UPTEC F05 000

Examensarbete 20 p
Maj 2007

Industrial wastewater treatment and other environmental problems in Wuhan - Is Swedish technology a solution?

Industriell avloppsvattenrening och andra miljöproblem i Wuhan - Kan svensk miljöteknik vara lösningen?

Anna Hagberg

ABSTRACT

**Industrial wastewater treatment and other environmental problems in Wuhan -
Is Swedish technology a solution?**

Anna Hagberg

In 2000 a co-operation between Wuhan in China and Borlänge Energi in Sweden started. The two parts decided in 2005 together with IVL, the Swedish Research Institute, to co-operate in the fields of sustainable energy production, sustainable waste management and the establishment of an Environmental Technology Centre, supplying Swedish environmental expertise to companies in Wuhan. As a first step for the establishment of an Environmental Technology Centre in Wuhan, an investigation was made to find out in which sectors Swedish environmental technology could be established.

The investigation took aim at observing the industrial wastewater treatment in Wuhan and to see which types of companies that have problems with the wastewater treatment and if there existed Swedish technology that could solve the problems. The investigation was performed through interviews with the authorities and some selected companies. It was difficult to get information about companies that did not comply with the National Chinese wastewater standards. This meant that some of the visits were made to companies that comply with the standards, also taking into consideration other problems with the environment that the companies might have. Visits were also paid to municipal wastewater treatment plants to get an overview over the municipal wastewater treatment situation. An overall survey of the environmental situation in Wuhan was also made and a presentation of the most important environmental departments and institutions is given.

The greatest challenge for Wuhan is to construct wastewater treatment plants for the around 3.5 million people that still discharge their wastewater directly to rivers and lakes, rather than to improve the industrial wastewater treatment further. The treatment rate of the industrial wastewater has reached 97%, but the municipal wastewater treatment rate has only reached 70%.

After the visits to the selected companies and municipal wastewater treatment plants the conclusion was made that Swedish technologies and expertise can be applied to the following areas; handling sludge from the wastewater treatment plants, construction of waste incineration plants and handling flue gas and dioxins. Most of the visited companies could follow the wastewater standards. Although much can be done to improve their technologies further, this is not done since it is too expensive. It is possible for Wuhan to apply stricter local wastewater treatment standards. This could be used as a tool to make companies invest more money in improvements of their technologies.

Keywords: Industrial wastewater, Swedish technologies, sludge, flue gas cleaning, Wuhan, China.

Department of Earth Sciences, Uppsala University, Villavägen 16, SE-752 36 Uppsala
ISSN 1401-5765

REFERAT

**Industriell avloppsvattenrening och andra miljöproblem i Wuhan-
Kan svensk miljöteknik vara lösningen?**

Anna Hagberg

År 2000 startades ett samarbete mellan Wuhan i Kina och Borlänge Energi i Sverige. De två parterna bestämde år 2005 tillsammans med IVL, Svenska Miljöinstitutet, att samarbeta inom följande områden; hållbar energiproduktion, hållbar avfallsproduktion samt grundandet av ett miljöteknikcentrum i Wuhan. Miljöteknikcentrumet är till för att vara en plattform för svensk miljöteknik och expertis. Som ett första steg inför grundandet av ett miljöteknikcentrum gjordes en undersökning för att se inom vilka sektorer svensk miljöteknik kan etableras.

Undersökningen var inriktat på industriell avloppsvattenrening i Wuhan; bedömning av vilka typer av industrier/företag som har problem med avloppsvattenreningen och i vilken utsträckning det finns svenska tekniklösningar på problemen. Undersökningen genomfördes genom intervjuer med myndigheter och en del utvalda företag. Det var svårt att få fram information om vilka företag som inte följer de kinesiska gränsvärdena, varför en del besök gjordes till företag som lever upp till gränsvärdena. På grund av detta togs även andra problem med miljön som företagen hade upp. Några kommunala reningsverk besöktes och intervjuades också för att få en bättre bild av den kommunala vattenreningssituationen. En generell beskrivning av Wuhans miljösituation utfördes också samt en beskrivning av de viktigaste miljömyndigheterna och institutionerna.

Wuhans största utmaning är att konstruera reningsverk till alla de 3.5 miljoner som fortfarande släpper sitt avloppsvatten rätt ut till sjöar och floder, snarare än att ytterligare rena det industriella avloppsvattnet. Behandlingsgraden av det industriella avloppsvattnet har nått 97 % medan behandlingsgraden av det kommunala avloppsvattnet endast nått 70 %.

Besök vid de utvalda företagen och kommunala reningsverk ledde till slutsatsen att svensk teknik och expertis kan införas i följande områden: hantering av slam från reningsverk, byggandet av förbränningsanläggningar för sopor och hur man löser problemet med att rena luften från gaser som SO_2 och dioxiner. De flesta företagen kunde följa de kinesiska gränsvärdena för utsläpp av avloppsvatten men mycket kan göras för att förbättra företagens tekniker ytterligare. Detta utförs dock nästan aldrig eftersom det är en ekonomisk fråga. Det är möjligt för Wuhan att sätta lokala, hårdare gränsvärlden för att tvinga företagen att förbättra sina reningstekniker ytterligare.

Nyckelord: Industriellt avloppsvatten, svensk teknik, slam, gasrening, Wuhan, Kina.

Institutionen för Geovetenskaper, Uppsala universitet, Villavägen 16, 752 36 Uppsala
ISSN 1401-5765

摘要

针对中国武汉的工业废水处理及其他环境问题，瑞典技术是否是一种解决之道呢？

Anna Hagberg

中国武汉同Borlänge能源公司的合作始于2000年。2005年，双方决定与IVL瑞典研究所一起展开可持续能源生产、可持续废物管理，于是成立了环境技术中心，向武汉相关部门提供技术支持等合作工作。通过对武汉市的调查，我们认为应用瑞典环境技术，第一步就是要成立武汉环境技术中心。

调查的目的是了解武汉工业废水治理的情况，搞清楚哪些类型的公司存在这方面问题，瑞典技术是否能解决这些问题。我们仅对官方的和有选择地对部分民营公司作了调查，这些公司都符合中国废水标准，因此没有得到未达标公司的相关信息。我们走访了部分市政污水处理厂以此来了解武汉市整体情况。同时，对武汉市环境情况、重要的环境部门和研究所作了介绍。

武汉面临的最大问题就是需要建立污水处理厂，目前约有350万人的污水直接排到河流和湖泊中，并未进一步改善工业废水的处理方式。虽然工业污水处理率已经达到97％，但是全市污水处理率仅达到70％。

在走访这些地方后，我们得出以下结论：瑞典技术和专家能够在处理污水处理厂的污泥、焚烧厂的建设、处理咽气和二氧化物方面发挥作用。大部分受访机构能够达到污水标准，尽管可以采取行动来进一步改善技术，但是并没有做出实际行动，这主要是因为经济方面的原因。武汉有可能制定更加严格的地方性废水处理标准。瑞典公司投入更多资金用于改善技术的确是一个好方法。

关键字：工业废水，瑞典技术，淤泥，咽气清洁，中国武汉

Department of Earth Sciences, Uppsala University, Villavägen 16, SE-752 36 Uppsala
ISSN 1401-5765

PREFACE

This thesis is part of an MSc degree in Environmental and Aquatic Engineering at Uppsala University and covers 20 Swedish academic credits. The thesis was initiated by Borlänge Energi and IVL, Swedish Environmental Research Institute, to be a first step in the establishment of an Environmental technology centre in Wuhan China. Ronny Arnberg has been the supervisor at Borlänge Energi and Lars-Christer Lundin has been the supervisor at the Department of Earth Sciences, Uppsala University.

The language has of course been a problem in writing this report. All of the documents have been in Chinese and the translation of the documents has been very time-demanding. There are also few people in China that can speak English. My level of Chinese wasn't good enough to discuss about technological issues. Anyhow, the staff at the Environmental Protection and Research Institute was really more than helpful and made me feel like one of them during my stay. So I would like to thank Gong Yuan, Zhang Naidi, Zhichao Zhu and Xiong Yu at the Environmental Research Institute, Li Zhan at the Environmental Bureau, Yixin Lin at the Wuhan University, and all other wonderful people that have helped me so much during my time in Wuhan. Finally I must thank Lars-Christer for all the help with writing the report and Ronny Arnberg at Borlänge Energi that initiated this report and supported me all the way!

Anna Hagberg

Borlänge, april 2007

Copyright © Anna Hagberg and the Department of Earth Sciences, Air- and Water Science, Uppsala University.
UPTEC W 07 017, ISSN 1401-5765
Printed at the Department of Earth Sciences, Geotryckeriet, Uppsala University, Uppsala 2007

CONTENT

1. INTRODUCTION

China is a country that is developing extremely fast. However, its rapid development has a severe effect on the environment. Eutrophicated lakes and watercourses, air-pollution and decreasing groundwater levels are only a few of the problems that China is facing.

In 2000 a co-operation and friendship exchange between the Chinese city Wuhan and the Swedish city Borlänge started. Since then the two parts have met on a regular basis to discuss future co-operation and projects. Borlänge Energy and IVL, Swedish Environmental Research Institute got involved early in the co-operation between Wuhan and Borlänge. They agreed in September 2005 that they would co-operate in the future in three fields 1) Sustainable energy production, 2) Sustainable waste management and 3) Establishment of an Environmental Technology Centre in Wuhan.

1.1 AIM

The aim of this master thesis is to investigate which Swedish environmental technology is feasible in supporting the Wuhan companies in achieving their environmental quality objectives. This report is also a feasibility study for the establishment of an Environmental Technology Centre in Wuhan. The Centre will supply Swedish environmental expertise to companies in Wuhan and work like a meeting place for Swedish and Chinese companies. This study includes the following steps;

1) Overall survey of the trade and industry in Wuhan.

2) General description of the environmental situation of Wuhan and different environmental departments and institutions. Investigate the municipal wastewater treatment situation in Wuhan.

3) Selection of around five different companies in Wuhan that have problems to comply with the Chinese wastewater standard. Visits and interviews at the companies to find out what types of problems they have and if they have other environment problems. Comparison between Chinese wastewater standards and Swedish standards.

4) Could Swedish technology solve the problems found in the companies? In which sectors could Swedish environmental technology be established?

2. BACKGROUND

2.1 CHINA'S ENVIRONMENTAL PROBLEMS

China's population of 1.3 billion people is the largest in world. The rate of urbanization in China is also very high and brings along many severe environmental problems. Historically it has been the industry that has been the main contributor to the increased pollution. However, since China has managed to apply some rules and regulations through out the industries and also has closed down several industries, the pollution load from the industry sector seems to be stabilized. Today it is rather the fast urbanization that causes the greatest environmental problems.

In 1980 the urban dwellers were less than 20% of the whole population, in 2000 they had increased to 36% and in 2020 they are projected to be 54%. The cities[1] in China have increased from being 190 in 1978 to 663 in 2000. The small cities, established towns and township concentrations have increased from being 8,000 in 1985 to almost 18,000 in 2004. This part of the urban dwellings represents 44% of the total urban population (World Bank[2], 2006).

China needs to improve its water supply systems, reduce its coal-based air pollution, increase its sanitary drainage systems and wastewater plant systems, reduce industrial pollution and improve its solid waste management (Fritz et al., 2004). OECD[3] has announced some suggestions for China's future environmental work:

Water
- Improve operational performance of treatment plants
- Increase cost recovery
- Distinguish responsibilities between water utilities and local authorities
- Integrate river basins management

Waste
- Adopt plans for waste management (provincial and local)
- Adopt targets for reducing, reuse and recycling
- Extend the waste treatment capacity
- Clearer and more streamlined responsibilities
- Establishing of financing mechanisms
- Supervision of old landfills

Air
- Cleaner fuels
- Energy efficiency targets
- Mass transport
- More ambitious emission reduction targets
- Supervision of wider range of pollutants

China needs to
1. Strengthen the effectiveness of the implementation of its environmental policies
2. Enhance the integration of environmental concerns into economical decisions

(From a speech the 7th of November 2006 by Mr. Olsson, vice director of Swedish Environmental Protection Agency.)

---

[1] According to the government in China a community is called a *city* when it has at least 100,000 non-agricultural population. A *city* with less than 200,000 non-agricultural population refers to a *Small city*, 200,000-500,000 non-agricultural population is a *Medium city*, 500,000-1,000,000 non-agricultural population is a *Large city* and >1,000,000 non-agricultural population is an Extra-large city (Wikipedia, 2007).

[2] References to homepages and other digital sources are underlined.

[3] OECD stands for Organisation for Economic Co-operation and Development.

2.1.1 Environmental policies

During the last 30 years China has managed to establish a strong water pollution control system including a variety of legislation and policy instruments. Recently there has been an increase in environmental management systems like ISO 14 000 and cleaner production but earlier the two main methods to control the water polluters were by command and control systems like for example industrial permit systems and by economic instruments like pollution levy fees.

China's main administrative body to handle environmental issues is the State Environmental Protection Administration, SEPA. SEPA cooperates with the local EPBs, Environmental Protection Bureaus, and other relevant ministries such as Ministry of Water Resource, MWR, to supervise the environmental aspects of Chinas development.

However, co-operation between different institutions and ministries is very bad and has lead to a lack of clarity of responsibility and even to duplication of tasks. The regulatory system is also incomplete and complicated. Since the water quality despite this control system in most places has stayed about the same or even worsened it's quite clear that something must be done to improve the present system (World Bank, 2006).

The Government of China's interventions and investment have led to some water resources improvement such as decline in industrial COD loads but much more needs to be done. The most important task for the Government is to create an environmental awareness and responsibility among the general population (World Bank, 2006).

2.1.2 Water resources and water pollution

China's annual renewable water resources are about 2,500 billion m^3. Water is abundant in the south of China but the water scarcity in the north is severe. The water quality in many places in China is still very bad. According to the Ministry of Water Resources more than 300 million rural residents consume unsafe water. The health risks from both biological and microbial pollutants are still widespread (World Bank, 2006).

The water pollution in the Chinese water system is a combination of organic substances, nutrients and heavy metals. The three main water pollutant sources are industrial, municipal and agriculture non-point sources.

China has established a water quality classification system based on purpose of use and protection target, following Environmental Quality Standard GB3838-2002, see Table 1. The ongoing water monitoring shows that the average water quality in China is poor. In 2004, only 28% of monitored river water was in categories I to III, while as much as 31% was in the worst two categories (World Bank, 2006).

Table 1: Water Quality classification, GB3838-2002 (World Bank, 2006).

GRADE	DESCRIPTION
I	Mainly applicable to the source of water bodies and national nature preserves.
II	Mainly applicable to class A water source protection areas for centralized drinking water supply, sanctuaries for rare species of fish, and spawning grounds for fish and shrimps.
III	Mainly applicable to class B water source protection areas for centralized drinking water supply, sanctuaries for common species of fish, and swimming zones.
IV	Mainly applicable to water bodies for general industrial water supply and recreational waters with no direct human contact.
V	Mainly applicable to water bodies for agricultural water supply and for general landscape requirements.
V+	Essentially useless.

2.1.3 Wastewater treatment in China

The water used 2005 in China was 557.3 billion m^3, distributed as 8.5% for domestic use, 90.1% industry use and 1.4% for ecological and environmental use. According to the Ministry of Water Resource, China produced 52.4 billion cubic meters of wastewater in 2005, which is an increase of 26% from year 2000. Only 52% of this wastewater was treated before discharge (MRW, 2006).

Sewage in most of the 17,000 towns in China still drains directly into rivers and lakes without any treatment. Since 2002, 310 out of 610 cities operate wastewater treatment plants. The most commonly used methods in old municipal wastewater treatment plants are secondary treatment processes such as screening, primary sedimentation, conventional activated sludge and secondary sedimentation. In newer plants technologies such as absorption-biodegrading process (AB), anaerobic-aerobic activated sludge process (A/O), anaerobic-anoxic-aerobic activated sludge process (A/A/O), cyclic activated sludge system (CASS), sequencing batch reactor (SBR) plus activated sludge process, oxidation ditches, and stabilized ponds are used (U.S. Department of Commerce, 2005). The municipal wastewater treatment plants are all owned by the government but operation may be leased to private companies.

Industrial wastewater treatment plants in China are usually owned by the enterprise itself. The authorities put pressure on the industries to improve their wastewater treatment plants but the quality is still low. Many factors contribute to this; high wastewater treatment costs, bad monitoring from the local Government, low penalties for environment violating, poor economy and low environmental awareness. Technologies used for industrial wastewater treatment in China are often biological treatments since they have low construction and operation cost. Some examples are upflow aerobic sludge bed (UAB), which is used in the brewing industry, immobilized micro-organisms technologies, which are used for textile wastewater treatment, and A/A/O processes that are widely used to treat wastewater containing elevated ammonium (U.S. Department of Commerce, 2005).

The recycling of water in the municipal wastewater plants is limited, whereas the recycling of water from the industries is more extensive. The water recycled in the industries is mainly the cooling water. Use of water-saving technologies, products, and equipment must increase (U.S. Department of Commerce, 2005).

In China sewage sludge is directly used for agriculture without any pre-treatment or it is deposited in landfills. Since more and more wastewater treatment plants are being built, China urgently needs to find sustainable solutions for dealing with the sludge (Songa et al., 2005).

2.1.3.1 Wastewater discharge system

The wastewater discharge system in China is divided into two different groups: The *polluted wastewater discharge* group, which includes industrial and domestic water, and the *non-polluted wastewater discharge* group, which includes storm water. Separate drainage systems for wastewater and storm water discharges are needed in facilities that discharge to a municipal wastewater treatment plant. For industrial and domestic wastewater discharges, the National Integrated Wastewater Discharge Standard (GB 18198-2002) applies, see Appendix 4. The wastewater discharges limits are divided into three classes, class I, class II and class III (U.S. Department of Commerce, 2005).

The EPBs issues permits for enterprises to discharge wastewater, according to the Implementation Regulation of Water Pollution Prevention and Control Law. The EPBs are also responsible for inspecting and controlling the wastewater discharges (U.S. Department of Commerce, 2005).

2.2 WUHAN

Figure 1: Map over China, showing the location of Wuhan.

Wuhan is the capital of the province Hubei and one of the top ten largest cities in China. Hubei is situated in central China and has an area of 167,400 km^2, see Figure 1. Wuhan has a population of 8.1 million people and its total municipal area is 8,467 square kilometres (Liou et al., 2000).

According to Feng et al. (2005) 42.8% of the city's area is ridge and 39.3% is plain, 18.1% is low-mountain and hill region. 34.5% of this area is covered with green land.

Wuhan has a southeast subtropical monsoon climate with abundant rainfall and four distinct seasons. The average temperature in January is the lowest, and in July and August the highest. Wuhan is also called the city of the lakes and rivers since there are 12 rivers and 140 lakes, making the city's water surface area ¼ of the whole city. The largest river is the Yangtze River, which is the third largest river in the world. The Yangtze River and the Haishui River join together in Wuhan to form the largest branch of the Yangtze River (Feng et al., 2005).

