewater for each sub-area in Jiaxing.

Table 44. Peak hour design flow for various areas.

AREA	POPU_2020	AREA_2020 [ha]	Average discharge (l/pd)	Peak hour design flow coefficient	Design flow l/s	Maximum discharge from area after combined sewer overflow	Design flow l/s ha
north	100000	849.2	300	3	1042		1.23
west	80000	551.4	300	3	833		1.51
south-west	50000	784.5	300	3	521		0.66
center	40000	0.0	300	3		2 500	
south	20000	289.7	300	3	208		0.72
south-east	120000	579.1	300	3	1250		2.16
east	0	450.4	300	3	0		0.00
weicheng	30000	250.7	300	3	313		1.25
north-east	60000	1005.4	300	3	625		0.62
SUM	**500000**	**4760**			**4792 + 2500**		

39.5.4 Step 5 - Design in Hydronet

The figure below shows the design in HYDRONET with drawing of areas and pipes. In HYDRONET a calculation of pipe dimensions has been carried out based on the given storm water runoff and waste water discharge coefficients.

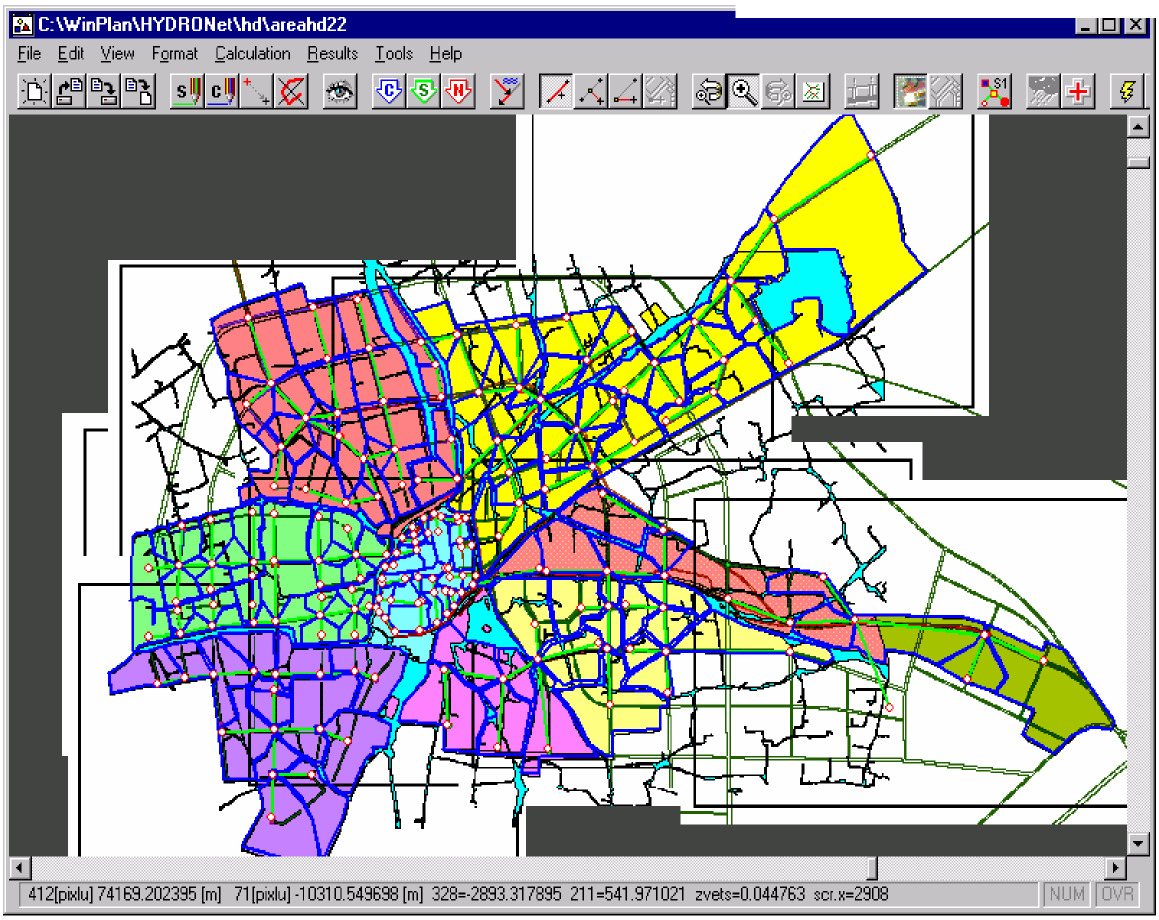


Figure 54. Design in hydronet with all sewer pipes.

39.5.5 Step 6 - Present and evaluate the results in ArcView

The ArcView figures below present calculated design flow, pipe capacity and necessity of sewer flushing.

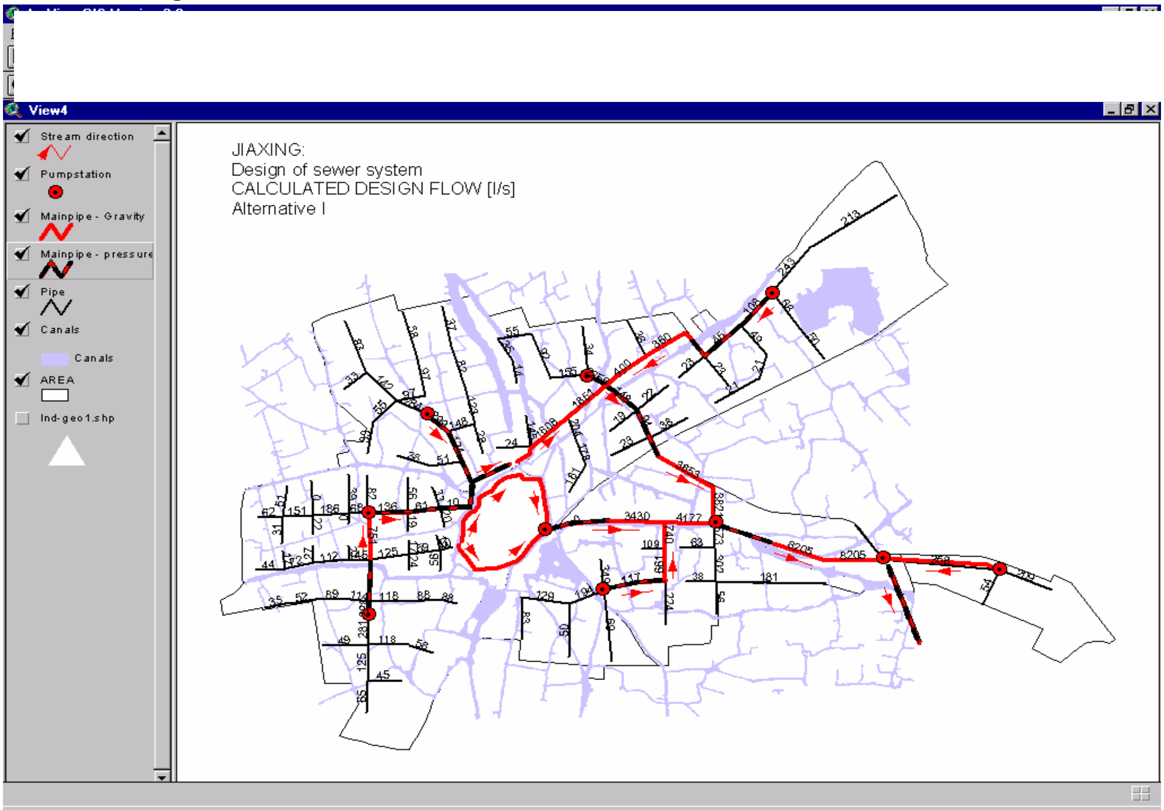


Figure 55. Calculated desing flow in sewage pipes.

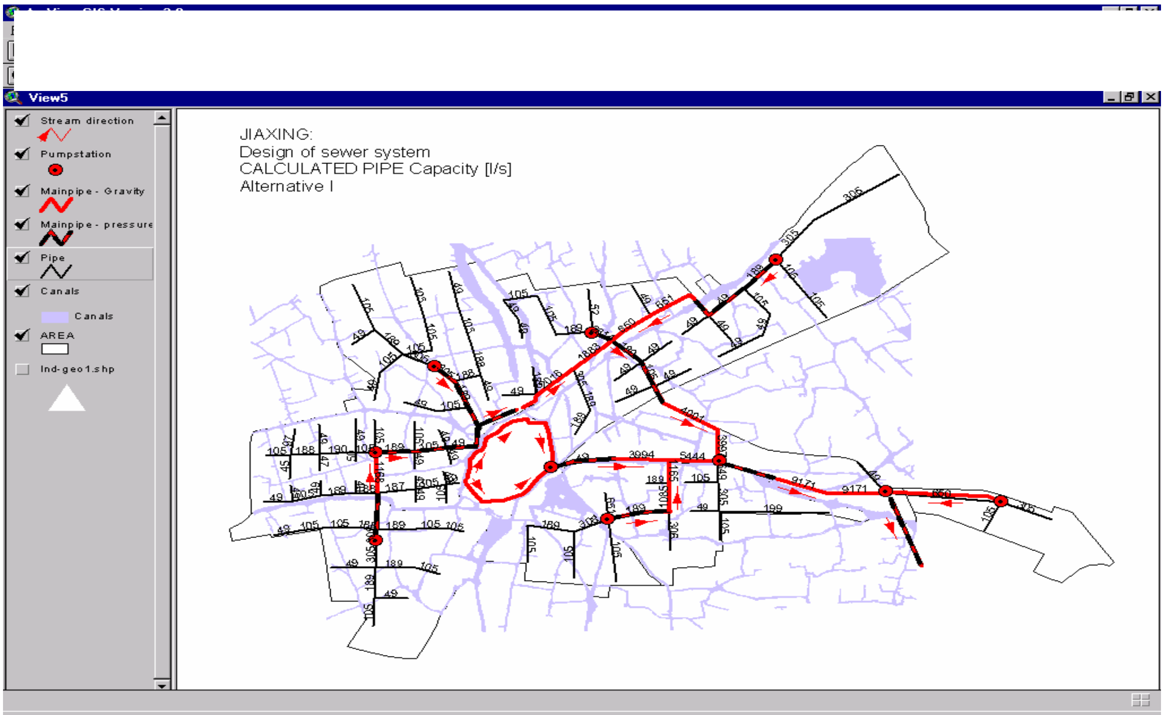


Figure 56. Calculated desing flow in sewage pipes.

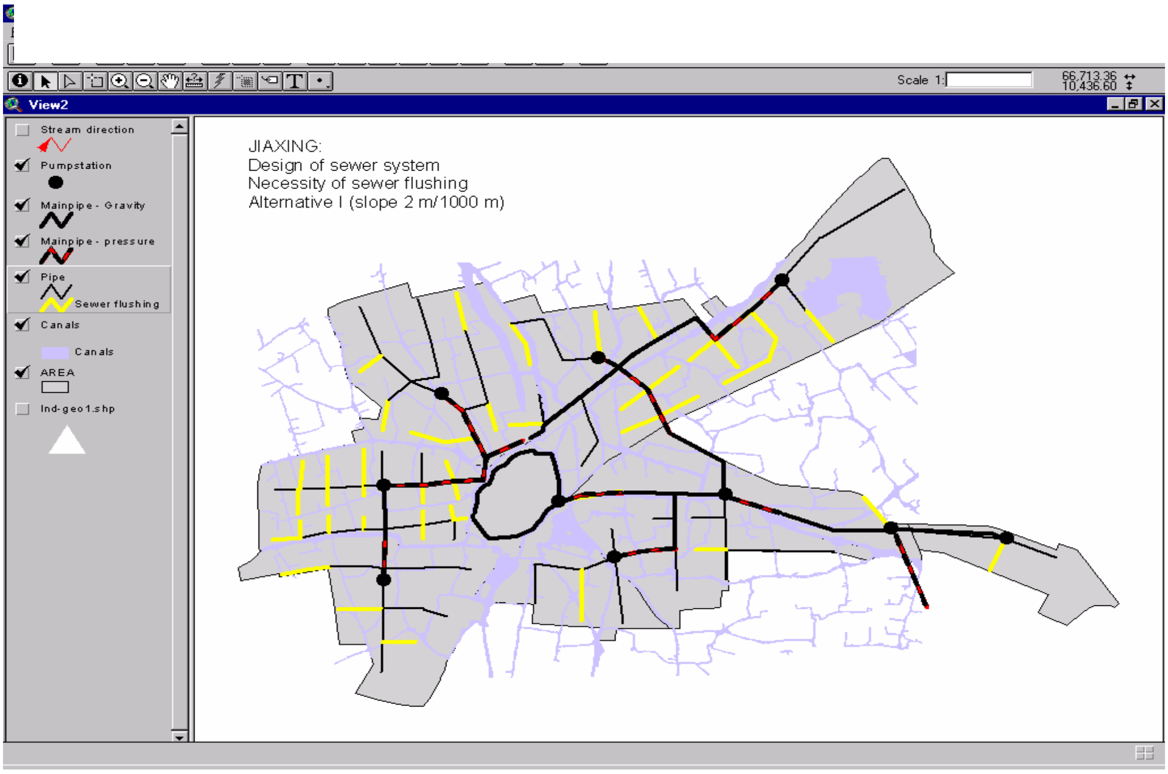


Figure 57. Necessity of sewer flushing.

CHAPTER 7

Project activity 8:

Wastewater Treatment Using Industrial Wastes

40. Introduction

Chemical coagulation is one of the most popular methods for water and wastewater purification in the world. The robustness of the process and the efficiency in removing particles and phosphates to necessary levels is probably the main reasons for it's popularity in domestic wastewater treatment plants. In many European countries, the coagulation is used or planned to be used in one or another way to handle phosphate removal. Some countries use this method as their major concept, and in Norway, Sweden and Denmark, more than 70% of wastewater is now treated by coagulation. Several other countries like USA and Hong Kong use the so called Chemically Enhanced Primary Treatment (CEPT), which uses only a fraction of coagulants used to achieve the full coagulation, but sufficient to remove a major portion of phosphates in parallel to a faster sedimentation process.

The most widely used coagulants in the world are aluminium and iron salts, while a number of organic polymers are also used as coagulants or flocculent aids. The removal of pollutants from water and wastewater occurs by the colloidal destabilisation and coagulation according to known mechanisms and by partial chemical co-precipitation with solid hydrolysis products. The efficiency of coagulation is governed by a number of physical and chemical factors of coagulants, influent water and process conditions.

The purpose of this sub-project activity was to investigate the possibility of treatment of various wastewater from the Jiaxing region by chemical coagulation. Jiaxing has a variety of industries with wastewater varying with compositions, concentrations and loads over time. With the national requirements to treat wastewater to acceptable levels and to face the environmental challenges in the 21st century, the city administration and the industries seeking efficient and economical solutions.

Undoubtedly, the treatment of wastewater is a costly affair, and the challenge is to find the most efficient and most economical solution that is not only cheap in the investment, but also in the long run – during the operation. In this aspect, the chemical treatment has many advantages for many wastewater types in a rapidly industrialising city where the industrial pollutants may complicate the traditional biological processes.

41. Objectives

Objectives of this sub-project was to:

- demonstrate the ability of coagulation as a promising process
- training of JEPB-engineers to conduct lab- and pilot scale experiments and evaluation of results
- understand the coagulation behaviours in various wastewater compositions at various pH and dosages
- investigate the possibility to produce coagulants from local industrial wastes to reduce treatment costs

42. Wastewater types

To represent the variety of industries in Jiaxing, we have selected wastewater from the representative industrial groups:

- paper and pulp industry
- textile industry
- pesticide industry
- domestic wastewater

The wastewater composition and concentration vary with human activities (bathing, cooking), industrial activities (shift-work) and natural phenomena (rain), etc. A perfect study should be carried out with most of these concentration in a continuos pilot treatment plant. However, such an activity requires much more resources than which was available in this project, so it was decided to select several types of wastewater from each source to study possible effects.

