AN INVESTIGATION ON PUBLIC ENVIRONMENTAL INVESTMENT IN THE P.R.C. FOR SUSTAINABLE DEVELOPMENT

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2013

THE HONG KONG POLYTECHNIC UNIVERSITY

Institute of Textiles and Clothing

An Investigation on Public Environmental Investment in the P.R.C. for Sustainable Development

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A thesis submitted in partial fulfillment of the
requirements for the degree of
Master of Philosophy

Apr 2011

CERTIFICATION OF ORIGINALITY

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_______________(Signed)

CHEN Keyu (Name of student)

Abstract

Abstract of thesis entitled:

An Investigation on Public Environmental Investment in P.R.C. for Sustainable Development. submitted by CHEN Keyu for the degree of M.Phil. at The Hong Kong Polytechnic University in Apr 2011.

Environmental problems, arising from overloaded fast-paced economic development, are faced throughout the world. These problems are especially pronounced in the Peoples Republic of China (P.R.C.), where environmental resource deterioration is beginning to hamper the sustainability of socio-economic development. The costs of environmental protection and restoration are increasing, and may, one day, offset the economic growth if bold and appropriate measures are not implemented in time. It has been the prime concern of the national environmental authorities to establish a reasonable annual environmental spending as a ratio of the GDP, in the coming five-year plan.

This work aims at establishing an appropriate public environmental spending as a ratio of the GDP, and a reasonable spending schedule in order to ensure sustainable development in socio-economy in the P.R.C.. The investigation was carried out based on an in-depth analysis of data and materials, from both the Government and academic sources, on the (1) current status of hydrospheric, atmospheric and lithospheric environmental quality, (2) economic structure and population density, and (3) shortfalls in current environment expenditure in the P.R.C.. These studies

were carried out by comparing and contracting with the situations in such countries as India, U.S., Japan and Germany to further fine tune and optimize the public environmental spending schedule and policies.

India was selected for comparison due to its population size and density which are comparable to that of the P.R.C.. U.S. was compared and contrasted with for the size of its GDP that is of comparable order as that of the P.R.C.. Japan and Germany were chosen for comparison because both these countries are major industrial manufacturing hubs in the Asia Pacific and European Union, respectively, which are of similar roles and economic structure as that of the P.R.C..

In-depth analysis has revealed that the present annual public environmental investment (EnvI) in P.R.C., after necessary adjustments, is less than 1.0 % of GDP. This is far from being sufficient, considering the annual rate of economic growth in excess of 10 % for the past one and a half decade, and the severe polluting nature of the manufacturing economy. Furthermore, 1 % of GDP for environmental spending is also substantially lower compared to developed countries. This underinvestment and the somewhat inappropriate spending schedule have resulted in ineffective pollution management and control, which have expressed as relatively severe hydrospheric, atmospheric and lithospheric pollutions.

Taking the experience of developed and developing countries into consideration, to ensure sustainable development, the public environmental investment should be set at 2.1 % of GDP to start with. Furthermore, this figure should build up annually at a

rate not lower than that of annual GDP growth. Public environmental spending should include capital investments on the construction of various waste processing facilities and the running costs of these facilities.

Assuming the GDP growth of the P.R.C. will maintain at an average level of 8%, it is recommended if the EnvI should grow at a tri-annual rate of 12%, thus reaching 2.15 % by the year 2024. This percentage will then maintain from then on, and closely tag onto the annual GDP growth rate. This recommended public spending should suffice, considering the currently fine tuning of economic structure to enter into more value-added high-technology productions with presumably lower level of pollution, and the substitution of no less than 35 % of conventional coal- and oil-fired power plants by green and renewable energy sources, such as solar-, hydro-, wind-, and biological sources.

In conclusion, concerted efforts in increased public EnvIs, economic structure transformation, research and development of novel and appropriate environmental technologies, enactment and implementation of environmental legislations and education in environmental consciousness are necessary. Additionally, the government should strategically invite commercial investments on a BOT (build-operate-transfer) basis, as in the U.S. experience, in order to improve the effectiveness and efficiencies of communal municipal waste treatment facilities.
Keywords: Environmental investment, GDP, economic structure, sustainable development, P.R.C.

Acknowledgement

I would like to express my sincere gratitude to my Supervisors，Dr KAN Chi-Wai and Professor Hong Chua for their kindly suggestions, supports and guidance.

I also wish to thank my teammates, Mr. CHAN Mo Chee Charles, Ms. CHEN Yin Carol and Mr. LIU Yaohui, for their encouragement, support and assistance to my study.

I am grateful to The Hong Kong Polytechnic University for providing me with the opportunity of being a MPhil candidate of this university and for providing me with the financial support.

Last but not the least, I wish to express my profound gratitude to my families, to whom this thesis is dedicated. Without their everlasting love, support, devoted help and encouragement I would never have embarked on my graduate study and would not have had the opportunity to write this thesis. I am indebted to them for so many things which cannot be described in words.

Table of Content

List of Figures

List of Tables

List of Abbreviations

AAPMS	Ambient Air Pollution Monitoring Station
AEGMS	Automobile Exhaust Gas Monitoring Station
BOD_5	Biochemical Oxygen Demand in 5 days
Cd	Cadmium
CHN	China
CO	Carbon monoxide
CO_2	Carbon dioxide
COD	Chemical Oxygen Demand
DEU	Deutschland
DO	Dissolved oxygen
EnvI	Environmental Investment
EPA	Environmental Protection Agency
EQS	Environmental Quality Standard
ESER	Energy Saving and Emission Reduction
ETPs	Effluent Treatment Plants
FDF	Forced-Draft-Fan
GDP	Gross domestic product
GHGs	Green House Gases
GNP	Gross national product
GW	Gigawatts
H_2SO_4	Sulphuric acid
Hg	Mercury
HKG	Hong Kong
HUDCO	Housing and Urban Development Corporation Limited
INR	Indian Ruppee
MSW	Municipal Solid Waste
N	Nitrogen
NO_x	Nitrogen monoxide and Nitrogen dioxide
OECD	Organization for Economic Cooperation and Development
P	Phosphorus
PAC	Pollution Abatement and Control
POPs	Persistent Organic Pollutants

PPP	Per capita gross domestic product
PRC	People's Republic of China
PRD	Pearl River Delta
SEPA	State of Environmental Protection Agency
SGP	Singapore
SO_2	Sulfur Dioxide
SO_x	Sulfur Dioxide and Sulfur trioxide
SPSS	Statistic Package for Social Science
TKN	Total Kjeldahl Nitrogen
TP	Total Phosphorus
TVOCs	Total Volatile Organic Carbons
U.K.	United Kingdom
UNCHS	United Nations Centre For Human Settlements
U.S.	United States
USA	United States of America
USD	United State dollar
WHO	World Health Organization

1. Introduction

1.1 Background

High-paced economic and industrial developments bring about substantial wealth at the cost of damaging the environment and breaking the ecosystem, making economy and environment to be two contradictory factors in the human societies. It has become increasingly apparent that pollution problems are becoming more global in nature in recent years. That is, socio-industrial activities in one region results in significant impacts on the environmental quality of a region many miles away from that one (Sawyer and McCarty, et al, 1994). The large quantity and chemical nature of many industrial effluents, solid and hazardous wastes, and gaseous discharges have surpassed the natural self-purification capability of the atmospheric, hydrospheric and lithospheric environments, hence causing localised accumulation and long distance transportation of persistent and recalcitrant pollutants (Stearns, 2007).

1.1.1 Effects of industrialization

Since the days of first industrial revolution in United Kingdom in the eighteenth century, there have been earthshaking changes to the style of human living, in addition to the all reshaped economy, society and environment. Industrialization not only produced new social classes, new job opportunities, large social productive capacity, rising population density in urbanised areas, and hence, increased adverse environmental impacts, but also totally reshaped agricultural production, such as increasing application of novel drugs, animal feed additives, soil conditioners and pesticides (Hass and Smith, 2002).

In modern days, industrialization continues in an increasing pace in the developing world, including China, Taiwan, India and Vietnam (Philip, 2007). Companies and multi-national corporate increase their profitability by utilising the cheap labour provided by these developing countries, and in this way, further speeding up of the pace of industrialisation happened there (Page and Harris, et al, 1977). Among these, China tops the list and has been the leader in terms of economic development during the past two decades. However, industrializing process of China encountered with the natural resource and environmental constrains that the developed countries have never encountered before. (Bai, 2005) Therefore, it is not difficult to imagine the confliction between economic development and environmental protection of the developing countries during their industrializing progresses.

1.1.2 Effects of urbanization

The acceleration of urbanization leads to more severe pollution due to extreme uneven distribution of population. Localised high population density further results in uneven allocation of resources. On the whole world over 75 percent of population of around six billion people lived in urban areas until the year 2000 (Philip, 2007), which brought tremendous environmental pressures on these areas.

Air pollutants, including atmospheric and eventually indoor air pollutants, mainly resulted from traffic emissions, factory smoke and major oil-fired and coal-fired power plants. Water pollution mainly comes from chemical discharges from manufacturing factory premises, untreated human wastes, ocean oil leak and marine dumping pollutants such as toxic, hazardous waste and even radioactive wastes.

Unreasonable application of pesticides, soil conditioners, feedstock additives and animal drugs in farming can lead to land pollution. In addition, radioactivity from nuclear power generation premises is also a contamination source.

Expanding urban populations, related urbanization and development of communal facilities brought about increased waste water, polluted air and solid wastes being discharged into the environment (Stearns, 2007). Furthermore, urbanisation calls for industrialisation in order to satisfy increased demands for products. On the other hand, industrialisation requires further urbanisation in order to better serve the expanded industries. This, in certain sense, is a vicious cycle in the case of inappropriate management of environmental problems.

1.1.3 Environmental costs of economic development

It is believed that environmental problems are not just caused by industrialization and urbanization. The environmental consciousness of a country or a corporate is, to a large extent, the key factor that could change the environmental costs of economic development. Alan Schnaiberg (1980) has pointed out that environmental damage is an unescapable problem of competitive capitalist market economies for its sole driving force which is profit-making. Philip (2007) also indicated that 'competitive pressure leads to a constant motivation for an increase in the production of cheaper goods'.

The constant seek for maximizing profit ultimately sped up the process of unregulated industrialisation. As Bell (2004) described, if the capitalistic production sets the environment on a treadmill to environmental damage, then modern consumerism helps to accelerate the running speed of this treadmill, and hasten the environmental deterioration.

During the last half century, industrial production was transfered to developing countries for the lower salary and taxes, and for less stringent environmental legislation. The commodity transaction has to be conducted, although producing and consuming may be occurred in different locations and markets. Goods tend to be produced in the places where the low production cost exists while purchasing happened wherever the best price can be gained. This results in a potential risk of misallocation of resources and lack of effective environmental management.

Some countries have set about some researches about environmental investment over the years. For example, an EnvI statistics survey of 399 manufacturing enterprises in Norway from 1974 to 1985 is conducted by Norwegian Government (Caprona and Hansen, 1987). The U.S. Census Bureau made a study of the Pollution Abatement Costs and Expenditures (PACE) Survey to investigate the environmental expenditures and costs of the manufacturing industries in 1973. (Becker and Shadbegian, 2007) In addition, since 1960s, Japan promoted to treat environmental pollution at the beginning of industrialization.

However, several politico-economic problems in some developing countries set up barriers for their environmental management, especially in terms of EnvI. (World Bank, 1992; Lo and Tang, et al, 1997) Fortunately, information of China is relatively abundant and is available for this study.

According to the study results of some international organizations and economic experts, the development of environmental pollution can be basically controlled only when a country’s public pollution treatment investment accounts for 1.0 to 1.5 % of the GDP, and the improvement of environmental quality can only occur significantly when the EnvI increases to 3 to 5% of GDP the corresponding period (Lu and Gao, 2004; Wang and Chang, 2003). However, this relies heavy on such factors as nature of economic structure, geographical and climatic characteristics, rate of economic development, and the level of involvement of commercial companies in investment and operation of environmental treatment facilities.

1.2 Critical Issues

It has to be emphasized that different countries have the peculiarity in their situations. Different stages of development also bring about diverse environmental problems with subtle and profound differences. Although many researches about environmental protection investment have been done by some development countries in these years, they used different definitions and methodologies, and an uniform assessment system has yet to be established (Hass and Smith, 2002). Because the enterprises didn’t have a clear and distinct concept about environmental expenditure, the data and relevant information about public environmental spending are difficult to be established as a good measurement and to be made a cross comparison without appropriate adjustments. Therefore, it may not make much sense by simply comparing environmental spending as a percentage of GDP of different countries without normalizing the basis for comparison (Guangzhou Environmental Protection Bureau, 2010).

For example, the theoretical concept of environmental protection cost of Norway has been developed and refined, but the means of calculation or estimation of the investment values have not changed essentially from 1980s. The biggest issues included investment pollution abatement industries and facilities (Hass and Smith, 2002). Also, commercial involvements, long-term operating costs and hardware depreciations add complication to the calculation of environmental costs. The situation is U.S. is another example. Since the year 1973, U.S. conducted a survey on environmental cost of enterprises. Nevertheless, some studies doubted the reliability of Pollution Abatement Costs and Expenditures data for the issues mentioned above (Becker and Shadbegian, 2007).

1.3 Objectives of research

1.3.1 General objective

The general objective of this research is to establish an appropriate public EnvI, as a ratio of the GDP, through assessing the current EnvI situation in the P.R.C. and comparison with other countries, in order to ensure a sustainable development in China by considering both the stage of development and the possible transformation of economic structure.

1.3.2 Specific objectives

There are five specific objectives listed here.

(1) To analysis the fast-deteriorating environmental quality in the P.R.C., in order to elucidate the urgent need of critical effort on specific environmental field.

(2) To explore the relationship between socio-economic growth and environmental pollution in China.

(3) To evaluate if the current public EnvI is sufficient in preventing the environmental deterioration from turning worse;

(4) To compare the environmental policies and public expenditures between the four strategically selected countries and P.R.C..

(5) To formulate a set of suggestions and recommendations on the implementation of effective environmental protection measures by adjusting the current magnitude of

EnvIs.

1.4 Structure of the thesis

The structure of this thesis is summarized in Figure-1.01.

Chapter 1 is an introduction to the critical environmental issues and provides information on the current focus on environmental deterioration on a worldwide perspective.

Chapter 2 is literature review and discusses available information on theories in environmental protection investment, and provides contextual background of the research.

Chapter 3 prescribes the scope of research and methodologies of this study.

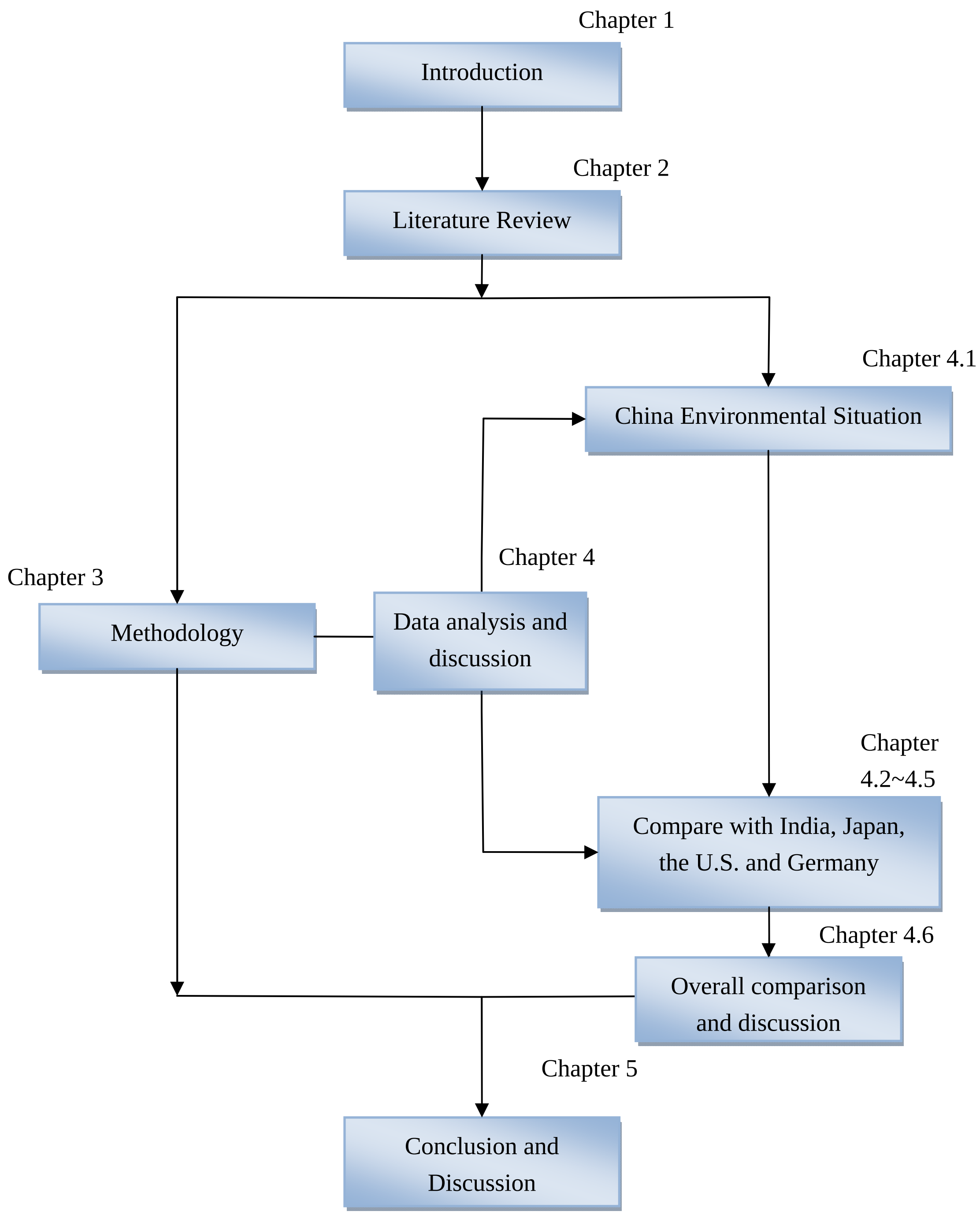
Chapter 4 is the data analysis and discussion section. Section 4.1 provides information on the current environmental situation in China and the relationship among economy, society and environment. The first two specific objectives of this study would be achieved in this section. Sections 4.2~4.5 undertake critical analysis of India, Japan, the U.S. and Germany on their environmental circumstances and investment. This shows relevant investment situations in developed and developing countries and their legislation frameworks for the comparison and essential basis for comparison.

In each chapter, an interim conclusion will be drawn, which will contribute to the overall general objective. After the specific comparisons, Section 4.6 carries out an overall comparison by adjusting the parameters in order to justify the basis for direct comparison among different countries. An optimal public EnvI is established for the

P.R.C..

Chapter 5 summarizes the whole research works to come to some conclusions and suggests the future directions as a continuation of this research.

Figure-1.01 Structure of the Thesis



2. Literature Review

2.1 Resistance to sustainable development due to environmental problems

2.1.1 Economic loss due to deterioration of environmental resources

The relationship between economy and environment can be divided into three categories that are coordination, imbalance and transition (Cao and Yu, *et al*, 2005). However, if the excessive exploitation of natural resources and serious pollutions carries on, the transition mode can developed into the imbalance mode. Today's China is in the transition type and it will suffer significantly if the environment is still being degraded.

The major problems associated with environmental resources are the fundamental resistances that slow down economic development and threaten sustainable development. The most obvious environmental impact on the socio-economy is the pollution expenditure incurred due to various environmental problems. It is estimated that economic losses caused by environmental pollution range from 3.5% to 8.3 % of China's GDP, according to a study by the Policy Research Center for Environment and Economy of the State Environmental Protection Administration (Lin, 2003; China Development Bank, 2010).

In accordance with the data of China Statistic Bureau, the average direct economic losses induced by environmental accidents and incidents from the year 2000 to 2006 was 140 Million Yuan, which accounted for about 0.013‰ of the average GDP in due years. Figure-2.01 shows the direct economic losses from 2000 to 2006 in absolute monetary terms (RMB).

The histogram in Figure-2.02, on the other hand, represents the economic loss as a fraction of the GDP over the same period as showed in Figure-2.01. The environmental accidents and incidents include such cases as marine oil spills, eutrophication and algal blooms in surface water bodies, chemical spills in inland water bodies such as rivers, land contaminations due to toxic organics and heavy metals, industrial fouled air discharges and chlorine leakages, etc. (Jiangsu Provincial Environmental Protection Bureau, 2010).

Figure-2.01 Direct economic losses in P.R.C.

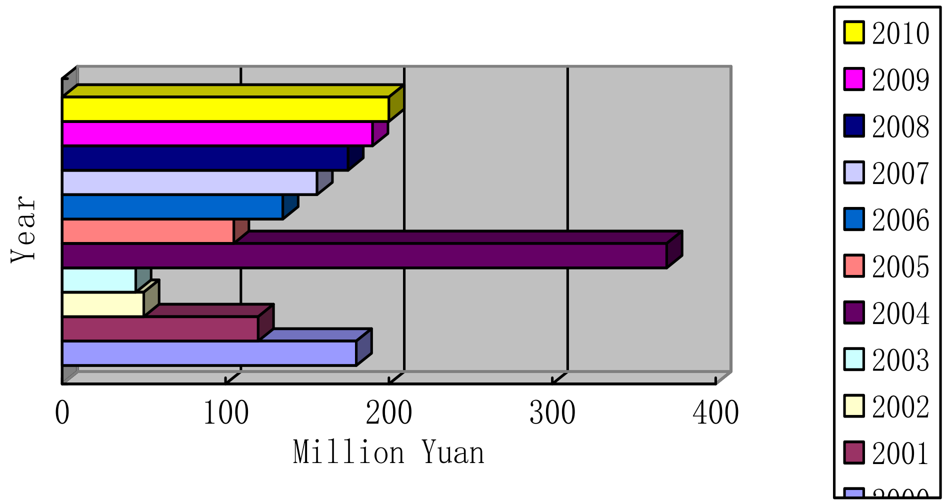
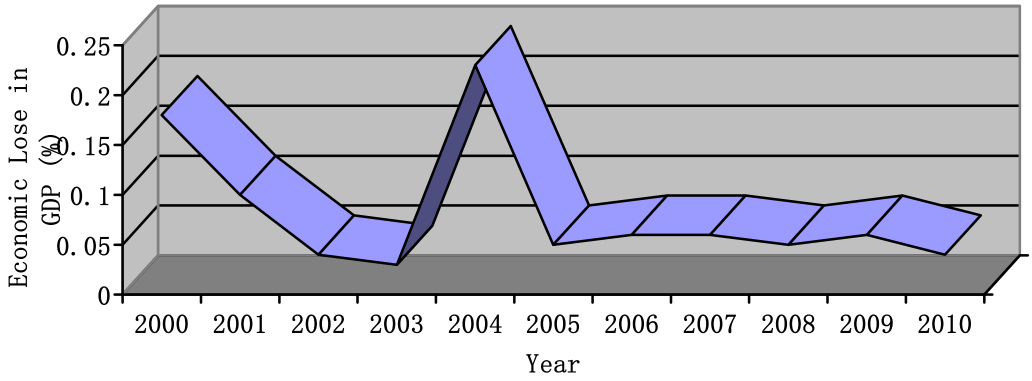


Figure-2.02 Economic lose take in GDP（1/10000）



Although direct economic losses took a small percentage in GDP for years, the absolute monetary amount of the average loss of 140 million Yuan approximately equals to the total investment in the primary industry from Hangzhou City, capital of Zhejiang Province in 2005 (Zhejiang Government, 2006). This is considered substantial to the standards of many small to medium sized countries.

2.1.2 Potential threat to public health and ecological balance

The environmental problems, particularly the severe cases, also result in the direct harm to the public health and ecological balances. The low-quality living conditions not only lead to a high rates of occurrence of diseases, result in a high public expenditure in medical care and social insurance systems, and also adversely affect environmental ecological balances and eventually the profound human food chain.

2.1.2.1 Threats from water pollution

Low water quality is the major cause which threatens the public health. These water borne pollutants are expressed in biological, physical, inorganic chemical and organic chemical problems, in accordance with the World Health Organization

Primary Health Standards and Secondary Esthetic Standards for potable water. Disease-causing bacteria, or otherwise known as pathogens, are present in organic wastes and domestic sewage. Poorly designed septic systems are important sources. The disease threatens public health and remains a real problem in less-developed rural areas in which medical systems are less established. One example of public health problems related to water pollution is the periodic appearance of cholera in some impoverished countries in Africa and Middle-east. The economic effects of organic pollutants are in term of the costs of treatment incurred in communal municipal sewage works in order to avoid the potentially dangerous epidemic diseases.

Furthermore, uncontrolled discharges of domestic sewage have resulted in eutrophication of water bodies. Localized accumulation of such pollutants associated with nitrogen and phosphorus has initiated massive algal blooms on major lakes and river courses, and eventually affected the sources of potable water (Jiang, 2005). The more common algae found in such incidents include dinoflagelates and bluegreen algae in major surface water bodies (Peng and Li, 2005).

Inorganic toxins in water, mainly represented by the commonly existing heavy metals applied in the industries, also presented considerable dangers to public health (Chan *et al*, 1995). This is of particular importance in the Southern China, namely the Pearl River Delta (PRD) Region, where metal finishing, electronic, and battery manufacturing industries are concentrated. The conventional poisonous chemicals and inorganic toxins are examples of the immediate dangers. Similar with organic pollutants, the economic costs took place in the control of the levels of inorganic contamination in domestic water supplies, in order to prevent both acute and chronic health problems due to abundant or prolonged exposures.

The less easily measured cost is the welfare damage and the potential human health costs. Exposure to toxic materials may lead to the risk of malignant neoplasms and this has been an urgent environmental health issues of the past quarter century. These are the long-term consequences of the human ingestion and the complex reactions of the substances with human body processes over extended lengths of time of exposure to some toxic pollutants, including point sources and area sources (Guangzhou Environmental Protection Bureau, 2010). For instance, scientists have proved statistical significant relationship between cancer deaths and domestic use of the water in Mississippi River which is contaminated with various heavy metals and organic toxins (Page and Harris, et al, 1977).

There is another kind of cost that must also be included. That is the treatment of esthetic characteristics of water such as taste, odor and colour, particularly in more developed urbanized cities in the coastal areas of China (Yangjiang Tourism Board, 2010).

2.1.2.2 Threats from air pollution

Poor atmospheric and indoor air quality directly affected human lives. Incidents of poor air quality due to illegal industrial fouled air discharges, industrial toxic gas leakages, traffic emissions, etc., has led to acute deaths and chronic respiratory problems (Lanzhou Daily, 2008). The problem is more severe in areas with higher population density. This observation is more pronounced in the Yangtze River Delta Region in the East (Jiangsu Provincial Environmental Protection Bureau, 2010) and the Pearl River Delta Region in the South (Guangzhou Environmental Protection Bureau, 2010) where urbanization and industrialization are in their more advanced stages. According to the World Health Organization (WHO) (2007), there are about 656 thousand Chinese deaths resulting from air pollution in various forms, during the period from 2001 to 2005. Globally, it is estimated that 800,000 people, including 600,000 in Asia, die prematurely each year due to air pollution (Schwela, 2006). It has been estimated that over 16 billion dollars in potential health benefits could be realized from significant reductions in sulfur dioxide (SO_2) and hydrocarbon from traffic emission and power plants if appropriate treatment facilities are designed and installed (China Development Bank, 2010).

All in all, the economic cost, due to air pollution in human health, mainly includes the treatment of air contamination, death losses, and related disease such as lung cancer, asthma, emphysema and bronchitis. Furthermore, formaldehydes, volatile organic solvents and other total volatile organic carbons (TVOCs) in indoor air are also identified as a major contribution to the aforementioned problems in the urbanized areas of the country (Chinese Research Academy of Environmental Sciences, 2010)

2.1.2.3 Threats from solid wastes pollution

The relationship between economy and environment also reflects apparently in aspects of solid wastes, especially domestic wastes, municipal sewage sludge and construction-demolition debris. In such processes as waste collection, disposal, and reuse, all solid waste treatment procedures require large numbers of human labor and facilities. All of these will easily bring about associated air pollution. Waste incineration causes potential air pollutions including dioxins and other airborne particulates. In addition, landfill sites generate leacheate and biogas problems, both of which may potentially cause human health diseases if not properly managed.

One aspect of the solid waste problems in P.R.C. that should not be omitted is that associated with plastics, including high-density and low-density polyethylene, polypropylene, poly vinyl chlorides, polystyrene, etc. (Guangzhou Liwan District, 2010). Megacities like Bejing, Shanghai, Guangzhou and Shenzhen in P.R.C. received plastic wastes which accounts for around 10%~12% (by weight) of total daily municipal solid wastes. The non-biodegradability and poor water-permeability nature of these materials bring permanent and tough environmental problems to us.

2.1.2.4 Threats from other pollution

The adverse effect of environmental pollution from secondary industry is obvious. Corrosion of various materials mainly comes from the application of natural high mineral content water in the industries (Seneca and Taussig, 1984). In order to remove economically damaging characteristics of water, such as hardness, acidity, alkalinity, or salinity, to meet the potable quality standards, water requires advanced treatment. Therefore, the economic cost is the expenses spent to avoid the industrial pollution, which is added on social costs if the quality of water resource continues to be deteriorated (China Development Bank, 2010). These problems are obvious and common in precious metal extraction industry, chemical plants which involve heat exchangers, and specialty chemical manufactories in the Southern China Region.

Air pollution on the other hand has direct harmful effects on the agriculture. The damages involved hundreds of millions of dollars annually to the Chinese economy (China Development Bank, 2010). In addition, air pollution such as acid rain can injure ecological systems and cause the loss of natural wildlife, upset ecological balances and adversely affect the profound human food chain.

The reduction of the value if outdoor recreational activity is also considered as a pollution-related damage cost. Therefore, restoration and recovery works have to be planned as part of the urban development master plans of cities.

2.1.3 Resource-based development

The high-pace industrial and economic developments in P.R.C. are greatly resource-based which will inevitably incur an extremely high cost for restoration and remediation of environmental resource. For instance, electricity industries in China greatly rely on coal. Researchers indicated that this dependence was expected to continue in the next five decades. During this period, over half proportion of the growth in power supply was expected to come from coal-fired and oil-fired power plants. This requirement for a large supply of water accounts for 35 % of total national water demand of China which is satisfied by surface water sources (accounting for 81 % with better rate of replenishment) and ground water sources (accounting for 19 % with poor rate of replenishment). The proportion of hydro power plants, which is disputed to upset aquatic ecosystem, and share of nuclear power will remain at about 24 percent and no more than 4 percent, respectively. However， the share of renewable solar and biological diesel plants is, unfortunately, still remaining negligible (Lin, 2003; China Development Bank, 2010).

Of cause, China is not peculiar in the aspect of massive water requirement in urban areas. All over the world, water demand is also rising at an alarming rate. Take a city in India, Delhi, for an example, water demands is met from the surface and subsurface water sources. The total requirement was about 3,200,000 tons per day (Subramanian, 2002).

Economic growth also needs an increasing number of population if we regard it as a kind of resource. On the one hand, factories were built up in order to produce merchandises and improve the quality of human lives. The production lines cannot effectively help the owners to achieve their targets without supporting the general workers and managerial personnel. On the other hand, the manufactured goods and commodities need a reasonable population size to support the consumer market. Therefore, population growth, urbanization, industrialization and generation of novel artificial materials are mutually interacting developments that if allowed to proceed in an uncontrolled manner, it will inevitably enter into a vicious cycle and harm the environmental quality and deplete the environmental resources.