Wuhan is an important connection point between the east-west communications and the north-south railway connecting Beijing and Guangzhou. Wuhan was originally built up by three different cities; Wuchang, Hanyang and Hankou. Wuchang is the oldest among the three towns and the most important in administration. Since 189-220 AD it has been the political and military centre of the Hubei and Hunan provinces. Hanyang is the smallest of the three and settled in the 600 AD. Hankou is the largest district among the three and was open to the world in 1861 as a treaty port (Chinats.com, 2006).

Figure 2: Districts in Wuhan (Han & Wu, 2004).

Wuhan is today organized into 13 different districts (see Figure 2); seven central districts and six sub-urban districts. The biggest district both when it comes to population and area is the suburban district Huangpi with its area of 2,261 km^2 and population of one million inhabitants, see Table 2. The smallest district is the urban Jianghan district (33.43 km^2).

Table 2: Statistics by district (2002) (Han & Wu, 2004).

District	Land area (km^2)	Population density (person/km^2)	Population (person)[a]
Jiang'an	64.24	9851	632,829
Jianghan	33.43	13,785	460,831
Qiaokou	46.39	11,584	537,378
Hanyang	108.34	4304	466,257
Wuchang	81.22	11,196	909,319
Qingshan	45.8	9832	450,314
Hongshan	509	1329	676,451
Dongxihu	439.19	537	236,042
Hannan	287.7	375	108,011
Caidian	1108.1	434	480,503
Jiangxia	2010	330	663,734
Huangpi	2261	490	1,107,565
Xinzhou	1500	634	951,724
Total	8494.41	904	7,680,958

Source: Wuhan Statistical Bureau (2003b).

[a]The population of Jianghan District including those boat people living on the water.

2.2.1 History

Wuhan has a history of 3,500 years. Already in the years of the Qing dynasty (221-206 BC), Wuhan was an important commercial centre since ocean-going ships could sail all the way up the river to Wuhan (Dorling Kinderleys Travel Guide, 2005). As a result of the Chinese defeat in the Opium war in 1840 Wuhan was opened up and served as trading port to western countries in 1861. The British, French, German, Russian and the Japanese (and even Sweden!) set up concessions and consulates in Wuhan. The rapid growing industry in Wuhan started with Chang Chih-tung's steel mills and arsenal in Hanyang together with several cotton mills in Wuchang (Han & Wu, 2004).

After the communist's victory in the civil war in 1949, Wuhan turned into a city of heavy industry with a focus on metallurgy, mechanical and textile production. With Soviet aid the first bridge over the Yangtze River was completed in 1957 (Dorling Kinderleys Travel Guide, 2005).

In mid 1992 the entire Yangtze valley was opened to foreign trade and investment. By 1995 Wuhan had approved 3,537 foreign investment projects with 1.15 billion USD invested (Han & Wu, 2004).

2.2.2 Trade and industry in Wuhan

Wuhan today has 13 industry zones. Their four main industry sectors are automobile, iron & steel, machinery, optic electronics, and hi-tech industries. There are also today 60,000 enterprises in Wuhan, 107,000 commercial shop chains, more than 300 open markets, eight commercial centres and 12 characteristic commercial streets (Wuhan economic and technology development zone, 2007). There are two state developing zones in Wuhan: Wuhan East Lake Hi-tech development zone (Hi-tech includes photo-electronics, environmental protection, laser etc) and Wuhan Economical & Technological development zone (auto-parts, modern manufacturing etc). Other industries which are big in Wuhan are food and textile industries, see Table 3.

Table 3: Enterprises in Wuhan (Wuhan Government page, 2005).

Type of enterprise	Number
Automobile industries	127
Steel industries	124
Mechanism	421
Medicine enterprises	69
Environmental protection enterprises	178
Food industry	1200
Textile industry	2 700
Petroleum industry	103
Architecture	98
Electronic & information technology	around 300

2.3 THE ENVIRONMENTAL SITUATION OF WUHAN

2.3.1 Air pollution

There are nine air-monitoring stations in Wuhan, see Appendix 2. The concentration of the major air pollutants such as NO_2, SO_2, IP (inhalable particulates), TSP (total suspended particles) and acid rain in Wuhan has decreased since 1998.

Table 4: Mean values air pollutants.

Parameter	2002*	2005**
TSP	131 µg/m^3	111 µg/m^3
SO_2	40 µg/m^3	45 µg/m^3
NO_2	50 µg/m^3	45 µg/m^3
Acid rain, pH	5.2 (3.2)	5.24

* Feng et al., 2005.
** Wuhan Environmental Report, 2005

Table 4 shows that the TSP and NO_2 levels have decreased since 2002 but the SO_2 level has increased. In 2002 half of the pollutants where discharged from fuel combustion. The vehicles in Wuhan have increased from 164,150 in 2002 to 652,700 in 2005 (Feng et al., 2005); an increase with 75% in only three years, and the discharges continue to grow.

2.3.2 Waste

The municipal waste is monitored by the Wuhan Environment Sanitation Bureau and the industrial waste is monitored by the Wuhan Environmental Protection of Science Research Institute. The industrial waste produced 2005 was 84.73 million tons. The produced municipal amount was 1.97 million tons and the municipal disposal amount was 1.57 million tons (Wuhan Environmental Report, 2005).

In Wuhan all the waste is deposited in landfills today but the government is planning to construct four incinerations plants. The plan is to decrease the waste to the landfills with 50% and burn the other 50% in incineration plants (Gong Yuan, personal communication, 2006).

In 2003, an incineration centre for harmful waste, such as waste from hospitals, was constructed in the Wuhan Economical & Technological development zone in Wuchang. Formal systems of recycling municipal waste exist so far not. Anyhow, municipal waste like plastic bottles, cans and metals are recycled by informal trash pickers. Batteries and other dangerous waste are sorted out according to the law of dangerous waste. The fee of the waste handling for every family is 5 Yuan[4] per month. The industry waste is recycled to 80%, almost totally covered by the cinder produced in the coal power plants, since they are the main energy sources for Wuhan. The cinder from the power plants is used to produce constructing materials as bricks. The dust is stored in a safe way to avoid pollution of the surrounding area (Gong Yuan, personal communication, 2006).

2.3.3 Water

2.3.3.1 Drinking water

The drinking water of Wuhan originates from the Yangtze River and the Han River. The Yangtze River, also called Changjiang River, is one of Chinas nine basins, with a flow rate of 951.3 billion m^3/yr (at the mouth). Both the surface waters and the water from the bottom of the rivers are used. The water is generally cleaned by sedimentation, addition of $AlCl_3$ and chloride.

The daily water-supply capacity in Wuhan is 2.36 million m^3 (WEDZ, 2007); 6 billion m^3 water was used in 2005. 97.1% of the drinking water reached the national standards for drinking water in 2005 (Wuhan Environmental Report, 2005).

2.3.3.2 Surface water quality

The biggest lake in Wuhan, the East Lake has an area of 33 km^3, Figure 3. The rivers and lakes of Wuhan constitute a great surface water resource but they are all polluted to different degrees. A large amount of municipal sewage is still discharged directly into the lakes, which pollutes them and make them eutrophicated.

There is ongoing monitoring of the surface water quality in 67 of Wuhan’s 140 lakes and in eleven rivers. The rivers and lakes are classified according to the GB3838-2002, see Table 1.

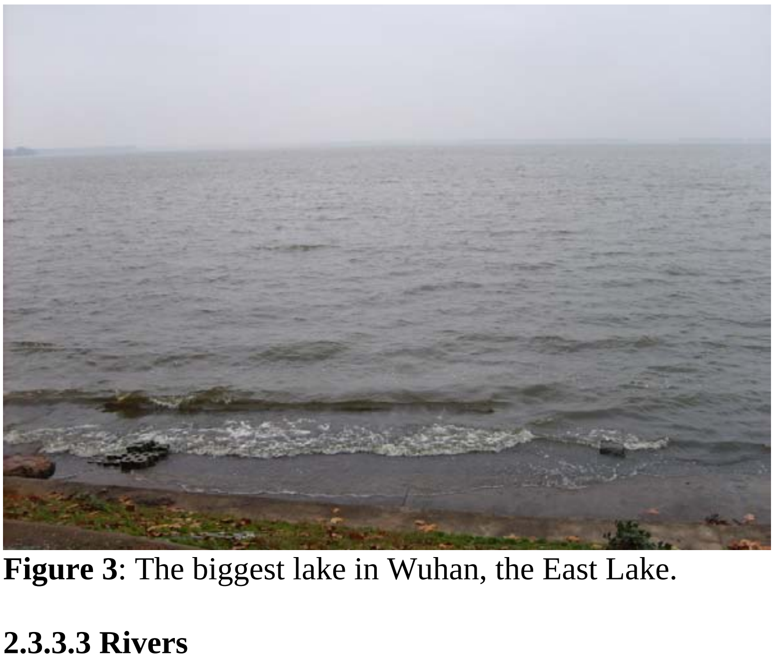

Figure 3: The biggest lake in Wuhan, the East Lake.

2.3.3.3 Rivers

The three main rivers floating through Wuhan the Yangtze River, the Han River and the Fu River are all polluted from upper reaches. According to the River table data from Wuhan Environmental Report (2005) six rivers out of eleven reach the national water quality class III

[4] 1 Yuan= 0,87SEK 2007-03-05 (xchange, 2007).

(see Table 1) in 2005. Four rivers were estimated as class IV and one river, the Fu River, as class V. The water quality of Green Mountain Harbour River and Easter Njin River has decreased from belonging to class III in 2004 to enter the group of class IV in 2005. All other rivers are stable in their classification, Figure 4. The Fu River is the only river that has reached class V and has NH_3-N and TP levels that exceed the standards. The petroleum levels of Nie River, Easter Njin River and the Green Mountain Harbour River exceed the standard level (Wuhan Environmental Report, 2005).

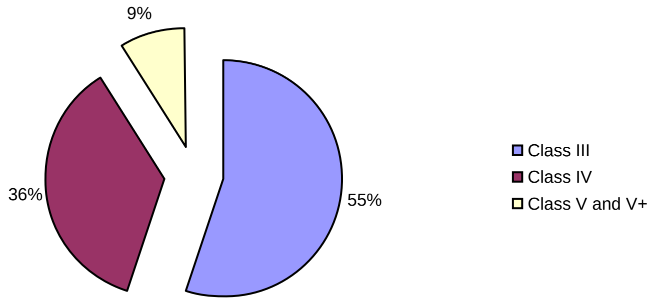

Figure 4: Classification of the Water Quality in the Wuhan Rivers according to the Environmental Quality Standard GB3838-2002, 2005.

2.3.3.4 Lakes

According to the Lake table data in Wuhan Environment Report (2005) three lakes fall into class II, six lakes fall into class IV, nine lakes into class V and as many as 32 lakes into class V+, Figure 5. The water quality in twelve lakes is regressive and has changed from a higher class to a lower class since year 2004. In four lakes the water quality has improved from 2004 to 2005. Traces of permanganate have been found in 16 of the lakes. In 54 of the lakes the level of the COD, BOD, NH_3-N, TP, TN and petroleum content have exceeded the standard (Wuhan Environmental Report, 2005).

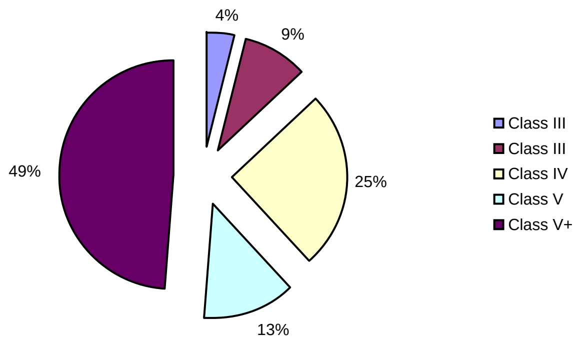

Figure 5: Classification of the Water Quality in 67 of Wuhan's 100 lakes according to the Environmental Quality Standard GB3838-2002, 2005.

2.3.3.5 Eutrophication

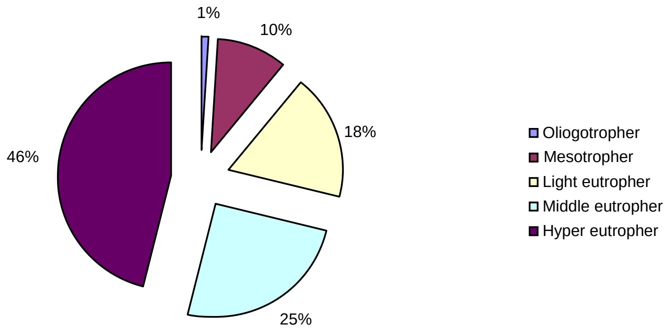

Figure 6: Grade of eutrophication of Wuhan lakes.

One lake belongs to the category oliogotropher and 30 lakes to the category mesotropher. All together 36 lakes belong to the low eutrophication categories: Twelve lakes belong to the category eutropher, 17 the category middle eutropher and seven the hyper eutropher category, (Figure 6), see Appendix 5 for the standard (Wuhan Environmental Report, 2005).

2.3.3.6 Organic monitoring

The monitoring of organic pollutants, GB3838-2002, detected 53 volatile organics, 61 half-volatile organics, 9 organic phosphor pesticides and 17 organic chloride pesticides in the surface water 2005 (Wuhan Environmental Report, 2005).

2.3.4 Water resource investigation in the Huangpi district

The central districts have come quite far with their environmental work but the six suburban districts have severe problems. Waste handling systems have not yet been developed, neither have wastewater plants been constructed. The quality of the drinking water is also very poor in most of the places. The Environmental Research Institute has done an investigation of the quality of the drinking water in these regions.

In the largest and also poorest of the regions, Huangpi, the surface water is the main water resource. For the largest city in the Huangpi district, called Huangpi, it is thus the Shè River (滠河). This river is also the water supply for many small villages. Dangerous industries are forbidden to discharge wastewater directly into the river. However, there is still no such restriction for municipal wastewater discharges (Gong Yuan, personal communication, 2006). The quality of the drinking water in the southern parts of the Huangpi district is not good. For example in one village there was a garbage heap beside the water resource, in another village tea was grown just beside the water resource and in many places the water resources are surrounded by farmland. Many areas of the She River are also badly eutrophicated. The cleaning methods of the drinking water is also poor, at many places only very old equipment exists, old pumps and tanks etc. and in some places only sedimentation is used to clean the water. Something must urgently be done to improve the situation in these regions. See Appendix 5 for the complete report.

2.3.5 Wastewater

The degree of urban sewage treatment will reach 70% in the end of 2006. The treatment rate of industrial wastewater has reached 97%. The main pollutants in industrial wastewater are chromium, NH_3-N and COD (Wuhan Environmental Report, 2005). 284 wastewater plants or equipments existed in the heavy pollution industries in 2002 and the rate of recycled water was 68.40% (Feng et al., 2005).

The amount of industrial wastewater has decreased since 1998 (Figure 7) but the amount of municipal wastewater has stayed the same or slightly increased.

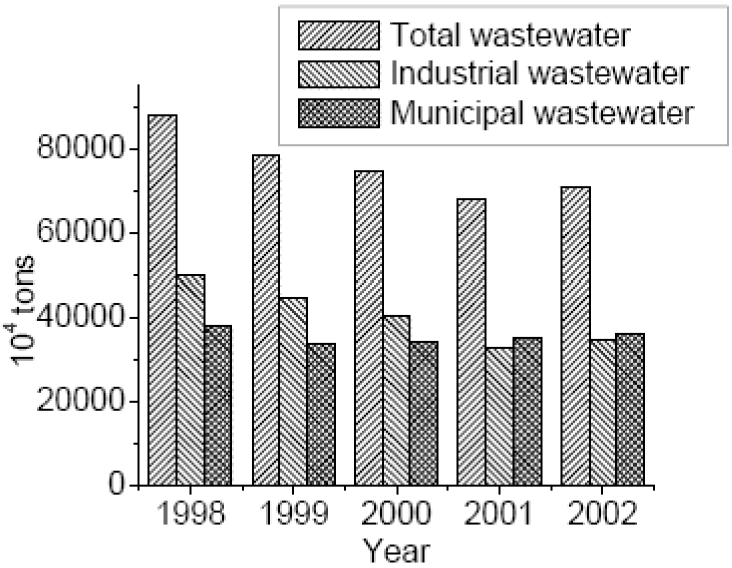

Figure 7: Industrial and municipal wastewater production in Wuhan from 1998-2002 (Feng et al., 2005).

Table 5 shows that in 2005 the discharge of municipal wastewater was 134 million tons more than the industrial wastewater discharge. During 2002-2005 the industrial wastewater discharge decreased by 90 million tons. The municipal wastewater discharge has increased since 2002. The increase can be reasonably explained by the development of the city. More and more houses are constructed and more and more people move from the countryside to the city.

Table 5: Discharge of chromium, NH_3-N and COD and wastewater.

	2002*	2005**
Chromium	3.01 tons	0.26 tons
NH_3-N	1731.96 tons	1484.88 tons
COD	55190.69 tons	27877.55 tons
Municipal wastewater	362.1 million tons	396.6 million tons
Industrial wastewater	349.8 million tons	260 million tons
Total amount of wastewater	711.9 million tons	656.6 million tons

* Feng et al., 2005.
**Wuhan Environmental Report, 2005.

2.3.5.1 Wastewater treatment sludge

Wuhan has a huge problem with sludge produced in the municipal wastewater treatment plants. When the degree of urban sewage treatment reaches 70% in the end of 2006, 2,000 tons of sludge will be produced per day. This means that in two days Wuhan produces as much sludge as Borlänge does during a whole year!

How to deal with the sludge is still a problem also in Sweden and so far there does not exist a perfect solution. In Sweden one million ton of sludge is still produced every year by the municipal wastewater treatment plants (Svanström et al., 2004). The municipal sludge is taken care of in many different ways today in Sweden; it is incinerated, it is used as cover of rest material from the mining, it is used for making soil, it is used as fertilizer for the Salix and it is put on beds of weed (Svenskt vatten, 2007). The sludge produced in the wastewater treatment facilities contains the nutrients phosphor, nitrogen and humus creating substances and is therefore an excellent soil conditioner. The problem with the sludge is that it can contain many hazardous substances like heavy metals, pathogens and bio accumulating organisms. Metals such as lead, copper, cadmium, chrome, mercury, nickel, silver and zinc in the wastewater plants end, more or less, up in the sludge. The contribution of these metals to the wastewater plants must decrease to provide a good sludge quality.

3. MATERIAL AND METHODS

During a period of two months, information was collected in Wuhan with help from people at the Environment Protection of Research Institute (EPRI). Staff from the institute helped to arrange the visits at the companies and helped with the translation.

The first step was to find out which companies have difficulties to comply with the Chinese wastewater standards, in order to choose which companies to visit. Information about companies' wastewater discharge and content is collected in a database by the EPRI, but this is not public information and, especially for companies that don't follow the standards, the local Government will not hand out the information. It is also difficult to know if a company has reported information incorrectly, which still happens. Interviews with the local EPB gave the information that coking plants are one type of industry in Wuhan that doesn't comply with the wastewater discharge standards. During a visit in the Huangpi region it was discovered that one paper mill in a village had problems to follow the standards and is under production stop until the problem is regulated. With this information as background a visit to a coking plant and a paper mill was proposed and could also be performed. Worth noting is that the visited paper mill was not the one in the Huangpi region. The visited paper mill and coking plant are both placed in the Wuhan economic and development zone.

