Implementing Ecological Improvement in Hong Kong

The Pearl River Delta Water Quality

An Interactive Qualifying Project Report
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by

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Abstract

This water quality project is sponsored by Civic Exchange, a non-profit think tank striving to improve Hong Kong's ecological infrastructures. The project's objective is to explore possible solutions to improve the water quality around Hong Kong. WPI students investigated the water pollution caused by agricultural runoffs, along with government policies and wastewater treatment technologies. The project concludes there has been improvement in the water qualities, however more efforts by government and its people are needed to achieve the goal.

Authorship

Acknowledgements

We would like to thank our liaison, Civic Exchange, for providing such an interesting project and the excellent opportunity for us to work in Hong Kong. We appreciate Christine Loh, the organizer of this project, for taking time out of her busy schedule to meet with us weekly and guide us through the process. Special thanks to Lynne Curry and Elizabeth Willmott for working closely with us and provided encouragements and assistants for our work. Last but not least, we would like to thank our project advisors, Prof. Zeugner and Prof. Ma, for spending their precious weekend times to revise our report.

Executive Summary

This Interactive Qualifying Project (IQP) is to work with Civic Exchange on the Pearl River Delta water quality project. The Pearl River Delta is located at the northern South China Sea. It is the main navigation route and water source for all of the surrounding cities. Cities surrounding the Pearl River Delta, especially Guangdong, have undergone dramatic economic reform since the "open door" policy in 1979. The average annual Gross Domestic Product in these cities maintained an incredible 17.9% increase for the past twenty years. Fast industrial and population growth in the area created heavy pollution to the Pearl River Delta. Since it provides water to a broad area and large population, its water quality raised concerns for many people. Civic Exchange conducted a seven-month project hoping to find a feasible solution to the deteriorating water quality in the Pearl River Delta. The project includes a literature review on water pollution and discussions of possible cooperation among Chinese and Hong Kong government agencies to improve the water quality.

WPI students participated in the research for the literature review to provide the necessary background material for this water quality project. The literature review contains comprehensive information on different types of water pollutions. The main water pollution sources in the Pearl River Delta area are municipal wastes, industrial wastes, and agricultural runoffs. Two Civic Exchange members are carrying out research on municipal and industrial pollution while WPI students focused on gathering information on agricultural runoffs for their IQP. In order to collect enough information to write a comprehensive report, students traveled to universities and institutes in Guangzhou and Hong Kong to interview professors and experts; visited environmental

research centers in Guangzhou, interviewed personnel from wastewater treatment consulting companies, and spent hours searching on the internet and reading literature on topics related to agricultural runoffs. All of these methodologies were used to obtain sufficient information given the complexity of agricultural pollutions.

Most agricultural pollutions are categorized as non-point pollutions. Non-point pollutions are pollutions that have undefined sources and are usually washed into the water by precipitation. A key non-point pollution is agricultural runoffs. Because the sources are vaguely located, agricultural pollutions are inherently difficult to analyze and compare quantitatively with other types of water pollutions. Typically, local government offices such as the Environment Protection Bureau would have statistical information on the water qualities of its covered areas. However, Guangdong's Environment Protection Bureau did not provide any statistical data upon request.

Research showed that the main agricultural pollutions come from pesticides, fertilizers, and livestock municipal wastes. Pesticides are substances used to kill, repel pests. By nature, they contain ingredients that are harmful to living organisms. Pesticides could contaminate water when washed into ground or surface water sources. Marine lives would be put in danger, people and animals that drank the water might experience health risks. Fertilizers have similar effects that pesticides have. The main difference is that fertilizers are added nutrients. They are seldom toxic and could boost the growth of some microorganisms in the water. However, the large amount of nitrogen oxide contained in the fertilizers could react with water and become nitric acid, thus causing cancer in human beings and animals drinking the water. Fertilizers could also destroy the ecological balance in the water by promoting the growth of some lives while

killing some others. Livestock municipal wastes are similar to human municipal wastes. Although they pollute the water by their very nature, in most parts they are degradable in water. However, the problem becomes more complicated when the municipal wastes are infected with diseases. People or animals that drink the disease-carrying water could be infected with such diseases. In most parts of the Pearl River Delta, pesticides and livestock municipal wastes are the most significant pollution sources.

The technological method of treating wastewater is by wastewater treatment facilities. There are two types of wastewater treatment plants: ones that clean the water and the others that treat the sewage in the water in order to maintain the water quality of a water body. The first type of treatment plant provides standard water to households. Such water cleaning facilities are essential to urban areas. Since consumers pay for their household water, water-cleaning plants are easy to finance and are usually owned by private companies. On the other hand, some cities do not require people to pay for the sewage treatments. As a result, government has more difficulties gathering funds to build and run sufficient sewage treatment plants. Today, much of the sewage in Guangdong, coming from all sources is dumped directly into the Pearl River. The Guangdong government has set up rules and regulations to stop companies and farmers from adding pollution to the Pearl River. Violators are generally penalized with fines. However, the enforcements of these laws did not show much effectiveness. Some medium to small size companies find that paying the fine is cheaper than establishing and running facilities to treat their wastewater. They would rather accept the penalties than meet the regulations. As for small farms, they create relatively small amounts of pollutions and it is difficult for official inspectors to locate them.

An alternative way to reduce pollution is through a social approach: educating pollution creators on the environmental concepts and methods to stop creating large amounts of pollutions. In terms of pesticide usage, some farmers in China have been heavily overusing pesticides, by up to 35%. This situation not only creates unnecessary pollution to the environment, it also maximizes farmers' expenses. Most farmers have strong beliefs that much of the yield loss is pest-related, and that applying more pesticides would yield higher harvests. In fact, once the amount of pesticides has reached the optimal limit, any additional pesticides have no positive effect on the crops. It is essential to convince farmers that they are using unnecessary chemicals on their crops and let them realize the importance of protecting their ecological environment. The education process would take years of efforts but it is the most important step in order to reduce water pollution in the future.

There is no immediate solution to the water quality problems in the Pearl River Delta. However, actions from the government and its people should be taken immediately. In order to maximize the effectiveness, government, scientists, bankers, and media need to work hand in hand with each other. Summarized from the research that have been done on the project, several recommendations were made:

- Increase communication among governments and its people concerning the issue of pollution through the media
- Increase farmers' appreciation of accurate use of pesticides through free seminars on pesticide use given by Civic Exchange or the proper government authority in convenient locations in the Pearl River Delta.
- Provide courses on the environment issues for students of all ages
- Establish more sewage treatment facilities around the Pearl River Delta
- Promote the usages of alternative wastewater treatment technologies

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1. Introduction

This Interactive Qualifying Project (IQP) took place in two major metropolitan areas in the Far East - Hong Kong and the Pearl River Delta. The high density of population and the first-class industrial developments in both of these areas create tremendous burdens on their ecological environments. Due to the lack of managements from the past, environmental issues have become alarming concerns. The liaison of this IQP – Civic Exchange, a think tank in Hong Kong, is working to bring ecological improvements to both Hong Kong and the Pearl River Delta area.

Civic Exchange is a newly developed, independent and non-profit think tank in Hong Kong. It was established in September of 2000 by former legislative counselor of Hong Kong - Christine Loh and other volunteers. Civic Exchange mainly focuses on existing environmental and social issues. Its objectives are to promote civic education, public awareness of social issues and participation in governance. It is currently working on three projects: Developing a Clean Vehicle Strategy for Hong Kong, Cross-Board Environmental Law Research, and Cleaner Water in the Pearl River Delta. In order to carry out these projects successfully, Civic Exchange established collaborations with organizations such as academic institutes, government agencies and private sectors for funding and technical help. Since Civic Exchange is non-profit, it acquires college students and interns from all over the world to help their work. This year, WPI sent students to work with Civic Exchange on their projects as IQPs.

This particular IQP focused on China's Pearl River Delta's water quality. The Pearl River Delta is situated at southern China, at the most northern port of the South China Sea. Guangdong Province, Hong Kong and Macao are the three tips of the delta.

The Pearl River Delta is the merging place for several main rivers in China, including Beijiang, Xijiang and Zhujiang Rivers. Since China introduced its "open door" policy in 1979, the Pearl River Delta has experienced dramatic changes. This new policy promotes establishing connections with foreign enterprises and welcomes investments from other countries. Knowing China's enormous potential, foreign investors rushed into this tremendous market trying to be the first ones to set their foot into this new place. The Pearl River Delta was one of the first regions to get the most out of the "open door" policy due to its strategic location. Nearby cities are the primary beneficiaries of the Pearl River Delta. The Gross Domestic Product (GDP) of the Pearl River Delta area remained at an average annual growth of 17.9% for the past 20 years, by far the fastest growing area in China.[1]

In the race to become a prosperous metropolitan area, people in the Pearl River Delta area put little thought into their living environment. A growing population increased human consumption, which included daily municipal wastes and household wastes. Industrial wastes are dumped into the water everyday; heavy navigating traffics abuse the delta more than ever. The inexpensive degraded diesel oils that many ships use put many inorganic chemical wastes into the water, which caused destruction to the marine life. These harmful substances not only cause mutations of fish and other marine organisms, but also put them in great danger of extinction. In addition to the negative effects to the marine lives, pollution to the delta also creates health hazards to human beings. Civic Exchange is working to be involved in the process of improving the water quality in the Pearl River Delta.

[1] http://www.shenzhenwindow.net/sez/g18years.htm

There are technological and social methods to address water pollution. One technological way is to use wastewater treatment facilities to treat the wastewater. Other social methods are to promote people's awareness of environmental issues and to raise public education on the environmental pollution. Civic Exchange wants to unite Chinese and Hong Kong authorities to face the water quality issues together and create an effective wastewater treatment method for the Pearl River Delta. Before discussing with the authorities, Civic Exchange conducted a research project to study all aspects of water pollution in the Pearl River Delta area and wastewater treatment technologies. There are three components to the water pollution, municipal wastewater, industrial pollution and agricultural runoffs. Two Civic Exchange members have begun research on municipal wastes and industrial pollution at the end of 2000. WPI students concentrated on agricultural runoffs and some wastewater treatment technologies. The objective of the research is to provide a comprehensive literature review that contains information on all aspects of agricultural runoffs to Civic Exchange. Research was done on the sources and nature of agricultural pollution and also the methods to address them. Since this water quality project is a long-term project, the students were not able to cover every aspect of these projects. Instead, students provided Civic Exchange with key information on agricultural runoffs as a cause of pollution in the Pearl River Delta area.

2. Background on Pearl River Delta

2.1 The Pearl River Delta

The Pearl River Delta is situated in the southern part of Guangdong Province. Guangzhou, Hong Kong and Macao are the three cities that made up the delta. Historically, the Pearl River Delta is the area between Hong Kong, Macao, and Guangzhou (the capital of Guangdong Province). Nowadays, the Pearl River Delta includes the cities of Guangzhou, Shenzhen, Zhyhai, Dongguan, Zhongshang, Foshan, Panyu, and Nanshi, as well as others (See Figure 1). There are 420 cities and towns in the region, and the cities that have the most economic and environmental impacts are Guangzhou, Hong Kong, Shenzhen Special Economic Zone, Zhuhai Special Economic Zone, and Foshan, primarily due to their economic reforms and industrial growth.

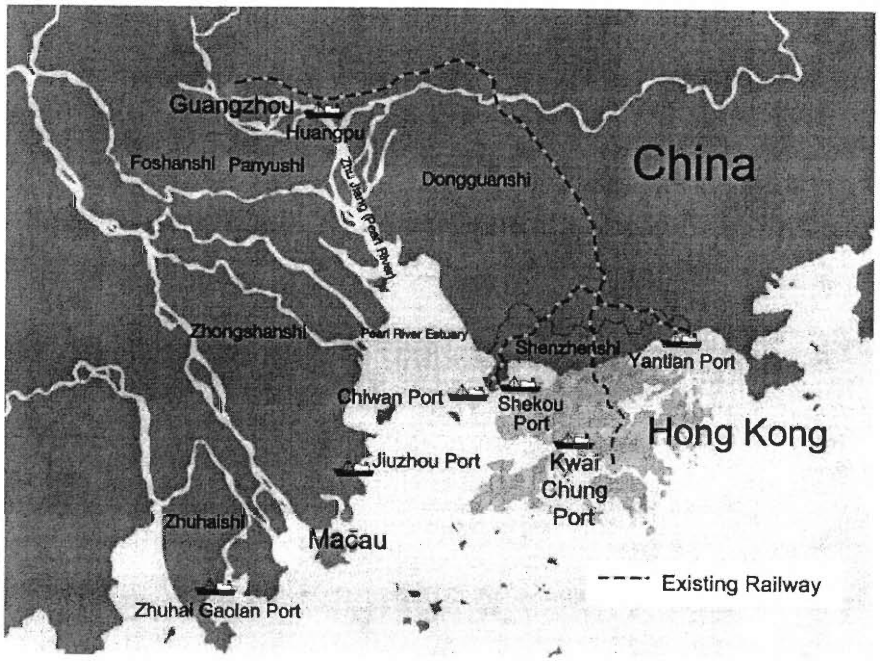

Figure 1. Map of the Pearl River Delta

2.2 Geographic Description

The Pearl River Delta is mainly merged by the Xijang, Beijiang, and Dongjing rivers. It is located in the southern China's Guangdong Province, latitude 21030' to 23040'N and longitude 112030N to 1150E[2].

The Pearl River Delta belongs to the subtropical zone. It has an annual average temperature of 22° C and an annual precipitation 1714 mm with an annual sunshine of 1900-2300 hours. The landforms in the delta consist of wetland, estuary, lowland, plain, dry land, and higher hilly land. The dominant natural soil is red, and the man made soil is paddy soil. Due to the subtropical climate and the fertile soil, the delta favors the growth of grain, sugar and vegetables[3]. It also produces silks, freshwater fish and a large variety of fruits. Therefore, the area around this coast is an important commercial food and cash crop base for China. It is also known as the "Fish and Rice Country".