In many surface water bodies, dissolved oxygen (DO) levels are so low, namely below 50 % of the point of saturation, and the pH falls out of the 6.5-8.0 neutral range. These can lead to the incapability of supporting fish life of water bodies (Chinese Research Academy of Environmental Sciences, 2010; University of Minnesota, 2008). Also, the aquatic ecosystem is upset and the water body can no longer be used as a source for potable water. There are many cases such as the eutrophication and pollution in Taihu Lake in Jiangsu Province, Dianchi Lake in Yunnan Province and a number of major water courses in Ninxia Hui Autonomous Region (Yinchuan Economic Zone, 2010). Furthermore, localized accumulation of such pollutants as pathogenic bacteria and viruses, heavy metals and toxic organics have brought about hyperaccumulators like mussels, oysters and other shellfishes which are not fit for human consumption (Biotreat Technology, 2010). These bivalve animals are capable of accumulating environmental pollutants to a few hundreds or a thousand times than the surrounding concentrations. Therefore they are far exceeding the toxicity thresholds, rendering them very dangerous if consumed (Tang, 1995; Jiangsu Provincial Environmental Protection Bureau, 2010).

2.2 Environmental investment in P.R.C.

2.2.1 Current environmental investment situation

Chinese government started to conduct public EnvI in the early 1980s and the investment amount has increased year by year, but the pace of growth in respect of the proportion of GDP has grown slowly in the past decade. The public environmental spending merely accounts for slightly less than 1.0 % of the GDP (Wang *et al*, 2004; Wan, 1998). China's EnvI has a gradual rise each year. During the Seventh Five-Year Plan, the EnvI was 476.42 billion Yuan. During the Eighth Five-Year Plan period, it was 1,306.57 billion Yuan, which was 2.74 times as much as that of the previous five-year cycle. The Ninth Five-Year Plan's EnvI was 2.69 times more than that in the Eighth Five-Year Plan, achieving 3,5164.4 billion Yuan. The Tenth Five-Year Plan's EnvI was 8,399.3 billion Yuan, which was, once again a substantial increase, attaining a 2.4 times increment compared with the previous five-year cycle (Xie, 2001; China Development Bank, 2010). The EnvI growth in Eighth, Ninth and Tenth Five-Year Plan was 43.56%, 33.8% and 27.7%, respectively. After the fast increase based on a relatively modest initial basis in these years, the subsequent EnvI increments were substantially slower. Take 2006 for instance, the annual growth was only 7.45% (Yi, *et al*., 2006; Shi, 2005; Chinese Research Academy of Environmental Sciences, 2010). Considering that the EnvI has to be normalized for the reason of increased price indices of equipments and materials in recent years, the effective EnvI since 2001 should have been significantly lower than the actual vast economic growth in the country (Chinese Academy of Social Sciences, 2009; China Development Bank, 2010).

The public EnvI based on a percentage of the annual GDP was somewhat unpromising for a number of reasons. Firstly, the EnvI accounting for a certain percentage of the annual GDP was growing at a lower rate on a year-on-year basis. The annual growth showed a breakthrough of 1% for the first time in year 1991. During the Tenth Five-Year Plan period, the EnvI proportion of GDP was 1.18%, with the maximum of 1.20 % in year 2004. The ratio of EnvI increased till 2004 while then it has been on a consistently declining trend. In 2005 and 2006, the EnvI ratio continued to decrease, despite the promoting efforts of the 'Further Energy Conservation' and 'Emission Reduction' actions in 2007 (Chinese Academy of Social Sciences, 2009). Secondly, the EnvI growth rate was less than the GDP growth rate in both Ninth Five-Year Plan and Tenth Five-Year Plan. Although the EnvI growth rate in Sixth, Seventh, Eighth and Ninth Five-Year Plan were higher than the GDP growth rate, but these were based on the modest initial basis. The actual adjusted EnvI growth rates in the year 1994, 1995, 1996, 2001, 2005 and 2006 were all less than the corresponding annual GDP growth rates.

These resulted in the fact that the environmental quality deterioration associated with rapid socio-economic development was not appropriately taken care of by effective public environment spending on relevant aspects.

2.2.2 Environment pollution situation

Research on environmental pollution in PRC had been carried out rather extensively since 1990s in China and much earlier in foreign countries. Only after late 1980s, people paid more attention on environmental quality in spite of the frequent recurrence of environmental problems throughout the history. However, environmental situation has caused enough attention of the government and the public in these years.

According to China National Radio, since 2001, when China won the bid for the Olympics, Beijing has invested more than 140 billion Yuan to achieve the commitment of the Green Olympic Games thorough pollutant emissions reduction and industrial economic structure adjustment. The number of blue-sky days in Beijing reaches 246 days in the year 2007, witnessing a increment of 15.6% of the blue-sky days in 2001 (Ma, 2008). During the Eleventh Five-Year Plan, Shanxi Province, spent 54 billion Yuan on the treatment of industrial pollution and the assessment result had to be calculated in the official achievements (Zhang E. and Zhang M., 2006).

The water pollution situation had been improved to a certain degree in these years in China as a result of pollution control measures such as industrial parks, more elaborate treatment and management facilities in the more advanced municipalities (Hailu and Veeman, 2000). Some of them, like Beijing, Shanghai, Guangzhou and Shenzhen, have been investing rapidly to expand wastewater and solid waste treatment facilities, hence water and land environment qualities are likely to improve gradually in the years to come (Jing *et al*, 2008).

Together with the development of urbanization and industrialization，total amount of wastewater has kept an increasing trend at a rate of about 4% during the last 10 years (Lo, *et al*, 2005). The total discharge quantity of wastewater reached about 50 billion tons in 2004, which increased by 4.9% compared with that in the year 2003. The discharge volume of domestic wastewater and the organic contents as measured in chemical oxygen demand (COD) and biochemical oxygen demand (BOD_5) in the wastewater gradually increased beyond those measured indicators in industrial wastewater in 1999.

Urban air pollution and its impact on urban air quality was a world-wide problem and should therefore be considered on a global comprehensive manner (Fenger, 1999). It is reported that China was the second largest air pollution source in the world with traffic exhaust gas responsible for 70% of the SO_2 in Beijing (Chinese Research Academy of Environmental Sciences, 2010; Watts, 2005). Fortunately, air pollution in PRC has received a lot of concern both domestically and from overseas since the 1990s (Feng, 1999). Air environmental quality in China had been improved because of a variety of air pollution abatement programs that promoted by the Chinese government recently (Yi *et al*, 2006).

2.2.3 Environmental legislations and regulations

Nothing can be accomplished without the establishment of effective standards. Legislation and regulations are therefore important tools for the government to restrain the irresponsible behaviours of potential polluters. Like many developing countries, the enforcement of environmental regulations in the P.R.C. was considerably more confused and relaxed than their counterparts in developed countries (Lo and Fryxell, 2005; Robins, 1990; Guangzhou Environmental Protection Bureau, 2010).

Most of regulations and legislations were not implemented uniformly and consistently across China and as a result, many of the country's environmental problems appear to be getting worse (Vermeer, 1998; Ma and Ortolano, 2000; McDermott and Stainer, 2002). There are two main factors that appear to be the most important and are responsible for the gap between promulgation and enforcement (Lo and Fryxell, 2005). The first one is the increasing levels of economic activity and its gains that are usually more than offset by the costs associated with environmental regulations (Xie, 2001; Xu, 2003). Another factor was the problem of achieving effective regulatory enforcement (Ross, 1988; Lo and Tang, 1994; Tang *et al,* 1997; Neller and Lam, 1994; Chan, *et al*, 1995; Sinkule and Ortolano, 1995; Sims, 1999). Numerous reasons had been cited for problems and resistance with regulatory enforcement in China (Swanson and Kuhn, 2001). In addition, the P.R.C.'s fragmented bureaucratic administration created crossed jurisdictions, conflicts over priorities, and insufficient coordination among different Departments (Chinese Academy of Social Sciences, 2009; Yuan and James, 2002).

However, the Chinese government has build up a set of environmental policies and regulation systems, such as the basic state policy of environmental protection, energy development and conservation policy, prevention and control of industrial pollution by technical transformation. China also promulgated regulations like 'Three-Simultaneous' regulation, environmental impact assessment and some other environmental policies.

2.2.4 Green GDP

Davis Pearce and his colleagues outlined an environmental economics approach in their book Blueprint for a Green Economy which was published in the year 1989 (Pearce *et al*, 1989). It was the first time to use the term 'Green Economy' to describe the equilibrium state between socio-economic development and environmental resource protection, and eventually to achieve sustainable development. The word 'green' is characterized by the target to translate environmental problems into economic problems and costs (Barry, 2007). Professor Dales (1968) defined waste disposal costs to be the sum of pollution prevention costs, and pollution treatment and damage costs.

The following simple equations (Seneca and Taussing, 1984) describe the method to calculate waste disposal costs:

$$C_{Waste\ Disposal} = C_{Pollution\ Prevention} + C_{Pollution}$$

$$C_{Pollution} = C_{Pollution\ Damage} + C_{Pollution\ Damage\ avoidance}$$

Where C : Cost

In China, the aforementioned concept is at its infancy and the implementation of 'Green GDP' is just at its beginning. However, more and more researchers began to put these calculations in practical usages and tried to well fit them into the local situations (Wang *et al*, 2004; Chinese Academy of Social Sciences, 2009).

2.2.5 Relationship between environment and society

Past experiences in socio-economic development indicated that one of the most important and contributing factors in the massive economic growth is the prosperity of industry (Shen, 1999; Wan, 1998; Chinese Academy of Social Sciences, 2009; 2010). If development pursues along the traditional path and means, development of industry would inevitably entail the inefficient consumption of limited and scarce environmental resources.

New concepts are recently being introduced and enforced by environmental authorities. These include environmental and related issues and matters such as human health, food hygiene, animal welfare, macro ecological balances and the application of new non-conventional reproductive technologies to the human species (Dickens, 1992).

The industrial-capitalist system forced landless. Many homeless peasants were forced to move from the rural land into industrialized cities, thus resulting in vast unevenness in distribution of population densities over different regions (Chinese Academy of Social Sciences, 2009). Similar events have also happened in the European history of socio-economic development (Barry, 2007).

It has been said that ‘air and water pollution and other environmental problems are as old as the human species’ (Seneca, 1994). The ‘Great Stink’ in London of June in 1858 was the consequence of using the Thames River as a common sewer rather than other environmental infrastructure. It has been the prime concern in the P.R.C. not to fall into the similar path of development. However, environmental protection measure has to be carefully devised by taking the current stage of development in China, like current per capita GDP and the economic structure, into consideration (Jiang *et al*, 2005; Chen, 2007; Chinese Research Academy of Environmental Sciences, 2010).

As the second largest electricity producer and consumer all over the world (Sinton *et al*, 1998), China is only after the U.S. (Lin, 2003). The installed capacity was 338 gigawattes (GW) and annual electricity generation was already 1,446 terawatt-hours by the end of 2001. Nuclear power contributes about only 1% of all while hydropower and thermal power come close to about one quarter and three quarters, respectively (Lin, 2006). Although alternative renewable forms of energy, namely biodiesel and other biological fuels, are on their way in research and development, actual full-scale applications are still minimal (Ren *et al*, 2011). In the past 20 years, demand for electricity has been increasing more rapidly in China than anywhere else in the world (Sinton *et al*, 1998; Lin, 2003; Levine, 2005). The average 9% annual growth rate approximately equals to the growth rate of GDP during the same period. These are supplied mainly by oil- and coal-fired power plants, which utilize non renewable form of fuels and inevitably cause severe pollution and upset ecosystems in the environment.

To meet the ever rising demand, it has been the prime concern in China to address such issues as how to meet the resulting enormous capital requirements and how to prevent environmental deteriorations (Ma *et al*, 2000; Lo and Fryxell, 2005).

According to research efforts conducted by Asia Development Bank, electricity demand will have an increase of over 60% for the period: from 1,446 terawatt-hours in 2001 to 2,362 terawatt-hours in 2010 (Lin, 2003; Lin, 2005). China, undoubtedly, contributes to a substantial share of this consumption.

As proved (Lin, 2003), China's high dependency on coal for electricity generation was expected to continue due to two reasons. One is the need to maintain low electricity tariffs and the other one is the abundant domestic coal supply with rather low price (Lin, 2006; China Development Bank, 2010).

There must be a great concern on the environmental impact of coal consumption because of the rapid growth of power demand in China and high dependency on coal for electricity generation. 138 GW was expected from coal-fired power plants in the total incremental capacity of 187 GW during 2002 to 2010 (Lin, 2003).

New environmental protection and pollution abatement processes such as flue gas desulphurization, electrostatic precipitator for particulate removal and chemical scrubber for volatile chemical (including volatile hydrocarbons) removal, were installed for only about 20 percent of new plants until 2003. Most of them were located in more developed regions, such as the Eastern Coastal and the Southern PRD regions (Guangzhou Environmental Protection Bureau, 2010; Jiangsu Provincial Environmental Protection Bureau, 2010). Therefore, it was estimated that 50% of newly constructed coal-fired power plants would be equipped with flue gas desulphurization and other relevant pollution treatment facilities before 2013 (Lin, 2003; China Development Bank, 2010).

The increased level of CO_2 (greenhouse gas) and other residual sulfurous gases (remains even after treatment) originated from the burning of fossil fuels cause severe atmospheric and even indoor air pollution that affect public health in the long run (Schneider, 1989; Gareth, 2004). It need a long way to go to pursue the ideal science and technology which allow people to live in a perfect world with well protected environment and well balanced ecosystems, in which every member of the world population recycles and reuses all waste and generates zero pollution (Gareth, 2004). It seems technologically impossible, but research and development efforts and legislative enactments are undoubtedly moving in that general direction.

Furthermore, human activities such as coal mining and land excavation, which is related to energy consumption and other infrastructure developments, result in other lithospheric environmental problems. In the process of acquiring the useful resources, all humans change the natural land environment and cause such environmental problems as deforestation (Philip, 2007). Rather than investing energy, time, and resources into simply ameliorating the worst effect of environmental deterioration, the concept of green economy calls for seeking into address the root of the causes of the problems (Barry, 2007).

These aforementioned aspects of environmental protection were discussed in many researches. However, these are mainly on the technology and management policy aspects of environmental protection. Very few studies were conducted on the appropriate monetary value of public and commercial EnvI, and on the suitable growth rates of these spending. There has been a serious lacking of efforts put in the comparison of EnvI amount and schedule in different countries, by taking the peculiarity of each country into consideration.

2.2.6 Energy saving and emission reduction strategy

Energy Saving and Emission Reduction (ESER) is one of the most important movements for implementing scientific outlook on social-economic development. Carrying out the ESER strategy is currently considered as the important movement to fulfill the implementation of the ‘scientifically-based outlook’ on development and the founding of the ‘harmonious society’ of China government (Chinese Academy of Social Sciences, 2009; 2010). It is also an important step in the P.R.C. for founding resource saving and environment-friendly society and policies. It is not only way to improve the process of economic structure, by adjusting the growth mode and transforming the emphases, but also the inevitable requirement for enhancing the quality of the public interests and safeguarding the long term and sustainable benefits of Chinese people. The ESER strategy helps to make sure that every functional district’s environment conditions satisfy with the standards. It is beneficial to enhance the development of techniques and resource saving, implement the government policies, attain the reasonable distribution of the resources and raise the positivity of pollution treating. At the same time, when the aim of industrial and traffic emission reduction is introduced in the plan of national economic and social development, the environment protection department can introduce the policies to make through the overall controlling strategy at a national level and scope (Chinese Development Bank, 2010; Lin, 2006).

Emission reduction is the most important measure for environment protection in the 'Eleventh Five-Year Plan' period. In the year 2010, the emission of COD (as a measurement of organic pollutants in water) and SO_2 (as a measure of pollutants in air) will be reduced to 90% of that in 2005 (Chinese Research Academy of Environmental Sciences, 2010). That is not only the serious promise which is made to public by Chinese government, but also the environmental target which should be reached by us in order to ensure sustainable development. According to this study, the emission reduction is more than an environmental problem. The essence will be the problem of social economics and politics. The key for achieving the overall emission reduction is to associate the marginal emission reduction control with the whole process such as the cost of resource and energy, cleaner production, recycle and reuse technologies improvement, pollution treatment and monitoring, and development of novel environment-friendly materials. In a certain period, the environmental policies need to be reconstructed based on the ever changing environmental factors and the vision of overall control strategy (China Development Bank, 2010; Lu and Gao, 2004). The reconstructed policies should place the overall emission reduction in the core and build up the mechanism to reduce the consumption of resource and energy, level up the development of economic and reinforce the pollution treatment from enterprises in a systematic, effective and efficient approach.

The task of emission reduction is tough and technologically challenging, but it still could be done. Since 2006, the Chinese government had carried out emission reduction work by the establishment of policies and development of novel engineering methods which have never been used elsewhere in the world (Chinese Research Academy of Environmental Sciences, 2010). The environmental departments and local governments had put a lot of efforts to implement the target for emission reduction, but completion of the task in 2006 was not as effective and fruitful as expected. According to the studies, to control the newly generated pollution, including the carbonaceous and sulfurous compounds in the atmospheric environment and the organic and heavy metals in the hydrospheric and lithospheric environments, is the task with highest priority (Yi *et al*, 2006; Gansu Daily, 2007).

However, the uncontrollable and somewhat overheated development of the economy has led to the biggest uncertain factor for attaining the aim of emission reduction. Judging by the studies and published statistical data, to realize the aim of emission reduction for major pollutants is a very tough goal to meet and the situation is still a negative end by far. Compared with the COD, BOD_5, suspended solids, heavy metals and organic pollutants in the water environment, SO_2 emission is still considered an easier goal to realize the targeted reduction. This is because the point sources of emission for air pollutants are more easily controlled than the line and area sources of discharges (Chinese Research Academy of Environmental Sciences, 2010; Xie, 2001; Sin *et al*, 2003; Xu, 2003).

In order to truly solve the systemic problems in environmental emission reduction, bold management measures and technology advancements are urgently needed. With the exception of shortfalls in the structural factors in the emission reduction plan, there are three other relatively severe problems, which affect the continuity and effectiveness of emission reduction. Major reforms are needed in these areas. Firstly, the powers and efforts of government investing in the various aspects of environmental protection are not enough. There are problems generated in the statistics of environmental treatment investment, authority division and performance management. For example, the investment for COD emission reduction is still not effective, especially the part of public spending which is invested by the government. Secondly, the monitoring abilities are not enough for providing feedbacks information in order to refine the policies. The incomplete emission control standards, the low rate of law implementation and enforcement, the weak abilities for environment monitoring and the reconstruction for the management policies are all the negative factors which weaken the abilities for emission reduction and environmental pollution remediation. Thirdly, the rate and strength of policy implementation is low. Especially the economic policies, aiming at the facilities running and producing emission reduction effects, such as punitive policies, are weakly and inconsistently implemented. Some directions of policies are even on the contrary to the emission reduction, so that the policies are not efficient in serving the aim and efforts of the continuity in the implementation of emission reduction and environmental protection.

The environmental problems are the fundamental and prime representation of general socio-economic problems, when the 'agrarian society waste cycle' was transformed into an 'industrialized society waste cycle' (Chinese Academy for Social Sciences, 2009; McAusland, 2004). In the past 30 years, too much resources and environmental costs had been paid and are regard as an expense to support the high-paced development of economic-civilization and commercial-industrial aspects. In accordance with the IPAT formula, the environmental loading is related directly to the population, per capita GDP growth and pollution loading per GDP (Chinese Research Academy of Environmental Sciences, 2010). In order to solve the environmental problems, rigorous answers are needed in the related social economic system and essential keys to solve ‘dependent variables’ through ‘independent variable’ outside the environmental system and waste cycles. According to the international experience, the environmental problems must be placed in the entire social economic system to solve. Hence, we must discuss the essence of emission reduction standards in the entire social economic layer and take comprehensive actions to solve the problems of system, harmony, balance and continuity between social economic and environment system. Only when the government reinforces its responsibilities, truly implements the targetted environmental monitoring and assessments, and carries out emission reduction in the entire commercial-industrial processes, the public could engage in the concerted effort of environmental protection. Therefore, the governments of P.R.C. usually play ‘number games’ in the annual reports in order to avoid the ineffective emission reduction efforts (China Development Bank, 2010).

The establishment and abiding by the pollutant emission standards directly reflect the quality and environmental efficiency of the economic operations. Generally speaking, the pollutant emission standards are indices to indicate the situation and quality of the economic operation and its sustainability. Though the intensity and public attention of industrial emission is diminished under the positive and exciting background of high GDP increasing rates, it is obvious that the degree of environmental pollution is substantially higher than that of the developed countries (Chan *et al*, 1995; Chinese Academy of Social Sciences, 2009). There is no ultimate change of the high investing, consuming and polluting development patterns, so that the quantity of emission and the cost of natural resource in China are always high. Most of the industries, which improve the GDP, are high in pollution and energy consumption. From the January to May in 2007, the long term loans, which main banks and financial organizations lend to the more economically and environmentally efficient industries, have been raised by 21.8% compared with the same period in previous years. Heavy chemistry, thermal power, iron and steel and cement industries are always the main culprits in pollutant emission. Some small steel, cement and thermal power factories, which are 'restricted' internationally, are still existing in some areas in the China, leading to excessive production. Some high polluting industries in the east area, which had been obsoleted in the industrial adjusting, change their faces and move to the west and less developed area. The power industries, by means of the thermos-electric united production, enlarge their production. The aluminum oxide and coat chemistry industries also develop rapidly. At the same time, the increasing amount of Chinese raw steel export occupies 33% of the increasing amount of steel production. The export of Chinese coat occupies more than 50% of the world. During the Tenth-Five Year Plan period, the SO_2 trade deficit coursed by the foreign trade is as high as 1.5 million tons. China receives the huge trade surplus for more than a decade while suffers the huge 'environmental resource deficit' and possibly 'public health deficit'. Great amount of high-quality goods are export each year while the remaining pollutants stay in China for many years to come. Therefore, bring in purchasing orders for manufactured products, to a certain extent, equals to 'importing' the pollution.

Prior to realizing the aim of emission reduction, the economic developing mode and structure must be refined and streamlined. The main aim of emission reduction, environmental resource protection and sustainable development could not be isolated from the serious consideration of economic operating elements such as GDP, energy consumption, water consumption, technologies improvement and industrial structure. Emission reduction is not to restrict the development, but to guide the direction to realize the sustainable development of the social economy and reinforce the harmony of development. According to this point, the aim for environment protection in the Tenth-Five Year Plan had not been realized, because the fundamental problems are the problems of the quality of economic operation and pattern of development. During the Tenth-Five Year Plan period, the average increasing rate of GDP is 9.5%, with the total 58%. Compared with the predicted average rate of 7.5%, there is 14.3% surplus (the planned rate for the next 5 years is 43.6% on a cumulative basis). The increasing rate of the high pollution products such as raw steel, cement, power generation, ethylene and paper are 175%, 68%, 64%, 84%, 61% and 149%, respectively (Jiangsu Provincial Environmental Protection Bureau, 2010). These increasing rates are obviously higher than that of the GDP. Therefore, realizing the targeted aim of overall emission control is inevitably difficult if these industries. An alternative that is worth considering is to relocate and place these pollutant emitting industries in the remote contrary sides. However, this has to be done on the expense of increased costs of transportation.

Environmental protection and emission reduction is also a political problem in China. Though the per capita emission is still not so high, the total emission of many pollutants (such as SO_2, CO_2, particulate and hydrocarbons in the atmospheric environment, COD, Hg and other heavy metals in the hydrospheric and lithospheric environments) has been ranked the top of the world (Guangzhou Environmental Protection Bureau, 2011; Ma, 2000). China has seriously promised to reduce the emission to the rest of the world, and it has attained high international praise and recognition. The emission reduction directly affects the economic development and the harmony of the society due to economic downturn and unemployment. Emission reduction has, therefore, been a political and social problem. The government is the major power to bear the responsibilities and implement the plans that may seem unfavourable in shorter terms. The implementation rate of emission reduction directly affects the assessment for the governments of each level, but this should eventually be beneficial to all in the long run.

2.3 Conclusion of literature review

Continuous high-paced economic development in the past twenty years has result in a viscous circle that deteriorates the environment, depletes the natural resources and adversely affects the ecosystems and human food chain. In the past decades, GDP and the per capita GDP of the P.R.C. have been growing in a high rate. However, the growth is depended on the high consumption of the environmental resources, many of which are not renewable. Wastewater, contaminated air and solid waste pollution problems become more and more obvious and severe, due to the uncontrolled and somewhat overheated economic development. The ignorance of environment protection leads to a lack of public and commercial investment on environmental-related facilities. As a result, the living environment was getting worse and public health is adversely affected. It not only harms the health of the labors in the relevant industry but also decrease the natural resources for the general public. It is high time that the government must pay more, in monetary terms, to treat the waste so that the cost for pollution treatment will not have to increase even further in the near future. Therefore, the losses of economic achievement will also increase, and offset or even nullify the benefits brought about by the development itself. Furthermore, the decrease of the natural resources will result in the increasing cost of the food and raw materials. As a result the unusual economic inflation will be eventually inevitable so that the economic development has to be slowed down. Therefore, the country will not be able to regenerate the environmental resources and sustain productivity.

There has been very few published researches and development works carried out in the aspects of establishing an appropriate level of public and commercial environmental spending, as a percentage of the annual GDP, by taking the specificity of economic structure, per capita GDP, rate and stage of socio-economic development, and other factors into consideration. There have also been very few investigations on comparing and contrasting between countries to normalize the difference in order to justify the basis for comparison. Therefore, efforts in these areas that relevant to the P.R.C. are in urgent need.

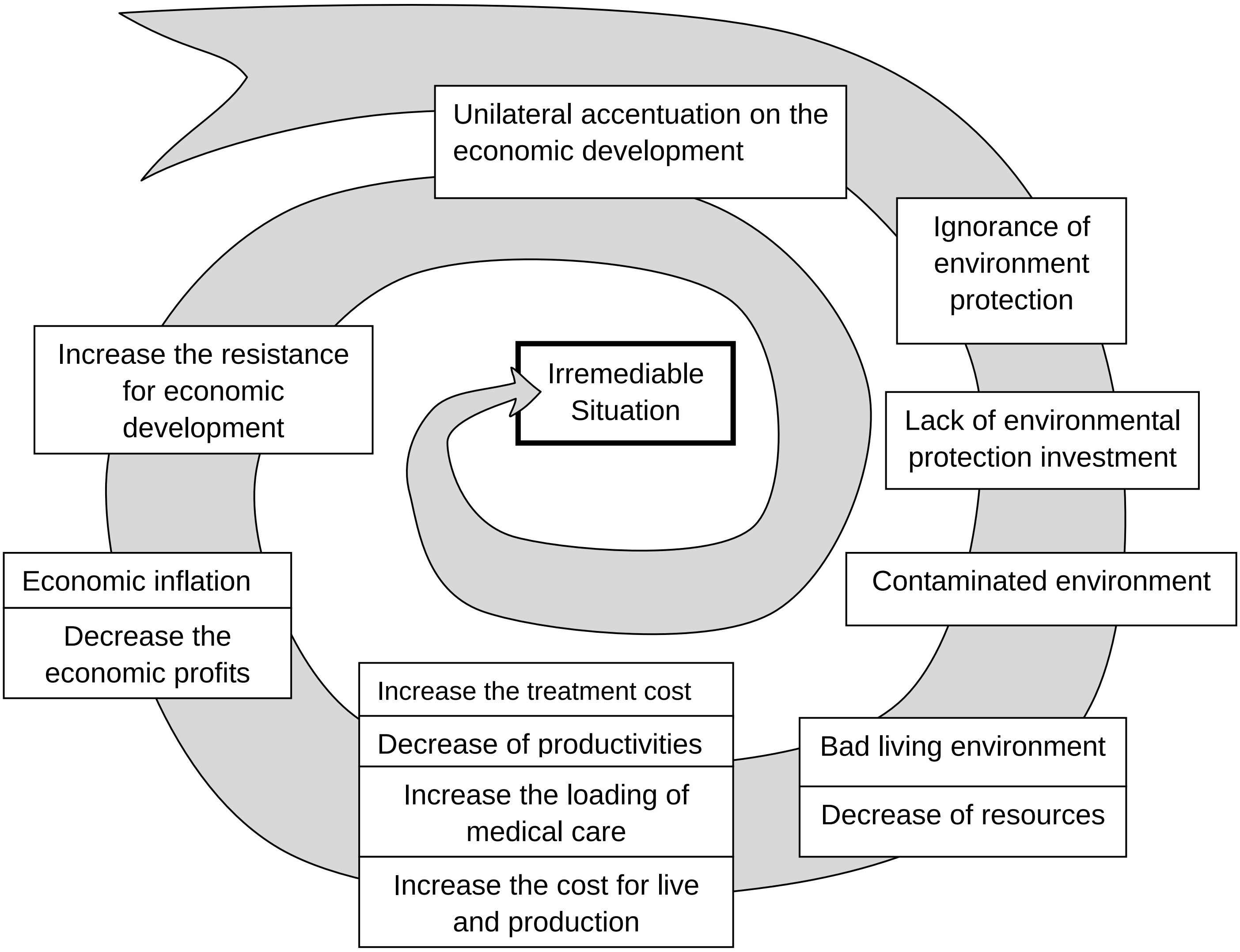


Figure-2.03 The viscous circle of unilateral accentuation on economic development

Figure-2.03 shows the final result of the ignorance of the environment protection, which eventually results in a situation that is beyond remediation. In order to avoid this, actions must be taken promptly. Therefore, a suitable scale of EnvI should be worked out and established to polish up the present unfavorable situation. The EnvI consists of two major parts, i.e., capital cost of environmental hardware fabrication and installation and operation and management expenditure for these facilities. The environmental hardware is composed of the treatment facilities, management organizations, research and development centers and relevant education premises.

The operation expenditure is generated from the operation and management of the treatment facilities, research and development of innovative technologies, culture of the professionals and propaganda and promotional drives for environment protection knowledge. The published literatures inclines that different countries have different situation, so every country should have suitable investment amount and distribution among the various aspects that are deemed fit for the specific contexts. For the P.R.C., it is in great pressing urgency to work out a suitable EnvI schedule for further development in order not to be in the expense of resource-dependent development path that many other countries have gone through. Green GDP and sustainable development should be the priorities among all options.

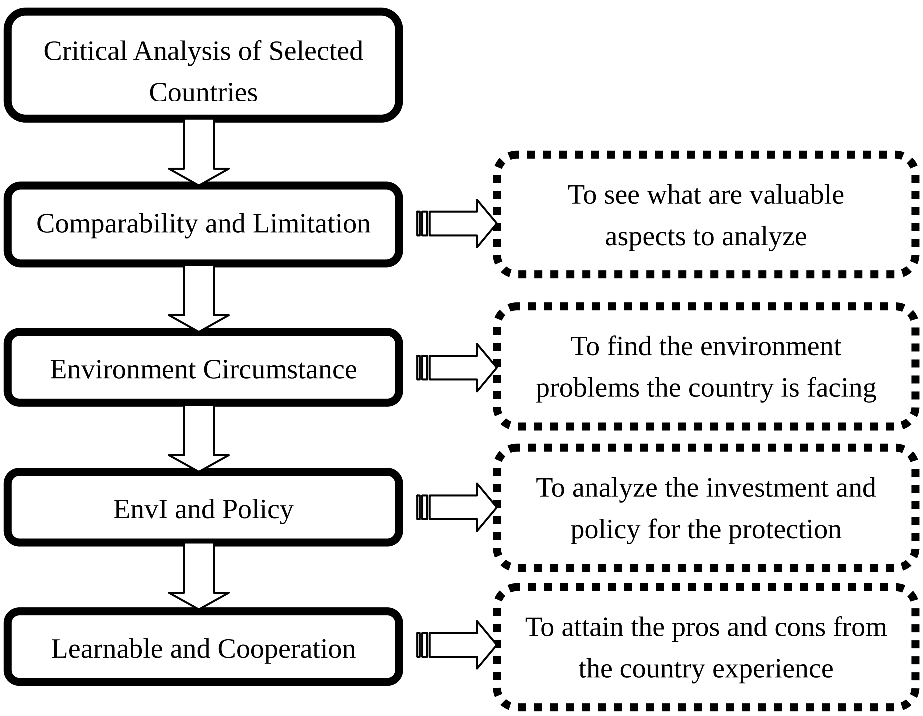
However, as it has been previously pointed out, most of the previous studies in these aspects were carried out based on the foreign circumstances. There is a serious lack of technical and scientific investigation for suitable EnvI, including both public and commercial spending in P.R.C..