Even though strong wishes were made to the EPRI to visit companies with problems with their wastewater treatment the rest of the visited companies all met the wastewater discharge standards. Three of the companies were situated in the Wuhan East Lake Hi-tech development zone monitored by the Wuchang EPB; a power plant, the Green World Company and the Wuhan Kernel Bio-Pesticide Co Ltd. A slaughterhouse situated by the Yangtze River and monitored by the Environmental Law Supervising Office was also visited after some new information was received from the EPB that slaughterhouses need improvement of their technology.

Visits to two municipal wastewater treatment plants were made to get a clearer picture of technologies used in the wastewater treatment plants and the municipal wastewater treatment situation in general in Wuhan.

The companies were asked to answer some questions, see Appendix 1, to describe their wastewater treatment. Process schedules of their wastewater treatment plants and their production were collected together with data on the content of the wastewater. Since many of the visited companies did not have any problems following the present national wastewater discharge standards other environmental problems at the companies were also taken into account.

Representatives for the most important environmental departments and institutions in Wuhan were also interviewed in order to elucidate their functions and environmental tools available to supervise the industries and companies in Wuhan. A comparison between Swedish and Chinese wastewater standard system was also performed.

3.1 STANDARDS

3.1.1 Chinese standards

The standardization system in China is a centralized administrative system that co-operates with official departments and civil associations. It is called the Standardization Administration of the People's Republic of China (SAC) and is authorized by the State Council under the control of AQSIQ[5]. In provinces and municipalities the national standards is promoted by local administrative departments with proper competence.

The standards are divided into national standards, professional standards, local standards and economical standards (Standardization Administration of China, 2007).

The Chinese standards are only available in Chinese. Some of the parameters and standards used in this report are found in the Table 6. It is possible, although rare in practice, for a province to have stricter standards than the national standards. The discharge standard of pollutants for municipal wastewater treatment plant, GB 18198-2002, is partly translated and can be found in Appendix 4.

Table 6: National standards for discharge of wastewater, China.

Parameter	Discharge from wastewater treatment plant (mg/l)	Discharge to wastewater treatment plant (mg/l)*	Discharge from industries (mg/l)**
CODcr	60	500	100
BOD_5	20	300	20
SS	20	400	70
NH_3-H	8 (15)	25	15
TN	20		
TP	1.5	1.0	0.5
pH	6-9	6-9	6-9

***** The standards for industrial discharge of wastewater to wastewater treatment plants.
******Discharge from industries after treatment directly to the recipient

[5] A.Q.S.I.Q stands for General Administration for Quality supervision Inspection and Quarantine.

3.1.2 Swedish standards

In Sweden a company needs to ask permission for *environmental hazardous activity*, as discharge of wastewater, according to the Environmental Code introduced in 1999. A wastewater treatment plant in Sweden can reject to deal with wastewater from industries if this wastewater content differs a lot from the municipal wastewater content. The industries are then responsible for their wastewater treatment themselves (Utsläpp av avloppsvatten från yrkesmässig verksamhet, 2000). The standards for discharge of wastewater from industries are decided separately for each industry when the environmental impact assessment is done. The recipients as well as recommendations from the Swedish Environmental Protection Agency are taken into account when the standards are set.

The Swedish County Boards' environmental permission delegations set standards for wastewater plants serving more then 2,000 pe[6]. For smaller wastewater plants it is the municipal environmental committee that sets the standards. For some parameters there are no general standards developed and the wastewater treatment plant can thereby decide the standards themselves. There are guidelines both from Stockholm Vatten and the Swedish Water & Wastewater Association how to set the standards. According to Klas Johnson at the Swedish county Board in Falun the BOD_7 and total phosphor standard are generally set to 15 mg/l respectively 0.5 mg/l. If wastewater discharge is higher than 10,000 pe there is a general standard for the total nitrogen of 15 mg/l. The wastewater treatment plant in Borlänge has only two standards to follow; BOD 15 mg/l and phosphor 0.5 mg/l (Solveig Barme, 2007).

3.2 REGULATIONS AND ENVIRONMENTAL AUTHORITIES IN WUHAN

3.2.1 Regulations for industries in Wuhan

Wuhan has formulated specific industrial guiding policies in accordance with the national industrial policy issued in 1989. The policies strictly control and restrict the development of the enterprises that are heavily polluting and fail to improve their integrated capacity in reducing pollutants (Wuhan Environmental Management Strategy Outline, 2000).

3.2.2 EPB and the Wuhan Environmental Protection of Science Research Institute

According to the Chinese environment protection jurisdiction, the Environmental Protection bureaus, EPBs, are responsible for industrial environmental management, but different EPB departments supervise different areas (Gong Yuan, 2007). EPB is subordinate to China's main administrative body for handling environmental issues the State Environmental Protection Administration, SEPA.

Wuhan Environmental Protection of Science Research Institute, EPRI, is subordinate to Wuhan EPB and was founded in 1977. It is an environmental protection scientific research organ for public welfare, specializing in application research and technical consulting service. There are several divisions in the institute, including the environmental integrative department, the environmental pollution controlling and solution department, the environmental impact assessment department, the environmental scientific information office and administrative offices (Facts from the EPRI, 2006).

3.2.2.1 Environmental Impact Assessment Department

The Environmental Impact Assessment Department, EIAD, is the most important department in the EPRI. This department receives around 200 projects per year. Today, according to the

[6] Pe, person equivalents, is the amount of degradable organic material that has a bio-chemical oxygen consumption of 70 gram dissolved oxygen per day under seven days, BOD_7= 70 g/day (SNFS 1994:7).

regulations, an EIA must be done before constructing new factories, for urban infrastructure, construction of wastewater plants etc. In Wuhan many new small economical zones are planned and the EIAD joins in the preparation work. The EIAD sets the standard and controls the wastewater for the new industries. The new projects must also set a distance for safety and sanitation from real estates.

Wuhan has many old companies that are all supervised by the EIAD and prompted to improve their processes if necessary. If these companies do not comply with the new standards, they must stop their production and the EIAD may even suggest new placement for the factory. The industry policy of the country is to get rid of small, heavy polluting companies and create big industries.

The industries called “the third industries” in China, like restaurants, real-estates, hotels and so on are also checked by the EIAD and they give suggestions for improvements, e.g. in the restaurants, a lot of oil is used.

The EIAD also work the urban development planning. An environmental impact assessment must be done of the area considered for the development. According to national regulations all major planning should go through an EIA (Qi Gongyi personal communication, 2006).

3.2.3 Wuhan Environmental Law Supervising Office

This office has three main tasks

1) Control big companies twice a month and small companies once every three months.
2) Interview people living around the factories, asking them if they have noticed any strange smells, smokes etc.
3) Supervise big companies online. Can see their COD-levels, flow levels etc. Also have a noise monitoring system.

The institute is working as an environmental police. If pollution accidents occur they will investigate it, see Figure 8. When new companies are built the office supervises law obedience. If companies exceed the standards it makes sure they pay a fine. Courses are held for the employees of the office when new guidelines and regulations are to be enforced.

80% of the polluting companies are monitored by the office all together 120 companies (Lei Ming, personal communication, 2006).

Figure 8: The Environmental Law Protection Office’s emergency services vehicle.

4. RESULTS

4.1 WASTEWATER TREATMENT PLANTS IN WUHAN

There are 15 wastewater treatments plants in Wuhan including the ones under construction, Figure 2, Appendix 2. These wastewater treatment plants are all situated in the seven central districts. According to Li Zhan (personal communication, 2006) at EPB wastewater treatment plants in the suburban districts Jiangxia and Xinzhou are under construction but the other four suburban districts have so far no wastewater treatment plants so far. Wastewater treatment plants are planned to be constructed in these areas before 2010. There is thus still a lack of wastewater treatment plants for about 3.5[7] million people!

The oldest wastewater treatment plant is the Sha Lake in Wuchang, which is 20 years old. A visit was made to two of the most newly built ones in Han Xi and Zhuankou. These two wastewater treatment plants are owned by the local Government but leased to private companies for 25 years. What is common for all the wastewater treatment plants is that they add chloride in their last step.

There are three main problems with the wastewater treatment plants in Wuhan: 1) Shortage of money/fees, 2) Illegal discharge and 3) Sludge. Most of the wastewater treatment plants have good equipment but not enough money to operate. The fees paid to the wastewater treatment plants are not enough for the management. The first problem leads to the second problem; illegal discharge from the wastewater plants. This is a very serious problem and it is impossible to control how much that is discharged illegally. The sludge from the wastewater plants will continue increasing, urgently calling for methods to deal with the sludge (Xiong Yu, personal communication, 2006).

4.1.1 The Han Xi wastewater treatment plant

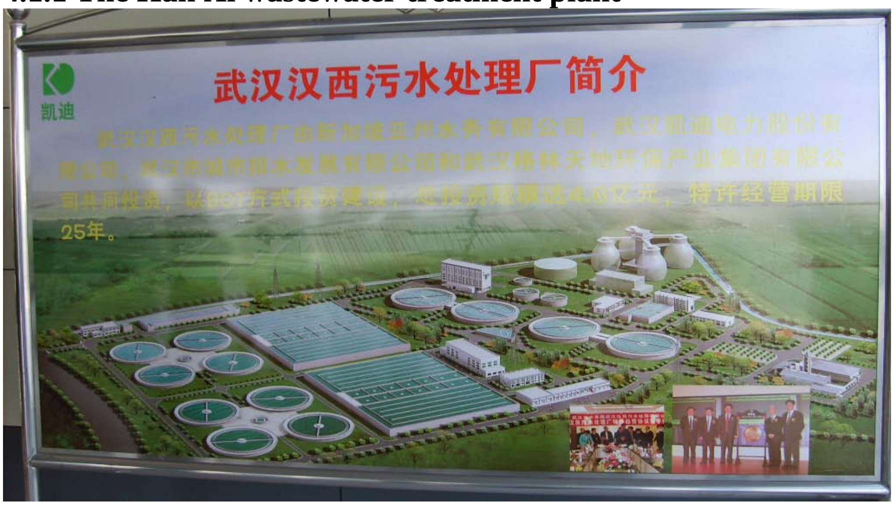

Figure 9: The Han Xi wastewater plant.

The Han Xi plant (Figure 9) was finished in 2006 and is situated in the area of Changqing. It has a capacity of 800,000 m^3 wastewater per day, but right now it is only treating 400,000 m^3/day. The incoming wastewater is mainly municipal wastewater, only 20% of the wastewater is industrial wastewater. The recipient is the Fu He River. The content of the

[7] The number 3.5 million is from year 2002, the population has probably increased since then.

outgoing sewage water can be read in Table 7; 60-70 tons of sludge is produced every day, which is deposited in landfills.

Table 7: Data of the outflow from the wastewater plant compared with the standards.

Parameter	Outflow (mg/l)	Chinese standards (mg/l)
COD	< 100	100
BOD_5	< 30	20
SS	< 30	20
NH_3-H	< 30	8(15)
TP	< 100	1.5
pH	6-9	6-9

In order to control the flow the water first enters a sewage ditch (see Figure 10). Then it passes through three different filters: First a very coarse screen (simple screen), then a coarse screen, and finally a rotating-drum fine screen. After that, the water is pumped into an aerated grit chamber where inorganic solids greater then 0.2 mm are filtered away. Thereafter it goes on to the primary sedimentation tank (post-settling), then to the activated sludge process, after that to the secondary sedimentation (pre-settling). Some of the sludge is recycled into the anoxic zone of the activated sludge process. The last step is to add chloride but right now the chloride is not in use. They are planning to build anaerobic digestions chambers for the sludge.

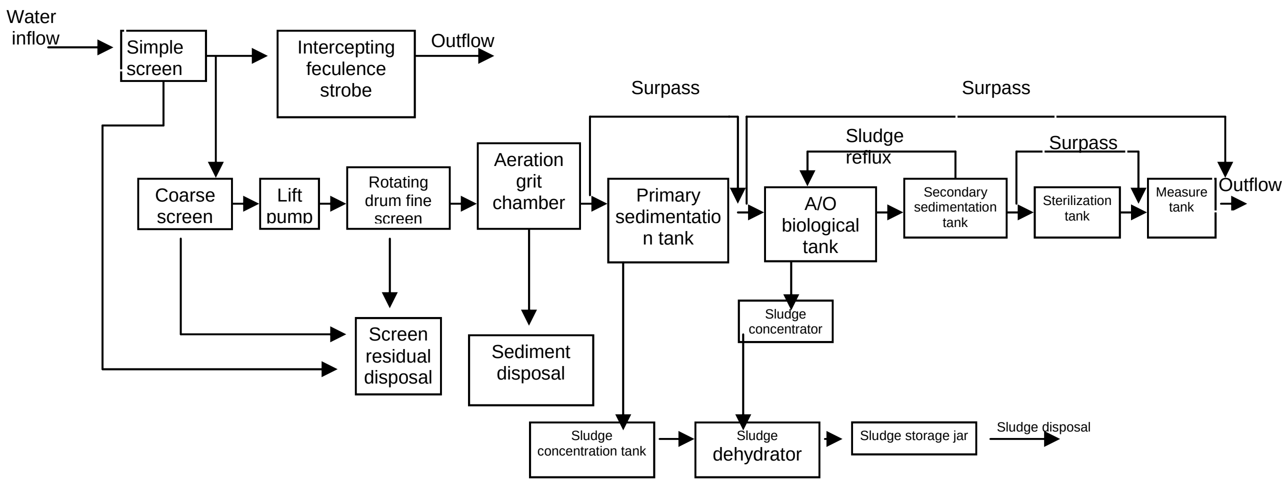

Figure 10: Han Xi wastewater treatment plant.

4.1.2 The Zhuankou wastewater treatment plant

Zhuankou wastewater treatment plant is one year old and has an inflow of 300-400 m^3/day; 60% of the wastewater is from the industry and mainly the automobile industry, and 40% is municipal wastewater. The recipient is the Nan-Taizi Lake with an area of 5.09 km^2. 16 tons of sludge is produced every day with a water content of less than 80%. The wastewater content is found in Table 8.

Table 8: Data of the inlet and outlet of the wastewater plant compared with the standards.

Parameter	Inflow (mg/l)	Outflow (mg/l)	Chinese standards (mg/l)
CODcr	871.98	34.01	60
BOD_5	282.4	16.03	20
SS	554.31	12.66	20
NH_3-H	14.4	2.88	8 (15)
TN	32.94	10.32	20
TP	9.56	1.03	1.5
pH	7.50	7.28	6-9
Pb		< 1.5 (exceed standard)	1.5

First the wastewater passes through a coarse bar screen then it is pumped to a rotary drum bar, and further to an aerated grit chamber, which is followed by an UNITANK single stage aerobic system, see Figure 11. The UNITANK system is a technology from Belgium. It consists of a three-compartment activated sludge reactor incorporating two basic processes; aeration and sludge settling. The UNITANK with biological nutrient removal can meet very stringent effluent requirements for BOD, nitrogen and phosphorus. The last step is adding chloride and then some of the water is reused and the rest is discharged into the lake.

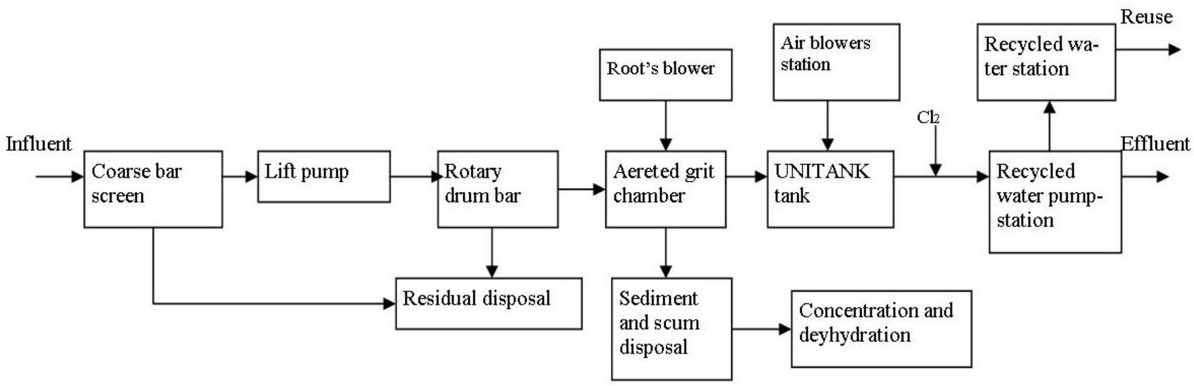

Figure 11: Zhuankou wastewater treatment plant.

What is worth remarking is that there are many houses and small agriculture around the wastewater plant, see Figure 12. Also in the lake, being the recipient for the wastewater plant, lotus cultivations are found.

Figure 12: Houses just outside the wastewater treatment plant and lotus cultivation in the lake.

4.2 INDUSTRIES

4.2.1 Wuhan Paper Mill

Wuhan has two paper mills, which are owned by the same concern. The two factories produce 300,000 ton paper per year. They produce all kinds of paper but mainly newspaper and stationary. The paper is mostly made from grass but trees are also used, see Figure 13. 3,000 people are employed in the two factories, which both are situated in the Zhuankou area (See Appendix 2, Figure 2). A visit was made to one of the two factories. This factory had its own power plant, which uses 0.3 million tons coal per year. 30,000 kWh per day is used at the visited factory. The factory produces paper mill chemically, see Figure 14 for the process schedule.

Figure 13: The grass used for making pulp.