2.3 History of Guangdong

Settlements were first found in Guangzhou early in the Qin Dynasty (221-207 BC), and around the 2nd century, Guangzhou had already traded with the Romans and Indians. Guangzhou's strategic position on the Pearl River estuary, which was an arm of the South China Sea, served as a great advantage to establish excellent trade links both inland and overseas. European traders initiated trades with Guangzhou in the 1500, seeking products such as silk, tea, and porcelain. However, the peacefulness of the city was ruined in 1773, when the British traders brought in chests of opium. Ultimately, this led to the

[2] http://www.mtl.com.hk/contact/hk_map.htm
[3] http://www.cityu.edu.hk/lib/collect/prd/indexb5.htm

Opium Wars and China's humiliating defeat by the British military settled with the "unequal treaties". These were the dark ages for Guangdong Province[4].

2.4 Economic Migration

The Pearl River Delta was the first region in China to introduce economic reforms since the current government took power in 1949. The long costal line enhanced the development of water transportation for the Pearl River Delta area. Moreover, the Chinese government established three Special Economic Zones (SEZ) in Guangdong Province, Shenzhen, Shantau, and Zhuhai, in order to attract foreign investments. The central government basically gave the SEZ special policies and flexible measurements, which allow the SEZ to utilize a special economic management system. The SEZ allowed special taxes for the foreign investments, and they have a greater independence on the international trades[5]. Moreover, the SEZ's local congress and government had legislation authorities and they were listed separately in the national planning. Furthermore, the SEZ had four characteristics. First, their constructions primarily relied on attracting and utilizing foreign capital. Secondly, the primary economic forms were Sino-foreign joint ventures and partnerships as well as entirely foreign-owned enterprises. Thirdly, the SEZ is export oriented. And finally, the economic activities were primarily driven by the market. For all these privileges and special polices and measurement that the Special Economics Zones enjoyed, they have changed their economy from agriculture to industrial base. Nowadays, the SEZ is aiming to produce more computer systems and software, telecommunication, microelectronics, bioengineering, and electronics integration.

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[4] http://www.lwa.com.cn/

[5] http://www.shenzhenwindow.net/sez/g18years.htm

The Special Economic Zones have been very successful. Foreign investments flowed into China and Guangdong have had great economic growths. People enjoy their improved living standards, but at the same time, they started to acknowledge the environment problems.

2.5 Environmental Problem

Since through the Pearl River Delta thousands of ships navigate every year and most of these ships use degraded marine diesel oil, they have released large amounts of toxic chemicals, which resulted in air and water pollution and eventually caused health hazards to both human and marine lives. People were not well educated on environmental issues and were not concerned about protecting the environment. The U.S. Consulate in Guangzhou has stated that there has been a major decrease in the amount of industrial pollution. Instead, most of the water pollution was caused by domestic use of cleaning products such as laundry detergents, which contained a high amount of phosphorus compounds. Research showed that the level of phosphorus in the Pearl River Delta water was ten times higher than the normal level! Unfortunately, there were not much advanced technologies for purifying water in China. Furthermore, to import advanced water treatment technology from abroad would cost a tremendous amount of money. These environmental problems have emerged publicly and the government is seeking ways to solve them.

3. Literature Review

3.1 Guangdong's Agriculture

Located in the subtropical region, Guangdong enjoys a warm climate, abundant sunshine and rainfall all year round. As a result, Guangdong is a favorable place to grow various crops and can lead up to two or three harvests per year. Major traditional crops that grow in Guangdong include grain crops, industrial crops and gardening crops.[6] These include rice, sugarcanes, vegetables, fruits, flowers and more (See Table 1).

Table 1. Growing area of major crops in Guangdong (Data for the year1997)[7]

	Growing Area (10,000 mu)
1. Grain Crops	5139
2. Industrial Crops	1212
Cane	361
~sugarcane	334
oil bearing crops	525
3. Gardening Crops	1762
vegetables	1416

3.1.1 Sugarcane

Guangdong leads the nation in producing sugarcanes. The growing area of sugarcane totals 3.34 million mu (1mu = 0.004km^2) in Guangdong. In 1997, its total output reached 16.82 million tons, supplying juice, sugar manufacturers and exporting them to cities including Hong Kong. The major Guangdong counties that supply sugarcane are Suixi, Leizhou, Xuwen, Yangchun, Lianjiang and Yingde. The abundant

[6] http://www.investgd.com/main/tzgd/cybg/ny-e/planting.htm
[7] Ibid.

sugarcanes led Guangdong to be the leading sugar production province. Its cane sugar accounts for 40% of China's total. 45,966 tons of granulated sugar was exported from Guangdong, earning 514.8 million USD for the province. Even households that plant sugarcane became more professional. As in 1997, 64,000 households reported to have over 10 mu of sugarcane fields in Guangdong.

3.1.2 Fruits

Guangdong is also famous for growing large varieties of fruits, over forty kinds of commercial fruits are grown annually in the province. Its climate is suitable for the growth of tropical fruits, such as pineapple, longan, mango, pear, etc. It is also a big supplier of oranges, bananas, persimmon and more. The total growing area of fruits in Guangdong reaches 12.93 million mu, which produces approximately 4.15 million tons of fruit annually (See Table 2).

Table 2: Growing area and total output of major commercial fruits in Guangdong (Data for the year 1998)[8]

	Growing Area (million mu)	Output (million tons)
Orange	1.39	0.87
Banana	1.13	1.33
Litchi	4	0.41
Longan	1.79	0.125
Mango	0.4	0.107
Pineapple	0.36	0.25

3.1.3 Vegetables

Just like fruits, many varieties of vegetables can be planted in Guangdong during all seasons. In addition to developing traditional vegetables, Guangdong imports many

[8] http://www.investgd.com/main/tzgd/cybg/ny-e/planting.htm

high quality vegetable species from other provinces and foreign countries. Its vegetable production distributes to 21 large and medium cities, including Nanhai, Gaozhou, Chenghai and more. In 1998, the export volume of vegetables totaled 535,186 tons with a value of 17.1 million USD.

3.1.4 Animal Husbandry

Besides crops, Guangdong is also one of the most important provinces in pig and poultry breeding. Pig is the most important domestic animal in Guangdong. There are approximately 130 pig farms with an annual production of over 10,000 pigs each, 261 pig farms with annual outputs of over 3,000 fattened pigs and 1177 pig farms with annual production of over 500 slaughtered pigs. In 1997, the total number of slaughtered fattened pigs reached 27.47 million heads.[9] With the formulated feed and new scientific techniques, the quality of commercial pigs has been continuously improving. Hong Kong and other provinces import pork meat from Guangdong. Besides pig farms, farmers usually raise a few pigs on their own, and keep them as family properties.

Poultry is another important meat production in Guangdong. Poultry cultivation has been developed rapidly in recent years, enabling Guangdong to become the second largest province next to Shandong in poultry production. There are 271 chicken farms that produce over 100,000 chickens; 8,205 farms have an annual output of over 10,000 fattened chickens. In 1997, Guangdong's poultry production numbered 1.147 billion heads and 1.28 million tons. Table 3 summarized Guangdong's animal production in recent years.

[9] http://www.investgd.com/main/tzgd/cybg/ny/ny-e/animal.htm

Table 3: Gross Output Value of Animal (USD billion)[10]

	1995	1996	1997	1998
Gross output value	2.16	2.375	2.49	2.69

3.2 Pesticide

A pesticide is any substance or mixture of substances intended to prevent, repel, mitigate, or destroy any pest. The stereotype that some people have against pesticides is that they are only used for agricultural purposes. In fact, pesticides are essential to every household. Some common household pesticides are insect repellents, rat poisons, bath disinfectants, and swimming pool chemicals. Plant regulators and defoliants are also considered as pesticides according to United States laws[11]. Pests are any living organisms that cause damage or economic loss or produce diseases. They can be insects, mice, unwanted plants, and microorganisms such as bacteria or viruses.

By their very nature, all pesticides can create different degrees of harm to human beings, animals and the environment. On the other hand, their ability to kill disease-causing organisms and to control unwanted insects helps to maintain a healthy society. Pesticides are widely used on agricultures, in swimming pools, households and gardens.

Some common types of pesticides are summarized in Table 4.

[10] http://www.investgd.com/main/tzgd/cybg/ny-e/plating.htm
[11] http://www.epa.gov/pesticides/whatis.htm

Table 4: Common Pesticides[12]

Algicides	Control algae in swimming pools, lakes, canals, and water used industrially or stored
Attractants	Attract pests (for example, lure an insect or rodent to a trap). Pheromones are chemical sex attractants often used to confuse mating behavior of insects.
Biocides	Kill microorganisms
Disinfectants and sanitizers	Kill or inactivate disease-producing microorganisms (bacteria, viruses, etc.) on inanimate objects
Fungicides	Kill fungi (many of which can infect and cause diseases in plants, animals, and people; examples of disease-causing fungi: rusts, mildews, blights, and molds)
Fumigants	Produce gas or vapor intended to destroy insects, fungi, bacteria, or rodents, used to disinfest interiors of buildings as well as soil before planting
Herbicides	Kill weeds and other plants that grow where they are not wanted
Insecticides	Kill insects and other "bugs"
Miticides	Also called acaricides, kill mites that feed on plants and animals
Microbials	Microorganisms that kill, inhibit, or outcompete pests, including insects or other microorganisms
Molluscicides	Kill snails and slugs
Nematicides	Kill nematodes (microscopic, wormlike organisms that feed on plant roots)
Ovicides	Kill eggs of insects and mites
Repellents	Repel pests, including birds and insects (for example, mosquitoes, fleas or ticks)
Rodenticides	Control mice and other rodent pests

Pesticides contain two types of ingredients, active and inert ingredients. The active ingredients are substances that prevent, kill, or repel the pests, and also substances that act as plant regulators or desiccants. The inert ingredients are used to assist in the

[12] http://www.cdpr.ca.gov/docs/factshts/whatis.htm

application of the active ingredients in many different ways. They can act as solvents to dissolve the active ingredients; serve as carriers to aid the delivery of the active substances; or as adjuvants that help make the pesticides stick or spread out on the application surface.[13]

When formulating a pesticide, manufacturers need to put many factors into considerations. These factors include the type of surface that pesticides would be applied on, the equipments needed for application, runoffs, habits of the targeted pest, and most importantly the safety of the pesticides. All pesticide products are required to have labels on the container listing all of the ingredients (except for non-toxic inert ingredients), the hazardous nature of the pesticide, and the proper techniques to use the products.

3.2.1 Agricultural Pesticides

Three types of pesticides are commonly used for agricultural purposes: insecticide, herbicide and fungicide. Insecticides are used to kill insects and bugs, for they could damage the roots and other parts of the crop, which in turn creates economic loss. Herbicides prevent plants from growing at unwanted places, for they will consume the nutrients in the soil that are intended for the crops. Fungicide kills fungi, for many fungi can infect and cause diseases in plants. Thirty-four agricultural pesticides are summarized in Table 5.

[13] http://ace.orst.edu/info/nptn/factsheets/formulations.pdf

Table 5. 34 common agricultural pesticides[14]

Pesticide	Pesticide Class	Soil Sorption (Koc)*	Hornsby Index** [15]	Leaching Potential***
Acifluorfen	Herbicide	32	32	High
Alachlor	Herbicide	170	113	Intermediate
Atrazine	Herbicide	100	17	High
Bensulide	Herbicide	1000	83	Intermediate
Butylate	Herbicide	400	308	Intermediate
Carbaryl	Insecticide	300	300	Intermediate
Carbofuran	Insecticide	22	4	High
Chlorothalonil	Fungicide	1380	460	Intermediate
Chlorpyrifos	Insecticide	6070	202	Intermediate
Cyanazine	Herbicide	190	136	Intermediate
Diazinon	Insecticide	1000	250	Intermediate
Disulfoton	Insecticide	600	200	Intermediate
Endosulfan	Insecticide	12400	>2000	Low
Ethoprop	Insecticide	70	28	High
Fenvalerate	Insecticide	5300	1510	Intermediate
Fluometuron	Herbicide	100	12	High
Linuron	Herbicide	400	67	Intermediate
Malathion	Insecticide	1800	>2000	Low
Methamidophos	Insecticide	5	12	High
Methyl Parathion	Insecticide	5100	>2000	Low
Metiram	Fungicide	500000	>2000	Low
Metolachlor	Herbicide	200	22	Intermediate
Molinate	Herbicide	190	90	Intermediate
Parathion	Insecticide	5000	>2000	Low
PCNB	Fungicide	5000	>2000	Low
Permethrin	Insecticide	100000	>2000	Low
Phorate	Insecticide	1000	167	Intermediate
Profenofos	Insecticide	2000	>2000	Low
Propanil	Herbicide	149	1490	Intermediate
Simazine	Herbicide	130	22	Intermediate
Terbufos	Insecticide	500	1000	Intermediate
Thiobencarb	Herbicide	900	429	Intermediate
Trifluralin	Herbicide	8000	1330	Intermediate
Vernolate	Herbicide	260	217	Intermediate

* Koc = Kd / (%) organic compound in soil (Kd = concentration of chemicals absorbed / concentration of chemicals dissolved)

** Hornsby Index: the smaller the index, the more likely that the pesticide will leach to ground water

*** Leaching Potential is the tendency for a pesticide to move with water through soil

[14] http://spo.nos.noaa.gov/projects/agchemuse/pesticides_35.html

[15] http://www.ott.doe.gov/oaat/hev.html

3.2.2 Bio-pesticides

In order to protect their crops, farmers need to use various amounts of pesticides. However, the applied pesticides can destroy the balance of the ecological system for they can kill other living organisms (besides pests) existing in the area. In finding solutions to address this problem, researchers discovered biological pesticides (bio-pesticides) for agricultural usages.

Bio-pesticides contain ingredients derived from natural materials such as animals, plants, bacteria, and certain minerals. There are three types of bio-pesticide, microbial pesticides, plant pesticides and biochemical pesticides. Microbial pesticides use microorganisms as active ingredients, such as bacteria, virus and fungus. Each separate ingredient, in general, specifically targets a particular kind of pest. The targeted insect species are determined by whether the particular active ingredient produces a protein that can bind to the larval gut receptor, which causes the insect larvae to starve.