3. Methodology

3.1 Research Framework

The research problem defined in this study was investigated through the following research flow diagram shown in Figure-3.01. The left-column part in Figure-3.01 is the research flow and the right-column part is the corresponding research objectives.

Figure-3.01 Research flow and objectives



The design and execution of the research methods are described as follows.

3.2 Materials and data collection

There are five sorts of resources for the research on the environment issue for China, India, Japan, United State and German. The materials and data used in this dissertation are collected from the following sources:

China:

(1) The website of National Bureau of Statistic of China and,

(2) Chinese statistics yearbook published by China Statistic Press and,

(3) China environmental yearbook published by China by Environmental Science Press and,

(4) The website of State Environmental Protection Administration of China.

India:

(1) The website of India Government and,

(2) The website of Ministry of Environment and Forests and,

(3) The website of Ministry of Finance and,

(4) Statistical year book India published by Ministry of Statistics & Programme Implementation and,

(5) India 2006~2011-a reference annual published by Ministry of Information and Broadcasting and,

(6) State of environment report published by Ministry of Environment and Forests and,

(7) Report to the people on environment and forests 2009-2010 published by Ministry of Environment and Forests and,

(8) Annual report 2010-2011 published by Ministry of Environment and

Forests.

Japan:

(1) The website of Japan Government and,

(2) The website of Ministry of Environment and,

(3) Air pollution report 2006~2010 published by Ministry of Environment and,

(4) Annual report on the environment published by Ministry of Environment and,

(5) Waste treatment report of Japan published by Ministry of Environment and,

(6) Wastewater disposal quality survey published by Ministry of Environment and,

(7) Annual Report on the Environment, the Sound Material-Cycle Society and the Biodiversity in Japan published by Ministry of Environment and,

(8) Environmental statistic published by Ministry of Environment and,

(9) Environmental accounting report published by Ministry of Environment.

United States:

(1) The website of the U.S. Environmental Protection Agency and,

(2) The website of World Bank and,

(3) The website of Organisation for Economic Co-operation and Development (OECD) and,

(4) Statistical abstract of U.S. published by the United States Census Bureau and,

(5) Municipal Solid Waste in The United States 2009 Facts and Figures

published by U.S. EPA and,

(6) National Water Quality Inventory: Report to Congress published by U.S. EPA and,

(7) National Water Program: Best Practices and End of Year Performance Report 2010 published by Office of Water of U.S. EPA.

Germany:

(1) The website of German Government and,

(2) The website of The German Federal Environmental Protection Bureau and,

(3) Germany Statistical Yearbook published by Federal Statistics Office and,

(4) National Trend Tables for the German Atmospheric Emission Reporting (1990~2008) and,

(5) Water Framework Directive published by Federal Ministry for the Environment, Nature Conservation and Nuclear Safety and,

(6) Diverting Waste from Landfill published by European Environmental Agency and,

(7) Data on the Environment 2000~2009 published by The German Federal Environmental Protection Bureau and,

(8) Report on the Environmental Economy 2009 published by Federal Ministry for the Environment, Nature Conservation and Nuclear Safety.

Many other investigation reports are useful data sources that were tapped on for relevant information in the course of this study.

There is a problem must be solved that data from the above sources is not exactly the same or they are not suitable for direct comparison and contrasting among different countries. When there are such discrepancies among data, two types of data have to be standardized in order to justify the basis for direct comparison.

For data related to China, those from the website of National Bureau of Statistics of China have the priorities because this study aims to assess the environmental protection investment in the P.R.C. and the National Bureau of Statistics of China has the authorities to publish statistical data, and renew and revise them in time. The second selected sources are China statistic yearbooks, China environment yearbooks and the website of State Environmental Protection Administration.

As for the more recent information and opinions of current development, a number of representatives from such authorities as the Chinese Research Academy of Environmental Sciences, Chinese Academy of Social Sciences, China Development Bank, etc. are interviewed. This information is cited as appropriate throughout the texts of this thesis.

For the other categories of data related to western countries and India, each country's websites of Statistical Bureau and Environmental Protection Agency will be firstly referred to. However, some data is not provided in English version in non-English language countries such as Germany and Japan. The situation in India is the same, limited authorities to access governmental website obstruct data collection. Data in publications are always corrected with updated information each year and it is considered to be a credible source in the world. Therefore, data from the website of the World Bank and other investigation reports also helped to make a judgement when data are selected and acted as an important supplement to official publications.

3.3 Methods for assessment

The literature review is used to shape an overview first. Various parameters, such as pollution emission amount, GDP, per capita GDP, population density, and EnvI amount, are adopted to elucidate the situation of environmental protection investment and economic position.

When the governments make regulations or conduct methodology of EnvI, they should take the local and national economic situations into consideration (Garner, 1996). Thus the economic features of China will be explored firstly by comparing with some representative developed countries, which were selected because they either have similar size in GDP or they are in similar economical structure, namely a major industrial production hub. In doing so, we need to analyze the three main factors in evaluating economies – GDP or GNP, employment rate, and inflation (Stiglitz *et al*, 1992). In these three factors, the value of the inflation rate in China has dissensions for a long period, and this rate is not so closely related to the environmental problems. Therefore, the inflation rate will be ignored when calculating the GDP and the environmental expenditures thereafter.

Pollution prevention costs involved directly laid by the government, to purchase resources to inhibit pollution. According to this nomenclature, the costs incurred by a local government to treat its sewage before dumping it into a river or any other receiving surface water bodies are pollution prevention costs.

Pollution costs shown on governments' materials were the aggregate of pollution avoidance costs and pollution damage costs to the receiving environment (Seneca and Taussing, 1984). In another words, pollution costs can be broken down into two categories: (1) the private or public expenditures undertaken to avoid pollution damage once pollution has already occurred and (2) the welfare damage caused by the pollution on the receiving environment and its inhabitants.

However, the full welfare costs of pollution damage are impossible to measure exactly (Seneca, 1984). The private expenditures mainly from related manufacturing enterprises hardly can be calculated accurately (Hass and Smith, 2007) either.

Thus in the dissertation, only pollution prevention costs and pollution avoidance costs will be used to forming following contrast between countries. In some cases, the pollution abatement and control (PAC) expenditure will be used to undertake contrast.

3.4 Methods for comparison and country selection

How to choose proper countries to undertake comparison and contrasting is a problem of importance in this study. Since environment quality determined by countless factors, such as its own variation within the country and surrounding forces complicated the matter. The most important ones were selected based on their fundamental representation of a unique category. The U.S. was selected for its comparable size of GDP and for its relatively good programme in environmental resource protection. Japan and the Germany were selected because these are important industrial production hub, which are similar in terms of roles and economic structure as China. Finally, India was selected due to is similar population size, population density and geographical characteristics and size.

3.4.1 Factors affecting environmental quality

All human societies change and transform the natural environment in the process of gaining the things they need for their continuing survival and reproduction (Philip, 2007). Society's relationship with the natural environment has been reshaped by large, densely populated urban areas, immensely long road and transport networks, the industrialization of raw material extraction and food production, and the twentieth-century mass consumption of goods.

3.4.1.1 Population and population density

A positive correlation between population growth and natural resources demand is expected. Population density directly determines pollutants discharge amount.

Energy, conservation of natural resources

The energy consumption will lead to higher demand for energy power. In most developing countries, non-renewable energy sources such as coal and lignite would be chosen. Coal and lignite are just the contributors of CO_2 and other GHGs.

3.4.1.2 Economic growth

The growth of commodity production has led to water pollution, soil erosion, destruction of fire wood resources and loss of genetic diversity of plants and animals, although it will improve the satisfaction of basic needs (Mohan, 2002).

3.4.1.3 Economy Structure

Heavy industry became the main contributor of electricity consumer in China, which used up about 60% of the total electricity consumption (Lin, 2003).

3.4.2 Countries classification

On the basis of analysing factors affecting environment, an overall comparison can be conducted between China and other countries in economic structure and EnvI.

First of all, the economic situation will be explored because the investment depends on economic strength. Although not all countries have similar economic strength as China, some economic features of theirs such as GDP growth rate, and economic structure will be compared with that of China in order to explore comparability. Similar features are the first foundation in choosing comparable countries.

The second phase is according to some of the factors affecting environment, such as population, industrial reliance and pollutant emission volume, to illustrate the economic development level between the two at the very beginning.

Then the environmental conditions and countries' environmental achievements will be compared. From this step, major pollutant sources, objectives of EnvI of the countries, and weather the investment is efficient will be explained.

3.5 Study's Scope

3.5.1 Definition of environment

There are different definitions and interpretations of the environment from dictionaries and researches. Here list some definitions of that can be found.

Environment is defined as 'surroundings, milieu, atmosphere, condition, climate, circumstances, setting, ambience, scene, and decor' by a computer thesaurus. Roget's Thesaurus (1988) explained environment as 'situation, position, locality, attitude, place, site, bearings, and neighborhood'. Environment also delineated as 'the natural world of land, sea, air, plants and animals.' (John, 1995)

In this dissertation, environment refers to the natural conditions and surroundings close to human's livelihood in atmosphere, hydrosphere and lithosphere. Ambient pollution, water pollution and solid waste will be discussed in this essay.

3.5.2 Environment pollution

Almost anything can be regarded as pollution to human societies (Philip, 2007). It includes but not limited to environmental noise, frouzy indoor air, nuclear or ocean oil leakages and so on. This thesis will focus on the main pollutants that affect the air, water and land, such as SO_2, NO_2, COD, BOD, heavy metals and others.

3.5.3 Definition of investment

In fact, the definition of investment can be divided into two aspects – finance and business. From the view point of finance, investment is the process that put money into something with the expectation of gain within an expected period of time. On the other hand, in business, investment can be defined as the purchase by a producer of a physical good, such as durable equipment or inventory, in the hope of improving future business (Peng and Li, 2005).

Nevertheless, in this dissertation, the investment refers to the expenditure on environmental protection from government or individuals.

3.5.4 Definitions of Environmental Protection Investment

There are several definitions about environmental protection investment all over the world. Generally speaking, Environmental protection investment is the expenditure taken from the accumulation of social capital and various compensation funds by relative investment communities, and is used for the control of environmental pollution, maintaining ecological balance and related economic activities (Shen, 2009). In this economic activity, financial resources were distributed to environmental protection industry to protect environment from contamination, to keep ecological balance, and to get access to a society with sustainable development (Peng, 2005).

Environmental protection investment can be divided into three main categories in China, according to investment directions, that are investment for environmental pollution treatment, investment for ecological protection, and investment for environmental management and services on technology and self-construction (Jiang at el, 2005).

In this essay, our concern is focused on investment for the government's treatment of environmental pollution which consists of the capital cost and the operation cost.

The government's environmental protection investment for anti-pollution industry includes expenditures on the equipment purchase and maintenance, expense on the construction and maintenance of waste treatment plants.

However, the social input in China can hardly be calculated. One reason is there isn't too much records about social investment on environmental protection. Another one is the social investment activities haven't been well stimulated (Lu and Gao, 2004; Wang and Chang, 2003). That means the social expenditure really takes a small part of the whole investment amount in China.

4. Data analysis and discussion

4.1 Environmental situation and investment in P.R.C.

Environmental problems which started to appear during the industrialization in western countries more than a hundred years ago, were rampant in China in recent 30 years. Due to the heavy pollution burden and inadequate per-capita resources, the deteriorating environment has great impact on governmental policies and human living conditions. Take China’s atmospheric air pollution for example, problems of sulfurous pollutants, hydrocarbons, particulates, etc., were caused by the extensive and irrational use of coal (Lin, 2006; Lu *et al*, 2004). This relatively serious environmental problem faced by China today, was faced by developed nations in the 1950s and 1960s, which were their worst pollution periods (Wan, 1998; McDermott and Stainer, 2002). In addition, the high population density in the eastern coastal cities of China exacerbates the environmental problems, for the pollutants from industries and residents which beyond the environmental carrying capacity. Although Chinese western provinces do not have such high population density, education and environmental consciousness there are relatively poor due to the lack of well-trained teachers, lack of rational environmental management, and scarce funding to support environmental protection programmes (China Development Bank, 2010).

According to China Daily, during the eleventh five-year plan, Shanxi Province, known as the coal-rich province in northern China, invest 54 billion Yuan on the treatment of industrial pollution and the assessment result had to be calculated in the official achievements (Zhang and Zhang, 2006). Northwest China's Lanzhou, known as one of the most polluted cities in the world, plans to spend 130 million Yuan (US$16.9 million) this year (2011) to tackle and fight the pollution in the Yellow River and its tributaries, which run through the center of the city. It can be found that the environment and ecology have attracted much attention of the state and local governments. However, weather the expenditure is enough for effective protection needs to be technically and administratively assessed because one city in Shanxi province is still listed in the top six polluted cities claimed by Blacksmith Institute in 2006, and also, Lanzhou's environmental quality was recognized to be the lowest level in all environmental quality standards and parameters in 2006 according to Lanzhou Daily.

4.1.1 Environmental pollution in P.R.C.

Pollution levels of many countries have already substantially surpassed those of western countries and Japan (Stearns, 2007). China contributes 9% of total chemical emissions in the world, compared with 5% of Japan, 14% of the Former Soviet Union, and a thriving 18% of the U.S. This figure may seem reasonable, but it is on a rapid increasing trend (Chinese Research Academy of Environmental Sciences, 2011; Shi, 2005).

4.1.1.1 Serious water pollution

The huge amount of wastewater is generated by the large population and the high fraction of heavy industries in the current economic structure in China.

4.1.1.1.1 Interrelation between industrial and domestic wastewater

Although the total discharge of main pollutants has widely surpassed the water environmental capacity for years, water pollution situation had improved somewhat recently in China. Most cities were investing rapidly to expand their existing wastewater treatment facilities and construct new ones. Therefore, it is expected that water quality might likely to continue to gradually improve in the years to come. The declined function of water use will be improved by suspension of irrational exploitation of water and forests damage.

With the rapid development of industrialization and urbanization，total amount of wastewater maintains at a high-pace increasing trend, with a rate of about 4% annual increase during the past 10 years. The total wastewater discharge increased stably from 41.52 billion tons in 2000 to 59.04 billion tons in 2009, by a rate of 2.7%~8.5%. The discharge volume of domestic wastewater gradually rise beyond that of industrial wastewater in the year 2000, and then it takes about 54.2% in total discharge quantity in 2004 (Figures-4.01 and 4.02). The traditional pollutants as measured in COD, BOD_5, suspended solids, total nitrogen, total phosphorus were also increasing over the years. Furthermore, other more toxic and hazardous components, such as heavy metals and toxic organics introduced by specific industries, are also found in municipal sewage, in which domestic sewage is blended with industrial effluents in the usual 70-30 proportion (Chinese Research Academy of Environmental Sciences, 2010).

Figure-4.01 PRC overall wastewater annual discharge status (including industrial and domestic discharge) (Adapted from the website of National Bureau of Statistic of China)

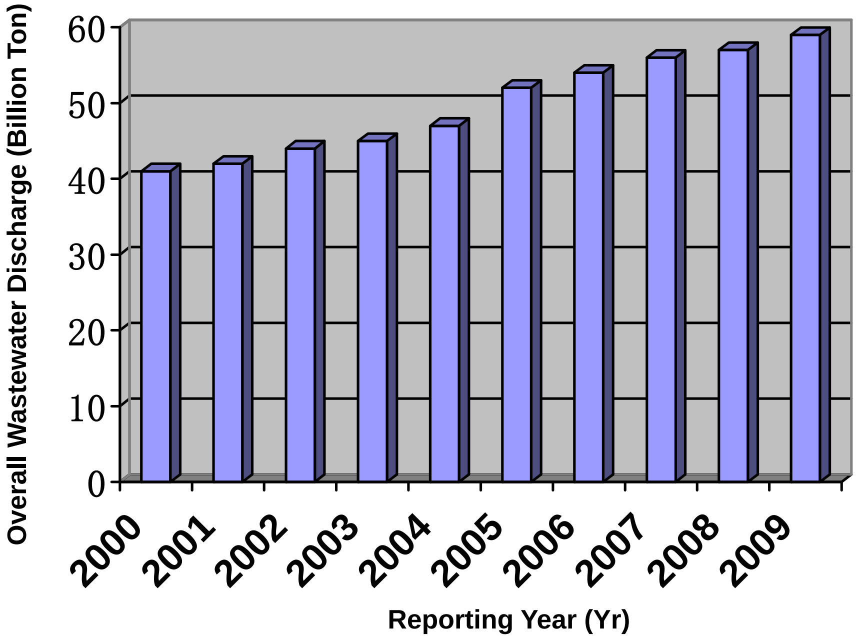
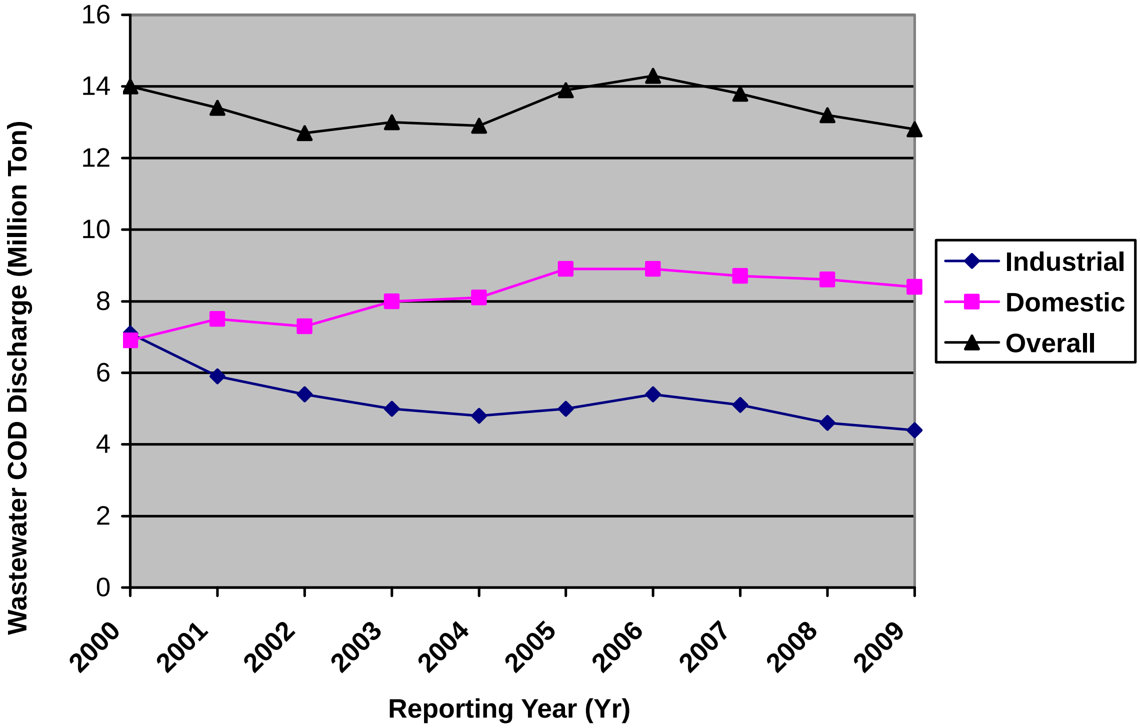
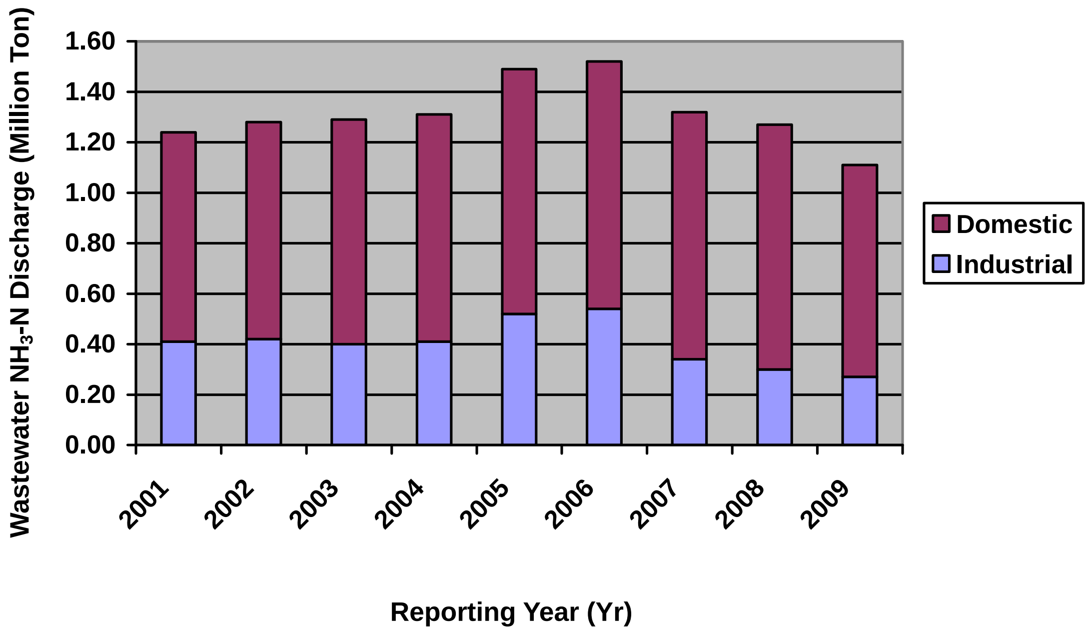


Figure-4.02 PRC wastewater COD annual discharge status (Adapted from the website of National Bureau of Statistic of China)



However the ammonia-nitrogen discharged volume from domestic sources has been growing at a rate higher than that from industrial wastewater (Figure-4.03). The volume of domestic wastewater was about twice than that from industrial effluents from 2001 to 2005. This indicated a more complex sewage from domestic households, which will in turn, results in eutrophications and massive algal blooms in the receiving water bodies (Sin *et al*, 2003), if those wastewaters are not extensively treated in the communal municipal sewage treatment works.

Figure-4.03 PRC wastewater ammonia-nitrogen annual discharge status (Adapted from the website of National Bureau of Statistic of China)

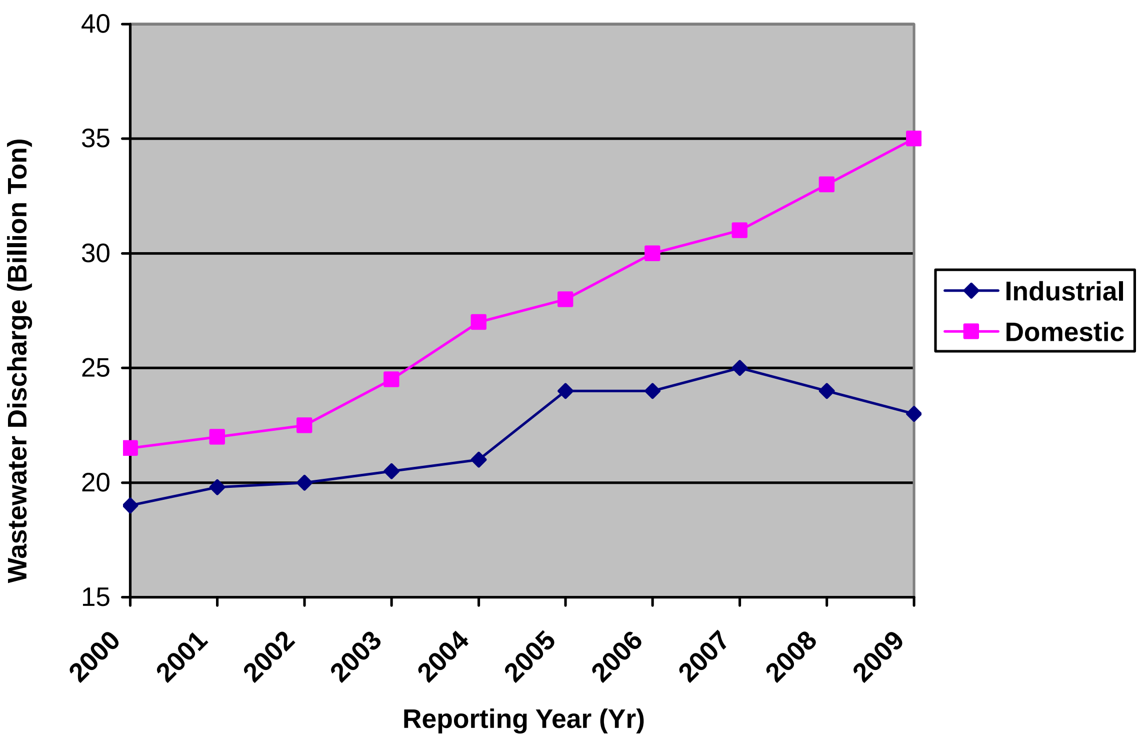


Dollar (2007), US national advisor, the World Bank's Country Director for China and Mongolia in the East Asia and Pacific Region, indicated that if over 90 percent of industrial discharge is treated, industry will no longer be the main source of water pollution. The biggest source of environmental pollution is un-treated or poorly treated household waste. Only a little more than 50 percent of urban household wastewater is treated is a complete secondary sewage treatment works. The remaining untreated domestic sewage contains high concentrations of carbonaceous components (COD > 500 mg/L), nitronenous components (TKN > 30 mg/L), and total phosphorus components (TP > 5 mg/L) (Chinese Research Academy of Environmental Sciences, 2010).

4.1.1.1.2 Industrial wastewater

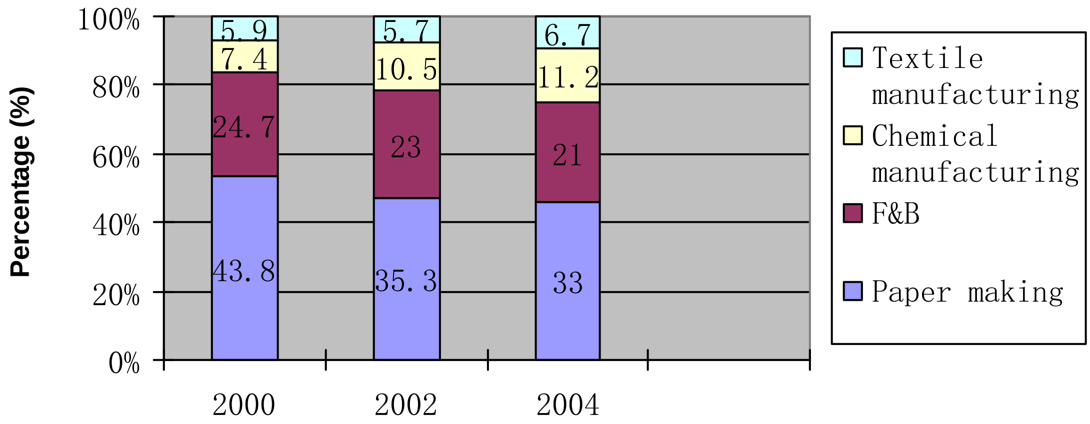
The above analysis stated that the key wastewater sources were from domestic usage, but industrialization has had very crucial pollution costs for China. In fact, the industrial wastewater still took about a half of total wastewater discharge in many cities (Figure-4.04).

Figure-4.04 PRC industrial and domestic wastewater annual discharge status (Adapted from the website of National Bureau of Statistic of China)



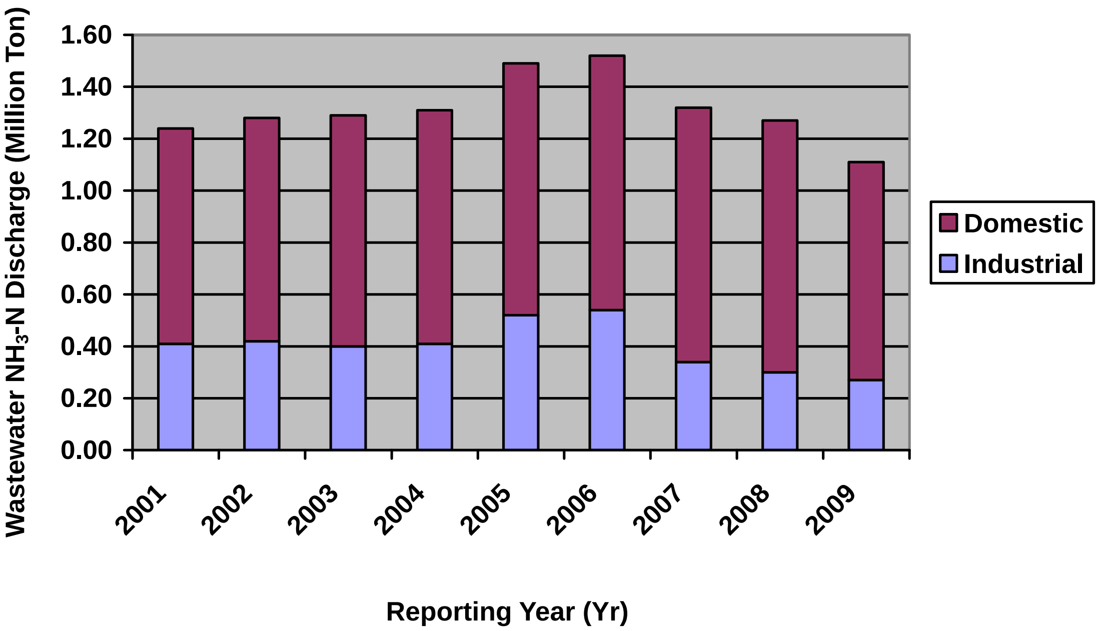
The top four waste and industrial effluent discharge sectors whose waste discharge took nearly 80% in the total wastewater discharge were manufacture of paper and paper products, manufacture of foods and beverages, manufacture of raw chemical materials and chemical products and manufacture of textile (Figure-4.05). We can see from the figure that manufacture of paper and paper products contributes the most while the manufacture of food and beverages is the second largest polluter. They account for almost 80% of all and the rest two sectors share the rest 20%. These industrial discharges will typically contain such heavy metals as cadmium, chromium, mercury, lead, nickel, cobalt, zinc, copper, etc., and a wide variety of toxic and xenobiotic organics that are resulted from different chemical additives used in the manufacturing processes.

Figure-4.05 Ratio of profits to COD discharged of four sectors in 2000, 2002 and 2004



As for the ammonia nitrogen discharge, figure-4.06 can give us a direct impression that the major pollutants come from domestic wastewater. The ammonia discharge in domestic wastewater is near 1 million tons in 2006, which occupies almost 70% of the whole ammonia in that year. The ammonia discharged from industry declines at a rate of 43% from the peaking point (0.53 million tons) in 2005 to the bottom (0.27 million tons) in 2009 (Figure-4.06).