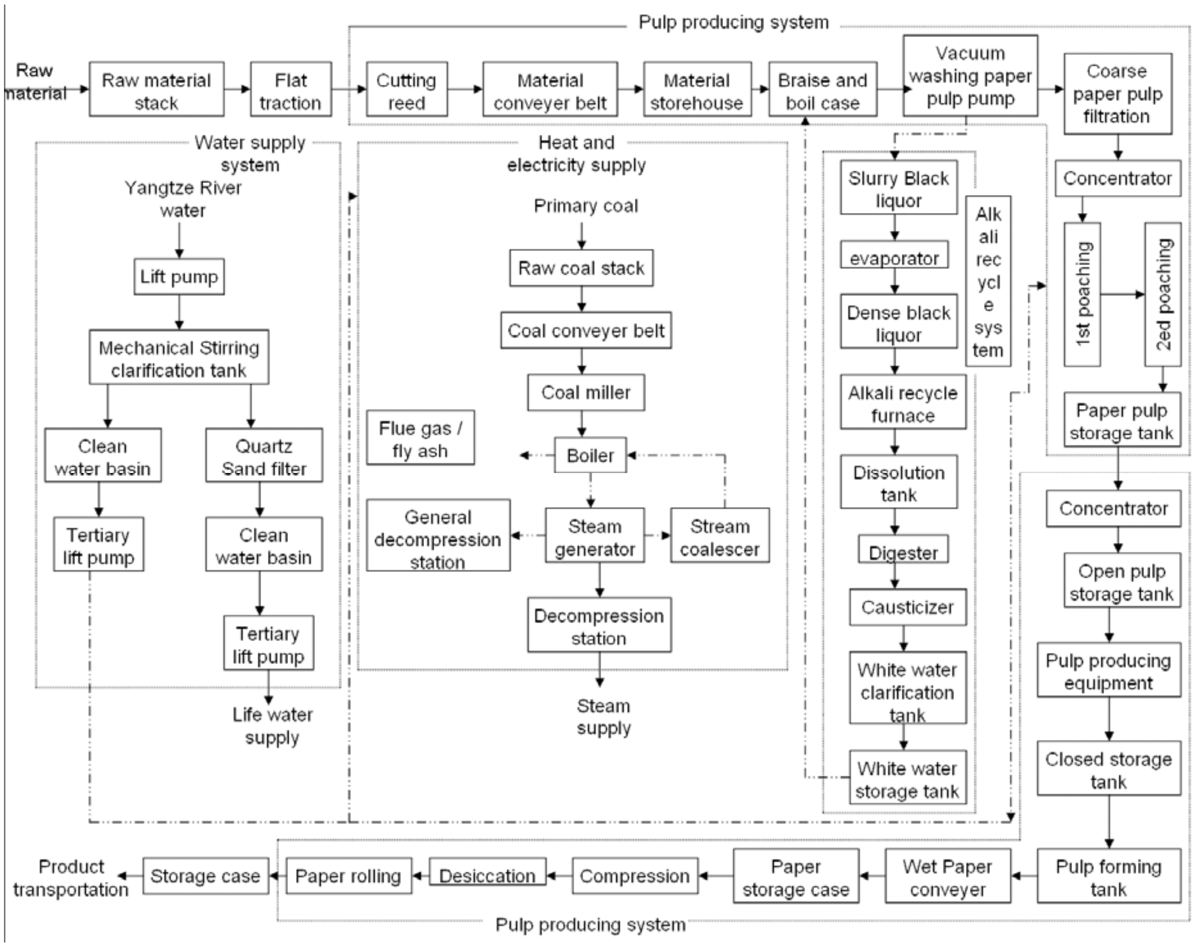

Figure 14: Paper mill process schedule.

The Government has recently issued some new standards for the paper mills. The new COD standard is 440 mg/l. The paper mill can live up to the standard but the manager thinks this standard is far too strict.

The total discharge of wastewater is 50,000 ton/day. The mill would like to increase the efficiency of the wastewater treatment cleaning to 65,000 ton per day. The wastewater contains small amounts of lead, mercury and larger amount of different aromates, see Table 9.

Table 9: Data of the inflow and outflow from the paper mill wastewater treatment plant.*

Parameter	Inflow (mg/l)	Outflow (mg/l)	Chinese standards (mg/l)
COD	2,000-3,000	440	440
Aromates	Slightly detectible		
Hg	Slightly detectible		
Pb	Slightly detectible		
pH	6-9		

* The director at the paper mill didn’t want to hand out any more data of the water content then this.

The amount of COD before the treatment is 2,000-3,000 mg/l and after treatment the level is 440 mg/l. 5,400 ton COD is discharged every year. 85 tons of water is used for making 1 ton of pulp. The recycle rate of the water is 50-60%. The paper mill wastewater standard is translated and can be found in Appendix 4, Table 1. According to Jan Kastensson at the wastewater technology company Mercatus are some of the Chinese paper mill wastewater standards more strict than the Swedish, for example the BOD standard (personal communication, 2007).

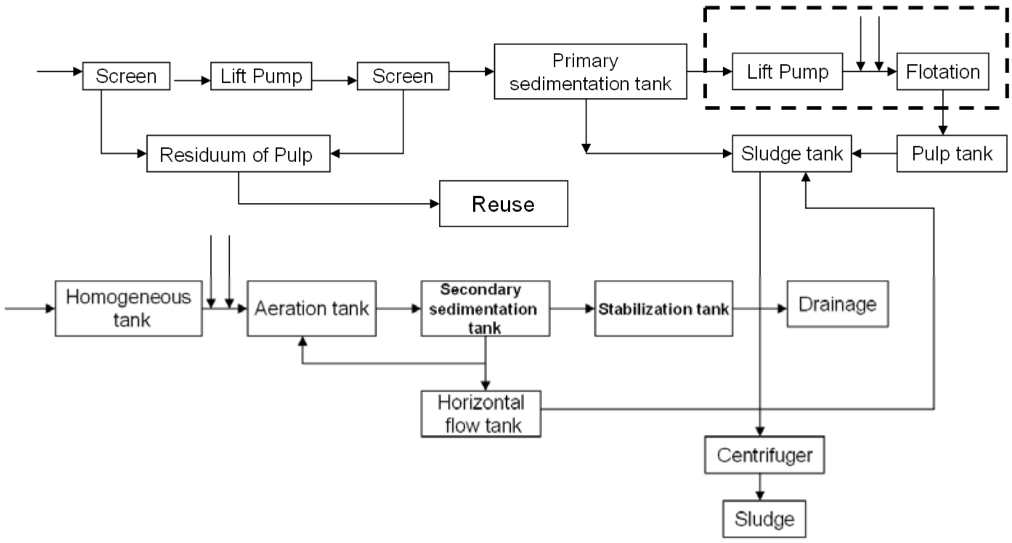

Figure 15: Paper mill wastewater treatment plant**.**

The paper mill wastewater treatment plant is six years old, see Figure 15. Before the installation of the wastewater treatment plant the water was discharged directly into the Yangtze River. The technique used is from Germany and is called BIOLAK. BIOLAK is a treatment method that was introduced to China in 1999 and it is used in the provinces Hubei, Shandong and Shenzhen. BIOLAK is a high performance wastewater treatment technology, which can remove nitrogen and phosphor at the same time (Biolak, 2006). See Appendix 4. 50 ton sludge is produced every day in the wastewater plant, which today is landfilled. The paper mill also recycles the white water (without chemicals) according to Figure 16 and they also have separated wastewater treatment of the oil wastewater, Figure 17.

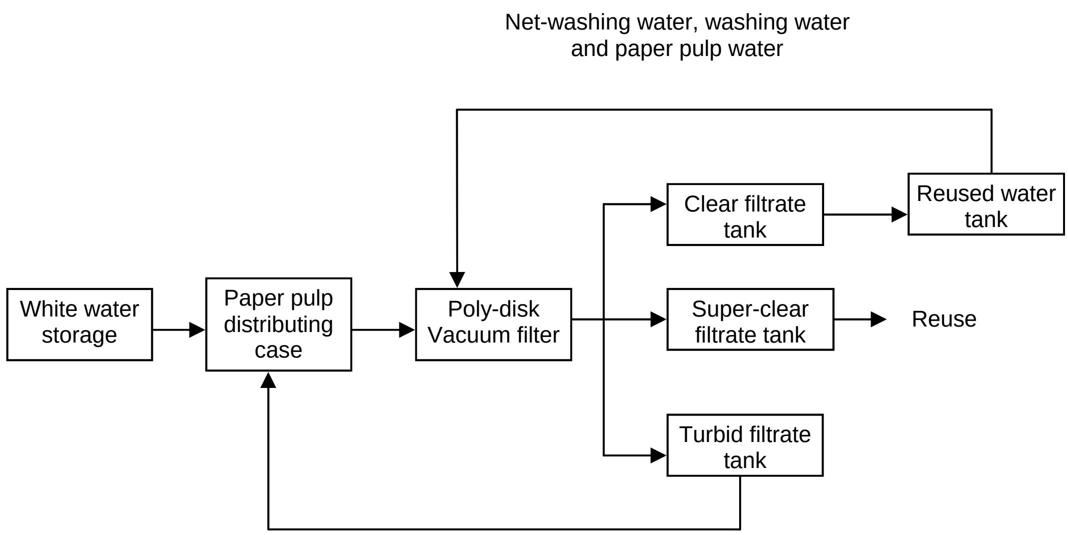

Figure 16: Paper mill recycling of water.

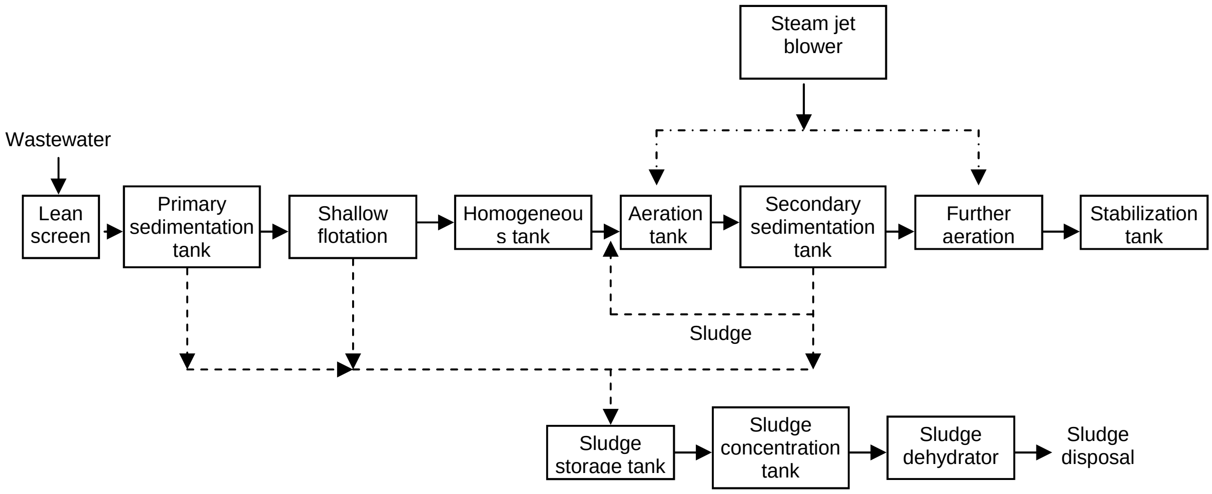

Figure 17: Paper mill oil wastewater treatment.

A plan exists to recycle the wastewater or the black water, dry it in a stove and then reuse the chemicals. This will cost 10 million Yuan. Their wastewater treatment costs 2.3 millions per month, of which 320,000 is paid to the Government. The manager and the engineers at the paper mill are not aware of any better solutions for the wastewater treatment in China. They are in contact with companies from Canada, Australia, America and Germany for buying new technologies to the paper mill or the wastewater treatment plant. Their company do not have any environmental plan; they put the product first and only want to lower the costs for the wastewater treatment.

4.2.2 Wuchang coking plant

The Wuchang coking plant belongs to the big Steel and Iron group in Wuhan. They supply heat for the steel production and gas for 40,000 habitants of Wuhan. The capacity is 200,000 tons coke per year but the present use is 170,000 tons per year. This factory has problems with meeting the wastewater discharge standards. The COD and the BOD levels exceed the standards. The local Government is planning to shut down this factory in 2008 or as soon as it is possible to replace the produced gas with natural gas.

In the coking plant hard coal is converted to coke, see Figure 18. The coal is heated in a coking oven with an oxygen-free environment (pyrolysis). The by-products produced, coke plant gas and steam, are required in other processes of the steel production and the hard coal tar is sold. The working environment in coking plants is particularly problematic as the gas from the pyrolysis of coal contains, among other compounds, ammonia, hydrogen sulphide, phenols and hydrocarbons, such as polycyclic aromatic hydrocarbons (PAH) (Pyya et al., 1997). In the Wuchang coking plant a wet method is used to produce the coke. Most of the water used in the process is used in the step of gas scrubbing. In this step the nitrogen is wept out.

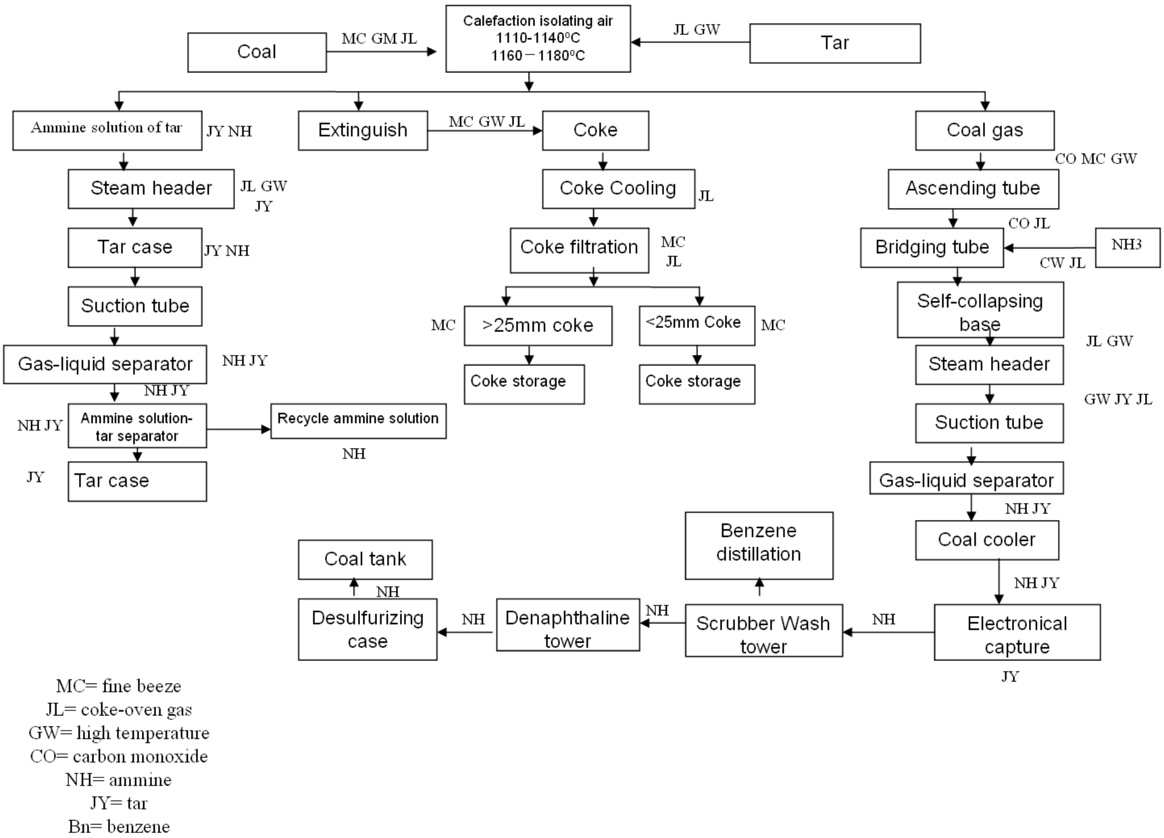

Figure 18: Process scheme from the coking plant.

The wastewater composition in the coking plants is complicated and varies from one factory to another depending on the quality of the raw coal and carbonisation temperature. The main organic constitutions are phenols, which accounts for about 80% of the total COD. Other organics are PAH and nitrogen, oxygen and sulphur which contains heterocyclic compounds. Many of these heterocyclic compounds are mutative and carcinogenic. Inorganics found in the wastewater are cyanide, thiocyanate sulphate and ammonia. Conventional activated sludge systems are not efficient for reducing the COD because of the presence of refractory organics. Many of the typical compounds found in the coke wastewater plant like phenol and alkylpyridine are inhibitory to nitrobacter at certain concentrations so nitrification is also difficult to proceed (Zhang et al., 1997).

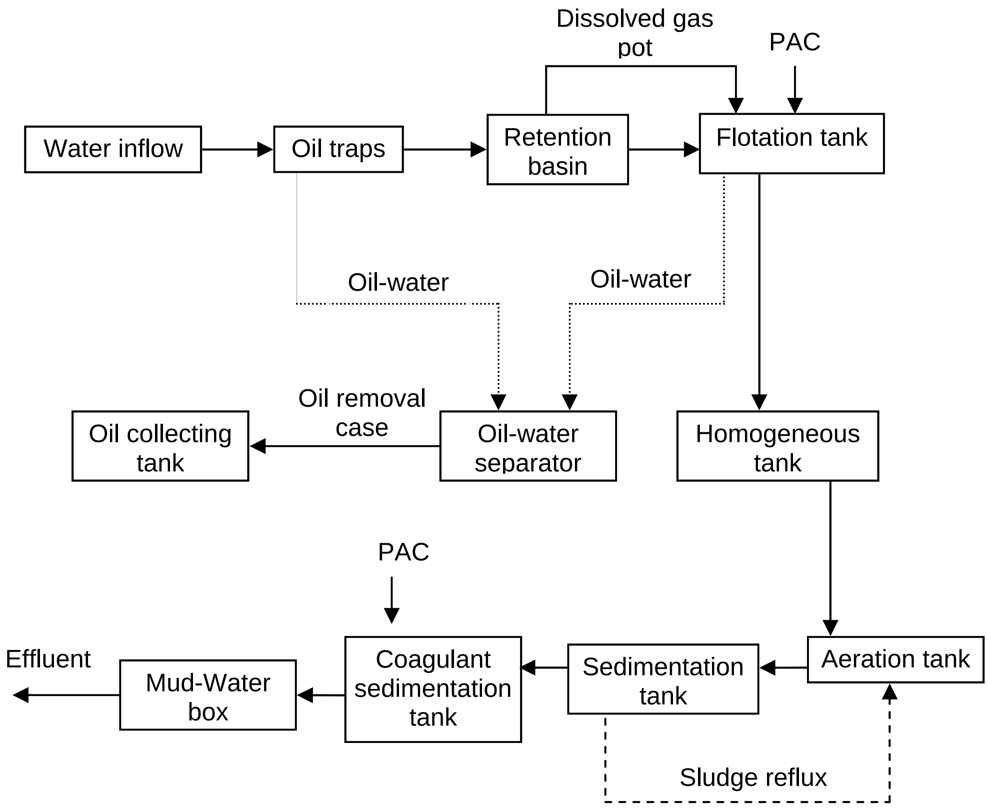

Figure 19: The coking plant wastewater treatment plant.

In 1994 a new stove was installed and the wastewater treatment system was changed to suspension and biological cleaning (Figure 19). The wastewater treatment faces some problems in the oxidization part. The oxidisation only occurs on the surface, which is a big problem since they want the oxidisation to occur in the whole tank. The equipment in the wastewater treatment is old and needs to be improved, see Figure 20.

Figure 20: The coking plant wastewater treatment plant.

The factory produces 360 ton wastewater every day, which after the treatment is discharged into the Yangtze River. No fees are paid to the local Government and the manager was not able to tell how much money the treatment costs every month. The wastewater content is represented in Table 10.

Table 10: Inflow and outflow data from the coking plant wastewater treatment plant.