Plant pesticides are pesticidal substances that a plant produces after genetic material that has been added to the plant. For example, an active ingredient from a microbial pesticide can be chosen and the gene of that microorganism is introduced to the gene of the plants. The plants then, will produce that pesticidal substances and kill the pests. The types of microbial genes that are allowed to be used for plant pesticides are regulated by the Environmental Protection Agency (EPA) in the U.S.

Biochemical pesticides are naturally occurring substances that are used to control pests by non-toxic mechanisms.[16] Biochemical pesticides have a very broad range of

[16] http://www.epa.gov/pesticides/biopesticides/what_are_biopesticides.htm

ingredients, meaning that many substances can be categorized as biochemical pesticides. For example, insect's pheromones and scented plant extracts are both biochemical pesticides according to the U.S. EPA. Insect's pheromones are used to affect the mating mechanisms of the pests, thus interfere with their reproduction system. Scented plant extracts are used to attract the pests to traps. Due to the wide range of biochemical pesticides, they are regulated by a special committee created in the U.S.EPA.[17]

There are many advantages of using bio-pesticides. Bio-pesticides are more environmental friendly compared to conventional pesticides. Applications of conventional pesticides accumulate chemicals in the soil that can contaminate the crops and destroy the soil. Bio-pesticides are effective in small quantities and often decompose quickly, therefore minimize the large amounts that cause pollution.[18] Unlike conventional pesticides, which destroy other non-pest organisms in the area, bio-pesticides have very specific targets and rarely affect other organisms. It takes significant knowledge of pests and the natures of different bio-pesticides in order to apply them correctly.

3.2.3 Pesticides in Drinking Water

There are two main sources of drinking water: surface water and ground water. Surface water comes from bodies of fresh water such as lakes and rivers. Ground water is water that comes from aquifers. Aquifers are underground areas that can be tapped to provide fresh water. Drinking water at rural or agricultural areas often comes from individual wells, and usually not treated. In urban areas, water is usually pumped to water treatment plants and then to buildings.

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[17] http://www.epa.gov/pesticides/biopesticides/what_are_biopesticides.htm
[18] Ibid.

Pesticides contaminate drinking water in many ways. Pesticides applied on plants could seep into the soil and get into aquifers. Dumped, spilled or misused pesticides have greater chances of reaching drinking water. Even pesticides that are applied correctly can be washed away from the application site to surface water, such as when rain falling on the treated area before the pesticide degrades or binds. In some cases, pesticides are intentionally put into drinking water to disinfect and protect people's health. This type of pesticide is called antimicrobials. In the United States, it is required by The Safe Drinking Water Act that public water be disinfected. The most commonly used antimicrobial is chlorine due to its low cost and high effectiveness. However, the disinfecting process can produce chemical by-products, some of which even have toxic effects.[19] In the US, the Environmental Protection Agency is responsible for setting water treatment standards to protect public health.

Pesticides in drinking water may be harmful to people's health, depending on the dose and toxicity of the chemicals contained in the pesticide, the length of exposure, and the health of the person. In large amounts, some pesticides can cause long term health effects, such as cancer or organ damage. In laboratory animals, some pesticides have effects on their reproductive system. For many pesticides, scientists from the U.S.EPA have determined the maximum amount that is allowed in drinking water. Luckily, pesticides in drinking water are usually found at very low levels and are not likely to pose health risks to people.

[19] http://spo.nos.noaa.gov/projects/agchemuse/pesticides_35.html

3.3 The Fertilizer Industry

As the world's population is growing, the demand for agricultural productions increases proportionally. In order to increase the output, the fertilizer industries take a very important role in this area. The economic benefits of using fertilizer are the increased productivity and a higher living standard. Although the fertilizer is good for agriculture, if the by-products (See Table 6) are deposed without any treatment, they would cause environmental problems. In addition, there is noise pollution resulting from plant washing. In the past few decades, people started to be concerned by fertilizers' effect on the environment and the by- product treatment. Thus, there has been a greater need to control the undesirable by-products and effluents to the environment.

The fertilizer industry can be divided mainly into three industries: Nitrogen Fertilizer Industry, Phosphate Fertilizer Industry, and the Potassium Fertilizer Industry. Nitrogen, phosphate and potassium are the basic nutrients for growing agricultural products. There are also two other fertilizer industries: The Mixed Fertilizer Industry and the Liquid Fertilizer Industry. They produce nutrients through chemical reactions or the use of liquid solutions.

Unfortunately, the by-products are inevitable. There are some regulations, measurements and controls to lower the production of toxic by-products. One of the essential regulations is that the fertilizer industry has to purify the water. Environmental concerns are becoming more closely linked with the economic decisions such as the location of new facilities, production cost, and international agreements. The growth of the world fertilizer industry will be affected increasingly by environmental concerns and pollution control compliance of production activities.

Table 6. Noxious Substances in the Fertilizer Industry

Pollutants		Waste	By-Product
Atmosphere	Water		
NH_3	NH_4^+	Wastes from phosphate mines	Pyrite ashes from sulfuric acid manufacturing from pyrite
CO_2	NO3-	Wastes and soluble salts at potassium mines	Phosphogypsum from wet-process phosphoric acid manufacture
F^-	PO_4^{3-}		
NO_X	SO_4^{-2}		
SO_X	KCL	Acid sludges in sulfuric acid manufacture from pyrites and gases from non ferrous metallurgy	H_2SiF_6 solution from fluorine gas washing in phosphate and phosphoric acid fertilizer
SiO_2 powder Pyrite ashes powder	NaCl		
Phosphate Powders	K_2SO_4 SiO_2	N/A	N/A
Fertilizer powders	F^- Sludges and polluted water	Spent catalysts	$CaCO_3$ from nitrophosphate manufacturing by Odda-type process

3.3.1 Nitrogen Fertilizer Industry

Ammonia is the principal component in the production of nitrogen fertilizers. The world ammonia capacity for 1995-1997 is estimated at 123,640,000 tons of nitrogen per year[20]. The production of ammonia by the 'steam-reforming process' is relatively clean and there is no special environmental problem by using that method. However, specialists have considered that ammonia is dangerous. Ammonia is highly flammable and toxic, and under a range of temperatures and relatively high pressures, ammonia will explode.

[20] Charles A. Hodge, Pollution Control In Fertilizer Production, Marcel Dekker, 1994.

The wastewater effluents from the Nitrogen Fertilizer Industry can be classified into four groups[21]:

- General manufacturing effluents resulting from the contact of water with gas, liquid, or solid. Generally, these effluents are continuous and are known as pollutant contributors.
- Particulate effluents likely to be separated either for a specific treatment, eventually accompanied by recovery of useful substances, or to be stocked and reinjected to the treatment circuit at a controlled flow rate.
- Effluents from general services such as steam blow-down, pretreatment sludge, and washings.
- Occasional effluents, fugitive leakages of products while being handled or stocked, platform washings, and polluted precipitations. Wastewater from the Nitrogen Fertilizer Industry is an active hazard to public health and especially to the aquatic life. Table 7 shows the different types of wastewater from the Nitrogen Fertilizer Industry.

3.3.2 Phosphate Fertilizer Industry

Phosphorus is an essential factor for every existent living organism. Usually the Phosphate Fertilizer Industry uses phosphate rock as their raw material. The supply of phosphate rock is adequate to meet the demand for the future. The future phosphate industry would be limited not only by the capital cost increases caused by inflation, but also by local, state, and federal regulations because they would cause a serious environmental problems such as calcium sulfate disposal; fluorine, cadmium, uranium

[21] Degremont, Memento technique de l' eau, 1989.

content; and radon emissions[22]. These kinds of problems are always being considered before a new project starts (See Table 7).

Table 7. Different types of Wastewater[23]

Process	Specific wastewater
Ammonia plant	Condensates from steam stripping and scrubber blow-down that may contain ammonia, ammonium bicarbonate, methanol, and other contaminates (metal traces)
Ammonium nitrate and calcium and ammonium nitrate plant	Condensates from neutralization, evaporation, blow-down from air scrubbing; may contain HNO_3 and NH_4NO_3
Urea plant	Discharge from crystallization and evaporator condensate that may contain ammonia, ammonium carbonate and carbamate, and urea
Nitric acid plant	Pump, valve, and piping emission and leakage; normally, there is no wastewater
Cooling system	Blow-down from cooling tower may contain all the contaminants from the entire fertilizer complex, including cooling water conditioners (corrosion inhibitors, scale remover, biocides)
Leakage (uncontrolled release)	Gasket, piping, pump, and tank leaks
Repair and maintenance	Prior to major repair, all piping and tanks are drained and the platform areas are affected
Leakage, release	Indoor and outdoor platform surfaces contain nitrogen compounds that may be washed off by precipitations

Since phosphate rock is the raw material, it has many impacts on the environment. Handling, storage, and application of phosphate rock or the final product affect environment conditions in more than one way: emission such as dust, fluoride, sulfur and

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[22] Charles A. Hodge, Pollution Control In Fertilizer Production, Marcel Dekker, 1994, Chapter 9
[23] Charles A. Hodge, Pollution Control In Fertilizer Production, Marcel Dekker, 1994, Chapter 5

nitrous oxides, acid mist, radon or other radioactive emissions, solid waste and contaminated fluid, such as gypsum, acidic eaters, and phosphate slimes.

Some phosphate rock contaminants, such as cadmium, are not only consternated during the process of producing fertilizers but are absorbed from the soil by plants and incorporated into manufactured food[24].

Because phosphate rock is insoluble in water, it would only dissolve in mineral acids such as sulfuric, nitric and phosphoric acids. These dissolutions would lead to another problem because too much sulfuric and nitric acid would cause acid rain. These kinds of strong acidic liquids will damage the facilities and cause a leakage if the manufacturers do not constantly check and maintain them. Acid rainfall is more and more frequent and very harmful to the environment. It is due to the presence of SO_x and NO_x in the atmosphere. In order to reduce the quantities of these harmful by- products, certain chemical reactions can be used to change them into harmless products. For example, Sodium and Ammonium Scrubbing[25]:

$Na_2SO_3 + SO_2 + H_2O \Leftrightarrow 2NaHSO_3$ or

$(NH_4)_2SO_3 + SO_2 + H_2O \Leftrightarrow 2(NH_4)HSO_3$

3.3.3 Potassium Fertilizer Industry

Potassium is one of the three primary nutrients to plant life. Potassium is essential to photosynthesis and protein. It also controls the reaction rates of enzymes and increases the tolerance of plants to disease[26]. Compared to the Nitrogen Fertilizer Industry and the Phosphorus Fertilizer Industry, the Potassium Fertilizer Industry causes less harm.

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[24] M. hutton, The environmental implications of cadium in phosphate fertilizer, Phosphorus and Potassium, February, 1983.
[25] Charles A. Hodge, Pollution Control In Fertilizer Production, Marcel Dekker, 1994, Chapter 11
[26] Soil Fertility and Plant Nutrition, Potash and Phosphate Institute, Atlanta, Ga., 1990.

Potassium Fertilizer Industries, mainly use potassium chloride. The effluents in a typical conventional processing operation for potassium chloride are liquid effluents, solid effluents, and air emission.

- **Solid Waste**

Sylvinite ore contains NaCl, KCl, and $MgCl_2$, and by conventional mining and refining to manufacture potassium chloride, produces solid wastes known as tails. About 300 million metric tons of tails have been produced over the last 30 years[27].

- **Liquid Waste**

Wastewater is produced from refining process and from precipitation falling on the mine site on or close to the waste management area. About $1m^3$ of fresh water is used for every mol/ton of potash (K_2O) produced[28].

- **Air Emission**

The principal sources for air emissions from a conventional potassium chloride producing operation are product dryer, refinery air exhaust, mine ventilation exhaust, and fugitive dust. The major environmental concern in these emissions is the chemical composition of the emitted particulates.

3.4 Wastewater Processing

Ordinary wastewater treatment is designed to remove the solids and organic contaminants from wastewater. The process usually involves several different treatments. Primary treatment is to remove the solids settled on the bottom of the solution and the scum that floats on the surface. In conventional wastewater however,

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[27] Charles A. Hodge, Pollution Control In Fertilizer Production, Marcel Dekker, 1994, Chapter 13
[28] R. T. Hart, A review of Waste Management in the Potash Industry and Options and Decommissioning and Abandonment of Potash Tailings Piles: Report on CANMET project 3504, Energy Mines and Resources, Ottawa , Canada, 1985

less than half of the waste organics are settle-able. Therefore the primary treatment has limited effectiveness. Nevertheless, it is an important first step in order to carry out the next treatments. Chemicals are used to improve the settle-ability of wastewater so the effectiveness of the primary treatment will increase. This addition is not the most popular method because it could be costly and the extra chemicals increase the organic wastes in water. Secondary treatment involves biological beds, which are biological solids serving as a filter to remove waste organics. As early as 1910, observations of rapid removal of organic matters were made when wastewater passed through stones coated with slimes. It was discovered later that biological solids developed in polluted water caused organic particles to form lumps. This process is referred to as the "fixed-media filter"[29]. The formed organic masses settle with gravity and can be easily removed. After primary treatment, water goes through the fixed-media filter (secondary treatment) before it enters the final settling where lumps of organic wastes are removed. Then the water is disinfected with chlorine before it goes to a water supplier. Sludge removed from the primary and final setting is disposed after the bacteria are treated with chemicals and water is extracted.

A typical flow diagram of a wastewater treatment plant is shown in Figure 2.

[29] Hammer, Mark J. Water and Waste-Water Technology, New York, 1975. Pages 345-346

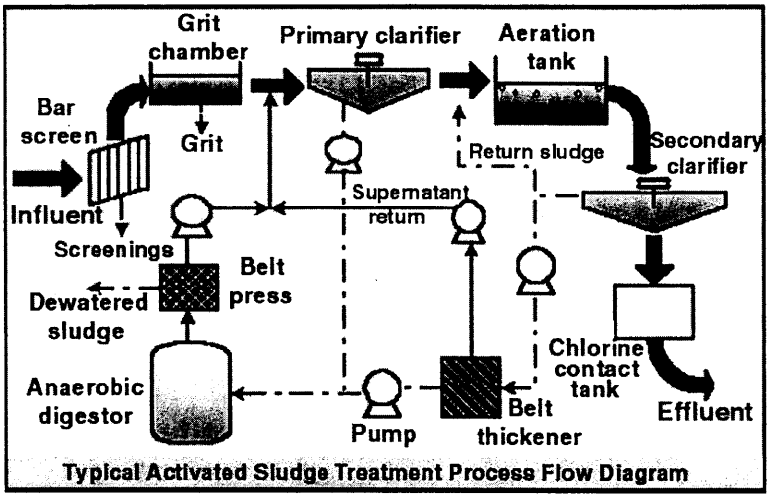

Figure 2. Flow diagram of a wastewater treatment process

3.4.1 Bar Screens

When wastewater first enters the treatment plant, it goes through the bar screens. Bar screens are part of the preliminary treatment, consisting of evenly spaced metal bars, which remove big objects such as bottles and twigs from wastewater. When large amounts of garbage gather on the bars, a plant operator usually manually rakes the objects off.