Figure-4.06 National ammonia-nitrogen discharge trend (Adapted from the website of National Bureau of Statistic of China, 2010)



4.1.1.1.3 Wastewater treatment plants

Until 2010, there are 80332 wastewater treatment plants, which were planned to dispose totally 61.73 billion tons of wastewater (including industrial effluents) every day. The total treated wastewater reached 60.61 billion tons in 2010, more than 61% of which (equals to 37.97 billion tons) is domestic wastewater. The actually collected sewage in public sewers and appropriately treated wastewater through the intended secondary biological processes has a mere volume of only a little more than half of that is schemed.

Government claimed that the main bottleneck is that the construction speed of municipal sewerage system is left far behind the development of environmental infrastructural facilities. Other reasons that substantially reduce the rate of wastewater treatment included the problems in operation system management, revenue ordinances, supervised regulations, and law enforcements, especially in the cases where the facilities are operated and managed by commercial companies on BOT basis.

4.1.1.2. Solid waste generation, discharge and utilization

4.1.1.2.1 Industrial solid waste

Although the country-wide generation of industrial solid waste obviously increased in the last ten years, discharge amount of certain industrial materials sharply reduced and the recycle and comprehensive utilization significantly increased. That means the techniques of treating and recovering solid waste has improved in various manufacturing industries over the years, and the public and commercial investment in treating industrial solid waste has increased significantly (Table-4.01). This situation is particularly pronounced in aspects of plastic wastes, which account for 10 to15 weight percent of total municipal solid waste generation. Industrial plastic scraps and other disposable products has been recycled, and environment-friendly substitute has been developed (Zhong, *et al*, 2011, Chinese Research Academy of Environmental Sciences, 2010)

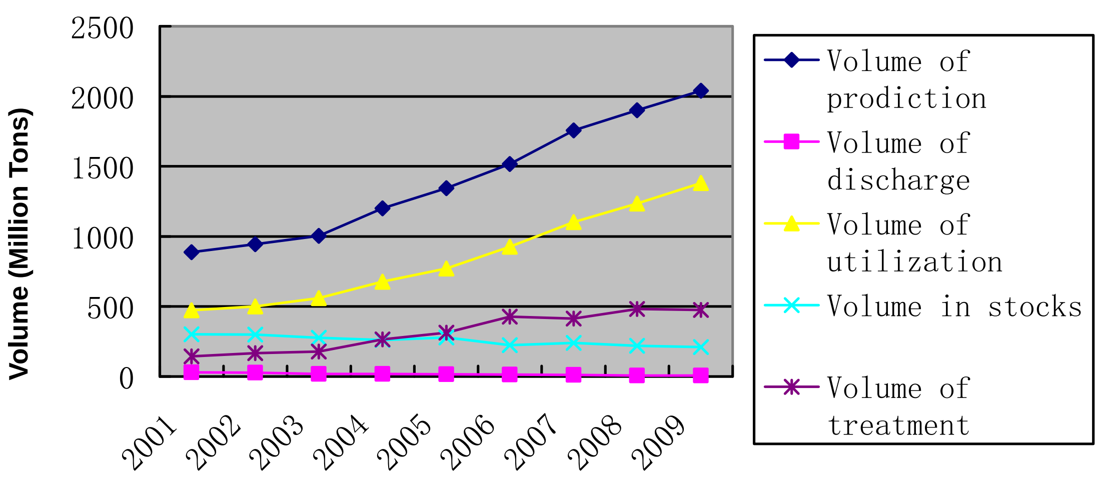
Table-4.01 Generation and processing of national industrial solid waste (Adapted from *the website of National Bureau of Statistic of China*)

Unit: million tons

Year	Volume of production	Volume of discharge	Volume of utilization	Volume in stocks	Volume of treatment
2001	887.46	28.94	472.90	301.83	144.91
2002	945.09	26.35	500.61	300.40	166.18
2003	1004.28	19.41	560.40	276.67	177.51
2004	1200.30	17.62	677.96	260.12	266.35
2005	1344.49	16.55	769.93	278.76	312.59
2006	1515.41	13.02	926.01	223.98	428.83
2007	1756.32	11.97	1103.11	241.19	413.50
2008	1901.27	7.82	1234.82	218.83	482.91
2009	2039.43	7.10	1381.86	209.29	474.88
Increased percentage	7.3%	-9.2%	11.9%	-4.4%	-1.7%

If we plot the data in the figure, it can be seen that the discharge volume of industrial solid waste decreased gradually from 28.9 million tons in the year 2001 to 7.1 million tons in the year 2009, although the generation volume is rising at a rate of 12% annually. This is because of the continuous increasing volume of industrial solid waste comprehensive utilization and treatment.

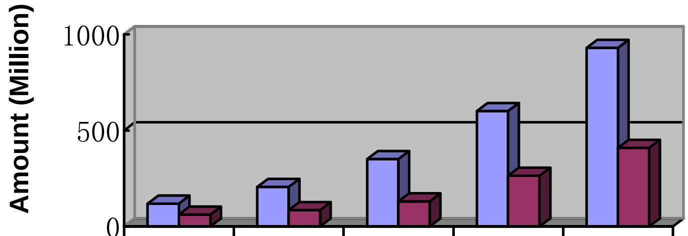
Figure-4.07 Situation of national industrial solid waste



4.1.1.2.2 Municipal solid waste

There is more than 100 million tons of municipal solid waste generating annually, at an increasing rate of 8%~9%, which accounts 27 percent of the generation amount all over the world (Liu, 2005). Figure-4.08 describes the relationship between the amount of municipal solid waste and the population. We can find that the former is proportion to the latter and the next 20 years is a peak period of booming of population and municipal solid waste.

Figure-4.08 Relation between urban population and MSW



	1985	1990	1997	2010	2030
Urban population	118	205	351	601	930
MSW	61	85	130	264	409

Sanitary landfill, composting, pyrolytic incineration and integrated utilization are the common processing methods of municipal solid waste in China recently, among which sanitary landfill is the dominating way used and treat more than 70 percent of all.

4.1.1.3. Air pollution

The air pollution is mostly contributed by the heavy industries with conservative technologies, such as thermal-power plants, cements factories and steel industries, and traffic emission from the increasing number vehicles. The air pollution characteristics of the P.R.C. relate closely to the huge population and the industry-leading economic structure.

Air pollution has attracted a lot of concern from both the domestic and international communities. The coal-based energy structure leads to the coal-smoke air pollution and the major pollutants are suspended particulates and sulfur dioxide, whose variation tendency from 2001 to 2009 is showed in Table-4.02. Among these pollutants, the discharge amount of SO_2 reached 22471 thousand tons in 2009, reduced by 3.19% than 2008. The industrial dust emission and soot emission also shows an decrease at a speed of 10.48% and 8.81%, respectively.

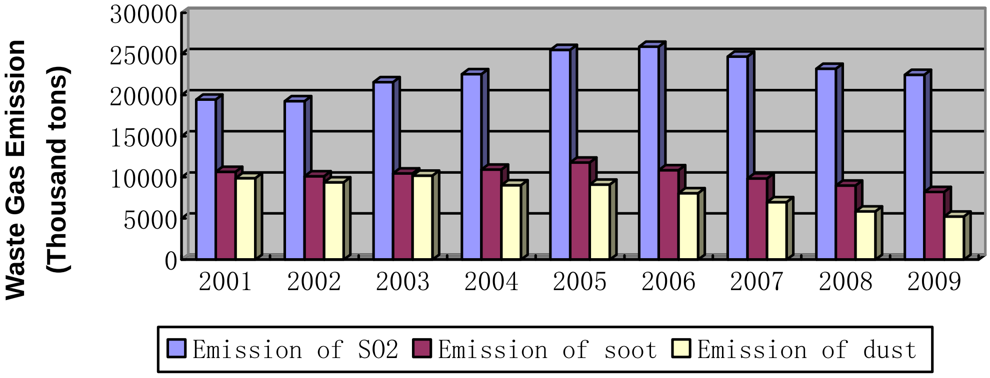
Table-4.02 National total waste gas emission (Adapted from Ministry of Environmental Protection of P.R.C.)

Unit: thousand tons

	Emission of SO_2			Emission of Soot			Emission of Dust
	Subtotal	Industrial	Domestic	Subtotal	Industrial	Domestic	
2001	19478	15666	3812	10698	8519	2179	9906
2002	19266	15620	3646	10127	8042	2085	9410
2003	21587	17914	3673	10487	8462	2025	10210
2004	22549	18914	3635	10949	8865	2084	9048
2005	25493	21684	3809	11825	9489	2336	9112
2006	25888	22376	3512	10888	8645	2243	8084
2007	24681	21400	3281	9866	7711	2155	6987
2008	23212	19913	3299	9016	6707	2309	5849
2009	22471	18659	3812	8222	6043	2179	5236
Increased percentage	-3.19%	-6.30%	15.55%	-8.81%	-9.90%	-5.63%	-10.48%

The variation tendency of emission of SO_2, soot and dust are showed in Figure-4.9. It is obvious that all these three pollutants undergo a steady decrease after a slight grow during the period between 2002 and 2005. Although this expresses an improvement of air quality after 2005, we have a long way to go to decrease the air pollutants to a satisfactory level.

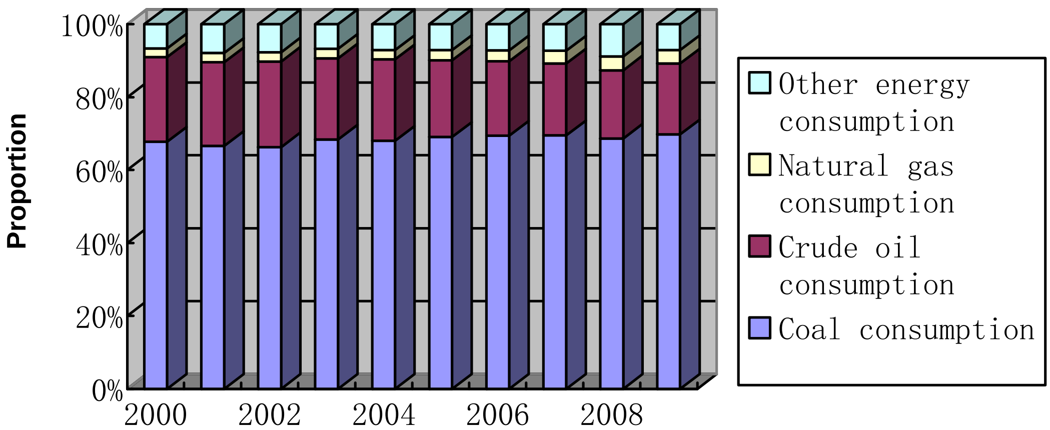
Figure-4.09 National total waste gas emission (thousand tons)



4.1.1.3.1 Consumption of coal and fuel

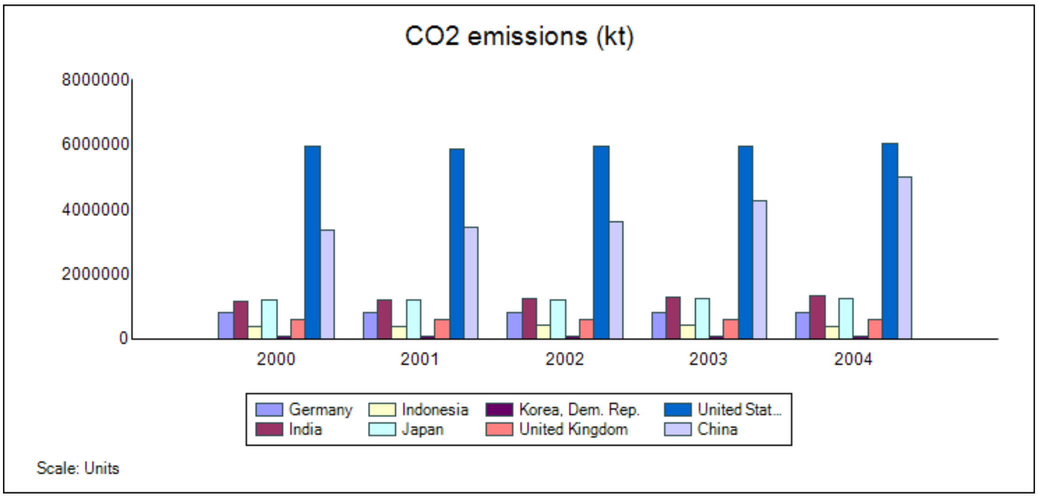
The air pollution in the P.R.C. is primarily due to coal combustion. The figure below indicates that almost 70 percent of energy comes from combustion of coal while crude oil contributes another 20 percent. Other energy source such as nuclear power, hydro power, wind power and nature gas share the rest 10 percent of energy.

Figure-4.10 National energy consumption proportion



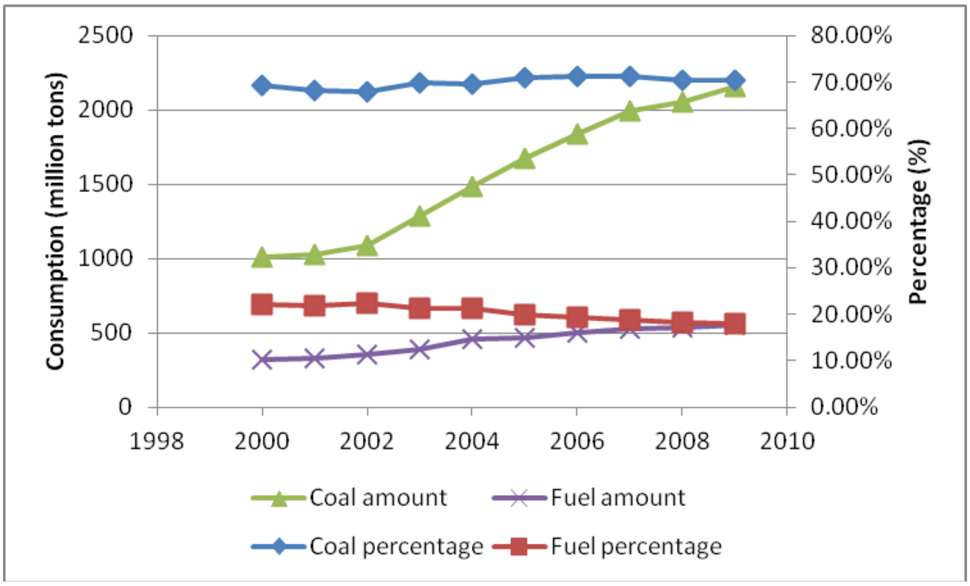
Coal and fuel burning in coal-fired and oil-fired power plants, as well as in the industrial parks, are the major causes for SO_x (sulfur oxides) and NO_x (nitrogen oxides) generation, which are related to acid rain and the eventual pollution in the downstream hydrospheric and lithospheric environments. Along with the fast-pace commercio-industrial development, the tendency of coal and fuel consumption experienced a steady increase during the last two decades. Coal consumptions with an average annual growth rate of 8% has made China to be the world's second largest CO_2 emitting nation, just after the U.S., for more than five years (OECD, 2005) as showed in Figure-4.11 below.

Figure-4.11 CO_2 emissions from different countries from 2000 to 2004



From the ten-year data that are currently available, we can see total consumption of coal in 2009 was 2.16 billion tons, which represented an increase by 114% as compared with that in year 2000. Industrial consumption of coal in the manufacturing sector accounted for about 90% of total consumption, which increased by up to 15% as compared to that in year 2003. An amount equivalent to 0.2 billion tons of domestic coal consumption in 2004, accounted for 10.2% of the total consumption rte, are on the contrary remain fairly stable, maintaining at the level during the last 10 years. On the other hand, total consumption of fuel in 2004 reached a historical high of 27.34 million tons which increased by 4.2% as compared with the year before (Figure-4.12).

Figure-4.12 National total consumption of coal and fuel (million ton)



The consumption of coal and fuel has been keeping its present increasing rate. A high proportion of 85% of all energy consumption in China was from coal burning (Murray and Cook, 2002, China Development Bank, 2010), which is showed in Table-4.03. It is of utmost urgency to change traditional industrial productions and energy consumption methods. Otherwise, the resource-dependent economy will experience the worst environmental pollution and resource depletion period well ahead of the forecast schedule (Chinese Research Academy of Environmental Sciences, 2010; Lin, 2005).

Alternative source, particularly the novel renewable sources of biological fuels including biodiesels and bio-hydrogen, should be developed and put on full-scale applications if the current unfavorable situation is to be significantly improved (Ren, *et al*, 2011; China Development Bank 2010; Chinese Research Academy of Environmental Sciences, 2010)

Table-4.03 Energy use in China (Adapted from *the website of National Bureau of Statistic of China*)

Unit: million tons

	End-use Consumption	Industry	Intermediate Consumption	Power Generation	Heating	Coking	Gas Production
1990	60205.9	35773.8	41257.8	27204.3	2995.5	10697.6	360.4
1995	66156.1	46050.3	69487.6	44440.2	5887.3	18396.4	763.7
2000	46821.39	34122.04	85178.61	55811.2	8794.07	16496.4	959.99
2004	59543.75	46082.95	134052.3	91961.56	11546.56	25349.58	1316.43
2005	62154.13	48040.74	154568.4	103263.5	13542.0	31667.06	1276.96
2006	61683.66	48006.53	177532.8	118763.9	14561.43	37450.09	1257.08

4.1.1.3.2 Industrial and domestic discharges of SO_2 and dust

In the year 2004, country-wide municipal fouled air and industrial waste gases have been discharged at a total amount of 23,769.6 billion cubic meters, which represented a considerable increase of 20% than previous year. Among these, a total discharge of SO_2 reached 22.55 million tons. More than 80% of them are discharged by industrial production in the manufacturing bases and industrial parks (Guangzhou Environmental Protection Bureau, 2010). Furthermore, power plants and traffic emission from vehicles are also substantial contributors of this air pollutant.

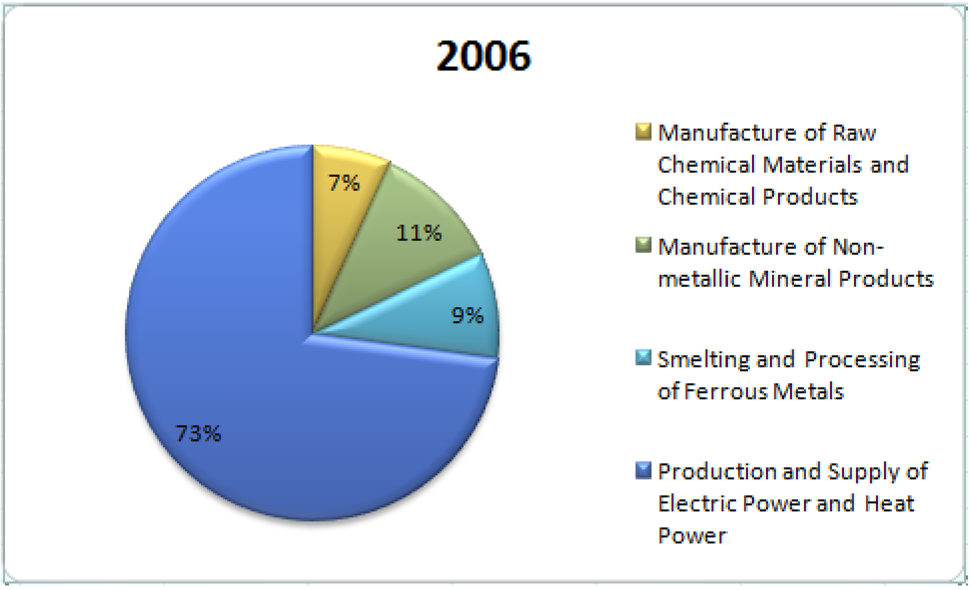
Great demand for materials in the fast developing economy has inevitably resulted in the overheated development and requirement of iron, cement and electrolysis aluminum. In addition, industrial dust exhaust, industrial discharge of SO_2 and industrial consumption of coal have been on the obvious increasing trend. Although domestic dust exhaust, domestic discharge of SO_2 as well as domestic consumption of coal have slightly fluctuated for the reason of alternative use of nuclear, hydro, solar and oil energy resources, discharge of SO_2 and dust also went up year by year on a countrywide basis. These various aspects have resulted in industrial air pollution, which took more than 80% in total exhaust of air pollution. These will, in the long run, cause severe downturn in public health and upset of environmental ecosystems, and also affects the related water and land resources.

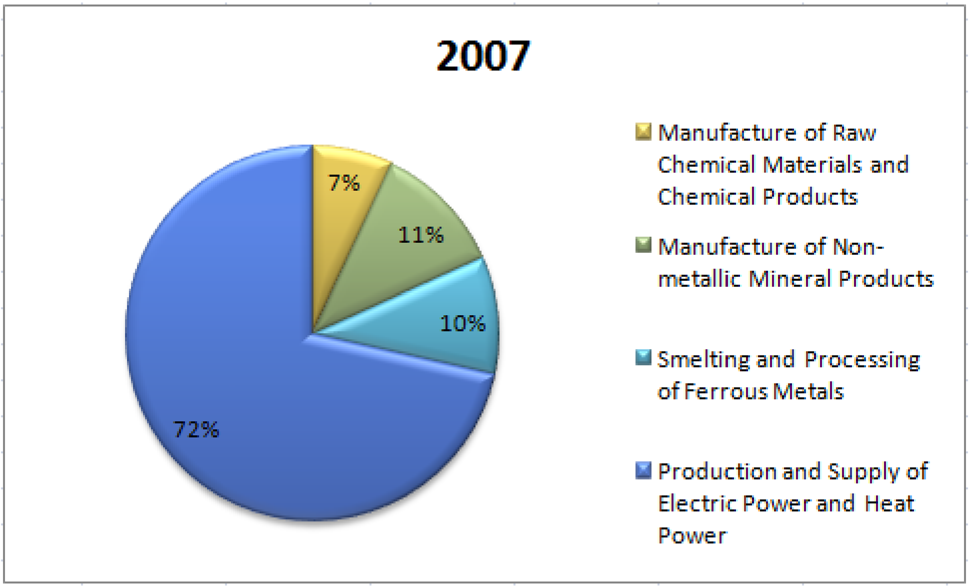
4.1.1.3.3 Industrial air pollution

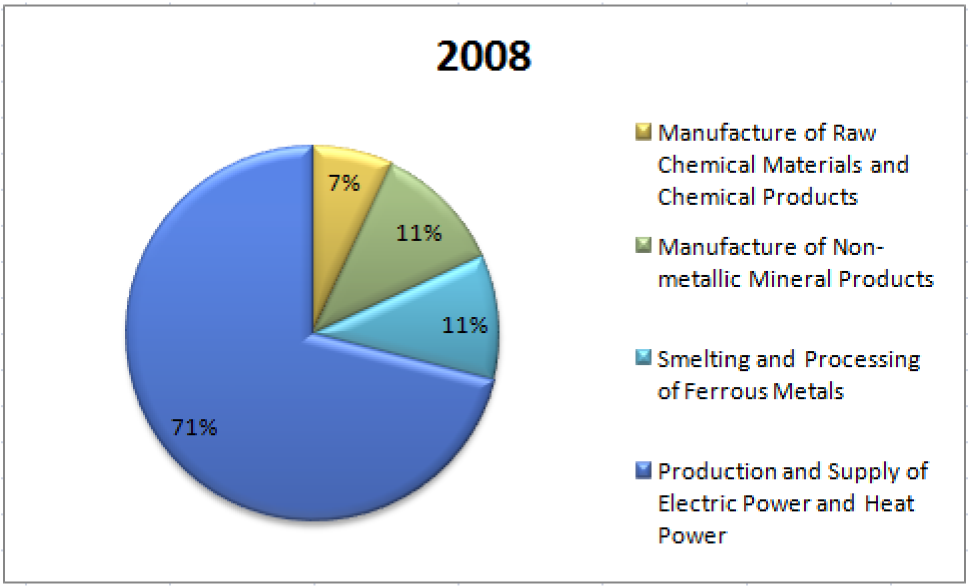
As mentioned before, the main air pollutant is sulfur dioxide and a high level of more than 80% of sulfur dioxide came from the manufacturing industries. The top four air pollution emission sectors as showed in Figure-4.13, whose discharge took more than 80% in the total sulfur dioxide are production and supply of electric power and hear power, manufacture of non-metallic mineral product, smelting and pressing of ferrous metal and manufacture of raw chemical materials and chemical products. We can see from Figure-4.13 that electric power and heat power produces more than 70 percent of the total industrial SO_2. The second largest polluter, manufacture of non-metallic mineral products, emits about 11% of all. The other two sectors share the rest portion of the pie chart.

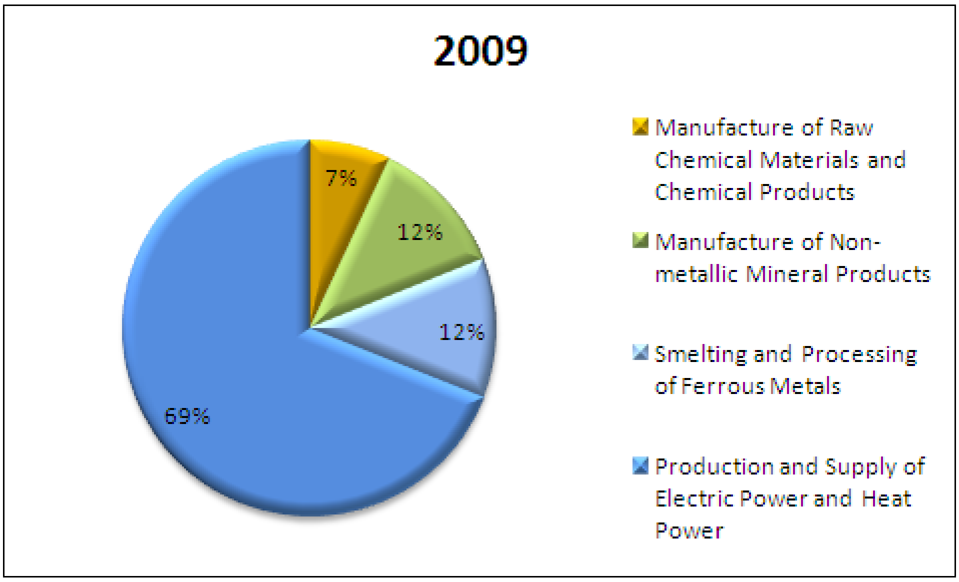
These four sectors, unfortunately, have been the heavy industries that contributed significantly to the national GDP, and it is therefore very difficult to take any drastic measures with them (China Development Bank, 2010; Jiangsu Provincial Environmental Protection Bureau, 2010).

Figure-4.13 Ratio of profits to sulfur dioxide of four discharge sectors in 2006, 2007, 2008 and 2009









From the economic point of view, the total ratio of profits contributed by these four sectors to China's economy maintains a little more than 30 percent, which is too substantial to be omitted. Compared with its contribution rate to GPD, the electric power industry discharges a larger amount of sulfur dioxide (Table-4.02).

Table-4.04 Ratio profits to GDP and SO_2 of electric power industry (%)

	2004	2005	2006	2007	2008	2009
SO_2 contribution rate	60	58.9	58.9	57.6	56.8	55.1
GDP contribution rate	3.6	3.7	3.8	3.7	3.5	3.6

4.1.2 The interrelationship between environment and economy in P.R.C.

From the perspective of the social development, industrial growth in China, as in other industrialized countries, brought in new wealth to many people and has substantially improved the general standards of living (Chinese Academy of Social Sciences, 2010). Central Government in China has always placed economic development ahead of the environmental concerns and resource depletion, which may be arguably the right choice for the current stage of economic development (Stearns, 2007; China Development Bank, 2010).

In retrospective, after the middle of the last ten years in the 20^{th} century, the real or actual increase rate of the economy was mostly determined by the market demand, particularly from the rest of the world, thanks to the globalization drives. At the same period of time, China has experienced a fabulous economic gain during the last ten years, which arguably was carried out on the expense of the deteriorating environmental quality and depleting environmental resources.

From another point of view, China is now in the middle of the process of industrialization, the high-rate growth of economy depends heavily on the development of energy-consuming and severe-polluting industries. Industrialization and social civilization promoted China’s development as happened in UK 200 years ago and USA 100 years ago, only on a much faster rate and on a much bigger scale. Rural residents flowed into cities due to fast urbanization and massive industrialization. The proportion of urban residents rises from 3/10 to 7/10. Thus increased urban population density has led to a larger pressure on city environmental problems and relevant infrastructural facilities that include environmental manage and pollution abatement facilities.

An in-depth investigation into the industrial layouts, at the time in the late 90s of the last Century, showed that there were 219,463 state-owned enterprises and non-state-owned enterprises above designated size, which was nearly 1.5 times of enterprises numbers in the year 1998 (There were 165080 state-owned enterprises and non-state-owned enterprise in 1998). Including 6086 manufacture of paper and paper products companies, 8282 manufacture of foods and beverages companies, 15,172 manufacture of raw chemical materials and chemical products companies and 17,144 manufacture of textile companies, all state-owned enterprises and non-state-owned enterprise made a Gross Industrial Output Value 18,722.07 billion Yuan which takes 13.68% of GDP in 2004. These data shows that high-polluting and resource-dependent industries are contributing a big share of effort to propel the national economic growth and social development (China Development Bank, 2010).

It is un-separable between the heavy industries and GDP growth in the current structure of economy. Table-4.05 showed the GDP growth rate, industrial production, and other relevant data on environmental protection from 1995 to 2004.

Table-4.05 Overview of Chinese economy (Adapted from the website of National Bureau of Statistics of China)

Year	2000	2001	2002	2003	2004
(1) GDP (billion Yuan)	8950	9730	10520	11740	13690
(2) Environmental investment (billion Yuan)	101.5	110.7	136.7	162.8	191.0
(1)/(2) (%)	1.13	1.14	1.30	1.39	1.40
Direct economic loss due to pollution (billion Yuan)	0.178	0.122	0.046	0.034	0.364
Industrial production take in GDP (%)	43.6	43.5	43.7	45.2	45.9
Total Population (1 billion persons）	1.27	1.28	1.28	1.29	1.30

From the table above, it is found that the growth rate of investment in the treatment of pollution was growing faster than GDP in P.R.C. However, the former was still a small part of the latter. It was forecast that, in 2020, the population in China would reach 1.4 billion to 1.5 billion, and GDP would increase double. In addition, there will be a greater population that has a strong consume ability and need a large amount of goods. So, a continuous and quick rise of economy is necessary in the following 5 to 15 years.

It may be understood from the utilization of resources, China has consume the world's 31%, 30%, 27% and 40% of coal, ironstone，rolled steals，cement, respectively, in 2003, while creating no more than 4% GDP in the world. Simultaneity, compare with developed countries, the discharge of wastewater per unit GDP in China is 5 times more than them. And solid pollution produced by Unit Gross Industrial Output Value is as 10 times as that in developed countries. In the year 2008, the sulfur dioxide emission was the most in the world. These data showed the highly increased economy results from the terrible environmental degradation. And the fast growing gross industrial output value was mainly dragged by heavy industries year by year. So, we can imagine that if we do nothing for the protection of environment, the pollution will be aggravated 4 to 5 times, which cannot be afforded by the environment and the relevant resources.

The entire social formation of China, as other developed countries, went along with the agricultural society, industrial society, and now became stronger in economy. The difference was that China hasn't completed its capital accumulation because its GDP, when looked upon on the per capita basis, was much lower than that of developed nations (see Table-4.06).