- high and low concentrations, based on time of the day
- wastewater after various batch processes (primary sedimentation, biological treatment)
- mixed wastewater to study a probable influent to a future WWTP

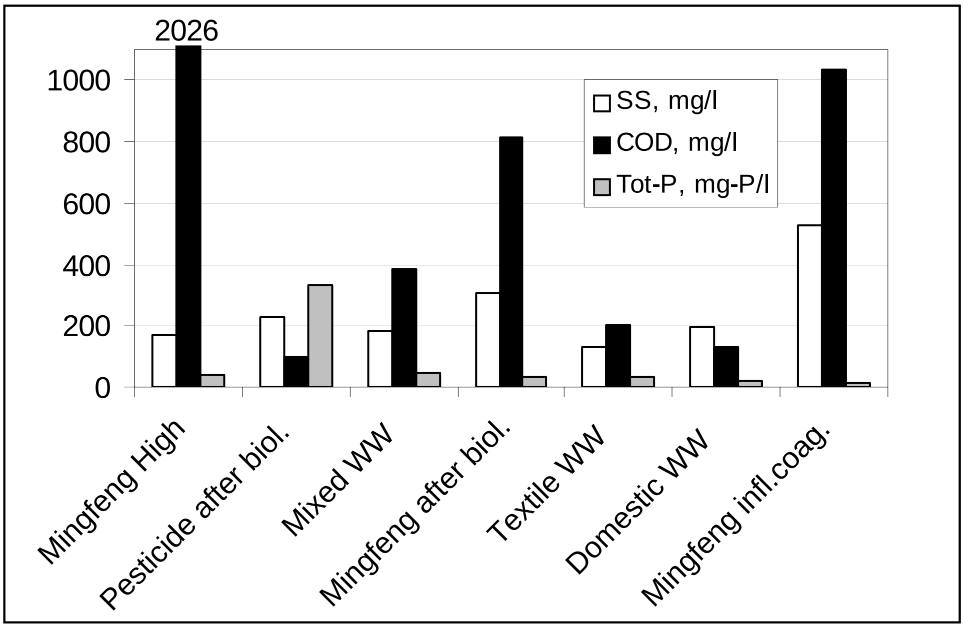


Figure 58 Composition of wastewater types investigated.

Figure 58 illustrates the composition of the wastewater types investigated in this study, and it shows a considerable variation in all parameters.

43. Experimental methods

The experiments were carried out in two phases: in laboratory scale and pilot scale. These are described in detail elsewhere in this report (Activity 4, chapter 4).

44. Coagulant preparation

The inorganic salt, which undergoes hydrolysis and cause coagulation, is called the coagulant. Often aluminium and iron (III) salts are used as efficient coagulants. Many users are reluctant to use the coagulation as their treatment process due to the fear of coagulant costs. However, the technological advantages have now shown the possibilities to develop coagulants from industrial wastes, which is both economical and ecological, as it is a rational use of industrial wastes.

Being an industrialised city situated in an industrialised region, Jiaxing has several industries with suitable raw materials for the production of efficient coagulants. The preliminary studies carried out by Kemwater LtD have shown the possibility to produce good quality iron-coagulants from Jiaxing industrial wastes. This issue will be addressed in a separate report.

The common product from such a process is iron chloride, and the content of micropollutants may vary with the composition of the acid and the industry which iron wastes are coming from. However, for the treatment of wastewater these micropollutants usually can not influence, thus it is possible to simulate the wastewater treatment process with any category or source of iron chloride solution. The amount of liquid necessary to dose will only be dependent on the concentration of Fe(III) in the solution. By reporting all values in mg-Fe/l rather than mg-FeCl3/l we can eliminate the comparative problems associated with coagulants of various concentrations.

For practical reasons, during this investigation we have used a $FeCl_3$ solution prepared from Kemwater's solid coagulant Ferrix. The solutions which were prepared in Jiaxing were analysed at NIVA for the iron content, and was found to be 175 g-Fe/l.

45. Experimental results

45.1 Mingfeng high concentrate wastewater

Figure 59 shows that the coagulation process is very much depend on the pH, and the process starts around 100 mg-Fe/l at pH=5.4, while at higher pH values it starts at higher dosages (175 mg-Fe/l at pH = 7.4). It also shows that it was possible to achieve 60-85% of SS removal at the dosages used. Under optimised conditions and with higher dosages, one should be able to achieve even higher SS-removals.

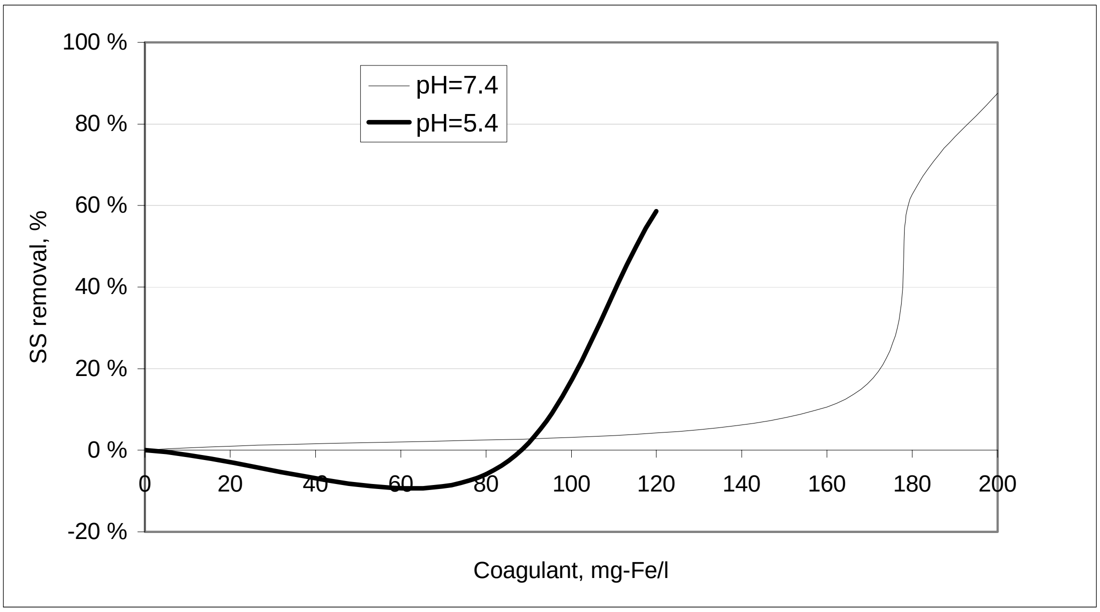


Figure 59. Removal of suspended solids from Mingfeng high concentrated wastewater with influent SS = 169 mg/l. (The negative SS-removal at low dosages are caused by unsettled hydroxide-flocs).

The jar-test experiments at two pH values (7.4 and 5.4) are shown in Figure 60. This indicates the possibility to remove > 60% of TCOD and > 90% of Tot-P with coagulation at both pH values. However, one should expect better SS removals in practice, which will also lead to better TCOD and Tot-P removals.

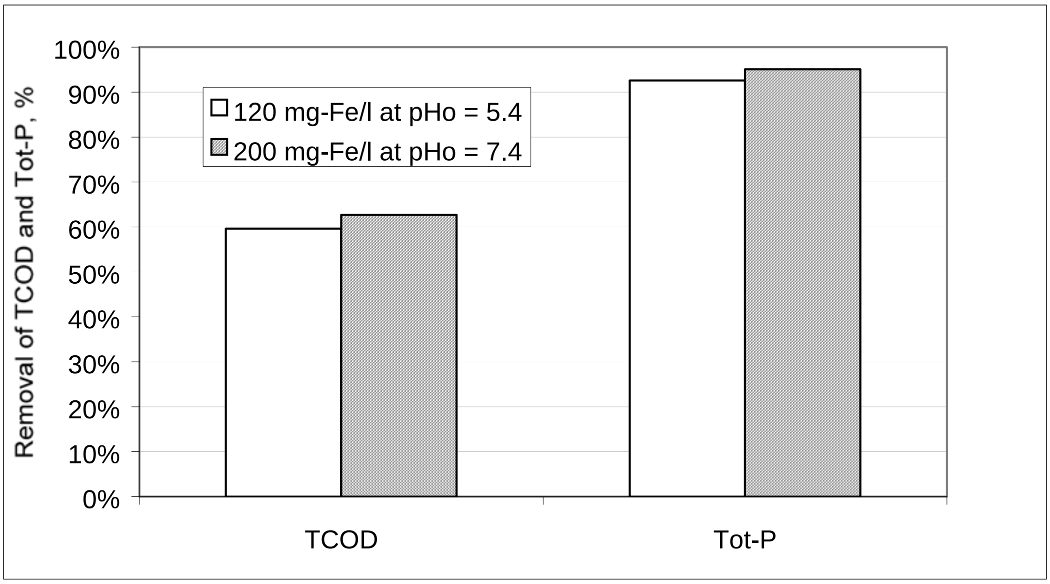


Figure 60 Removal of TCOD and Tot-P from high concentrated Mingfeng wastewater. TCODo= 2026 mg/l and Tot-Po= 3.66 mg-P/l.

The figure below indicates a slightly better performance in jar-tests. During the pilot scale experiments sludge escape was observed, which will be able to eliminate with better sedimentation tanks and/or with polymers. The important information coming from this figure is that even with a non-optimal SS removal, it was possible to achieve >90% Tot-P and > 60% TCOD removals, and with obvious possibilities to increase the SS removal rates, the coagulation process should give very good results.

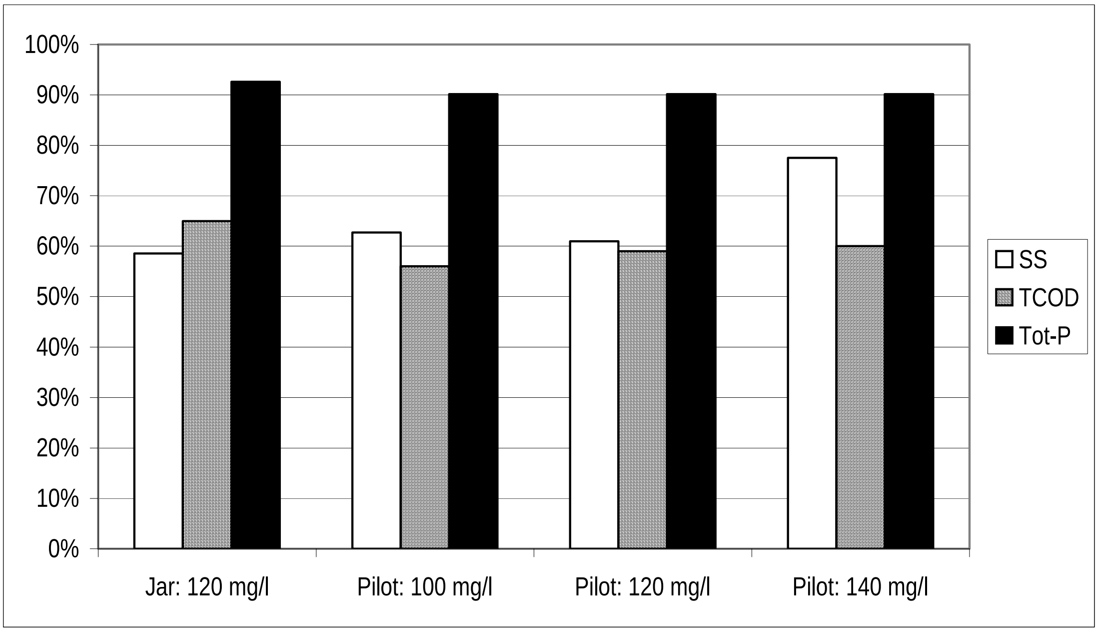


Figure 61. Comparison of SS, TCOD and Tot-P removal in jar-tests and pilot-tests at pH = 5.4 and variable Fe-dosages.

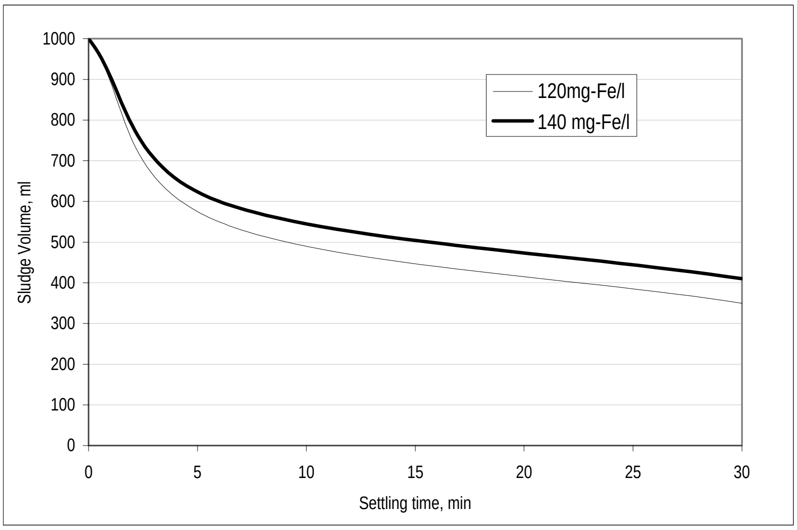


Figure 62. Mingfeng high concentrated wastewater: Sludge settling in a cylinder.

The sludge was collected from the bottom of the sedimentation tanks and observed for settling in a glass cylinder. It shows that such sludge could be gravity compressed further by 60%, within a 30 min. time. In practice, sludge settling may continue up to few hours before taken in to a de-watering system which will reduce the water content to considerably low levels.

45.2 Mingfeng wastewater – after biological treatment

A part of Mingfeng wastewater is treated in an activated sludge based biological treatment plant. It was interesting to study the possibility to treat the effluent form this wastewater with coagulation, reduce the pollution discharge to the canal system.

The wastewater after biological treatment had SS = 308 mg/l, TCOD=815 mg/l, FCOD = 374 mg/l, Tot-P = 3.12 mg-P/l and Dissolved-P < 0.04 mg-P/l. The relatively high suspended solids amount in this effluent indicates the poor settling in the sedimentation tanks, which also gives high Tot-P and TCOD values.

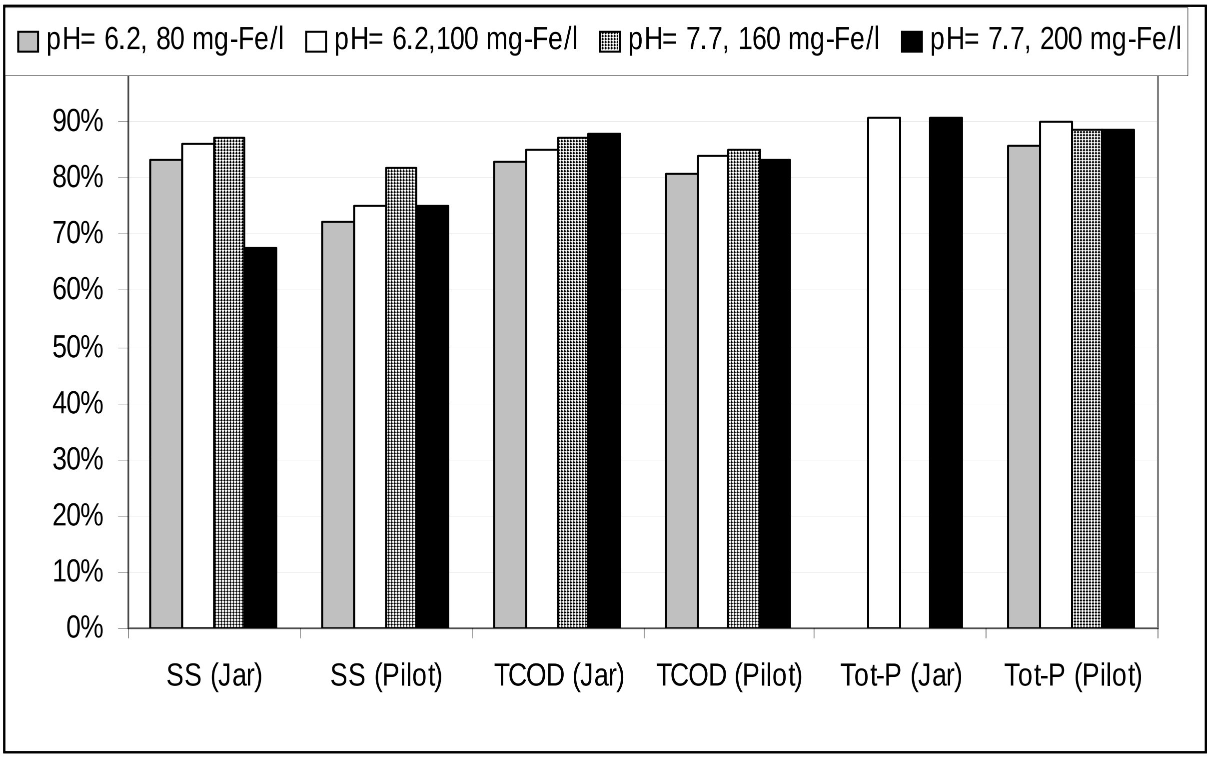


Figure 63. Comparison of SS, TCOD and Tot-P removal in biologically pre-treated Mingfeng wastewater with Fe-coagulants. (SS= 308 mg/l, TCOD=815 mg/l and Tot-P = 3.12 mg-P/l).

