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Establishment of Swedish waste water technologies in Chinese automotive industry - case studies in Wuhan

Etablering av svensk vattenreningsteknik i den kinesiska fordonsindustrin - fallstudier

Kristina Källander

Abstract

Establishment of Swedish waste water technologies in Chinese automotive industry-case studies in Wuhan
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Wuhan is the most populous city in central China and a big industrial city. Borlänge Energi AB has in cooperation with IVL, and partners in Wuhan started a project with an aim to establish a Swedish-Chinese Environmental Technology Centre in Wuhan. An important goal with this centre is to attract Swedish environmental technology companies into the Wuhan market. Three Swedish companies in the waste water business were therefore chosen to be studied, Mercatus, Vilokan and Polyproject. A survey of the Swedish sustainable waste water technologies that these companies provide and the demand, interest and implementations of these technologies in the automotive industry in Wuhan was then carried out. The general potential for Swedish waste water treatment technology on the Chinese market was as well studied.
The waste water treatment in the automobile industry was chosen as it is a major industry in Wuhan where the waste water treatment technologies of the three Swedish companies could be applied. After China's entry into the WTO in 2001, the automotive industry is also one of the most affected industries by strengthed environmental requirements. The requirements have emerged in order to increase their international competitive ability and this implies that automotive industry is an interesting market for Swedish waste water treatment.
Conventional waste water treatment was used at the automobile factories that were visited and this kind of treatment generates large amounts of waste and is therefore not sustainable in the long run. Cleaner production waste water treatment implementations have therefore been evaluated. The waste water treatment at the visited companies was very efficient. Therefore they didn't have any demand of any improvements of their waste water treatment at this point. Water saving techniques as counter current rinse is although a feasible implementation at the moment.
One alternative implementation of an ultra filter to treat waste water from a bus maintenance-field was also studied but the stakeholder considered the technology to be too expensive.
If cost-benefit analysis could be done it would probably be easier to market the waste water technologies. Cleaner production technologies could probably be implemented in the visited factories, instead of diluting the waste water with municipal waste water in order to minimize the waste amount that is formed.
There is a great potential for the Swedish companies Vilokan, Mercatus and Polyproject to establish themselves in the Wuhan market as there is a big interest for the waste water technologies but generally the technologies are considered to be too expensive. Establishment through the Swedish-Chinese Environmental Technology Centre could be a very good way for the Swedish companies to establish themselves on the Chinese market.

Keywords: Wuhan, Borlänge energi AB, IVL, Mercatus, Vilokan, Polyproject, waste water treatment, automobile industry, cleaner production, cost-benefit, counter current rinse

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REFERAT

Etablering av svensk vattenreningsteknik i den kinesiska fordonsindustrin - fallstudier i Wuhan
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Wuhan är den mest befolkade staden i centrala Kina och en stor industristad. Borlänge Energi AB har i samarbete med IVL och partner i Wuhan startat ett projekt för att etablera ett Svensk – kinesiskt miljöteknikcentrum i Wuhan. Ett viktigt mål med miljöteknikcentrumet är att skapa en mötesplats för svenska och kinesiska miljöteknikföretag för att lättare kunna marknadsföra svensk miljöteknik i Kina. Tre svenska företag i vattenreningsbranschen som har studerats är Mercatus, Vilokan and Polyproject. En industriell sektor har sedan evaluerats med avseende på efterfrågan av Svensk hållbar vattenreningsteknik och dess möjliga implementering i Wuhan. En undersökning av vattenreningen i den valda industrisektorn, fordonsindustrin och en marknadsanalys för svensk vattenreningsteknik på den kinesiska marknaden har också utförts.

Vattenrening i fordonsindustrin valdes eftersom det är en stor industri i Wuhan där de tre svenska företagens vattenreningsteknik kan appliceras. Fordonsindustrin är också en av de industrier som är mest påverkade av strängare miljökrav efter Kinas inträdande i WTO 2001. Detta ökar de internationella konkurrensmöjligheterna för fordonsindustrin vilket också gör den till en intressant marknad för svensk vattenrening,

Konventionell vattenrening användes i de båda bilindustrierna som besöktes och sådan rening generar mycket avfall och är inte hållbart i längden. Så kallad cleaner production inom vattenrening för fordonsindustrin har därför studerats. De besökta företagen visade sig ha väl fungerande konventionella reningsanläggningar och de hade därför inget behov av förbättring av vattenreningen i nuläget. Vattenbesparande åtgärder såsom motströmssköljning skulle dock kunna införas.

Om ordentliga cost-benefit-analyser skulle kunna göras skulle det säkerligen vara enklare att marknadsföra vattenrening. Effektivare vattenreningsmetoder kan troligen implementeras i de besökta fabrikerna istället för att späda ut det industriella avloppsvattnet med kommunalt avloppsvattenvatten i fabrikerna.

En alternativ applikation av ultrafilter för rening av emulgerad olja i en busstvätt och bussverkstad för rening av emulgerad olja har också studerats men de ansvariga ansedde att det var en för dyr teknik.

De svenska företagen Vilokan, Mercatus and Polyproject har goda förutsättningar för att skapa sig en god marknad i Wuhan eftersom det finns ett stort intresse för svensk vattenrening men svensk vattenrening anses dock vara för dyr. Etablering genom det Svensk-kinesiska Miljöteknikcentrumet kan vara ett bra sätt att komma in på Wuhans marknad.

Keyword: Wuhan, Borlänge energi AB, IVL, Mercatus, Vilokan, Polyproject, vattenreningsteknik, fordonsindustrin, cleaner production, cost-benefit analyser, motströmssköljj

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摘要

瑞典污水处理技术在中国武汉汽车行业的研究

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武汉是中国中部地区人口最多的工业化城市。瑞典博朗厄能源公司联合瑞典环科院与武汉合作者共同在那里成立瑞典—中国环境技术中心，
目的在于吸引瑞典环境技术公司进入武汉市场。
本文以 Mercatus, Vilokan Polyprojec这三家瑞典污水处理公司为例，
评估瑞典可持续性汽车行业污水处理技术在武汉市场所产生的效益和可行性。同时本文对于瑞典污水处理技术在中国市场推广的可能性也进行了研究。

选择汽车行业污水处理，是因为汽车行业是武汉市的主要行业，这三家瑞典公司的先进污水处理技术可在此得以广泛应用。中国自2001年进入WTO以来，汽车行业已成为最具影响力行业之一。他们提升了环境方面的需求以增强其国际竞争力。这就意味着对于瑞典污水处理技术而言，中国汽车行业是一个极具吸引力的市场。

我们所参观过的汽车公司所采用的普通污水处理技术产生了大量的污水，从长远看来是非可持续发展的，所以需要更为清洁的工业污水处理。这些公司已很高效地采用了这些技术，因此他们在这一点上并没有新的需求。但是目前节水技术如逆流槽仍具有可行性。我们也研究了另外一种汽车冲洗水的过滤处理和储存技术，但是他们认为技术价格过高。

如果进行成本—效益分析，就比较容易知道污水处理技术的市场性。
清洁生产技术有可能被采用，从而替代用生活污水稀释以降低污染物浓度的方法。

Vilokan□Mercatus□Polyproject 这三家瑞典公司在武汉市场的建立有着广阔的前景，因为这里对于污水处理技术有着极大的需求，但是当地人觉得这些技术太昂贵了。中瑞合作环境技术中心的成立对于瑞典公司在中国市场的发展是一个好的开端。

关键词：武汉 瑞典博朗厄能源公司 瑞典环科院 Mercatus, Vilokan, Polyproject
污水处理
汽车行业 清洁生产 成本-效益 逆流槽

PREFACE

This master thesis was done for Borlänge Energy as a feasibility study in the cooperation between Borlänge and Wuhan. This is an MSc degree thesis in Environmental and Aquatic Enginering at Uppsala University counting for 30 Swedish academic credits. For the field study I got a Minor Field Study scholarship by Sida through the Committee of Tropical Ecology at Uppsala University that covered the “field study” in Wuhan.

The idea for this thesis work was initiated by my supervisor Ronny Arnberg at Borlänge energy but I had free hands to choose what I wanted to study. I choose the automotive industry that turned out to be a very time consuming project in order to understand the processes but yet very interesting. Thank you Ronny for making this possible!

I want to thank Jonas Röttorp at IVL for the time and knowledge and suggestions for the structure of this report.

I would like to give my gratitude to my supervisor at Uppsala University Professor Lars Christer Lundin at the Department of Earth Sciences for revising all of these pages!

I want to thank Shaq, Phoebe, Ms Kong, Mr Yuan and my Chinese supervisor Mr Zhu as well as other people at the EPRSI office for the help and good time in Wuhan. Some data have been impossible to get and as almost all data and information was in Chinese it was time consuming but thank you Shaq for all the times you helped us! This has really encouraged me to learn Chinese better! I also want to thank my friend Anna Hagberg at Borlänge energy who joined us for a while in Wuhan for support and practical help during the way.

I also want to thank Jan Kastensson, Lars Rosell and Daniel Hård at Mercatus, Vilokan and Polyproject for the time and information and all the people that have helped me through the process of writing my master thesis.

Finally I want to thank my “co-workers” Sofia, Annika and Oscar for the friendship, good company and support in Wuhan.

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Populärvetenskaplig sammanfattning

Wuhan är en stor industristad i centrala Kina och huvudstaden i provinsen Hubei. De flesta floder och sjöar är förorenade av kommunalt och industriellt avloppsvatten i Wuhan och både kommunal- och industriell vattenrening behöver förbättras. Miljömedvetenheten är stor i Kina nu och under drygt tio år har Kina infört en rad miljölagar och administrativa beslut för att förbättra miljösituation. Tio år är dock en ganska kort period i ett miljöperspektiv. Det råder också en brist på lokal nivå för att effektivt samordna miljöarbete mellan myndigheterna.

Den här rapporten är en förstudie till det miljöteknikcentrum som Borlänge energi och IVL försöker etablera tillsammans med de kinesiska parterna Wuhan Environmental Protection Research Science Institute (EPRSI) och Environment Protection Bureau. Ett viktigt mål med miljöteknikcentrumet är att skapa en mötesplats för svenska och kinesiska miljöteknikföretag för att lättare kunna marknadsföra svensk miljöteknik i Kina och därför har intresset för svensk vattenteknik studerats inom en industriell sektor i Wuhan.

Tre svenska företag i vattenreningsbranschen har studerats, Mercatus, Vilokan och Polyproject. Dessa företag visade sig ha bra tekniker för vattenrening inom ytbehandlings-industrin.

En industriell sektor evaluerades sedan med avseende på efterfrågan på svensk hållbar vattenreningsteknik och deras möjliga implementering i Wuhan. Vattenrening i fordonsindustrin valdes eftersom det är en av de största industrierna i Wuhan där de tre svenska företagens vattenreningsteknik kan appliceras eftersom ytbehandling är en stor del av tillverkningsprocessen i fordonsindustrins. Fordonsindustrin är också en av de mest påverkade industrierna efter Kinas inträdande i WTO 2001. Det har resulterat strängare miljökrav och miljöledningssystem för fordonsindustrin för att öka den internationella konkurrens-möjligheten och detta tyder på att det är en intressant marknad för svensk vattenrening.

En undersökning av vattenreningen i den valda industrisektorn, fordonsindustrin, och en marknadsanalys för svensk vattenreningsteknik på den kinesiska marknaden har också genomförts baserad på litteraturstudier, en fältstudie i Wuhan och de svenska företagens åsikter.

Grovt kan man dela in ytbehandlingsprocesslinan i fordonsindustrin i ett avfettningssteg, fosfateringssteg och lackeringssteg. Ytbehandligsprocessen är ungefär densamma inom verkstadsindustrin och därför är denna vattenrening även intressant för hela verkstadsindustrin där ytbehandling utförs.

Konventionell vattenrening inom ytbehandlingsindustrin är end-of-pipe rening genom hydroxidfällning. Sådan rening användes på de båda bilfabrikerna Wuhan Dongfeng Peugeot Citroen Automobile Company Ltd och Dongfeng Honda Automobile Company Ltd som besöktes. Denna typ av rening generar dock mycket avfall och är inte hållbar i längden. ”Cleaner production” vattenrenings applikationer har därför evaluerats men endast end-of pipe data kunde erhållas och det gick inte att få någon inblick i själva ytbehandlingsprocessen. För att kunna förstå vattenreningen i fordonsindustrin måste man ha information om ytbehandlingsprocessen och föroreningar. Faktorer som spelar stor roll vid optimering av vattenreningen är kemikalieförbrukningen, process optimering, produktkvalité, vilka material som behandlas och den kemiska sammansättningen i varje processteg.

De besökta bilfabrikerna visade sig ha väl fungerande konventionella reningsanläggningar och de hade därför inget behov av förbättring av vattenreningen i nuläget. Vattenbesparande åtgärder såsom motströmssköljning skulle dock kunna införas.

”Cleaner production” vattenrening kan troligen implementeras i de besökta fabrikerna istället för att späda ut det industriella avloppsvattnet med kommunalt avloppsvatten i fabrikerna. Genom att integrera återvinning och återanvändning av metaller och kemikalier i ytbehandlingsprocessen och recirkulera sköljvattnet kan man gå mot slutna system och avloppsfri rening.

Några möjliga tekniker för att återanvända och återvinna metaller och kemikalier i produktionsprocessen har därför studerats. Potentiella tekniker som skulle kunna används för att minska den mängd avfall som annars måste deponeras och minimera vattenförbrukningen har studerats. Vattenreningstekniker som skulle kunna användas är jonbytare, omvänd osmos, ultrafilter, lamellseparatorer, aktivt kol och centrala system för behandling av skärvätska. Möjliga implementeringar av dessa har studerats genom litteraturstudier och kunskap som IVL har inom separationsteknik. Resultatet tyder på att det inte finns någon optimal generell lösning, men en avloppsfri eller s.k. ”sluten” anläggning kan uppnås genom att flera av dessa separationstekniker används. Det är också väldigt viktigt att minska utdragsförluster och minska vattenförbrukningen med motströmssköljning i varje sköljsteg och andra vattenbesparande åtgärder. Cost-benefit-analyser skulle kunna göras baserade på mer noggrann data vilket också säkerligen skulle göra det enklare att marknadsföra vattenrening.

En alternativ applikation av Vilokans ultra filter i en busstvätt och bussverkstad för rening av emulgerad olja har också studerats. Tekniken ansågs vara väldigt intressant men de ansvariga ansåg slutligen att det var en för dyr teknik.

Vattenreningen på de två stora bilföretagen är relativt bra och ny men andra företag inom fordonsindustrin i Wuhan skulle vara intressanta att studera. Vattenreningen i buss- och andra fordonsfabriker, fabriker som tillverkar bildelar och gamla fordonsfabriker från sjuttiotalet där vattenreningen är mycket sämre eller där de inte renar vattnet alls skulle t,ex vara intressant att studera vidare. En framtida identifiering av företag i Wuhan som är i behov av förbättrad vattenrening skulle också vara bra. Denna identifiering skulle med fördel göras i samarbete med pollution control department på ESPRI ellert EPB i Wuhan eftersom de är mer involverade i vattenrening.

Det är väldigt viktigt att hitta en bra lösning på hur man ska behandla slammet från fordonsindustrin i Wuhan, i nuläget läggs det på deponi och EPB har inte hittat en bra lösning på hur man ska behandla det.

Det finns ett intresse för svensk vattenreningsteknik och det finns goda förutsättningar för etablering av svensk vattenrening på Wuhans marknad. Det är dock viktigt att svenska företag och aktörer samarbetar för att ta sig in på den kinsesiska marknaden och att de har en representant på plats, t.ex. genom ett framtida miljöteknikcentrum i Wuhan. Etablering genom miljöteknikcentrumet kan vara ett bra sätt att komma in på Wuhans marknad för de svenska företagen Vilokan, Mercatus and Polyproject. En svensk demonstrationsanläggning för vattenrening skulle också vara väldigt bra att ha i Wuhan.

TABLE OF CONTENT

1. INTRODUCTION

China’s fast industrialisation has led to severe environmental problems. More than 30 percent of China’s water is heavily polluted and 16 of the most air polluted cities in the world are found in China. Hence a development towards more environmental friendly and energy effective technologies is of great importance (Clark, 2007). Efforts to control China's pollution problem have therefore become a top priority.

Borlänge Energi AB has in cooperation with the Swedish Environmental Institute, IVL, started a project aimed to build up a Swedish-Chinese Environmental Technology Centre in Wuhan. This project is meant to help and teach representatives in Wuhan on ecological environmental sustainability and help to supply Swedish environmental technology expertise (Hagberg, 2007).

An important goal with this centre is to attract Swedish environmental technology companies to the Wuhan market. The companies should preferable develop new and innovative environmental technologies. The centre will hereby act as a project management office and a matchmaker for Swedish and Chinese companies (Arnberg and Röttorp, 2007). Three Swedish companies in the waste water business that have these qualities and therefore were chosen to be studied are Mercatus, Vilokan and Polyproject.

IVL (2007) has a unique pilot research centre and a unique laboratory with pilot scale equipment such as ion exchange, sorbents, evaporation, electro dialysis, membrane filters. Within the field of industrial processes IVL’s research is mainly addressing water treatments technologies. It used to work mainly with separation technology for waste water treatment but nowadays progress in this area has resulted in work in order to achieve waste-water-treatment free processes. Substitution of chemicals into more sustainable ones is very important in this field.

This report is a feasibility study for the Environmental Technology Centre with the aim to study the demand and potential for implementation of Swedish water technology in China and foremost in Wuhan. The waste water treatment in the automobile industry has been chosen as a case study as it is a major industry in Wuhan where the three Swedish companies’ waste water treatment technologies could be used.

The water treatment in the automobile industry is very similar to all metal workshop industries so the waste water applications studied should also be relevant to other metal workshop industries. This report is limited to cover the waste water treatment of phosphating cutting oil and painting in the automotive industry.

One alternative application of the studied technologies was also studied, namely treatment of emulsified fluid in a bus maintenance field. Wuhan Environmental Protection Research Science Institute was managing this bus wash and maintenance field project and found the ultra filtration technology interesting. The same technology could also be used to treat emulsified fluid and other substances in the automobile factories.

The aim of this feasibility study is to:

- Assess the waste water treatment in the automotive industrial sector based on case studies and a brief overlook.
- Assess the demand of and interest for Swedish sustainable waste water technologies and their implementation in the automotive industry.
- Briefly study the potential for Swedish waste water treatment technology on the market in China and especially in Wuhan based on a literature study, the case studies, interviews and the opinion of the Swedish companies.

2. BACKGROUND

2.1 THE SWEDISH-CHINESE ENVIRONMENTAL TECHNOLOGY CENTRE IN WUHAN

Wuhan is the capital of the province Hubei and the most populous city in central China with over 9 million people living at the confluence of the Yangtze River and the Han River. The Yangtze River is the third longest river in the world and it flows from Tibet into the East China Sea at Shanghai. Since 1927 Wuhan has included the three cities Hankou, Hanyang and Wuchang (Wuhan.com, 2007).

Wuhan (figure 1) is an important industrial hub and its central position in relation to metropolises like Hong Kong, Beijing and Shanghai is very favourable for distribution of products (Archersdirect, 2007).

Figure 1: Map of China showing the central position of Wuhan in relation to metropolises like Hong Kong, Beijing and Shanghai (Archersdirect, 2007).

Most of the rivers and lakes in Wuhan are polluted by municipal waste water and industrial waste water. Wuhan is a big industrial city and many industries in Wuhan are still lacking efficient waste water treatment (Hagberg, 2007).

The partners who have established the Swedish-Chinese Environmental Technology Centre in Wuhan are Wuhan Environmental Protection Research Science Institute (EPRSI), Wuhan Environmental Protection Bureau (EPB), Borlänge Energi AB and IVL. They have collaborated since 2000 with the aim to develop an independent Environmental Centre and to identify and initiate relevant projects on sustainable development between Sweden and China and promote knowledge and capacity building for sustainable development. The four following areas have been chosen according to the partners' priorities and the fast urbanisation in Wuhan that create demands for:

- Sustainable solid waste handling system
- Domestic waste water treatment
- Sludge management
- Urban ecological planning

The centre will therefore act in these areas to try to get a general picture of the problems and demands. Feasibility studies will be carried out in these four areas.