Table-4.06 GDP per capita in representative countries, PPP

Unit: current international $

	1975	1980	1985	1990	1995	2000	2005
CHN	226	412.2	822.7	1303.1	2517.7	3928.0	6571.6
HKG	2935.4	6514.9	10319.6	16512.1	21622.0	26044.5	NA
SGP	2498.0	5265.4	7590.9	12040.7	17968.8	23744.3	29921.4
JPN	5456.1	9209.8	13330.9	19241.8	23040.1	26219.8	30821.1
USA	7529.7	12200.1	17532.5	23155.2	27780.4	33970.1	41853.6
DEU	5497.3	9209.6	12664.9	17149.3	21352.1	25480.9	29308.6

There is another important indicator to evaluate economic policy is the unemployment rate. For the social stability, the unemployment rate should be kept in a limited value. The unemployment rate in P.R.C. is around 4% after 2000. However, until 2002, there is also 16.5% employed people working in manufacturing and construction industry which was closely related to industry structure as mentioned above. Table-4.07 makes a comparison of the employment structure between China and some developed countries. It indicated that both the industrial structure and unemployment rate show that the economy's high dependency on heavy industry in P.R.C., and reveals the difficulty for China to treat environmental pollution and abate industrial pollutants from these sectors, while ensuring fast economic growth and high employment rates.

Table-4.07 Employment comparison between different countries by type of industry

Unit: %

Country	Primary industry		Secondary industry		Tertiary industry	
	2000	2001	2000	2001	2000	2001
China		50.0	22.5	22.3	27.5	27.7
United Kingdom	1.5	1.4	25.4	24.9	72.7	73.4
Unites States	2.6	2.4	22.9	22.4	74.5	75.2
Germany	2.7	2.6	33.4	32.5	63.8	64.7

Economy structure is also a factor affecting the pollution situation. Compare with the developed countries, the primary industry (Agriculture) takes much more proportion (half) in industrial structure than the others. It seems that the employment by type of industry is another factor affects environmental problems because the developed countries with large portion of tertiary industry employment maintain a better environment.

4.1.3 Environmental investment in P.R.C

The EnvI in P.R.C. was increasing in the total amount, but the fraction in the GDP was in different situation. In the recent years, the growth of EnvI could not catch up with that of GDP. Besides, most of the investment in P.R.C. had been used in waste treatment but little portion used for research and development.

Since the early 1980s, the total amount of environmental protection investment experienced a stable increase. Especially in the end of 20^{th} century, the total number had a huge leap. The EnvI ratio (percentage of GDP) also underwent a rise somewhat. (Table-4.08)

Table-4.08 Gross amount and ratio of GDP of environmental investment in P.R.C.
(Adapted from *the website of National Bureau of Statistic of China*)

(Unit: billion Yuan)

Years	GDP	Total investment in environmental protection	The proportion of investment in environmental protection
During the Sixth Five-Year Plan （1981-1985）	3240.18	16.63	0.51%
1981	489.16	2.5	0.51%
1982	532.34	2.87	0.54%
1983	596.27	3.07	0.51%
1984	720.81	3.34	0.46%
1985	901.60	4.85	0.54%
During the Seventh Five-Year Plan （1986-1990）	7303.67	47.73	0.65%
1986	1027.52	7.39	0.72%
1987	1205.86	9.19	0.76%
1988	1504.28	9.99	0.66%
1989	1699.23	10.25	0.60%
1990	1866.78	10.91	0.58%
During the Eighth Five-Year Plan （1991-1995）	19303.05	130.66	0.68%
1991	2178.15	17.01	0.78%
1992	2692.35	20.56	0.76%
1993	3533.39	26.88	0.76%
1994	4819.79	30.72	0.64%
1995	6079.37	35.49	0.58%
During the Ninth Five-Year Plan （1996-2000）	42344.36	349.04	0.82%
1996	7117.66	42.82	0.60%
1997	7897.30	50.23	0.64%
1998	8440.23	72.18	0.86%
1999	8967.71	82.32	0.92%
2000	9921.46	101.49	1.02%
During the Tenth Five-Year Plan （2001-2005）	70890.64	839.39	1.18%

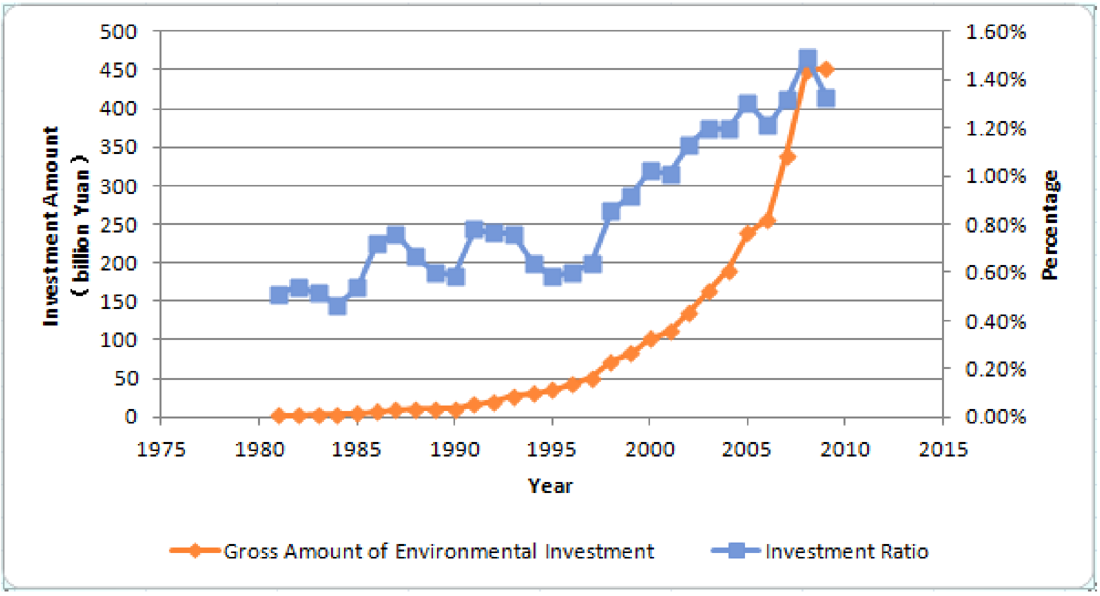
Years	GDP	Total investment in environmental protection	The proportion of investment in environmental protection
2001	10965.52	110.66	1.01%
2002	12033.27	136.34	1.13%
2003	13582.28	162.73	1.20%
2004	15987.83	190.86	1.19%
2005	18321.74	238.8	1.30%
During the Eleventh Five-Year Plan （2006-2010）	85937.50	1375	1.60%
2006	21192.35	256.78	1.21%
2007	25730.56	338.76	1.32%
2008	30067.00	449.03	1.49%
2009	34050.69	452.53	1.33%

Note: the data in red is predicted.

From the table above, we can see that the total investment in environmental protection was growing in recent years. The investment during the 7th Five-Year Plan increased to 47.74 billion from 16.63 billion in the 6th Five-Year Plan with an increasing rate of 287%. Compared with 7th Five-Year Plan, the 8th Five-Year Plan also experienced a high growth rate of 274%. In 2003, 136.34 billion Yuan was invested in treatment of environmental pollution, 23.2 percent more than in 2002. Of the total investment, 78.53 billion Yuan was used in construction of environmental infrastructure in urban areas, 18.84 billion Yuan in treatment of sources of industrial pollution, and 38.97 billion Yuan in environmental protection in new construction projects （SEPA）.The total amount of EnvI goes through a fast growth period and it was expected to reach 1375 billion Yuan during the 12th Five-Year Plan.

However, the proportion of EnvI in GDP is still very low and it rose with fluctuation during these years. (Figure-4.14) In general, the investment ratio shows an upward tendency. It rose from 0.51% in 1981 to 1.33% in 2009. Nevertheless, before 1998, the investment ratio rose and fell from time to time. Take the investment during the 7th Five-Year Plan for an example, the EnvI ratio achieved more than 0.7% of GDP in 1986 and 1987, but it fell to 0.58% from 0.66% in the coming 3 years. For another example, compared with former 3 years of the 8th Five-Year Plan in which EnvI had reached over 0.76%, the investment ratios the following two years dropped to 0.64% and 0.58%, respectively. In 2000 it surpassed 1% for the first time. Since then the EnvI ratio was rising stably and achieved 1.33% in 2009.

Figure-4.14 Gross amount and ratio of GDP of environmental investment in P.R.C



Until now, environmental protection industry in P.R.C. has developed at an average rate of 17%. In 2002, the production value of environmental protection industry achieved 220 billion Yuan, compared with 4 billion yuan in 1992. At present, these enterprises are located mainly in more developed areas along the coast and rivers of southern and eastern China, among which 6% are large enterprises with fixed assets worth more than 50 million Yuan. It can be predicted that the environmental industry will maintain its fast momentum in the near future (Table-4.09).

Table-4.09 Investment Completed in the Treatment of Industrial Pollution (Adapted from the website of Ministry of Environmental Protection of the P.R.C.)

Unit: billion Yuan

	Investment Completed in the Treatment of Industrial Pollution this year	Treatment of wastewater	Treatment of waste gas	Treatment of solid waste
2000	23.94	10.96	9.09	1.15
2001	17.45	7.29	6.58	1.87
2002	18.83	7.15	6.98	1.61
2003	22.18	8.74	9.21	1.62
2004	30.81	10.56	14.28	2.26
2005	45.82	13.37	21.3	2.74
2006	48.57	15.11	23.13	1.82
2007	55.24	19.61	27.53	1.83
2008	54.26	19.46	26.57	1.97

4.1.4 Correlation analysis of factors affecting environmental investment

In order to study the relationship between EnvI and other related factors, Correlation analysis is used as an attempt. Correlation analysis is a process of surveying the intensity of linear correlation degree between two variables and expressing it by proper indicators. Correlation analysis only can be done under circumstance that there exists some relationship or probability among the factors that are to be analyzed.

Although there are different kinds of methods to make analysis, I choose double interval variable to conduct the correlation analysis for reason of accuracy. By this way, the calculation of pairwise correlation coefficient helps to indicate the degree of correlation.

4.1.4.1 Data selection

In this section, I choose three factors to be the variables that are GDP, GDP per capita, investment efficiency and investment structure. The explanations of data are as follows.

1) GDP

GDP is a universally accepted best indicator of national economic development level. It not only can express a country's economic performance, but is also a representation of comprehensive national strength and wealth.

2) GDP per capita

GDP per capita is the result of GDP associated with population. It is often considered to be an indicator of a country's standard of living. It has more representativeness for EnvI discussion compared with GDP.

3) Investment structure (IS)

The following formula expresses the investment structure:

$$IS = \frac{\text{Industrial pollution treatment investment}}{\text{total investment}}$$

I use the proportion of investment on industrial pollution treatment of total EnvI to express the investment structure. That means, the bigger the result is, the more simplified the investment structure is.

4) Investment efficiency (IE)

$$IE = 1 - \frac{\text{direct loss by pollution}}{\text{total investment}}$$

As expressed by the formula, if the direction pollution loss is tiny, the investment efficiency can be considered high.

The useful data are summarized in Table-4.10.

Table-4.10 Useful data in the correlation analysis (Adapted from the website of Ministry of Environmental Protection of the P.R.C.)

Year	GDP (billion Yuan)	GDP per capita (Yuan)	Environmental investment (billion Yuan)	Direct loss by pollution (million Yuan)	Industrial pollution treatment investment (billion Yuan)
1986	1027.52	963	7.39	14.041	2.53
1987	1205.86	1112	9.19	80.872	3.2
1988	1504.28	1366	9.99	75.924	3.82
1989	1699.23	1519	10.25	33.825	3.95
1990	1866.78	1644	10.91	52.368	4.15
1991	2178.15	1893	17.01	62.937	5.57
1992	2692.35	2311	20.56	96.632	5.93
1993	3533.39	2998	26.88	118.272	6.34
1994	4819.79	4044	30.72	126.283	7.72
1995	6079.37	5046	35.49	99.379	9.28
1996	7117.66	5846	42.82	169.291	8.46
1997	7897.3	6420	50.23	83.661	10.78
1998	8440.23	6796	72.18	198.437	11.45
1999	8967.71	7159	82.32	57.106	12.81
2000	9921.46	7858	101.49	178.08	23.94
2001	10965.52	8622	110.66	122.72	17.45
2002	12033.27	9398	136.34	46.41	18.84
2003	13582.28	10542	162.73	33.75	22.18
2004	15987.83	12366	190.86	363.66	30.81
2005	18321.74	14053	238.8	105.15	45.82
2006	21192.35	16165	256.78	134.71	48.39
2007	25730.56	19524	338.76	32.78	55.24
2008	30067.00	23648	449.03	181.86	54.26
2009	34050.69	25439	452.53	433.54	44.25

4.1.4.2 Correlation analysis

Pearson Correlation Coefficient is adopted to make this correlation analysis. Its function is to assess the linear correlation degree of specific double interval variable, with computation formula as follows (Yuan and Pang, *et al*, 2002).

$$r = \frac{\sum_{i=1}^{n}(X_i - \bar{X})(Y_i - \bar{Y})}{\sqrt{\sum_{i=1}^{n}(X_i - \bar{X})^2}\sqrt{\sum_{i=1}^{n}(Y_i - \bar{Y})^2}}$$

Where

X and Y=specific variables

r=linear correlation degree of X and Y, $-1<r<1$

n=the number of samples, n=24

As we know, if $r>0$, it means the two variables are positive correlation. If $r<0$, that indicate a negative correlation and the bigger the absolute value results in the stronger correlation. If r=0, we believe that the two variables have no linear relationship.

The correlation analysis is conducted by Statistic Package for Social Science (SPSS) 17.0. The analysis result is summarized in Table-4.11.

Table 4.11 Correlation analysis result

		Investment	GDP	PPP	IE	IS
Investment	Pearson Correlation	1	.990**	.990**	.634**	-.714**
	Sig. (2-tailed)		.000	.000	.001	.000
	N	24	24	24	24	24
GDP	Pearson Correlation	.990**	1	1.000**	.678**	-.776**
	Sig. (2-tailed)	.000		.000	.000	.000
	N	24	24	24	24	24
PPP	Pearson Correlation	.990**	1.000**	1	.682**	-.782**
	Sig. (2-tailed)	.000	.000		.000	.000
	N	24	24	24	24	24
IE	Pearson Correlation	.634**	.678**	.682**	1	-.750**
	Sig. (2-tailed)	.001	.000	.000		.000
	N	24	24	24	24	24
IS	Pearson Correlation	-.714**	-.776**	-.782**	-.750**	1
	Sig. (2-tailed)	.000	.000	.000	.000	
	N	24	24	24	24	24

**. **.Correlation is significant at the 0.01 level (2-tailed).

From the table, it can be found that the EnvI and GDP (or GDP per capita) show significant positive correlation, with Pearson Correlation Coefficient 0.990. The gross amounts of EnvI and investment efficiency (IE) have a medium positive correlation, with Pearson Correlation Coefficient 0.634. Nevertheless, on the other hand, the EnvI and investment structure (IS) exhibit a medium negative correlation, with correlation coefficient -0.714. The result shows that for the reason of positive correlation, the rise of investment efficiency and GDP (or GDP per capita) will lead to the increase of EnvI scale. However, simplification of investment structures could bring negative impact on the growth EnvI for the reason of negative correlation.

Thus, following enlightenments can be gotten:

(1) Develop economy level to provide a solid economic foundation to promote EnvI.

(2) Enhance EnvI efficiency and reduce pollution losses.

(3) Optimize and diversify the structure of EnvI and avoid single investment direction.

4.1.5 Environment plan in P.R.C.

As the largest developing country in the world and being accompanied with economic prosperity of China during the last 20 years, environmental problems have attracted much attention of the central government. The government has proposed a grandiose objective that constructs an overall affluent society before 2020, in the meantime, makes the favorable environment an important content in this goal.

Had been issued on February 3rd in 2005, a decision about enhance environmental protection, stated briefly to strengthen the environment technical construction of basis platform, and the momentous research program of the environment has the priority to be listed in the state technology plans.

It has become the final goal for the development of environmental protection industry during the period of the 10th Five-Year Plan that providing the environmental protection with technological guarantee and material basis in order to adapt to the increasingly strict environmental protection requirements for the environmental protection industry and make it to be a new growth point for economy. This showed a clear attitude of the government to accelerate the development of environmental protection technologies.

4.2 Critical analysis of India

India is one of the oldest civilizations in the world with a kaleidoscopic variety and rich cultural heritage. India lays on the southwest of the Himalayas Mountains and abut with China in its north and the northeast region.

Figure-4.15 The geographical interrelation between China and India

India has witnessed a dramatic rise in environmental concerns in the past two decades. It is the first country which explicit the environmental protection in its constitution (Malik *et al*, 2005).

As the fast growing investment for the construction, mining and manufacture industries, India is facing the environmental problems of declining air and water qualities. The huge population of India and the fast pace of urbanization also increase the load of the environment.

Obviously, the multi-economy development experience of India is thought to be a good example for the developing countries in the world. (Bagchi, 1970; Mahan, 2007).

4.2.1 Comparability and limitation

4.2.1.1 Fundamental condition

If you look at the relative growth rates of China and India, you will find that about 15 years ago, current consumption of India was the same with that of China (Muralidhar, *et al*, 2004)

India holds the second largest population in the world with over 1.2 billion people. It is likely to be in the vicinity of 1.4 billion by 2026, and could well approach 1.6 billion by 2051 (Tim *et al*, 2004). The geographical area of India, 2.98 million square kilometer, is the seventh-largest in the world.

India's economy grew at about 10.365 % of the year 2010, with the economic structure portion of approximately 17.5% : 19.9% : 62.6% for the three sectors (agriculture, industry and service). It is obviously, that the GDP of India, which is INR 51,980.23 Billion (US$ 1,537.97 Billion), is largely contributed by the service industry, especially the IT industry. Due to its great population, the 2010 per capita GDP of India, INR 42,749.05 (US$ 1,264.84), is relatively low compared to the high growth rate (Economywatch, 2011).

Since India is one of the giant developing countries in the world as China, it is valuable to analyze and learn the environmental protection merit of India.

4.2.1.2 Comparability

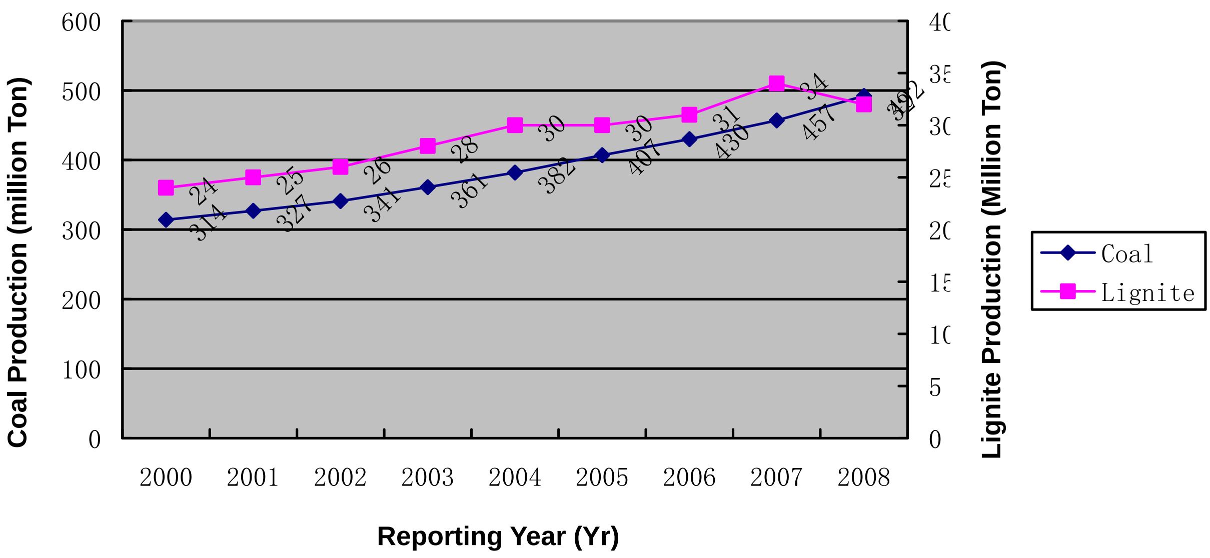
Environment aspect

From the energy consumption and power generation aspect, India is similar to China for their growth trend and structure. The major material for power generation in India and China are the same, i.e. the coal, which will greatly contribute to the green house effect and SO_2 pollution.

Subramanian (2002) found that the GHGs concentration varies from time to time in a day due to the varying traffic density and human activities.

Coal and lignite, which are thought to be the non-renewable resources (Joosten, 2007), are the two major materials for power generation in India. From the Figure-4.16, we could find the coal production keeps in a fast growing pace compared to the fluctuating growing of lignite from 2000 to 2008. It revealed the energy consumption is growing in a high speed in the resent years. The fast growth of the use of these two materials will bring a direct environmental problem, acid rain.

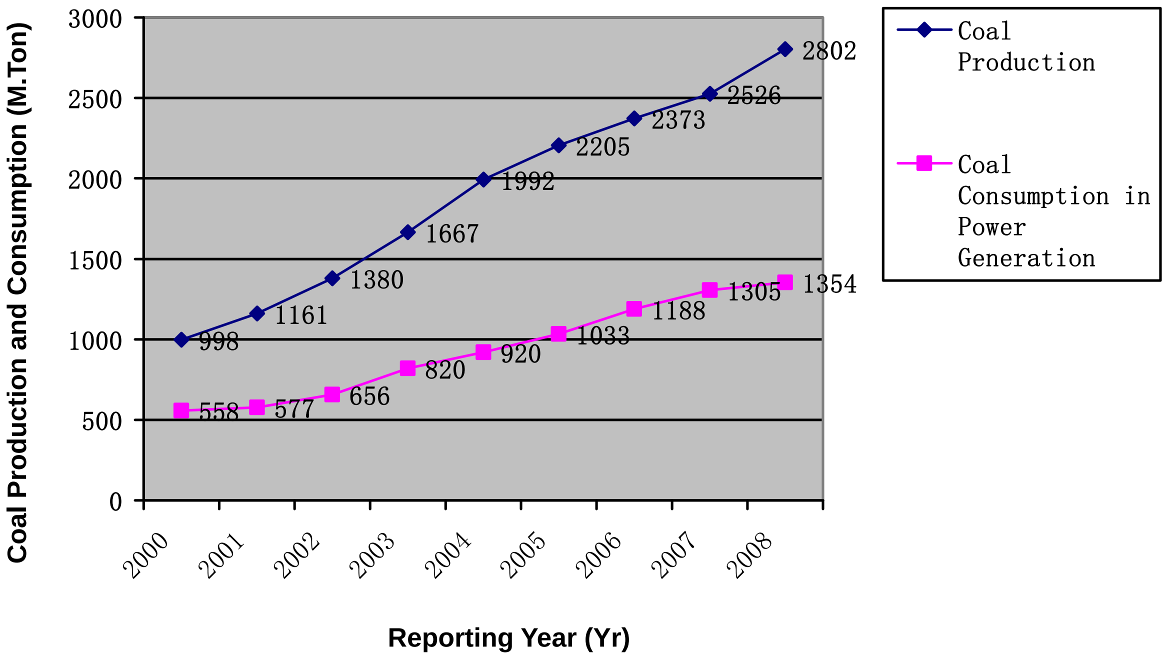
Figure-4.16 Production of coal and lignite in India from 2000-2008 (Adapted from the website of Ministry of Environmental Protection of India)



From the trend of the production of coal, it is predict 500 million ton will be produced and 70% of them will be utilized for power generation (Subramanian, 2002).

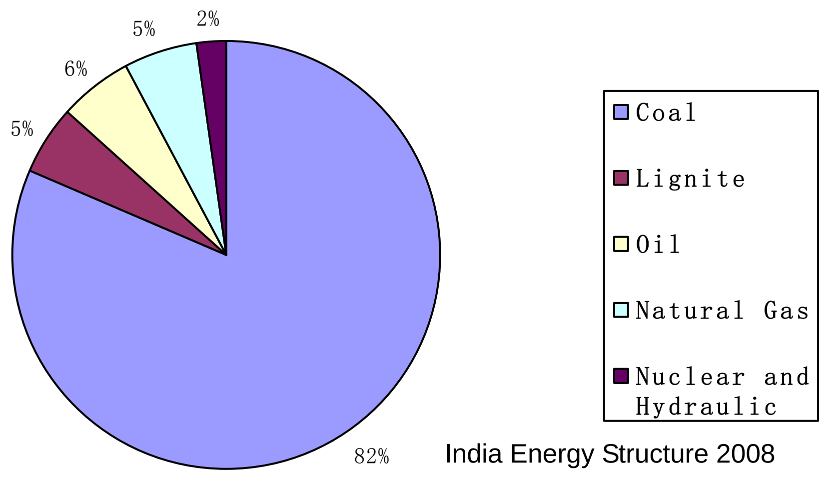
Similar to India, China boosts the power consumption during from 2000 to 2008 due to the fast growing economic, especially the industry production.

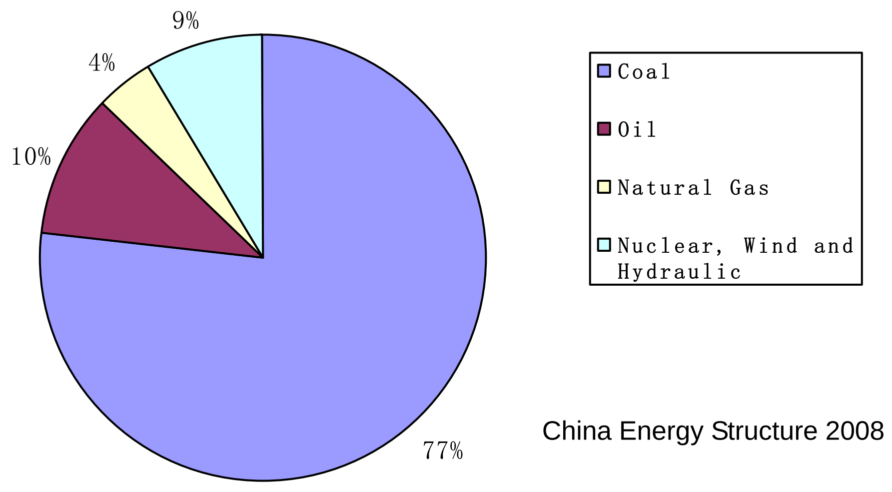
Figure-4.17 Coal production and consumption in energy generation in China (Adapted from the website of National Bureau of Statistic of China)



Compared to India, China also keeps the coal production growth trend in recent years (Figure-4.17). The coal consumption in power generation around 50% of the total coal production, but its growth is less than the production. That's because the energy generation structure had been modified in these years. The portion of green energy production area is arising. It is reported that the ratio of power generation of the year 2009 from kinds of resources are: coal-77.3%, oil-9.9%, natural gas-4.1% and other-8.7% (National Bureau of Statistic of China, 2011). The other resources contain the nuclear, wind and hydraulic. The comparison on power generation structure between India and China of the year 2008 is shown in Figure 4.18.

Figure-4.18 Energy production structure in China and India (Adapted from the website of National Bureau of Statistic of China and Ministry of Environmental Protection of India, 2011)





From the Figure-4.18, the energy generation of India is mostly relied on the coal resources, which will generate huge amount of GHGs and TSP contributing to the air pollution. The energy structure of present India is similar to that of China few decades ago, so that it is valuable to analyze and get from India to see whether China had neglect some important aspect in the developing ways.

China and India are facing the mission to reform their energy generation structure, i. e. to enlarge the use of green energy and minimize the consumption of non-renewable resources. To analyze the experience of India, it is expect to gain valuable concepts and opportunities in the resource conservation and environmental protection.

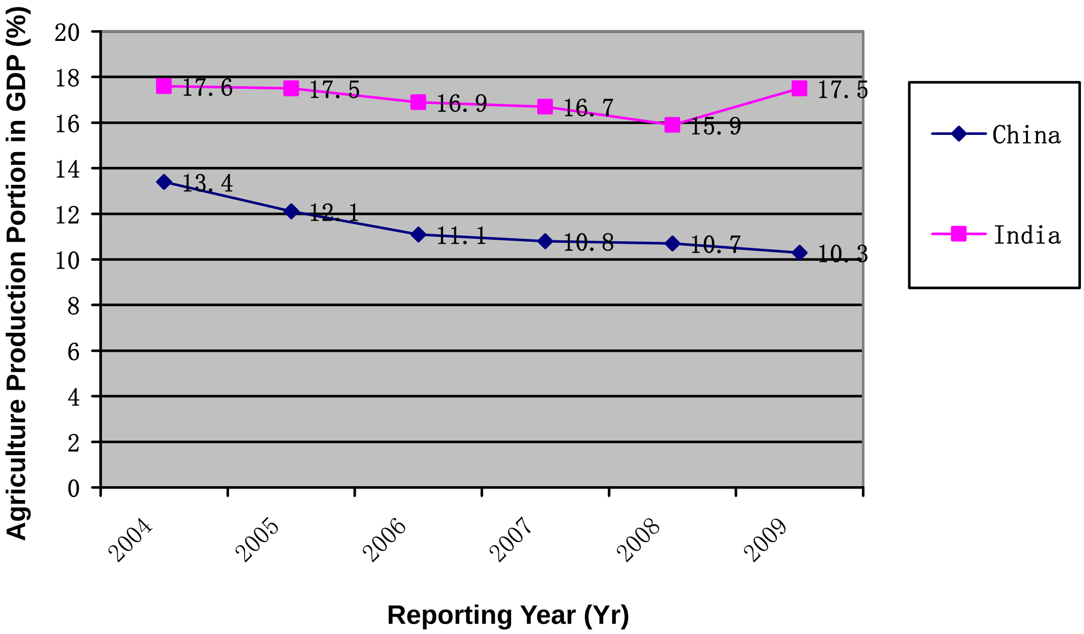
Social aspect

Huge population is one of the major aspects that bring environmental problems. Similar to China, India holds the second place in population amount in the world and the first place in population density. The high density of population leads to huge internal consumption of products and results in huge waste generation.

Liquid and solid wastes generation and disposal is the obvious sign for human culture (Subramanian, 2002). India's towns and cities are significant centres of production, employment, and income generation and are estimated to contribute about 60% of the country's GDP (UNCHS and HUDCO 2001). Hindustan Times (2000) reported that average 1300 tons solid wastes per day was generated of every major cities in India with 0.457 kg per capita waste generation. Such amount of per capita waste generation on the huge population leads to great environmental pressure in India. Similar to India, the human generated solid wastes mostly come from the major cities in developed areas.

Agriculture product export plays an important role in the economic profit in India and China. The agriculture production portion in GDP from 2004 to 2008 is shown in the Figure-4.19. The figure showed that around 16% and 11% of GDP is contributed by agriculture production in these two countries respectively. Compared to the stable portion of the agriculture production, China is reducing the agriculture sector portion due to the rising service sector. Agricultural population occupies most of the total population in these two countries. According to China Statistical Yearbook (2011) and Statistical Year Book India (2011), approximately 53.4% of China and 72.2% of India is agricultural population. The data showed that India and China are first two biggest agriculture countries in the world and with the most similar characteristics in the social aspect.