Figure 63 shows that the biologically pre-treated Mingfeng wastewater can be easily treated by coagulation, achieving a further > 80% removal resulting in TCOD 100-140 mg/l. The jar-test results show slightly better removal results.

The sludge production at these dosages were about 16-24% on volume basis (1-2% TS), which were further reduced to 4% v/v after a gravity settling for one day.

45.3 Mingfeng wastewater –proposed influent to the coagulation process

Mingfeng intends to treat a portion of its wastewater by coagulation and the facilities were under construction during these experiments. The coagulation efficiency with Fe-coagulants was studied in jar-and pilot scale experiments, and the results are presented in Figure 64.

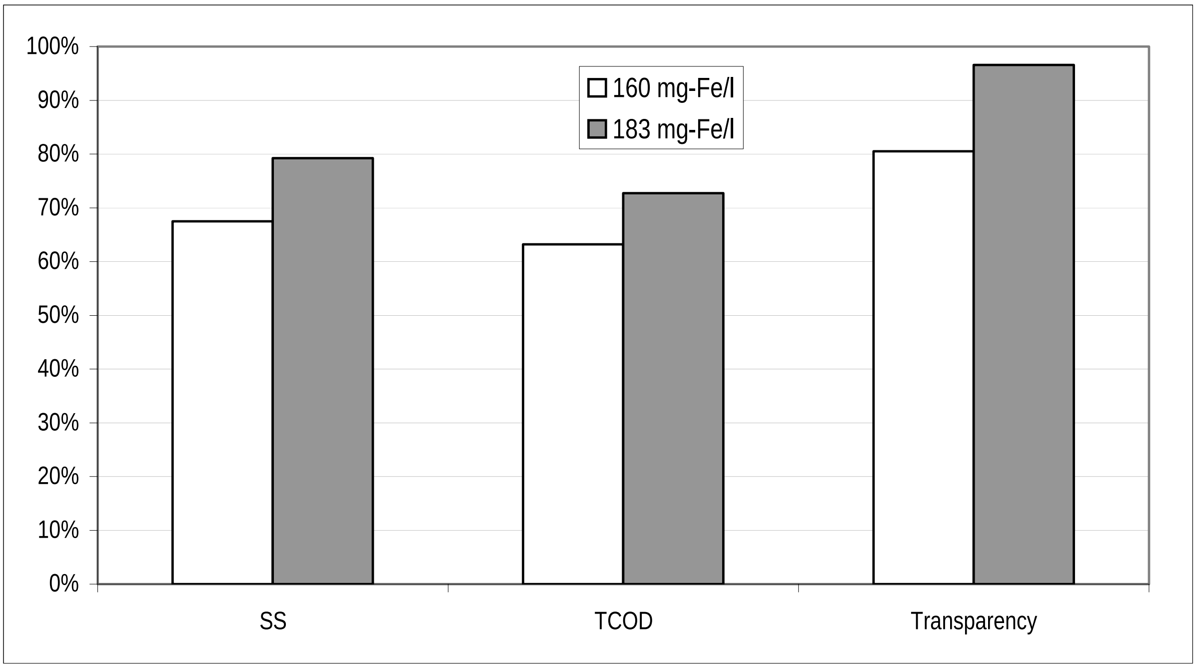


Figure 64. Jar-test studies with Mingfeng influent proposed for coagulation: Efficiency of Fe-coagulant at coagulation pH <5.0. (Influent: SS= 529 mg/l, TCOD = 1033 mg/l).

The figure above illustrates that at 60-80% of SS removals resulted in about 70% removal of TCOD resulting in values around 300 mg/l. Transparency, which also indicates the turbidity and colour removal has been very good during these experiments, reaching values around 97%. Floc formation and sludge composition seems to be similar with other experiments.

The preliminary studies conducted with reductive coagulation, dosing H_2O_2 simultaneously with iron chloride gave treatment efficiencies similar to the above at lower coagulant dosages. However, this process should be studied further.

45.4 Wastewater from the pesticide plant

Jiaxing pesticide plant discharges high phosphate concentrations after their biological treatment plant. The Tot-P concentrations were about 61 mg-P/l, where 88% was in the dissolved form. It also had about 230 mg/l of SS and about 100 mg/l of TCOD.

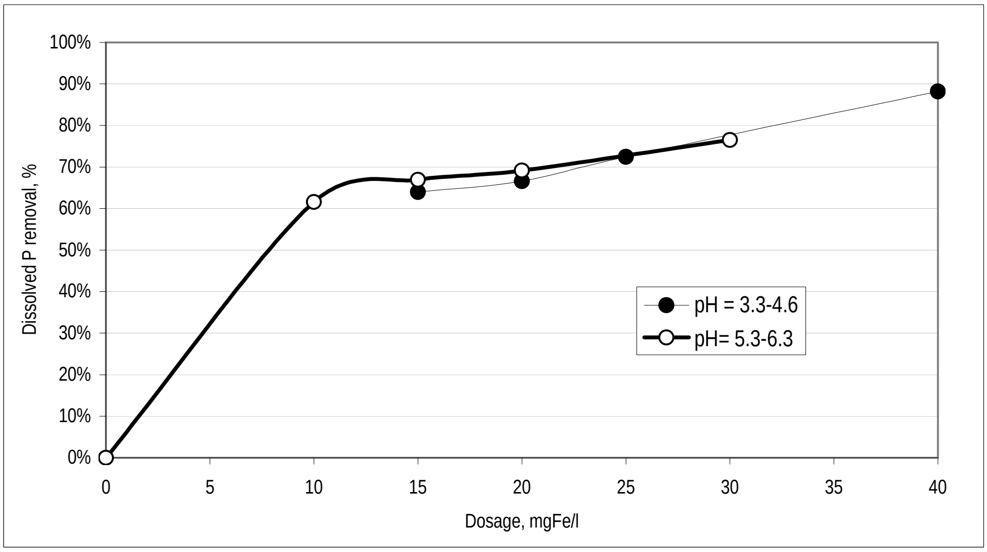


Figure 65. Dissolved phosphate removal in jar-tests from biologically pre-treated wastewater from the Jiaxing pesticide treatment plant.

The figure above illustrates that the phosphate removal increases with the Fe-dosage, but the removal is independent on the coagulation pH. At the tested dosages, 88% removal of dissolved phosphates was achieved. The Tot-P removal at this stage was about 89%.

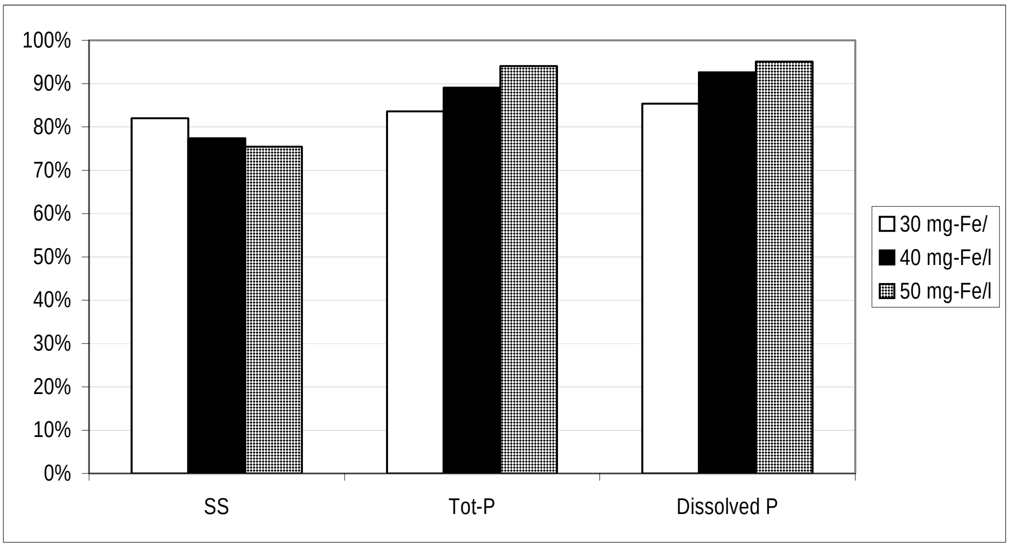


Figure 66. Treatment efficiency of biologically pre-treated wastewater from a Pesticide plant. Influent: Tot-P= 61 mg-P/l, dissolved-P= 54 mg/l, Effluent: Tot-P < 3.7 mg-P/l.

During the pilot plant experiments, the coagulant dosages were further increased to 50 mg-Fe/l with improving results. A further increase up to 60 mg-Fe/l was tested, but was resulted in pH values < 3.5. The conclusion is that it is relatively easy to treat this wastewater by coagulation.

45.5 Biologically pre-treated wastewater from a textile plant

Jiaxing has several textiles processing plants, which discharges their wastewater with and without pre-treatments. The treatment of biologically pre-treated wastewater from such a plant was investigated with FeCl3 as the coagulant.

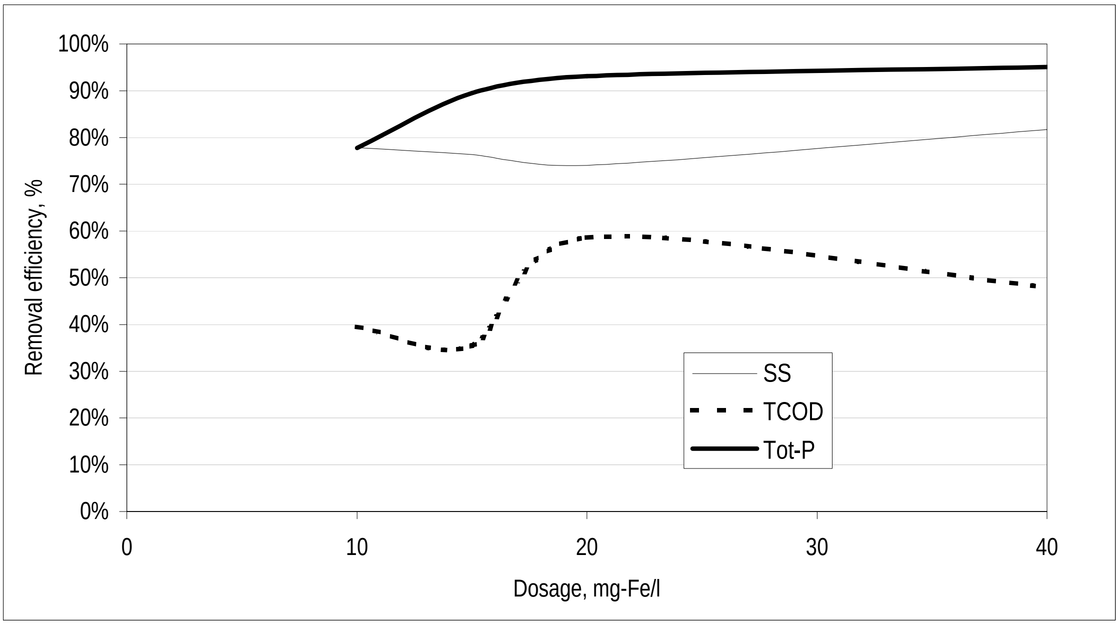


Figure 67. Jar-test treatment efficiency of biologically pre-treated wastewater from a Textile plant. Influent: SS=131 mg/l, TCOD=200 mg/l, Tot-P = 3mg-P/l; Effluent: SS = 24 mg/l, Tot-P < 0.15 mg-P/l.

The study shows that a significant portion of SS, TCOD and phosphorous are removed by a very low dosage of about 19 mg-Fe/l. Since the TCOD is relatively low in this type of wastewater, the main task will be to remove SS and phosphates, which is efficiently achieved by coagulation.

The pilot scale experiments gave similar results confirming the jar-test observations. The sludge production was quite low, and was about 20% v/v (of sludge) after 10 min.

45.6 Domestic wastewater

Treatment of domestic wastewater is one of the major challenges in a developing city. Coagulation has proven to be one of the most efficient and economical treatment method for domestic wastewater in the world. A preliminary evaluation of treatment possibility of Jiaxing's domestic wastewater was studied in jar-tests and the results are given in Figure 68. The wastewater was collected from a sewer connected to a large group of high housing blocks, during the assumed highest concentration.

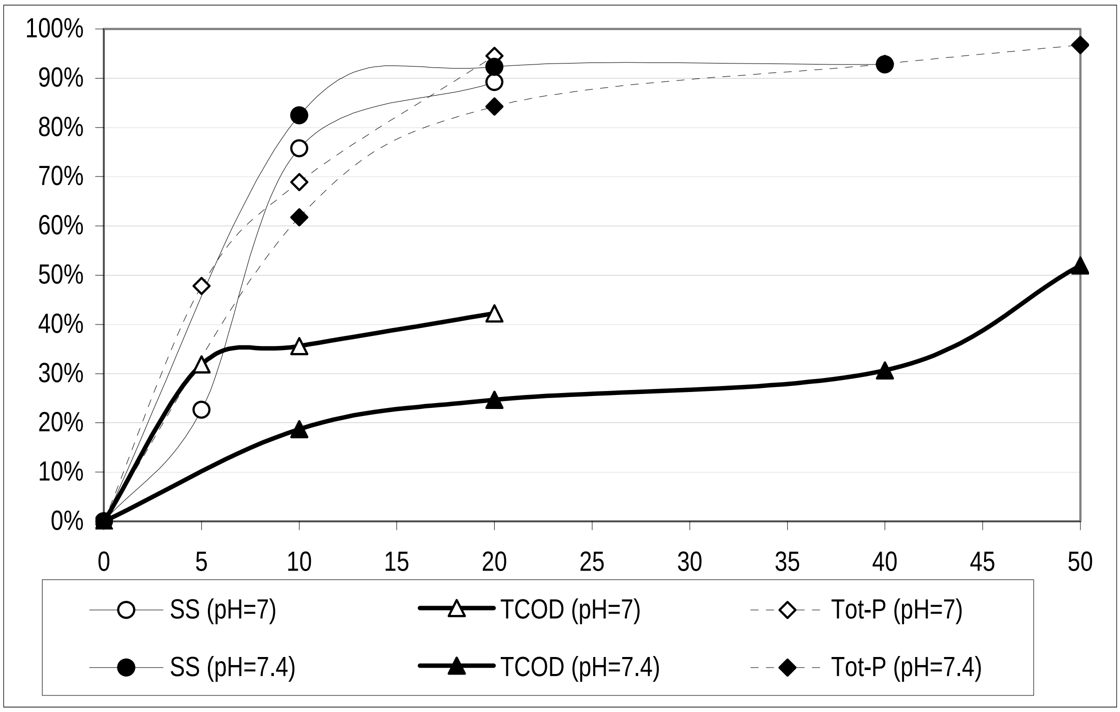


Figure 68. Treatment efficiency of Jiaxing domestic wastewater with iron coagulants in jar tests. Solid lines with influent pH = 7.5 and dotted lines with pH = 7.0. Influent: SS = 194 mg/l, TCOD = 128 mg/l, Tot-P = 1.8 mg-P/l; Effluent: SS = 15 mg/l, TCOD = 60 mg/l, Tot-P = 0.6 mg-P/l.