Parameter	Inflow (mg/l)	Outflow (mg/l)	Cleaning rate (%)	Total discharge, average value of 3 days (mg/l)	Chinese standards (mg/l)	Amount (kg/day)
pH	9.46-9.61	8.50-9.08	---------	7.75-8.05	6-9	----------
SS	431	76.4	82.3	33	200	----------
COD	6559	273.1	95.8	128	200	123
BOD_5	2641	257.4	76.3	36.2	60	----------
S^{2-}	431	94	78.2	0.04	1.0	----------
NH_3-N	3.91	1.02	73.9	1.64	25	1.57
CN^-	0.69	0.08	88.4	0,007	0.5	----------
Ar-OH	690	42.0	93.9	1.22	0.5	---------

4.2.3 The East Lake hi-tech development zone

The East Lake hi-tech and development zone started up in the 90s and is situated in the Wuchang district by the East Lake, see Figure 21. The development zone consists of an area of 120 km^2 and has a population of 400,000 people (Planning to extend the area to 224 km^2). The zone itself is divided into smaller districts; Guanor, Guandong, Dongyi, Donger, Fuzulin (Sun Xujun, personal communication, 2006).

The main industries in the zone are laser, optics, medicine, manufacturing, electricity, IT and pesticides industry. All together there are 175 companies in the zone. Many universities and institutions in this area are engaged in teaching of and research in optoelectronics and information technology. They are cooperating with the optoelectronics and information technology companies both in Wuhan and abroad (Wuhan East lake high-Tec development zone, 2006).

Figure 21: Map of the development zone.

The Wuchang EPB has online monitoring of the wastewater content from 16 of the companies in the zone. They also have one online air-quality monitoring station. The air has high SO_2, NO_2 and Pm_{10} levels. This area has two wastewater treatment plants; Tang Xing Hu wastewater treatment plant and South Lake wastewater treatment plant. The Tang Xing plant has a capacity of 50,000 tons/day and the South Lake plant a capacity of 100,000 tons/day. The wastewater is discharged in Tang Xing Lake and South Lake, respectively, after treatment. Next year an underground pipeline to the Yangtze River is going to be constructed to allow cleaned wastewater to be discharged into the river. Two new wastewater treatment plants are planned in this area.

The solid waste in this area is deposited in landfills except for the hazardous waste, which is burned in a special incineration plant for hazardous waste situated in the north of the area. There are plans of building an incineration plant in the south of the development zone.

All the companies in this area can meet the environmental standards but they don't put any effort in improving their environment further. It is in most cases a question of money. When the companies in this area have cleaned their wastewater, if they have reached the standards for discharge to the wastewater treatments plants, they are allowed to discharge the wastewater to one of the two wastewater treatment plants for further cleaning. The companies in this area use Chinese technologies for cleaning their wastewater (Sun Xujun, personal communication, 2006).

4.2.3.1 Wuchang coal power plant

The Wuchang coal power plant started up in year 2000. They are using 800 tons of coal every day in two burners to produce electricity. 94,000 KWh is produced every day and 178 tons of vapour is produced per day.

A lot of water from the river is used in the process which must be cleaned before it enters production. It is cleaned by some kind of chemical[8]. The dust from the power plant is cleaned by Electric Dust Precipitation; the efficiency is about 99.2-99.6%. The dust is then used as construction material.

The wastewater is cleaned by neutralization, by sedimentation and by adding chloride. This is enough since the wastewater after cleaning enters the municipal wastewater plant. 500-600 m^3 of wastewater is produced every day. The cost of wastewater treatment is about 50,000 Yuan/year. A lot of water is used for cooling. This water is recycled and cleaned two times a year from a special product[9]. They don't have any COD problem. The COD level is 30-60 mg/l and the standard is 100 mg/l, see Table 11.

Table 11: Data of the wastewater from the Wuchang power plant.

Parameter	Inflow (mg/l)	Outflow (mg/l)	Chinese standards* (mg/l)	Discharge to wastewater treatment plant** (mg/l)
CODcr	90.5	59.8	100	500
BOD_5	26.7	18.7	20	300
SS	30	23	70	400
NH_3-H	10.2	8.9	15	25
TN				
TP			0.5	1.0
pH	9-10	7.8	6-9	6-9

* National standard for most of the industries in China.
** The standards for entering the wastewater treatment plants are the same for all industries.

[8] The Chinese word for this chemical couldn't be translated.
[9] The company that supplies this product keeps the content secret.

The power plant can meet the standards and has no major problem with the environment. Next year[10] the standard of SO_2 is going to decrease from 2,100 mg/Nm^3 to 400 mg/Nm^3. The power plant must then install some kind of desulphurization technology since today it's enough to only add $CaCO_3$. The two concerns of this company are to improve the efficiency and to decrease their SO_2 emissions.

4.2.3.2 Wuhan Kernel Bio-Pesticide Co., LTD.

Kernel produces bio-pesticides such as Bacillus thuringensis (B.t.) and Jianggangmycin. Traditionally chemicals are used as pesticides, but chemicals have many negative sides such as leaving residues in environment, resistance and resurgence of insects. Bio-pesticides are low in toxicity and have high environment compatibility. No chemicals are used in the production. The B.t., which is the most applied bio-pesticide works like this: It is a naturally occurring soil bacterium, which destroys the insects from inside; it corrodes their intestine wall cell organ, destroys intestine membrane, and enters the lymphoid tissue of blood. Finally, the pests die of hunger or appear septicaemia (Wuhan Kernel Bio-Pesticide Co., Ltd, 2002). No dangerous chemicals are used in the production process, see Figure 22 and 23. The products are mainly produced by fermentation.[11]

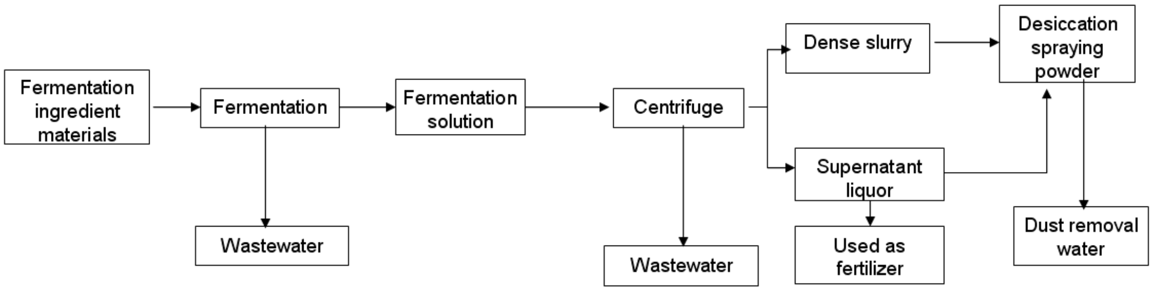

Figure 22: Process schedule Kernel product B.t. (Bacillus thuringensis).

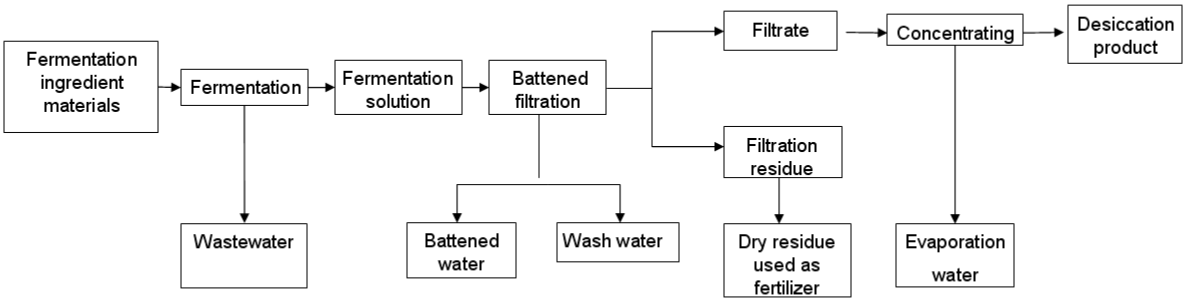

Figure 23: Process schedule Kernel product.

The discharged amount of wastewater from the Kernel wastewater plant is 623,47m^3/day and the wastewater data is represented in Table 12. Kernel uses a Chinese technology from the company Jinan Shifang for cleaning their wastewater, which includes automatic monitoring.

[10] 2007

[11] Fermentation in the industry is a process of breaking down organic substances into simpler substances.

The methods used since three years are UASB[12] reactor, aeration and filter, see Figure 24. Seven tons of water is used for every ton of product and around 80% of the water is recycled. The wastewater plant discharges the wastewater after cleaning to the Tang Xu lake treatment plant. The sludge, 500-600 tons, per year is used as fish food.

Table 12: Data of the wastewater of the Kernel wastewater plant.

Parameter	Inflow (mg/l)	Outflow (mg/l)	Chinese standards* (mg/l)	Discharge to wastewater treatment plant** (mg/l)
CODcr	3043	69	100	500
BOD_5	973	20	20	300
SS	154	21	70	400
NH_3-H	26	1.6	15	25
TN				
TP	14	0.6	0.5	1.0
pH	4	8.6	6-9	6-9

* National standard for most of the industries in China.
** The standards for entering the wastewater treatment plants are the same for all industries.

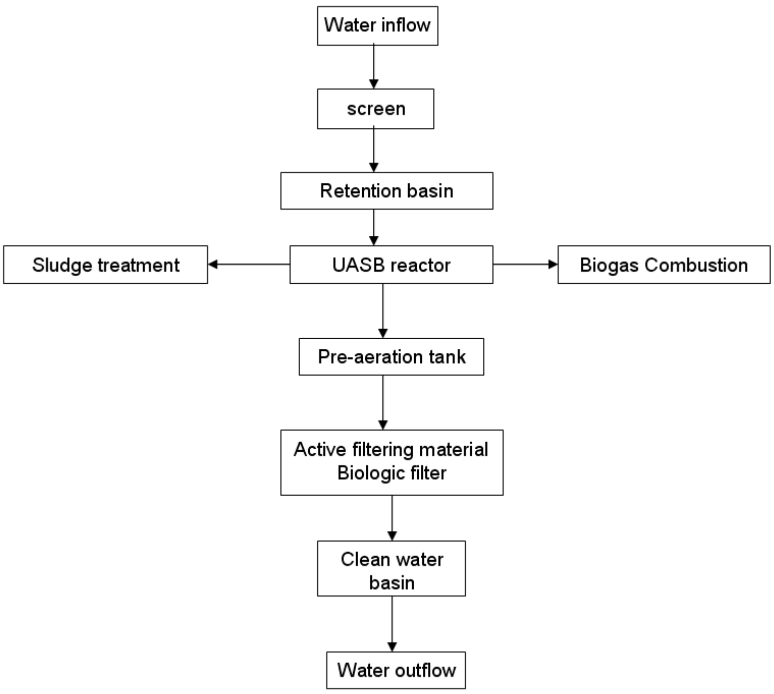

Figure 24: Wastewater treatment of Kernel Bio-Pesticide.

4.2.3.3 Green World

The Green World Company is a high-technology company founded in 1997 by Xiao Hai Su. Its total asset is 550 million Yuan. Green World has 1,100 employee and 50% of them are educated in universities or in colleges. The main scope of Green World is research,

[12] UASB= upflow anaerobic sludge bed.

production and marketing of degradable or disposable products for daily-use, food-packing and new environmental protection material (Green World Company, 2007).

The motto of the company is “Growing environmental protection trees and creating a green world together” (Green World, 2006). The factory has received the ISO 14001 and ISO 9001 certificates. They produce paper plates, paper bowls, napkins, packing material, new plant starch loose fill pack, environmental protection starch, papers; 500 different types.

The wastewater is mainly the water that comes from a “washing part” in the production; no process schedule could be received. The wastewater is treated by sedimentation and biological treatment, the technology comes from a Chinese company, see Figure 25. The wastewater content is shown in Table 13. The wastewater is discharged to one of the municipal wastewater plants in the area.

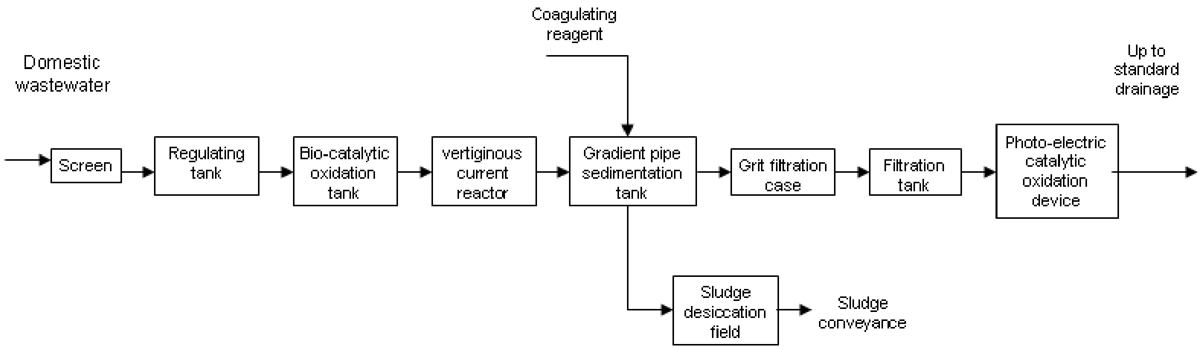

Figure 25: Green World washing wastewater treatment plant.

Table 13*:* The wastewater data of the Green world washing wastewater

Parameter	Average scope (mg/l)	Chinese standards* (mg/l)	Discharge to wastewater treatment plant** (mg/l)
pH	9.63-9.74	100	500
SS	39.6	20	300
COD	238	70	400
BOD_5	80.9	15	25
NH_3-H	1.54		
TP	1.63	0.5	1.0
Grease	12.3	6-9	6-9
LAS*			

* National standard for most of the industries in China.
** The standards for entering the wastewater treatment plants are the same for all industries.
*****Surface active detergent

4.2.4 Wuhan Slaughterhouse (Wǔhàn Ròu Lián Yǒuxiàn Gōngsī 武汉肉联有限公司)

Wuhan has four slaughterhouses, The Wuhan Rou Lian Youxian slaughterhouse being the oldest; built in 1958. 1,200 pigs are slaughtered per day, but the factories capacity is 3,000 pigs per day. The slaughter starts at 23.00 every night and stops at 06.00 so that the meat arrives fresh to the shops.

Bare screen → Sedimentation → Anaerobic → Aerobic → Desinfection → Discharge

Figure 26: Profile of the SBR wastewater treatment.

The wastewater treatment plant was built according to a Russian technology, SBR,[13] see Figure 26 and 27. The wastewater is added to a batch reactor, which when full behaves like a conventional activated sludge system without continuous inflow or effluent flow. Equalisation, aeration and denitrification occur in the same tank; see Appendix 5 for more information about this technology.

Figure 27: One of the two SBR tanks.

In 1996 some improvements where implemented when the SBR technology was improved by a Chinese company. 600 tons of wastewater is produced per day. The last step is to add chloride before the treated water is discharged into the Zhou Jie River, which is a branch of the Yangtze River. See Tables 14 and 15 for information on the wastewater content. The treatment plant is five years old and before the installation sedimentation and addition of chloride was the only method for cleaning the wastewater. No water is recycled but there is a plan for recycling the water used in the slaughter. No changes of their wastewater treatment plants are planned. The cost for the wastewater plant is 10,000 Yuan/year, including power, waste etc.

Table 14: Bio-chemical disposal, outlet of wastewater.*

Parameter	Total discharge per day (mg/l)	Discharge volume (kg/d)	Chinese standards (mg/l)	Exceed standard ratio (%)
SS	48	19.2	100	/
COD_{cr}	50.1	20.1	60	20
Grease	5.90	2.36	30	/

*Water samples are collected five times a day for the analyses.

[13] Sequence Batch Reactor

Table 15: Monitoring program

Parameter	SS	COD_{cr}	Grease	Discharge volume (m^3/t)
Total discharge volume (kg/d)	19.2	20.1	2.36	
Kg pollution produced per ton animal (kg/ton)	0.214	0.224	0.026	4.45
Chinese standard (kg/ton)	0.8	0.8	0.13	6.5

5. IDENTIFICATION OF PROBLEMS AND POSSIBLE SOLUTIONS

In this chapter there follows an identification of the problems found at the visited companies and wastewater treatment plants. Then there follows a report of different technologies and methods used in Sweden for dealing with the same types of problems. These solutions are examples of how the problems found in Wuhan could be solved.

5.1 IDENTIFICATION OF PROBLEMS AT THE SELECTED COMPANIES AND MUNICIPAL WASTEWATER TREATMENT PLANTS IN WUHAN

The biggest problem when it comes to wastewater treatment in Wuhan is that 30% of the municipal wastewater still is discharged directly into rivers and lakes. Most of the industrial wastewater is treated today and the amount of industrial wastewater is decreasing. On the other hand the amount of municipal wastewater is increasing. The amount of municipal wastewater was 134 million of tons more than the amount of industrial wastewater in 2005. The municipal wastewater discharge will continue to increase since more and more people will move into the cities. Many suburban areas are not connected to the urban pipeline and in these areas some solutions for dealing with the wastewater are urgently needed. The economical problem is big; the suburban districts are very poor and cannot afford investments.

5.1.1 Wastewater treatment plants

The biggest problem at the municipal wastewater treatment plants is the illegal discharge of wastewater, the large amount of produced sludge, and that many regions still lacks wastewater treatment plants.

The technology used in the two visited wastewater treatment plants is advanced and seems to work well. The Han Xi wastewater treatment plant has been operating for less than a year, and is only running on half the capacity so possible problems with the treatment might not yet have been detected. The same applies to the Zhuankou wastewater treatment plant. The main problem with the wastewater treatment in Wuhan is not the lack of good technologies; it’s a lack of a sustainable economical systems. The fee for industries and the municipal for discharging wastewater to the wastewater treatment plants are too low. This leads to lack of money to operate the plants and further to illegal discharge of wastewater, which is a very serious problem. Important to mention is that it is only the seven central regions of Wuhan that have wastewater treatment plants. In the six suburban regions, with the largest region

Huangpi, the wastewater is still discharged without cleaning, directly into rivers and lakes. This region is a less developed region and very poor. The EPB in Wuhan asks for “cheap” wastewater treatment solutions that could bee implemented in these areas. The sludge problem is also huge; 2,000 tons of sludge per day will be produced when all the wastewater treatment plants are taken into operation. Some of the visited companies also have problem to deal with the sludge from their wastewater treatment plants.

5.1.2 Paper mill

The visited paper mill already uses a foreign technology for their wastewater treatment, called Biolak. This plant doesn’t have any problems with the wastewater treatment. The only improvement of the treatment would be to increase the efficiency of the wastewater treatment plant from handling 50,000 ton/day to 65,000 ton/day. The biggest problem today at this paper mill is that 50 ton of sludge is produced daily, which is landfilled.

5.1.3 Coking plant

The coking plant wastewater cannot meet the standards for COD and BOD. The wastewater treatment plant faces problems with oxidisation part, which seems a bit unexpected. If air were blowing in a correct way inside the tank, oxidisation would occur everywhere in the tank. Probably this is a problem caused by bad equipment at the plant. The equipment is generally old and needs to be improved.

5.1.4 Coal power plant

The coal power plant does not have any problem with the wastewater treatment since the only treatment of the wastewater is neutralization. The power plant has instead a great need to find some technology for desulphurization of the gas. Today the gas is only cleaned by addition of $CaCO_3$ but the limits will be decreased from 2,100 mg/Nm^3 to 400 mg/Nm^3 in 2007. Since the main energy source in China still is coal, power plants all over China need to implement some changes that can deal with this problem.