Figure-4.19 Agriculture production portion in GDP of India and China (Adapted from the website of National Bureau of Statistic of China and Ministry of Environmental Protection of India, 2011)

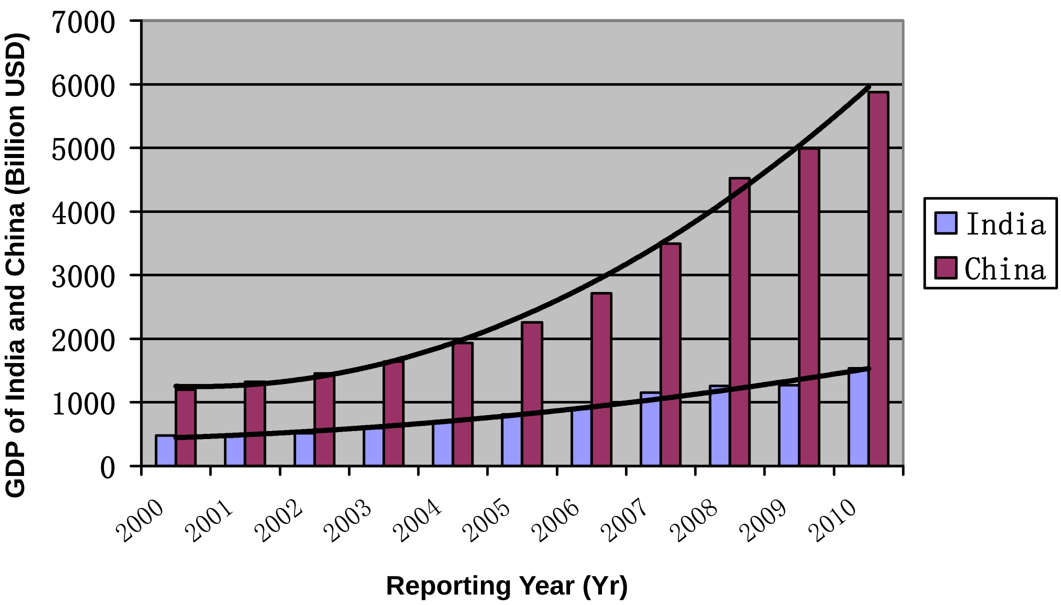


Economy aspect

India and China occupied the fifth and sixth place of the fast growing countries in the world in 2010 respectively. The growth of India in 2010 reached 10.36% and is a bit greater than 10.3% of China (Economywatch, 2011). The fast growing speed of these two countries indicated the similarity of them. It will be valuable to analyze the resources consumption during the high growing courses to gain the sustainable development concepts. Figure-4.20 and Figure-4.21 showed the GDP and per capita

GDP of India and China from 2000 to 2010 respectively.

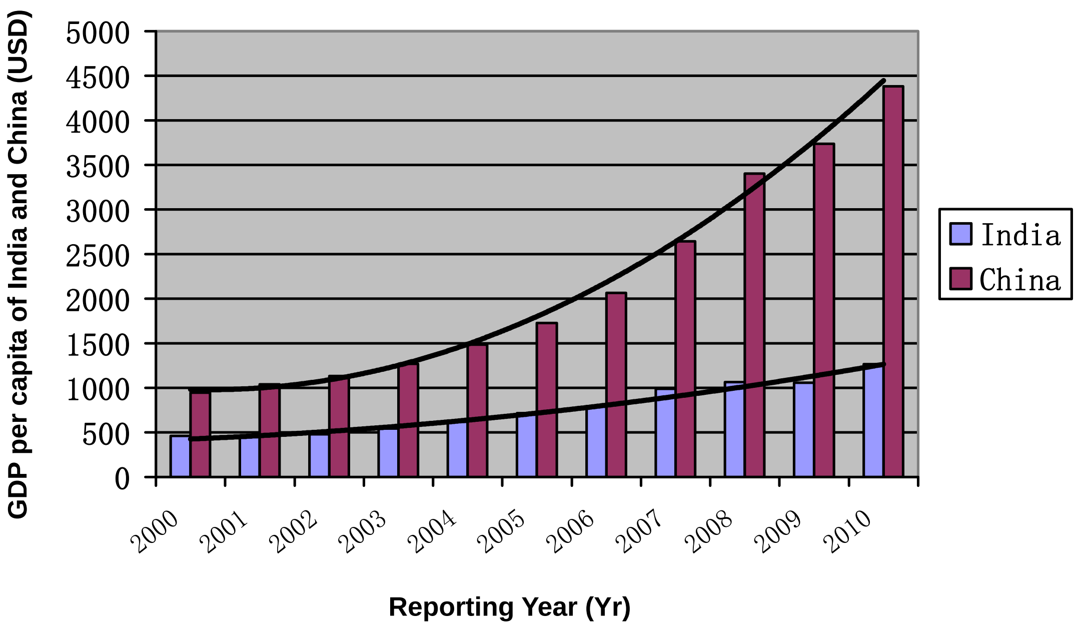
Figure-4.20 GDP in India and China (Adapted from Economywatch, 2011)



Stearns (2007) stated that the economy of China and India relied on the low technical labor force, which may increase the economy in developing status. However, this kind of labor force could contribute less in the high technology industry.

As well as the GDP, India also keeps a high GDP per capita growth (approximately 7%) as China in recent years. It is expected to learn from India what environmental policies were taken during the economic development.

Figure-4.21 GDP per capita in India and China (Adapted from Economicwatch, 2011)



The increasing IT industries boosted up the development of service sector in the economic growth in India. It is report that the production of software industry occupied up to 55% of the total production of service sector. The IT products are exported to the Southeast Asia and other developing countries. The high portion of IT industries also contributed to less environmental problem due to their low waste generation.

The industry sector growth trend in both India and China are nearly the same, which is shown in the Figure-4.22. Compared to about 47% of China, the industry sector in India is about of 22.5% of the total GDP production. But India is focusing on enlarging the industry sector (Stearns, 2007) while China government decides to reduce. That will result in enrich of the environmental pollution and hence environmental expenditure.

Figure-4.22 Industry sector portion in India and China (Adapted from the website of National Bureau of Statistic of China and Ministry of Environmental Protection of India, 2011)

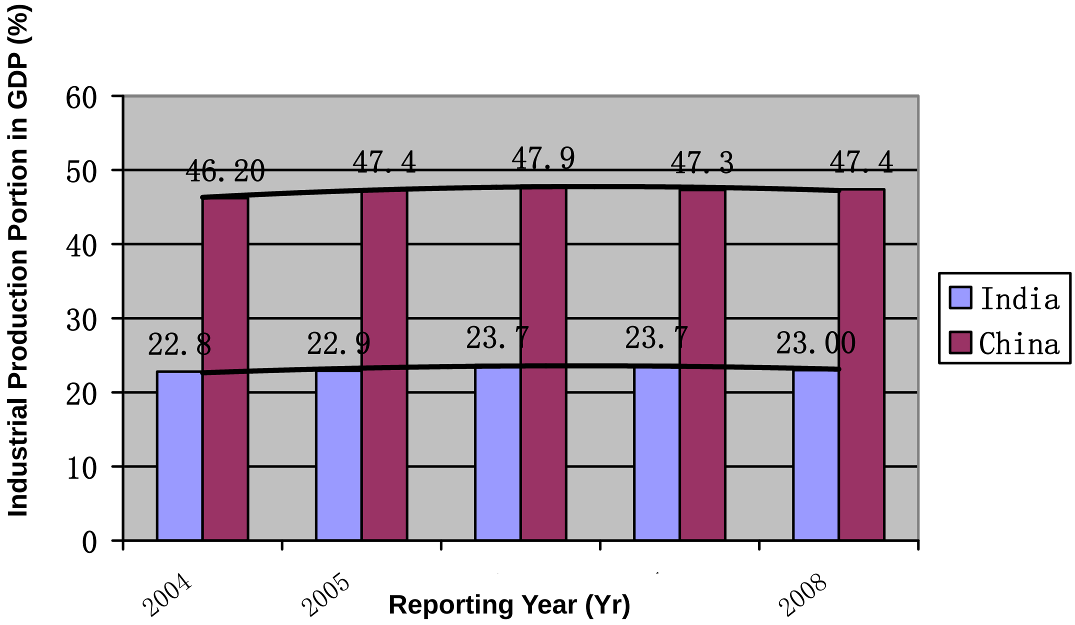
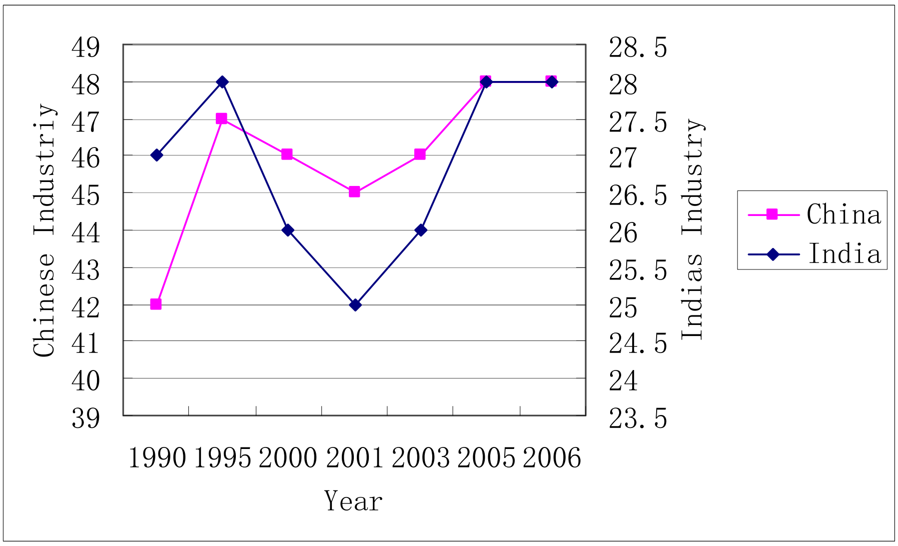


Figure-4.23 Industry growth trend in India and China (Adapted from the website of National Bureau of Statistic of China and Ministry of Environmental Protection of India)



In order to eliminate the poverty in India, the government prefer to create more employment opportunities through enlarge the industry sector. This decision may result in building up another 'World Factory' like China (CE, 2007) but could effectively improve the under-level living circumstance due to huge population (Mona, 2007). Therefore, it is valuable to analyze the industry in India and search international cooperation opportunities.

4.2.1.2 Limitations

1) Due to the language resistance, it is difficult to collect some essential data in the government web site of India. The English publication in India about EnvI is limited, since the major data was written in local languages.

2) From the data of economy, India is in the developing status like 10~15 years ago of China. Therefore, it is more or less looking back on the development course of China. Mohan (2007) stated that capital industry led growth model was no more dominate in present Indian economy. However, in order to reduce the environmental pressure, China encourages enlarge capital industries.

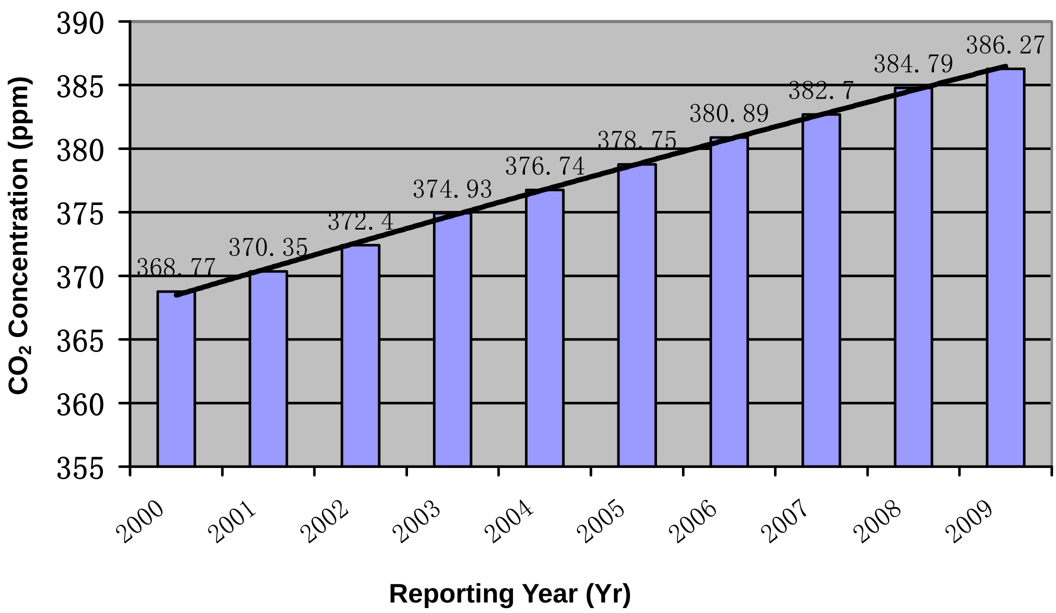
3) Although India had some achievements on raising environmental quality, there was still a long way to reach well standard environmental quality.

4.2.2 Environmental circumstance and trend

4.2.2.1 Air quality

Since coal and lignite are the major material used in power generation in India, it is going to become third largest GHGs producer in the world by 2015. About 60% of GHGs emissions were from coal and lignite burning, especially in power generation, resulting in the fifth place in the world for the GHGs discharge of India.

Figure-4.24 Ambient CO_2 concentration in India (Adapted from the website of Ministry of Environmental Protection of India)



The increase of industrial production in India including the power generation had greatly boosted up the CO_2 emission (Subramanian, 2002). Figure-4.24 showed that the CO_2 increase approximately 0.4% per year while the concentration reached 386.27 ppm in the year 2009.

Subramanian (2002) stated the SO_2, NOx and SPM concentration even excess of healthy standards in many industrial places of India. Increased vehicular fleet, industrial expansion, and increase in use of diesel generator sets have contributed towards increase in air pollution levels in almost all Indian cities. While ambient air pollution is a concern in most of the urban centres of the country; the problem of indoor air pollution plagues the rural areas of India (Ministry of Environment and Forests, 2011).

Figure-4.25 Percentage of cities with kinds levels of SO_2 (Adapted from Report to the People on Environment and Forest 2009-2010, 2011)

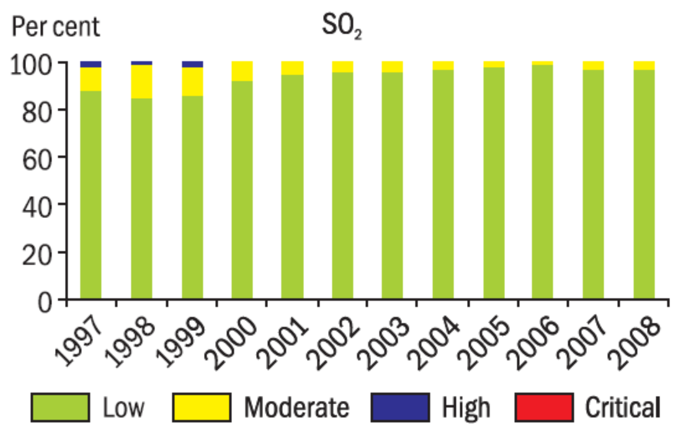


Figure-4.26 Percentage of cities with kinds levels of NO_x (Adapted from Report to the People on Environment and Forest 2009-2010, 2011)

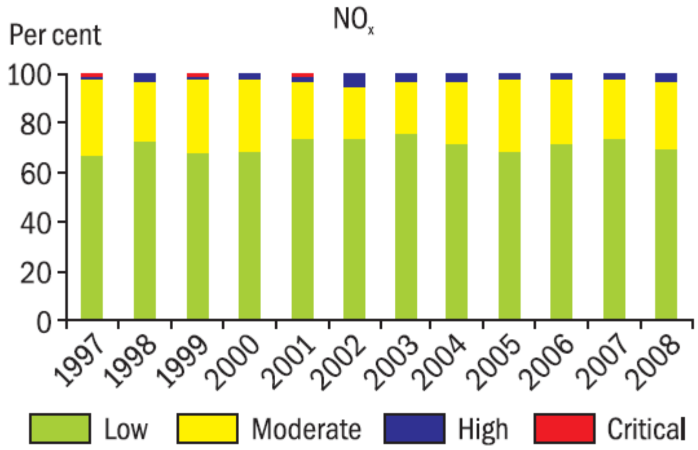


Figure-4.27 Percentage of cities with kinds levels of PM_{10} (Adapted from Report to the People on Environment and Forest 2009-2010, 2011)

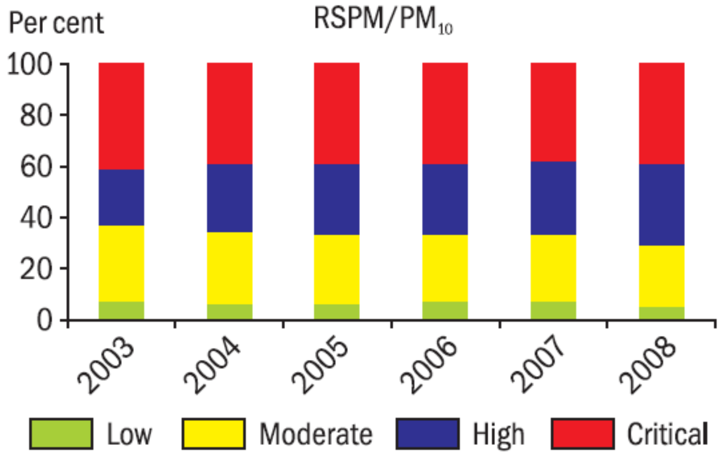


Figure-4.25~4.27 showed the percentage of cities SO_2, NO_x and PM_{10} level in critical, high, moderate and low status. The SO_2 and PM_{10} emissions are mainly comes from the burning of the sulphur contained coal and lignite while NO_x from vehicular fuel usage. From the data, it is valuable to learn that the main directions for China to reduce the air pollution are to reduce the use of coal by developing more green energy and to lessen the private car amount by building more public transportations.

CO, which is due to vehicular fuel burning, was the obvious air contaminant in the major city in India according to the Figure 4-28. Compared with China, the dormant air pollutant in the major cities was SO_2 in recent years, which occupied 58% of the total pollutants. Additionally, the other pollutants such as NO_x and PM_{10} were occupied 24% and 18% respectively.

Figure-4.28 Decadal variation in pollutants in the atmosphere in India (Average data in Delhi, Mumbai and Calcutta)

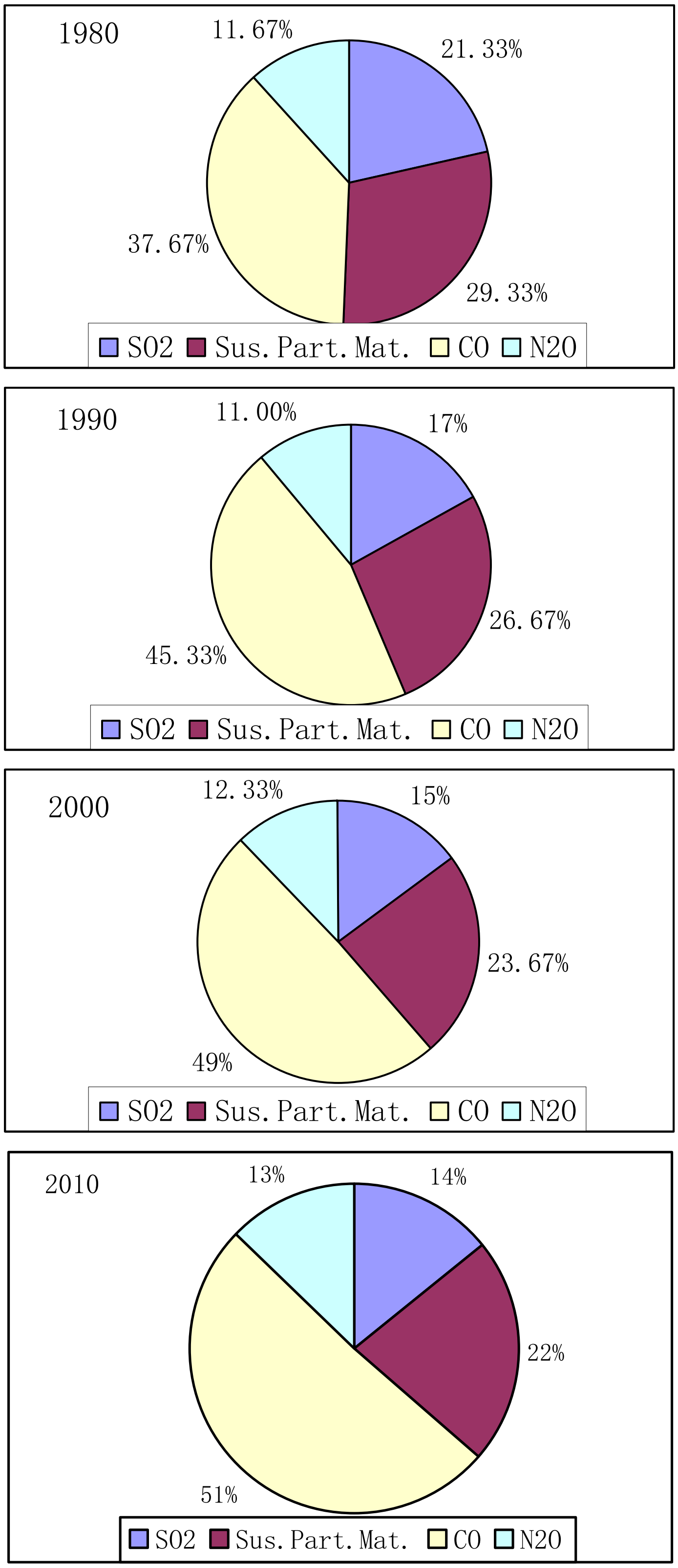


Figure-4.29 Average concentration of air pollutants in India industrial areas (Adapted from the website of Ministry of Environmental Protection of India 2011)

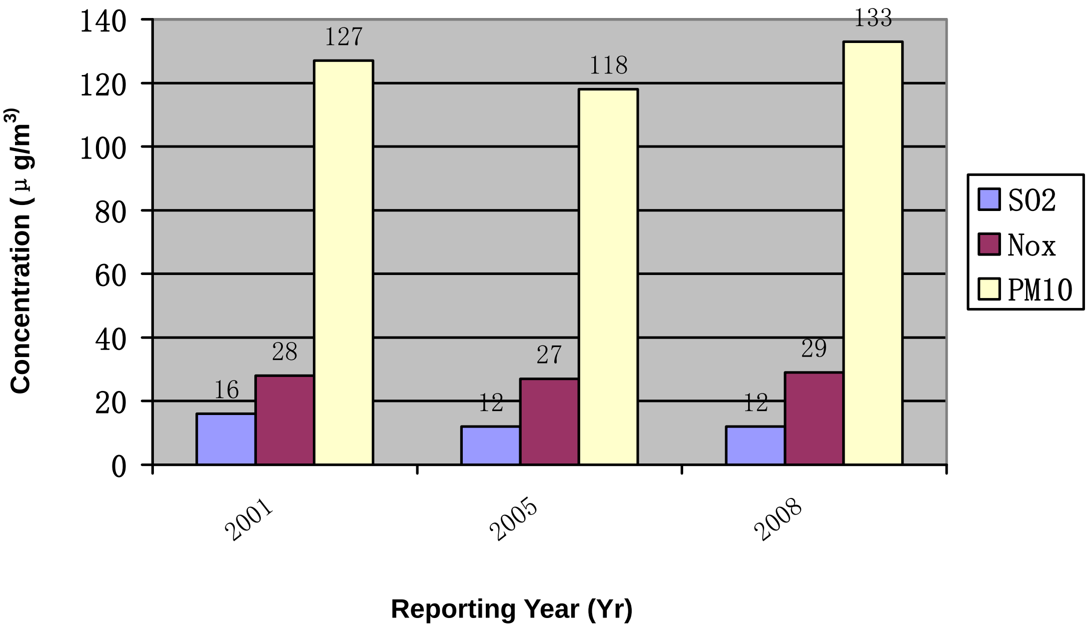


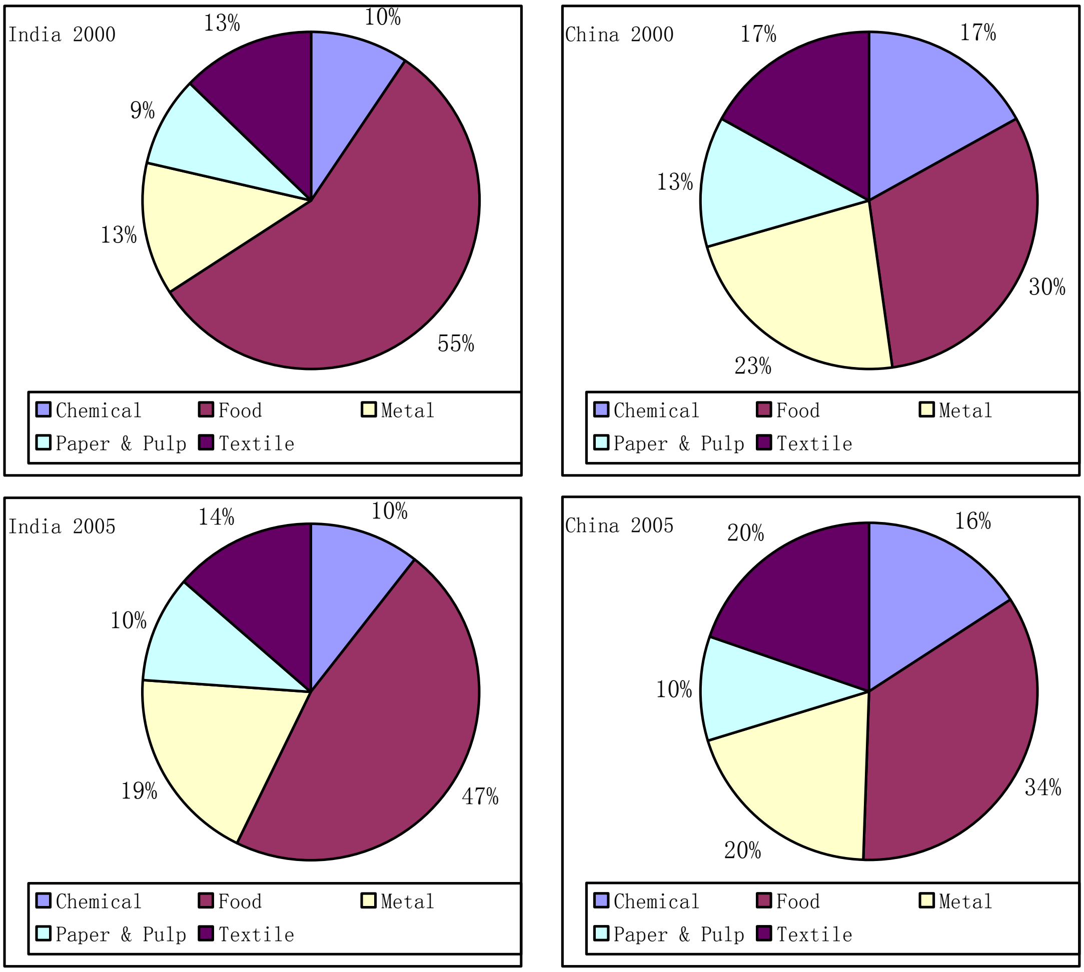
Figure-4.29 showed that the SO_2 concentration was decreasing while NO_x and PM_{10} are increasing because of the environment control in fuel gas desulphurization and urbanization in India. China is also facing the same air pollution problem with India. It inclined that India and China could have more cooperation opportunities on air pollution control.

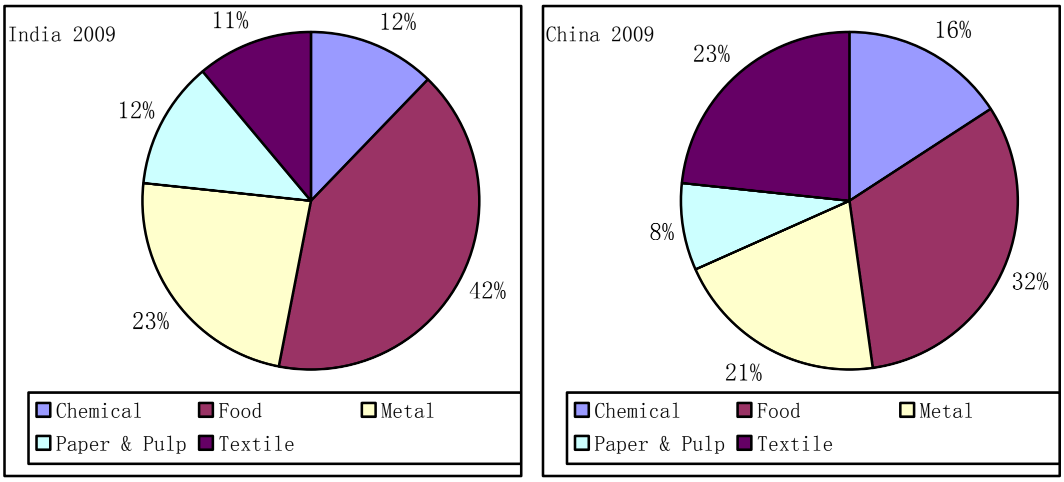
4.2.2.2 Water environment

For thousands of years, rivers have been an objective of worship in India, and almost all rivers are named after gods, goddesses, or sages (Awaji *et al*, 2003). It showed that how important of the rivers in Indian heart are. However, the water quality in India is undergoing polluted. From 1970s, when the industrial reformation happened in India, water quality was becoming troublesome matters. In the 1990s, at least a million children was dead from diarrhea and gastrointestinal disorders due to the bad water quality since little had been done to treat deteriorating water quality. Since that, the government started to take the water environment issue into agenda.

The great pressure on India on water environment included the deficit of water production and little wastewater treatment abilities. Subramanian (2002) stated the present annual water requirement was 634 km^3 and it is expected to more than double down within the first half of 21^{st} century. According to the development plan of India, Domestic water requirements were predicted to increase 70 percent in 2025 while industrial requirements would reach up to 5 times growth speed in the next 20 years.

Figure-4.30 Wastewater discharge structure in India and China represented by BOD (Adapted from the website of National Bureau of Statistic of China and Ministry of Environmental Protection of India, 2011)





The Figure-4.30 showed the wastewater discharge structure, which was represented by the BOD discharge, in India and China industries. The data showed that the dominant polluting industry in both China and India is food industry, which generate high biodegradable wastewater. However, due to the high industry sector portion in China compared to India, the other industries such as chemical, textile, paper and metal industries would discharge huge amount of recalcitrant pollutants leading to high treatment cost. Regarding the differences, China should put more investment in technologies development for the treatment of the recalcitrant pollutant and industrial wastewater reuse.

4.2.2.3 Solid waste circumstance

Like most common countries, the major solid waste problem occurred in India was the plastic waste pollution for the urban areas. The plastic waste is strewn widely in cities and causes the asphyxiation deaths of zoo animals that swallow them (Awaji *et al*, 2003).

4.2.3.1 Municipal solid waste

At present, 57 million tons solid waste, including 9% plastic waste, was generated per year in India. The municipal solid waste (MSW) in India has high moisture content (45%–65%) and calorific value, at 550-3600 k cal/kg. The density of waste is 330-560 kg/m^3, and the C/N (carbon/nitrogen) ratio is between 25 and 30. The MSW of India is quite suitable to be composted for agriculture reuse.

From the report, up to 60% of MSW was recycle in India but the plastic waste like thin polythene bags and PET bottles still remains a matter of concern due to low collection efficiency (Ministry of Environment and Forests, 2011).