3.4.2 Grit Chamber

The grit chamber is the other part of the preliminary treatment. It primarily removes grits, which includes sands, little rocks and other hard objects. It is very important to remove the hard objects prior to other treatments because the abrasiveness of the objects will wear out the equipment. When wastewater goes into the grit chamber, its flow is being slowed to a rate of about 3 feet per second. This slowing allows grits and other settle-able inorganic matters to settle. Then these objects are removed from the bottom of the chamber.

3.4.3 Primary Clarifier

Primary clarifiers are huge tanks that usually have a skimmer on the top and some kind of chain systems along the bottom. In the clarifier, the flow is also slowed down to approximately 3 feet per minute, allowing even smaller objects to settle. The skimmer along the top removes the grease from the water and helps to maintain the slow rate of the flow. The chain system on the bottom removes the objects from the bottom.

3.4.4 Aeration Tanks

Aeration tanks are enclosed tanks that supply adequate oxygen to maintain an aerobic environment inside the tank. The idea of an aeration tank is to provide an optimal condition for microorganisms to reproduce and to consume all of the organic materials in the water. This is the "fixed-media filter" process discussed in the introduction. The mixer located at the bottom of the tank adds oxygen during mixing and blended oxygen in the water. The constant mixing helps the organisms to grow and digest most of the organisms in the wastewater. This process takes 11 hours in the Shatin Sewage Treatment Plant[30].

3.4.5 Secondary Clarifier

A Secondary clarifier is very similar to the primary clarifier. It removes all the biological matters that settle on the bottom. Part of the biological matter is pumped back into the aeration tank to make sure that enough microorganisms are in the tanks to carry out the process. The cleaned wastewater will go to the last step of the process, the disinfecting process.

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[30] Source from: http://civcal.media.hku.hk/sewage/shatin/default.htm

3.4.6 Chlorination Contact

Chlorine is used to kill all the disease-carrying germs in the water. Gaseous chlorine is dispensed into the water at a number of locations at the chlorinating channels. The chlorination channels are designed to be long and narrow so the water can travel for a long time. This provides sufficient time for the chlorine to mix into the water and kill all the germs. After this last stage, cleaned water is dispensed back into the river.

4. Methodology

During the two months in Hong Kong, the WPI students worked independently most of the time and attended weekly meetings with Civic Exchange. Civic Exchange members that focused on this Water Quality Project in the Pearl River Delta were Lynne Curry and Elizabeth Willmott. Lynne was a formal financial journalist who is interested in researching and solving environmental issues. Elizabeth is a college graduate who is teaching English at Chinese University in Hong Kong. She is working for Civic Exchange on a part-time basis. Lynne and Elizabeth had started the research work before the WPI students' arrival in Hong Kong. As stated in the introduction, there are three components to water pollution: municipal wastes, industrial wastes and agricultural runoffs. Lynne, Elizabeth and the WPI students each covered one of the components. Lynne focused on municipal wastes; Elizabeth researched on industrial wastes, and the WPI students concentrated on agricultural runoffs. In addition to water pollution, Lynne will also look at the different aspects of wastewater treatment plants, such as costs and government regulations. The WPI students covered part of the wastewater treatment technologies also.

Each group will present a comprehensive literature review on the assigned area to Civic Exchange before May 2001. As for agricultural runoffs, a comprehensive literature review should include the followings:

- Identification of all the agricultural water pollution sources.
- Information on each type of pollution, qualitatively and quantitatively
- Nature and components of the types of pollutants

- Current situations of each pollution sources, including the degree of harmfulness and current methods used to address the issues
- Alternative and more effective ways to address these pollutions (technologically or from other approaches)

On wastewater treatments, the studies included the following:

- Technological aspects of wastewater treatment technologies
- Alternative wastewater treatment methods
- Requirements to establish wastewater treatment facilities (financial, governmental issues)

In order to obtain sufficient information to finish the literature review, students traveled to different places for interviews; read literatures on agricultural pollution and related topics; and spent hours on the internet to collect information on the world wide web. For interviews and information gathering, visits to the following places were made:

- Universities in Hong Kong (Hong Kong University of Science and Technology, Hong Kong Chinese University, Hong Kong University)
- Universities and institutes in China (South China Agricultural Institute, South China University of Science and Technology)
- South China Environmental Protection Research Institute
- Libraries in Hong Kong
- Suze Lyonnaise des Eaux Wastewater Consulting Company
- U.S. Consulate in Guangzhou

The objectives of going to the universities were 1) to search on their databases to find articles that were published by the universities; 2) to research on their faculties, find

experts in both agriculture and/or the Pearl River Delta and set up interviews with them. In doing article researching, special attentions were paid to materials that specifically discussed the agriculture and animal husbandry of the Pearl River Delta, including the types of wastes that the farms produced and the current methods farmers used to address the agricultural wastes. After the sources were identified, research on each source was carried out. The information on each pollution sources included the nature and origin of each source; the ingredients of the pollutions; the negative effects they imposed on the environment, and the degree of harmfulness of the pollutions.

Hong Kong's University of Science and Technology (HKUST) was carrying out an on-going project named Pearl River Estuary Protection Project (PREPP). This project focused on the study on the water quality in the Pearl River estuaries and the effects of the water quality on the society. The supervisor of this project, Dr. Jay Chen, showed interest in working with Civic Exchange to expand their program, so their research can be widely introduced to the public. Civic Exchange will work closely with HKUST and utilize their science knowledge to help carry out their project.

On the internet, the research group found technological information on each pollutions, such as pesticides, fertilizers and livestock wastes. Methods that other countries have been using to address agricultural pollution were also found on the web. In collecting quantitative information such as statistics on water quality, the research team contacted Guangdong's Environmental Protection Bureau. However, the EPB was reluctant to provide any data upon request.

Lynne Curry proposed a trip to Macao. A case study on Macao showed that Macao adapted wastewater treatment technology years ago and now became one of the

few cities in Asia to provide potable water for its people. For its dramatic improvements, Lynne believed that a trip to Macao would be helpful for this project. However, due to the packed schedule, Civic Exchange only met with the wastewater treatment consulting company that assisted Macao in Hong Kong. The wastewater company provided many insights on wastewater treatment technologies.

Christine Loh also proposed a trip to Guangzhou to talk to government officials and experts. Statistical information on pollution is often not available on the internet, Civic Exchange wanted to obtain information from the local officials. However, Guangdong's EPB did not agree to meet with Civic Exchange. Therefore for the Guanzhou trip, Civic Exchange people met with non-governmental organizations, including universities, research centers and the U.S. Consulate.

5. Results

The liaison of this project, Civic Exchange, is conducting a seven-month long project to find feasible methods to improve the water quality of the Pearl River Delta. Before discussing the water quality issues with government officials and scientists, Civic Exchange needed to have a comprehensive literature review on water pollution. The objective of this IQP is to assist Civic Exchange to research on the water pollutions caused by agricultural runoffs. During the seven weeks in Hong Kong, WPI students traveled to universities and institutes in Hong Kong and Guangzhou, the U.S. Consulate, wastewater treatment consulting company, research institutes to interview experts on agriculture, water pollution and related fields. Interviewees included professors on water quality studies, consultants from a wastewater treatment company, personnel from agriculture and science institutes, journalists, experts from research centers, an officer from the U.S. Consulate and others. Besides interviewing personnel, the research team also spent hours researching on the internet to find up-to-date information on the Pearl River Delta, visited the libraries and read books and articles on the Pearl River Delta and other agriculture topics. The collected information was organized and to be used as the basis for the agricultural pollution section of Civic Exchange's literature review for the Pearl River Delta water quality project.

5.1 Pesticides in China

Various kinds of pesticides have been used in China since the 1950s. Pesticides are essential to farmers for their ability to protect their crops by killing insects and disease-carrying organisms. In the past 20 years, China has seen a dramatic increase in the use of pesticides. It was the second largest pesticide-using country in the world in the

1980s and became the leading pesticide-using country in the 1990s.[31] In most places in China, researchers have found overuses of huge amounts of pesticides by farmers. Although pesticides yield higher crop production, they have serious environmental and health drawbacks if used improperly and excessively. Highly intensive use of pesticides may not only contaminate the crops, but also cause damages to the surrounding soil and water sources. Realizing the environmental and health risks related to pesticide use, the Chinese government created rules and regulations attempting to solve the problem. The government banned the use of highly hazardous pesticides (e.g., calcium arsenate, carbon tetrachloride) and set up standards for daily maximum allowable amount of pesticides used (e.g., total use of Guthion during a growing season is limited at 4.5 pounds per acre). Although Chinese regulations are similar to that of the international standards, the regulations did not seem to make dramatic improvements on the situation. The reasons were that there were many obstacles in enforcing the laws (details in Section 4.4). The amount of farm pesticide used is still climbing in recent years. Experts estimate farmers overuse pesticides by 40%! [32]

To understand the reason farmers overuse pesticides and to quantify the impact that pesticides have on both agriculture and human health, researchers from the Center for Chinese Agricultural Policy undertook an in-depth case study in a rice production town attempting to figure out the situation of pesticide usage in that particular area. Through interviewing farmers, their results indicated that the education level of the farmers has the most impact on their perception of the importance of pesticides. For

[31] http://spo.nos.noaa.gov/projects/agchemuse/pesticides_35.html
[32] Ibid.

example, their awareness of the fact that the effectiveness of pesticides is not always directly proportional to the amounts used is sometimes lacking.

Farmers' perceptions of the importance of pesticides directly affect the amount of pesticides they use. The farmers' perspectives relate to the consequences they perceive for not applying enough pesticides. For example, if a farmer perceives that 90% of his crop's yield loss is pest-related, he or she believes that the consequence of not using enough pesticides is very costly. That farmer would more likely apply more pesticides than a farmer who perceives only 20% of his yield loss is pest-related. Many studies have reported actual rice yield losses due to pests in Asia. Although their results vary, most studies showed that pest-related yield losses in Asia ranges from 20% to 40% (See Table 8).

Researchers from the Center for Chinese Agricultural Policy interviewed farmers from four villages in Zhejiang province on their perception on crop loss due to pest problems. The farmers' average estimate of their crop loss caused by pests was 75.6%. This figure is significantly higher than the ones published by other researchers. In addition to the higher estimates, the variation among the farmers' perceptions was relatively small. This indicates that most farmers perceived very high yield losses due to pests (See Table 9).

Table 8. Crop loss due to pests in Asian countries[33]

Author	Year	Country	Source	Estimated crop loss due to pests (%)
Cramer	1967	Asia	Insects	34
			Diseases	10
			Weed	11
Ahrens et al	1982	East and Southeast Asia	Insects	24
Pathak and Dyck	1973	Philippines	Insects	20~25
Way	1976	Philippines	Insects	16~30
Pathak and Dhaliwal	1981	Philippines	Insects	35~44
Kalode	1987	Philippines	Insects	29
Litsinger et al	1987	Philippines	Insects	18
Waibel	1990	Philippines	All Pests	35
Waibel	1990	Thailand	All Pests	50
Way	1976	India	Insects	35
Fernando	1966	Sri Lanka	Insects	20
Huang, Qiao, Zhang and Rozelle	1999	China	All Pests	42
			Average	28
			Standard Deviation	12.68

(All figures, except China were summarized in Rola and Pingali[34] and Waibel[35])

Table 9. Sampled farmers' perception on crop loss due to pests[36]

Village	Crop loss estimate (%)	Standard Error
Zhengbei	70.2	18.5
Yangzhuang	74.3	18.9
Yushanwu	80.8	17.6
Shuikou	77.0	22.6
Average	75.575	19.4

[33] http://spo.nos.noaa.gov/projects/agchemuse/pesticides_35.html

[34] Rola, A.C. and P. L. Pingali. 1993. Pesticides, Rice Productivity, and Farmer's Health: and Economic Assessment. Los Banos, Philippines, and Washington D.C.: International Rice Research Institute and World Resource Institute.

[35] Waibel, H. 1990. Requirements for An Economic Interpretation of Crop Losses. In IRRI, Crop Loss Assessment in Rice.

[36] http://spo.nos.noaa.gov/projects/agchemuse/pesticides_35.html

Researchers then further analyzed the data, considering all the variables, including age, gender, educational level, per capita land, and per capita income. There are no significant differences on farmers' perceptions by their ages nor per capita land or per capita income. Conclusions could not be drawn between the genders due to the small sample of women farmers. Farmers with higher education (more than 9 years), however, showed a more accurate perception than farmers with less than 9 years of education. When applying pesticides, the crops absorb approximately 30% of the pesticides, the rest of them enter into the ecosystem. Of the farmers interviewed, nearly one-third of them did not know that pesticides reside on grains and the environment. The more knowledgeable farmers were the more aware they were of the residue problem compared to farmers with less knowledge.

Farmers in Zhengbei were informed by the plant protection technicians that the recommended doses of each pesticide during application. Most farmers, however, did not believe the recommendations and felt that they were under-dosages. 30% of the farmers considered the recommendation as "adequate". During applications, only 14% of the farmers followed the instructions. The rest applied more than the recommended dosage. This indicated that the belief of "the more pesticides the better" had deeply implanted into farmers' minds. It will take much effort to correct their thinking. Estimation made by the researchers indicated that a 10% decline in farmer's perception of yield loss due to pest could reduce farmer's pesticide use by 2.2%. Previous studies showed that farmers overestimated pest problems by about 35%. If farmers could be convinced that they were overestimating the amount of pesticides they used would decrease significantly. It is essential to provide farmers adequate education on the actual

effects of the pests and the drawbacks of pesticides. Most likely it will be a difficult task to accomplish but it would bring tremendous benefits to the environment.