In order to attract Swedish environmental technology companies to the Wuhan market the centre will act as a project management office and a matchmaker as well as a platform for other Swedish companies that want to get established on the Wuhan market. The benefit will be that the employees at the centre can provide marketing service for the companies and have the knowledge and ability to present it for the customers in Wuhan (Arnberg and Röttorp, 2007).

One of the general main purposes in the "Partnership Memorandum of Understanding" in 2007 is to develop innovation and technology transfer projects, oriented to solve practical problems for different industrial sectors with multiple applications in Wuhan and China (Lundberg and Zhu, 2007).

Many companies have shown interest in the development of the centre and some of them that are interesting in the waste water treatment field are Läckeby/PURAC, Mercatus, Polyproject Kemira, and SET (Arnberg and Röttorp, 2007).

Anna Hagberg was the first student that went to Wuhan in this project to establish the environmental technology centre. This resulted in her master thesis "Industrial waste water treatment and other environmental problems in Wuhan - Is Swedish technology a solution?" (Hagberg, 2007). Quoting one of her conclusions "The greatest challenge is to construct waste water treatment plants for the around 3.5 million people that still discharge their waste water directly to the rivers and lakes, rather than to improve the industrial waste water further".

However, Wuhan has a very heavy industry and the companies visited by Hagberg (2007) had really good waste water treatment conditions. In many other heavy industries much more can be done to improve the waste water treatment, though. Hagberg (2007) concludes that this is not done because the industrial waste water technology solutions are too expensive. She writes that one solution could be to apply stricter local waste water standards as a tool to make companies invest more money in their technologies.

2.2 ENVIRONMENTAL AWARENESS

2.2.1 The Environmental awareness in China

According to China's governmental environment authority, State Environmental Protection (SEPA), there is now a growing awareness of environmental problems. SEPA is planning to adopt or revise about 1,400 environmental standards during a five-year period. At the end of 2005 there were about 8,000 national standards in China. The fast industrialisation triggers this growing awareness as the environmental standards are believed to be an important tool to get a hold of the pollutions and prevent the depletion of natural resources. The most severe environmental problems in China are now air and water pollution, land degradation, loss of biodiversity and depletion of natural resources (ITPS, 2006).

Follow ups of the environmental work in China have showed major deficiencies in the control systems. China has introduced new environmental legislation to stimulate the environmental responsibility during the last ten years but ten years is a short time in an environmental perspective (Gullbransson, 2007).

The environment is now the highest ranked area in China's long term strategy for science and technical development, which was presented in February 2006. In the 11th five year plan it is stated that cooperation between science and companies should be stimulated (Gullbransson, 2007). The Health Ministry in China estimates that approximately 200 million people risk getting sick due to their jobs and the most dangerous are the mining, textile and jewellery industries. The increasing environment awareness in China has also increased the number of "environment protecting" organisations rapidly.

In the latest five-year plan (2006-2010) there are some goals to improve the environment. One of them is to lower the energy consumption by unit BNP by 20 percent compared to previous five-year plan. Furthermore, environmentally hazardous emissions shall decrease with at least 10 percent compared to 2005 and the forest area shall increase from 18.2 to 20 percent (ITPS, 2006).

The environmental awareness for the upcoming 2008 Olympics is also high in Beijing. Four of the five Olympic mascots reflect the "Green Olympics" concept (figure 2). They are representing the natural elements and environmental awareness. The fifth mascot represents the Olympic Flame.

Figure 2: The green Olympic logo to the left and the four Olympic mascots presenting the environmental awareness (UNEP, 2007).

2.2.2 Industrial waste water situation in Wuhan

A large amount of municipal waste water is discharged without treatment in Wuhan, which has led to nearly all the lakes having eutrophication status. The main pollutants in the industrial waste waters are according to EPB (2006) chromium (VI) (3.0 tons), NH_3-N (1,732.0 tons), and COD (55,190.7 tons). 92 percent of the industrial waste water reached the emission standard, and the rate of recycled water was up to 68.40 percent according to EPB (2006). All the waste water treatment plants that exist in Wuhan's main heavy-pollution industries are in good performance according to the EPB.

The sewage charges have been doubled over the past tree years to 0.8 Yuan per ton and according to the Wuhan EPB (EPB, 2006) these rates are more than enough to cover the operating costs and expanding the treatment capacity.

2.2.3 Industrial waste water administration, standards and water pollution law

Industrial waste water is controlled by environmental protection bureaus (EPB) on different levels shown in figure 3. In Wuhan, EPB on city level/county level has about 800 employees and is responsible for implementing and enforcing environmental regulations in the city and oversees 13 district/county level EPB's. Its funding comes from the city of Wuhan. Employees at Wuhan EPB have law enforcement powers and are therefore entitled to give levy fines and file criminal charges. They have three different fee areas; noise, waste water and air pollution. On solid waste from the industries there are no fees as it is believed that the industries take care of their own waste. Either they pay an authorised company to take care of it or they take care of it themselves. Only the municipal waste and medical waste from hospitals are controlled. In 2006 they collected approximately 70 million Chinese Yuan in pollution fees. Wuhan EPB reports to EPB on provincial level and in theory the provincial level then have to report to SEPA, the State EPB that is located in Beijing.

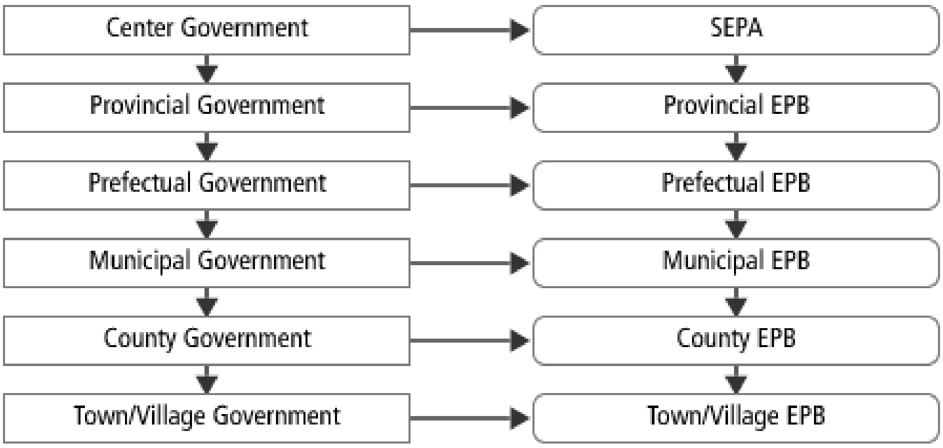

Figure 3: Water environment administration structure (WEPA, 2008).

Every year the city EPB in Wuhan performs some automatic and some manual monitoring of the major industries to ensure that they follow the standards. When they do this the industry has to reach 80 percent of its capacity to assure accurate values. Big companies are controlled by city EPB and smaller companies are controlled by town/village EPB.
The industrial waste water standards are gathered in the Integrated Water Discharge Standard GB8978-1996.

In the Law of the People's Republic of China on Prevention and Control of Water Pollution that was adopted in May 1984 and updated in May 1996 many relevant actions are stated that should be taken to prevent and control water pollution (China.org.cn, 2007).

2.2.4 The industrial water resources awareness in China

For many years the waste water treatment industry was a commonwealth enterprise in China, i.e. controlled by the Government, which resulted in huge amounts of water being polluted but fortunately this has changed today. The need for better treatment performance is nowadays even emphasized by the government although public pressure hasn't been noticed as much yet. Factors that contribute to the low quality of operations and maintenance of water treatment are:

- High water treatment costs
- Low equipment costs
- Low environmental awareness
- Spotty monitoring by government
- Low penalties for environmental violations

China's widely ongoing water reforms are according to US Department of Commerce fortunately moving towards a "user-pay" driven market sector. This development of increasing waste water fees is undoubtedly promoting the improvement of waste treatment and water pollution control. The change from a state-planned to a market-oriented water sector is very important in order to keep up with future developments in the ever changing and expanding industry as new approaches and new waste water technologies also have to be considered (U.S. Department of Commerce, 2005).

According to Swentec the low prices on water and lack in technology are also the factors that contribute to companies in the Chinese industry using four to ten times more water than their equivalents in industrial countries (Gullbransson, 2007).

The Chinese Government is aware of the need of more efficient management of its water resources and this is also given high priority in the last five year plan. Especially the water resources in northern China are very affected. To get a hold on this problem China has so called "supply and demand side policies", also referred to as the South-North Water Diversion Project (SNWDP). More than 40 billion m^3 of water is transferred from the south to northern industrial and urban regions in the Hai basin (figure 4) aiming at solving the water shortage problem in north China. Furthermore, China has tried to adjust its water use in order to handle its water demand and to match the ecological capacity. Actions like making the irrigation more effective through better technologies and increasing the industrial water prices and other new regulatory measures have also been taken (Hu and Song, 2007).

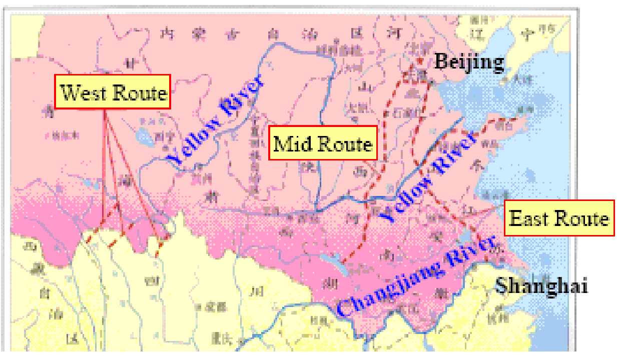

Figure 4: The routes for the SNWDP: West Route, Mid Route and East Route (Hu and Song, 2007).

2.3 ESTABLISHMENT OF SWEDISH ENVIRONMENTAL TECHNOLOGY ON THE CHINESE MARKET

Early construction of Swedish water supply and sanitation led to high expertise in this area compared to many other countries. Today, Swedish technology and expertise is still world-leading and Swedish companies in the waste water business have a very important comprehensive view in this area. Sweden is most competitive in industry sectors that are the most important in Sweden; forest industry, iron and steel, metal workshop and pharmaceutical industry. Since the 20th century Swedish Industry has worked according to the Cleaner production principle (Solyom, 2005). According to a survey by Swentec (2007) the know-how is foremost found in small and middle sized companies.

Swentec is the Swedish Environment Technology Council and a sector program within the Swedish Trade Council. The aim of Swentec is to boost the Swedish companies' business opportunities on the environment technology market in the Swedish as well as on the international market (SWENTEC, 2007). Sweden has made a big effort on the Chinese market already but the result hasn't been as successful as hoped for. One big problem is that the efforts are so scattered in different programs and "Swedish-Chinese Centres" and need to be more structured.

In order to better structure efforts Swentec has been commissioned by the Swedish Government to help to market environment technology. Based on Swentec's studies of needs and demand of Swedish environment technology, environment friendly products, production processes and services in China it has concluded that Sweden has a good chance on the Chinese market.

Today there are about thirty Swedish environment-related companies represented in China. Many of them have been able to establish through Sida's earlier efforts. One prime example is Purac, a major water company in the water purifying and biological waste treatment business.

Henrik Danielsson (pers. comm.) at the Swedish Export Council in Beijing remarks that there is a big pressure from the Chinese Government on the Chinese companies and industries to adjust their environmental conditions. Some of the most heavily polluted cities have been given environmental directives to adjust their activity to a sustainable level. In these places Swedish environmental technology companies have started to screen the market.
Besides different needs in different areas also the economic perspective is of great importance. In order to invest, companies must have the means but of course also the knowledge (Gullbransson, 2007).

Swedish Environmental Technology (SET) is a network for Swedish companies, organisations and authorities and is meant to strengthen the Swedish environmental technology export. SET represents about 35 small- to middle-sized companies with the potential to strengthen Swedish environmental know-how. Borlänge energi and the three Swedish waste water treatment companies Vilokan, Mercatus and Polyproject, that are presented in this report, are all members of the organisation and their logos are shown in figure 5.

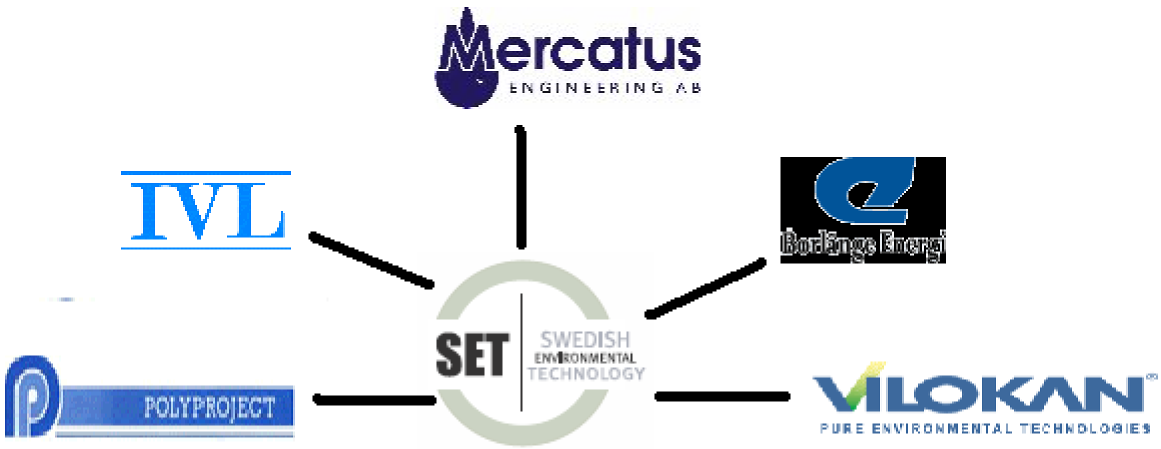

Figure 5: IVL, Borlänge energi, Vilokan, Mercatus and Polyproject and the organisation SET in the middle (Modified from SET, 2007).

2.4 THE AUTOMOTIVE INDUSTRY

2.4.1 The industry in Wuhan and foremost the automobile industry

Wuhan has a long history of trade and has undergone a significant growth in economy. It is an important national industrial base and the most important industries are automotive, steel, mechanics and high-tech industries (All roads lead to China, 2007). The number of factories in the most important industry sectors 2005 is listed in table 1.

Table 1: The number of factories in the most important industry sectors (Hagberg, 2007).

Type of enterprise	**Number**
Automobile industries	127
Steel industries	124
Mechanics industries	421
Medicine enterprises	69
Environmental protection enterprises	178
Food industries	1200
Textile industries	2700
Petroleum industries	103
Architecture enterprises	98
Electronic and information technology enterprises	Around 300

As a result of the economic growth the incomes of Wuhan's residents have risen and the city is now attracting the attention of high end developers, auto manufacturers, and foreign branded consumer-goods companies. Business areas, where the Government of Wuhan is encouraging investment include:

- Automotive
- Bioengineering and Pharmaceutical,
- Electronics
- Agriculture

Many of the industries that were once restricted in terms of ownership, such as automotive, logistics and others has now become open to wholly owned foreign enterprises and the number of contracts appears to be increasing, indicating a promising future for Wuhan (All roads leads to China, 2006).

The automobile industry was once the starting point for China's economic growth. The Hubei province is also one of the main four automotive manufacturers in China and contributed to about 12 percent of the provincial total industry output in 2006. Two of six main vehicle producers in Hubei are situated in Wuhan, the joint-ventures Citroen Dongfeng Honda Automobile Company Ltd and Dongfeng Peugeot Citroen Automobile Company Ltd that have entered joint-venture with the company Dongfeng that is owned by the state (WEDZ, 2007). At the meeting considering the collaboration between EPB, Borlänge and EPB held on the 11th of October, 2007 Anna Hagberg (2007) mentioned that Volvo has plans to get established in Wuhan. The rapidly increasing domestic car demand is good for business and the cars are easily distributed from Wuhan because of its central position in China (Wuhan.com, 2007).

In Wuhan Economic & Technological Development Zone (WEDZ) one of the absolute major industry sectors is automobile and automobile parts (WEDZ, 2007) and China has decided that Wuhan is one of the eight export zones for the car industry in China. At the same time it was decided that 160 car and car parts manufacturers from these zones will be national export companies whereof 61 are foreign financed. This is believed to be a way to approach strategically important foreign markets and also to gather knowledge and technology.

It is more expensive with big cars from the 1st of April, 2006, as taxes were considerably raised on cars that consume much petrol whereas smaller cars got a tax relief. Chinas five-year plan 2006-2010 emphasises energy saving and considering that China now is the third biggest car market and the demand for cars is still increasing it is very important to prevent Chinese people to buy even more SUV's (ITPS, 2006). For example the SUV Honda CR-V (figure 6) is produced at the Dongfeng Honda Automobile Company in Wuhan.

Figure 6: The car model Honda CR-V (WDHAC, 2007).

2.4.2 Economical and environmental sustainability in the automobile industry in China

After China's entry into the WTO in 2001, the automotive industry is one of the most affected by strengthed environmental requirements. Chinese automotive manufacturers have been provided with more opportunities to export their products and become suppliers of foreign customers in China. However, for exporting products or becoming suppliers of foreign customers. Chinese enterprises are required to address environmental sustainability and to increase their international competitive ability. As a result, the Chinese automobile supply chains have struggled to improve their economic and environmental performance.

The Chinese automobile industry, and its corresponding supply chains, has faced challenges by its international counterpart manufacturers, such as Volvo, Isuzu, Hitachi and Hyundai that have entered into the Chinese market.

The entry into the WTO has also triggered the growth in transportation vehicle and component demands by consumers, organizations, and international partners. It is expected that China will become one of the largest producers and users of automobiles and their parts.

Green supply chain management (GSCM) has therefore emerged as a systematic approach within the automobile industry in China to balance the economic and environmental sustainability as well as other environmental practices such as ISO 14001 certification and cleaner production (CP) (Zhu et al, 2007).

A stricter certification, ISO/TS 16949:2002, means certification according to technical demands applicable to the vehicle industry or their supplier and it is structured according to ISO standards to make it more compatible. It is or will be needed for the auto/auto-parts production compared with other sectors after China entered WTO. Most parts suppliers in the Hubei province have ISO 9000 certification but very few have passed ISO/TS 16949:2002 certification because of high costs and because it will take some year before there will be compulsory implementation of the standard (NBSO, 2006). The advantage with this certification is that it adopts process approaches, which are more consistent with most effective companies and it also contains many global quality norms (DNV, 2007).

2.4.3 The car production process

There are many different product processes employed to manufacture a vehicle and they generate large amounts of waste. The car production process is complicated, the major processes being stamping, jointing and assemblage, anticorrosion, priming, finishing, and assembly.

The first two steps in figure 7 is the first step in figure 8, in other words stamping, jointing and assemblage are included in body assembly. After that comes an anti corrosion treatment, then priming, finishing and at last the final assembly.

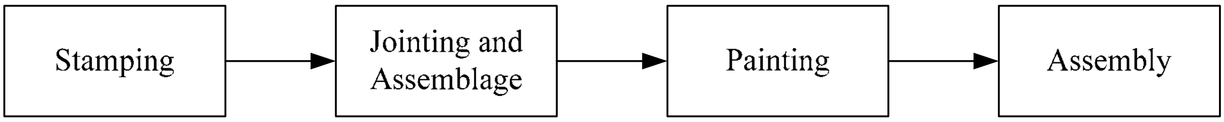

Figure 7: Showing the production processes stamping, jointing and assemblage, painting, and assembly (DPCA, 2007).

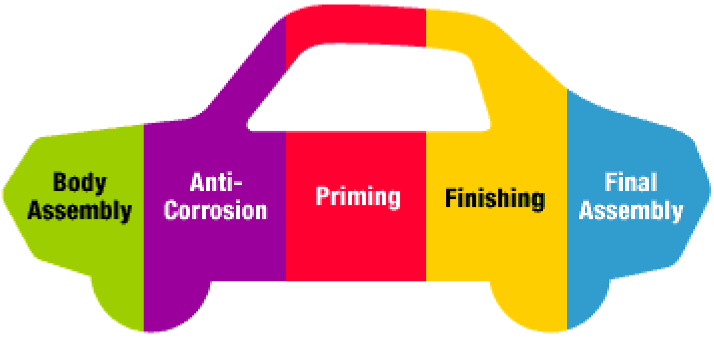

Figure 8: The car manufacture process (Green Cars, 1995).