The figure above shows that at a very low dosage of about 10 mg-Fe/l, 60-70% of Tot-P and 70-80% suspended solids were possible to remove. When the dosage was doubled, the treatment efficiencies were improved by 10-30% further. The relatively low TCOD removal is explained by the high content of dissolved COD (55%).

It is also interesting to note that a relatively small change in influent pH may cause 5-15% change in treatment efficiencies at similar coagulant dosages.

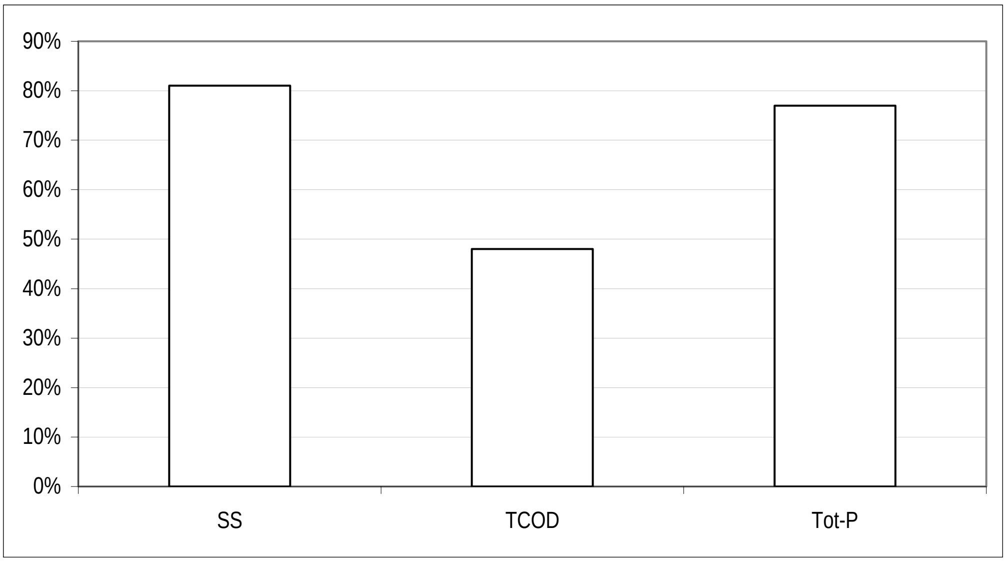


Figure 69. Pilot plant treatment efficiency of domestic wastewater with iron coagulant at a dosage of 5 mg-Fe/l. Influent: SS = 194 mg/l, TCOD = 128 mg/l, Tot-P = 1.8 mg-P/l; Effluent: SS = 33 mg/l, TCOD = 67 mg/l, Tot-P = 0.4 mg-P/l.

A pilot plant experiment was conducted with a very low coagulant dosage, 5 mg-Fe/l, and the results are shown in Figure 69. Treatment efficiencies of 60-70% for SS and Tot-P were achieved with this dosage and nearly 50% TCOD was also removed.

The results indicate that even with extremely low dosages the pollution discharges can be significantly reduced.

45.7 Mixed wastewater

The proposed wastewater management plan for Jiaxing assumes to have an influent mixed with both treated and untreated industrial wastewater combined with domestic wastewater. Although it is difficult to predict the composition of this influent, JEPB together with NIVA has estimated the following mixture of wastewaters most likely to imitate the composition in future. Details and the assumptions for this are given elsewhere in this project report.

Estimated mixed Wastewater composition:	
WW type	**% of total**
Domestic	50
Mingfeng	25
Textile	16.7
Chemical	6.7
Pesticide	1.6
SUM	**100 %**

The treatment efficiency of the proposed mixed wastewater water was studied in jar-and pilot-scale experiments.

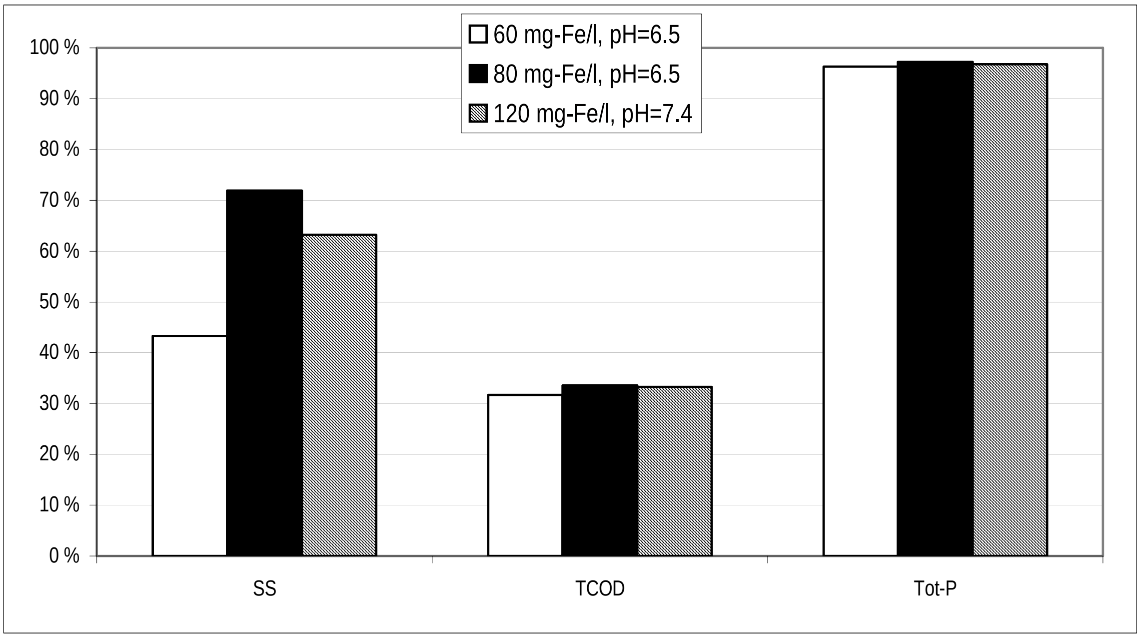


Figure 70. Treatment of mixed wastewater with iron coagulant in jar-tests.

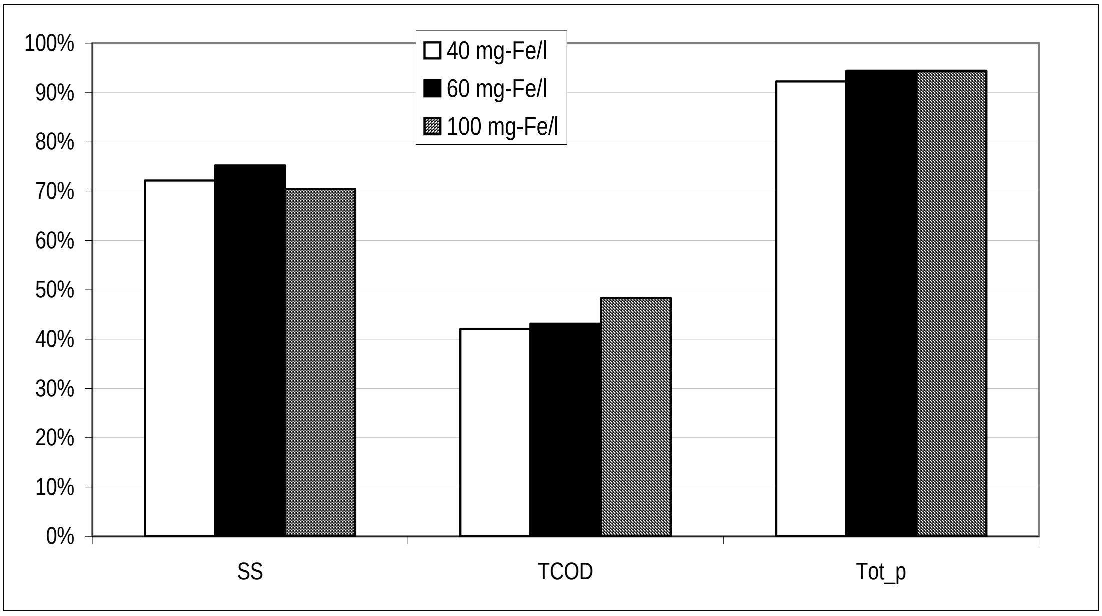


Figure 71. Treatment of mixed wastewater in a pilot plant with iron coagulants.

The results shown in Figure 70 and Figure 71 confirm that at dosages of 40 mg-Fe/l, it is possible to achieve >90% of Tot-P removal, together with up to 70% removal of SS. TCOD removal stays between 30-40%. The efficiencies at lower dosages should be tested under better process conditions, such as with increased sedimentation times.

46. Production of coagulants from industrial wastes

In many occasions, industrial wastes are used for the production of coagulants. It solves a waste problem in other industries and makes it possible to produce cheaper coagulants than producing it from Bauxite. For Jiaxing the iron-containing coagulants were important, as there are several steel works and waste acid production.

46.1 Access to raw materials

A survey on raw materials available in Jiaxing and surroundings was carried out and the results are summarised in Table 45.

Table 45. Raw material availability for coagulant production in Jiaxing

Company name	Chemical plant		Jinyi company	Zhonghua chemical plant	Steel plant
Distance to Jiaxing Km	0	0	22	10	0
Waste from which process	absorb	absorb	Acid-washing on steel surface	Chemical reaction	Mangle
Chemical formula	Fe_2SO_4	HCl	HCl	Fe_2SO_4	Fe
Fe^{2+}%			8%		
$CuSO_4$				10	
HCl%			18%		
H_2SO_4%	55%	12%		22%	
Amount T/Y	11000	2000	3000	5500	200
Appox. price RMB/ton	50	80	50	180	

Both the quality and quantity for the production of Fe (III) coagulants from these resources were considered to be good.

46.2 Planning of experimental production

The Mingfeng paper & pulp plant has previously produced aluminium sulphate in their premises, and the equipment is still remained unused. Mingfeng is a major consumer of coagulants and have the necessary technical expertise to carry out experimental production. Therefore it was decided to use Mingfeng's old coagulant production facilities with necessary upgrading/modifications.

46.3 Production process

NIVA does not have the expert or detailed knowledge on $FeCl_3$ production. However, NIVA agreed to provide information about the general production procedures, which are available in the open literature. The use of this information is JEPBs own responsibility.

It was expected that the coagulant producers like Kemira would play an active role in establishing in Jiaxing with their own factory. However, at present this seems to be delayed than the required project progress. Before and during the production process, it was decided to obtain support from Kemira.

46.3.1 Production processes as described in the literature

Raw materials:
Fe: steel scrap or iron residue
HCl: spent acid, 15-20.5%
Cl_2: Chlorine gas.

Continuos production
Process has 3 steps:
(1) production of $FeCl_2$
(2) converting to $FeCl_3$
(3) concentrating $FeCl_3$

(1) production of $FeCl_2$
HCl & Fe-scrap are mixed in a chamber for 3-15 hours, at 35-45°C, around atmospheric pressure. $FeCl_2$ is produced.

(2) conversion of $FeCl_2$ to $FeCl_3$
$FeCl_2$ contacted with Chlorine, in the presence of $FeCl_3$ for max 4 hours, at 50-100°C, atmospheric (?) pressure.

Preferably, this is done in a packed distillation- absorption type column. 60-90°C is preferred in the column; at the base, $FeCl_3$ has 65-90°C, and the incoming recycled $FeCl_3$ has 55-90°C. $FeCl_2$ & recycled $FeCl_3$ is added from the top and the Cl_2 from the bottom. Produced $FeCl_3$ is collected from the bottom.
Diluted $FeCl_3$ is produced.

(3) concentrating $FeCl_3$
The diluted $FeCl_3$ shall be expanded in the next chamber, at 0.3-0.005 atm pressure. H_2O is separated and $FeCl_3$ is concentrated to 12-15% Fe weight.

Part of $FeCl_3$ is recycled to the step (2) and the rest is the final product.

Batch production:
Although it is difficult to define the conditions exactly, the following are estimated to give satisfactory results, based only on general knowledge on chemical production.

It is assumed the whole process could be carried out in one reactor.
- Mixing of Fe & HCl at 35-45°C, no pressure, for 3-15 hours, mixing
- Add Cl/ hypocholrate and some $FeCl_3$ (10%?) for < 4hours at 65-90°C, no pressure, mixing to increase contact.
- Vacuum 0.3-0.005 atm to separate H_2O. Check how to do this in practice.

46.4 Proposed workplan

It was planned to run a screening test in the laboratory before starting the pilot scale tests. The laboratory tests should be completed within one week, after the experimental set-up is available and mounted.

The pilot scale production shall then be planned. We should generate sufficient coagulants to run the pilot plant.

At Q=200 l/h and a high dosage of 20 mg-Fe/l, we need appox. 96 g-Fe/d. At 12% Fe concentrations, this equals to 1.2 liters-$FeCl_3$/day. It is suggested that at least 200 litres of $FeCl_3$ should be produced (containing 12% Fe) in the pilot tests.

46.5 Abandoned plans of the production process

One of the major motivations for the production of coagulants in Jiaxing was the possibility of using it within the Mingfeng plant. However, Mingfeng has found a supplier of cheap aluminium sulphate, a price which Fe(III) will not be able to compete at all. After many considerations, the trial production was abandoned.

47. Conclusions

The coagulation process has proved to be a robust and efficient process for the treatment of industrial and domestic wastewater. It efficiently removed particles, phosphates and particulate fraction of organic matter.

The amount of coagulant dosages needed for treatment of various wastewaters varied significantly. Jiaxing's domestic wastewater could be treated efficiently at 10 mg-Fe/l, while mixed wastewater demanded 4-6 times higher dosages.

The production process of iron chloride is fairly simple, although it requires special equipment that tolerate the high temperature acidic environment.

The raw material needed for iron chloride production in Jiaxing is good - both in quality and quantity. However the production process was not able to compete with the waste aluminium sulphate available to the Mingfeng plant.

CHAPTER 8

Project activity 9:

Stepwise Development of Treatment Plant

Process, Treatment and Economical Evaluation of Upgrading Alternatives -Sketch Design Example

48. Introduction

Jiaxing City and region is developing strategies for integrated management of municipal and industrial wastewater. A highly recommended strategy is to develop treatment plants step-wise. The WWTP plant (or plants) to be build must therefore be designed in a way that allows for cost-effective upgrading to higher removal efficiencies at a later stage. Step-wise planning and construction also gives advantages with respect to flexibility in the future and provides valuable process information about the waste water and chosen first step configuration before choosing the further steps.

In order to select the optimal WW treatment strategy the overall economy for the various processes has to be considered. On a regional basis we recommend to use estimates of unit costs for pollutant removal as a guide for strategy development.

This document gives an overview of a strategy based on a step-wise WWTP development. This overview, however, is a based European cost estimates.

We have also included an example of a sketch design of a suggested first development step, based on one of the earlier suggested strategies for wastewater treatment with local treatment of Jiaxing north-west cities waste water. Later this strategy was rejected and a regional based strategy was chosen. However, this example should be illustrative as a general design method for the step-wise concept.

49. Step-wise development

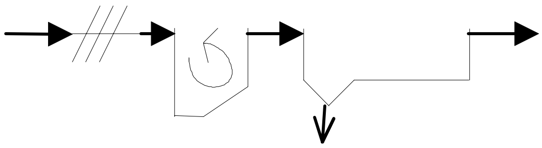
49.1 Assumed efficiency for various WW treatment methods

Figure 72 and Figure 73 show a flow sheet of various step-wise treatment methods. The different processes are numbered according to Table 46.