5.1.5 Kernal and Green World Company

The companies Kernal and Green World have no problems with their wastewater treatment. Both companies use Chinese wastewater treatment technologies based on biological cleaning. Even though companies can follow the standards many improvements can still be executed but since there is no economical gain in doing that this is almost never done.

5.1.6 Slaughterhouse

The wastewater plant at the slaughterhouse uses the SBR-technology, which seems to work well. No water is recycled but some ideas about recycling the wash water from the slaughter exist. Improvements that could be done are just recycling of water.

5.2 POSSIBLE SOLUTIONS– EXAMPLES FROM SWEDEN

5.2.1 The sludge problem

The general best solution to the sludge problem would be to spread the sludge directly on the arable land so the phosphor, which is a scarce resource, could be recycled back to the crop (Petterson, 2004). The organisations LRF[14] and ARLA[15] in Sweden have stopped the spreading of sludge on the arable land since the concentration of heavy metals, pathogens and

[14] LRF=Lantbrukarnas riksförbud or Federation of Swedish Farmers.
[15] Arla or Arla Foods is a cooperative organisation that is owned by 10,557 milk farmers in Sweden and Denmark (ArlaFoods, 2007).

bio-accumulating organisms in the sludge is too high. In Sweden only around 10% of authorised sludge is spread on the arable land. Most of the sludge is used as soil conditioner improvement and covering (SVA, 2007). According to Mats Ek (personal communication, 2006) at the Swedish Environmental Research Institute, IVL the best way to deal with sludge is to use it to produce biogas by digestion. If the biogas unit is big enough the biogas can be upgraded to fuel for vehicles. By the digestion of 50 degrees some sanitation will also take place of the sludge. A digestion rest is received in the digestion which can be used as fertiliser if the sanitation level is good and if not it must be taken care of in some other way like incineration (SVA, 2007). The biogas produced can also be used to cover the wastewater plants heat and energy consumption (Levlin et al., 2001). If digestion chambers are built at the wastewater plants, transportation costs and landfill costs will be saved. It costs about 600 kr/ton to incinerate and landfill the sludge and only 220 kr/ton to use it as fertiliser in the agriculture or as facility earth in Sweden (Svenskt vatten, 2007). Some companies that have different solutions for dealing with sludge are presented below.

5.2.1.1 Scandinavian Biogas

Scandinavian Biogas has its headquarters in Uppsala, Sweden. The company provides solutions for making biogas of organic matter such as sludge from sewage plants, slaughterhouse waste and crop or manure.

For sewage sludge or slaughterhouse waste, the organic matter is hygenised for one hour at a temperature of 70˚C. Then it is mixed in different concentrations in a process, which is called homogenization. The mixture is then continuously fed into a digestor. The Scandinavian biogas provides different types of digestors depending on the organic matter. For digestion of wastewater the ScandGas 600 can be used.

The produced sludge, the digestion rest, can be used as a high-quality bio fertilizer or fuel pellet. Scandinavian Biogas also offers the possibility to upgrade the produced biogas to high-energy rich gas, for example vehicle fuel standard (Scandinavian Biogas, 2006).

5.2.1.2 Ragnsells Agro

Ragnsells is the largest environment and recycling company in Sweden. In co-operation with local governments, provision industry and agriculture authorised sludge is spread on the farmland or used for making soil. Sludge from the wastewater plants is first stored some months for sanitation before it is spread on the fields. The sludge replaces artificial fertilizers (Svanström, et al., 2004).

5.2.1.3 Econova Company

The idée of the Econova Company is to take care of the bi- and rest products from municipalities and industries in a closed cycle and in an environmental friendly way. Econova has, based on natural processes in the material and eliminating pathogenic bacteria, developed their own sanitation method for the sludge. The method is very cost-effective since no heat or chemicals are needed (Econova, 2007). An example is the sludge from Käppala wastewater plant in Stockholm which is used to produce topsoil to golf-courses: The sludge is first mixed with bark, ash and forest industry coal material from the pulp industry. The mixture is oxygenated and the sanitation biological process begins. When micro-organisms decompose the organic material, heat is developed and the bacteria such as Salmonella, which is not adapted to this heat, dies and the sludge gets sanitized. A layer of forest industrialized coal material to isolate and decrease the smell problem covers the mixture. It’s stored during 9 months for decomposing and the mixture is oxygenated once every month (Svanström et al., 2004). The continuous decomposing stabilizes the mixture and the risk of re-infection is minimized. Gradually the temperature decreases and the compost mature. The mature compost is mixed and prepared for the requested end product (Econova, 2007). Other end products are soil conditioners used in parks and green areas, landfill and noise-walls cover. The process can be modified depending on the end product; sometimes sanitation is not needed (Svanström et al., 2004).

5.2.1.4 Chematur Engineering and Feralco

Aqua reci is a new technology developed by the two companies Chematur Engineering and Feralco and is built on oxidisation in supercritical water (SCWO). Chematur Engineering is a group of chemical engineering companies in Sweden, USA, Finland, and India. Feralco is a leading supplier of high performance chemicals for water treatment and the pulp and paper industry (Chematur, 2006). The process can be applied to both drinking water sludge and wastewater sludge. The water obtains supercritical characteristics by a temperature of 374 ^{o}C and a pressure of 221 bar. In the Aqua reci process the sludge is pressurised to 250 bar and heated to around 400 ^{o}C before it is pumped into the reactor where oxygen is added, see Figure 28. The addition of oxygen leads to a complete oxidisation of the organic material and the reaction heat increases the temperature to 550 ^{o}C- 600 ^{o}C. Energy can be extracted from the increase of temperature, which can be used as heat. What is left after the process is just an in-organic rest, which mainly contains silicates. Phosphor and coagulants can easily be extracted from this rest and it can then be used as filling material. An advantage with this technology is a huge volume reduction, less then 10% of the original volume of sludge is left after the process. Another advantage is that the organic pollutants in the sludge can be completely eliminated. No external energy source is needed since the heat from the oxidisation step can be recovered to produce hot water or steam for different heating purposes in the process (Svanström et al., 2004).

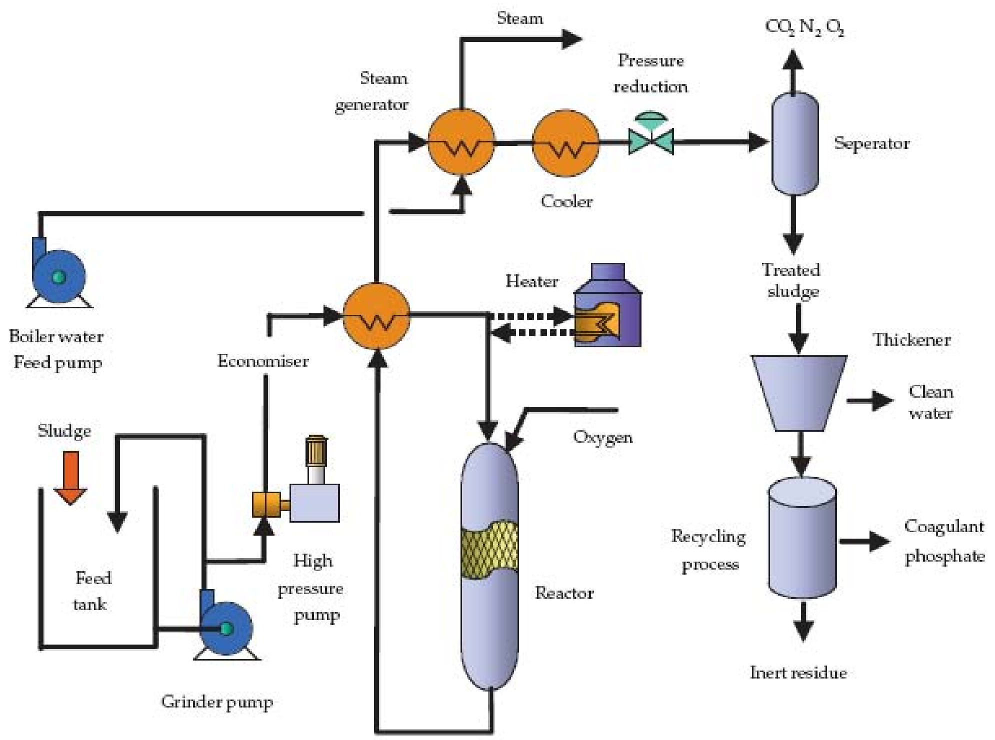

Figure 28: The Aqua reci process (Svanström, et al, 2004).

5.2.2 The coking plant wastewater problem

According to Mats Ek (personal communication, 2007) a normal problem with the water from the coking plant is the content of cyanides and phenols. The cyanide is poisonous for the bacteria so it is important that by the start-up of the wastewater treatment plant, the cyanide level must be held on a low level. After a while the bacteria has grown large enough to oxidise the cyanide and break down the phenols. The load on the wastewater plant may gradually be increased. If the system starts too quick or experience a loading shock, the bacteria will dye from cyanide poisoning (Ek, 2007). This is probably what has happened at the Wuhan coking plant and the reason why the COD and BOD levels are too high. Starting up the wastewater plant gradually and allowing the bacteria to grow can solve the problem. The problem with oxidisation is solved by checking the equipment. Something must be wrong with the inblow of the air because if air is blowing inside the tank from the bottom, oxidisation will take part also there.

To deal with wastewater from the coking plant can be difficult, and problems often occur, also in Sweden. There are two coking plants in Sweden, one in Oxelösund and one in Luleå. Anki Lidar at the coking plant in Oxelösund reports that they sometimes get too high levels of suspended matter. If the suspended matter concentration is high the COD will follow and high COD concentrations in the outflow of the treatment plant will occur. This is caused by overcharge in the biological cleaning when to much water comes in at the same time and the bacteria are flushed away. Even the wastewater treatment plant in Luleå faces some problems (Anki Lidar, personal communication, 2007).

5.2.3 The power plant SO_2 problem

In Sweden there are many companies that have solutions for the flue gas cleaning of the SO_2 in the incineration plants of waste. However, the flows in the coal power plants are 10 times larger then the flows in an incineration plant for waste, so these companies are too small to deal with the coal power plants flue gas cleaning problem (Sven Andersson, personal communication, 2007). According to Bo Andersson (personal communication, 2007) at the company Polyproject it is not a problem in practice to construct these bigger systems to coal power plants in China, but the investment is too big. It costs about 2 billions Yuan to deliver a system to a coal power plant with an effect of 2000 MW. The Danish company BVE has the capacity to deliver systems in this size.

In Wuhan several incineration plants for waste are planned for and according to Li Zhan (personal communication, 2007) at the Wuhan EPB they have so far not solved the problem of how to clean the SO_2 and the dioxins from the gas. The need for construction of incineration plants in China will probably increase in coming years; right now almost no incineration plants exist. Incineration is a very good way to deal with the increasing amount of waste. An advantage of incineration is that energy can be recovered from the heat. A company that supplies this type of technology in Sweden is Götaverket Miljö AB in Göteborg. They have, e.g., supplied the flue gas cleaning and energy recovery system to the incineration plant in Umeå in the North of Sweden, which works as follows: The flue gas is cleaned by a fabric filter, by an acid scrubber, and by a SO_2-scrubber and a condenser. Water is recovered from the gas, which can be reused in the process, so the system is self sufficient in regards to water (Götaverket Miljö AB, 2007). In the SO_2 scrub the gas is washed with some type of alkali, which is dissolved in the water, as lye and slaked lime. The SO_2 will then react with the hydroxide ion and form calciumsulphite, which by the addition of oxygen continues to oxidise to form calciumsulphate (gypsum), which then can be removed (Jörgen

Carlsson, personal communication, 2007). The Götaverket Miljö AB also has solutions for cleaning the dioxins from the gas.

It could be the same problem to deliver flue gas cleaning to incineration plants as with the coal power plants, that the investment is too big. In most of the cases the local governments wants a company not only to construct the incineration plant but also to run it for at least five years before they buy it. It demands a big investment for this and is mostly done by big multinational companies with a lot of money.

5.2.4 The paper mill

The visited paper mill had problems with sludge management. The environment director, Maria Edling-Hanson (personal communication, 2007) at the paper mill Kvarnsveden outside Borlänge explains that they mix the sludge with ashemanating from the steam production of the plant. The mix is then used as covering material for landfills and has also been used as covering material on old mine tailings in Falun. The covering material is very impermeable. This is a method that could be used to deal with the sludge at the paper mill in Wuhan.

5.2.5 Slaughterhouse

The wastewater treatment in the slaughterhouse can be improved by a floatation step before the biological step, in this case before the SQB. In the floatation step rests of grease and other particles are removed, so the SS is decreased and thereby also the COD. Digestion of the slaughterhouse rests would be a good way to deal with the rest of the slaughter instead of depositing it in landfills, but it is an expensive investment. The water used for cleaning after the slaughter could be recycled to save water.

6. DISCUSSION AND CONCLUSIONS

A survey of trade and industry has been done, indicating that the main four industry sectors in Wuhan are automobile, iron & steel, machinery, optic electronics, and hi-tech industries. The food and textile industry is also big. The information gathered was obtained during an eight-week visit to Wuhan, visiting six companies.

Wuhan is facing many environmental problems; the most serious one being the pollution of all the lakes and rivers. The lakes supply the city with water and are also a very important cultural and social resource for the city. Almost every lake is eutrophicated and as many as 54 lakes have too high levels of COD, BOD, NH_3-N, TP or TN. Many different types of organic pollutants are also found in the lakes. The 13 rivers of Wuhan are also polluted, both from upper reaches and from the city of Wuhan.

The air quality in Wuhan is very bad; the TSP, NO_2, and SO_2 levels are high. The main causes for the bad air quality are the increasing amount of cars in the city and the fact that the burning of fossil fuels still is the main energy source. The air quality is checked by nine different monitoring stations, placed at different locations in the city.

The municipal solid waste is deposited in landfills and it exist no formal recycling system. The six suburban districts lack so far waste collection systems. Wuhan has one incineration plant for hazardous waste from hospitals and four incineration plants for municipal waste are in planning for construction. Only the ash from the coal power plants is recycled, but this accounts for 80% of the industrial waste.

The main drinking water resource in Wuhan is the surface water from the Yangtze and Han Rivers. The drinking water quality in the suburban regions is very poor. Surface waters are in most regions polluted by the surrounded farmland, from garbage heaps and discharge of wastewater.

The most important environmental authorities in Wuhan are the Environment Protection Bureau, EPB, and their subordinate Environmental Protection of Science Research Institute (EPSRI). The EPB tells the EPSRI to make investigations and write reports. The EPSRI is divided into many different departments. One of the most important is the Environmental Assessment Impact Department. It produces EIAs for new economical zones, new companies and tries to force old companies in Wuhan to comply with the new standards, which is often a problem for them. According to the director Qi Gongyi the main problem of doing an EIAs is to judge how to fit the planning of economical zones with national regulations.

The different environmental authorities do not seem to be aware of what the other departments do; for example, industrial waste is monitored by the EPSRI but it had very little information about the municipal waste, which is monitored by another department; the Wuhan Environment Sanitation Bureau.

It is difficult to make a comparison between Swedish and Chinese industrial wastewater discharge standards since necessary information about the Chinese wastewater standards was lacking. One difference is that the standards for each type of industry are the same all over China unlike in Sweden where they are defined separately for every industry. In Sweden most municipal wastewater plants only have two or three standards to follow in comparison with China where municipal wastewater treatment plants have around 60 standards to follow. This might depend on that many heavy industries discharge their wastewater to municipal wastewater plants, while in Sweden heavy industries must construct their own wastewater treatment plants.

A more economical sustainable system is needed for the wastewater treatment plants. It must cost more to discharge the wastewater to the wastewater treatment plants so these plants receive enough funding to operate. This will stop the problem with illegal discharges from the wastewater treatment plants.

It was difficult to get information about which kind of industry that has problems to follow the wastewater discharge standards, even after interviews with the local EPB and the EPSRI. If there are companies that exceed the wastewater discharge standards the local government hesitates to hand out the information since it is not public. It was therefore not possible to receive a representative picture of which industrial sectors that needs improvement of the wastewater treatment. This is also the reason why I ended up visiting some companies that didn't face any wastewater treatment problems, entering also into other problems with the environment that the companies might have.

This report shows that further improvement of the industrial wastewater treatment is not the first priority in Wuhan. Wuhan's greatest challenge is to construct wastewater plants to the around 3.5 million people that still discharge directly to rivers and lakes. When it comes to the industrial wastewater discharge the next step may be to better control the companies and motivate them to improve their technologies further. For example it is possible for a region to have local standards that are stricter then the national standards. This could be used as a tool to put pressure on the companies to improve their environment further, which is mostly not done voluntarily. Economical means of control as higher fines for polluters might also be a feasible way to decrease the pollution from the industries. Workshops and education to rise the environment awareness at the companies and teach them about environmental management systems like ISO 14 000 and cleaner production is also very important.

Swedish technology solutions and expertise is applicable for many of the problems found at the selected industries in Wuhan. The areas of interest are flue-gas cleaning, construction of incineration plants for waste and dealing with the wastewater treatment sludge. It should thereby be a great potential for an export of Swedish environmental technology to Wuhan. The problem for many Swedish companies might be that they often are too small and don't have the capacity for making business with China. A good solution both for Swedish and Chinese companies is to start joint-venture companies together; then both parts can gain. To create an environmental technology centre would be a good platform where Swedish and Chinese companies can meet, and expertise can be exchanged.

There are many different methods to deal with the sludge problem in Sweden that can be applied in Wuhan. The sludge quality in Wuhan is probably not so good since the water is much more polluted from the beginning than the water in Sweden. It is not recommended to put the sludge directly back on the farmland. To use it for making biogas is one solution. Other solutions are to use it as top soil or as a soil conditioner improvement. Expertise and technologies for this can be provided by many different Swedish companies.

There are many companies in Sweden that can provide solutions for cleaning the SO_2 in incineration plants for waste, but Swedish companies are too small to provide technologies for cleaning the SO_2 in coal power plants. However, incineration of waste may be the future solution for dealing with the solid waste in China. This is a big area for Swedish companies since four incineration plants are planned to be built in Wuhan and they need expertise in this area. So far in China, almost no incineration plants for waste are built at all.

The visited company Green World has a profile of an environmental friendly company. It is interesting to find this kind of environmental thinking in a Chinese company. A contributing factor for this might be that the founder of the company studied in Germany and got some western influences. I met in most companies a lack of basic understanding in environmental protection. Another important step to take in China is to make the population aware of the environmental problems. The government really has a huge responsibility to inform and teach the public about these questions. I believe and hope that more and more NGOs, dealing with these questions, will start up in the following years, engaging more and more Chinese people to start fighting for a better environment!

7. REFERENCES

Dorling Kindersleys Travel Guide, 2005. *China,* 1th ed., Dorlin Kindersley Ltd, London.

EPA, 1999. *Wastewater treatment fact sheet, Sequence batch reactor*.