Body assembly

The body assembly includes stamping, jointing and assembly cutting operations. Metal stamping is a process where a machine press or stamping press is used to form sheet metal to the shape wanted. The various metal pieces are joint at vehicle assembly to form the vehicle body. Welding and adhesives are used to join them. In these processes air emissions of volatile, often toxic, chemicals from adhesives are emitted because adhesive solvents evaporate.

Possible pollution: The primary waste is air release, Volatile Organic Compounds (VOCs), and likely chemicals are acetone and toluene

Improvement: Alternatives to solvent-based adhesives that can reduce or eliminate the air releases from assembly processes include low-solvent and solvent-free formulations and two-part adhesives (Green Cars, 1995).

In the car manufacturing process there are most likely *cutting operations* as well (Kastensson, 2007), and these lead to consumption of cutting oils. A simplified description of cutting operations comprises hole, opening and trimming operations and they also include engine manufacturing (Röttorp, 2007).

Pollution: Cutting oils

Improvements: Cutting fluid purification

Anticorrosion

Three steps are included in the anticorrosion pre-treatment: degreasing, zinc phosphating, and a pacifying rinse. A water rinse step follows the zinc phosphating and pacifying rinse (Green Cars, 1995). After assembly the vehicle body is treated with a detergent/degreasing in the degreasing bath to remove oil, grease, organics substances and inorganic particles from the product (Ekengren and Bjurhem, 1989). This process is also called alkaline wash, since the water solution is basic. Thereafter follows the phosphating process; the vehicle body is submerged in a bath of chemicals to achieve the desired coating that applies crystalline coating of zinc phosphate to the vehicle body. Before the phosphating, an activating step is applied with the aim to give a thin phosphate layer and give the sheet good adhesive properties for phosphate, i.e., making it easier for the growing layer, usually consisting of $ZnPO_4$. A water rinse follows the phosphating process to remove excess chemicals (Carlsson et al., 1992). A pacifying step follows the phosphating process and further enhances the anticorrosion properties of the zinc-phosphate coating and is again followed by a rinse to remove excess pacifying solution from the parts (Green Cars, 1995). The main components in the phosphate solution are normally phosphoric acid, Ni and Zn ions (Filipsson et al., 2001). The detergent that is used as degreasing agent can also vary.

Possible pollution: Waste water including emulsified oil and phosphate, oils, solvents and heavy metals (mostly Ni, Cu and Cr) etc. and hazardous solid waste.

Improvement: Large quantities of water are used in the anticorrosion step for rinsing the vehicle body. Ultra filtration and counter current rinse etc can be used to reduce chemicals and water consumption.

Another possible improvement is to eliminate chromium and zinc from anticorrosion operations, which is positive for end-of-life management. It is possible to replace chromium with a chromium-free solution and other initiatives may eliminate the need for zinc. At this time, zinc recycling is the only economically feasible option for the wastes originating from the anticorrosion operation according to Green Cars (1995).

Priming

Normally the car is treated in the following order when it is painted (Kastensson, 2007): basecoat, topcoat (basecoat and clear coat) and final coat. The primary colour coat is also called the basecoat. On top of this a clear coat is applied to protect the primary colour coat from damage. The primary colour coat and the clear coat, combined, are typically called the topcoat. The car body is then “baked” in an oven to set the final finish.

Possible pollution: Air releases, hazardous/solid waste, waste water. The chemicals that may be used are acetone, ethanol, ethyl benzene, formaldehyde, glycol ethers, methyl isobutyl ketone, n-butyl alcohol, toluene, xylene, and various metals for example chromium, lead and zinc (Green cars, 1995). The chemical composition of pigments varies according to its colour (EPA, 1995). The majority of volatile organic compounds are emitted from painting and coating processes.

Improvement: Paint may not stick to the product surface but instead stick to floor or walls, or being move out by ventilation air flowing through the paint booths. This may be prevented by Electrostatic painting (ED; see Appendix 1) that increases the transfer efficiency of the application process. The consumption of paint is also reduced by ED painting. To use a more environmental-friendly colour and to reuse colour with ultra filtration technology are good improvements

Finishing

Finishing is when the final so called topcoat is applied. The colours are changed periodically in a car factory and between the applications of different colours. Solvents are used to clean the equipment to prevent colour cross-contamination. The majority of volatile organic compounds are emitted from painting and coating processes.

Possible pollution: Air releases, hazardous/solid waste, waste water, including heavy metals and solvents etc (EPA, 1995).

Improvement: To use more environmental-friendly colour (water based) and to use a proper waste water treatment method.

2.4.4 Pollution from car production

Paint

Formulations continue to evolve to meet a variety of environmental and performance goals. Initially paint contained high quantities of solvents (i.e. high-solvent, low-solids) but paint formulations have changed and now include high-solids, low-solvent formulations, water-borne formulations and powder coatings.

Degreasing agents

Chlorinated solvents have been and are still used as degreasing agents because they have good properties to treat for example metals in the surface industries and chemical treatment liquids. In Sweden the use of chlorinated solvents was limited in the end of 20th century. These chemicals are volatile and therefore easily airborne in degreasing processes. In many other countries action has been taken to prevent the use of these chemicals quite recently. The chemicals are short-lived but fat-soluble and are often injurious to health and even believed to be carcinogenic and ozone degrading in some cases. The most spread chlorinated solvents are trichloroethylene, tetra ethylene and methyl chloride and these are forbidden in both Sweden and EU (SNF, 2007).

When chlorinated solvents are used in metal finishing it should be treated in a closed system (ADMIX, 1992). Nowadays alkaline degreasing is used with totally different properties (Welding Institute, 2000).

The alkaline degreasing agents that usually are used nowadays don’t cause any significant environmental problems. It is foremost the content of tensides, complexing agents and metals and other additives from the cutting fluids that are most environmentally unfriendly. Among the tensides it is foremost the non-ionic ones that are questioned (Carlsson et al., 1992).

Hexavalent chromium

In the passivating step in metal surface treatment Cr^{6+} was previously used and then the precipitation had to be treated at the end of pipe. Nowadays in Sweden passivating without chromium is used when it is possible, because chromium is environmentally unfriendly and also does not have good properties at high temperatures (70 °C) (Teknik och tillväxt, 2005).

In Europe during the last years the automobile industry has worked very hard to fulfil the EU directive 2000/53/EC, the so called End-of-life Vehicle, that was implemented on the 1st of July 2007. This Directive forbids sale and delivery of cars containing chromium (VI), cadmium, lead and mercury (Swerea IVF, 2007). The prohibiting concerns chromium (VI) but not when it is transformed to another form at for example surface treatment including the surface treatment of cars. IVF[1] has participated in the EU-project Chromatex that concerns alternatives to chromating without chromium (VI) (Teknik och tillväxt, 2005).

Waste

The main waste is sludge from waste water treatment or from spent solutions i.e. spent process baths and cutting oil. Most process waste is classified as hazardous (EPA, 2007).

Most chemical precipitation operations lead to large volumes of sludge being produced, metal hydroxide sludge mostly. When lime is used the sludge volume often reaches 0.5 percent of the volume of waste water.
One of the biggest problems is the handling and disposal of the sludge resulting from the chemical precipitation (Tchobanoglous et al., 2003). Techniques that both reduces the chemical consumption and water volume in the treatment plant should be considered to reduce the sludge volume (Toller and Innes, 1982).

Reuse of metals from mixed metal hydroxide sludge is carried out today at several places in the world. In Scandinavia the reuse technique that separates metals from sludge is not yet found feasible and therefore not used (Clarin and Luoma, 2000).

2.5 Conventional waste water treatment at Volvo cars automobile factory in Sweden; a reference study

The process water treatment plant in Volvo's automobile factory in Torslanda, Sweden, is not a closed system and much water is used. However, the phosphating and the ED-painting steps are closed steps. According to Allan Dunevall (pers. comm.) at Volvo Car Corporation this is the best solution because there is no lack of water and it is more environmental-friendly that the municipal waste water treatment plant treats the water further. Volvo doesn't use evaporation because the water amounts are too large. The waste water treatment is an old conventional and dependable method based on precipitation and mechanical and physical separation.

The process and water flow in Volvo's automobile factory is roughly shown in figure 9. The process steps include degreasing, activating, phosphating, passivating and ED-bath. After each process bath there are rinse steps (Steps 4-5, 8-9. 11-12 and 14-20 in Fig. 9).

[1] Industrial research and development cooperation

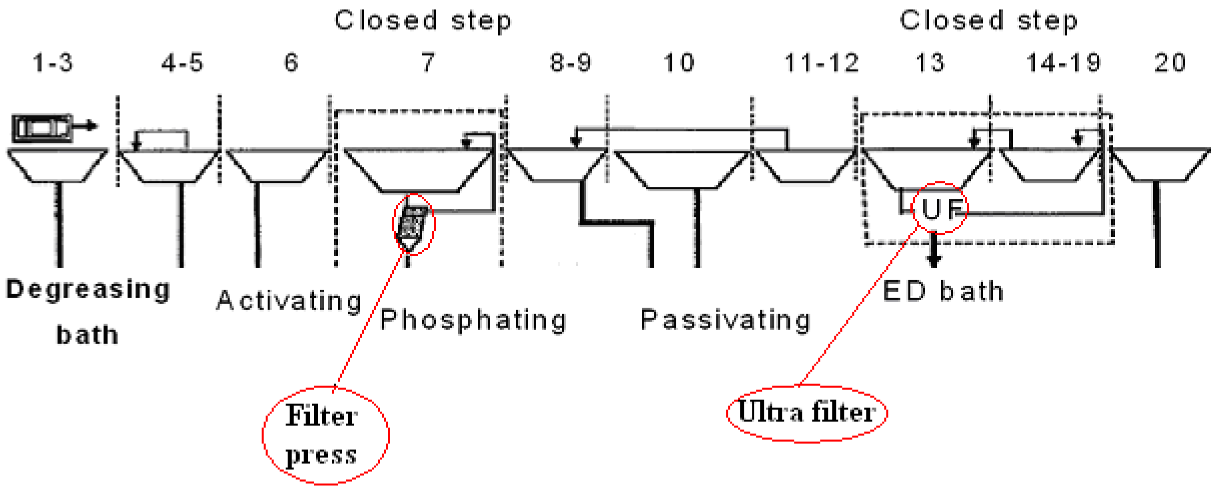

Figure 9: Rough draft of the process steps at Volvo's automobile factory, including degreasing, activating, phosphating, passivating and ED-bath (Utbult, 2007).

The process waste water mainly comes from the degreasing, phosphating and ED processes. The car body is treated in different baths with solvents, sodium nitrite, hexafluoride/zirconium and ED-colour. Counter current rinse, which is a very good water saving method, is used in the whole process. The water from these processes is led to the treatment plant where it is cleaned from metals, oil and solvents etc.

The treatment in the waste water plant consists of three different treatment lines, called the desalination, the sludge treatment and the paint separation line. Each of the treatment lines consists of different treatment steps, both chemical and mechanical. In the treatment plant every year approximately 250,000 m^3 of industrial waste water is treated.

Rinse water from the ED process and external screen water is treated in one line. Phosphate and passivating process water is treated in another line. This water contains relatively high amounts of metals and organic pollutants. The effluent from this process runs out in the storm water system. The oily water from the degrease baths and oily water from the oil separators and similar processes are also treated in a separate line. Reject water from drained sludge is as well treated in that line. All of the "cleaning processes" of the sub flows in the mentioned three separate treating lines are relatively similar to each other. At first the cleaning is based on chemical precipitation.

The chemical precipitation process has the following steps (Utbult, 2007):

- pH is reduced with sulphuric acid and microbial flock is added.
- Lime is dosed to neutralize the process water to pH 9. At this pH different metals precipitate and the pH has to be at least 9 to precipitate nickel.
- The polymer is added during this process and at the same time water is slowly stirred.
- The polymer makes the micro flock expand, which makes flocks easier to handle.
- The process water is led to a lamella separator, where the sludge phase is separated from the "clear" phase. The sludge phase then sediments and is led to the sludge treatment plant.

The sludge from the subflows is thereafter treated in the sludge treatment plant. The sludge is pressed in a filter press and the water from this process is left to its last treatment. The ultra filter gives a high separation rate for paint, approximately 95 percent according to Allan Dunevall (pers. comm.). Figure 10 describes the concept of chemical precipitation.

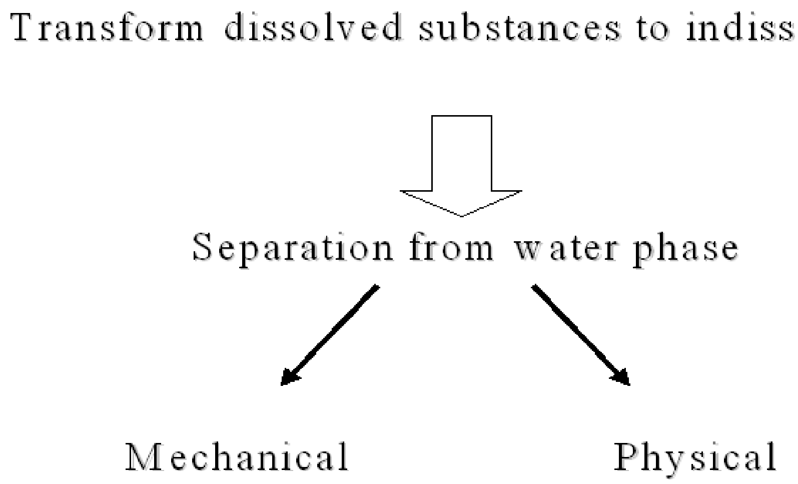

Figure 10: The concept of chemical precipitation (STF, 2007).

2.6 Cleaner production in the automobile industry

According to the UNEP (2007) definition of Cleaner production for production processes Cleaner Production (CP) is ”Results from one or a combination of conserving raw materials, water and energy; eliminating toxic and dangerous raw materials; and reducing the quantity and toxicity of all emissions and wastes at source during the production processes”.

The conventional waste water treatment in the automobile and the metal workshop industry is an end-of pipe treatment with hydroxide precipitation (Klingspor, 1997), see section 2.5. The waste accumulation from this treatment is mainly in the form of metal hydroxide and isn’t sustainable in the long run; the waste has to be minimized (Clarin and Luoma, 2000**).**

To be able to understand the waste water treatment in automobile industry you have to have knowledge about the industrial process and the pollution.
Factors that are important to evaluate in order to decide the environmental improvements that can be done in the metal workshop industry, including the automotive industry, are (Solyom 2005):

- chemical consumption
- housekeeping
- process optimization
- product quality
- material that is processed
- chemical composition in the different manufacturing steps

In order to reduce water and chemicals and minimize the waste and energy, waste water streams should be considered individually as long as possible. Knowledge about the subflows amounts are therefore important to be able to calculate the flux[2] etc. After that it could be mixed with other effluents streams (Solyom 2005). Furthermore the waste water should be considered separately for each flow and treatment method that is needed and in order to obtain sludge with a composition that makes it possible to reuse (ADMIX, 1992).

Suitable sample points should be chosen and screening analysis should be done according to its main constituents. From result and ranking of the subflows concentrations, bio-degradability, toxity etc. conclusions about which treatment to use can be obtained. Knowledge about the interplays between chemicals in the waste water is also needed. This information and knowledge about the specific content in the subflows of the waste water can be used to evaluate reuse and substitution of chemicals and reuse of water (Solyom 2005). Multivariate techniques to simulate and optimise processes are a good tool to do this (IVL, 2007).

Some of the most important actions according to Klingspor (1997) in order to “close the waste water treatment” or rather minimize the waste and waste water is to reduce the drag out and minimize the rinse water. To minimize the waste and waste water, the drag-out has to be reused in the process baths and metals and chemicals have to be separated and be reused either internally in the factory or externally. In the Scandinavian countries there are just a few surface treatment factories that have closed treatment, i.e., waste water treatment plants without an effluent, but in America it is more common (Clarin and Luoma, 2000).

Examples of treatment technologies that could be used for “closing the waste water treatment” are presented in Appendix 7. The chosen separation technologies are chosen based on the Swedish companies’ products so technologies such as electro dialysis and dialysis etc. that also are used for closing treatment are not considered (Clarin and Luoma, 2000).

To be able to implement waste water technology, water samples from the specific industries in that process step are needed, steps where the waste water technology could be applied. According to Daniel Hård (pers. comm.) the parameters needed are identification of metals, water amounts, temperature, and pH, in addition to the usual parameters such as Biological Oxygen Demand (BOD), Suspended Substance (SS), and phosphate. It is also very important to know the amount of water in the different steps in the production and waste water process to be able to calculate flux. With these values the membranes could for example be properly dimensioned. The benchmarks for water use are expressed in terms of litres per m^2 of treated surface area (EPA, 2007).

[2] Flux is fluid amount that passes trough an area unit, expressed in [l/m^2/h] (STF, 2007)

3. METHODS AND MATERIALS

To begin with, the technologies that the three Swedish companies in the water technology business provide were studied to get a basis for a first screening. The questionnaire is found in App. 2. A short presentation of the companies is found in section 3.1. From that I scouted for suitable industry in Wuhan where this kind of technology could be applied. The industrial sector must be assumed to have an important effect on the society and its waste water should be heavily polluted. Therefore a detailed study of the pollution from the industry was carried out.

The fieldwork was carried out in cooperation with the Chinese Environmental Protection of Science Research Institute[3] (EPSRI), similar to the Swedish IVL, which supported in setting up meetings with interesting companies and to translate relevant documents and at meetings during the stay in Wuhan. The questions for the Chinese companies can be found in Appendix 3 and a Chinese translation of these questions was handed to them. A visit to the Wuhan University of Technology was also paid as their major in automobile industry is one of the preponderant and key majors.

The major automobile factories in Wuhan (presented in section 3.2), Dongfeng Peugeot Citroen Automobile Company Ltd and Dongfeng Honda Automobile Company Ltd, were visited. These factories perform stamping, welding, painting, assembly and the waste water treatment; these processes was thus chosen to be studied. The processes include treatment of degreasing baths, cutting oil, phosphating and painting similar to all metal workshops and finishing industries. The waste water treatment methods studied are therefore applicable to other metal workshop industries.

A bus maintenance-field case, see section 3.2, was also studied as the same waste water treatment was applicable to that case.

It was not possible to visit other companies in the automotive industry as they did not have any monitoring reports according to EPSRI.

The work process in short was as follows:

1. Contacting and visiting the Swedish companies and literature studies as well as oral information at IVL's office in Stockholm.

2. Parallel studies of the industry in Wuhan and the potential waste water market in China.

3. Decision on which type of industrial sector and which type of waste water technologies that the Swedish companies provide that could be used in the chosen industrial sector, the automotive sector.

[3] EPSRI is sub-ordered to Wuhan EPB and it is an environmental protection scientific research institute that is specializing in application research and technique consulting service. (ESPRI, 2006)

4. Fieldwork in China with the aim to answer the question what the demand is for new sustainable waste water technology in the industrial sector chosen and how these can be implemented and the general potential for Swedish waste water treatment technology on the Chinese market and especially in Wuhan.

No comparison between Swedish and Chinese standards have been done as the Swedish standards of discharge of waste water from industries are decided separately for each industry according to a environmental impact assessment and because the manufacturing processes within the metal workshop industry doesn’t have any set standards for pollution. There are technical general requirements for the manufacturing process and maximal allowed concentrations for substances that are harmful for the environment (ADMIX, 1992).

3.1 THE SWEDISH COMPANIES

3.1.1 Polyproject

Polyproject is situated in Kolmården, central Sweden, where it also has some production. Just as the other companies, Mercatus and Vilokan, this company foremost does business with Scandinavian countries; other countries to mention are Lithuania and Poland but also Holland, Israel, other Baltic countries and South Africa.

The Export Sales Manager Daniel Hård (pers. comm.) says that the transports of their products can be a problem and limiting as it is very expensive. Usually Polyproject cooperates with counterparts in France and Germany where often just components are delivered.

The company is owned by an investor company. The advantage with this is that it is easier for them to get bank assurance. The strategy is to recruit companies abroad to establish in the new markets. Until now the company has done most business with European countries and sporadically with Asia.

Polyproject has cooperated with companies like Saab and Volvo, primarily in the airplane industry. It has good solutions for very heavy polluted industrial water and can deliver some products and in some cases buy the rest at the location to cut the price as the transportation would be too expensive otherwise. This enables Polyproject to provide complete waste water treatment solution even at foreign markets.