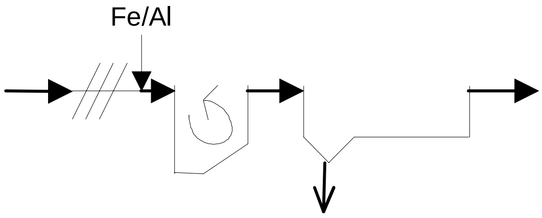
Table 46 gives a summary of assumed treatment efficiency for:

1. Mechanical treatment
2. Chemical treatment:
    a) Chemical enhanced mechanical treatment, high load, (CEPT)
    b) Chemical treatment, low load, called primary precipitation
3. Biological treatment:
    a) High load activated sludge method (0,5 kg BOD_5/kg SS*d)
    b) Normal load activated sludge method (0,2 kg BOD_5/kg SS*d)
4. Biological/Chemical treatment:
    a) Simultaneous precipitation (by normal load activated sludge)
    b) Pre-precipitation (pre-precipitation followed by normal load activated sludge)
5. Nitrogen removal, biological/chemical (by pre-de-nitrification, simultaneous precipitation)

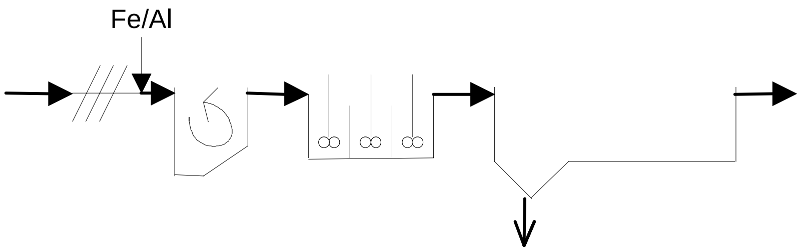
Process no. 1: MECHANICAL TREATMENT



Process no. 2a: CHEMICALLY ENHANCED MECHANICAL TREATMENT



Process no. 2b: PRIMARY PRECIPITATION



Process no. 4b: MECHANICAL/ or CHEMICAL/BIOLOGICAL (PRE-PRECIPITATION)

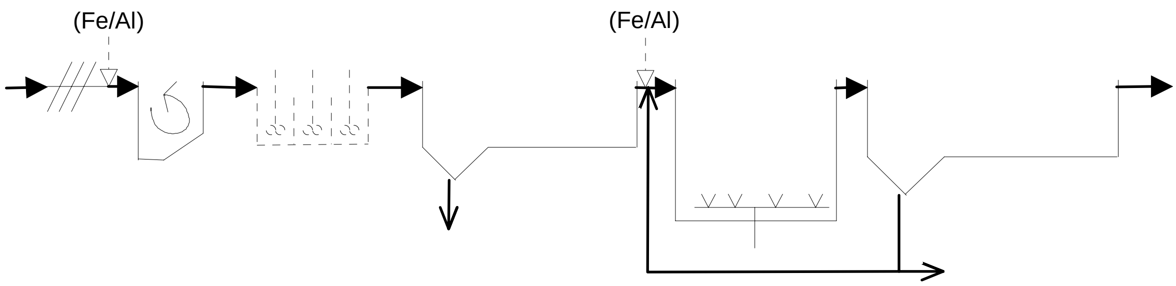
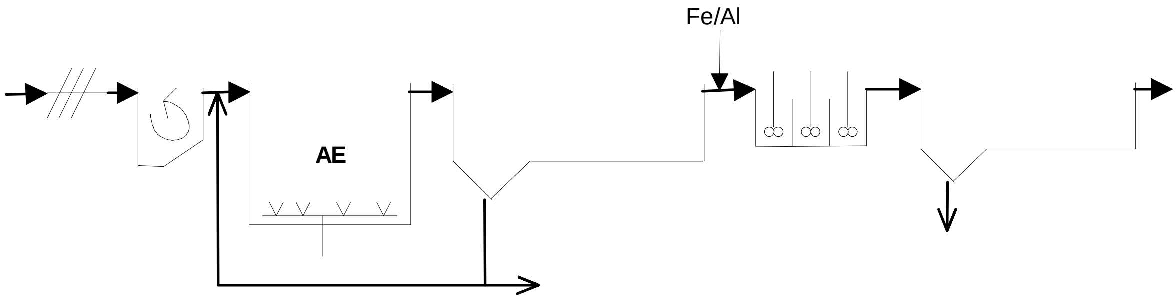


Figure 72. Selection of some common alternatives for waste water treatment

BIOLOGICAL/CHEMICAL TREATMENT (POST PRECIPITATION)



Process no. 5a: NITROGEN REMOVAL (PRE-SEDIMENTATION/PRE-PRECIPITATION and PRE-DENITRIFICATION)

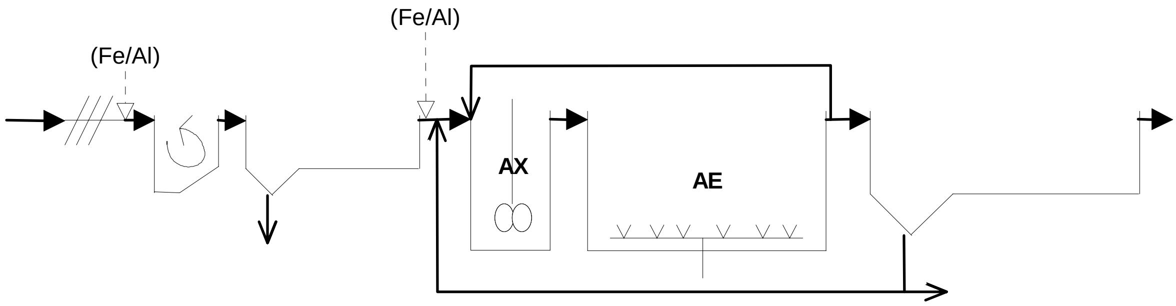


Figure 73. Selection of some common waste water treatment alternatives (cont'd.)

Table 46. Assumed efficiency of various WW treatment methods (assumes mainly domestic wastewater to be treated)

	BOD_5		SS		Tot. P		Tot. N		Sludge production	
	%	mg/l	%	mg/l	%	mg/l	%	mg/l	g DS/m^3	%
Raw WW	0	250	0	250	0	12	0	48	-	-
Mechanical	30	175	60	100	15	10	15	40	125	4
Chemical:										
a) High load	50	125	80	50	70	3.6	25	36	250	3
b) Low load	70	75	90	25	90	1.2	30	34	350	3
Biological:										
a) High load	70	75	80	50	30	8.4	25	36	185	2
b) Normal load	~90	20	90	25	30	8.4	30	34	205	2
Biological/chemical										
a) Simultaneous precipitation	~90	20	~90	20	~90	1.0	35	31	250	2
b) Pre-precipitation	~95	10	~95	15	~95	0.5	35	31	380	2
Biological/chemical, N-removal: Pre-denitrification, simultaneous prec.	~95	10	~97	10	~90	1.0	70	15	275	1.5

49.2 Economical evaluation

49.2.1 European Cost estimates for WW treatment plants

Table 47 shows European cost estimates for waste water treatment plants. The costs are based on a plant of 100000 p.e. and a specific water discharge of 400 l/p.d. The costs for a situation with undiluted waste water (250 l/p.d) would be slightly lower, but probably not more than 10 % lower on capitalised unit costs.

Table 47. European total cost estimates for WW treatment plants, RMB/m^3 WW (assumed 100 000 p.e, $Q_{spec.}$=400 l/pe*d, capitalised, sludge treatment not included)

Treatment process	Capital cost	Operation and maintenance cost	**Total cost**
Mechanical	0.89	0.4	**1.29**
Chemical:			
a) High load	0.95	0.61	**1.55**
b) Low load	1.08	0.67	**1.76**
Biological:			
a) High load (no presettling)	1.21	0.67	**1.88**
b) Normal load (presettling)	1.46	0.67	**2.13**
Biological/chemical			
a) Simultaneous precipitation	1.5	0.87	**2.37**
b) Pre-precipitation	1.35	0.81	**2.16**
Biological/chemical, N-removal: Pre-denitrification, simultaneous prec.	2.29	1.28	**3.57**

(1 US $ = 8.088 RMB)

49.2.2 European unit costs for step-wise development of WW treatment plants

When establishing a strategy for a step-wise development of WW treatment in a region, the unit costs for removal of the pollutant represent an important factor. In Table 48 some unit costs have been calculated in order to illustrate how these change with the process and the degree of removal.

Table 46 shows that primary precipitation and high load biological treatment give the same effluent quality with respect to BOD. In addition, primary precipitation removes phosphorus efficiently. The total cost effectiveness is higher for pre-precipitation than for high load biological treatment, as seen in Table 48. Based on these evaluations primary precipitation should be the first stage in a step-wise development.

Table 48. European unit cost estimates in RMB/kg pollutant for step-wise development of waste water treatment plants. The percentage of the total cost attributed to the removal of the given pollutant is also given.

Step:	**BOD**		**Phosphorus**	
	RMB/kg BOD	%	RMB/kg P	%
NO (No existing plant) => Mechanical	32.4	100	-	-
NO => Biological, high load	16.2	100	-	-
NO => Chemical, high load (Chemically enhanced)	10.5	50	153.7	50
NO => Chemical, low load (Primary precipitation)	8.1	50	121.3	50
Mechanical => Chemical, low load	3.2	50	32.4	50
Mechanical => Biological, high load	8.1	100	-	-
Biological => Biological/Chemical	2.4	5	80.9	95

49.2.3 Chinese Cost estimates for WW treatment plants

Information about the real costs associated with operation and construction of the WWTP is crucial for a project like this. Similarly to what we have presented for European treatment plants, cost estimates or Chinese WWTPs should be developed. During this project it has been somewhat difficult for the project to reveal sufficient amounts of information about WWTP costs in China. Therefore, in-depth analyses and presentations of costs have not been carried out. Presentations of Chinese costs should be broken down and presented for Chinese conditions in a similar way to what has been done in Table 47 and Table 48 for European conditions.

Thereafter, Chinese costs associated with WW treatment should be compared to European costs and choices should be made.

50. Sketch design example of step-wise WWTP development

50.1 Introduction

This section shows an example of a sketch design of a step-wise development of a new municipal wastewater treatment plant. This design example was made in an early phase where a local strategy with two treatment plants in Jiaxing City was evaluated. This strategy was rejected and a region-based strategy was chosen. However, this example should be illustrative as a general design method for the step-wise concept and the ocean discharge alternative.

The following design example is based on an evaluation of a Northwest WWTP in Jiaxing. Estimated wastewater was dominated with domestic and commercial wastewater.

50.2 Flow-sheet and description of proposed step-wise development

European experiences show that the chemical treatment is the most cost effective process when it is required to remove about 70% of BOD and over 90% of phosphates. This process becomes the most cost-effective process, especially when there are high industrial wastewater inputs and variations in the waste water quality during the day/year. The next conceptual stage is a combination of chemical and aerobic biological treatment, which enables a BOD removal of up to 90%.

Further treatment of wastewater is possible, but should only be considered when the removal of organic matter in the region is satisfactory. Theoretically, the upgrading of the treatment plant to remove nitrogen may then be evaluated. However, according to the information currently available to NIVA on the freshwater recipients in the Jiaxing region, nitrogen removal is a low priority measure. The treatment plant should also be able to be upgraded to receive more wastewater that will follow the population increase in the region. This will result in an estimated total volume of up to 50 000 m^3/d by the year 2000, 100 000 by the year 2010 and 150 000 by the year 2020.

Given that the relative Chinese cost level is comparable to European levels, and based on the above discussion of step-wise development strategy and costs calculation, the following steps are suggested:

1. step: Pre-treatment and primary precipitation (low load), capacity: 50 000 m^3/d.
The plant will consist of; coarse screen bars, fine screen bars, grit chambers and settling tanks with precipitation (primary precipitation). (Process number 2b in Figure 72).

Between 1. and 2. step:
Optimisation and evaluation of existing plant. Pilot scale testing of different biological treatment possibilities (primary sedimentation or pre-precipitation, simultaneous precipitation and activated sludge treatment with different configurations, sludge-ages, retention times etc. If relevant, evaluation of biofilm-alternatives).

2. step: Upgrading from chemical to chemical/biological treatment. Parallels of above process for increased capacity and extension with biological treatment for increased removal of organic matter. Total capacity: 150.000 m^3/d. (Go from process no. 2b to process no. 4b, Figure 72.)
Additional biological stage for efficient removal of organic matter based on results from pilot-scale tests. Existing primary precipitation tanks may also be used as primary sedimentation or post-precipitation instead of using them as primary precipitation. This assures flexibility when upgrading from step 1 to 2.

Between 2. and 3. step:
Optimisation and evaluation of existing plant. Evaluation of the need for nitrogen removal based on recipient quality and regional wastewater treatment development. Pilot scale studies.

3. step: Parallels of 2. step process for increased capacity. Total capacity: 200 000 m^3/d.

T**able 49** summaries the suggested stepwise Plant design and construction, Research & Development activities and Laws/Regulations.

T**able 49.** Step-wise development of a possible (but rejected) North-west WWTP in Jiaxing

Step	Plant design and construction	Research & Development activities	Laws and regulations
1	Pre-treatment & primary precipitation (coarse + fine screen bars, grit chambers, settling tanks with precipitation)		BOD 60-70% + Total-P 90%
Inter-mediate step		Optimisation of the existing plant, pilot-plant investigation of biological treatment	
2	Introduction of biological treatment to improve BOD-removal		BOD 90% + Total-P 90%
Inter-mediate step		Optimisation of the plant, recipient evaluation, see text.	
3	Possible upgrade with N-removal		BOD 90% + Total-P 90%. If BOD 90% is achieved for the whole catchment of the freshwater system, N-removal may be implemented if the water quality of the recipient so requires.
		Optimisation	

50.3 Example of sketch design of proposed WWTP

50.3.1 Design loads and discharge limits

Table 50 shows the design flow rate, influent wastewater composition and the suggested discharge limits for effluent wastewater, as provided by JEBP, for this example study.

Table 50. Design loads and discharge limits for a possible (but rejected) WWTP-1.

Parameter	Design load		Discharge limits
	Influent		Effluent
	Dry weather	Rainfall periods	
Design flowrate, Q_{dim} (m^3/d)	50 000	75 000	
BOD_5 (mg/l)	180	100-120	15
COD (mg/l)	350	350	60
SS (mg/l)	180	120-350	15
NH_4-N (mg/l)	36	20-30	5
TP (mg/l)	6	3-4	1,5
TN			10

The suggested discharge limits are very stringent, and can not be achieved with biological treatment only. The nitrogen discharge limits will require biological nitrogen removal. However, removal of nitrogen from wastewater is very expensive and has in most cases only minor influence on the quality of freshwater recipients, as long as there is no overall efficient removal of organic matter and phosphorus. The project group believes that the discharge limits should gradually be set more stringently, according to the environmental development of the whole region. Efficient removal of organic matter and, to a certain extent phosphorus, should be the first goal. Nitrogen removal should be considered only when the whole region has a satisfactory removal of organic matter and phosphorus, and only if the water quality of the freshwater recipients so requires.

The influent wastewater composition is given as a preliminary estimate. The final discharge limits should therefore be set when the wastewater composition is known.

Below follows suggested discharge limits based on a stepwise development of WWTPs in Jiaxing. This is the concept the project team recommends.

Table 51. Proposal for discharge limits for the years 2000, 2010 and 2020 based on step-wise development of WWTPs in Jiaxing.

Parameter	Influent	Discharge limits (% removal in parenthesis)		
		Year 2000	Year 2010	Year 2020
Design flowrate, Q_{dim} (m^3/d)		50 000	100 000	150 000
$TBOD_5$ (mg/l)	180	70[1] (ca. 60-70%)	15 (ca. 92%)	15 (ca. 92%)
COD (mg/l)	350	BOD and SS discharge limits are sufficient		
SS (mg/l)	180	30[2] (ca. 83%)	20 ca. 89%)	20 (ca. 89%)
NH_4-N (mg/l)	36	-	-	To be evaluated[4]
TP (mg/l)	6	1,0[3] (ca. 83%)	0,5[3] (ca. 92%)	0,5[3] (ca. 92%)
TN (mg/l)		-	-	To be evaluated[4]

1) Achievable removal is highly dependent on the particulate organic matter fraction (further information is needed to be more precise)
2) Achievable removal with suggested chemical process is higher, app. 15-20 mg SS/l in effluent
3) Achievable removal with suggested chemical process is higher, app. 0,3 mg TP/l in effluent
4) The need for nitrification and nitrogen removal should be evaluated after year 2010, based on the regional environmental development.

Figure 74 shows a simplified flowsheet of the suggested first stage of the WWTP (called WWTP-1). In the figure only two parallel lines with fine screens, grit removal and sedimentation tanks are sketched. It is suggested that at least four parallel lines are built.