5.2 Pesticides in Guangzhou

Guangdong is located near the subtropical zone and has warm, humid climate all year round. The moisture and heat provided excellent conditions for pests to reproduce. As a result, farmers in Guangdong needed to use more pesticides than farmers in a milder climate do in order to protect their crops. If the farmers in Guangdong overuse pesticides as some Chinese farmers do, then the situation in Guangdong would be more disastrous compared to other provinces. According to experts from the South China Agriculture Institute in Guangzhou, the over-usage of pesticides is not an issue worth bothering about in Guangzhou, this is because the farmers in Guangzhou do not show tendencies of overusing pesticides (see Appendix G). However, they did not provide any statistical data to support their assertions.

As mentioned in the previous section, the farmers' education level directly affects the amount of pesticides they use. The case study by the Center of Agriculture Policy indicated that farmers with higher education have more awareness of the negative effects of pesticides and have more accurate perception of the appropriate amount of the pesticides that should be used (see Section 4.1). Education concerning the danger of pesticide overuse is apparently wide spread in Guangzhou. Experts from the South China Agriculture Institute explained the three approaches by different organizations in Guangzhou to educate the farmers on environmental issues and accurate agriculture methods.

The local governments took the first approach. Governments advertise the issues through radio broadcasts and television programs. Those programs promote the importance of protecting the environment and negative ecological effects of chemicals used in agriculture and unite the people to work toward the same goal of improving the environment. Programs are in forms of brief advertisements, television shows that discuss the issues in depth, and short educational programs that usually last for fifteen minutes. Besides educating through the media, the government also brings knowledgeable volunteers from the cities to visit and communicate with the farmers. Programs of this nature are very beneficial to the farmers. Farmers not only get assistance in labor, they also widen their knowledge on the latest technologies in agriculture and proper methods to reduce agricultural pollution.

The second type of organizations that educate the farmers are research institutes. Research institutes continuously develop new and improved agricultural technologies, including pesticides, fertilizers and machineries. After a new product is developed, research institutes hold seminars targeted at farmers to promote their products. In such seminars, people from the research institutes discuss various aspects of agriculture and environment protections, which in turn, promote their products. Farmers that attended these seminars widened their exposure to issues that experts from the research institutes were concerned about and raised their awareness of these issues.

Agriculture or environmental universities and institutes made the third approach. Similar to the program carried out by the local governments, the universities such as the South China Agriculture Institute, send students periodically to visit the farmers. The purpose of these programs is for students to obtain on-site experiences on their studying

area and communicate with farmers the knowledge they learned from school. These programs are beneficial to both farmers and students. Students could apply their knowledge on actual farmlands and farmers could receive recommendations and informal lectures without attending school.

From these three approaches by the government, research centers and universities, farmers in Guangdong receive many opportunities to obtain adequate education on agriculture. The more the exposure to knowledgeable persons, the more chances for farmers to gain accurate perceptions of agricultural issues. Although Guangdong's climate required farmers to use large amounts of pesticides every year, farmers in Guangdong showed professionalism by using adequate pesticides. Therefore the over-usage of pesticides is not a major concern in Guangdong. However, convincing data that can show the actual effectiveness of these programs were not provided by any of the experts.

5.3 Fertilizers

Due to the rapid population growth, farmers need to provide more food using the same land area they have. In order to do that, farmers use fertilizer to provide more nutrients to the crops and fruits to make them grow faster. The fertilizer which farmers used mainly contains nitrogen, phosphorus, and potassium. The ratio among them is estimated as 1: 0.32: 0.11[37]. This means that one mole of nitrogen per 0.32 mole of phosphorus per 0.11mole of potassium. The official standard in China is 1: 0.5: 0.2 and the world's standard is 1: 0.47: 0.37. The difference between these different scales

[37] Tao Chang, Agricultural Environmental In China, China Publisher, Chapter 7

is that farmers in China are using fertilizer, which has very high nitrogen content, and less phosphorus and potassium. Because farmers used excess fertilizers, as a result, there are extra nutrients, mainly nitrogen left in the soil. The nutrients in the soil are imbalanced and it would lead to a nutrients runoff and soil change.

The excess nitrogen will undergo chemical reactions and nitric acid is formed[38]. The nitric acid will be washed to the nearby rivers by rainfall. Crops and fruits that absorb the nitric acid through rainfall, and the polluted crops and fruits will cause cancer or fatal poison. Esophageal cancer is one of the most fatal cancers in China.

Besides forming the nitrite-nitric acid, the excess nutrients will cause an imbalance of nutrient concentration in the rivers. This imbalance would affect the marine lives. The excess nutrients would lead to the Red Tide. Red Tide can destroy the marine lives and decrease the production of seafood.

Moreover, as farmers grew and harvested more crops and fruits, the soil loosened. The soil was washed into the nearby river and eventually narrowed the river estuary.

5.4 Stockbreeding

The main pollution from stockbreeding is the municipal waste. Without appropriate treatments, the sewage would cause various kind of diseases. The Chinese main concern is on pig and chicken farms because pork and chicken are highly consumed everyday. Since in China, farmers practice intensive farming, if the livestock are infected with diseases due to improper treatment of municipal waste, it may eventually affect human beings. According to Prof C.S. Kiang from Georgia Institute of Technology,

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[38] Tao Chang, Agricultural Environmental In China, China Publisher, Chapter 9

if there were no treatment for the sewages, the concentration of ammonia would increase and cause a series of dangerous results. Ammonia is a highly flammable substance if the concentration is very high. Since farmers in Guangdong Province practice intensive farming, chickens are kept in small places or cages. This could eventually lead to a high concentration of ammonia and it might cause an explosion.

Another pollution from stockbreeding is the usage of growth hormones. Within the intensive farming, chickens and pigs are living in cages or a limited space, leading to a lack of exercise. Moreover, in order to get a high profit, farmers use growth hormones to enhance the growth of livestock. Steroid and growth hormones take a key role in gene regulation, expression, cell growth, division and maintain vitality in immune systems, organ, tissue, brain and mood at its peak performance through its receptors. Once the livestock are injected with these hormones, the hormones would remain in the body. If these chickens and pigs were consumed by human beings, the hormones would eventually enter the consumer's body and would cause various kinds of effects such as cancer. The usages of hormones has caused both moral and environmental problems.

The livestock is also one of the victims due to the Industrial pollution. Since heavy metal and various chemicals pollute the water, the livestock are highly poisoned. Some of the livestock mutated and died; others might have been infected by a virus. These polluted and poisoned meat would be harmful to human beings[39].

5.5 Government Control and Legislation

In the 1980s, regulations were developed for the safe use of pesticides. Pesticides such as BHC (666) and DDT, which contained organochlorine, organomercurial and

[39] Tao Chang, Agricultural Environmental In China, China Publisher, Chapter 13

organoarsenical, were banned because of their highly hazardous nature. The government has also created standards for acceptable daily intake level and maximum levels of residue on crops. However, these kinds of data are not possible to find in Hong Kong. Besides banning certain kinds of pesticides and fertilizers, both the central government and the local congress had established laws and regulations to reduce the pollution level.

On July 2nd, 1993, the central government had established 66 laws[40] for the agricultural industry. These laws were approved by Chairman Jiang, and they covered areas such as promoting agricultural education and technology, protecting the natural environment, marketing the products and the trading policies. The central government also authorized the local congresses to set up their own laws. The central government encouraged the local congress to provide education in villages, and promote the new technologies in farming for the farmers. The central government would give financial assistances so that the local congress could run the programs without additional financial burden. Finally, the central government also provided 'violations and penalties' guidelines for the local congress to follow.

On April 3rd, 1997, the Guangzhou government modified their water quality protection laws. The government divided different tasks for different departments. For example, the Environmental Protection Department has to inspect the water pollution, organize and assist companies to prevent contaminating water sources, and set up regulations and 'daily pollutant output' standard for companies. The Agricultural Department should establish strict rules for the use of fertilizer and pesticides. The department should also promote environmentally friendly fertilizers and pesticides to

[40] Lok Yu Pung, China: Laws and Regulation on Agriculture, China University of Political and Law, Chapter 6 & 7

protect and reduce the soil loss. The Guangzhou government also established a system to honor those districts where the water quality improved. For companies that violated these laws, they might either pay a fine or be sued by the government if no further improvement took place.

On November 27th, 1998, the Guangdong Provincial Government established 37 treaties for protecting the water quality in Pearl River Delta. Under these treaties, the local congress needs to report the water quality regularly and provide clear guidelines on protecting the water quality to the higher governor. The local congresses should also have a better urban planning so that under the protection areas, certain industries, such as pesticides and oil refining industry, are not allowed. The Guangdong government had established these guidelines to enforce the local congresses for the protection and improvement of the water quality.

5.6 Current Situation in Guangzhou

Civic Exchange organized a two-day trip to Guangzhou and arranged several meetings with Guangzhou's officials and research experts. The objective of the visit was to gather more information on water pollution and to listen to the opinions on the Pearl River Delta's water quality of the Guangzhou people. During the trip, the Civic Exchange Pearl River Delta water group met with officials from the U.S. Consulate, professors from South China Agricultural Institute and South China University of Science and Technology, also experts from South China Institute of Environment and Science. All of the people that met with the Civic Exchange group were very friendly, open and provided tremendous amounts of useful information (i.e., current agricultural pollutions in Guangzhou, government issues).

In the 1980s, when industrial growth of the cities surrounding the Pearl River Delta first blossomed, industries and human consumptions created heavy burdens for the water. Due to the high profit of industrial companies compared to agricultural based farms, agriculture areas gradually converted to be used for industrial purposes. In other words, agriculture was diminishing and industrial growth was dominating the Pearl River Delta area. Seeing the growth of the cities as golden opportunities to raise their living standards, people from other parts of China began to rush into this area. Therefore the Pearl River Delta was rapidly undergoing two main changes: converting to an industrial base and becoming the major water source for millions. There were negative environmental effects of these two changes. Industries such as paper mills and steel manufacturing produced large amounts of wastewaters that were toxic and extremely harmful to human beings. Also the rapid population growth increased human consumption of resources and products of this area. Back in the 1980s, the government did not enforce regulations on the wastewaters that were dumped into the Pearl River and no advanced wastewater treatment technologies were implemented. As a result, the water quality of the Pearl River Delta worsened dramatically in that decade.

Since the early 1990s, the Guangdong government tightened the regulations on the wastewater produced by enterprises and farms. The Government set wastewater quality standards that companies had to meet. Inspections were performed before giving out work permits to make sure that companies had effective facilities to treat their wastewater. Enterprises that did not have sufficient wastewater treatment would not be allowed to build any facilities in Guangdong. These standards also applied to old enterprises. They were required to treat their wastewaters until they met local standards.

The same laws also applied to farms. Inspections periodically took place to check the wastewater quality produced by factories and farms, usually by analyzing the water samples taken at the factory and near the farms.

If the inspections proved that the factory or farm had violated the law and created wastewaters that are below standards, local officials gave the owners appropiate penalties. Usually violators will receive a warning the first time, if problem continues, officials will assess the violators with fines. The amount of fines varies, depending on the size of the factory/farm and the degree of violations. Newly established enterprises and farms meet the standards more often than old and smaller ones do. Some old enterprises did not build facilities to treat their wastewaters simply because they were not required to do so when they built the factory. It is a very expensive investment to build and run a wastewater treatment facility. In most cases, it is actually cheaper to pay the fines. The same situation applies to smaller factories. It was observed that even enterprises and farms that have the wastewater treatment facilities do not run their facilities full time. They would only run them before inspectors' visits just to pass the inspections. Reasons are the high cost of running the facilities and reduction of the profits and some owners do not have environmental concerns. These factories, however, are usually caught by unexpected visits by the local officials.

Although local officials have knowledge of the unlawful acts of some enterprises, it is still very difficult to enforce the laws on the irresponsible owners. One way to enforce the law strictly is to shut down the companies that violated the laws. That would definitely be very effective in convincing enterprises to treat their wastewater but on the other hand, would cause hundreds to thousands of workers to lose their jobs. In China,

there are no welfare programs for unemployed workers. Also, due to the large population, job hunting is very competitive and its unemployment rate is already high. In cities like Guangzhou, there are thousands of people who came from other parts of China that are jobless. Therefore shutting down a company would cut the income of hundreds of working families. This act would lead to horrendous confusion and serious unemployment. Protests to the government would take place. More unemployment would destabilize the society, meaning that acts of robbery and stealing would increase. The Government simply cannot afford the consequences of shutting down companies that violate wastewater laws because in China today, there are more immediate concerns than water quality concern. Raising the fines could lead to similar results. If companies cannot afford the fines, they would either shut down their facilities or ignore the fine. Shutting down the company would lead to the same result and if owners choose to ignore the fines, regulations would become ineffective. It is a very difficult task for government to enforce the regulations on wastewater.

Although there are violators, there are also many enterprises meeting the standards and treat their wastewater everyday. Most of the enterprises that do so are big and have sufficient funding, such as foreign invested facilities. As for small farms, the amounts of wastes they produce are relatively insignificant compared to the wastes created by factories and bigger farms. In general, the wastes created by farms are less toxic and wastes such as animal municipal wastes are degradable in water. Also much of the agricultural pollutions are non-point. Therefore it is easier and more efficient for the government to perform tighter inspections on factories rather than farms.

The argument that China has worse water quality control because it does not have strict laws is inaccurate. In fact, the Chinese laws on environment protections are comparable to the ones of other well-developed countries. The main difference is that it is more difficult to enforce the laws in China due to the large population and the overall poverties of many parts of China. It will take a long period of time to perfect the enforcements but provinces such as Guangdong are making significant progress. The water quality of the Pearl River in Guangzhou has improved recently. A few years ago there were always large amounts of garbage, including plastic bags, bottles and food containers floating on the Pearl River. Nowadays, the government hires workers to collect the garbage continuously so very little could be found floating on the surface. According to the people interviewed in Guangzhou, the situation in Guangdong, especially in Guangzhou has greatly improved. People's awareness of environment protection has gone up in recent years and more dramatic improvements are waiting to happen in Guangdong.