Polyproject is also specialised in glass fibre construction and has its own production of waste water equipment. Polyproject has the knowledge to produce glass fibre and this glass fibre could also easily be produced in China.

Polyproject has very good solutions for surface treatment industries and works closely with the surface treatment industry and they can offer complete surface treatment plants, treatment tanks, purification plants, service and spare parts, and the execution of conversions, repairs and modernisations.

3.1.2 Vilokan

The company Vilokan is situated on the Swedish West Coast in Strömstad. Their CEO Lars Rosell is also the director of SET (Swedish Environmental Technology). The company is very interested in exporting to China. Right now a lot of money is invested in export.

The company's motto is to be able to make money at home and commit themselves to put the money at stake abroad and being "product superior".

The biggest customers are Volvo, Scania, ABB and Sandvik. Vilokan has for example supplied ultra filter membrane treatment to Volvo Cars Torslanda (section 4.2).

Until now it has exported a lot to Scandinavian countries, especially Norway (it is situated close to the Norwegian border) but also to Europe and America and some to China. It is exporting about 15 percent of the company's turnover. About 10 years ago the company was established on the Chinese market through a main entrepreneur; ABB finishing. (Lars Rosell, pers. comm.)
Recently Vilokan installed a closed surface water treatment system at the NUCO factory in China that manufactures reflectors for lamps (figure 11; Vilokan, 2007).

Figure 11: Service technician from Vilokan together with a staff in charge of the treating plant at NUCO (Vilokan, 2007).

Just as the other companies it has good waste water treatment equipment for the metal workshop industry but their speciality is evaporation. There are lots of different techniques, for example one-step evaporation, several-step evaporation and forced evaporation. In the metal workshop industry, evaporation can be used to decrease the pollution and the water can be reused as the purity is very high with this treatment (Lars Rosell, pers. comm.).

3.1.3 Mercatus

Mercatus is a company with mainly two specialities; the cutting oil and coolants and the process water treatment. It has solutions for internal processes, but normally not for end of pipe solutions. It has very good membrane technology solutions.

The company does not have its own production but buys its components from German suppliers. It also has some destruction solutions, e.g., small destruction reception stations.

Mercatus has already taken part in SEC's[4] program in Tianjin, China, where IVL has an office. That time it wasn't successful and Jan Kastensson (pers. comm.) believes that their technology was considered to be too expensive. According to them the standard seems to be rather good at many of the companies that they visited in Tianjin.

For the specific waste water treatment in the automobile industry their solutions on recirculation of chemical in degreasing bath and cutting oil treatment and paint recovery are most interesting. They can provide good solutions for all the major production processes in the metal workshop industry, which includes the automobile industry as well

Mercatus already has a broad market as shown in figure 12 and exports about 15 percent of the company's turnover. Its market includes processing and manufacturing industry, chemical industry, power plants and automotive industry/paint finishing.

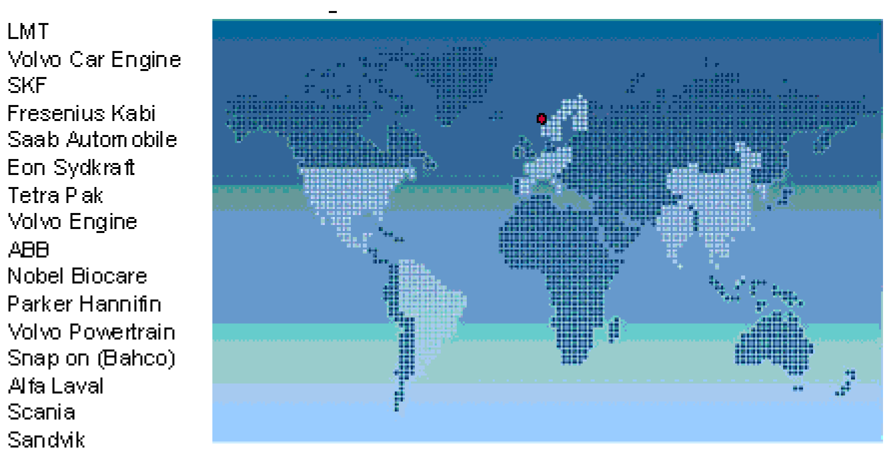

Figure 12: Mercatus market areas in light colour. On the left panel there is a reference list (Mercatus presentation, 2007).

3.2 CASE STUDIES - TWO AUTOMOBILE FACTORIES AND A BUS MAINTENANCE-FIELD

3.2.1 Dongfeng Peugeot Citroen Automobile Company Ltd (DPCA)

The Dongfeng Peugeot Citroen Automobile Company Ltd (DPCA) in Wuhan produces Citroen and Peugeot cars and engines. It produced approximately 300,000 cars and 400,000 engines in 2006 (DPCA, 2007). The factory performs stamping, welding, painting, assembly as well as engine production.

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[4] Since 2001 IVL has a joint-venture corporation in Tianjin, China, with their cooperation partner TAES, an environmental science institute. The cooperation is called SEC; Sino-Swedish (Tianjin) Environmental Technology Development Co Ltd.

DPCA produces the following cars: FuKang, Elysee, Picasso, Xsara, C-Triomphe and C2 under Dongfeng Citroen and Dongfeng Peugeot 307 and Dongfeng Peugeot 2006 under Dongfeng Pegeot.
The total accumulated sale ranked number ten on the Chinese national market. In July 2006 it was also decided that a second factory with a capacity of 150,000 cars annually will be built and it will start the production soon. This will enable the company to reach the goal of achieving a Chinese car market share of above 7-8 percent before 2010, which means that the car production will attain above 450,000 cars a year.
The company is ISO 14001 certified since 2005 (DPCA, sustainable development report 2006; 2007).

3.2.2 Dongfeng Honda Automobile Company Ltd (DHAC)

Dongfeng Honda Automobile Company Ltd (DHAC) was established 2003 and is also a joint-venture company between the Chinese Dongfeng automobile company and the Japanese company Honda, each holding an equity interest of 50 percent. The company has a staff of 1,011 persons of whom 65 percent are university or technical secondary school graduates and with Japanese employees on higher positions.

The manufacturing process includes welding workshop, coating workshop, engine assembly as well as general automobile assembly. The line has an efficiency of one car in 5.5 minutes. This company is also ISO 14001 certified (wdhac.com, 2007).

The company produces HONDA CR-V cars and HONDA CIVIC cars, 50,000 respectively 70,000 cars a year according to the monitoring report from April 2007 (Honda, 2007).

The expansion project that was finished in 2006 increased the annual production capacity from 30,000 units to 120,000 units (DHAC, 2007). The aim is to continually expand to establish amongst the heavyweights in the Chinese auto industry (wdhac.com, 2007).

3.2.3 Bus maintenance-field

The bus maintenance-field contains cleaning workshop and some mechanism processing workshops and it has problems to treat emulsification fluid. Mr Du is the leader of Pollution Control Department in ESPRI and he is managing this project facility (Jiang Du, pers. comm.).

4. RESULTS

The general waste water treatment in the automotive industry is described to give an overview of the waste water treatment in this industrial sector in Wuhan. Potential problems and companies within this industry that might be in need of better waste water treatment are treated.
Detailed descriptions of the waste water treatment and its efficiency in the three studied cases are also presented, based on monitor reports, personal communication and visits paid to the two automobile factories DPCA and DHAC in order to understand what kind of improvements that can be made.

Possible waste water treatment technologies that can improve the waste water treatment in the studied cases as well as in general in the automotive and metal workshop industry have then been evaluated.

The waste water treatment market in China and Wuhan is then desribed briefly as well as the potential for Swedish waste water treatment technologies based on the field study in Wuhan and literature studies.

4.1 THE WASTE WATER TREATMENT MARKET IN CHINA

4.1.1 THE GENERAL WASTE WATER TREATMENT IN THE VEHICLE INDUSTRY IN WUHAN

According to the vice professor Ji Min Fang (pers. comm.) at the Wuhan University of Technology the waste water treatment at the big car factories DPCA and DHAC are quite good. He has foremost contact with the vehicle parts manufacturers. Many students that have graduated from the university work in the car industry, especially in the painting step. For bus and other vehicle factories waste water is probably much polluted because the vehicles are cleaned manually, although some of the biggest companies have waste water treatment. Old factories from the seventies often don't have any waste water treatment at all. He estimates that it is approximately two or three companies that produce about 2,000 vehicles a year that lack any waste water treatment. And for the car parts he knows that the big companies have relatively good waste water treatment in contrast to the smaller ones.

Very few companies use ultra filtration (UF) (see Appendix 6) in the degreasing bath because it is expensive but some use UF in the ED painting step in China to reuse paint. Ji Min Fang (pers. comm.) thinks that most of the techniques that I presented are too expensive but he knows that Shanghai Volkswagen Company is planning to use electrodialysis to treat phosphide waste water.

According to Ji Min Fang (pers. comm.) there are no chemicals in use that are forbidden. The chlorinated degreasing agents such as trichloroethylene may still be used although it is not common. Because no chemical controls are performed, this can't be controlled and the companies are not forced to inform.

The degreasing and phosphating water is in almost all cases treated with flocculation. According to Ji Min Fang (personal communication, 2007) the transformation of Cr^{6+} to Cr^{3+} is used because it is an easy solution. He thought it would be very interesting to know if Sweden has any good alternative for the transformation in the chromating step. He knows that there are some factories in the east of China that are looking for this kind of solutions.

In the passivating step PO_4^{3-} and CrO_3 are used according to Ji Min Fang (pers. comm., 2007).

The phosphating process is performed at low temperature, which leads to less waste.
In the treatment for phosphorous waste water Fe^{2+}, Mn^{2+} and Zn^{2+} are used to remove phosphate.

According to Ji Min Fang (personal communication, 2007) there exist three types of painting techniques in Wuhan's automotive industry. When one of the techniques is used it is possible to treat the waste water with membrane technology, namely the ED painting from the American company Dupont that is a giant on the market.

Types of Painting:

- Painting chemicals: Acrylic acid; polyurethane
- The first layer: Electrophoresis painting (ED)
- The second layer: Surface painting
- The third layer: Clear finish (acrylic acid)

In the painting process of vehicle parts factories, watery painting is used to varnish (Ji Min Fang, pers. comm., 2007).

Besides the case studies of DPCA and DHAC there are ten companies in the automobile parts and fitting manufacturing industry, one vehicle body manufacturing company, two carriage manufacturing companies and a special vehicle manufacturing situated in Wuhan that have data about their sludge but no waste water treatment information could be obtained (EPB, 2007).

4.1.2 THE CASE STUDIES

The production processes in the two companies DPCA and DHAC are shown in figures 8 and 13. Both companies perform the four processes stamping, jointing and assembly, painting and assembly, which also includes all the steps described in section 2.4.

Both companies also perform cutting operations and manufacture engines and therefore cutting oil treatment is needed (Röttorp, 2007).

Right now the sludge from these industries is put on a landfill and EPB has not identified a proper way to treat it yet. EPB have plans to treat it but they don't want to give out that information. The companies pay approximately 50 Yuan/ton for the transport but the price is gradually increasing every year. The data of the sludge content at the automobile industry landfill shown in Appendix 6 are based on two samples taken on November the 7th, 2005 (Gong Yuan, pers. comm., 2007).

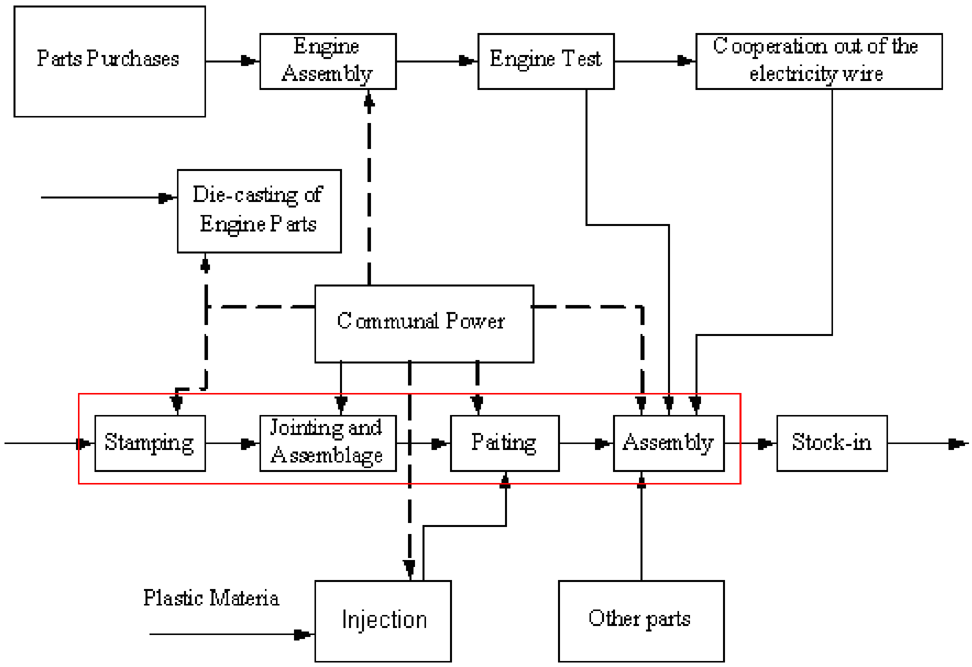

Figure 13: The production process at Dongfeng Honda Automobile Company Ltd (Honda, 2007).

4.1.2.1 DPCA

The DPCA is a French company, so their waste water treatment is from the PSA Peugeot Citroën, which is a French automobile company (Zhu, 2007). The waste water treatment plant was implemented in 1997.

First the waste water is treated separately in the following steps:

- Degreasing sewage
- Passivating sewage
- Phosphate and painting sewage
- Electrophoresis

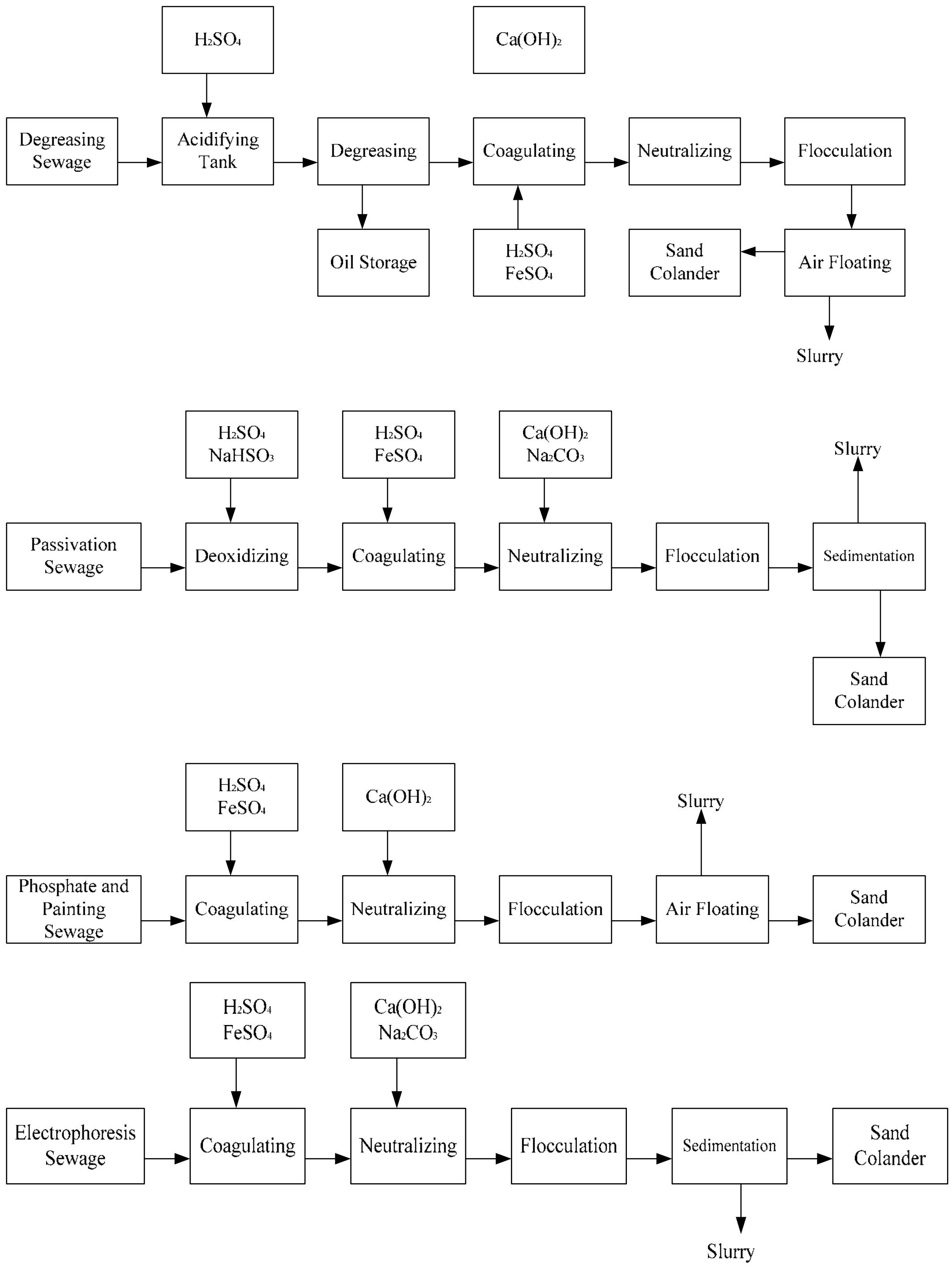

Figure 14: The separate treatment processes in the waste water treatment step of DPCA.

All of the processes are based on chemical precipitation and then the waste sediments or flotates and the waste is then treated in a slurry. The separated water is led to sand colander for further treatment, see figure 14. Cr^{6+} is reduced to Cr^{3+} in the passivating step. Then the water is treated in a biochemical waste water treatment station together with the municipal waste water (Peugeout, 2007). The waste water from the painting room is rooted in the sewage from the production processes of degreasing, phosphating, passivation and the electrophoresis waste water is led in separately.

The treatment of bio-chemical waste water including a sequencing batch reactor (SBR, see Appendix 4). The SBR technology does not have a lot to do with waste water treatment in the automobile industry; with this technology foremost oil residues can be treated. SBR technology is therefore not a normal part of a closed process but rather a finish treatment of unwanted organic residues (Ek, 2007). The process scheme is shown in figure 15.

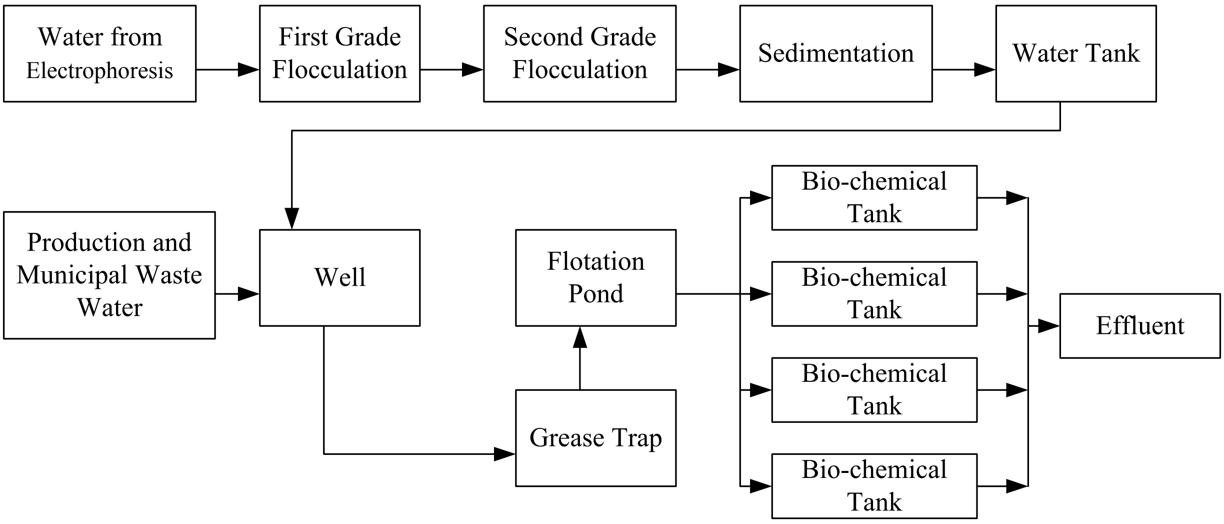

Figure 15: A flow chart of the bio-chemical treatment of DPCA (Peugeout, 2007).