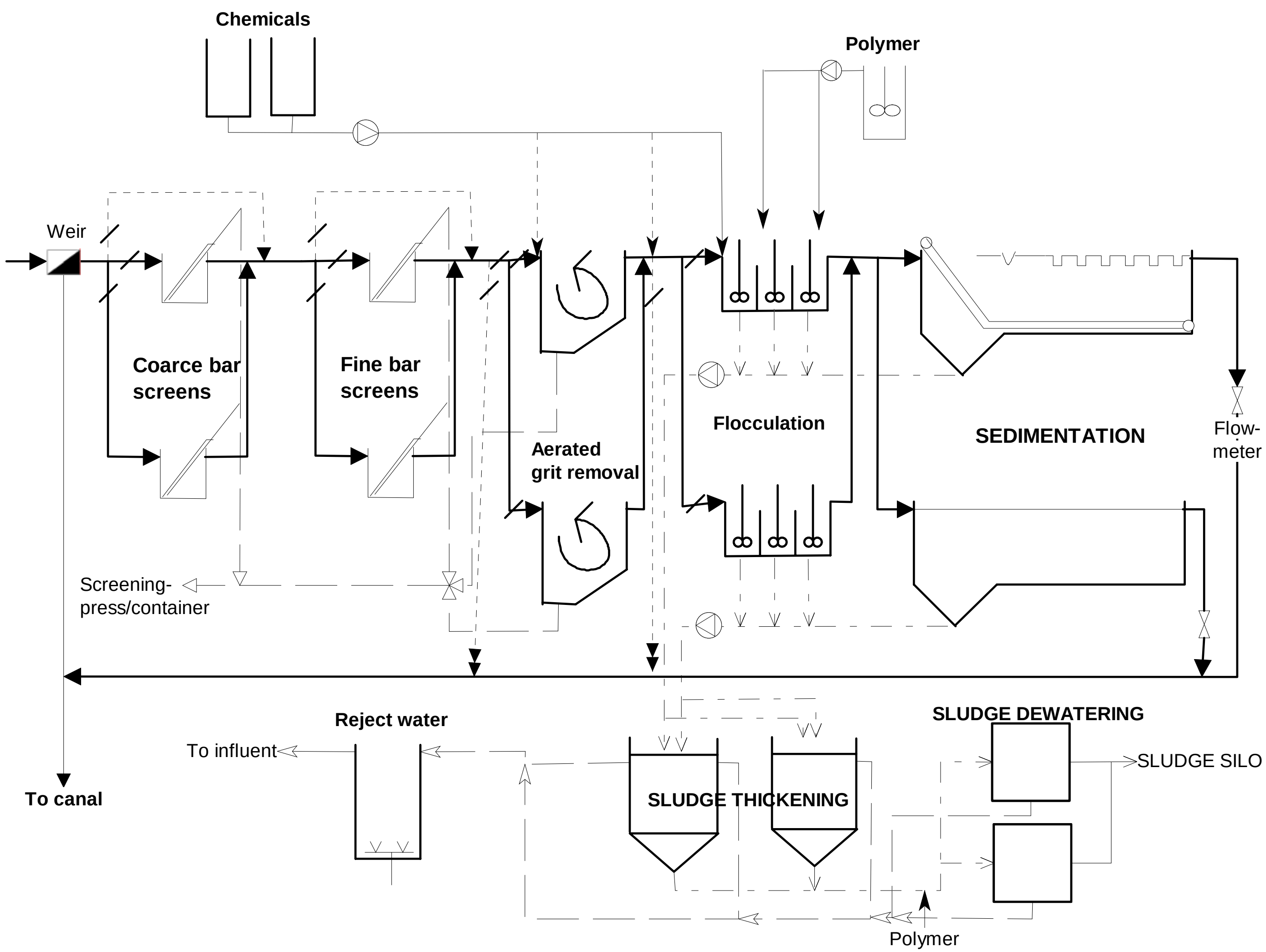


Figure 74. Simplified flowsheet of suggested first stage of WWTP

50.3.2 Discharge loads for WWTP-1

Design hydraulic load

This examples design hydraulic load was set to 50 000 m^3/d (equals app. 200.000 p.e.). No data was received about estimated minimum, average and maximum flowrate to be treated. A common method for separate systems is to design the WWTPs pre-treatment according to maximum flow rate and construct a weir after the pre-treatment. The secondary treatment is designed according to design loads. In the following the term "maximum load" is used for the design load to the pre-treatment and 50 000 m^3/d as the design load for chemical treatment.

Design screenings

Upper and lower limit for specific screenings can be estimated to 0,05-0,1 l screenings/p.d. with app. 15 % dry solids (DS). Design p.e. is set to 200 000 which equals app. 10-20 m^3/d. Design screenings should therefore be set to 20 m^3/d.

Design organic load

Design organic load to chemical treatment is set to 9000 kg BOD_5 /d.

Design sludge production

Specific sludge production is stipulated to 90-120 g TS/p.d. (which equals app. 360-480 mg DS/l waste water treated). Sludge production will be app. 18 000 -24 000 kg DS/d.
The thickening capacity is estimated to be:
- from sedimentation basins: 3 % (2-5 %)
- thickened sludge: 5 % (4-6 %)
- dewatered sludge: 25 %

Sludge productions is estimated to:
Sludge from sedimentation basins: 600-800 m^3/d
Thickened sludge: 360-480 m^3/d
Dewatered sludge: 72-96 m^3/d

The sludge production will be reduced with app. 25-40 % with anaerobic sludge digestion.
Sludge production is then estimated to be 50-63 m^3/d.

50.3.3 Waste-Water treatment

Introduction
The wastewater treatment should be constructed in to phases:
1. Phase : Construction of influent pipelines with inlet duct, pre-treatment and effluent pipe-line with relevant outlet constructions into the canal.
2. Phase: Construction of chemical treatment step

Mechanical treatment (pre-treatment)

Coarse bar screen
The wastewater is distributed to two parallel screens, mechanical removal of screenings, with slotted openings of 10-15 mm. The size depends on the choice of screens. Design hydraulic load should be set equal to maximum load. De-watered screenings are conducted to containers.

Fine bar screen
For removal of smaller particles the wastewater is distributed to at least two (recommended 4) parallel screens with openings of 3-5 mm. The size is dependent on the choice of screens. Design hydraulic load should be set equal to maximum load. De-watered screenings are conducted to containers.

Aerated grit chamber
Two (or more) aerated grit chambers should be constructed in order to avoid grit accumulations. Retention time at design load should be set to > 10 min. Detention time at peak flow rate > 3 min. Typical Width-depth ratio: 1,5:1. Typical Length-width ratio: 4:1.

Typical air supply: 0,19-0,47 m^3/min.*m of length. De-watered grit is conducted to containers.

Chemical treatment

Chemical feeder
The chemical addition should be flexible in the plant. It should be possible to add chemicals at the following stages:
- aerated grit chamber
- in canal between grit chamber and flocculation basin
- in influent to flocculation basin

Chemical addition should be flow proportional with pH overriding possibilities. This could be achieved by using a flow meter (Venturi meter) in the effluent canal after sedimentation, a pH sensor just after chemical addition, a pump with a speed variable according to an analogue/digital signal and a common control unit (PLC- programmable Logic controller).

A wide range of commercial coagulants, based on aluminium and iron salts, are commercially available. However, the preliminary evaluations indicate the possibility of producing coagulants from local industrial wastes, which will reduce the chemical costs of the process considerably.

The coagulant consumption varies considerably with the process conditions (e.g. mixing, flocculation, pH, etc.) in addition to the quality of the influent. Therefore the selection of optimal coagulation process conditions for the plant should be defined carefully, and should be based on laboratory scale jar-tests with further verifications at pilot- and full-scale levels.

It is assumed that iron chloride is the suitable coagulant, if produced from local wastes. If the coagulant is to be purchased directly, one can select between iron chloride, aluminium sulphate and poly-aluminium chlorides, according to price, performance and availability.

As a rule of thumb, the chemical costs in a low-loaded chemical plant are in the range of 15-25 RMB/person per year. This is equal to approximately 0,10-0,25 RMB/m^3 of wastewater, depending on the specific wastewater production in the area. The CEPT process requires much less coagulants, and the costs usually 10-20% of the above.

In addition to coagulants, it is possible to use organic polymers (poly-acryl amide) as flocculation aids, which may also be used to increase the surface loads considerably. The typical dosages are 0,2-0,5 g/m^3, while the price range between 15-25 RMB/kg.

Flocculation basin
It is necessary to have at least two flocculation basins in parallel each containing of three chambers in series with paddle-induced flocculation. The total retention time in flocculation basins is typically 20 min. for iron-salts and 30 min. for aluminium salts.

Sedimentation tank
It is necessary to have at least 4 rectangular sedimentation tanks in parallel. The entrance of the influent is submerged and is evenly distributed in the influent zone. The sludge is removed either by chain-and-flight sludge collectors or travelling-bridge type collectors. The solids settling in the tank are scraped to sludge hoppers in small tanks and to transverse troughs in large tanks. Settled water is withdrawn in saw-tooth effluent weir troughs located in the last 2/3 of the basins. Settled water is conveyed to a collecting flue for all lines. The floating sludge trough is located before the effluent weir troughs. The sedimentation tanks are designed based on the following data:

- Surface loading rate at design flow rate, $Q_{dim.} = 1.3\ m^3/m^2*h$
- Surface loading rate at maximum design flow rate, $Q_{maxdim.} = 2\ m^3/m^2*h$

It should be noted that 2-3 times higher surface loading rates are observed during controlled tests on CEPT with good treatment efficiencies.

Recommended water depth: 3,5-4 m. The length-width ratio should be > 6, and the turbulence disturbance in the influent zone should be compensated. (Compensated area, app. width in m^2.)

50.3.4 Effluent, weirs and shut-down system

Weirs, by-pass and shut-down systems are shown in Figure 74.
With regard to the recipient of the wastewater effluent it is necessary to make a thorough assessment of the location and the mean by which the waste water from the treatment plant is discharged into the canal.

Discharge site:
The choice of outlet discharge site should take account of the entire waterway system in Jiaxing and any further development of wastewater treatment plants in Jiaxing.

Discharge mechanisms:
There are several ways as to how the wastewater may be discharges into the canal. Factors to be taken into account are, *inter alia*, the flow pattern of the canal, the water depth (taking seasonal variations into account) and the canal bed conditions (physical and chemical).

50.3.5 Sludge treatment

The sludge treatment commonly consists with thickening, stabilisation and dewatering. There are three goals for sludge treatment:

- To make it hygienic safe (i.e. removal of parasites, parasite eggs, viruses...)
- To stabilise the sludge by degrading the easily degradable organic matter
- To reduce odours and the aesthetic problems associated with sludge

The first stage is thickening of sludge, to reduce the volumetric capacity of the subsequent treatment and improve performance of stabilisation. Sludge stabilisation reduces the organic content, and can be achieved by either anaerobic, aerobic or chemically by lime-addition. After stabilisation, the sludge should be de-watered (in centrifuges or filter presses) to reduce the final water content and the total volume. This makes the final product easier to handle and transport, and reduces the volumes needed for temporary storage.

First stage: Sludge thickening

The sludge from the OD-WWTP might be relatively difficult to settle and to dewater. We will therefor recommend that pilot tests are carried out to reveal more information about the sludge properties. In the following we have given some general recommendations, but it was not within the scope of this project to give detailed suggestions about the sludge treatment processes.

Conventional gravity thickeners give in many cases excellent results when used for thickening untreated primary sludge or sludge from chemical precipitation processes. Gravity thickeners are relatively inexpensive to operate and robust. However, these thickeners are significantly less efficient in treating waste activated sludge. We recommend that gravity thickeners are installed from the start. These thickeners can increase the solids concentration to 4-6 percent. Alternatively, centrifugal thickening can be used. These are often more efficient in removing water, but are less robust and have higher operating costs. On the other hand, centrifugal thickening units are compact, and hence become increasingly popular in Europe.

For dewatering, we recommend that belt filter presses or centrifuges should be considered. We are not familiar with either the Chinese cost-structure of these systems or the sludge quality to give further specifications at this stage.

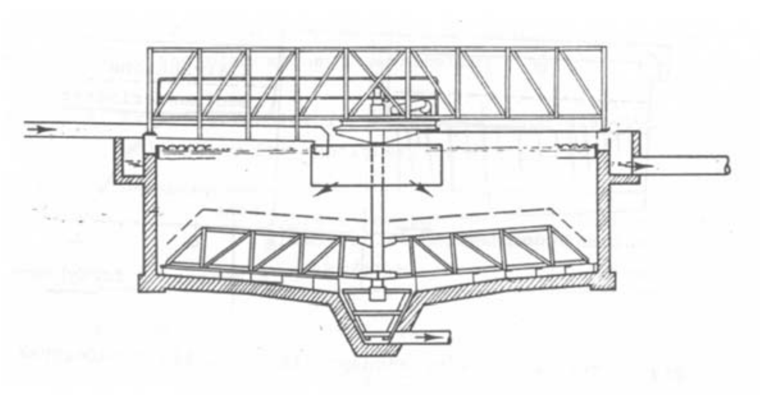


Figure 75. Traditional design of a gravity thickener.

Second stage: Extended sludge treatment with anaerobic sludge digestion

Large WWTPs often finds it beneficial to treat the sludge anaerobically in large digesters, in order to utilise some of the chemically bound energy as biogas for electricity and heating. We believe that anaerobic sludge stabilisation is beneficial also in the Jiaxing case. Anaerobic treatment provide energy for operation of the WWTP, it reduces the sludge volume and converts the sludge into a biological stable matrix.

Third stage: Dewatering

After stabilisation, the sludge should be de-watered (in centrifuges or filter presses). This is a physical process, although it can be enhanced using chemical additives. During this process, the solids content will be increased to 15-45%, while drying beds are capable of resulting in even higher percentages. Final disposal route depends on the level of toxic compounds in the final sludge product.

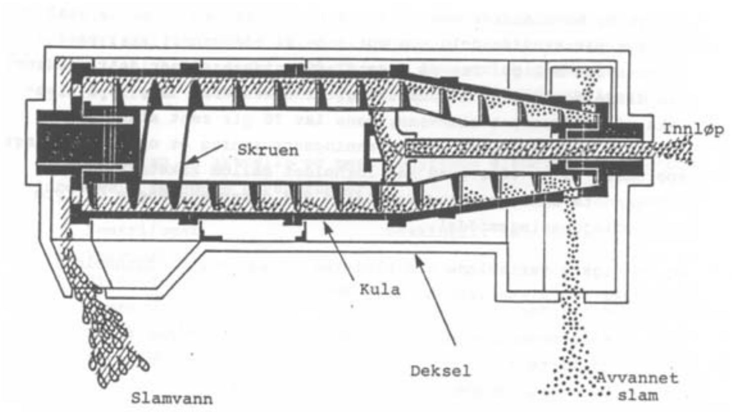


Figure 76. Schematic drawing of a centrifuge.

Figure 77. A modern anaerobic digester

CHAPTER 9

Project activity 11:

Institutional Strengthening

- Technical Upgrading and Visit to Norway

51. Introduction

From the application in 1995 we can read the following background:

> "As a result of the intensive industrialisation and growing environmental concern, many Chinese cities face an enormous challenge to solve basic problems in wastewater management. Poor- or none existing wastewater treatment facilities, sewer systems and pre-treatment system for industrial wastewater leaves rapidly growing Chinese cities with an enormous backlog in the provision for such facilities. To meet this challenge, there is not only a large need for suitable technology**, but also a need for institutional strengthening** and suitable and orderly procedures. Such technology and procedures would also give the possibility for a well planned wastewater management system from the beginning, which is not common for a city in the western world."

52. Status and Development

It is important to make a clear distinction between institutional **strengthening** and institutional **building.** The Chinese administration has long traditions, even in the environmental sector. The environmental protection hierarchy follows the pattern of other administrative hierarchies repeating the same units from the national level on down to the county level. Jiaxing EPB belongs on the third level, between the provincial level and the county level.

In the beginning there were some doubts on the Chinese side whether the project belonged on the third or the second (provincial) level. Most of the other Norwegian funded environmental projects in China were anchored on the province level.