5.7 Solutions in the United States

Since agricultural pollutions create problems to almost everywhere in the world, it is helpful to research how other developed countries treat their problems. In the United States, the U. S. Environmental Protection Agency (USEPA) established Section 319 National Monitoring Program (NMP) in 1995. The purposes of the program are to "provide credible documentation of the feasibility of controlling non point sources, and to improve the technical understanding of non point source pollution and the effectiveness of non point source control technology and approaches"[41]. Currently there were 22

[41] Section 319 National Monitoring Program http://h2osparc.wq.ncsu.edu

surface water-monitoring projects under Section 319 NMP. Each project is designed to solve different problems that are concerned in the particular area. As mentioned before, agricultural pollutions are mostly non-point pollutions. The 319 NMP project describes successful ways the U.S. treated their non-point pollution. According to their publications, the Section 319 NMP has done thorough data collecting and analysis every year. Here is a summary of the efforts this program has made to one of the project areas. (Eastern Snake River Plain, Idaho was chosen because it has a similar agricultural pollution situation as the Pearl River Delta area)

5.7.1 Eastern Snake River Plain

Under the 319 NMP project, 30000-acre area of south Minidoka County was under the monitoring activities. Within the area, various kinds of crops were grown: beans, wheat, barley, potatoes, sugar beets, alfalfa, commercial seed, and confined animal feeding operations[42]. The pollution sources came from the heavy nitrogen application and the excessive irrigation caused some leaching of pesticides into ground water. The project was framed from October 1991 to October 1998. Within those years, the United States Department of Agriculture Demonstration Project "focused on nitrogen, pesticide and irrigation water management practices that would reduce the amount of nutrients and pesticides reaching surface water and leaching into the ground water"[43]. Different strategies were implemented:

- Fertilizer evaluations and recommendations based on soil tests, petiole analysis, crop growth stage, crop type, rotation, and water sampling were adopted.

[42] http://h2osparc.wq.ncsu.edu/99rept319
[43] Section 319 National Monitoring Program http://h2osparc.wq.ncsu.edu

- Farmers had been asked to incorporate pesticide management strategies into farm in the practices.
- An irrigation management program had been implemented for each participating farm in the Demonstration Project.
- Riparian restoration and stream stabilization on Goose Creek.

5.7.2 Financial Issues

By comparison, the Pearl River Delta area has a similar agricultural industry as to the Eastern Snake River Plain. Unfortunately, there are two critical differences between the two places that add difficulties to Guangdong Province to carry out similar programs. First of all, this kind of project takes a long time and much effort to keep up the works. In order to get the up-to-date information on the water quality, experiments to collect data need to be performed continuously. This requires a large labor force and many super computers to achieve. The cost of the Eastern Snake River Plain as of now is approximately $500,000 USD[44]. Converted to RMB, it will be approximately $4 million RMB. That is a large sum of money that smaller cities simply cannot afford by themselves. The problem for the Guangdong Province government is how to get the funding to start the project.

Secondly, this project is highly dependent on the farmers' attitudes and the area of farmlands. The Eastern Snake River Plains is a closed area and the farmers were cooperative with the project center. In Guangdong, farmlands are scattered everywhere. And in general, farmers' education level is lower than those in the U.S. As a result, it will take more effort to convince the farmers in Guangdong to participate in the program.

[44] http://h2osparc.wq.ncsu.edu/99rept319/

These two uncertainties lead to difficulties in carrying out similar projects in Guangdong Province.

5.8 Wastewater Treatment Facilities

Several cities in Guangdong have established local wastewater treatment plants. In Guangzhou, a "wall" was built on the coast of the Pearl River to prevent untreated wastewater entering the river. The "wall" then directs the wastewater to a water treatment plant. However, this wastewater treatment plant only deals with the treatment of local municipal wastewater. Other municipal, industrial and agricultural wastewater still gets into the Pearl River at some other locations. Guangzhou is considering building another wastewater treatment plant in a few years. Municipal wastewater treatment plants usually consist of the following units:

- Mechanical screens and aerated grit chambers
- Biological treatment (aeration tanks)
- Clarifiers to enhance sludge to settle
- Disinfecting unit
- Sludge treatment unit

In designing a wastewater treatment plant, there are many considerations:[45]

- Background information:
    - Years to build the plant, life of the plant
    - Service area, including geology, hydrology, climate, etc

[45] http://www.h2osparc.wq.ncsu.edu/99rept319/

- Characteristics of wastewater, quality and quantity
- Effluent limitations

- Technical aspects:
  - Degree of treatment
  - Treatment process (units)
  - Plant layout
  - Equipment selection

- Other Considerations
  - Economics – cost of the plant, maintenance, replacement of equipment, chemicals needed for treatment
  - Location selection
  - Energy requirement

Most of the wastewater treatment plants take on average two to four years to complete.[46] Besides the time factor, the economic aspect is another concern for building a wastewater treatment plant.

Bei Shi Qiao city hired Camp Dresser & McKee (CDM) to make an estimated cost of a wastewater treatment plant in 1997. The project coordinator estimated the costs would be about $1.35 million USD for a municipal wastewater treatment plant and $5.7 million USD for an industrial wastewater treatment plant. Beside the costs of building the facilities, it is also very costly to run them. Since new funds are needed continuously, the Chinese government alone would not be able to provide enough funding to all the wastewater treatment plants. As a result, the government promotes private sectors to

[46] http://ace.orst.edu/info/nptn/factsheets/formulations.pdf

sponsor wastewater treatment facilities. In return, the government will pay the private companies fractions of the money they receive from cleaned water consumers (the government puts a flat rate that users pay when they enjoy the cleaned water). Major cities usually have decent wastewater treatment facilities.

5.8.1 Reed Bed System

For smaller cities and farms, it is nearly impossible to come up with sufficient funding to build million-dollar plants. A more cost-effective system is the reed-bed system. The reed bed technology is similar to the aeration tanks of a wastewater treatment plant. The roots of the reed provide oxygen to boost the growth of natural occurring microorganisms. The microorganisms then consume organic material contained in the wastewater passing through the reed bed.

Meanwhile, the processes of plant uptake and digestion of organic materials transform the sludge into a fertilizer, which provides an end product of a nutrient rich soil.[47] The reed beds use natural sunlight to drain and dewater the sludge. In conventional sand drying beds, dried sludge must be removed before new sludge can be added. In reed beds, water keeps the sludge moist and also brings more sludge to the reed bed naturally. The life cycle of a typical reed bed is approximately ten years. The construction of a reed bed system is fairly simple and inexpensive. The cost of the equipment for a typical system is about $80,000 USD with little additional cost to keep it working. Besides the low cost, it takes minimum maintenance and supervision to maintain a reed bed. Since the reed beds have high water demand in order to be kept saturated, these systems are suitable to be built near farms where water is constantly

[47] http://www.enviroaccess.ca/fiches_5/FA5-02-96a.html

being used. Reeds can be harvested every year to serve other purposes. This technology is environmentally friendly, inexpensive and effective. A study by the Australian Wetlands in conjunction with the Oceans Environmental Engineering Limited (OEEL) showed that the reed bed technology is very effectively treating the wastewater coming out of a large pig farm, maintaining over 55,000 pigs in Nordhausen[48] (See Table 10 for the details of the Nordhausen reed bed system).

Table 10. Performance of reed bed system in Nordhausen[49]

Compound	***Inlet (kg)***	***Outlet (kg)***	***Percent Elimination (%)***
Total N (nitrogen)	1573.80	173.80	88.9
NH_4 (ammonia)	1363.60	92.70	93.2
NO_3 (nitrate)	34.10	2.30	93.2
PO_4^{3-} (phosphate ion)	133.51	0.49	99.6
K^+ (potassium)	884.60	116.50	86.8
Cu^{2+}	1.14	0.08	93.0

As studies shown, reed beds can be very effective. It is most suitable for farmlands, where sizeable area of land is available. In the Pearl River Delta however, due to the large population and limited size of farmlands, especially when more farmlands are converting to industrial lands, reed beds might not be very feasible for the area. Regardless, it is an excellent alternative to high-tech wastewater treatment facilities.

5.9 Government and Wastewater Treatment Facilities

In order to carry out adequate wastewater treatments to improve the water quality in the Pearl River Delta, the local governments need to establish sufficient wastewater

[48] http://www.wetlands.com.au/industrialwaste.htm
[49] http://www.enviroaccess.ca/fiches_5/FA5-02-96a.html

treatment facilities. There are two categories of wastewater treatments. The first category is treating polluted water to provide clean water to households. Water companies pump water directly from a water body and process that water until it meets government standards. Then the water companies supply households the cleaned water for ordinary usages. Since consumers pay for their water, water companies are technically selling water and profiting from the process. As a result, most water companies are privately owned and local governments rarely provide financial aid for the water companies.

The second category of wastewater treatment is sewage treatment. Tons of sewages are dumped into the Pearl River Delta everyday. These sewages accumulate in the water and deteriorate the water quality. Sewage treatments are needed in order to prevent the sewage to accumulate and worsen the water quality. Treating sewages is more complicated and more costly than cleaning the water. However, in many cities in Guangdong, only local government is sponsoring such treatment facilities. People from many cities are not responsible for contributing to the sewage treatments. Even cities that required its people to pay for sewage treatments are still losing money running the facilities. For example, recently in Guangzhou people are required to contribute to sewage treatments in addition to the clean water for what they pay. However, the rate that they are paying is $0.20 RMB per cubic meter of water for sewage treatments. In fact, the government spends approximately $2.00-$3.00 RMB to treat that same amount. So for every cubic meter of water that goes through the sewage treatment plant, government is losing $1.80-$2.80 RMB. Considering the large population in Guangdong

and the amount of water consumed, the government is losing large amounts of money everyday carrying out the sewage treatment plants.

Affordability is the key why the government is not increasing the rate. There are some very wealthy people in Guangzhou but there are many that still live in poverty. Overall the living standard is relatively low and many people simply just cannot afford paying an additional $2.00 RMB for every cubic meter of water they use. The government has to set up rates that correspond to the surrounding living standard. Experts in Guangzhou believe that the rate will go up gradually, but it will be a while until the government stops losing money. As a result, it is very difficult for the government to finance additional sewage treatment facilities in Guangdong.

6. Analysis

After obtaining information through interviews, readings and web surfing, the WPI team concluded that results from the research indicated that the main sources of agricultural pollutions are pesticides, fertilizers and livestock municipal wastes. The negative effects of these three sources are different. They vary in the degree of harmfulness depending on the very nature of the contaminants. Pesticides contain toxic chemicals that destroy pests. Once the pesticides runoff gets into the water source, its destructive ingredients could create harm to marine lives. Also, the toxic chemicals could accumulate and affect the balance of the ecological system by destroying or forcing migrations of living organisms in the area.

Fertilizers are nutrients added to the soil. They typically contain large amounts of nitrogen and phosphorous. Fertilizers in China have higher nitrogen concentration (1 mole of nitrogen per 0.32 mole of phosphorous) compared to the world's standards (1 mole of nitrogen per 0.47 mole of phosphorous). Nitrogen oxides could undergo chemical reaction with water and become nitric acid, which could cause esophageal cancer (one of the most common and most fatal cancers in China).

Livestock municipal wastes also create many problems in Guangdong. Pesticides and fertilizers travel through soil and take a period of time before they reach the water source, whereas most animal wastes are directly dumped into the water. Livestock wastes are similar to human municipal wastes in nature. Although in most parts they are degradable in water, however, bacteria and virus contained in the wastes could spread diseases to other organisms sharing the water. Out of these three sources, the most harmful ones are the pesticides and livestock wastes. In order to reduce the agricultural

pollution in the Pearl River Delta area, ways to improve the usage of pesticides and managements of livestock wastes are essential.

In the Pearl River Delta area today, agricultural runoff does not create as large of a negative impact as it did years ago. This change resulted from the economic shifts of most cities surrounding the Pearl River Delta. Due to the rapid industrial growth, agriculture areas have been converted to industrial areas. The agriculture lands are diminishing while more and more cities become heavy industrial bases. Meanwhile prosperity brought many people from other parts of China to the Pearl River Delta area. The increase in population results in increasing human consumption thus creating more domestic wastes. Compared to domestic and industrial pollution, agricultural pollution is relatively minor in the Pearl River Delta area. However, agricultural runoff still produces dangerous contaminants to the environment and pose harmful effects on human lives as discussed in the previous paragraphs.

Building wastewater treatment facilities is the technological way of treating polluted water. A complete wastewater treatment plant not only effectively cleans the polluted water, but also treats the sewage. These wastewater treatment facilities first pumped polluted water from the targeted water body. After effluents enter the treatment plants, they undergo several processes including grit removing to disinfecting (discussed in Section 2.4). The treated water is then pumped back into the water source or to household water distributors. The resources needed to build and run such plants are very expensive. The expenses cover labor, equipment maintenance, electric power, etc. Therefore, for cities that do not have sufficient funding, it is very difficult to gather sufficient resources to build, operate and maintain a wastewater treatment plant.

Wastewater treatment facilities are mostly privately owned. Besides the cost of building the plants, it takes considerable amount of money to operate the plants. However, since consumers pay for their water supply, companies still profit from the process. Therefore the government could convince private sectors to fund the building and operating of the wastewater treatment facilities. On the other hand, it is more difficult to raise funds to build and operate sewage treatment facilities. Most of the population is not concerned with the sewage situation because of the lack of direct interactions. Compared to the water quality of their drinking water, the water quality of the nearby water body has less significant impact on their lives. The general stereotype is that only the government is responsible for treating the sewage. In fact, not until recent years in some cities in China, people were not required to contribute to the sewage treatments carried out in their cities. The sewage treatment process is more complicated than wastewater treatment. The expenses of building and operating sewage plants are also significantly higher than those of wastewater treatment plants. Due to the high cost and lack of sponsors, sewage treatments are not as common and well managed as wastewater treatments. The accumulating sewage causes the water quality to deteriorate and destroy the ecological balance in the surrounding area. If problems persist, the water source would become scarce and marine lives would be put at serious danger.