The degreasing bath (about 500 m^3 waste water) is dumped twice a year. For the waste water let out 0.8 Yuan per ton waste water have to be paid and the estimated waste water treatment costs are 400,000 Yuan per year. What was included in the cost of the waste water treatment was uncertain (Liu Dong Qing, pers. comm.).

The monitor positions are the inlets and outlets of the waste water stations in the degreasing, phosphate, passivating and electrophoresis process in the painting workshop. At the bio-chemical waste water treatment station the inlet and outlet are as well monitored.

The monitored parameters are different for the different treatment flows. In the painting shop the monitored waste water constituents are Cr^{6+}, Pb and Ni and in the biochemical treatment station they are pH, SS, BOD_5, P, Volatile phenols, Cr^{6+}, Pb, Ni, Zn, petroleum and NH_3-N. The stations are monitored six times a day during three days at a time. The monitoring methods follow the GB8978-1996 standard.

Finally the waste water is released into the municipal pipeline and at last to the Zhuankou Waste water Treatment Plant. All of the waste water constituents beside the heavy metals obey the third grade GB8978-1996 standard. The heavy metals are Cr^{6+}, Pb and Ni and follow table 1 in the GB8978-1996. Table 2 shows the heavy metals data and table 3 shows the inlet and outlet data in the biochemical treatment station.

The efficiency of the final bio-chemical waste water treatment stage is shown in table 3 and sludge content is shown in table 4.

The sludge from different processes is separated. The waste that is classified as hazardous includes sludge from the painting process and the non-hazardous waste that comes from the phosphating step. The content of non-hazardous waste that goes to landfill is presented in table 4. The waste is put on landfill and there is a charge (unclear how much) for transportation and for taking care of the waste.

Table 2: The monitoring data from the phosphating, electrophoresis, passivation and degreasing room (Peugeout, 2007).

Monitor position	**Monitored constituents**	**Inlet**	**Outlet**	**Equipment efficiency (%)**
		[mg/l]		
Phosphating room	Cr^{6+}	0.015	0.015	
	Pb	0.06	0.06	
	Ni	5.50	0.31	94
Electrophoresis room	Cr^{6+}	0.002	0.002	
	Pb	0.49	0.06	88
	Ni	0.45	0.11	76
Passivation room	Cr^{6+}	0.024	0.002	92
	Pb	0.08	0.06	
	Ni	0.15	0.06	60
Degreasing room	Cr^{6+}	0.002	0.002	
	Pb	0.35	0.10	71
	Pb	0.89	0.08	91

Table 3: Inlet and outlet data for the biochemical treatment station of DPCA (Peugeout, 2007).

Monitored parameters	**Inlet**	**Outlet**	**Standard**	**Equipment Efficiency (%)**	**Effluence (kg/d)**
	[mg/l]				
pH	7.10-7.43	7.08-7.44	6-9		
SS	225	17	70	92	21.42
COD	342	57	100	83	71.82
BOD_5	97	23	30	76	28.98
volatile phenols	0.048	0.009	0.5	82	0.011
Cr^{6+}	0.002	0.002	0.5		
NH_3-N	15.7	9.13	15	42	11.5
petroleum	6.13	0.55	10	91	0.69
TP	4.09	0.336	0.5	92	0.42
Pb	0.07	0.05	1.0		0.063
Ni	0.21	0.18	1.0		0.23
Zn	0.282	0.082	2.0	71	0.1

Chinese waste water technology is used because it is considered to be cheaper. The company had never heard about any Swedish waste water treatment. Reuse of chemicals in the degreasing bath is considered interesting but probably too expensive.

In the future the water is planning to be reused and activated carbon is going to be used but there are no other plans to improve. Because of a planned expansion these are necessary improvements.

Table 4: The sludge content of the non-hazardous waste that goes to landfill (Peugeot, 2007)

Monitoring parameters	[mg/kg TS]
COD	30.8846
Cr^{6+}	0.0008
Pb	0.0088
Petroleum	0.2851
SS	25.7843
BOD	9.7595
Ni	0.0495
ZN	0.0229
NH_3-N	0.494
Volatile phenols	0.002

4.1.2.1 DHAC

The DHAC waste water treatment plant is very new; it was installed in 2003 and the company is satisfied with it (Ning Luo, pers. comm.). The waste water treatment plan is shown in figure 16.

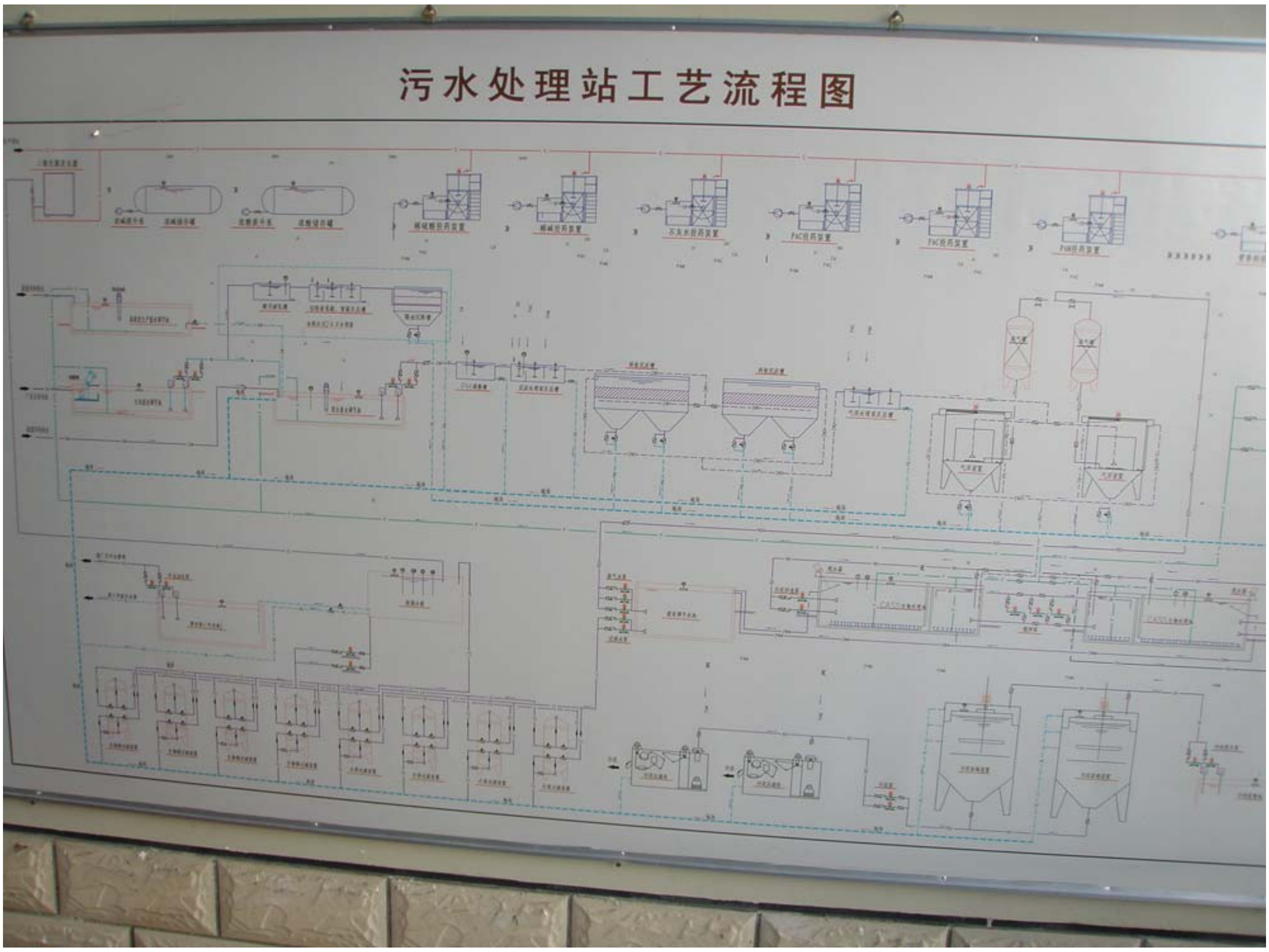

Figure 16: Picture of the process schedule taken at the waste water plant.

The DHCA's waste water treatment is from Xin Yu Tai Hua Company, which is a Chinese company in Jiang Su province (Zhu, 2007).

In 2006 a new water based paint system was introduced that reduces emission of VOC:s. Improvements of the manufacturing process efficiency also reduced the gas and water use**.**

Honda uses “hot water knock off” and the concept of this method is to clean the product with hot water before the degreasing step and therefore the contamination in the degreasing bath will be lower. With this method it is easier to gravimetrically separate the grease and thereafter scrape the waste away (Kastensson, 2007). The “hot water” concept is shown in figure 17 as cleaning 1, cleaning 2 and cleaning 3 and the surface scrape. There is also a counter current rinse, which is a very good water saving technique.

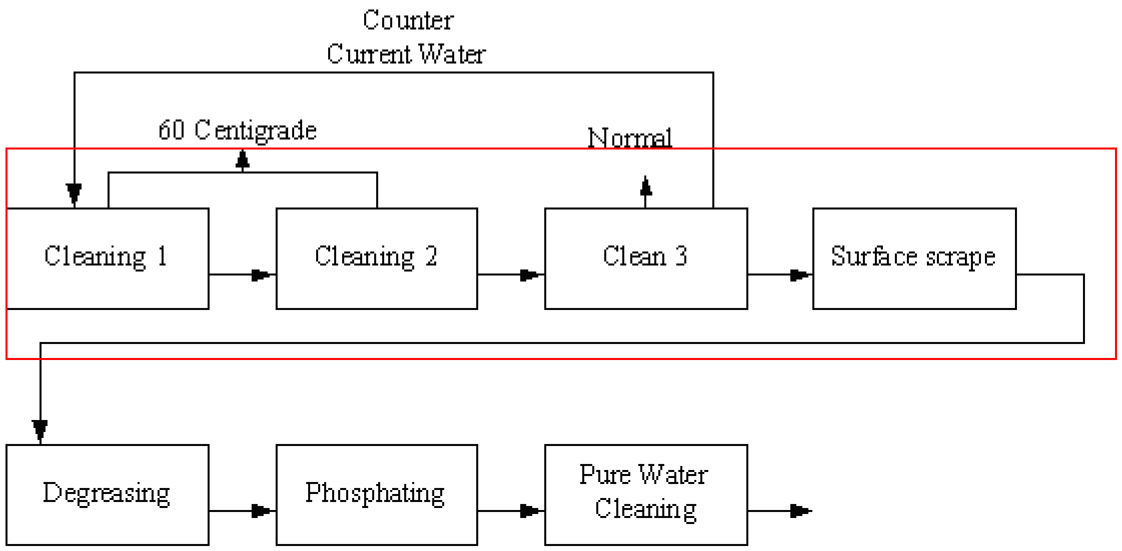

Figure 17: The "hot water knock off" step followed by degreasing, phosphating and pure-water cleaning.

The phosphate waste water and the electrophoresis waste water are treated separately and then go into the bio-chemical waste treatment station with the municipal waste water. The "former process" in figure 18 includes the pre-treatment of the surface, degreasing, activating step, phosphating etc. Paint and "former process" sewage go through a nickel treatment to reduce nickel before the bio-chemical waste water treatment station. Municipal and other workshop sewage is also led to the bio-chemical treatment station (figure 18).

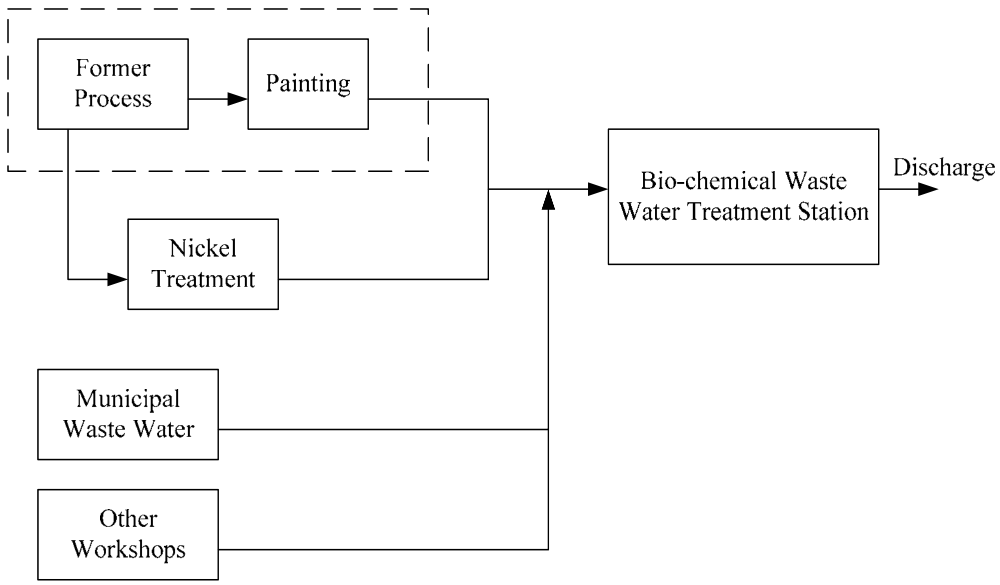

Figure 18: The different flows that go to the biochemical waste water treatment station.

A brief description of the whole waste water treatment plant is shown in the monitor scheme in figure 19.

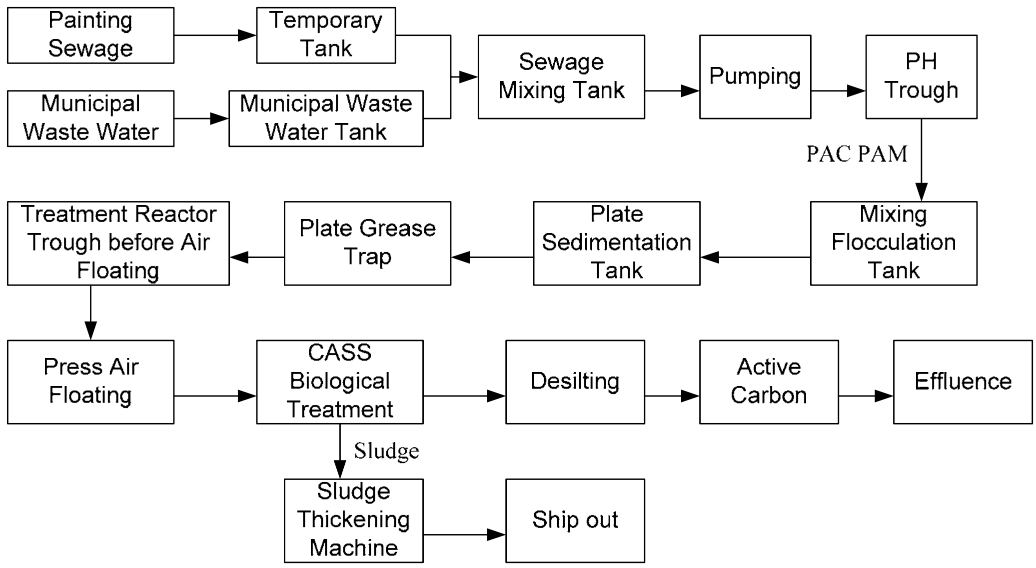

Figure 19: Monitoring scheme of the waste water treatment plant.

Grease is first removed after the first chemical treatment step, and after that the water is led to the biochemical treatment station where the rest of the sludge is removed and the water is treated with activated carbon as polish step in the end. Figure 20 shows the procedure for how the grease first is removed by adding flocculating chemicals, separated in a plate sedimentation tank and finally pressed to separate sludge and the waste water. The waste water that is separated is then recirculated.

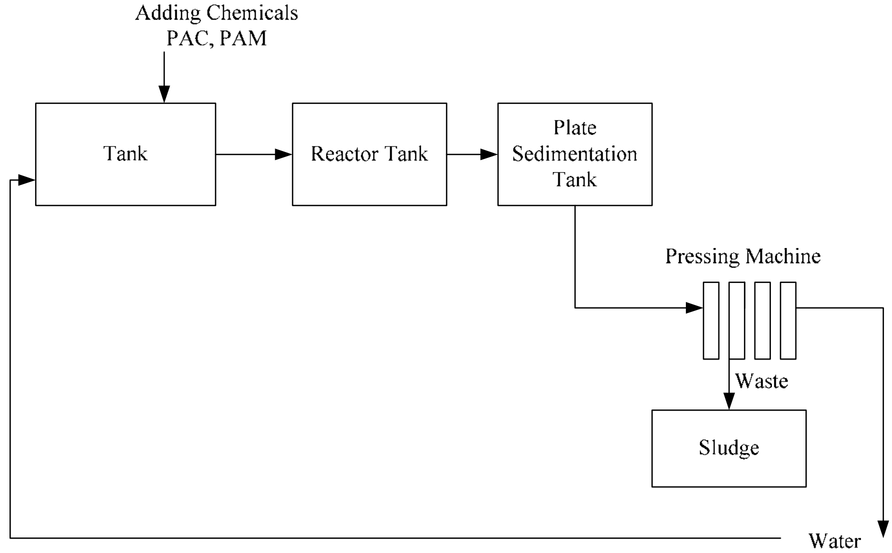

Figure 20: The procedure for how the grease first is removed.

At DHAC, the primary contamination in the phosphate waste water is constituted by COD, phosphate, SS, and Ni. In the electrophoresis waste water the pollutants are mainly COD, BOD_5, petroleum, and SS.

The monitor positions are the inlet and outlets in the phosphate step, painting process at the painting workshop (table 5) and the inlets and outlets of the bio-chemical waste water treatment station (table 6). In the workshop Cr^{6+}, Pb, Ni, COD, and P (TP) are the monitoring parameters and in the bio-chemical step the monitor factors are pH, SS, COD, BOD_5, nitrobenzene, P (TP), volatile phenols, petroleum, Zn, Cr^{6+} and aniline.

Table 5: Monitor positions and data before the final treatment in the bio-chemical station (Honda, 2007).

Monitor parameters [mg/l]	Inlet of phosphate equipment	Outlet of phosphate equipment	Outlet of Painting equipment	Standard	Equipment efficiency (%)
Cr^{6+}	0.017	0.016	0.002	0.5	5.88
Pb	0.02	0.02	0.03	1.0	0
COD	38	24	1136	100	36.8
Ni	14.8	0.07	0.03	1.0	99.5
TP	17.6	6.1	0.574	0.5	65.3

Table 6: Monitoring data from the bio-chemical treatment station (Honda, 2007).

Monitor Parameters [mg/l]	Inlet	Outlet	Standard	Equipment efficiency (%)
pH	7.4-7.9	7.7-7.9	6-9	-
SS	944	19	400	98
COD	457.2	72.5	500	84.1
BOD_5	90.24	22.93	300	74.6
petroleum	23.49	0.521	30	97.8
phosphate	28.47	0.521	-	98.2
nitrobenzene	0.1	0.1	5.0	-
volatile phenols	0.0463	0.0042	2.0	90.9
Zn	4.83	5.0	5.0	86.1
Cr^{6+}	0.002	0.002	-	-
aniline	0.015	0.015	5.0	-

The total volume of inlet water at DHAC is about 2,300 m^3/day and the total outlet is 1,000 m^3/day. The waste water volume from the painting workshop is about 1,400 m^3/day and from the bio-chemical waste water treatment station about 900 m^3/day. 60 percent of the water is reused.

According to Mr Ning Luo (pers. comm.) at the Department of Plan Development at DHAC the degreasing bath is dumped once a year. Every third month DHAC pays 12,000 Yuan for all the pollution besides the solid waste as EPB consider their waste water treatment to be very good.

DHAC sends their solid waste, sludge, to a special company that has permission from the Government to dispose solid waste and dangerous waste. The price of solid waste from Dongfeng Honda is about 2,000 Yuan/ton. This waste includes sludge from the bio-chemical waste water station (1.5 ton/day) and the painting workshop (0.72 ton/day).

The waste including metal nickel from the painting workshop is first given to the company that takes care of the waste. After that the company makes the waste non-hazardous, and it is then put into the landfill. The sludge content of the non-hazardous waste that goes to landfill is presented in table 7.