2006. *Facts from the Environmental Research Institute*,translation and help given by Xiong Yu, [In Chinese].

Feng, W., Zhan, L., Nansheng, D., Jinbao, W., 2005. *Economic development and eco-environment protection in central China- the Case of Wuhan city.* Fresenius Environmental Bulletin, Volume 14, No.11, pp. 1077-1080.

Fritz, J., Palmer, M., 2004. *Process design parameters for Chinese municipal wastewater treatment plants*, Water Quality Research, No 39(2), pp.103–12.

Green World, 2006. *Company description: Green World. Wuhan fare east green world group co*, ltd [In Chinese].

Han, S.S., Wu, X., 2004. *City profile Wuhan*, Citites, Vol. 21, No. 4. 349-362.

Hutchings, G., 2000. *Modern China*, Penguin Books Ltd, Middlesex, England.

Levlin, E., Tideström, H., Kapilashrami S., Stark, K., Hultman B., 2001. *Slamkvalitetet och trender för slamhantering,* VA-forsknings rapport. [In Swedish, English title: Sludgequality and trends for sludge management].

Liou, C., Cambon, M., English, A., Hutch, T., Miller, K., Wong, B., 2000. *Lonlely Planet China*, 7th ed., Lonely Planet Publications, Australia.

Petterson, G., *Livscykelanalys av fyra slamhanteringstekniker*, 2004. Chalmers tekniska högskola, Göteborg [In Swedish. English title: Lifecycle analysis of four different sludgemanagement technologies].

Pyya, L., Mäkelä, M., Hakala, E., Kakko, K., Lapinlampi, T., Lisko, A., Yrjänheikki, E., Vähäkangas, K, 1997. *Ambient and biological monitoring of exposure to polycyclic aromatic hydrocarbons at a coking plant*, The Science of the Total Environment 199, pp.151-158.

SNFS 1994:7, *Statens naturvårdsverk författningssamling*, 1994 [In Swedish. English title: The Governmental environment protection bureaus constitution].

Songa, Z., Zheng, Z., Li, J., Suna, X., Hana, X., Wang, W., Xua, M., 2005. *Seasonal and annual performance of a full-scale constructed wetland system for sewage treatment in China,* School of Environmental and Municipal Engineering, Qingdao Technological University.

Svanström, M., Frölund, M., Johansson, K., Olsson, M., 2004. *Livscykelanalys av aktuella slamhanteringsmetoder för Stockholm Vatten*, Kemisk miljövetenskap Chalmers, Rapport nr 8 [In Swedish. English title: Lifecycle analysis of actual sludge management methods for Stockholm Water].

U.S. Department of Commerce, International Trade AdministrationWashington, D.C, 2005. *Water supply and water Wastewater treatment market in China*. Available at: www.ita.doc.gov.

Råd och regler Maj 2000. *Utsläpp av avloppsvatten från yrkesmässig verksamhet.* [In Swedish. English title: Discharge of wastewater from vocationally operations].

Wang M. J, 1997. *Land application of sewage sludge in China,* The Science of the Total Environment 197, pp. 149-160.

2000, *Wuhan Environmental Management Strategy Outline*, United Nations development programme.

Zhang W., Tay J.H., Qian Y., Gu X.S., 1997. *Coke Plant wastewater treatment by fixed biofilm system for cod and NH3-N removal*. China Water Resources Vol. 32, No. 2, pp. 519-527.

DIGITAL SOURCES

Arla foods, Jan 2007.
http://www.arlafoods.se/templates/PlainPage2.aspx?id=6520

Biolak, December 2006.
http://www.biolak.de/

Chematur, January 2006.
http://www.chematur.se/sok/download/Aqua%20Reci%20060615.pdf

Chinats.com, November 2006.
http://www.chinats.com/wuhan

Econova, January 2007.
http://www.econova.se/energy/page.php?c=8

Ecosan, Ecological sanitation research project by the Stockhom environment institute, 2006.
http://ecosanres.sei.se/pdf_files/Fact_sheets/Fact_Sheet_11ls.pdf

Götaverket Miljö AB, 2007-01-11.
http://www.gmab.se

Green World Company, January 2007.
http://www.china-greenworld.com/ind.asp

Inland areas now major polluter, 2006-09-28.
http://www.mwr.gov.cn/english1/20060928/79348.asp

MRW; The ministry of water resource of the Peoples republic of China, November 2006.
www.mwr.gov.cn

OECD, November 2006.
http://www.oecd.org/

Sanitet.nu, En tidning om hållbar sanitet utgiven av Stockholm Environment Institute, 2006.
http://ecosanres.sei.se/pdf_files/sanitetnu_nr1_2006.pdf

Scandinavian Biogas, 2007-02-08.
http://www.scandinavianbiogas.com

SVA, Statens veterinärmedicinska anstalt, January 2007.
http://www.sva.se/static/932.html

Svenskt Vatten, 2007-02-08.
http://www.svensktvatten.se/Templates/Article1.aspx?PageID=4f3e6673-185d-487f-a6c2-9c554fca7fee

Statens naturvårdsverks författningssamling, SNFS 1994:7.
http://www.naturvardsverket.se/dokument/lagar/foreskri/snfstext/nfs1992/SNFS1992_07.pdf

Standardization Administration of China, SAC, 2007-02-08.
http://www.sac.gov.cn/english/home.asp

US Environmental agency, 2006-11-28.
http://www.epa.gov/safewater/contaminants/index.html

VA-begrepp, 2007-02-08.
http://www.pfr.nu/pages/va_begrepp.htm

WEDZ, Wuhan economic and technology development zone, 2007-01-12.
www.wedz.com.cn

World Bank, *China Water Quality management Policy and Institutional Considerations*, Environment and Social Development Department, East Asia and Pacific Region. 2006-10-25.
http://www.worldbank.org/eapenvironment

Wuhan East lake high-tech development zone, 2007-02-08.
http://www.wehdz.gov.cn/en/en_yqjs/advantages.htm

Wuhan Environmental Report, 2005. 2005年武汉市环境状况公报 [In Chinese].
http://www.whepb.gov.cn/ ,

Wuhan Government page [In Chinese].
http://www.whec.gov.cn/index.asp

Wuhan Kernel Bio-Pesticide Co., Ltd, 2002, 2006-12-17.
http://www.kenuo.com.cn/english/

Xchange, 2007-03-05.
http://www.xchange.se/

Mats Ek, IVL, 2006.
Mats.ek@ivl.se

Klas Johnson, January 2007.
länsstyrelsen Falun.
Klas.Jonsson@w.lst.se

ORAL SOURCES

Bo Andersson, 2007-02-13.
Polypoject
Phone: 46 (0)11- 32 01 06
bo.andersson@polyproject.com

Sven Andersson, 2007-01-18.
Processengineer at Götaverket AB,

Solveig Barme, 2007-02-13.
Wastewater treatment plant in Borlänge

Maria Edling-Hanson, 2007-01-30.
Environment Director at Kvarnsvedens papper mill
Maria.edling-hansson@storaenso.com

Qi Gongyi, December 2006.
Director of Environmental Impact Assessment department

Jan Kastensson, 2007-02-07.
Mercatus engineering AB,
jan.kastensson@mercatus.se

Anki Lidar, 2007.
Oxelesund coking plant wastewater treatment plant

Lei Ming, 2006.
Wuhan Environmental Law Supervising Office

Gong Yuan, 2006.
Deputy-director
Wuhan Environmental Protection Academy of Sciences
Fazhandadao164, floor 8,Wuhan city, Hubei Perfecture, P.R.China
Postcode:430023
Phone: +86-027-65692329
Mail: ygonglpa@126.com

Li Zhan, 2006.
Environmental Protection Bureau
liz@wh.gov.cn

Sun Xujun, Wuchang EPB, 2006.
xu_jun@hotmail.com

Xiong Yu, 2006.
Environmental Research Institute
xyphobe@gmail.com

Mr. Olsson vice director of Swedish Environmental Protection agency, 2006-11-07.

APPENDIX 1 INTERVIEW QUESTIONS

1. QUESTIONS TO EPB AND EPRI IN WUHAN

1. How does the sewage treatment system look like in Wuhan today? Who are the major pollutants?
目前武汉污水处理的总体状况如何？污水中的主要污染物是什么？

2. How is your wastewater plants working? Could I visit one?
污水处理厂是怎样运行的？我可以去参观一个吗?

3. What do you do with the sludge from the wastewater plants?
污水处理厂的污泥是怎么处置的？

4. What is the content of the sludge? Amount of water, heavy metals etc?
污泥的主要成分是什么？如水、重金属的含量等。

5. Are there any discharge data available from industries in Wuhan?
你们有工业污染物排放量的数据吗？

7. How much water uses the industry yearly in Wuhan?
武汉每年的工业用水量大概是多少？

8. Which are the regulations for discharges into the water?
对于污水排放有哪些相应的政策？

9. What is the greatest environmental problem that Wuhan is facing today?
目前武汉面临的最突出环境问题是什么？

2. QUESTIONS TO INDUSTRIES IN WUHAN

1. Describe in a simplified way your production and its flows in a process schedule.
请简要介绍一下你们的生产工艺流程。

2. Specify possible sub flow size (m^3/s) and their composition.

3. What is the total discharge of wastewater?
废水排放总量是多少？

4. What composition has the wastewater discharged from the company? Specify the content of the different substances in the wastewater, e.g. salts, metals etc.
贵公司排放的废水中主要有哪些成分？盐类、重金属等各种物质的具体含量
是多少？

5. What is the amount of COD in the ingoing water (kg/m^3) or (mg/l)?
进水的COD 含量是多少？

6. What is the amount of COD in the outgoing water (kg/m3)?
出水的COD 含量是多少？

7. Which quantities COD is discharged yearly (kg/m^3 year)?
每年排放的COD 总量是多少？

8. What is the yearly use of water per kg/l product?
单位产量的耗水量是多少？

2.1 WASTEWATER TREATMENT TECHNOLOGIES AT THE INDUSTRIES

1. What kind of technology is used to treat the wastewater today? During how long time has this technology been used?
目前采用哪种污水处理工艺？这一工艺已经使用多久了？

2. Are there any short term or long term plans about changing the production, for example reuse of more water and chemicals.
你们是否有改变生产工艺的长期或短期计划？比如能够使水和化学品得到循环利用的工艺。

3. Do you intend to change your wastewater treatment? Which demands do you have?
你们打算改变目前的污水处理设施吗？这方面有什么需求？

4. What is the yearly cost of your wastewater treatment? / What do you pay or do you pay something to the governmental wastewater plant?
污水处理每年的成本是多少？你们如何支付？你们向政府的污水处理厂付费吗？

5. Do you think it exist good technology solutions for improving your wastewater treatment in China?
您认为中国可以通过技术手段提高污水处理能力吗？

6. Could you consider consulting a foreign company for help with improving your wastewater treatment or for the improvement of any other environmental technology solutions in your company?
您是否考虑过咨询外国公司以帮助你们提高污水处理能力或其它环保技术？

APPENDIX 2 MAPS OF WUHAN

Figure 1: Air-monitoring stations in the central of Wuhan

吴家山： wujiashan
汉口花桥：hankouhuaqiao
汉口江滩：hankoujiangtan
汉阳月湖：hanyangyuehu
武汉神龙：wuhanshenlong
武昌紫阳：wuhanziyang
东湖梨园：donghuliyuan
青山厂前：qingshanchangqian
武汉高新：wuhangaoxin

Figure 2: Wastewater treatment plants in the central parts of Wuhan.

APPENDIX 3 WASTEWATER TECHNOLOGIES

1. WASTEWATER TECHNOLOGIES

1.1 BIOLAK

It works like this, Figure 1:

Stage I
Speed-controlled combined fine screening for separation and thickening of fine and coarse solids and sand with full odour control.

Stage II
Biological P-Zone.

Stage III
Activated sludge stage with sludge stabilization, advanced treatment and simultaneous nitrification/denitrification and biological hygienisation.

Stage IV
Post-aeration and polishing: "the savety stage".

Stage V
Bio filter: root layer and sand filter for very fine separation.

Stage VI
Advanced hygienisation for our environment and recycling.

Stage VII
Total treatment for industrial water and drinking water quality.

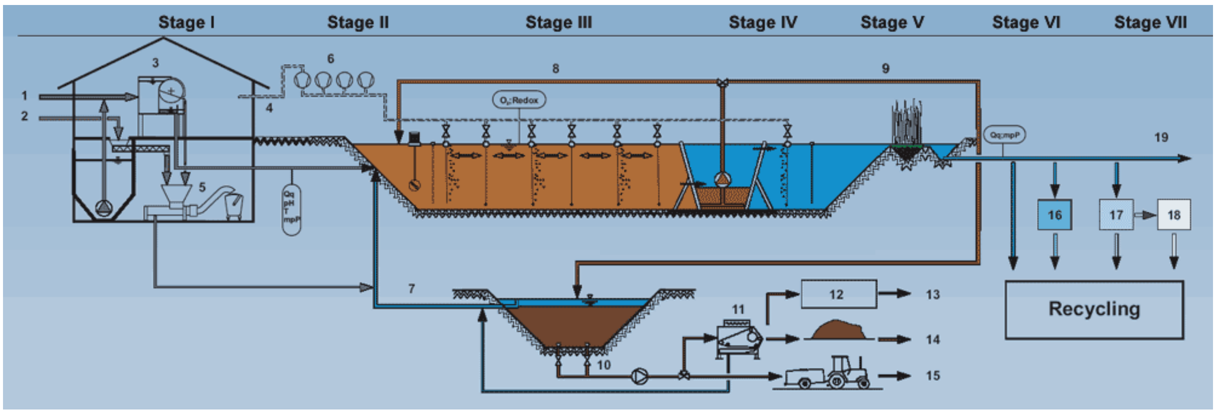

Figure 1: BIOLAK system (www.biolak.de).

1 Inlet
2 Faecal sludge
3 Fine screen
4 Odourless
5 Hydraulic screening press
6 Blower station
7 Supernatant
8 Return sludge
9 Excess sludge
10 Autom. sludge discharge
11 Sludge press
12 Drying
13 Sludge 85% DS
14 Sludge 20-25% DS
15 Sludge 4% DS
16 UV-treatment
17 Ultrafiltration
18 Reverse osmosis
19 Outlet

1.2 SBR, SEQUENCED BATCH REACTOR

The Sequence batch reactor wastewater technology is a fill- and draw activated sludge process. Wastewater is added to a single batch reactor and equalisation, aeration and denitrification all occur in the same tank using a time controlling sequence. The SBR technology is a quite old technology. It was taken into use already in 1914-1920. Along the years improvements have been made in aeration devices and controls, allowing this technology to compete with the conventional activated sludge systems. SBR is applicable to low or intermittent flow conditions. A typical process flow schematic for a municipal wastewater treatment plant using SBR can be seen in Figure 2. The water first passes through a screen or a grid. It then enters a partially filled reactor, containing biomass. Then the water fills up the reactor and when it's full it behaves like a conventional activated sludge system without continuous inflow or effluent flow. The aeration and mixing is terminated once the biological reactions are complete. The biomass settles and the treated supernatant[16] is removed. After passing through the reactor the water pass through a filter and is disinfected. The sludge may be taken care of as in Figure 2, by thickening and digestion. There is no need for return activated sludge pumps and primary sludge pumps as in conventional activated sludge systems (Wastewater technology fact sheet, 1999).

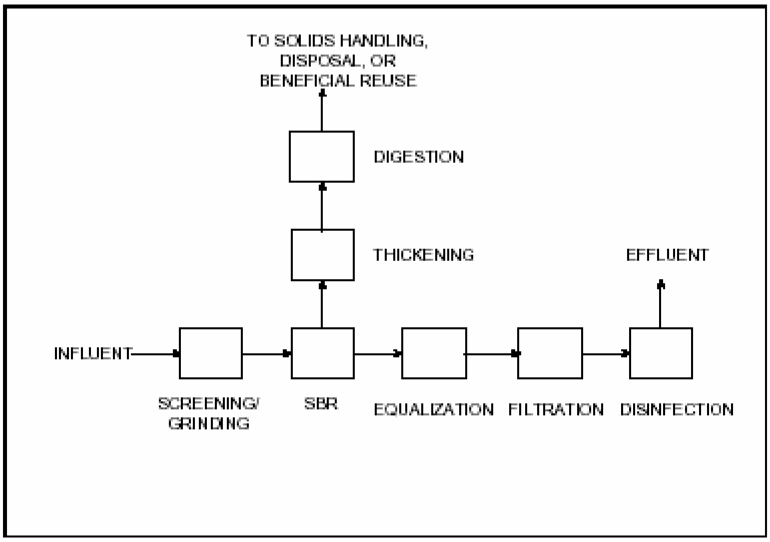

Figure 2: A typical process flow schematic for a municipal wastewater treatment plant using an SBR (Wastewater technology fact sheet, 1999).

Some advantages and disadvantages of the SBR-system are listed below (Wastewater technology fact sheet, 1999).

Advantages

- Equalization, primary clarification (in most cases), biological treatment, and secondary clarification can be achieved in a single reactor vessel.
- Operating flexibility and control.
- Minimal footprint.
- Potential capital cost savings by eliminating clarifiers and other equipment.

Disadvantages

- A higher level of sophistication is required (compared to conventional systems), especially for larger systems, of timing units and controls.

[16] Clear liquid above non-soluble solids (Wikpedia, 2006).

- Higher level of maintenance (compared to conventional systems) associated with more sophisticated controls, automated switches, and automated valves.
- Potential of discharging floating or settled sludge during the DRAW or decant phase with some SBR configurations.
-Potential plugging of aeration devices during selected operating cycles, depending on the aeration system used by the manufacturer.
-Potential requirement for equalization after the SBR, depending on the downstream processes.

2. REFERENCES

Biolak, 2006
http://www.biolak.de/

1999. *Wastewater technology fact sheet*, *Sequencing Batch Reactors*, United States environmental Protection Office.