An alternative, more economical wastewater treating facility is the reed-bed system. Reed-bed applies the similar principle as the aeration tanks in the wastewater treatment plants. Reed beds use the roots of reeds to provide the optimal condition for the growth and reproduction of bacteria, and the bacteria consumed the microorganisms contained in the polluted water, which in turn cleans the water. Reed-beds are more

economical, however, they do not contain other steps necessary in the wastewater treating process, such as disinfecting. They are more suitable for farmlands that provide sizable areas and can effectively remove most chemicals in the polluted water.

Although technologies could effectively improve water quality, solely relying on technology is not the best approach. In order to protect the environment, it is essential to reduce the pollution that enters. The root of water pollutions should not be ignored. As mentioned in the earlier paragraphs, the main agricultural pollution sources are pesticides, fertilizers and livestock municipal wastes. In order to minimize the amount of pollution created from each of these sources, education and government enforcements are the keys. Most farmers in China showed little knowledge of the harmful effects of pesticides and fertilizers to their ecological environment. Studies done in the past indicated that Chinese farmers use pesticides extremely heavily. In some cases the farmers were found to over use pesticides up to 40%. The main factor for farmers to over use pesticides is their perspective that more pesticides yield better harvests. It was surprising that other factors, such as the cost of the pesticides and the farm size do not affect the amount of pesticides farmers used. Studies also showed that the amount of pesticides used was directly related to the farmer's perspective of how much the yield loss was due to pests. For example, if a farmer believes that 90% of the yield loss is due to pests, then he is more likely to apply more pesticides. In fact, any amount of pesticides beyond the optimal limit has negligible effect on the crop yield, which means all of the extra pesticides that farmers used did not help them to get better crop yields. Instead, it added more potential pollutants to the nearby environment and higher expenses for the farmers. However, studies showed that farmer's perspective about the effect of pests was

about 30%-35% above the actual effect of pests. Correspondingly, they use more pesticides than they need to.

To reduce the pesticides applied by the farmers, the first step would be to educate them. Observations have shown that farmers that have over 9 years of education perceive more accurately the effects of pests than farmers having less than 9 years of education. It is necessary to inform farmers with the facts about the harmfulness of pesticides and the ineffectiveness of using excess pesticides. It is not an easy task to alter farmers' strong beliefs and will take much effort to do so. If farmers are convinced that excess pesticides do only harm to the environment in their expenses, it is likely that they will use less. It is essential for farmers to know how to use pesticides accurately and read the hazardous labels on each pesticide. For example, farmers should spread the pesticides while the pests are in their early development stage. At the early development stage, pesticides are easier to diffuse into the pests and it helps to prevent pests from reproducing. In addition, they should be informed that some ingredients are more harmful to the environment than others. Instead of using chemical based pesticides, a better alternative is to use bio-pesticides. Bio-pesticides use bacteria or virus to infect the spurious pest by rupturing its skin or attacking its nervous system, which ultimately kills the pest. Bio-pesticides are environmentally friendly and introducing them to the farmers would greatly benefit the environment.

In terms of fertilizers, farmers could learn to use different kinds of fertilizer to keep the soil fertile. For example, using fertilizers that are made of livestock municipal wastes could benefit the environment in two ways. First it reduces the amount of livestock pollution and secondly, the fertilizers that contain bio-wastes are more

degradable in the soil and more environmentally friendly compared to chemical based fertilizers.

Government regulations and assistances also play important roles in reducing agricultural pollution. Some toxic pesticides have been banned by the Chinese government in the early 1980s due to their toxic nature. However, frequent inspections are needed in order to keep the banned substances away from illegal operators. It is possible that banned substances are still appearing in the black markets because they are in general very effective and relatively inexpensive. Officials performing surprise inspections at pesticide vendors would reduce the sales of banned, illegal pesticides. The government could also subsidize higher quality pesticides, such as newly developed bio-pesticides in order to promote manufacturers to produce better pesticides and farmers to use them. The government could save a significant amount of money on water treatment if farmers are willing to use biodegradable pesticides appropriately. Besides inspecting the types of pesticides being used, regulations on the amount of applied pesticides are also very important. The Chinese government has set up standards on daily maximum allowable amount of pesticides used. However, these standards did not show much improvement in the environment due to the lack of strict enforcements. Water samples from farms should be frequently collected for analysis. If excess chemicals were discovered, then proper penalties should be levied on the violators. On the other hand, farmers that meet the standards should be rewarded.

According to the experts in Guangzhou, the Guangdong government has been carrying out programs to educate farmers and raise their environmental concerns. Although data to substantiate the claim are not available, according to the Guangdong

government, the overuse of pesticides is not an issue in Guangdong, especially in cities surrounding the Pearl River Delta, because those farmers are better educated compared to northern farmers. Guangdong farmers also receive up-to-date information on new technologies from the government, research centers and academic institutes. Many experts believed that the water quality and environment in Guangdong has improved in recent years due to the regulations by the local governments. Guangdong people are now more aware and are making efforts toward protecting the environment. Although experts from different institutes agreed that the water quality in Guangdong has been improving and agricultural runoffs have been reduced, they did not offer any statistical data to support their assertions.

Part of the methodology was to contact the Guangdong's Environmental Protection Bureau to get statistical information on agricultural pollution. However, the attempt was unsuccessful. The people from that office were not willing to give out any information, qualitatively or quantitatively related to water pollution. This attitude is misleading. It makes people wonder if the officials have done their job properly gathering information as they were supposed to. If the officials have gathered and analyzed the statistic data, what are the reasons that the data are not available to the public? After all, people should have the right to have knowledge on the current water quality situations around them.

By studying the ways that other countries used to control agricultural pollution, the conclusion was that it takes much effort and the government plays the most important role in preventing agricultural pollution. In the United States, its Environmental Protection Agency established a 319 Non-point pollution monitoring program. This

program successfully reduced the non-point pollution in 39 cities. The U.S. government invested hundreds of thousands of dollars in each city and each project takes at least five to eight years to see significant results. The Chinese government has established laws and regulations to control water pollution. However, it would be useful to adapt the methods that have been carried out in other countries that are more developed in dealing with environmental issues.

Improving water quality and reducing agricultural pollutions are not an easy tasks. There is no immediate solution and it takes tremendous resources and a long period of time. The non-point sources of agricultural runoffs add complication in attempting to control the pollution. Education and government are the absolute essential components to reach the goal of reducing agricultural runoffs. The government provides the funding to educate farmers and the education that farmers receive in turn improves the quality of the environment. Lacking one or the other would not effectively reduce the pollution. According to some experts in Guangzhou, the Guangdong government has been working to educate the farmers and regulate the water pollutions created by factories and farms. However, these regulations are difficult to enforce. It needs people's cooperation to work with the government and most importantly, people's living standard needs to be high enough to meet government's wastewater standards because these standards are expensive to implement. Other types of organizations that are necessary for the improvement of the water quality include bankers, scientists and media. They have to work hand in hand to maximize the effectiveness of the adopted methods. Bankers could give loans to the projects; engineers and scientists design the structures and run the project; media help to get attention from the people. It will be a very complicated

project, however it is certainly worthwhile and necessary. It is believed that in the near future, the liaison of this project Civic Exchange and other organizations could work together to improve the water quality and the agricultural pollution situation in the Pearl River Delta area.

7. Conclusions

Summarizing all of the results collected and analyzed, the following conclusions are made:

- More areas surrounding the Pearl River Delta are converting from agricultural to industrial production, resulting in a reduction in agricultural runoffs.
- Major water pollution sources are industrial and domestic wastes.
- Major agricultural pollution in the Pearl River Delta area comes from pesticides and livestock municipal wastes.
- The Guangdong government and public are raising their concerns on environmental issues.
- The Guangdong government has established programs to educate farmers in order to minimize agricultural runoffs.
- According to interviewees from Guangzhou, the environmental situation in Guangdong has gone through significant improvements.
- People from Guangzhou did not show any data to support their assertions, which raises questions concerning their statement.
- The lack of communication with outsiders and unrevealed statistical information to the public lead people to think that the Chinese government is not working on environmental issues.
- In order to improve the water quality further, Guangdong needs to construct more wastewater treatment facilities.

- Guangdong has the technology to carry out wastewater treatment plants; however, financing the plants is a serious issue.
- Investments on sewage treatment facilities are long term and non-profitable, and therefore hard to obtain financing.
- It will take a long period of time and large amount of effort to improve the water quality in the Pearl River Delta, however, the task is necessary and worthwhile.

8. Recommendations

From the research that has been done, most agricultural pollution problems have been identified. They include technological problems, social problems and governmental issues. Having studied the problems and potential solutions of the agricultural pollution in the Pearl River Delta area, the following recommendations are made.

- Government needs to tighten the regulations on banned pesticides and fertilizers, and prevent violators from selling them to farmers.
- Government could subsidize the higher quality pesticides and fertilizers thus promoting their use by farmers.
- Chinese brochures on information regarding pesticides and fertilizers should be produced and distributed to farmers.
- Communication among government officials, scientists and bankers concerning the issue of pollution through some kind of literature or net access should be increased.
- Cross-border (Hong Kong and mainland China) cooperation should be set up to clean up the water.
- Chinese government should consider publishing the analysis data on the water quality of the Pearl River Delta and make them available to the public.
- Farmers in the Pearl River Delta area should be educated on the proper usage of pesticides through free seminars by Civic Exchange or proper government agencies.

- Teach farmers the negative environmental effects of pesticides and fertilizers, and show them the consequences of overusing these chemicals. For example, let them know the diseases that pesticides could cause in human beings.
- Teach courses on environmental protection to school children, including kindergarten, elementary school, high school and college to raise their awareness.
- Get media to participate in the projects. They could get the public's attention and opinions.
- Promote farms to use livestock municipal wastes as fertilizers.
- Set up scientific research centers that would allow farmers to use computers and the internet to obtain information that they need.
- Establish more wastewater treatment facilities that could clean the water and treat the sewage.
- Improve existing wastewater treatment plants to work more efficiently and cover larger areas.
- Establish monitoring program to monitor the usage of pesticides and fertilizers by taking water samples for analysis.

Appendix A

Civic Exchange

Civic Exchange is an independent and non-profitable think tank. It is formed from different organizations, professionals, volunteers and interns, and Christine Loh is the Chief Executive. Their works cover many different fields and most of them are addressed to environmental and social and political problems. Their objectives include:[50]

- To promote civic education, public awareness and participation in governance by strengthening civic participation in public life.
- To undertake research and development of economic, social and political policies and practices to help shape the breath and depth of public policy debate and so to advance polices that are sustainable, resilient, non-violent, economically efficient, just, participatory, locally appropriate and spiritually rewarding.
- To integrate skills and experience across various disciplines including academic, business, politics, finance, technology and the non-profit sectors.

Established in September 2000, Civic- Exchange now has three projects in hand. They are [51]"Developing a Clean Vehicle Strategy for Hong Kong", " Cross- board Environmental Law Research" and " Civic Exchange for the Environment". Besides these current projects, Civic Exchange had already published two publications[52]: " A Return of Sanity on Housing" and " A Comprehensive Review of Marine Policy" in late November. There are also some up coming publications which concern pollution, and the disabled people in Hong Kong.

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[50] http://www.civic-exchange.org/main.asp
[51] Ibid.
[52] Ibid.

On December 11th, 2000 Civic Exchange launched a newly designed web page which contained the "Environment Pilot Site[53]". This Pilot is a very informative source, and its main concern is environmental issues. Inside the site, Civic Exchange provided a lot of information such as law and environment, political structure, and economics and the environment, etc. Civic Exchange is now getting feedback from schools and community groups so that they can develop the Pilot into a more advanced level. Civic Exchange hopes that the community finds it informative and useful, and people could get the greatest benefit from the Pilot[54].

[53] http://www.civic-exchange.org/enviro/politic_n_enviro/politics_n_envir_a01.htm
[54] Ibid.

Appendix B

Christine Loh

According to BusinessWeek[55], Christine Loh is one of the Stars of Asia. She was sent to a boarding school in Britain at the age of 15 and returned back to Hong Kong with a law degree from the University of Hull. After being a successful businesswoman for 12 years, she was appointed to the Legislative Council (LegCo) by the British Governor Chris Patten in 1992. Ms. Loh had a very successful career in the LegCo. She was famous for her fights against the land reclamation and for pushing the governor to protect the environment. After running in two elections subsequently, she decided to retire from the LegCo in 2000, but this did not mean that she retired from politics. Ms. Loh described [56]the executive branch and LegCo as formal big "P" politics. There was also politics with a small "p", which comprised the media, non-governmental organization (NGOs) and the general public. After nearly 9 years in big "P" politics, she was simply crossing the road to the side of the small "p". She believed that the small "p" would eventually expedite formal political reform.

Due to her experience in the LegCo, she found out that ordinary people wanted to engage in public affairs discussions and decision- making. She realized that [57] " the more people understand, the more they were appalled by the inherent unfairness of it." She started to write weekly e-Newsletter and nearly 2000 supporters received her reports. Unfortunately, sending emails were not enough to achieve her goals. She started a project called the Civic Exchange. This web site provided easy access for the public to gather

[55] http://www.businessweek.com/2000/00_27/c3688062.htm
[56] http://www.hkdf.org/newsletters/0010/0010_4.htm
[57] Ibid.

information on environmental issues and researches. This think tank was also to provide a "parking" space for "brain power". After all, Ms Loh would promote the "idea" to the government and she believed that she could be very effective behind the scene.

Appendix C

Interview with Zhang Yong Xi, a journalist on agriculture for the Guangzhou Daily

Q: From your experience, how bad are agricultural pollutions in Guangdong?

A: Agricultural pollution is not that bad. Industrial and municipal pollutions are worse in Guangdong. Especially the detergents the households use, people use a lot of them and the chemicals contaminates the water.

Q: What are the main agricultural pollutions?

A: Fertilizers and pesticides. Farmers use pesticides very heavily. The chemicals go into the water and those are the biggest pollutants.

Q: How about chicken and pig farms? I understand that Guangdong exports pigs to Hong Kong.