Table 7: The sludge content of the non-hazardous waste that goes to the landfill (ESPRI, 2007)

Monitor parameters	[mg/kg TS]
SS	2.43
Petroleum	0.0603
COD	4.266
BOD	1.2119
Ni	0.0032
SS	0
NH_3-N	0.036
PH	0.0001
Phosphate (P)	0.0001
Volaltile phenols	?
aniline	0.0617
nitrobenzene	0.0365

Assuming 300 working days a year this means that the total cost for the waste is 1,332,000 Yuan per year. The total cost for all the other pollution is 48,000 Yuan per year so the total cost for the pollution is 1,380,000 Yuan. In addition to the waste water pollution cost, staff and chemical cost, some of the running costs in the WEDZ area are presented in Appendix 5.

4.1.2.3 Bus maintenance-field

The waste water treatment for a bus maintenance-field was managed by Jiang Du (pers. comm.), the leader of Pollution Control Department in ESPRI. He usually works with waste water treatment projects and this was a project that he was managing where he thought that Swedish waste water technology could be interesting to use.

This bus maintenance-field contains a cleaning workshop and some mechanical workshops. The cleaning of the waste water was not the big problem in this project, but cleaning the emulsification fluid was a problem. The mechanical workshops had problems to treat emulsification fluid. Jiang Du (personal communication, 2007) said that if the price and efficiency of the Swedish company equipment was appropriate they would truly consider it.

The volume of emulsification fluid is about 3-5 m^3/h for eight hours a day and in the Chinese traditional treatment some chemical is added into the liquid, for instance $CaCl_2$.

The process is presented below in figure 21:

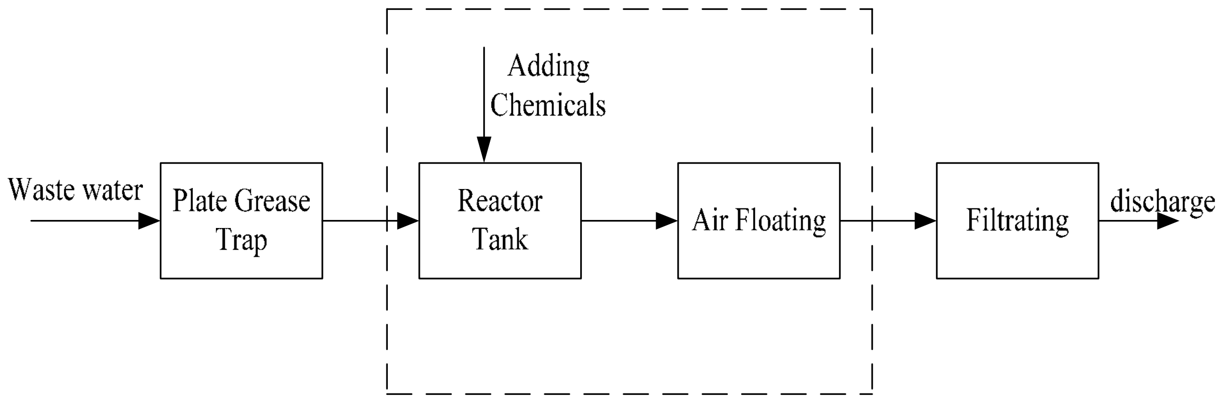

Figure 21: The waste water treatment process in the bus maintenance-field.

Ultra filter can be used to separate emulsification fluids and this could also be applied to the waste water from the bus maintenance-field. The bus maintenance-field company considered it to be too expensive but very interesting. Jiang Du (pers. comm., 2007) also considered doing a DemoEnvironment application to cut the price but found it too expensive. With this DemoEnvironment grant they could cut the price up to 50 percent and the service cost with 80 percent (Demomiljö, 2008).

DemoEnvironment is a support that small and medium companies are offered to do pilot studies on project development and project identification and it is targeted at developing countries including China. Demo-environment projects for modern environmental technology solutions in the areas of sustainable urban development and renewable energy can provide up to SEK 3 million[5] for demonstration support (Nutek, 2007). These kinds of support are very important for small and medium size companies to export and establish themselves in developing countries.

According to Lars Rosell (pers. comm.) at Vilokan the price for this kind of treatment with ultra filtration for flow quantities of 3-5 m^3/h would be from SEK 900,000 to 1,400,000, depending on capacity. He recommended an ultra filter (figure 22) for emulsification oil. The water can also be reused with this technology.

[5] SEK 1 = CNY 0.905 (Forex, 2007)

VILOKAN Ultra filter

Figure 22: Vilokans ultra filter.

Vilokan's ultra filter plant is built as a compact plant with everything included and in some cases a pre-filter, tanks, pumps and controlling can be included as well. Technical and efficiency data are presented in tables 8 and 9 (Vilokan, 2007).

Table 8: Technical data for Vilokan ultra filters

Type	Capacity [l/h]	Dimension [L*W*H mm]
EC CB-01	30-50	1050*1100*1900
EC CB-03	100-160	1050*1100*1900
EC CB-07	250-360	1750*950*1900
EC CB-207	500-700	1950*1450*2000
EC CB-19	700-1000	2900*900*2450
EC CB-219	1400-2000	2900*900*2450
EC CB-237	2000-4000	3000*1375*2270

Table 9: Efficiency data for Vilokan ultra filters

Feed contamination	Removal
Suspended solids	100 %
Non-emulsified oil and grease	> 99.9%
Emulsified oils and grease	> 96%

The bus maintenance-field company considered the offer for a couple of months and then Jiang Du (pers. comm., 2007) said that the budget of the bus cleaning station project was done and the investor of this project had chosen- a cheaper solution than the Swedish equipment. Jiang Du (pers. comm., 2007) said that he is interested in this kind of cooperation between Sweden and China and he would like to cooperate with Swedish companies another time.

4.2 CLEANER PRODUCTION TECHNOLOGIES - POSSIBLE IMPROVEMENTS

All of the Swedish companies presented, Polyproject, Vilokan and Mercatus, have good solutions for surface waste water treatment, metal workshop industries - and heavy polluted waste water treatment that can be applied to automobile and automotive industry. In Appendix 7 there is a short presentation of technologies that are applied by the above companies in the metal workshop industry and in this case the automobile industry including:

- ion exchange (IE)
- reverses osmosis (RO)
- ultra filtration (UF)
- evaporation
- lamella separation
- active carbon
- central systems for cutting oil treatment

The technologies that the Swedish companies provide are applied by the companies in the metal workshop industry but the question is if they are feasible. A closed treatment consists of several different separation equipments and often the energy costs for these are higher than for conventional treatment.

The separation treatment solutions presented in this report suggest more closed systems and higher reuse efficiency and much of IVL's research concerns waste water free processes with application of separation technology. Much experience needed in the possible implementations is therefore based on IVL's and the Swedish companies's knowledge. To know if these possible solutions would be feasible a cost-benefit analysis should be made.

4.2.1 Closing of the rinse step in the phosphating line

The phosphate line includes the degreasing step, phosphate step and the passivating step and this is an application for closing of its rinse system (figure 23). Membranes (UF and or RO etc) and ion exchange (IE) are used extensively in this system (Filipsson et al., 2001). IE has the ability to separate even low amounts of substances and substances that are dissolved in water (Miljösamverkan Västra Götaland, 2001)

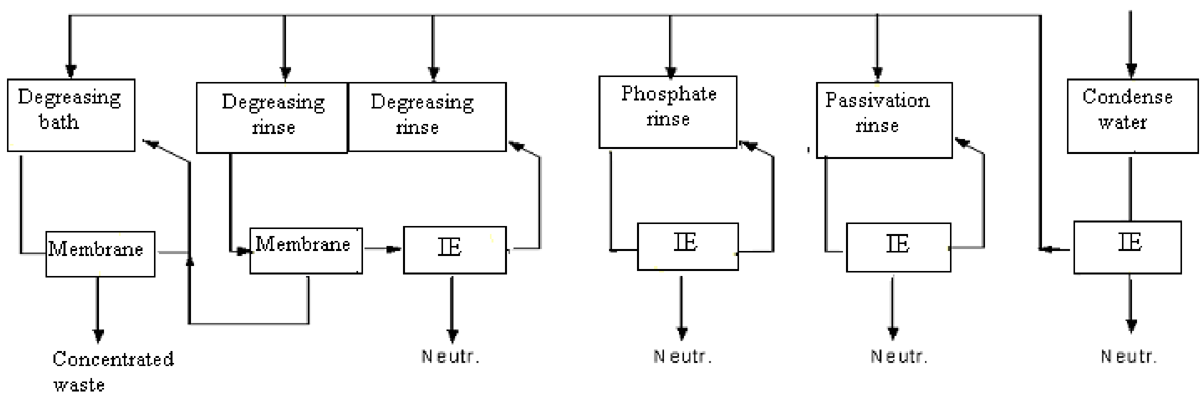

Figure 23: Phosphate line for closing the rinse system.

4.2.2 The degreasing bath

When one is to choose a treatment method for degreasing baths one can roughly separate methods in such that are suitable for free oil and such that are suitable for emulsification fluid. Free oil /grease, can as well as particles, be treated with lamella sedimentation, patron filter, cyclones or gravimetrical separators of different kinds that work almost as “kidneys”. Emulsification fluid can be treated with membrane technology (Carlsson, 1992).

Ultra filtrating is today the common treatment of cutting oils and is also used in many companies to treat the used degreasing baths and rinse water; the principle is described in figure 24.

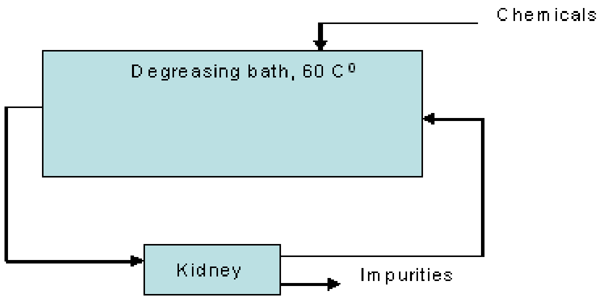

Figure 24: Recovery of process chemicals with the use of “kidneys” in degreasing baths (Filipsson, 2002).

The combination of UF and RO gives the best result (figure 26). RO is a natural polish step for this solution. Recycling of the degreasing bath or rather continuous treatment of the degreasing bath is rather usual nowadays (Uwe Fortkamp, pers. comm.). With this treatment the degreasing water that contains emulsified oil is cleaned as water molecules are let through the membrane and some of the degreasing agents, whereby the oil is separated and concentrated (Mercatus, 2007). The quality, i.e. the efficiency, of the degreasing bath decreases after a certain time but a prolonging of the bath can be obtained by separators and in this case, when a major amount of oil is emulsified it is suitable to use membrane technology (Ekengren and Bjurhem, 1989). It is foremost tensides that have skimming-decreasing properties that are decreased with time (Filippson et al., 2001).

There are lots of advantages with this treament. For example you do not have to interrupt the production when you don’t “dump” the degreasing baths as often. This technology also reduces the effluent volume, save water and energy, reduces waste and recycles the degreasing solutions/detergents. The qualities of the degreasing baths and therefore the product will be better with this technology. Without this technology; if you replace the process water by time it will look like curve 1 in figure 25 (Kastensson, 2007).

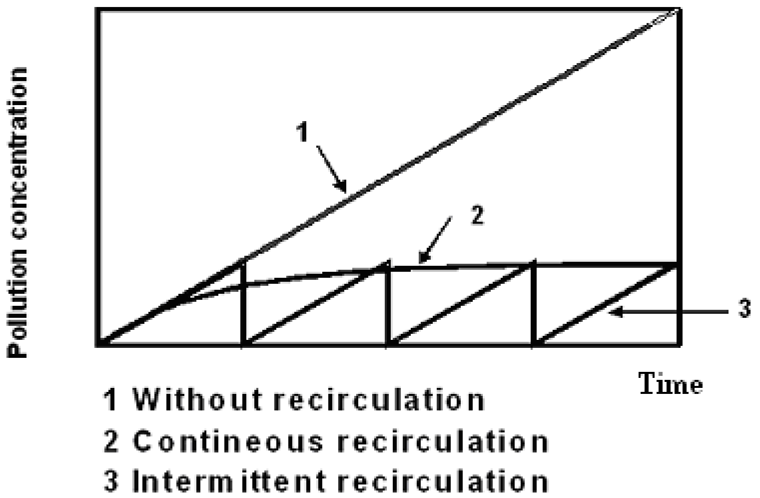

Figure 25: The variation of the pollution concentration. Curve 1 shows a degreasing bath without treatment and curve two describes continuous circulation. Curve 3 shows intermittent recirculation, i.e., the membrane is used when it is needed (Kastensson, 2007).

It is very important to optimize the membrane for the specific application and decide which chemicals that need to be added to the system (Carlsson, 1992).
To obtain a better quality of the treated water the UF should be complemented with RO or IE (Ekengren et al., 2007).

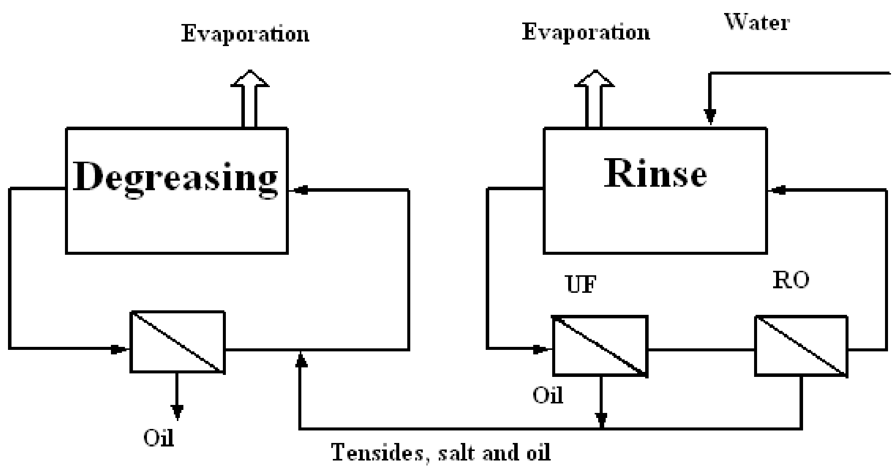

Figure 26: Prolonging the life time of the degreasing bath with ultra filtration and reverse osmosis for rinse water recycling.

Evaporation is also a method that can be used for treatment of degreasing water. The water is then reused and some volatile components whereas most of the detergent chemicals and pollutions are separated. Evaporation calls for very high investment costs but is very reliable for different waters and gives a very good treatment result. A polish treatment step is often needed, though, depending on the substances that the process bath contains, and it can for example be RO or activated carbon (Miljösamverkan Västra Götaland, 2001).

The treatment methods for emulsified fluid and degreasing baths that are considered to fulfil the BAT are (Bergström, 2007):

- Ultra filtration and reverse osmosis
- Evaporation and activated carbon or reverse osmosis plus activated carbon or reverse osmosis
- Evaporation with reuse of condensate

Final treatment after both degreasing baths and cutting oil can be that waste is treated by evaporation, UF and RO and this will minimise the waste amount considerably and lead to that the waste water will not be toxic (Röttorp, 2007; Filipsson, 2002). In Appendix 5 an example of a cost-benefit analysis of this application is shown.

4.2.3 Ultra filtration in the painting step

Using ultra filtration in the electrophoretic painting step is a technology to improve the paint finishing quality and recycle paint (figure 27). It is used at Torslanda automobile factory for example. With this technology water is also saved and the amount of waste water reduced.

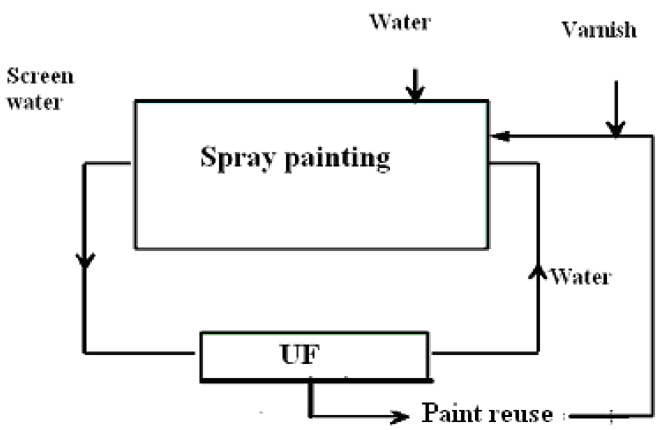

Figure 27: Ultra filtration treatment in the painting step (Bjurhem, 2004).

4.2.4 Treatment of the phosphate bath

The most usual method in the car industry is zinc phosphating and in the alkali-zinc process activated carbon and evaporation treatment can be used (figure 28). Activated carbon separates unpolar oil residues and works best as the water contains low concentrations of grease. With this technology the process chemical and water can be reused.

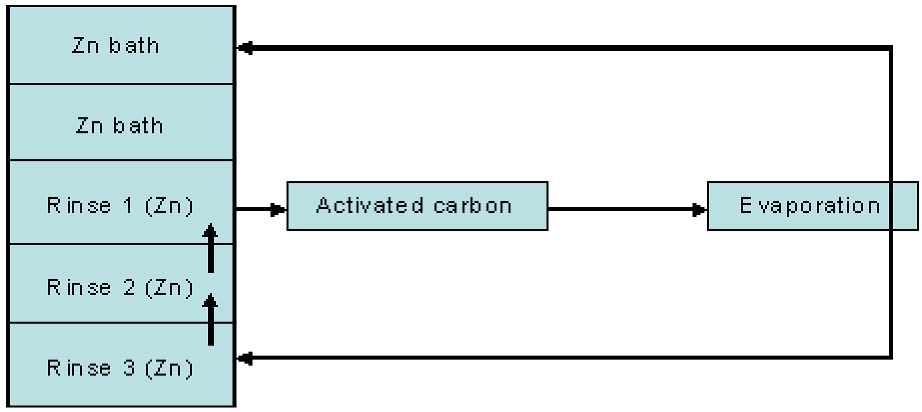

Figure 28: The alkali-zinc process and the applications of activated carbon and evaporation (Filipsson, 2002).

An example of the separation rate with evaporation treatment of rinse water after alkaline zinc plating, with a very high separation rate, is shown in table 8.

Table 8: Separation rate with evaporation treatment (Filipsson et al., 1996)

Treatment	**Zink [mg/l]**	**pH**	**Conductivity**
Rinse water	60	13	106,000
Evaporation	<0.009	9.3	4

The rinse step in the zinc phosphating step could also be treated with RO and IE followed by evaporation.

4.2.5 Passivating rinse step

The passivating rinse step could be treated with ion exchange and evaporation according to Jan Kastensson (pers. comm.). The ion exchange carefully maintains the iron and zinc concentrations. This method reduces the operating cost greatly and gives an absolutely reproducible deposit quality (Autotech, 2007).

4.2.6 Treatment of cutting oil

Cutting oil can be treated with UF, RO and evaporation. This combination of treatments is used in Volvo’s factory in Skövde, Sweden (STF, 2007), but according to Jan Kastensson (pers. comm.) evaporation is a better solution as it is more dependable and trouble-free.

As both companies have cutting operation a central cutting oil system is a very good technology to use as the cutting oil and its quality can be improved With Mercatus cutting fluid purification the quality of what you manufacture is improved while saving money and the environment through effective purification, time gains and reduced maintenance needs (Mercatus, 2007).

4.2.7 Reduction of water use

The water consumption varies a lot, mainly depending on water saving applications but also on type of process and the product shape. Reduction of water use is very important in order to reduce water effluent, which also minimizes the quantity of pollutants that is emitted and the waste that is produced (Klingspor, 1997).

To reduce the water use it is very important to use the appropriate water rinse technique as the largest use of water is within the process of rinsing between the process steps (EPA, 2007). The aim with the rinse is to decrease the amount of unwanted substances from the product. This is very important in order to avoid poor quality of the product and also in order to assure that following baths will not be contaminated. Rinsing is usually carried out between nearly all process steps.

Counter current rinse is the most efficient water saving solution (figure 29). The number of rinse steps has to be at least two. Clean water is added to the last rinse bath. The water and the products come from opposite directions. The first rinse step is therefore the most contaminated and the following rinse steps get cleaner and cleaner.