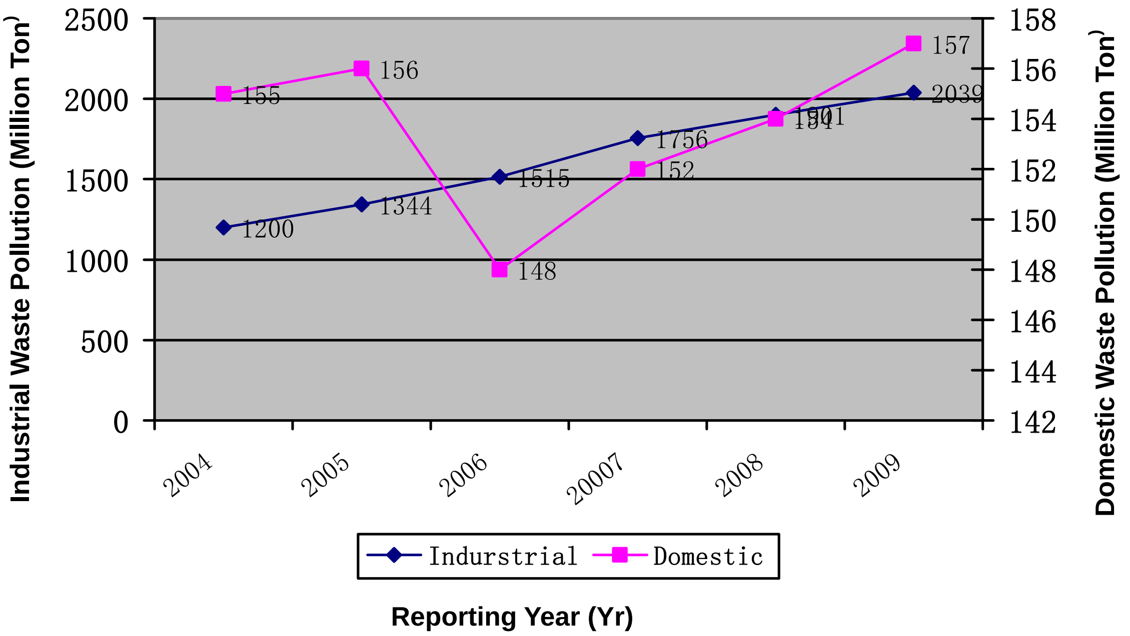
4.2.3.2 Industrial solid waste

According to the documents reported by Ministry of Environment and Forests (2011), 6.23 million tons of hazardous wastes are being generated by 36135 industrial units in the country, as compared to 4.4 million tons from 26566 units in 2006. In addition to hazardous waste, about 130 million tons of fly-ash is generated from thermal power plants.

Due to the high development of IT industry in India, the e-waste is also an obviously environmental problem. It is reported that Mumbai currently topped the list of major e-waste generating cities, at around 11017 tons per annum, followed by Delhi at 9730 tons, Bangalore 4648 tons, Chennai 4132 tons, and Kolkata 4025 tons.

Compared to India, the major solid waste pollution was contributed by industrial production and the per capita pollution was much greater (Figure-4.31). At the same time, the composting rate of the MSW in China is much less than India. According to the statistic 2010, only 1.1% MSW was sent to composting while 56.6% to landfill and 12.9% to incinerate. The total treatment rate of MSW is only 70.6%.

Figure-4.31 Industrial and domestic solid waste pollution in China (Adapted from the website of National Bureau of Statistic of China)



The valuable aspect China should learn from India is the solid waste recycling method. If the solid waste recycling rate could be raised up to 60%, it will greatly reduce the solid waste treatment cost, landfill leachate treatment cost and GHGs generation.

4.2.3 Environmental policy and investment

4.2.3.2 Environmental policy

It is studied that the existing regulation regimes in India contributed little in industrial pollution abatement according to the present status of on industrial plants (Pargal *et al*, 1997). Parikh *et al*. (1999) also stated that there were little safety and pollution control management in industries operation in India.

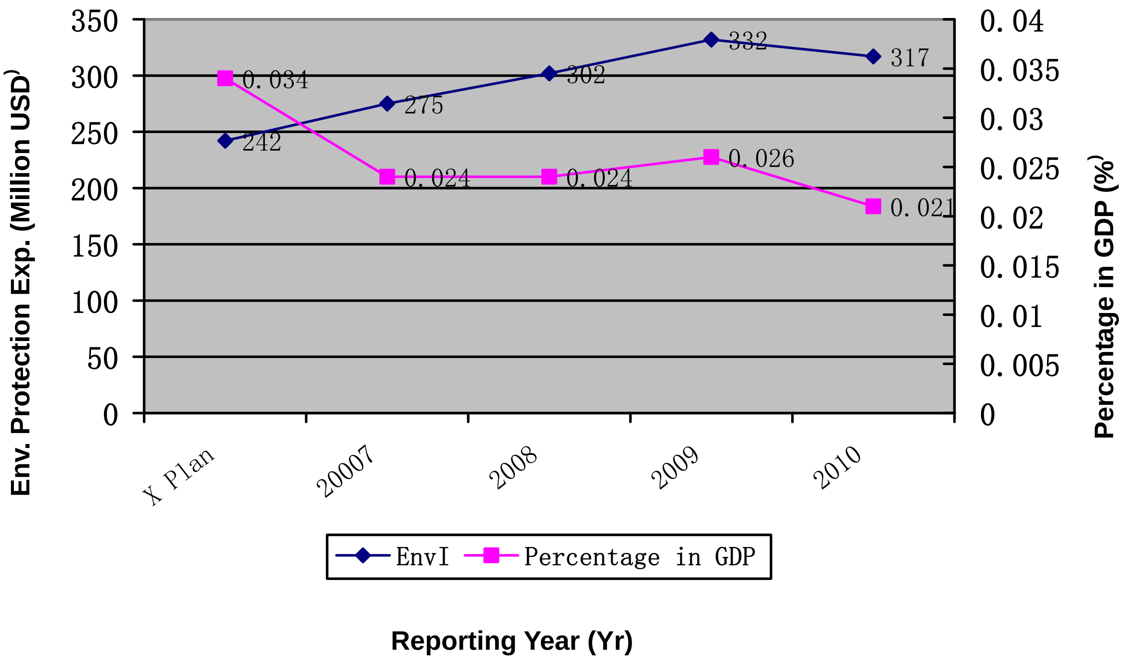
India government set up the Ganga Action Plan (GAP) since 1985 to solve the problem of the quality of river. This is to clean up the Ganges Rivers and mainly entailed building gutters and treating wastewater before running it into rivers because 75% wastewater poured directly into river is from municipal gutters and 25% was from industrial pollution. The plan aims to collect the wastewater to treatment other than pouring into the river. Although the Ministry of Environment and Forests says there has been an improvement in the biological oxygen demand (BOD) under GAP, wastewater treatment facilities do not function due to insufficient electric power and general public see no improvement in water quality.

Regarding the bad ambient air quality and the energy deficiency in India, the Organization for Economic Cooperation and Development (OECD) predicted that it needs to invest approximately 1250 billion USD in energy generation structure till 2030. Among the 1250 billion USD, 75% should be used for enlarging the power generation capacity to be more than 400 GW, which is equal to the sum of the capacities of Australia, Korea and Japan.

4.2.3.1 Environmental investment

Due to the language limitation, the data in English publication was studied. However, the EnvI statement in English is limited. Hence, the EnvI in this analysis is adapted on the financial statistics for environment protection related budget and expenditure.

Figure-4.32 Environmental expenditure for environment protection plan in India (Adapted from Annual Report 2010-2011, 2011)

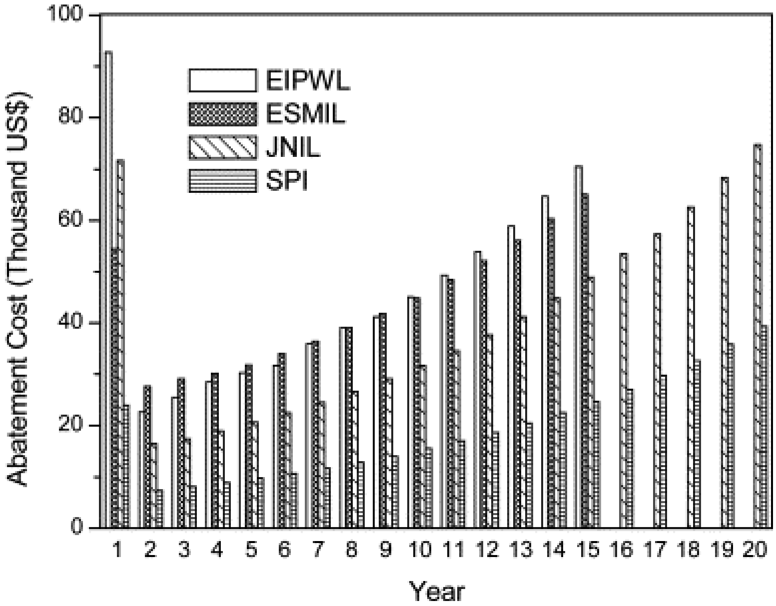


The Figure-4.32 showed the environment protection expenditures from the Ministry of Environment and Forests in India. In the definition of environment expenditure in India represented on the expenditure for forest, river and biodiversity conservation. The pollution control expenditures were not stated in this data since they had been named as pollution abatement expenditures or investments which were not collected in the national statistic ministry in India.

The X Plan represented the 10th development plan in India from 2002 to 2006, the environmental expenditures were increased in a relative low growth from 2007 to 2010 compared to the fast growth rate of GDP. Therefore the percentages on the environmental expenditure in GDP were running down. We could learn that the environmental expenditure or investment should keep in the same growth rate with GDP or even higher, so that the environment quality would not result in a worse circumstance.

The private investment of pollution abatement was made up with the capital and operation cost. Figure-4.33 showed the total water pollution abatement cost of some major effluent treatment plants (ETPs) in India, which represented the total trend of water pollution abatement investment.

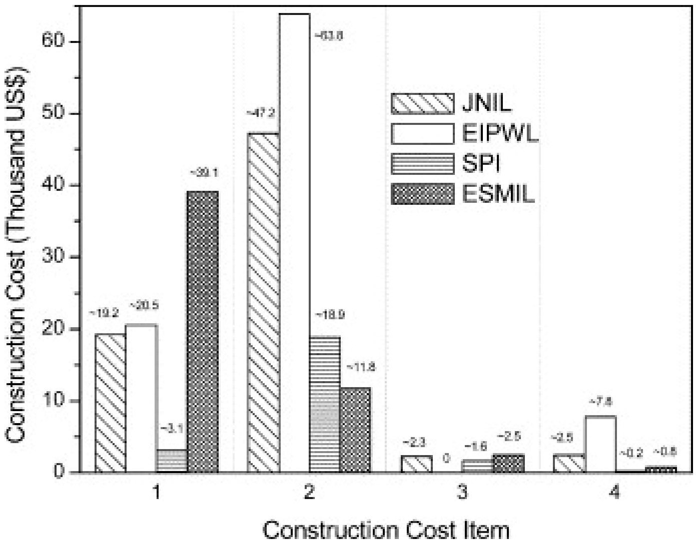
Figure-4.33 Yearly total abatement cost of ETPs (Effluent Treatment Plants) for the JNIL, ESMIL, EIPWL and SPI over the lives of their ETPs (Adapted from Malik, et al., 2004)



(i) Jenson & Nicholson Ltd. (JNIL), a large-scale paint industry;
(ii) Eastern Spinning Mills & India Ltd (ESMIL), a large-scale textile industry;
(iii) East India Pharmaceutical Works Ltd. (EIPWL), a medium-scale pharmaceutical industry;
(iv) Samson Processing Industry (SPI), a small-scale textile dyeing industry.

The Figure showed that, in 20 years, the operation cost of the pollution abatement increased in a high growth. In 15 to 20 years time, the operation cost occupied beyond 70% of the capital cost (Figure-4.34) due to the rising salary and consumption price.

Figure-4.34 Installation/construction cost summary of ETPs for the JNIL, ESMIL, EIPWL and SPI. Construction cost item: (1) equipment; (2) civil work; (3) consultancy and (4) others (Adapted from Malik, et al., 2004)



4.2.4 Learnable aspects and cooperation opportunities

4.2.4.1 Learnable aspects

India has the most similarity with China in the world due to the development status, population and GDP growth speed. India is facing the same environment problems as China in its high speed developing way. However, the developing status of India felt behind China. Hence, little could be learnt from India's experience but the awareness could be analyzed from India in order to avoid falling in the wrong direction.

According to the comparison to India, whose economic structure is composed by 17.5% agriculture, 19.9% industry and 62.6% service, China has deficiency in the service sector, which generates less pollution than that from the other two sectors. However, the environment status of India is unsatisfied due to the energy supply structure. From the comparison, China should adjust the economic structure and the energy supply structure to ensure the valuable usage of the EnvI. Another valuable experience which China should learn from India is the effort that the government put into the forest and biodiversity conservation. The forest and biodiversity should be considered as a kind of non-renewable resources if they were disappear.

From the pollution abatement experience in India, China should be aware that the EnvI is not only the common expenditure on the construction of pollution treatment plants. It is important to distribute the funding in the reasonable aspects so that the whole system could be operated without any disjunction. The environmental expenditure or investment should keep in the same growth rate with GDP or even higher, so that the environment quality would not result in a worse circumstance.

4.2.4.2 Cooperation opportunities

Regarding the pollution abatement status and economic development trend, India and China could cooperation on the areas of environmental technologies, IT industries and metal industries.

Since India could make steel in a cheap way, China could consider the cooperation on the metal production technologies in order to lessen the present high polluting production status in China.

India is famous for its IT industries, which generates less pollution but huge benefit to GDP. If China could cooperate on this area, great effort on education should be put to train more high level professors. The development of IT industries could obviously increase the service sector portion in GDP, but it is a long way to raise the education level of national people to achieve the goal.

As India is poor in pollution abatement, China could also consider the cooperation on the environment protection technologies. China had passed the same period that India was facing, hence, the experience from China could be very valuable to India in its development way.

4.3 Critical analysis of Japan

4.3.1 Comparability and Limitation

4.3.1.1 Fundamental condition

Located in the Northwest of Pacific Ocean, Japan is an archipelago of 6852 islands, with the world’s third-largest economy by nominal GDP and fourth largest economy by purchasing power parity (Inman and James, 2011). It is also the world's fourth-largest exporter and fourth-largest importer.

The geographical features of the Japan determined its land and resources situation. As an island country, Japan has a long coastline and large territorial sea area. These characteristics provide a vast space for exploitation of seabed resource and development of marine transport enterprises. However, the land resources are not as rich as marine resources. There are only 49896.7 square kilometres land area in total and 442 square meters per capita.

Although varying greatly from north to south, the climate of Japan is predominantly temperate. The average temperature in winter and summer in Japan is 5.1 °C and 25.2 °C, respectively. There are 9 forest ecoregions that reflect the climate and geography of the island. 90000 species of wildlife show the biodiversity of Japan.

4.3.1.2 Comparability

As a developing industrial country, Japan was far more eager for growth than for environmental preservation, and their leaders argued that they lacked the funds to afford types of controls (Stearns, 2007). The previous government's agenda in Japan was similar to that in China as mentioned before. The priority in economy boost rather than environment protection led Chinese government and societies ignore environmental issues at the begging of their development. However, since 1960s, Japanese government and societies began deal with environmental problems.

Economic aspect

Just like China, Japan preferred to grow first and cleaned up later. In this sense, the Japanese model may be exactly suitable for China to draw lessons from (Inui and Kato, 2002).

The Japanese economy was one of the largest in the world with a per capita GDP 24700 U.S. dollars in 2008. As Figure-4.35 illustrated, after growing 140% over 1970 to 1990, GDP rose only by 14% in the 1990s. And the variation tendency since 2000 experienced a fluctuation between 4000 to 5000 billion U.S. dollars.

Figure-4.35 Growth trend of Japan's GDP from 1970 to 2010

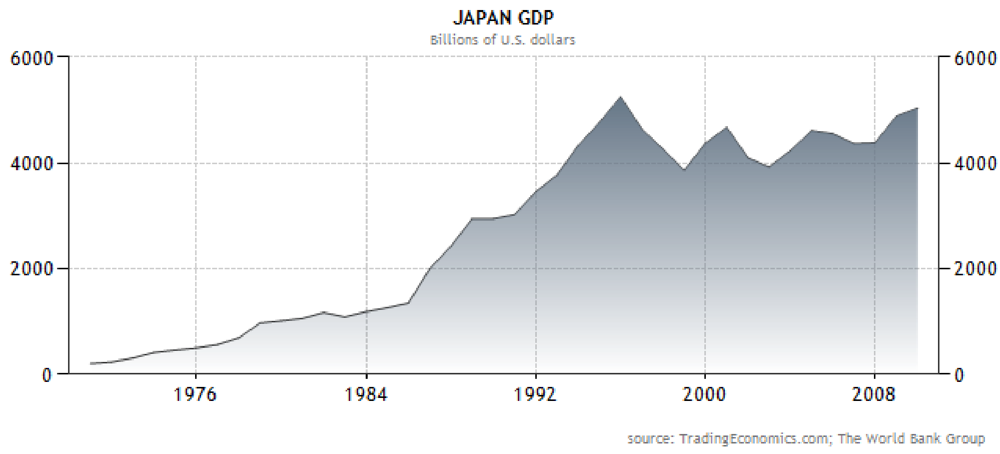
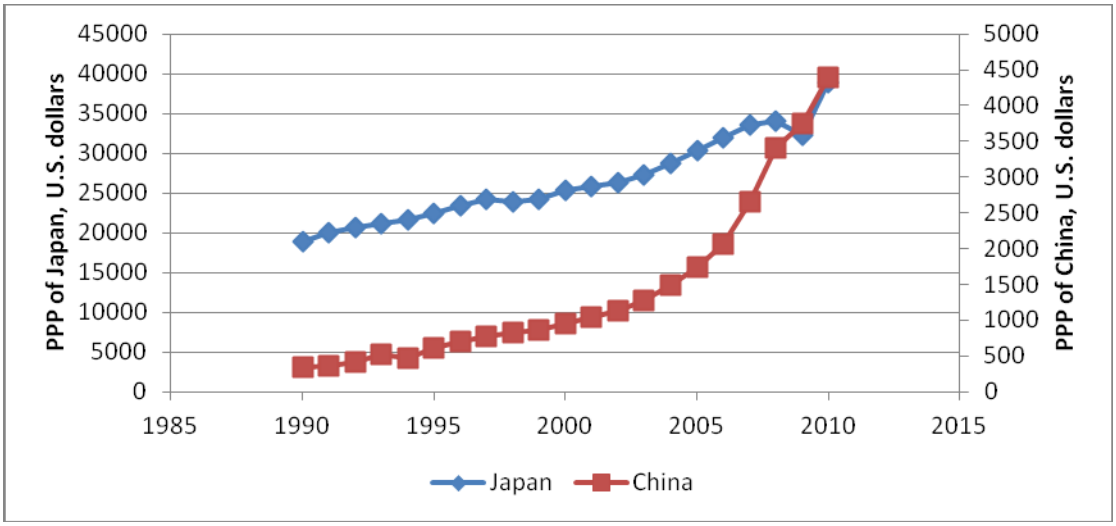


Figure-4.36 showed a comparison of GDP per capita (PPP) between Japan and China from 1990 to 2010. Although PPP of Japan was more than 25 times than that of

China, the growth tendencies of PPP are approximately the same before 2008.

Figure-4.36 Variation tendency of PPP in Japan and China from 1990 to 2010 (Adapted from International Monetary Fund - 2011 World Economic Outlook)



Social aspect

Japan has a population of about 127.07 million in 2009, with 351 inhabitants per square kilometer on average. Its population density is about three times than China's population density. At the same time, the uneven distribution of population had a great resemblance with that in China, that is, most Japanese lived in coastal plains which have much higher population density. More than 1060 million Japanese live in the east coastal region that is 1.5% of China's total area. This kind of population distribution made intensively pollutants discharge and emission in the large cities.

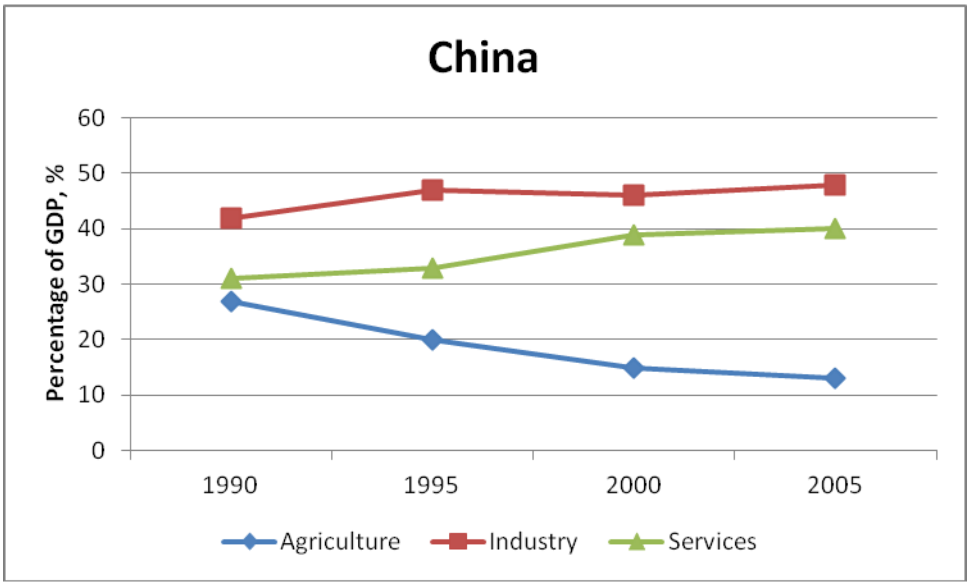
Japan had high quality environmental information. Their white papers on the environmental quality had been published every year for almost 40 years since 1969. The public have a more easy access to environment-related information nowadays than previous years. Especially, the data on air and water pollution in Japan were very comprehensive, detailed and reported frequently. Although China also conducts environmental statistic annually, the statistical data were not as detailed and well-categorized as that of Japan.

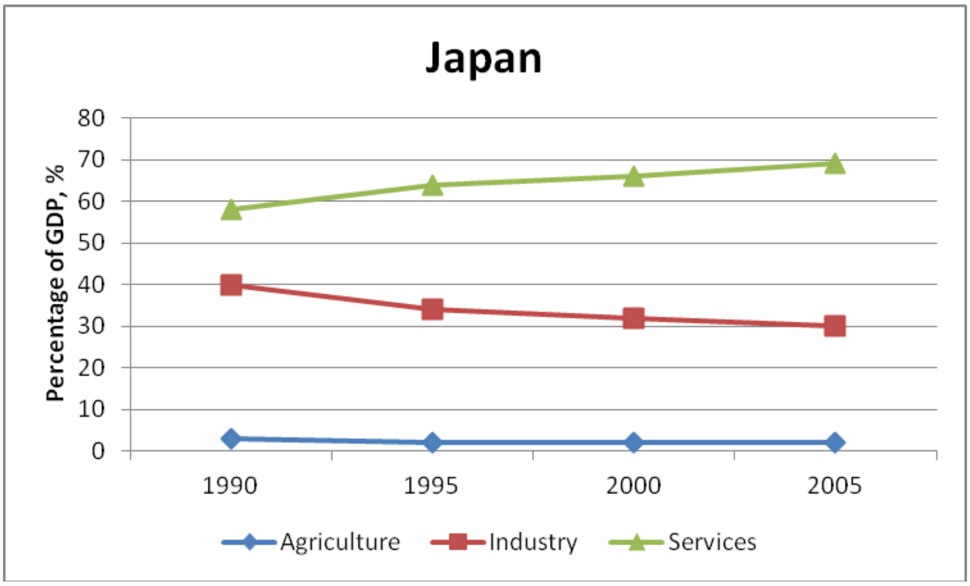
Industrial aspect

The share of GDP held by energy-intensive industries decreased from 1980s, meanwhile the proportion held by high-tech industries increased.

The economic structural can obviously affect environmental quality. In Japan, the share of industry in GDP decreased to 37% of GDP in the 1990s while the proportion of services rose to 61%. Agriculture maintained its share of about 1.7% of GDP. High value-added industries and highly technological industries take the largest shares. The change of economic structure in Japan and China was showed in Figure-4.37.

Figure-4.37 Economic structure of China and Japan

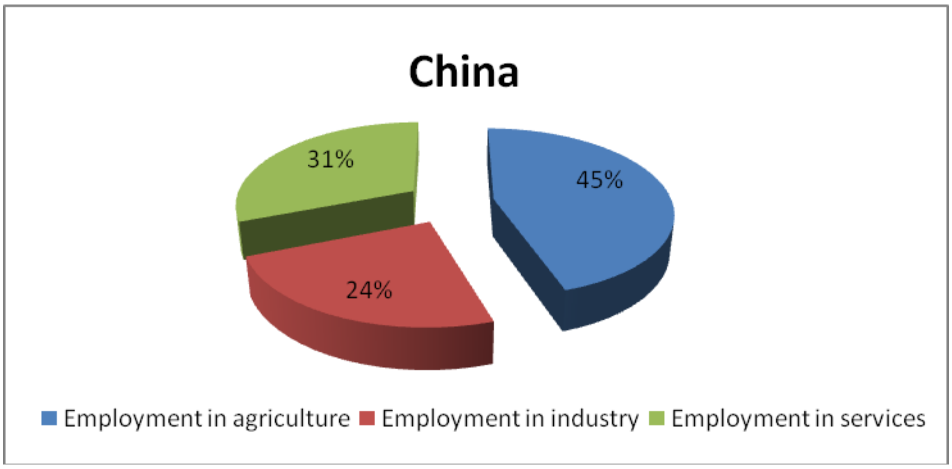


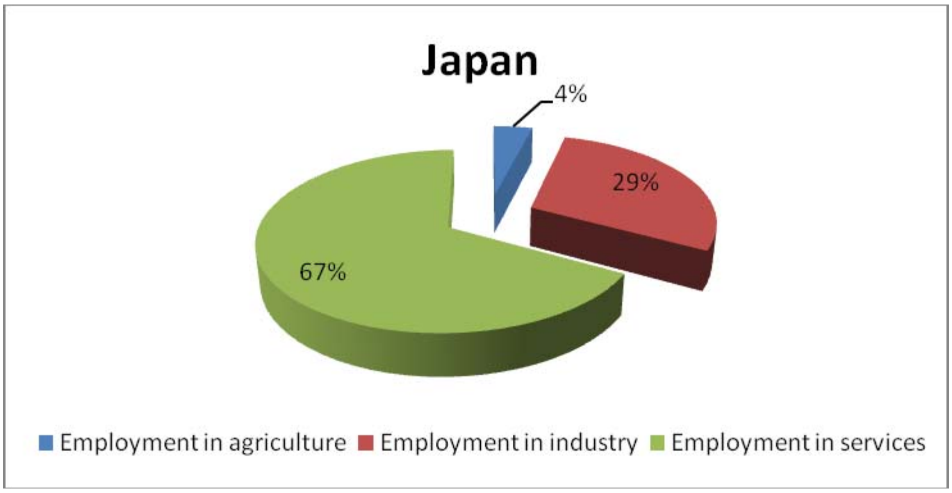


From this figure, we can see that the economic structures in the two countries are not the same, especially in agriculture and services industries. However, the GDP contributions from secondary industry are approximately the same. And the contributions of services both in China and Japan showed an increase.

Take the employment distribution in 2006 for another example, the employment distribution in secondary industry perform a similar situation with GDP contribution. The proportion of employment in secondary industry ranges from 24% to 29% (Figure-4.38).

Figure-4.38 Employment distribution of China and Japan

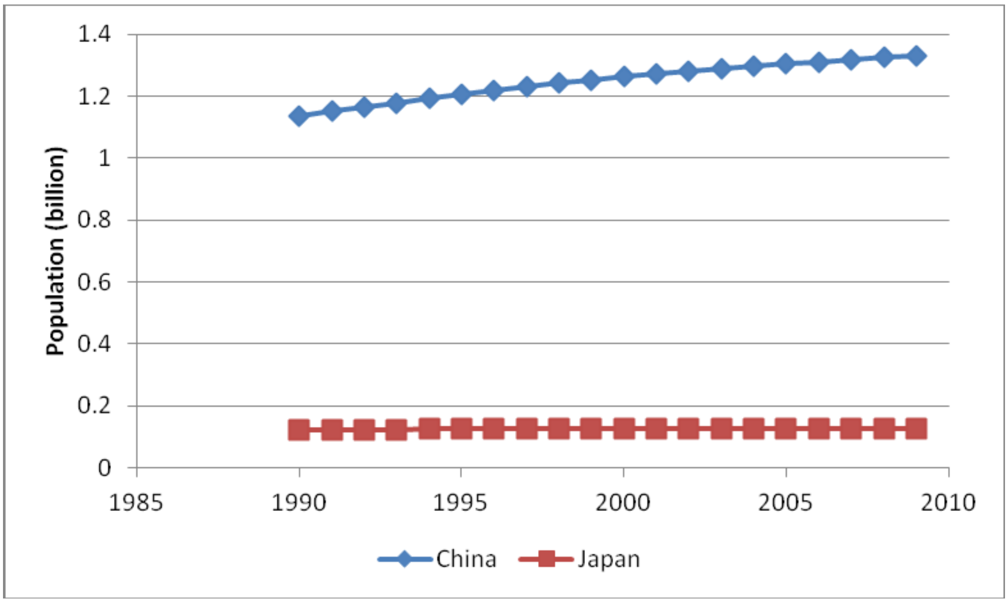




4.3.1.3 Limitations

1) Although the uneven distribution of population in Japan had a great resemblance with that in China, the large gap of population size between the two countries bring differences in waste generation and treatment. It also brings a large gap of the GDP per capita. What's more, the population in Japan increase from 1135million in 1990 to 1276million in 2009, only at a rate of 12.4%. However, the population in China grew from 1.135 billion in 1990 to 1.331 billion at a rate of 17.3% (Figure-4.39).

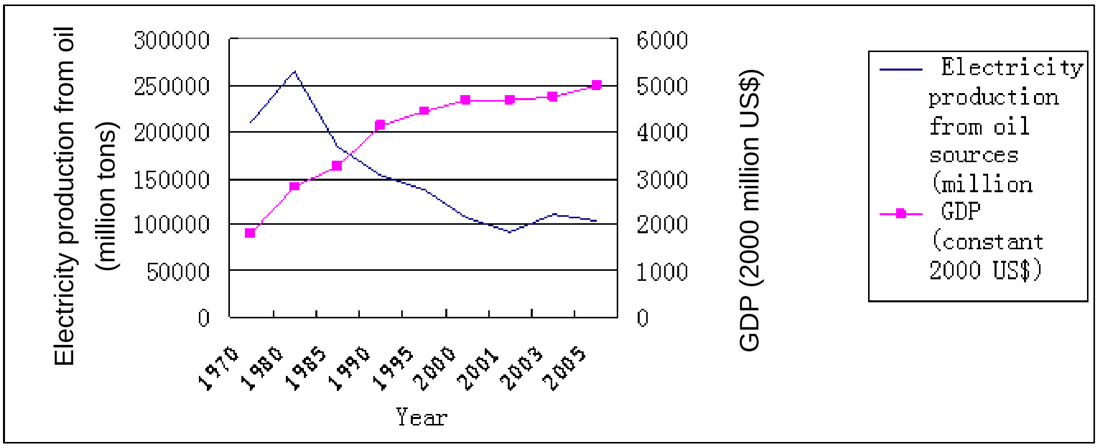
Figure-4.39 population growth tendency of Japan and China (Adapted from Google public data explorer)



2) China faced environmental issues such as pollution control, energy conservation, natural resource preservation, and global environmental issues at the same time, whereas Japan was able to face them one by one (Inui and Kato, 2002). This feature made environmental protection problems in China more complicated than that in Japan. Environmental protection needed more feasible legislations and more demand for higher techniques and investment. In this point of view, China didn't stand at the same level with Japan when considering EnvI.