A: Guangdong does export pigs to Hong Kong, however, it imports more pigs than it exports. Guangdong mainly imports pigs from Hunan because pigs are cheaper there. Even if Guangdong do not export, it's own pig farms cannot supply enough pigs for the province. In terms of poultry, however, Guangdong is the leading province. That's why chickens are getting cheaper than pork at the markets.

Q: Do these animal farms produce a lot of municipal wastes that pollute the water source?

A: To my understanding, municipal waste of the farms is not a big concern compared to the fertilizers and pesticides. Because those wastes will be decomposed in the water. Big chicken farms reprocess the municipal wastes to fertilizers and sell them to farmers. I don't know how smaller farms treat their municipal wastes but I don't believe that those wastes will be more dangerous than the pesticides and fertilizers.

Q: Do you have any statistical information that I can have? Such as the amount of chemicals contained in the water.

A: It's hard to get that kind of information. Farmers would not admit that they dumped chemicals into the water, and some maybe don't even realize that they did. The amount of chemicals contained in water vary everywhere, they can't get the right numbers on those measurements. I don't recall seeing much of those numbers.

Q: Currently does Guangdong have any wastewater treatment plants?

A: There is one here in Guangzhou, near Tinhe. What they do is that they stop the wastewater from entering the Pearl River and direct them to the wastewater plant. The plant releases the treated water back to the Pearl River.

Q: How big is the wastewater treatment plant?

A: I'm not sure about that. I think that they're building another plant, but really not sure. I have never visited that place.

Q: What do you think about the water that you're using? Any comments?

A: The water is all right, of course it could be much better. It will be nice to have portable water. But it's not bad. It has gotten better in the recent years. It's hard to get very good water because Guangzhou is such a populated city. Every household uses a lot of water daily. It's already difficult to maintain the supply.

Appendix D

Interview with Prof Ng Sai Leung from the Chinese University of Hong Kong

On January 12th, 2001, Jennifer and I visited the Chinese University of Hong Kong and interviewed Prof Ng Sai Leung. Prof Ng taught geomorphology, applied geomorphology and environmental studies. His research interests were environmental reconstruction, environmental assessment, applied geomorphology, and quaternary studies. He has done a lot of services to the Geography Department and the University; for example, he is the chairman of the Staff Student Consultative Committee, Geography Department, from 1998 to now. He did a lot of researches for the Agriculture & Fishery Department, HKSRA Government.

The purpose that we wanted to interview Prof Ng was to get a good start for our project. Because Prof Ng was an expert on the environmental studies in China, he did give us a lot of valuable information about the Pearl River Delta. The following was the summary for the interview:

Q: What do you think about the water quality in Pear River Delta?

A: It is not the worst among the five most important rivers in China. Sometimes, the mass media mislead the public and the pollution in Pearl River is not that bad.

Q: What do you think about Industrial, agricultural and municipal pollution in Pearl River Delta?

A: It was very hard to identify which industries polluted the river the most. Researchers usually used analyzed date to do the predictions. For example, if the proportion of Nitrogen and Phosphorus were higher, it should come from the

agricultural industry. So there was no official statistics showing how each industry polluting the Pearl River.

Q: How does the agricultural industrial in China different from the others?

A: The agricultural industry in China was very different from the United States. In the United States, farmers usually practiced extensive farming. They had a very large farm and so farmers could separate animals and plants into different places. In China, farmers usually have an intensive farming. The farming area was limited. Animals farming were closed to the houses and this caused a lot of environmental problems. Moreover, in order to harvest faster and earn more, farmers used a lot of fertilizers and pesticides. The overused fertilizer and pesticide caused a lot of pollution on both the air and water in the Guangdong Province.

Q: What about the Industrial pollution?

A: Recently, the heavy metal pollution has been decreased a lot compare to the last few years. It depends where to measure the pollution level. If the measurement is taken next to a factory area, then the pollution from heavy metal is very high.

Appendix E

An interview with Suze Lyonnaise des Eaux

On Feb 16, 2001, we went to meet with Mr. Jacques Letondot. Mr. Jacques Letondot works for a French company.

Mr. Jacques Letondot started the interview by introducing their company's works in China. The company started this business 15 years ago, and now they owned 3 water plants in Pearl River Delta to supply portable water. Mr. Jacques Letondot said that Guangdong Province was rich in water resource, but the problem was how to provide water to the public. At the same time, industries moved up to Guangdong, and this caused the pollution to increase. So, their company is now starting on wastewater and sewage treatment plants. Mr. Jacques Letondot told us that running a portable water plant was inexpensive, and the cost was low. Since power and water were daily necessities, consumers were ready to pay for the water fee.

Unfortunately, it was a different case in the wastewater and sewage treatment plant. Mr. Jacques Letondot said that one of the problems in China was getting fundings from either the government or the private sectors. Since the cost of running sewage treatment plants was far more than running a portable water plants, it was difficult for a private company to do this alone. Moreover, it was not a profitable business, and it might take a long time to get a balance. So, there was no credit to get the funds. Mr. Jacques Letondot told us that some companies failed to manage the plants after they built the infrastructures. It was because they were already out of money and funding. He suggested that the government should subsidize or build the infrastructures, and let

companies to mange those plants. It was because foreign companies have experienced in managing the plants.

Mr. Steve Clark, executive director from Sino French Water Development Company Limited, also said that the wastewater treatment was a failure in Guangdong Province. He said that most of the factories had pre-treatment plants. The reason why they did not use these plants was because running the plants were expensive, and manufacturers only used these plants as an inspection sample or met a certain requirements from the government. Mr. Clark said that the factories would rather pay for the sewage fee than using the pre-treatment plants. So, the sewage and wastewater treatment plants were not profitable.

At the end of the interview, we asked Mr. Clark what he thought would help decreasing the pollution in Guangdong Province. Mr. Clark said that the polluter paid the fines and fees. He also suggested the government to improve the education and limited the use of pesticides.

Appendix F

Interview with the South China Institute of Environmental Sciences, NEPA

South China Institute of Environmental Sciences, NEPA, is one of the three-research centers under the government. They did scientific research for the government and then they evaluated the data for preventing the environmental pollution

Mr. Peng Haijun, a senior engineer, said that early in the 80, the Pearl River was polluted heavily because of the industrialization. Different kinds of chemicals were directly pumped into the Pear River from the factories, and those chemicals were toxic. During 1990~2000, the pollution level was in a stable condition. It was because of a slow down on industrialization and the government had strength the regulations and control.

During 1990~ 2000, the government of Guangzhou had established both regulations and inspection teams to control the pollutants level. Factories were forced to have a wastewater treatment plant inside the factories. Once the factory did not pass the inspection, the government would shut down the factory until there were improvements. Moreover, the government would fine the factory for over producing the pollutants. These fees would go back to clean up the water.

Although the water quality of the main stream had improved, some of the sub-streams were still having a heavy pollution. These sub-streams were not well inspected by the government, and most of the small and middle size firms were there. Mr. Peng Haijun said that usually large firms had organized better on the environmental protection, but small and middle firms were lack of money to consistently run the wastewater plant. So the sub-streams were polluted by various kinds of chemicals, these included the agricultural waste and domestic waste.

According to Mr. Peng Haijun, although excess fertilizer and pesticide were toxic and harmful, they took a long time to diffuse or leach into the water sources. Unlike fertilizer and pesticide, animals' wastes were directly pumped into the water sources without treatment. Compare the large amount of animals' waste and the relatively small amount of fertilizer and pesticides, the major pollutant from agriculture was the animal waste.

Mr. Peng Haijun explained that the agricultural pollutants were not the main concern for the public. Although there were a large amount of animals' waste pumped into the water sources, those pollutants were organic and they would eventually decompose after a period of time. Unlike the heavy metals and the toxic chemicals, those substances would not decompose and they would stay into the water.

Finally, Mr Peng Haijun said that there were hidden problems on the government's regulations. The weakness of the government regulation was the management. In China, the central government established some guidelines for the local congress to follow, and the local congress would establish regulations that fit their cities, county or villages. Unfortunately this might be a misunderstanding between central government and the local congress. Moreover, if the local congress did not follow up the policy from the central government, the whole system would collapse.

Mr. Peng Haijun concluded that the publics were now having the sense of environmental protection. Farmers were taught how to use fertilizer and pesticide correctly, and factories treated their own wastewater. The situation was changing better and better, and hopefully they could see and use the clean water from Pearl River in the future.

Appendix G

Interview with South China Agriculture Institute on February 28th, 2001

Civic Exchange group met with two personals from the South China Agriculture Institute. Due to the confusion on the Institute's part (they were not expecting Civic Exchange to come at that time), the professors that expertise on agriculture and agricultural water pollution were occupied and were not able to meet with Civic Exchange. Instead, two people from the international relations department brought us to their office and discussed some general issues on agricultural pollution. The two personals from the Institute were very friendly and helpful.

Civic Exchange: Civic Exchange is an independent think tank of Hong Kong that mainly focuses on environmental issues. We are currently carrying out two research projects, one of air pollution and one on water quality. We are the water group. The purpose of our visit is to get information on agriculture in Guangdong. As well as agricultural pollutions, current situation of wastewater treatment and some other aspects relate to those. We have done researches in Hong Kong but had trouble finding some specific and statistical information. We wanted to come to China and talk to people like you to get a clearer picture of the situation in China. Hope you can help us.

Institute: We'll try our best to help you. But we are not professors that have many experiences on these topics. The professors are all busy today. We called their office and home but still could not find any of them. We

apologize for this confusion. We didn't know you were coming today. Because at the time we schedule the meetings, we realized that some paper works were missing. We informed the U.S. Consulate but they never replied to us. So we were not expecting you today. Feel free to ask any questions though.

Q: For the pass fifteen to twenty years, has the water quality of the Pearl River Delta improved, worsened or remind at the same level?

A: I would say the water quality has improved. There is really no reason for it to get worse because the government has worked to improve the environment in recent years.

Q: Out of the three water pollution sources, which are industrial, domestic and agricultural, which one is the most harmful or create the most pollution in this area?

A: I would say it's either domestic or industrial. Domestic include all of the municipal wastes created and the detergents used in the households. Tons of those pollutants enter the river everyday. Industrial wastes used to be really bad but now there are regulations to control industries.

Q: How do agricultural runoffs fit in the picture?

A: Well, in Guangdong, especially around the Pearl River Delta, more and more areas are converting from agricultural to industrial. In other words, agriculture area is diminishing. So I will be surprised if agricultural pollution plays a major role in the water pollution, at least in Guangdong.

Q: There are several types of agricultural pollution, pesticides, fertilizers and livestock municipal wastes. From the articles that we've read, pesticide is the main agricultural pollution. What do you think about that?

A: Pesticides could be dangerous contaminants to water. Years ago we used to hear stories about food poisoning and in some cases, are caused by pesticides reside on the food. We don't hear that kind of stories anymore. Mainly because people's awareness of food poisoning has gone up, and farmers are using less toxic pesticides.

Q: We have read about bio-pesticides, is that what you meant by "les toxic pesticides"?

A: Yes. They are the newly developed pesticides. Basically instead of using chemicals as bases, they use bacteria and other microorganisms to kill the pests. Some manufacturers even put herbal ingredients in some pesticides to kill the pests. Bio-pesticides are more environmental friendly because not much harmful chemicals are used.

Q: If the bacteria could kill the pests, wouldn't they cause harms to other organisms, including human beings?

A: Of course the researchers will find bacteria that do not cause harm to human. It wouldn't make sense to add more harmful bacteria to the environment.

Q: We have also read articles indicating that the farmers in China overuse pesticides by large amounts. Do you think that is true?

A: I really don't believe that farmers would overuse pesticides by large amounts. Only people that have no idea of the harmful effects of pesticides would do that. Farmers know that the pesticides have negative effects to their environment. At least farmers in Guangdong probably do. Overusing pesticides is an act of ignorance.

Q: We agree. So do farmers in Guangdong get educated on the negative effects of pesticides, fertilizers? Are they aware of the importance of the environment?

A: Farmers in Guangdong do. There are three ways that farmers get educated: by local government, by research centers, and by educational institutes like us. Government teaches farmers the importance of protecting the environment using several methods. Perform promotion in the radio broadcasts, perform on-site inspections and bring people to the farm to educate the farmers. Research institutes develop new agricultural products, including pesticides, fertilizers, machineries, etc. They would visit the farmers and carry out seminars to promote their new products. In turn they educate the farmers on various aspects of agriculture, including methods to farm and pesticides to use in order to protect the environment. Also universities and institutes like us would send students periodically to the farms to get experiences. The students will communicate with the farmers on the latest technologies and exchange their knowledge. So I would say that the farmers in Guangdong have plenty of opportunities to get educated.

Q: So over-usage of pesticides is not an issue in Guangdong?

A: I don't think so. It could be worse at the southern province but not in Guangdong.

Q: How about livestock municipal wastes? Some people believe that it's the main agricultural pollution in Guangdong.

A: Livestock municipal wastes are similar to human municipal wastes. They are degradable in water. Some of these wastes are used in fertilizers. Manufacturers combine wastes with chemicals to produce fertilizers. There isn't much that can be done to treat the municipal wastes. It would need wastewater treatment facilities to clean up those wastes.

Q: Are there big animals farms near the coast of the Pearl River Delta?

A: There are several big animal farms in Guandong. I can't locate them exactly but I believe that some are near the coast. Animal farms need water to raise the animals so it would make sense to build them near water bodies.

Q: Are farms required to clean their own wastes?

A: The local government regulates bigger farms. Farms have standards on the waste they create and they have to meet those standards in order to prevent punishments. For small farms, such as households that raise several pigs, it is hard to regulate. But the amount of pollutions created by these small farms are relatively insignificant anyways.

Q: How are the farmers being punished if they fail to meet the standards?

A: At first they will receive a warning. And if problems continue, they will have to pay fines. And the amounts of fine vary.

Q: We are at the end of this meeting. Is there anything that you can add?

A: I think the situation in Guandong is improving. Agriculture in Guangdong is becoming more professional. It will take time to perfect the situation but to me, it is pretty good already.

Civic Exchange: Thank you very much for your time, is there any statistical data that we could look at?

Institute: The professors would have them but we don't. Come back next time and we'll arrange meetings with some professors.

Civic Exchange: That's okay. Thank you so much. Hope to see you in the future.

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