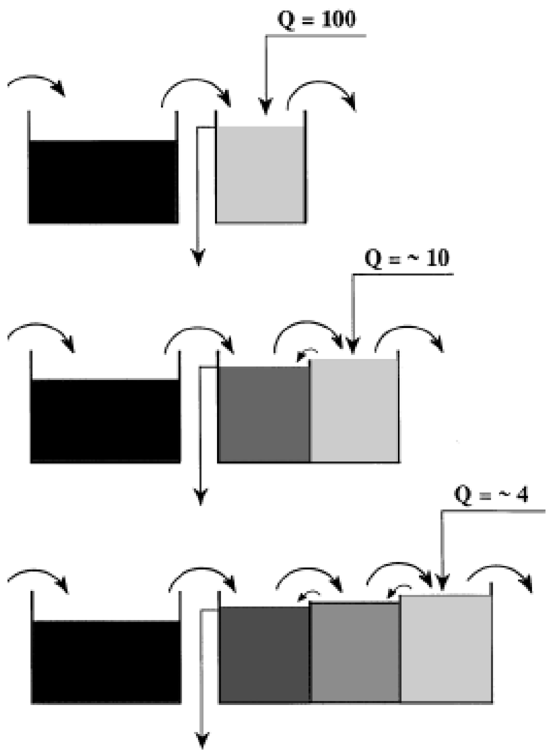

Figure 29: Counter current rinsing (Risberg, 2006).

In the rinse step, counter current rinse is used and this technology saves a lot of water. Preferable is three-stage counter current steps as it saves much more water (table 9). Counter current rinse is used very much in the Swedish industry (Bjurheim, 2007).

Table 9: The efficiency of counter current application.

Rinse system	Relative consumption of water
Single stage	1000
Two-stage counter current	32
Three-stage counter current	10

It is also very important to limit the so called drag-out, the liquid, which remains adhered to the product surface when removed from a process bath (EPA, 2007).

A deficient rinse treatment system can cause bad quality of the product but also that water that is low-polluted is not used sufficiently (Ekström et al., 1970). Low-polluted water in a sufficient rinse treatment system with counter current applications and a low drag can instead be reused without pollution content disturbing the process (Solyom, 2005).

4.3 THE WASTE WATER TREATMENT MARKET IN CHINA

When China first started to import water and waste water technology equipment it received multilateral and bilateral loans. Nowadays countries that have good market shares in China are: Germany, Japan, France, Canada, Australia and Israel (U.S. Department of Commerce, 2005). Some of the drivers of the waste water treatment facilities and equipments could be:

- National Western Development programs
- Projects of introducing water from the South to the North of China
- The Beijing Olympic Games due to environmental pollution control projects related to this.
- New business chances in environmental Protection Market brought by Chinas entry into WTO

The demand and need for waste water technology improvements in the domestic market in China resulted in further introduction of advanced technology in the 10th five-year plan. Technologies such as membrane technology, anaerobic technology, grey water[6] treatment technology and recycled water quality stabilization technologies were introduced. It is estimated that the export of industrial waste water treatment equipment will increase and make the cooperation between local and foreign enterprises more common.

Outsourcing of the waste water treatment amongst key industries (large-scale industries) to professional contractors is becoming more popular. This enables the enterprises to concentrate on their main business instead of tackling the strengthened water pollution control (China Business, 2006). One problem is that the strengthened water pollution control only concerns the key regions and enterprises above the county level whereas the township and the non-key enterprises should be included as well (SEPA, 2004).

[6] "Household water" from the kitchen, bath or laundry, which generally does not contain toilet water or excreta.

In Wuhan there are more than 40 certified companies established on the market that are involved in waste water treatment in Wuhan, but there is no company that is dominating

Research in this area is encouraged and in Wuhan there is for example a pilot plant for testing waste water technologies at Wuhan University and Wuhan Safety & Environmental Protection Research Institute (Zhu et al, 2007).

4.3.1 Establishment of Swedish waste water treatment in the Chinese market

Swentec emphasises the importance of having economic incitements to accomplish a more resource efficient society and brings up the problem of China having too low prices on water and electricity and almost non-existing taxes on petrol. Another problem that Swentec emphasises is the weak structured governmental management on local levels and the badly working cooperation between authorities.

Listed environmental technology will be duty and tax free, making it easier and cheaper to import (Gullbransson, 2007). The reduction in VAT [7], giving a price reduction on energy intensive goods, implemented last February, will be further complemented by export taxes on similar goods starting in June 2007 (WTO, 2006).

One of the major problems on the Chinese market according to Swentec is that it usually takes a very long time to close a deal, implying high risks and high costs. One way for smaller companies to get established on the Chinese market could be as suppliers for European companies that are already established. Another way could be to make a coordinated campaign to market products and services and to learn from other Swedish companies that have penetrated the Chinese market, like for example Purac. It is also very important to be present in China either by a representative or for example through the Swedish Export Council or other organisations as for example environment technologies centres.

The proposals on how to increase the export achieved by the members of the organisation SET was summarized shortly by Rosell (2007):

- Finance demonstration plants
- Stimulate purchase of sustainable environment solutions
- Stimulate BAT
- Improve cooperation when marketing abroad

The SET members are therefore welcoming the DemoEnvironment project.

[7] VAT
Value added tax is tax on exchange and it is levied on the added value that results from each exchange.

5. ANALYSIS AND DISCUSSION

The three Swedish companies Vilokan, Mercatus and Polyproject provide good waste water treatment solution for surface treatment industries, including the automotive industry.

The automotive industry was chosen to be studied as it is a major industry in Wuhan. The Hubei province is one of the four automotive manufacture regions in China, and two of six main vehicle producers in Hubei are situated in Wuhan, DPCA and DHAC. China's entry into the WTO in 2001 brought new business chances in the environmental protection market. Chinese automotive industry has thereby been provided with more opportunities to export its products and become suppliers of foreign customers in China. It has been forced to address environmental sustainability and to increase its international competitive ability. It is furthermore expected that China will become one of the largest producers and users of automobiles. Environmental practises as Green supply chain management (GSCM), ISO 14001 certification, cleaner production (CP) (Zhu et al., 2007) and ISO/TS 16949:2002 as well indicate strengthened environmental requirements on the automotive industry. This implies that the automotive industry should be very interesting to study and an interesting market for Swedish waste water treatment.

Conventional waste water treatment in the automobile and the metal workshop industry is an end-of pipe treatment with hydroxide precipitation. The waste accumulation from this treatment is mainly in the form of metal hydroxide and isn’t sustainable in the long run. Cleaner production waste water treatment has therefore been studied, waste water technologies that the Swedish companies provide. The following waste water technologies were chosen be studied was:

- ion exchange (IE)
- reverse osmosis (RO)
- ultra filtration (UF)
- evaporation
- lamella separation
- active carbon
- central systems for cutting oil treatment

5.1 CASE STUDY ANALYSES

Both DPCA and DHAC dumped their degreasing baths very seldom, which implies that the prolonging of the degreasing bath might not be a feasible improvement. “Hot water knock-off” is used at least in the DPCA factory. This might improve the quality of the degreasing bath, i.e. remove the free oil, but the emulsified oil still remains to be treated.

Result and ranking of the sub flows concentrations, bio-degradability, toxicity etc, as well as knowledge about the interplays between chemicals, are needed in order to draw conclusions about which treatment should be implemented. Such information can be used to evaluate reuse and substitution of chemicals and reuse of water. All data provided by DPCA and DHAC were end-of-pipe data and this wasn’t enough to evaluate the treatment implementations. During the visits to the companies I wasn’t able to see the treatment process or get information about the treatment process in the factory. The monitoring data provided were based on samples taken during a three-day interval. The accuracy and representativity of these values can't be assured but all of them lived up to the pollution standards.

Some of the most important actions to "close the waste water treatment" or rather minimize the waste and waste water are to reduce the drag out and minimize the rinse water with, preferably, counter current rinse. As for DPCA, counter current wasn't used and could be implemented extensively in the factory. The DPCA factory is ten years old, which may account for this. DPCA is, however, planning to expand and water saving measurements are considered as well as implementation of activated carbon as a final treatment. DHAC has a counter current rinse in the pre-treatment before the degreasing and could implement this in the process line as well. Counter-current rinse takes quite much space, implying that it might not be feasible in the process rinse steps.

Both DPCA and DHAC are mixing their production process water with municipal waste water and this dilution increases the waste water amount that is formed after the chemical precipitation treatment. Another disadvantage is that more hazardous waste is formed. The dilution may be required in order for the following biological treatment to work satisfactory as the water treated in the biological step will be less toxic. Cleaner production technologies could instead be implemented in order to treat the water before the biological treatment.

The waste water treatment at the big car factories DPCA and DHAC is quite good but other companies in the automotive industry in Wuhan do not have as good waste water treatment, if or any at all. Besides the studied DPCA and DHAC in the automobile manufacturing industry there are ten companies in the automobile parts and fitting manufacturing industry, one vehicle body manufacturing company, two carriage manufacturing companies and a special vehicle manufacturing company situated in Wuhan that had data on their sludge, but for these no waste water treatment information could be obtained.

Because no chemical controls are performed and because companies are not forced to inform, chlorinated degreasing agents can still be used. If chlorinated degreasing agents are used the treatment line should be constructed and managed in such a way that the treatment of the product are performed in a closed treatment plant.

The reduction of Cr^{6+} to Cr^{3+} is used by the automotive industry because it is an easy solution. Ji Min Fang (pers. comm., 2007) at Wuhan University of Technology thought it would be very interesting to know if Sweden has any good solutions for this. He knows that there are some factories in the east of China that are looking for this kind of solutions. IVF has done a lot of research about this including the Chromatex project. This could be interesting for a future master thesis.

For the ED painting, where watery painting is used to varnish, in Wuhan's automotive industry, membrane technology such as ultra filtration is possible to use. Ultra filtration in the ED-painting step is a technology to improve the paint finishing quality and recycle paint and it is very efficient according to Allan Dunevall (pers. comm.) and also known in China as feasible treatment. It is unknown if they use this ultra filtration application at DPCA and DHAC but according to Ji Min Fang it is very likely. I still assume that they don't use it as I was told at the visits that they didn't use any membrane technology, including ultra filtration, at the factories. As the painting step is a step in the manufacturing process it is possible that they didn't want to reveal their production process as much was secret.

Very few Chinese companies use ultra filtration (UF) in the degreasing bath because it is expensive but some use UF in the ED painting step to reuse paint. The techniques that were presented for this kind of treatment were considered to be too expensive generally, although there was an interest at both the EPRSI office and the companies as well as at the university.

Evaporation calls for very high investment costs but is very reliable for different waters and gives a very good treatment result. A polish treatment step, for example RO or activated carbon, may be needed depending on the substances the process bath contains.

The waste water treatment of both DPCA and DHAC is based on chemical precipitation, mechanical and bio-chemical treatment and is working very efficiently. The DPCA waste water treatment plant is ten years old and the DHAC waste water treatment is very new, just four years old. DPCA and DHAC have relatively good waste water treatment and they live up to the Chinese standards and they didn't have any demand for any change/improvements of their waste water treatment. The companies found their waste water treatment satisfactory at this moment.

Implementation of an ultra filter at the bus maintenance-field would be very good to minimize the emulsified oil but too expensive according to Bjurhem (2007) for these big amounts of flow. He also remarks that the water should be reused at least in the bus wash.

5.2 SWEDISH COMPANIES

The Swedish companies Vilokan and Mercatus are already established on the Chinese market but Polyproject is not yet. They all have in common that they want to expand on the Chinese's market. If they can market their technology well they could probably have a good market in Wuhan as well. The environmental technology centre could be a very good way to do this as the employees at the centre can provide marketing service for the companies and have the knowledge and ability to present it for the customers in Wuhan. Good ways to market the Swedish waste water technology could then be:

- An exhibition at the ESPRI office
- Education
- Demonstration equipment in Wuhan

Mr Du at the ESPRI office showed an interest in the Swedish technology and he was really positive about Mercatus having their homepage available in Chinese: A good example for all the Swedish companies in order to market their products better in China.

It is very important to have contact with the right persons in order to market the Swedish waste water treatment. The department of pollution control at ESPRI should be more involved in this environmental centre as it is handling waste water treatment projects. Cooperation with EPB would also be very good as it is handling the control of industrial waste water.

6. CONCLUSIONS

6.1 THE CASE STUDIES

- The waste water treatment in DPCA and DHAC was rather good and new and they had an interest in Swedish waste water technology but it was considered to be too expensive solutions. They consider their waste water treatment to be “good enough”. Furthermore, both DPCA and DHAC are following the standards, so they are not in need for any new implantations.

- In the long run the cleaner production application can probably be good solutions for DPCA and DHAC as the environmental regulations are strengthened, especially in the automotive industry, but right now water saving techniques as counter current rinse and end-of-pipe treatment with these techniques are more interesting.

- The conventional waste water treatment used in DPCA and DHAC, and most likely in all other waste water treatment in the automotive industry in Wuhan, leads to that the main part of the heavy metals and the process chemicals end up in sludge that has to be put on landfill or incineration. Cleaner production could therefore be implemented extensively in these factories.

- Cleaner production technologies may be implemented instead of dilution with municipal waste water in order to treat the water before the biological treatment and minimize the waste amount that is formed.

- Counter current rinse could be implemented extensively in both DPCA and DHAC and would reduce the water consumption considerably

- The ultra filter that could be used in the bus maintenance-field was considered to be good but too expensive.

- The Swedish companies and IVL have the knowledge to optimize the waste water treatment in these case studies.

6.2 STIMULATING ENVIRONMENTAL REGULATION

- Fees based on both flow and pollution amount and not like now when it is just based on the waste water flow amount would be good.

- The monitoring data in the monitoring report from DPCA and DHAC are based on three days monitoring but should be mean value over the year instead, i.e. with samples taken at least every month.

6.3 ESTABLISHMENT OF SWEDISH WASTE WATER TECHNOLOGY ON THE CHINESE MARKET

- China is an interesting market for Swedish waste water treatment.

- Good marketing is needed. The environmental technology centre could be a very good way to do this through education and exhibitions and the employees' knowledge of the Chinese market. It is important for Swedish companies to cooperate and share knowledge to other Swedish companies in order to establish in the Chinese market.

- Swedish technology is generally considered to be too expensive compared to Chinese technology. The only way to "sell" this technology is to present a really good solution and pay off plan. It is unfortunately very difficult to get data to be able to do a cost benefit calculation, as many of the parameters are not documented or "business secrets".

- Very important for the Swedish waste water treatment companies in order to establish on the Chinese market would be to have some really good pay-off technology solutions that would "save money" over time or production in China to cut the prices considerably.

- Demonstration plants are a perfect way for Swedish waste water treatment companies to establish on the Chinese market. Support instruments like DemoEnvironment that sponsor such projects will probably make Swedish waste water treatment more known.

- It is very important to have contact with the right persons in order to market Swedish waste water treatment.

Indicators that are positive for the waste water business in China are:

- The Chinese Government promotes foreign waste water technology and know-how and EPB and ESPRI in Wuhan had an interest in Swedish waste water technology

- The pressure on Chinese industries is becoming stronger and the pollution fees are getting higher as well as pollution standards

- Reduction of VAT

- In Wuhan as well as in all of China, Swedish water technology is rather unknown but has a good reputation

- The environment awareness in the automobile industry is very high so this should be a good market.

6.4 FUTURE PROJECTS AND IDEAS

- I think this report could be a good platform for a second feasibility study in the metal workshop industry in Wuhan and China

- Volvo is going to establish in Wuhan and that could be a perfect opportunity to implement Swedish waste water equipment

- Industrial waste water treatment is controlled by EPB and it has the authority to take samples on waste water. Future feasibility studies on industrial waste water studies should be more coordinated with EPB. Data that are needed to do cost-benefit analyses could then more easily be obtained.

- The pollution control department at EPRSI is also managing waste water treatment projects and it would be very interesting to cooperate with them

- It is very important to find a proper way to treat the waste from the automotive zone. Presently the waste is put on a landfill and EPB has not found a proper way to treat it yet.

- Good solutions for reduction of Cr^{6+} to Cr^{3+} could be interesting for a future master thesis.

Interesting to study could be:

- To do a more thorough study of the whole automotive industry and its corresponding supply chains in Wuhan.

- Bus and other vehicles factories' waste water, as the water is probably much polluted because the vehicles are cleaned manually, although some of the biggest companies have waste water treatment.

- Small car parts factories.

- Old factories from the seventies that often don't have any waste water treatment at all.

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APPENDIX 1 – ED PAINTING

The principle of ED painting is described in figure 1. The electrically charged particles are attracted to the vehicle part, thus improving the transfer efficiency of the system. This ED varnish is used for the corrosion protecting basecoat.

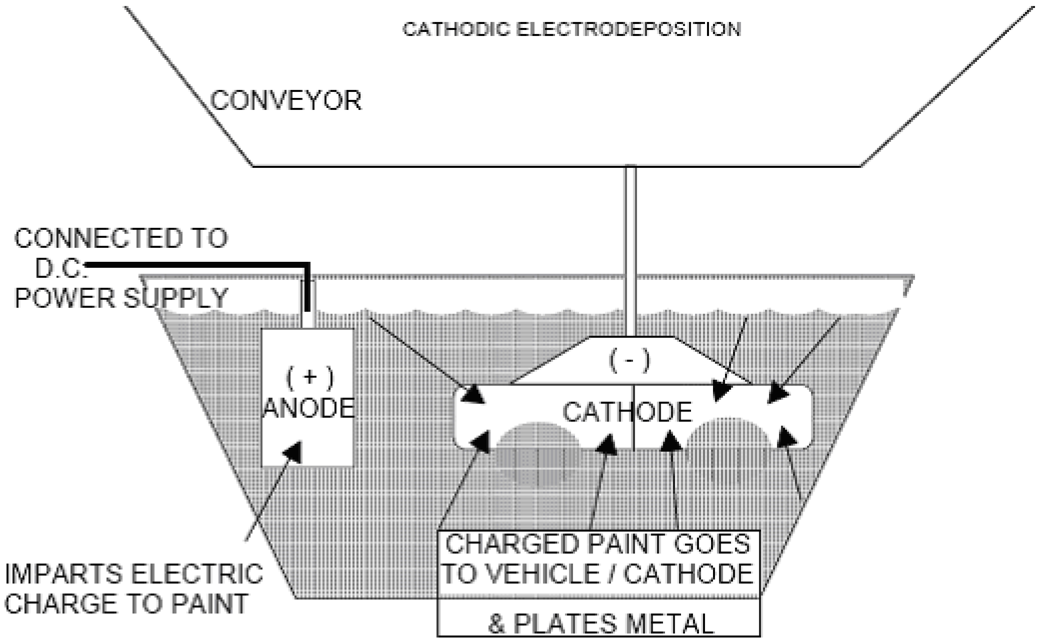

Figure 1: ED painting procedure (EPA, 1995).

APPENDIX 2 – QUESTIONS FOR THE SWEDISH COMPANIES

Questions for Swedish companies

1. In what countries are you present today?
2. Do you have any companions/partners in Sweden or other countries?
3. Can you describe your waste water technologies and their main purpose?
4. What kind of waste water technologies could be possible to export?
5. Are you interested in exporting your technologies abroad?
6. Where are your technologies used today i.e. in what industrial sector etc.?
7. Do you have any timeframes for exporting technology? (This question is asked if they haven't done that to get a time perspective on when the technology can be implemented in China)
8. What are the advantages and disadvantages of these technologies?
9. Are there any special data on substances that are needed to be collected, for example BOD7, SS, P, N and heavy metals i.e. for implementing reasons?
10. Are there any other parameters that can be of importance for example dimensions, capacity, aggressiveness, temperature and pH?
11. Are there any collected material on your technologies and how they can be implemented? For example brochures, data sheet, technology specifications etc.

APPENDIX 3 – QUESTIONS FOR THE CHINESE COMPANIES

Questions for Chinese companies

1. What's your profession at the company?

2. Do you know any Swedish companies in the water purifying business?

3. What kind of technology is used to treat the waste water today? During how long time has this technology been used?

4. Are there any short term or long term plans about changing the production, for example reuse of more water and chemicals.

5. Do you intend to change your waste water treatment? Which demands do you have?

6. What is the yearly cost of your waste water treatment? / What do you pay or do you pay something to the governmental waste water plant?