In hindsight after three and a half years of co-operation, we feel certain that for several reasons this project was correctly placed. Firstly the project even called a demonstration project, has a very technical, feasibility type approach. The city and region of Jiaxing were under heavy pressure to move forward on several serious water-pollution problems. The project was started at the same time as the city, undergoing a major economical and physical expansion, discussed several alternative approaches to solve the pollution-problems in the canal-system. The alternatives spanned from how many treatment units were needed for serving the city; and which industries should be included in the schemes and which industries should solve the water pollution problems separately.

At this time (in 1996) it is fair to say that JEPB was an institution with limited influence on the development of the city in general and on water pollution abatement actions in particular.
JEPB was at this time monitoring and overseeing requirements and discharge permits for the various industries, in practice receiving fees as a sort of penalty from the delinquent industries. The fees were later to be used for implementing the building of waste- water treatment plants and other installations to reduce the negative effects from polluting industries.

The bureau had even less influence on the handling of, and solutions to the municipal waste waters flowing untreated into the canals at dozens of small and large discharge points.

At the end of the project period, which has been extended with a year, the Chinese and the Norwegian partners feel that the JEPB has developed into a much stronger institution. The bureau now plays a more visible and active role when environmental matters are discussed and plans are being made for treating the waste-waters from the city and the region.

The project can of course not claim the credit for this positive development alone. The circumstances have been such in China and in the Taihu-lake region that this development would to some degree have happened regardless of the project. We feel however, certain that the project has contributed in no small way to enabling JEPB to utilise modern equipment, modern methodologies, modern soft- and hardware in the process of planning a cleaner environment for the city and the region.

The following tools and education have JEPB taken advantage of as a result of this project:

- New computer facilities
- Internet and e-mail facilities
- Upgrading of telecommunication facilities
- New office furniture
- Upgrading of laboratory equipment
- Various knowledge transfer
- General computer education
- Advanced computer use (models, GIS)
- English education
- Experience with the design, construction and operation of a pilot plant
- Establishment of a useful monitoring database
- Training program in Norway

Aside from the extensive equipment purchases, the study trip to Norway in 1998 by a highly skilled group of experts from Jiaxing EPB was one of the most successful elements of the project both with regard to giving insight in the Norwegian ways of dealing with water-pollution and to strengthen the social ties between the project partners.

Aside from these obvious effects we have a strong feeling that the most important criteria for a successful institutional strengthening is the mere time-span that has elapsed from the inception to the finish of the project. It has been said many times in various annual reports that the project should be regarded as a process rather than results with pre-defined indicators. Such a process needs a minimum of time where highly different traditions, social and cultural relationships has to be understood to a certain degree by both parties. This makes the foundation for mutual trust. Without mutual trust it is impossible to carry through a project of this size and nature with the results all involved parties expect.

It should also be mentioned that the project was able to translate "Layperson's Handbook to Urban Wastewater Projects" published by the European Environmental Agency into Chinese. Further, Chinese publishing and printing was arranged. This book gives non-technical administrators an insight to all the relevant issues within planning, process selection, design and financing of wastewater projects. The book is now available in China for a well-affordable price of approx. RMB 18,- (US$ 2,-).

53. Conclusions

The chapter describes subjectively the observed changes in status of the Jiaxing Environmental Protection Bureau (JEPB). One should bear in mind that the entire Chinese environmental administrative system underwent rather dramatic changes at the time the project in Jiaxing took place – between 1996 and 2000. All levels from SEPA (which at the outset was named NEPA) on down to the city and county levels gained status, competence and recognition as an important player on the local scene. We recognise this development in many countries including Norway. The participating institutions feel that the Norad-financed project has played a major role in the forming of regional development in the greater Jiaxing area on water pollution abatement actions.

The project has also contributed in a more tangible way by furnishing JEPB with hard- and software-solutions as well as with other modern tools and equipment for assisting in the planning process of water pollution control measures.
There have been several exchanges of personnel visiting Norway of shorter and longer duration, giving key personnel the opportunity to observe and participate in Norwegian practices.

The most important building block for institutional strengthening is in our opinion, the mere duration of the project where a combination of technical, cultural and social relationships can be developed over time.

CHAPTER 10

Project activity 12:

Preparation of a Methodological Guide

54. Introduction

China has a substantial number of middle and small size cities that face considerable problems related to pollution of water bodies caused by industrial and municipal wastewater. With the development of industrialisation and urbanisation and the increasing awareness of the impact of such developments, the Chinese public pays more and more attention to environmental issues.

Many Chinese cities are facing a great challenge to solve the problems related to integrated wastewater management. The history of simple sewer, primary treatment facilities and the treatment of industrial pollution sources create difficulties for centralised treatment of wastewater. There is a great challenge in trying to develop a well-planned management system of wastewater.

The rencounter in a technical, scientific project such as the project on "Integrated Management of Industrial and Municipal Wastewater in China. - Demonstration Project in Jiaxing, Zhejiang Province", is not only the rencounter between people of different scientific background, but also between people of different socio-economic and cultural background. It has been important to bear that in mind throughout the project period.

This activity should primarily:

- Facilitate the work in the starting phase of projects similar to the project on "integrated management of industrial and municipal wastewater—a demonstration project at Jiaxing, Zhejiang province".
- Provide an outline of the general principles of integrated wastewater management.
- Point to potential problems in the running of similar projects in China.
- Suggest solutions to such problems.

55. Experiences

55.1 General

Although the various activities carried out within this bilateral project varied considerable:

- Framework for a Master Plan for Wastewater Management
- Water Quality Status and Resource Management
- Preliminary Evaluation of an Alternative Location for the WWTP-1
- Impact Assessment of Combined Wastewater
- Cleaner Production Study in Selected Industries
- Planning of Wastewater Collection Systems and Design Alternatives
- Wastewater Treatment using Industrial Wastes
- Stepwise Development of Treatment Plant
- Institutional Strengthening
- Dissemination of Results

It appears that there are some common features that have become apparent during the project period and that may serve as check-points for any similar future projects in China, both for Chinese and Norwegian institutes and authorities. These points relate to technical, scientific, human relational, socio-economic and working method aspects.

These points are, *inter alia*,:

1. Preparatory work- time prior to the actual project tasks are being addressed
2. Definition of objectives- mutual understanding
3. Linguistic aspects- working environment
4. Mapping of parties involved or to be involved
5. Data requirements- working procedures
6. Technical challenges

55.2 Preparatory phase

This project has shown that the preparatory phase of a project such as the project on "integrated management of industrial and municipal wastewater—a demonstration project at Jiaxing, Zhejiang province" is of uttermost importance. Good preparatory work will greatly facilitate both the scientific part of a project, but may also overcome any scepticism towards foreign culture and different working methods.

Knowledge should be acquired prior to the starting-up of the project on, *inter alia*,:

- Inter-institutional conditions in the area
- Choice of treatment requirements related to recipients, regulations and economy
- Current local and regional treatment processes

55.3 Objectives

When planning a project it is important to have a common understanding of the task/the problems to be solved, and to clearly define the objectives of the project. It is easy to be trapped by different understandings of the defined tasks.

55.4 Linguistic aspects- working environment

The linguistic related potential problems should not be neglected, as they concern not only the direct communication between the involved scientific people, but also the foreign people's access to the necessary documentation. The availability of highly competent interpreters and translators is therefore an issue that should be given priority in any future projects.

There may also be differences in data availability, restrictions on documents that from the onset may appear strange to a foreign party.

55.5 Mapping of parties involved or to be involved

It is important to establish a good dialogue between the scientific environment and local and regional decision-makers. It may happen that there are more 'interested' parties in the project than it appears from the onset of the project. It is therefore important to make a thorough survey of potentially interested parties at an early stage. This will benefit the project to a large extent.

It should also be borne in mind that the growing public awareness towards environmental issues may require the taking into account of 'user interests' as regards the water bodies involved.

55.6 Data requirements- working procedures

Reliable and sufficient background (historical) information is of importance. The data compilation phase should therefore be carried out carefully. The holistic approach as regards data collection and compilation when dealing with abatement strategies for example (consider all sources of the environmental problem identified, take account of all user interests) may still appear 'strange' to some communities. It is important to explain why the data is necessary, i.e. for which purpose, how will the data be used. The value of such a project is therefore not only result-based as regards the design of a industrial and wastewater management tool, but also very much related to the principles and methods applied.

55.7 Technical challenges

On the technical side, the Guide intends to provide:

- An overview of the technical achievements of the project.
- Information on appropriate software for design of wastewater treatment plant technology and sewerage purposes.
- A concept of a master plan of a municipal wastewater project.
- An outline of integrated management of industrial and municipal wastewater.
- A method of pilot plant experiments for wastewater treatment projects.

The answer to which process should be used in the treatment of wastewater with complicated compositions and difficult biodegradation pollutants is often difficult to give. The situation as regards the aquatic environment and the economy may also differ from one city to another. It is therefore important to have a clear concept and a good understanding of the problems to be solved.

Experience shows that the application of computer assistant design software packages combines pollution sources, pre-treatment, standard for discharge into sewer, collection system, treatment plant and water capacity beneficially to increase the precision of design and the ability of integrated management.

This project has used:
- ArcView to establish GIS for pollution sources
- Hydronet to design the sewer system
- STOAT to design the WWTP
- WASP5 to simulate/predict the quality of the aquatic environment

GIS related information might be:
- Infrastructure related (canals, roads, highways, bridges, villages, names of places etc.)
- Pollution sources (point and diffuse sources)
- Quality definition of the environment (classification of water quality, air quality)
- Objectives for the environment (water, air and noise)

55.8 Dissemination

For the entire water pollution sector an important step in disseminating methodology, in a broad sense, was the translation of the book “Urban Wastewater Projects – A layperson’s guide” published by the European Environment Agency (EEA) into Chinese. NIVA considers that this achievement will provide the Chinese reader, who may have a wide spectre of responsibility in the water pollution sector, with modern systematic and holistic approaches to a wide variety of tools for planning and implementation of actions.

56. Recommendations

Firstly, NIVA considers such bilateral projects between China and Norway to be stimulating both with regard to the technical and scientific challenges, and the social aspects. When such projects are carried out on the basis of good preparatory work, with the knowledge that not only the working methods may be different, but also the socio-economic background may vary considerably, they are highly recommended and likely to be beneficial for all parties.

1. An early awareness of possible/potential cultural and/or technical problems is of utmost importance.
2. The preparatory phase should be carefully and thoroughly carried out- a successful project may be decided at that stage, during such preparations
3. It is necessary to be prepared to revise the objectives during the project period due to unforeseen events; however good preparatory work will reduce the risk for this happening
4. It is important to ensure that the Chinese partners have acquired necessary knowledge/skills of any equipment/procedures/methods required to make use of the results of the project after the finalisation of co-operation project.
5. An inception meeting with all parties involved should be held in order to provide parties with a feeling of ‘ownership’ in the project
6. A ‘wrapping-up’ meeting should also be held in order to discuss the results of the project and any discrepancies with regards to initial objectives- success and failure

57. Activity 1- an example

Activity 1 concerns a Sketch of a Master Plan for City of Jiaxing – Methodology. It is referred to in order to show how the objectives of the activity were met (or not met) and to outline the general experiences with this particular activity in the project.

57.1 Objectives and background

The report for activity 1 describes a *framework* for Master plan with specific examples of the content of a master plan for the city of Jiaxing, not a complete Master plan for the city. The structure of the report is based on the current Norwegian Master plan guidelines for wastewater management. It was assumed that parts of the Norwegian planning methodology might be valuable for specific planning purposes in China.

There were three main objectives of the master plan sketch:

1. To provide information about how a Norwegian Master plan for wastewater management is developed, what it describes and how it is being used by the decision-makers in the municipalities, local authorities and other parties involved in wastewater management.
2. To provide information about the development of a Master Plan for wastewater management to parties without technical background.
3. To contribute to further developing Master plans for Chinese cities by using the city of Jiaxing and its surrounding areas as a demonstration case, together with a conceptual presentation of Norwegian methodology.

To demonstrate how the planning theory may be implemented and applied in Jiaxing, specific information about the situation in Jiaxing was presented in part 2 of the report of activity 1.

57.2 Methodology

The Master Plan methodology used is based on the Norwegian guidelines, published in 1994 the Norwegian Pollution Control Authorities. This section summarises these guidelines. The municipalities are facing large environmental challenges, both of regional and local character. To attain the environmental objectives, the politicians demand a cost-effective strategy.

In Norway, it is recommended that each municipality develop a Master Plan in order to achieve an integrated approach to the wastewater sector, and to identify different elements influencing the water quality. For the environmental authorities the plan contributes to the municipalities by determining environmental goals for the water resources. This reflects the Norwegian policy with a frequent use of *environmental standards* instead of detailed *technical standards*. The local approach for wastewater management is based on co-ordinated work towards established objectives together with frequent reporting to regional authorities.

57.3 Experiences during the running of the activity

NIVA has tried to implement parts of the Norwegian planning strategies into the Chinese way of planning. This has been a challenging task, but it is considered that at least parts of the Norwegian way of planning maybe used in developing a master plan for wastewater management in the Jiaxing region.
NIVA has experienced that the Chinese project partners have found the Norwegian way of systematic planning interesting, although not all aspects of the Norwegian planning concept matches the current way of planning in China. It seems to be the approach of integrated planning and long-term thinking that is of most interest to the Chinese partners.

57.4 Assessment of the activity results compared to the initial objectives

By and large, both the Chinese partners and NIVA are quite satisfied with the master plan sketch. The final master plan sketch in quite in accordance with the initial objectives for the activity, although there was not sufficient time to discuss all parts of the plan with the Chinese, as originally planned.

57.5 Recommendations for any similar activity/project to be carried out in China

If a similar activity should be carried out in China at a later stage, it would have been beneficial to have access to details about the existing Chinese planning tools and ways of developing plans in China. Furthermore, it would have been beneficial if NIVA had had closer contact with the Chinese partners during the development of the plan sketch in order to assess and discuss all parts of the planning processes.

58. Activity 2- an example

Activity 2 concerns Water Quality Status and Resource Management. It is referred to in order to show how the objectives of the activity were met (or not met) and to outline the general experiences with this particular activity in the project.

58.1 Objectives and background

The report for activity 2 covers data compilation, abatement strategy related principles and simple model running. Furthermore, it suggests future work on water quality related issues, outlines as a number of recommendations.

The objectives of this activity were changed several times during the running of the project, subsequently to changes of the number and/or location of the planned wastewater treatment plants.

The first objective was linked to data management procedures and to show which data and how to compile these data in a Water Quality Status and Resource Management study.

The objective related to models was linked to showing the principles of using a water quality model as a management tool for authorities in Jiaxing in conjunction with abatement considerations in the canals.

The development of an outline of methods and procedures for an abatement strategy for Jiaxing formed the final objective of this activity.

58.2 Methodology

The methodology description is also divided into three sections, as the report itself, namely:

Data compilation: Integrated catchment management (in this case integrated canal system management) has not reached an advanced stage in Jiaxing to date, the data compilation, with indications of which data to compile, took a considerable part of the activities of this part of the project. It was important to apply a holistic view when considering the specific parameters and their concentrations in water, the water flow, population densities, discharges of specific parameters from industrial plants, barge traffic, information about agricultural practices and land-use.

Model running: QUAL-2E was used in the first half period of the project time with some preliminary simulations. The model is originally made for river systems and needed special coding to handle the canal network in Jiaxing. When NIVA was asked, not only to produce simulation results, but also deliver the model for later use in Jiaxing, it was decided to use the WASP model. The eutrophication part of the model was used in this project. That included possibilities to handle nutrients, oxygen and algae. Focus was on phosphorus, nitrogen and biological oxygen demand (BOD). The situation in 1995 was simulated, with mostly observed data to represent the situation today. Thereafter the simulations were related to the situations in 2000 and 2020 with data that should represent the suggested population and industry developments. The simulations were made to study the effect of the planned wastewater treatment plant. Furthermore, simulations were made that took account of the effects of the ”circular canal” around the city. Each of these alternative scenarios was studied for low-, mean- and high water flow.

Planning of Water resources development and management in an integrated manner, incorporating environmental, economic and social considerations, using an abatement strategy as a comprehensive methodology in the management of rivers and lakes to reach a better water quality.