APPENDIX 4 CHINESE STANDARDS

1. Chinese standards

1.1 Paper industry standards, GB 3544-2001

Table 1: GB 3544-2001. Discharge standard of water pollutants for paper industry (2002-01-01). Translated by Xiong Yu and Anna Hagberg

			Discharged volume	**BOD5**		**CODcr**		**SS**		**AOX**		**pH**
Unit			**m^3/t**	**kg/t**	**mg/l**	**kg/t**	**mg/l**	**kg/t**	**mg/l**	**kg/t**	**mg/l**	
	Wood pulp	**Natural colour**	150	10.5	70	52.5	350	15	100			6~9
		Bleached	220	15,4	70	88	400	22	100	2.64	2.64	6~9
	Other raw and processed material	**Natural colour**	100	10	100	40	400	10	100			6~9
		Bleached	300	30	100	135	450	30	100	2.7	2.7	6~9
			60	3.6	60	6	100	6	100	100		6~9

3 技术内容

3.1 排入 GB 3838 中Ⅲ类水域（水体保护区除外）、Ⅳ、Ⅴ类水域和 GB 3097 中二、三、四类海域的造纸工业废水，应根据生产工艺分别执行本标准规定的标准值。

3.2 排入设置二级污水处理厂城镇下水道的造纸工业废水，应达到地方规定的污水处理厂进水标准。

3.3 标准值

2001 年 1 月 1 日起，造纸工业的水污染物排放均执行表 1 规定的标准值。

表 1 造纸工业水污染物排放标准值

类别 \ 项目 单位			排水量[3]	生化需氧量 (BOD_5)		化学需氧量 (COD_{Cr})		悬浮物 (SS)		可吸附有机卤化物 (AOX)[4]		pH
			m^3/t	kg/t	mg/L	kg/t	mg/L	kg/t	mg/L	kg/t	mg/L	
制浆、制浆造纸[1]	木浆	本色	150	10.5	70	52.5	350	15	100			6～9
		漂白	220	15.4	70	88	400	22	100	2.64	12	6～9
	非木浆	本色	100	10	100	40	400	10	100			6～9
		漂白	300	30	100	135	450	30	100	2.7	9	6～9
造纸[2]	一般机制纸、纸板		60	3.6	60	6	100	6	100			6～9

注：1）制浆、制浆造纸：单纯制浆或浆纸产量平衡的生产。
2）造纸：单纯造纸或纸产量大于浆产量的造纸生产。
3）排水量为生产工艺参考指标。
4）AOX（可吸附有机卤化物）为参考指标。

Figure 1: The original GB 3544-2001.

1.2 Eutrophication standards

湖泊（水库）富营养化评价方法及分级技术规定

1、湖泊（水库）富营养化状况评价方法：综合营养状态指数法

综合营养状态指数计算公式为：

式中：—综合营养状态指数；

Wj—第 j 种参数的营养状态指数的相关权重。

TLI（j）—代表第 j 种参数的营养状态指数。

以 chla 作为基准参数，则第 j 种参数的归一化的相关权重计算公式为：

式中：r_{ij}—第 j 种参数与基准参数 chla 的相关系数；

m—评价参数的个数。

中国湖泊（水库）的 chla 与其它参数之间的相关关系 r_{ij} 及 r_{ij}^2 见下表。

中国湖泊（水库）部分参数与 chla 的相关关系 r_{ij} 及 r_{ij}^2 值*

参数	chla	TP	TN	SD	CODMn
r_{ij}	1	0.84	0.82	-0.83	0.83
r_{ij}^2	1	0.7056	0.6724	0.6889	0.6889

※：引自金相灿等著《中国湖泊环境》，表中 r_{ij} 来源于中国 26 个主要湖泊调查数据的计算结果。

营养状态指数计算公式为：

(1) TLI（chl）=10（2.5+1.086lnchl）

(2) TLI（TP）=10（9.436+1.624lnTP）

(3) TLI（TN）=10（5.453+1.694lnTN）

(4) TLI（SD）=10（5.118-1.94lnSD）

(5) TLI（COD_{Mn}）=10（0.109+2.661lnCOD）

式中：叶绿素 a chl 单位为 mg/m^3，透明度 SD 单位为 m；其它指标单位均为 mg/L。

2、湖泊（水库）富营养化状况评价指标：

叶绿素 a（chla）、总磷（TP）、总氮（TN）、透明度（SD）、高锰酸盐指数（COD_{Mn}）

3、湖泊（水库）营养状态分级：

采用 0～100 的一系列连续数字对湖泊（水库）营养状态进行分级：

TLI（∑）<30　贫营养（Oligotropher）

30≤TLI（∑）≤50　中营养（Mesotropher）

TLI（∑）>50　富营养（Eutropher）

50<TLI（∑）≤60　轻度富营养(light eutropher)

60<TLI（∑）≤70　中度富营养(Middle eutropher)

TLI（∑）>70　重度富营养(Hyper eutropher)

在同一营养状态下，指数值越高，其营养程度越重。

注：此规定由总站生态室负责解释

Figure 2: Eutrophication standards, received by Li Zhan at the EPB office.

1.3 Discharge standards of pollutants for municipal wastewater treatment plant, GB 18198-2002

This standard is translated by Xiong Yu at the Environment Research Institute.

Table 2: The highest allowed discharge concentration, mg/l.

	Parameter		Standard I***		Standard II	Standard III
			A	**B**		
1	**COD**		50	60	100	120*
2	**BOD_5**		10	20	30	60*
3	**SS**		10	20	30	50
4	**Grease**		1	3	5	20
5	**Petroleum**		1	3	5	15
6	*Not able to translate*		0.5	1	2	5
7	**TN**		15	20	-	-
8	**N-NH4****		5(8)	8(15)	25(30)	-
9	**TP**	**Built before 2005-12-31**	1	1.5	5	
		From 2006-01-01	0.5	1	5	
10	**dilute**		30	30	40	50
11	**pH**		6-9			
12	**Coliform**		10^3	10^4	10^4	-

***COD of inlet is >350mg/l. Removing rate is >60%. BOD >160mg/l, removing rate >50%**

****The number outside the brackets is when water temperature is over 12 ^oC, and inside bracket when temperature is below 12 ^oC.**

*****The Standrad I A and B, Standard II and Stanard III depends on different conditions as the recipient, but the exact conditions is not mentioned in the document.**

Table 3: The highest allowed discharge concentration, mg/l.

	Parameter	Standard
1	**total Hg**	0.001
2	**total CH4**	Can’t be measured
3	**total Cd**	0.01
4	**total Cr**	0.1
5	**+6 Cr**	0.05
6	**total Arsenic**	0.1
7	**total PB**	0.1

Table 4: The highest allowed discharge concentration, mg/l.

Number	Parameter	Standard	Number	Parameter	Standard
1	**total Ni**	0.050	**23**	**Trichloroethylene(CHCL =CCl2)**	0.3
2	**total Be**	0.002	**24**	**tetrachloroethylene**	0.1
3	**total Ag**	0.1	**25**	**benzene**	0.1
4	**total Cu**	0.5	**26**	**toluene**	0.1
5	**total Zn**	1.0	**27**	**p-xylene, 106-42-3**	0.4

6	**Total Mn**	2.0	**28**	**o-xylene, 95-47-6**	0.4
7	**Total Se**	0.1	**29**	**m-xylene, 108-38-3**	0.4
8	**Benzo(a)pyrene**	0.00003	**30**	*Not able to translate*	0.4
9	**Volatiled hydroxybenzene**	0.5	**31**	**chlorobenzene**	0.3
10	*Not able to translate*	0.5	**32**	**1.4-dichloro benzene**	0.4
11	**Sulfid**	1.0	**33**	*Not able to translate*	0.5
12	**Formaldehyde**	1.0	**34**	*Not able to translate*	0.5
13	*Not able to translate*	0.5	**35**	**phenol**	0.3
14	*Not able to translate*	2.0	**36**	*Not able to translate*	0.1
15	**Organic P pesticide**	0.5	**37**	**2,4-dichotomcus**	0.6
16	*Not able to translate*	1.0	**38**	**2,4,6-trichotomcus**	0.6
17	*Not able to translate*	0.5	**39**	*Not able to translate*	0.1
18	**Parathion**	0.05	**40**	*Not able to translate*	0.1
19	**Methyl parathion**	0.2	**41**	*Not able to translate*	2.0
20	**Sinituho**	0.5	**42**	*Not able to translate*	1.0
21	**Trichlormethane CHCL3**	0.3	**43**	*Not able to translate*	1.0
22	**Ccl4**	0.03			

APPENDIX 5 WATER RESOURCE INVESTIGATION

1. WATER RESOURCE INVESTIGATION IN THE HUANGPI DISTRICT

The Huangpi province is the largest of Wuhans 13 districts with an area of 2,261 km^2 and population of over one million people (Han et al., 2004). Since this district has been dependent on the agriculture and not yet developed any industries it is the poorest district in Wuhan. The main water resource for the largest city in the Huangpi district called Huangpi, is the Shè River (滠河). Dangerous industries are forbidden along this river but they discharge the municipal wastewater directly into the river (Gong Yuan, personal communication, 2006).

The investigation of the water resources in this area was conducted in cooperation with a group from the Wuhan Environmental Research Institute, with help from the local governments and the local EPB. In this area the Government is constructing many new high flat buildings for the peasants. The Government aims for the peasant to live in a more concentrated area so it will be easier to provide them with clean water and take care of their waste and wastewater. A lot of land resources could also be saved if people live in more concentrated areas (Gong Yuan, personal communication, 2006). The visited villages are marked out in the map in the end of this report, Figure 18.

1.1 Sān Lǐ village (三里镇)

The population in the San Li village uses groundwater as drinking water, Figure 1. The water is pumped from a depth of 82.6 metres and is then piped to five villages, which together have a population of 22,000 people. 10,000 people use this groundwater while 12,000 people have their own wells. The price of the water is 1.7 Yuan/ton. This pump was built in 1983 and uses 22 kW (10 kW before 2003). Heavy metals have been found in this water. The local Government would like to drill a new well somewhere else to solve the problem.

Figure 1: The pump and pump house in the San Li village.

1.2 Wǔ Hú town (武湖)

The Wu Hu town gets its water from the Yangtze River. The pump station (Figure 2) in the river is designed for 10,000 tons water per day but only 5,000 tons per day is used. It is built in year 2000 and the water pumped out is the surface water. The deepest it is possible to pump water from is nine metres. The water is pumped to a water plant where $AlCl_3$ is added, then the water goes through sedimentation and filtration, and finally chloride is added. Mr Zhang from the local government that followed us to visit this place is afraid that municipal wastewater is discharged into a pond not far away from this spot. The biggest power plant in Wuhan, Yang Lu power plant, which is situated around one kilometre from here, also uses this water.

Figure 2: The pump station in the Yangtze River.

1.3 Shè kou village (滠口)

The She kou village uses the surface water from a small river that springs out from the Xia Jia reservoir, Figure 3. The water level in the river is very low around 0.5 metres. The locals have tried to build a temporary dam to store the water. 5,000 tons of water is pumped out every day and the pump station is built in 1998. The water is pumped to a water plant for cleaning. There is a paper mill not far away from this surface water resource, which has production stop until they can reach the new harder standards.

Figure 3: Small river from the Xia Jia reservoir.

1.4. Pán Lóng village (盘龙)

The Pan Long village receives their water from Lake Hòu hú (后 湖), Figure 4. The quality of the water in this lake is rated class II (see Table 1), which means that the water quality is good. There are no discharge points in the lake. The pump at the Hou Lake pump station, Figure 5, is designed for 30,000 tons per day but only 15,000 tons per day is used. The pump station is built in 1995 and the water costs 1.5 Yuan/ton. The net outside the inlet of the water is placed there to stop waste to enter the pumps.

Figure 4: Inlet of the water from the Hòu Lake.

Figure 5: The pump station at Hou Lake

1.5 Tiān Hé town(天河)

The city Tian He gets its water from the Bai Lai Lien Lake, which is a part of the Tong Jia Lake. There is also another town on the other side that takes its water from this lake. The water plant is called Tian He village water plant and is constructed this year. The water plant is situated 500 metres from the pump station beside the lake. Beside the pump in the lake there is a pump that can pump up the groundwater if the lake water gets polluted (contingency water). The locals grow fish around the inlet and in this lake. The area of the fish agriculture is 20,000 km^2. The fish agriculture seems not to affect the water quality since the farmers doesn’t feed the fishes.

1.6 Héng Diàn town (横店)

In the Heng Dian city, the water from the Hòu Lake is collected in a small pond, Figure 6. The water level is very low in the pond. This is because of the pump that pumps the water from the Hòu Lake is not working properly and also because of that it is the time for the fish agriculture farmers to fish out their fish. They do that by draining away the water from the lake so it thereby is easier to catch the fish alive. The water level in the lake then sinks drastically. There is also little rain in the wintertime, so this village has a problem to get enough water in then.

Figure 6*:* Discharge point of water from the Hou Lake.

The water is pumped from the discharge point (Figure 6) to the pump station (Figure 7). In the grey house, water is pumped out for irrigation and in the white house it is cleaned for public use. The cost of the water is 1.4 Yuan/ton. The water quality is not sure to bee good. The local Government would like to improve the situation. The water looked very dirty and was full of green algae.

Figure 7: The pump station.

1.7 Qí jiā wān village (祈家湾)

The Qu jia wan village collects their water, originating from the Mei Yuan Li reservoir, in a pond, Figure 8. There are farmlands all around the pond. 6,000 people get their water from here and every family pays 30 Yuan/month. 200 tons water/day is used. Just beside the lake there is a big garbage heap (see Figure 9). Both the garbage and the farmland pollute the water.

Figure 8: The pond.

Figure 9: Garbage heap just beside the water.

1. 8 Lǐ Jí village (李集)

The pump station by the Lóng Xū River(龙 须 河) was built in 1986 and supplies water to 12,000 people in the village Li Ji (see Figure 10). 1,500-2,000 tons water per day is produced and the cost is 1.5 Yuan per ton. The equipment used in this pump station is very old. The only cleaning of the water is sedimentation in a tank and addition of chloride. The water quality is not so good and there is farmland all around the river indicating possible pollution. When the water content in the Long Xu River is to low to meet the needs the sluice to the Mei Yue Li reservoir is opened to receive more water. The local Government would like to build a pipeline straight ahead from the reservoir. The people running the water plant have difficulties to collect the water fees since the people are to poor to be able to pay it.

Figure 10: Long Xue River

1. 9 Pào Tóng village (泡铜)

The Pao Tong village gets its water from a small pond built in 1986 (Figure 11). The water comes from the Mine San reservoir. There is an area of 134 km^2 (20 mu) of tea-bushes growing around the pond, see Figure 11. That is not good since a lot of chemicals are used in the tea-farming and this is surely affecting the water quality negatively. The water only goes through sedimentation before it's distributed to 825 families (Figure 12).

Figure 11: The left picture; water gathered in a pond. The right picture; tea farmland just a few meters from the pond

Figure 12: *S*edimentation tank.

1. 10 Luó Hàn village (罗 汉)

In this village they have two water plants that receive their water from the Shè Rriver (**滠河)**. One is built in 1987 and provides 2,000 tons of water per day for a population of 5,000 people. The other one, which we visited, is built in 1983. This plant provides 3,000 people water (1,000 tons/day). The equipment in the pump stations is very bad so the local Government are constructing a new pump station upstream. The cost of the water is 1.5 Yuan/ton.

The water in this part of the She River is highly eutrophicated. There are plenty of plants growing in the water and especially at the site of the new pump station, see Figures 13 and 14. The area of the new pump station is also surrounded by farmlands. The local government will remove this farmland.

Figure 13: The inlet of the new pump station.

Figure 14: Farmland around the river and many plants in the water.

1. 11 Huàngpì town(黄僻)

The She River(**滠河)** water plant is the biggest water plant in Huangpi; 60,000 tons water is pumped out everyday, whereof 45,000 tons is piped to the population in the city Huangpi. The other 15,000 tons is used for irrigation. 6-7 km downstream of the water plant there is a discharge point but this shouldn't impact on the water quality. At the water plant a petroleum monitoring system is installed since boats passing sometimes pollute the water.
The municipal wastewater from the city Huangpi is discharged in this river. See Figure 15.

Figure 15: Left picture show upstream of the plant and the right downstream

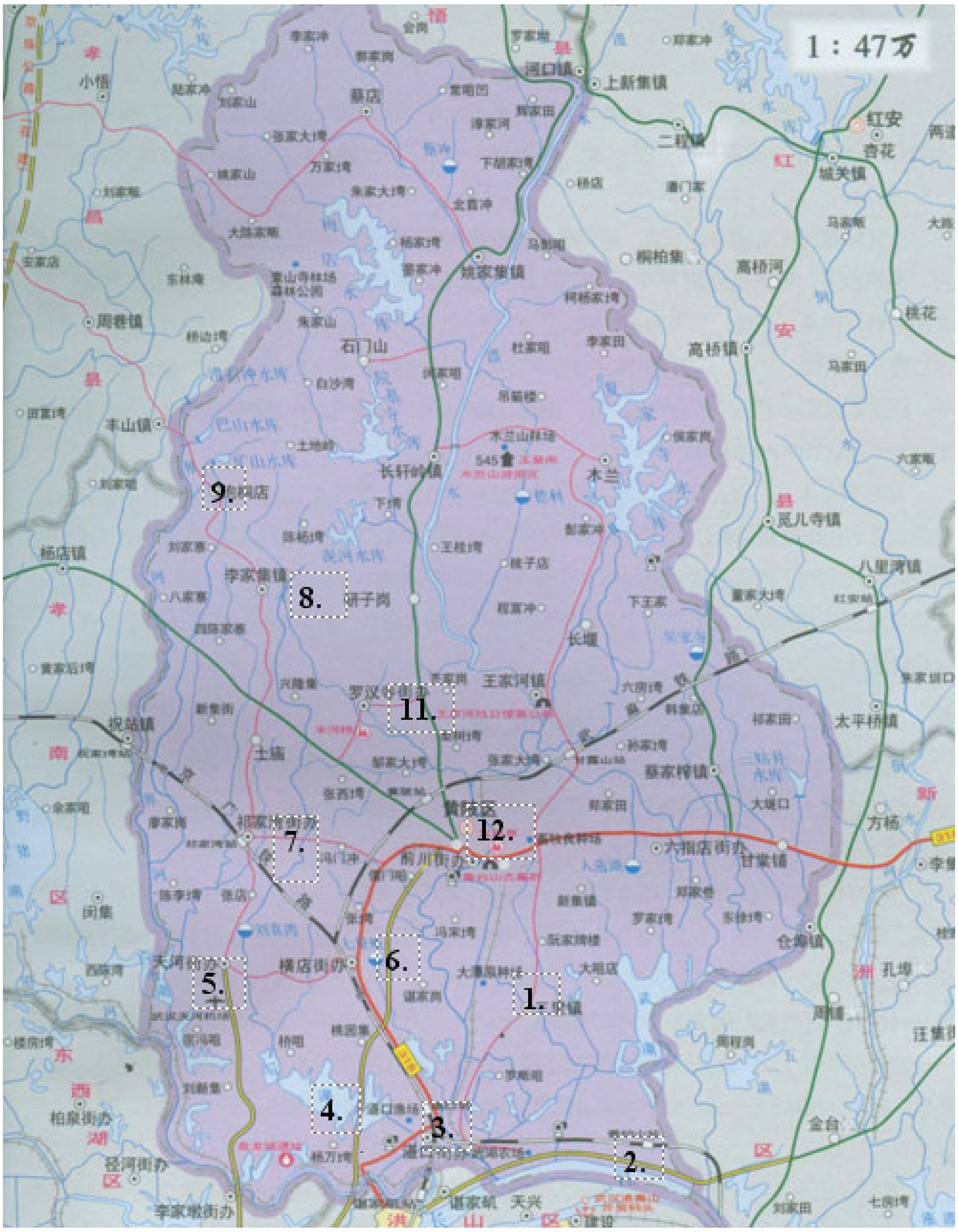

Figure 18: Map over the Huangpi region

2. REFERENCES

Han, S.S., Wu, X., 2004. *City profile Wuhan*, Citites, Vol. 21, No. 4. 349-362.