7. What kind of routines do you have to control your control systems?

8. Do you think it exist good technology solutions for improving your waste water treatment in China?

9. Could you consider consulting a foreign company for help with improving your waste water treatment or for the improvement of any other environmental technology solutions in your company?

10. Describe in a simplified way your production and its flows in a process schedule.

11. Specify possible sub flow size (m3/s) and their composition

12. Do you have backward flush and in that case where in the process? If not backward flush save a lot of water and money.

13. How often do you dump the baths and how much does it cost inclusive water.

14. In the degreasing step IVL have developed a technique that continuously separates waste and lengthen the life span of the "baths" i.e. the cleaning chemical can be reused. This is built on membrane technique and reuse. With this technique the baths never degrade and one does not have to "dump" the baths. Continuous treatment of the baths also counteract that the quality of the baths becomes less effective. This leads to better quality of the products, in this case varnished cars. A pay off solution to this can be offered if one is interested. .

.
15. What is the total discharge of waste water? Can I have some data of this?

16. How much water do you use in the production (m3/s), both intake and outflow? Can I have some data on this?

17. What composition has the waste water discharged from the company? Specify the content of the different substances in the waste water, e.g. salts, metals etc. Can I have some data of this?

18. What is the amount of COD in the ingoing water (kg/m3) or (mg/l)?

19. What is the amount of COD in the outgoing water (kg/m3)?

20. Which quantities COD is discharged yearly (kg/m3 year)?

21. What is the yearly use of water per kg/l product?

22. What kind of chemicals do you use in each step of the production and what kind of chemicals do you use to clean the water?

23. What/which products that I presented did you find most interesting and why?
(I will present some Swedish waste water treatment products that three Swedish companies
in the water purifying business provide. These companies collaborate with the Swedish environmental institute and Borlänge energi AB, an environmental company on municipal level).

24. Are there any persons that I can contact if I need to ask some further questions? What are the opportunities for a follow up during the project?

Specific questions concerning the degreasing bath:

A. How big is the volume of the degreasing bath?
B. How big is the area that is treated in the degreasing bath?
C. How much often do you dump/clean the degreasing bath every year? Do you tap out some waste water continuously it that case how much.
D. How much do the chemicals that are used in the degreasing bath cost?
E. How do you treat the waste?
F. What is the chemical composition of the permeate

(These questions was presented in a version translated to Chinese)

APPENDIX 4 - SBR

SBR is a biological treatment that is used in the Chinese automobile factories. SBR stands for Sequential Batch Reactor and is a sequential variety of biological treatment. Figure 1 shows the same tank at different times. The most important difference from regular active sludge treatment is that the sedimentation of biological sludge occurs in the same reactor. The advantage of this is a compact treatment, but a buffer container before the reactor is needed if it is not a part of a continuous system.

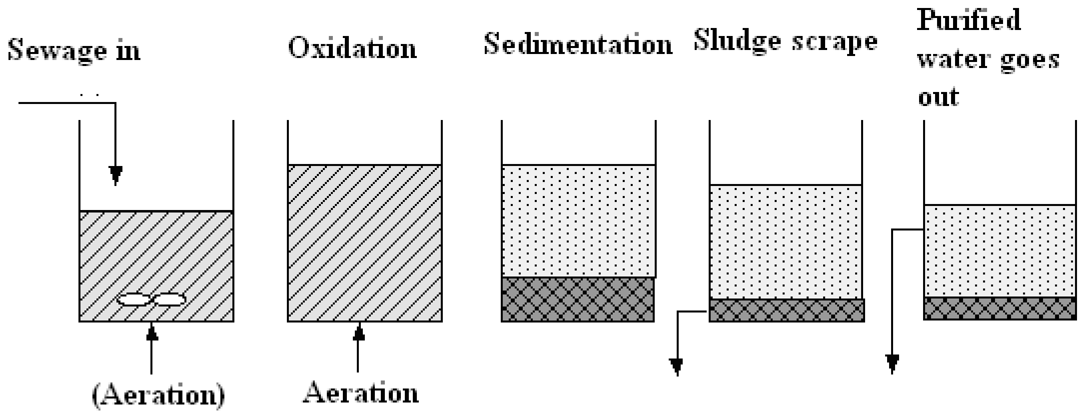

Figure 1: Active sludge with SBR-method.

Approximately 20-40 percent (by volume) of the already treated water (the last step in figure 1) is let out depending on what kind of water is treated and which substances are going to be decomposed or transformed. After that, corresponding amounts of untreated water is pumped into the first step. This can be done with or without aeration. In the second step the system is aerated and it is foremost during this step that the decomposing of organic matter occurs. At that step ammonium can be oxidised to nitrate. If removing of nitrogen is wanted, denitrification, a step/phase with no aeration and just stirring is needed in between steps 2 and 3. An external carbon source has to be added in that case to enable denitrification as the nitrate oxide transforms the carbon source to CO_2 and water, and the nitrate is reduced to N_2.

I the next phase the stirring is shut down and the biological sludge sediments. After that a small amount of the sludge is taken out to maintain a steady amount in the system as the sludge is continuously growing.

At last a part of the treated water is taken out of the system. The whole cycle takes about four to eight hours.

In automobile factories sequential sedimentation without biological treatment can probably be used according to Mats Ek (2007, pers. comm.). An advantage with this technology is that it is a compact solution.

APPENDIX 5 -VALUES THAT MAY BE NEEDED TO DO A COST-BENEFIT ANALYSIS AND AN EXAMPLE

1.1 A cost-benefit analysis

Example of a cost-benefit analysis of final treatment of degreasing baths:

Table 1: Efficiency data (Filipsson, 2002, modified by Jan Kastensson, pers. comm., 2007)

	Mineral oil [mg/l]	**COD [mg/l]**	**TS [mg/l]**	**Toxity [100/EC20, t=5 min]**
Bath 1:				
Untreated	2 800	14 600	22 800	500
UF-permeate	0,3	2 000	14 100	36
RO-permeate	<0,2	52	395	5
Bath 2:				
Untreated	1 500	11 000	4 200	7700
UF-permeate	27	3 300	1 800	21
RO-permeate	<0,2	46	50	<<1

Table 2: UF/RO and evaporation (Filipsson, 2002, modified by Jan Kastensson, pers. comm., 2007)

Capacity (UF+RO)	**20 l/h**
Membrane area UF	1 m^2
Membrane area RO	2 m^2
Costs for UF membrane (tubular)	2 500 Yuan/m^2
Costs for RO membrane (spiral)	1 500 Yuan/m^2
Energy (UF+RO)	10 kWh/ m^3
Energy, evaporation	160 kWh/ m^3

Table 3: Investment costs 20 l/h (Filipsson, 2002, modified by Jan Kastensson, pers. comm., 2007)

	UF/RO	**Evaporation**
Investment costs	300 000	400 000

Table 4: Running cost (Filipsson, 2002, modified by Jan Kastensson, pers. comm., 2007)

	UF/RO	**Evaporation**
Service	6 000	8 000
Energy	500	7 000
Membranes	5 500	
Cleaning agents (UF+RO)	1 000	
Total [Yuan/year]	13000	15 000

Table 5: Total cost (Filipsson, 2002, modified by Jan Kastensson, pers. comm., 2007)

	UF/RO	**Evaporation**
Investment costs [Yuan/year]	60 000	80 000
Running costs [Yuan/year]	13 000	15 000
Total [Yuan/year]	73 000	95 000

1.2 Running cost in the WEDZ

Both DPCA and DHAC are located in the Wuhan Economic and technology area, which is a national development zone oriented towards the automotive industry (WDHAC, 2007).

Table 6: The power prices in the WEDZ development area. Note that peak load is at 10:12 am and 18.00-22:00 pm and valley at 00:00-08:00 am and the rest of the time is so called normal charge (WEDZ, 2007)

Categories	**Specification (Yuan/kwh)**			**Basic charge**	
	1-10 [kw]	35-110 [kw]	≥10 [kw]	Maximum demand (RMB7kw/month)	Transformer capacity (RMB/kwa/month)
Normal	0.450	0.435	0.42	30	20
Peak load	0.769	0.742	0.715		
Valley	0.242	0.235	0.228		

Table 7: The water cost in the WEDZ development area (WEDZ, 2007)

Categories	**Cost (RMB/m^3)**
Industrial	1.0
Drainage fee	0.8

Table 8: Common salaries in Wuhan (WEDZ, 2007)

Profession	**Salary (Yuan/month)**
Management personal	1 000-1 600
Technician	800-1 200
Skilled operator	600-800
Low-skilled operator	460-600

APPENDIX 6 – THE SLUDGE CONTENT OF THE AUTOMOBILE ZONE LANDFILL

Table: The sludge content from the automobile zone landfill

Monitoring Factor	Mg	Pb	Cd	Cr	Cu	Zn	Ni	As
	[mg/kg DS]							
Sampling no WT051025	3.0	470	17.4	53.4	178	9529	163	7.5

APPENDIX 7 - WASTE WATER TREATMENT TECHNOLOGIES

Membranes

Membrane technology is a separation technology and two phases are separated, the permeate and a smaller part called retendate (concentrate) counting for 1-20 percent of the treated volume. The substances that can not go through the membrane due to size, shape and charge stay on inflow side and build up a concentrated phase. The membranes separation character is specified as a “cut -off”; the molecular weight of the smallest special molecule that is held back of the membrane, see figure 1 (Klingspor, 1997). The cleaned water that goes through the membrane is named permeate. How much permeate that is formed can be described with pressure difference over the membrane (Low et al., 2004). The goal with this technology is to separate unwanted substances and reuse water and process chemicals. The filter capacity should furthermore be maximal and the waste should be minimized.

In the automotive industry membranes can be used to treat:

- varnish
- emulicified oil
- degreasing baths
- water containing metal etc.

The applications areas could be:

- kidney in process systems
- final treatment of used waste water flow
- pre-treatment before biological systems or together with evaporation.

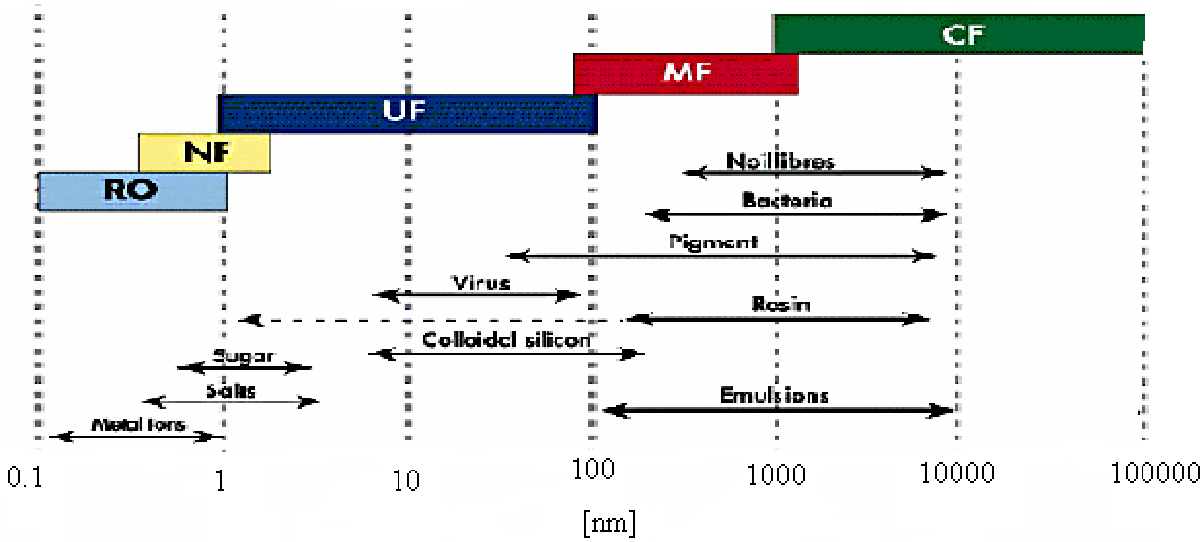

Figure 1: Types of membranes and their “working areas” (Mercatus presentation, 2007).

Reverse osmosis

The principle of RO, short for reverses osmoses, is that the water molecule is pressed trough a semi-permeable membrane due to the force of the water pressure (KTH, 2006). The pores in the membrane are smaller than 10^{-10} m and the pollution is separated from the water with different molecule forces. RO has a "cut-off "of less than 500 and this demands high pressure, 20-80 bar (Klingspor, 1997).

RO has a very good separation potential for aqueous low molecule mass solutions and aqueous organic solutions. It takes away a major part of all sorts of pollutions as for example several ions, heavy metals, organic material, pyrogens, virus, bacteria, particles and colloids. Some other advantages and disadvantages with this technology are listed in table 1.

Table 1 Advantages and disadvantages with reverse osmosis**.**

Advantages	**Disadvantages**
Removes a major part of different sorts of pollutions	The membranes may be useless after a while if they are not protected.
Can be used to recover process chemicals	Expensive but usually not in the long run if used properly
Minimum maintenance	Requires higher osmotic pressure if salt content is high
Good control of parameters	
No electricity or chemicals are needed	

Reverse osmosis could also be used to reuse rinse water after the phosphating. IVL has tried this application at Volvo and concluded that RO was to be preferred when the water was more concentrated and ion exchange was better when the water was more diluted (Filipsson et al., 1996).

Ultra filtration

Ultra filtration is a pressure driven process where polluted water is pumped with high speed parallel to the membrane surface. The pollution is held back by the membrane and is concentrated in a process tank. When there is a high concentration the process tank is emptied and the membrane is cleaned when it is needed. After that a new filtering cycle begins.

Ceramic membranes are especially suitable for industrial applications due to its resistance against chemicals, pH, solvents and high temperature.

Ultra filtration separated pollution in the interval of 0.001 mm-0.1 mm and demands a pressure of 2-5 bar and it has a "cut-off" between 500 and 300 000 (Klingspor, 1997) and can be used to treat:

- Oily waste water
- Fine solids water
- Metal hydroxide filtration

(Vilokan, 2007)

Advantages and disadvantages with membranes are presented in table 2.

Table 2: Advantages and disadvantages with membranes (KTH, 2006)

Advantages	**Disadvantages**
Chemicals do not need to be added	Expensive compared to conventional treatment
More efficient water treatment compared to conventional treatment.	Can be more sensible than other technology due to risk for fouling, concentration polarities, on the membrane surface
Reuse of process chemicals and prolonging of bath lengths	
Minimal waste	
Saves water	

Ion exchange

Ion exchange is used to separate substances dissolved in water, foremost salts and metal ions but also organic compounds (Vilokan, 2007). The ion exchange has an certain selectivity for certain ions. The ion exchangers' active groups create ion bounding with the ions that are separated from the water (Filipsson et al., 1996). There are mainly two types of ion exchange material; cat ion exchange that separates cat ions and an ionic exchange that separates an ions.

The ion exchange reaction is reversible, which makes it possible to regenerate the ion exchange. When the ion exchange is regenerated, restored to its original state, chemicals are added and an eluate containing for example metals ions are obtained from which the ions could be reused (Klingspor, 1997). In this case the application areas could be:

- Inflow water to improve the water quality
- Rinse water in surface treatment lines
- Final treatment after ultra filtration (Vilokan)
- Gas separation (KTH, 2006)

Through this technique, water can be reused for example for rinse water and the total water consumption decreases as well as the need for final treatment of the waste. In figure 2 are shown Mercatus' and Vilokan's ion exchange equipment.

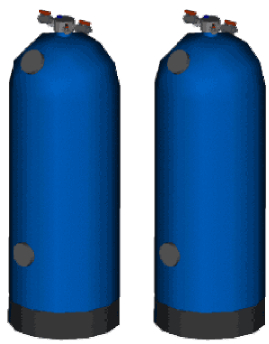

Figure 2: Mercatus' ion exchange (Mercatus, 2007) equipment to the left and Vilokan's EnvoCange ion changer to the right (Vilokan, 2007).

Ion exchange is normally used after a process bath that is containing metals and an eluate is gained with the metal, that can be reused.
Selective ion exchange is used when one ore more ions are separated, for example at the final treatment for the end-of-pipe treatment (Clarin and Luoma, 2000)

Evaporation

Evaporation is based on heating and transmission of heat that leads to condensation after which a concentrate is obtained that can be either separated or reused.

In the first step, the pre-treatment, oil and grease are separated from the water in the evaporation.

The following liquids can be purified in the metal workshop industry with evaporation:

- Consumed cutting oil and coolants
- Rinse water
- Consumed rinse- and surface water baths
- Water based paint and rinse water
- Rinse water/counter current rinse from surface treatments lines.
- Tumbling water
- Water containing solvents
- Water from chemical production

Advantages and disadvantages with evaporation are presented in table 3:

Table 3 Advantages and disadvantages with evaporation

Advantages	**Disadvantages**
Rinse and process water can be reused	Expensive equipment
The concentration grades give low cost i.e. less waste (depends on the fees)	High salt amount limits the volume reduction factor (VRF), the concentration rate, and can be adjusted by adjusting pH
Oil-emulsions drains and the oil can be used as fuels	Skimming, which can be avoided through adding a skimmer decrease
Energy can be reused or be used in the evaporation process	Corrosion, which can be avoided through choosing the right material
Evaporation can handle heavy polluted waters.	Incrustor, deposit on the heat transfer surface
High automatization gives low cost	Energy consumption
No chemicals added and easy to maintain	
The purity is very high after treatment and the water can be reused	

Vilokan for example has low vacuum, falling film technology, multi-step evaporation and forced circulation. Both Mercatus and Polyproject provide evaporation as well.
The choice of method depends on the water characteristics and the type of application.

The energy consumption varies for different evaporation methods but theoretically 650 kWh is needed to evaporate 1 m^3. In real installations the energy consumption could be minimized through energy reuse:

- Energy consumption for a evaporator with a vapour compressor is approximately 50-100 kWh/m^3
- Vacuum evaporator with heat pump/freon system has an energy consumption of 150-250 kWh/m^3.
- Evaporator with falling film technology has an energy consumption of 10 kWh/m^3.

One of Vilokan’s evaporators for industrial waste water, Envovap, is shown in figure 3.

Figure 3: One of Vilokan’s evaporators for industrial waste water, Envovap.

Central systems

Central systems are used for cutting-fluid purification. With this technology the quality of the manufactured product improves through effective purification. The technology is environmental friendly and reduced maintenance is another advantage. Mercatus collaborates and develops systems with companies such as Knoll Maschinenbau GmbH – the world's largest manufacturer in this industry sector (Mercatus, 2007).

Lamella separator

The flocculated sewage water flows into the intake that works as a pre-sedimentation. The liquid is then evenly spread between the lamella. The pollution deposits on the lamella and the water is led out (SedSep, 2007). Polyproject has three different versions of SedSep lamella separators (figure 4).

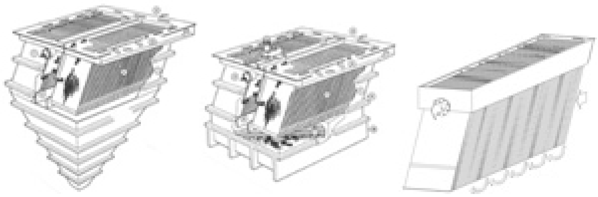

Figure 4: Polyproject's Lamella separators.

Activated carbon

Activated carbon is charcoal with a large specific surface and an enormous interior surface. In this technology all the molecules larger than the water molecule are adsorbed at the surface of coal. The advantage with this technology is that it is possible to separate even dissolved organic material and not just particles, other advantages and disadvantages are presented in table 4. In waste water treatment activated carbon is mainly used to treat water with low amounts of adsorbed substances, for example organic compounds (Klingspor, 1997).

Table 4: Advantages and disadvantages with Active coal treatment for waste water treatment (KTH, 2006)

Advantages	**Disadvantages**
Effective removal of organic substances through van der Waals force/bounding. It also works for molecules with low molecule weight.	Very little effect on inorganic pollutions
High capacity	When all the places on the active carbon are occupied equilibrium is reached and the material is released.
	If the filter is not used for a while bacteria can start to grow on the filter.

Polyproject has an activated carbon product called CarSep (Hård, 2007) that is a continuously working filter but in intervals, when polluted carbon is pumped from the bottom of the filer to cleaning device, the carbon is cleaned (CarSep, 2007).