58.3 Experiences during the running of the activity

It was, at least in the beginning, difficult to obtain data for many of the main aspects of an Abatement Strategy. This was probably partly due to ‘a new way of thinking’ and a difficult internal data flow, partly due to misunderstandings regarding why data particular types of data were necessary. This concerns both the collection of background data (e.g. from agriculture) and monitoring data (industry and river/lake monitoring)

Due to the fact that the objectives of this activity were changed several times during the running of the project, subsequently to changes of the number and/or location of the planned wastewater treatment plants, too much was time spent on each sub-activity.

More time should have been spent by NIVA on the preparatory work, i.e. the time prior to the actual project tasks were being addressed. This would have enabled a better activity description and a more realistic view on what can be achieved within the agreed timeframe and budget.

During the running of the project there were misunderstandings concerning the actual content of the activity (what should be the outcome). This again implies that more time should have been spent in the preparatory phase.

It would also have been beneficial to have had, from the outset, a better overview of all parties to be involved.

There was also a clear difference in working procedures that should have been discussed during the preparatory phase.

On the more positive side, it should be noted that the Chinese partners showed a very strong adaptability to new working procedures; an eagerness to learn both the English language and a different approach to the issues studied. When a mutual understanding was reached of why the data required from NIVA was necessary, the Chinese partners put considerable efforts into providing the said data.

58.4 Assessment of the activity results compared to the initial objectives

Due to the fact that objectives of this activity were changed several times during the running of the project, it is difficult to assess the outcome of the activity compared to the initial objectives. This is also linked to the fact that there were misunderstandings as regards what should be the outcome of the activity.

However, it is considered important that both parties now acknowledge that the implementation of a holistic approach to data compilation and assessment for canal system management (catchment management) is of great importance. In that respect, the initial objectives have been reached.

An other objective was also reached, i.e. to successfully carry through a scientific project with two partners of different cultural and educational background.

On that basis, it may be of minor importance that some of the more detailed, minor objectives were not reached.

58.5 Recommendations for any similar activity/project to be carried out in China

If similar activities were to be carried out in China at a later stage, it would be beneficial to have prior access to details about data availability, and the procedures for 'internal Chinese data flow' (flow between institutes/agencies)- 'who has the responsibility for what'. In this particular project, it would have been beneficial if NIVA had had closer contact with the Chinese partners during the model running in order to assess and discuss more in detail input data and preliminary results of the model running.

It is also recommended that the classification in water quality criteria take account of the suitability of the water for different uses, such as swimming, fishing, irrigation and drinking.

Furthermore, a stronger emphasis should be put on mapping user interests (swimming, fishing, irrigation, others) for the entire water body system, as an improved basis for decision-making related to mitigation and cost-effectiveness analysis.

CHAPTER 11

Project activity 13:

Dissemination of Results

59. Objectives

The dissemination of results is among the most important sub-tasks in a demonstration project, which the Jiaxing project is. Dissemination is also an activity that draws on all the other activities constituting the project.

The objective is to create and produce sustainability of the project.
Another objective is to identify suitable candidates for new implementations of similar projects with preferably reduced input from the Norwegian side.

60. Activities

The dissemination activities started on a modest scale in 1998, as the first year and a half of the project cycle was spent on getting the project off to a smooth start, producing a variety of intermediate and finished results. The dissemination culminated with a broad based seminar in January 2000 where the entire Chinese/Norwegian team presented the finished results to a group of 44 participants from 11 cities and 4 provinces (?). A comprehensive CD-ROM has been produced that will ease the facilitation of future presentations.

During the life cycle of the project the following presentations and participation took place:

March 1998 – The project participated and was presented by the Chinese project manager Song He Ping on the Sino-Nordic Conference on Sustainable Development held at the Fudan University in Shanghai. The three-day conference had Chinese participation from businesses and province officials from Eastern China, as well as business representatives from Nordic industries catering to the environmental field.

March 1998 The project was presented in Jiaxing to a group of Norwegian visitors representing NORAD, The Norwegian Ministry of Environment, The Norwegian Embassy in Beijing, as well as the CEO of NIVA.

May 1998 - A group of eight specialists from JEPB visited Norway, presenting Jiaxing and the project to a variety of Norwegian business enterprises in the environmental field as well as government (local and national) institutions. The main purpose of the visit was – however - one of institutional strengthening.

November 1998 A three-day Sino-Norwegian Trade Seminar was held in Jiaxing. The seminar was arranged by the Norwegian Export Council. The purpose was to introduce Norwegian companies engaged in the environmental business to project owners from the Jiaxing region. A broad presentation of the project together with wastewater treatment projects from other cities in the region was made. The seminar included participation from SEPA and MOFTEC as well as from various local institutions. A spin-off of the seminar was a coming business relationship/friendship between the cities of Jiaxing and Sandefjord, where the first meeting will take place in the latter city in June 2000.

March 1999 Environmental seminar in Beijing led by the Norwegian environmental minister and her Chinese counterpart from SEPA. This highly prestigious seminar attracted considerable media attention. The Jiaxing project was presented at a group session and was intensely discussed by university representatives as well as by attending representatives from EPB's from a dozen provinces.

June 1999 The project was presented on a stand organised by the Zhejiang Science and Technology Commission on a trade and investment symposium in Ningbo. A presentation in MS PowerPoint file was animated on a computer continuously which attracted the visitor's attention. A board presentation was also included showing pictures from various field activities in Jiaxing.

January 2000 Dissemination seminar. Extensive planning and preparations for this seminar was done in 1999. The dissemination seminar was held in Jiaxing during January 18-19, 2000. The Jiaxing government chaired the seminar. The opening speeches were held by the late General Consul Torill Oftedal Sjaastad from the Norwegian consulate in Shanghai and the vice-mayor Wang Xin Min of the Jiaxing Municipal Government. Attending and giving speeches were also the Environmental Counsellor Leif Landro from the Norwegian Embassy in Beijing, and the Director of Jiaxing Environmental Protection Bureau – Pan Qi Ming.
A delegation of five from Zhejiang Science and Technology Commission headed by Director Wu Jian from the Department of International Co-operation played an important and active role throughout the seminar. From SEPA attended Mr. Cheng Yong who also delivered an opening speech. Representatives from 11 cities of 4 provinces, a total of 44 Chinese and eight Norwegians attended enthusiastically the seminar and the group discussions. Norwegian experts and JEPB's leader and technicians delivered 10 presentations. Presently the co-operating Chinese/Norwegian team is following up some of the contacts made with potentially new project owners.

61. Results

In addition to these more formally structured events the project team has had numerous discussions and presentations for Chinese Design Institutes (consultants), university professors and representatives from other city government institutions, that have various responsibilities in carrying out the water pollution abatement plans. The team feels that the project and its results have had considerable impact on the decisions Jiaxing has made on solutions to the principles of the regional water pollution scheme that presently is being implemented in the Greater Jiaxing Region. These discussions took place throughout 1998 and the first part of 1999.

An important measure of spreading knowledge of European methods for handling water pollution problems is the translation of the book "Urban Wastewater Projects – A Layperson's Guide" issued by the European Environmental Agency into Chinese. The book has been made available to the Chinese Environmental Protection Bureaus.

The project is presently finishing a total of ten reports describing each sub task, all of which will be translated in both English and Chinese.

62. Conclusions

This chapter highlights the most important events during the project cycles. The project has undoubtedly given JEPB status and visibility in the internal municipal government of Jiaxing, which has been an important achievement. Aside from this has the project been presented and discussed in numerous events in China as well as in Norway. The project has been presented at national and international conferences, seminars and trade- exhibitions.

Of these we will mention the Environmental Seminar in Beijing in March 1999 where the Norwegian and the Chinese ministers were present. The final dissemination seminar in Jiaxing in January 2000 gathered broad attendance and formed the basis for locating similar projects in other provinces in the Peoples Republic of China, according to the government's policy of developing the Western parts of China.

The dissemination of results is among the most important sub-tasks in a demonstration project, which the Jiaxing project is. Dissemination is also an activity that draws on all the other activities constituting the project. The objective is to create and produce sustainability of the project. Another objective is to identify suitable candidates for new implementations of similar projects with preferably reduced input from the Norwegian side.

ANNEX 1

Water Quality Criteria and Water Quality Goals

Annex 1:WATER QUALITY CRITERIA AND WATER QUALITY GOALS

Most countries have adopted “Water Quality Criteria” (WQC), for water used for various beneficial purposes. For the use category “drinking water”, WHO has a set of quality criteria that are internationally well accepted, but no such agreement exists with regard to classifying the water quality after the degree of pollution. While it is well agreed that pollution is defined as the deviation from natural conditions, there are considerable differences among the WQC-systems adopted by the different countries throughout the world. In effect, it is difficult to quantify acceptable levels of pollution as fixed limit values.

National Chinese Water Quality Criteria

The water quality criteria adopted by China (Environmental Standards for Surface Waters, GB 3838-88) divides the water quality into 5 classes. The classes are not described after the suitability for different purposes, or in what kind of water bodies we find such water quality in China. The description of the classes is given in the Table A below, whereas the list of concentration levels of the different parameters belonging to the different classes are given in Table B.

Table A: Quality Classes defined by the National Water Quality Criteria for P.R. China

Class no.	Description of class
Class I	Water resources and nationally protected bodies of water
Class II	Potable water resource class 1 protection areas, high value fish protection areas, spawning habitats for fish, shrimp, etc.
Class III	Potable water resource class 2 protection areas, general fish protection areas, and swimming areas
Class IV	Water bodies for industrial and recreational use
Class V	Water bodies for agricultural and general scenic amenity

Table B. National Water Quality Criteria for Surface Waters. Unit: mg/ if not stated otherwise

Class Parameter|	**1**	**2**	**3**	**4**	**5**
Total –P	0,02	0,1	0,1	0,2	0,2
COD_{Cr}	15	15	15	20	25
COD_{Mn}	2	4	6	8	10
BOD_5	3	3	4	6	10
Total Kjeldal N	0,5	0,5	1	1	2
Nitrate	10	10	20	20	25
Nitrite	0,06	0,1	0,15	1,0	1,0
Ammonia	0,02	0,02	0,02	0,2	0,2
DO	90%	6	5	3	2
T. Coliforme Bacteria			10 000		
Cadmium	0,001	0,005	0,005	0,005	0,01
Chromium $^{+VI}$	0,01	0,05	0,05	0 ,05	0,1
Lead	0,01	0,05	0,05	0,05	0,1
Mercury	0,00005	0,00005	0,0001	0,001	0,001
Dissolved iron	0,3	0,3	0,5	0,5	1,0
Phenols	0,002	0,002	0,005	0,01	0,1
Oil	0,05	0,05	0,05	0,5	1,0

Table C. National criteria for waste water*

Chemical parameter	Class I (mg/l)		Class 2 (mg/l)		Class III (mg/l)
	New	Current	New	Current	
pH	6-9	6-9	6-9	6-9	
BOD_5	30	60	60	80	300
Oil	10	15	10	20	30
Ammonia	15	25	25	40	-
COD_{Cr}	100	150	150	200	500
Phosphorus	0,5	1,0	1,0	2,0	-

*:The concentrations represent the maximum concentrations of the specific pollutants for discharges to water.
'New' means new factories or reconstructed factories.

The situation in Norway

Classification of quality status

The Norwegian is based on measured concentrations which have two components; a natural component which stems from natural processes in the catchment area, and a component which stems from human influence, *i.a*. acid rain, effluents from industry and sewage, and agricultural runoff. The latter is defined as ‘pollution’.

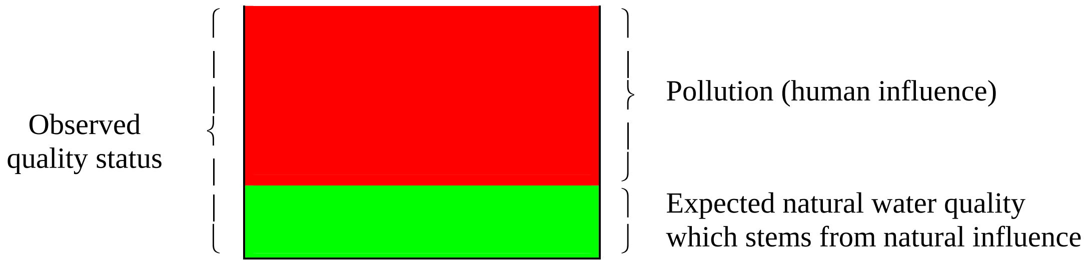


Table D: Pollutants and their various states and matrixes.

Effect categories:	**Ecosystem -type**	**Parameters**	**Sampling frequency**	**Calculation method**
Nutrients	Lakes	*Total phosphorus* *Chlorophyll a* *Secchi depth* Primary production Total nitrogen (Orthophosphate)¤ (Phytoplankton) (Zooplankton)	At least monthly. Mixed sample, May-October. Deep-profile (3-5 samples) late-summer and late-winter	Arithmetic mean.
	Rivers	*Total phosphorus* Total nitrogen (Periphyton) (benthic fauna)	At least monthly.	Arithmetic or time-weighted mean.
Organic matter	Lakes	*TOC* *Colour* *Oxygen* *Secchi depth* COD Fe Mn	Deep-profile (3-5 samples) in spring, late summer, fall and late winter.	Arithmetic mean. Oxygen: lowest value Fe and Mn: highest values
	Rivers	*TOC* COD (Periphyton) (Benthic fauna)	At least monthly [#]	Arithmetic or time-weighted mean.
Acidifying components	Lakes and rivers	*Alkalinity* *pH* (Benthic fauna)	Spring, summer, fall and winter in lakes. Monthly in rivers.	Lowest value.
Micro pollutants (heavy metals)	Lakes and rivers	Dependent on problematic component(s)	Spring, summer, fall and winter in lakes. Monthly in rivers	Highest value
Particles	Lakes and rivers	*Turbidity* *Suspended matter* *Secchi depth (in lakes)*	At least monthly.	Arithmetic or time-weighted mean.
Faecal bacteria	Lakes and rivers	*Thermotolerant Coliform bacteria*	At least monthly.* Deep-profile (3-5 samples)	Highest 90-percentile.

Classification of the water quality status for nutrients, organic matter, acidifying components, particles and faecal bacteria.

Table E: The Nowegian classification system for fresh water quality

Effect categories:	**Parameters**	**Quality class**				
		I "Very good"	**II "Good"**	**III "Fair"**	**IV "Bad"**	**V "Very bad"**
Nutrients	*Total phosphorus*, µg P/l	<7	7-11	11-20	20-50	>50
	Chlorophyll a, µg/l	<2	2-4	4-8	8-20	>20
	Secchi, m	>6	4-6	2-4	1-2	<1
	Prim.prod., g C/m^2 y	<25	25-50	50-90	90-150	>150
	Total nitrogen, µg/l	<300	300-400	400-600	600-1200	>1200
Organic Matter	*TOC*, mg C/l	<2,5	2,5-3,5	3,5-6,5	6,5-15	>15
	Colour, mg Pt/l	<15	15-25	25-40	40-80	>80
	Oxygen, mg O_2/l	>9	6,4-9	4-6,4	2-4	<2
	Oxygen, %	>80	50-80	30-50	15-30	<15
	Secchi, m	>6	4-6	2-4	1-2	<1
	COD_{Mn}, mg O/l	<2,5	2,5-3,5	3,5-6,5	6,5-15	>15
	Iron, µg Fe/l	<50	50-100	100-300	300-600	>600
	Manganese, µg Mn/l	<20	20-50	50-100	100-150	>150
Acidifying Components	*Alkalinity*, mmol/l	>0,2	0,05-0,2	0,01-0,05	<0,01	0,00
	pH	>6,5	6,0-6,5	5,5-6,0	5,0-5,5	<5,0
Particles	*Turbidity*, FTU	<0,5	0,5-1	1-2	2-5	>5
	Susp. matter, mg/l	<1,5	1,5-3	3-5	5-10	>10
	Secchi, m	>6	4-6	2-4	1-2	<1
Faecal bacteria	*Thermotol. coli. bact.*, num./100 ml	<5	5-50	50-200	200-1000	>1000