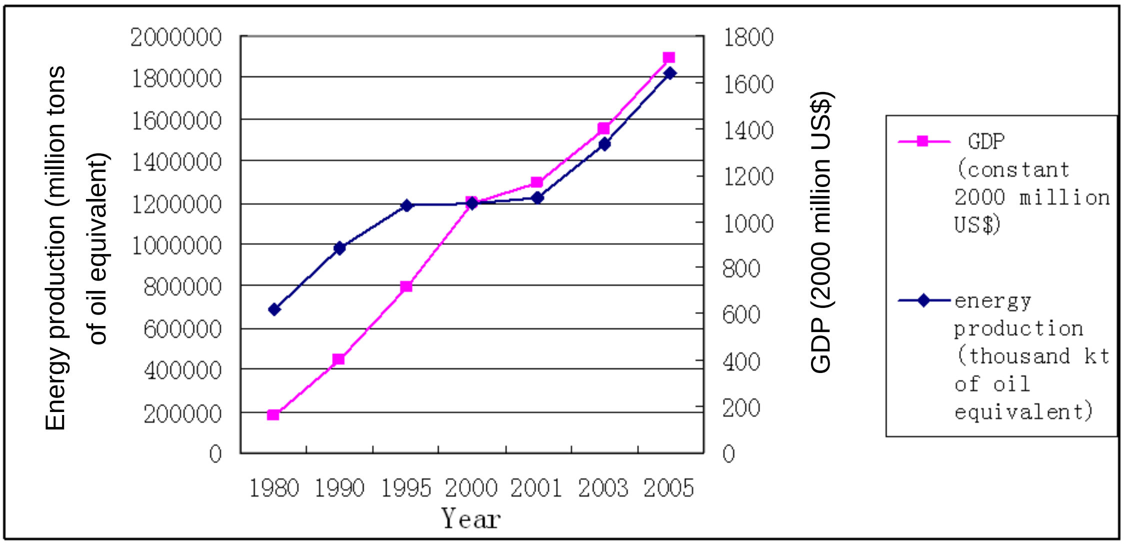
3) China conducted a resource-based development while Japan pursued a technology-based development. For example, Japan's GDP increased by approximately 200% (from 1358 to 3361 U.S. dollars) at the cost of 90% (from 270 to 510 million tons of oil equivalent) increasing of the total energy consumption between 1971 and 1996 (Figure-4.40).

Figure-4.40 Electricity production and economic growth in Japan



On the contrary to this case, the economic growth was based on a high energy use in China. It can be seen from the Figure-4.41, China's energy consumption and GDP growing trend went along the same tendency during this period.

Figure-4.41 Energy production and economic growth in China



4.3.2 Environmental circumstance and trend

Resulting from efforts made by the central and local governments as well as private companies, Japan's environmental quality had been improved substantially (Inui and Kato, 2002).

4.3.2.1 Ambient air quality

The records of air quality indicators are from two sources which are 1) ambient air pollution monitoring station (AAPMS) and 2) Automobile exhaust gas monitoring station (AEGMS).

Figure-4.42 and Figure-4.43 show the variation of air pollutants' concentration recorded by the AAPMSs and AEGMSs, respectively. All of the concentration of air pollutants exhibits a steady decline since 1971. Sharp decreases happened in the 1970s. The concentration in 2009 dropped to 38% or less of that in 1971. This indicates a great improvement of ambient air quality in Japan.

Figure-4.42 Changes of concentration of selected air pollutants recorded by AAPMS (Adapted from Environment Policy Bureau, Ministry of the Environment of Japan)

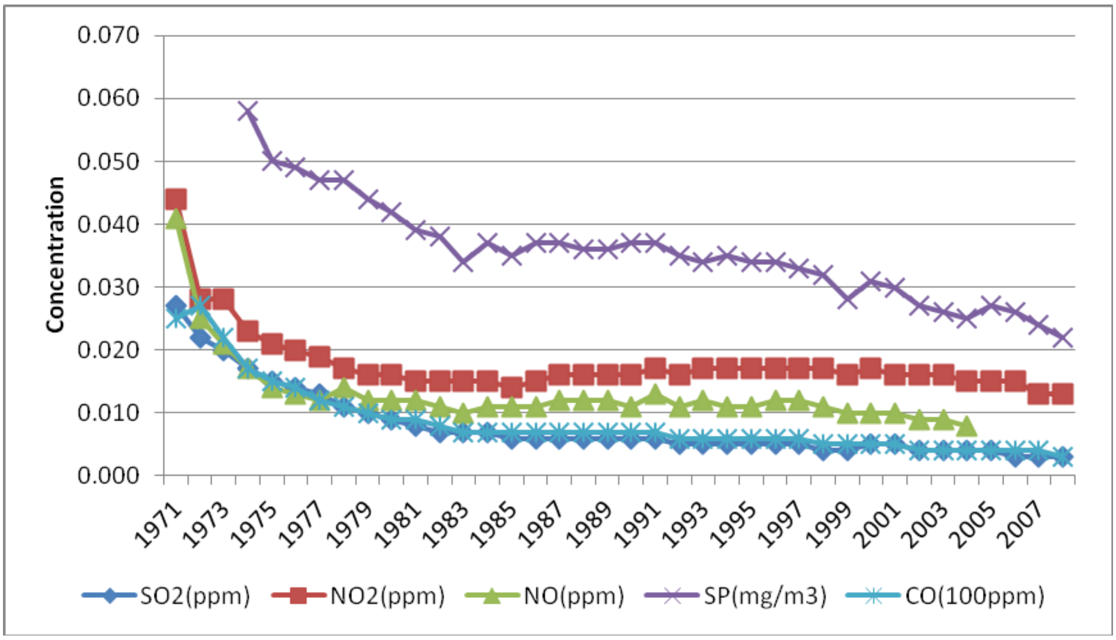
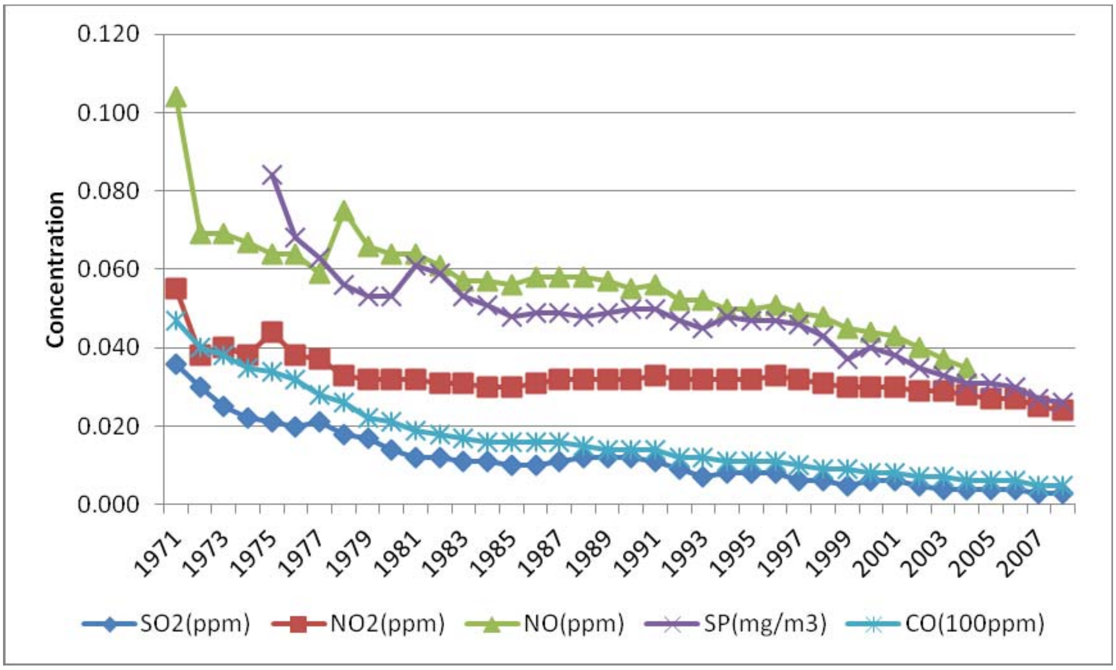


Figure-4.43 Changes of concentration of selected air pollutants recorded by AEGMS (Adapted from Environment Policy Bureau, Ministry of the Environment of Japan)



On the other hand, we can see the air quality improvement from another point of view that is the rate of environmental standard achievements. Figure-4.43 shows the achievement rates of the specific five air pollutants from 1999 to 2008. Obviously, the achievement rates of CO recorded by both AAPMSs and AEGMSs reached 100% in the assessed years. The situation of SO_2 also exhibited pleased results. The most unsatisfied factor is the achievement rates of photochemical dioxide. It had never surpassed 0.5% by AAPMSs records and 11.1% by AEGMSs records. The situation of SPM and NO_2 show a medium level compared with those mentioned above.

Table-4.12 Rate of environmental standard achievements on air pollution (Adapted from Ministry of the Environment, 2011)

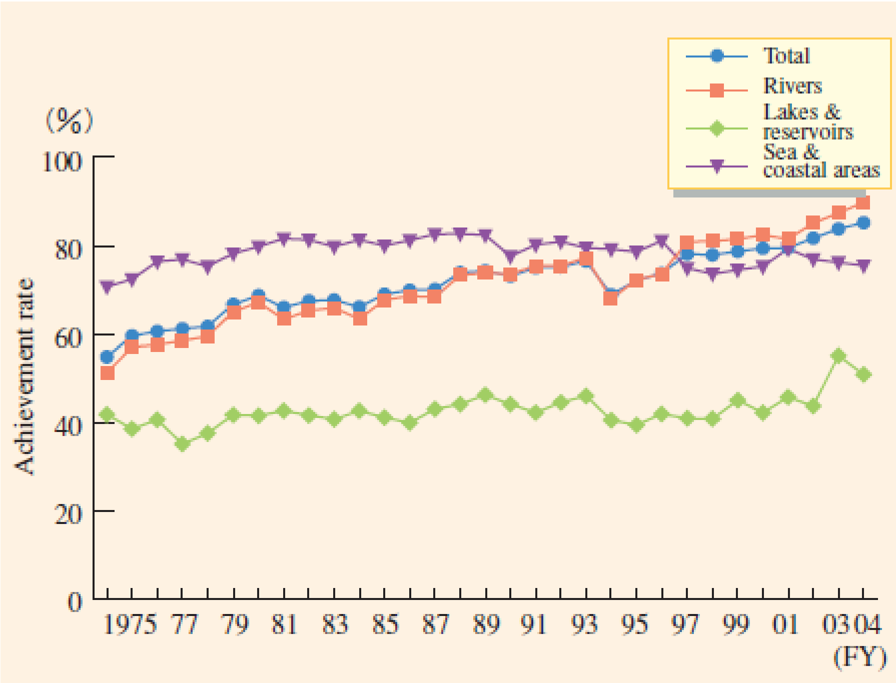
Unit: %

	SO_2		SPM		Photochemical dioxide		NO_2		CO	
	AAPMS	AEGMS	AAPMS	AEGMS	AAPMS	AEGMS	AAPMS	AEGMS	AAPMS	AEGMS
1999	99.7	100	90.1	76.2	0.1	5.9	98.9	78.7	100	100
2000	94.3	93.8	84.4	66.1	0.5	3.3	99.2	80	100	100
2001	99.6	100	66.6	47	0.5	3.4	99	79.4	100	100
2002	99.8	99	52.5	34.3	0.3	11.1	99.1	83.5	100	100
2003	99.7	100	92.8	77.2	0.3	--	99.9	85.7	100	100
2004	99.9	100	98.5	96.1	0.2	--	100	89.2	100	100
2005	99.7	100	96.4	93.7	0.3	0	99.9	91.3	100	100
2006	99.8	100	93	92.8	0.1	3.7	100	90.7	100	100
2007	99.8	100	89.5	88.6	0.1	3.3	100	94.4	100	100
2008	99.8	100	99.6	99.3	0.1	0	100	95.5	100	100

4.3.2.2 Water environment

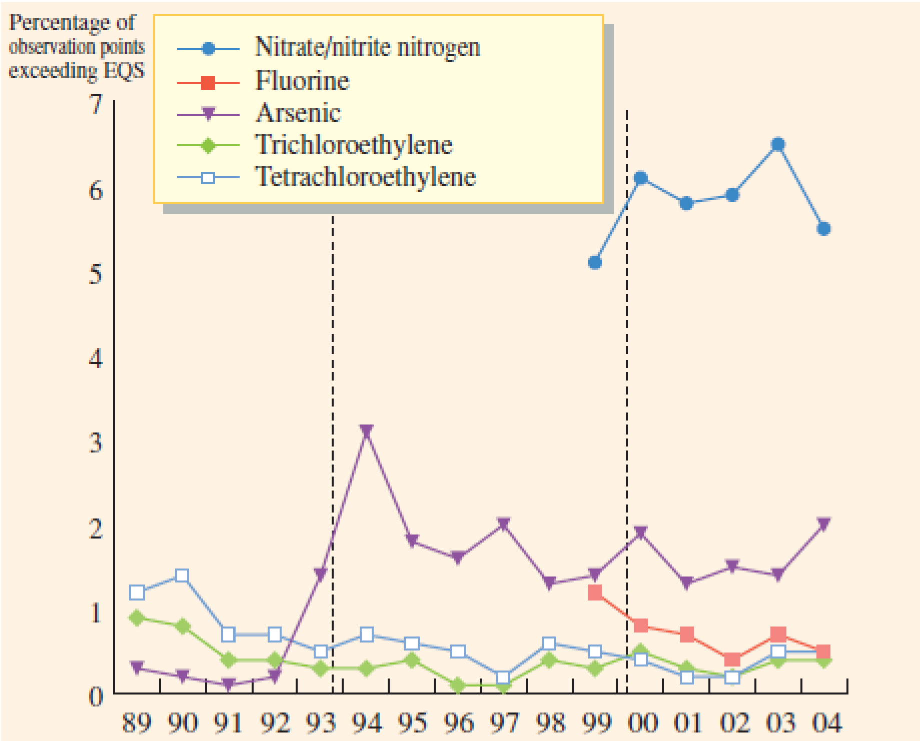
According to the Results of Measurement of Water Quality in Public Waters in 2004, the achievement rate of the environmental quality standard (EQS) for the protection of human health from substances in water, such as cadmium, was 99.3%. Standards set for protecting the living environment were achieved at slightly lower level. As we know, the BOD (or COD) level is an EQS for the assessment of the living environment and is a typical water-quality indicator for organic contamination. Its EQS achievement level in Japan remained at 85.2%. Specific to water body, in 2004, the achievement levels for rivers was 89.8%, for lakes and reservoirs was 50.9%, and for sea areas was 75.5%. From Figure-4.44, we can find before 1996, the EQS achievement rate of BOD (or COD) was higher than others while since then, that in river remained the highest level. However, achievement rates for enclosed water areas, such as lakes and reservoirs were about 40% or so.

Figure-4.44 Trends in EQS Achievement Rate (BOD or COD) (Adapted from Ministry of the Environment, 2004)



When comes to the groundwater, the situation is different. According to the Results of Water Quality Survey of Groundwater in 2004, 7.8% of the total wells investigated exceeded the EQS. Specifically, 5.5% of the wells did not meet the EQS for nitrate or nitrite nitrogen (Figure-4.45). These wells were likely contaminated by fertilization, livestock excreta, or domestic wastewater. Therefore, mitigation measures are urgently needed to prevent groundwater from pollution of nitrate and nitrite nitrogen.

Figure-4.45 Percentage of Observation Points Exceeding the EQS for Groundwater Contamination (Adapted from Ministry of the Environment, 2004)

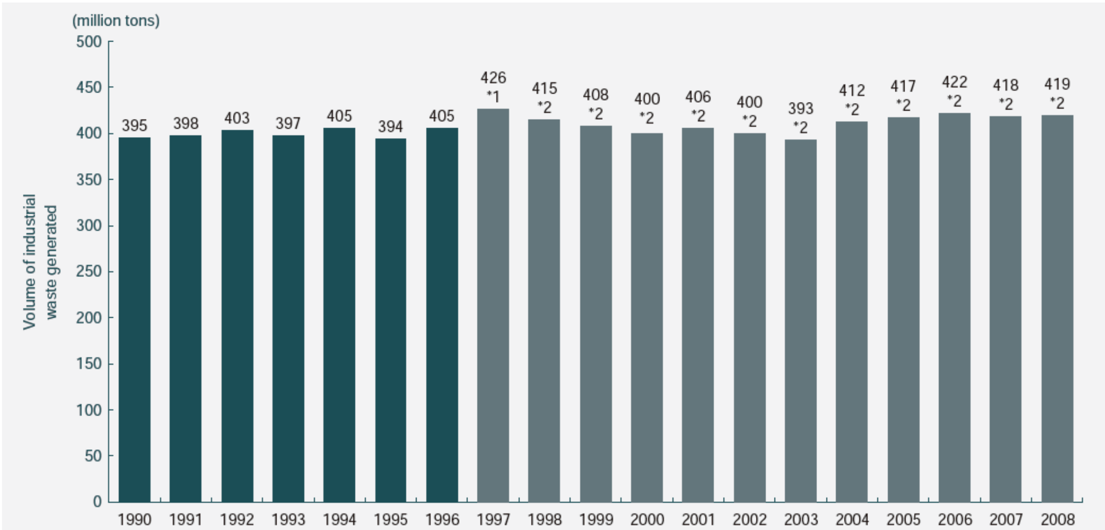


4.3.2.3 Solid waste environment

4.3.2.3.1 Industrial solid waste

Obviously, the figures below for industrial wastes generated since the year 1990 have stayed more or less constantly at around 400 million tons, with no major yearly differences.

Figure-4.46 Changes of the generation amount of industrial solid waste (Adapted from Ministry of the Environment, 2011)



The number of permits given to new facilities for disposal of industrial wastes incineration facilities and final disposal sites) have sharply decreased since 1998, when compared with the years before revision of the Wastes Management Law in year 1997.

Figure-4.47 Numbers of newly approved incinerators (Adapted from Ministry of the Environment, 2011)

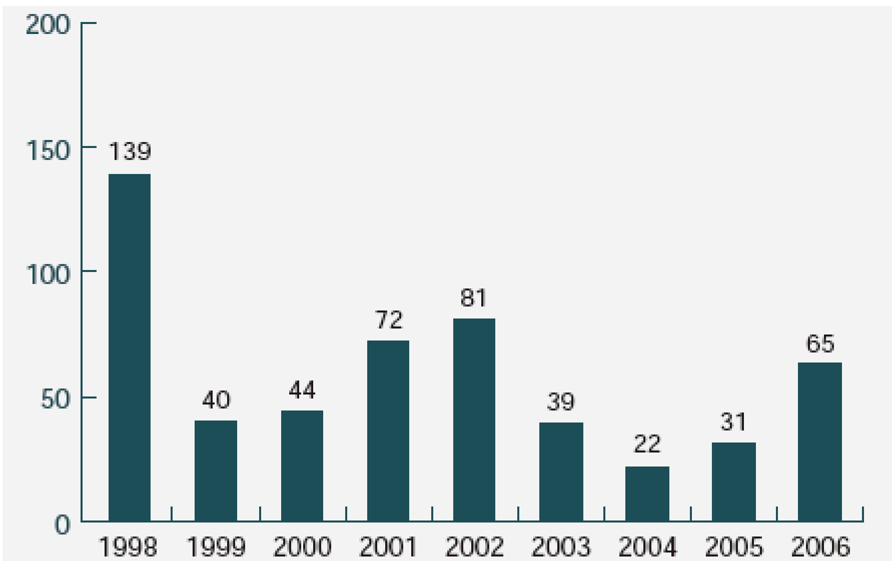
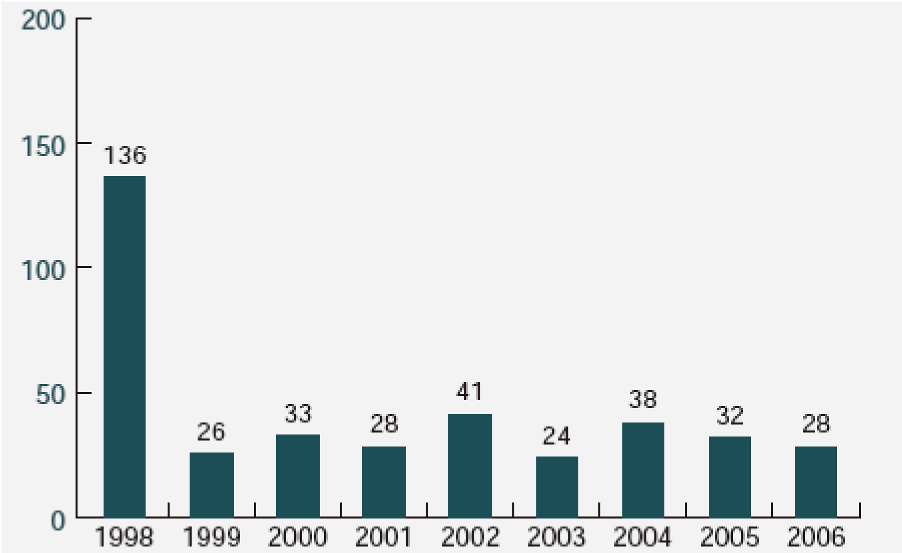


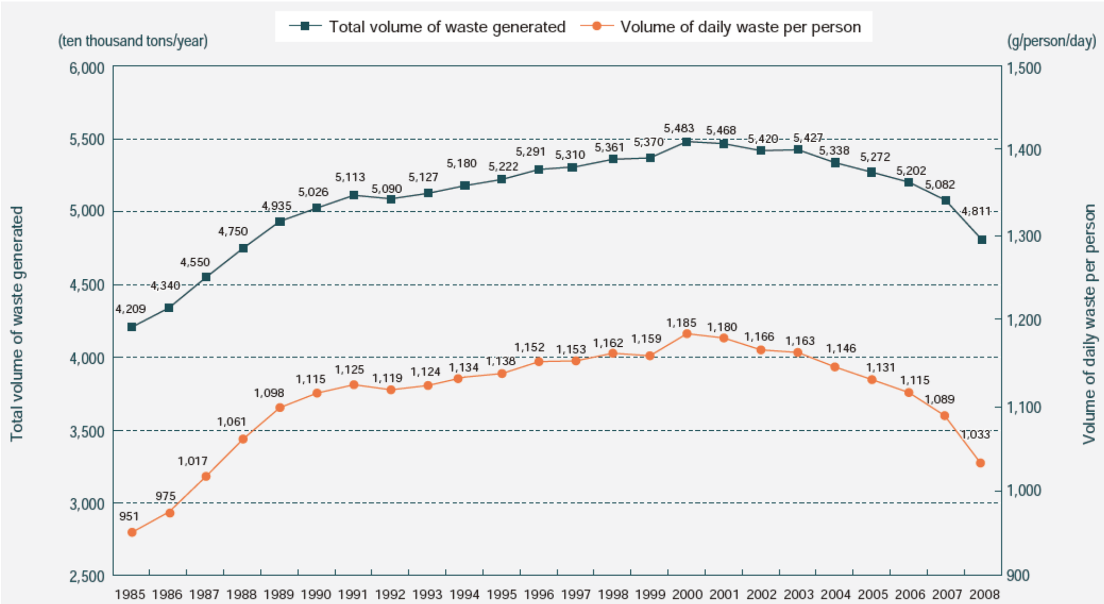
Figure-4.48 Numbers of newly approved final disposal sites (Adapted from Ministry of the Environment, 2011)



4.3.2.3.2 Municipal solid waste

The total amount of municipal solid waste generated and the daily amount per person dropped slightly after 1979 (the year of the second oil crisis), but since 1985 the world had witnessed a sharp increase which leveled off in 1990s. However, there has been another decrease from 2001 to 2008. This decline may caused by the improvement of waste recycling and environmental awareness of the public.

Figure-4.49 Domestic waste generation in volume (Adapted from Ministry of the Environment, 2011)



When considering the changes of processing methods of municipal solid waste, we can get Table-4.13 which shows the changes of amount of MSW in different processing methods. The direct incineration occupies almost 80% of the total treatment capacity.

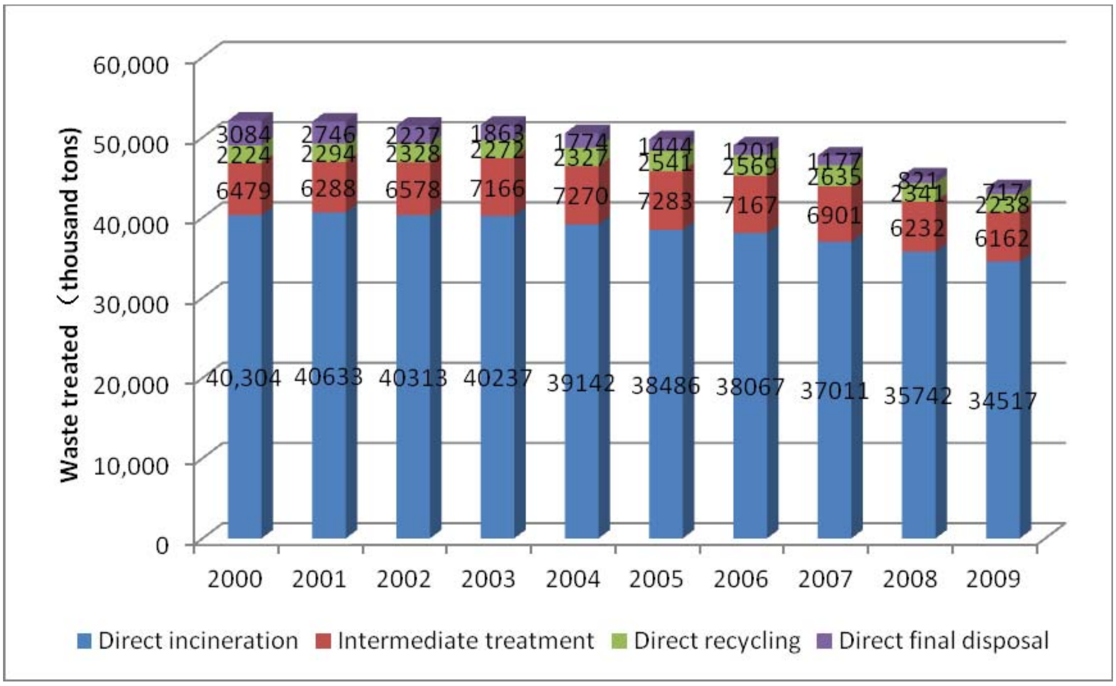
Table-4.13 Changes of the processing methods of municipal solid waste (Adapted from Ministry of the Environment, 2009)

Unit: thousand tons

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Direct incineration	40304	40633	40313	40237	39142	38486	38067	37011	35742	34517
Intermediate treatment	6479	6288	6578	7166	7270	7283	7167	6901	6232	6162
Direct recycling	2224	2294	2328	2272	2327	2541	2569	2635	2341	2238
Direct final disposal	3084	2746	2227	1863	1774	1444	1201	1177	821	717
Total	52091	51961	51446	51538	50513	49754	49004	47724	45136	43634

If we plot the data on the figure, we can find a steady decrease of direct incineration by a rate of 14.4% from 2000 to 2009. In addition, the amount of garbage directly sent for final disposal has steadily decreased in 2009, with a ratio of 23.2% compared with 2000.

Figure-4.50 Changes of the processing methods of municipal solid waste



4.3.3 Environmental policy and investment

4.3.3.1 Environmental policy of Japan

Generally, the environmental policy of Japan can be divided into three stages. First one is the End-of-Pipe Treatment period which lasted from 1953 to 1971 when the Japan EPA was established. During this period, the Basic Law of the Public Nuisance Countermeasures was issued 1967 and the Air Pollution Prevention and Control Law were promulgated in 1968. The second stage is a transient period (1992~2000) from sustainable development to development for circular society. Basic Environmental Law and the first phase of Environmental Basic Plan were set up during this period. As a sign of the third stage of environmental policy of Japan, the second phase of Environmental Basic Plan and Basic Law of Circular Society were published since 2000. (Lin, 2007)

Enacted in November 1993, Basic Environment Law set out basic principles and directions for the formulation of environmental policies. The ‘National Action Plan for Agenda 21’ was submitted to the United Nations in that year and in the following year the Basic Environment Plan is adopted. This plan was the most significant measure introduced under the Basic Environment Law. The plan comprehensively clarified the measures to be taken by the governments and actions to be carried out by citizens and organizations at the beginning of the 21st century.

In all, the main policy of environmental protection of Japan can be summarised as follows:

1) Promotion of environmental protection legislation
2) Implement of environmental protection plan
3) Reinforcement environmental management
4) Increase of governmental EnvI
5) Enhancement of environmental management and supervision
6) Encouragement of development of environmental protection industry
7) Establishment of ecological industrial park

4.3.3.2 Environmental investment in Japan

Being different from China, the EnvI in Japan is classified more detailedly. It not only consists of the expenditure on water, air and solid waste environmental protection, but also includes the investment on global environmental protection, chemical substance, natural environment conservation. The following table exhibit the distribution of EnvI of Japanese government in recent years. It's obvious that the environmental protection investment in Japan decreased steadily from 2365.5 billion Yen in 2005 to 1259 billion Yen in 2010 with fluctuations.

Table-4.14 Environmental protection investment in Japan (Adapted from Ministry of the Environment, 2005-2010)

Unit: billion Yen

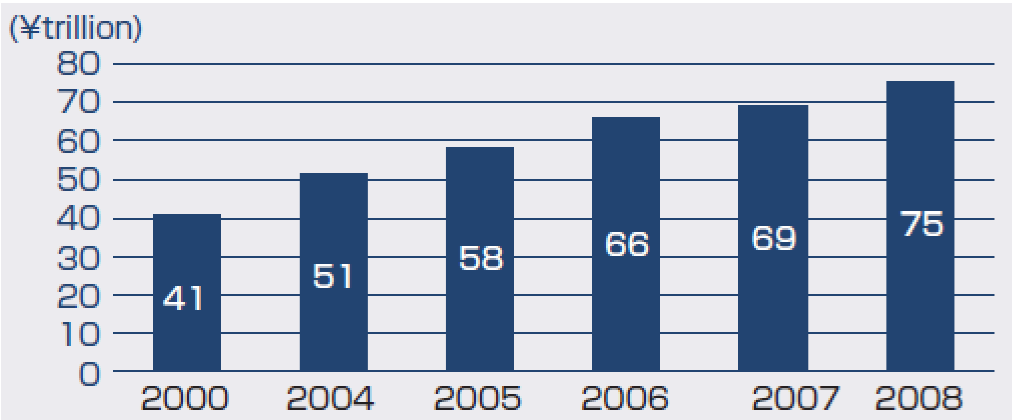
Expenditure classification	2005	2006	2007	2008	2009	2010
Global environmental protection	544	460.1	491.2	659.7	678	619.4
Air environmental protection	314.2	303.6	279.7	282.1	234.2	212.1
Water and soil environmental protection	923.1	818.3	819.5	786.8	743.2	102.6
Waste management and recycling	149.5	144.2	132.1	120.6	114	85.8
Chemical substance	13.1	12.3	9.8	9.2	8.2	8
Promote conservation of the natural environment	332.4	317.4	285.1	279.6	261.2	147.2
Other measures	89.2	78.2	77.6	76.1	78	84.5
Total amount	2365.5	2134.1	2095	2214.1	2116.8	1259.6

Take the GDP into consideration, although the environmental expenditure from Japanese government decrease gradually, the total investment from public pollution abatement and control (PAC) expenditure and investment for water supply, storm water sewerage and nature protection was estimated to be nearly 2% of GDP in 1999.

From the decrease of governmental environmental expenditure we can see the hard core of Japan's EnvI had shifted to the market. The most important one is the booming of environmental industry in Japan.

Surveys on the market size and employment size of Japan's environmental industry have been conducted by The Ministry of the Environment of Japan. From Figure-4.51, it can be seen the market size and employment size have been continuously expanding since 2000 (Figure-4.51). The flourish of environmental industry helps to promote the environmental expenditure from non-government organizations such as private companies.

Figure-4.51 Trends of market size of Japan's industry (Adapted from the Ministry of the Environment, 2011)



4.3.4 Learnable aspects and cooperation opportunities

By contrast with China, the environmental protection and investment in Japan have a lot of enlightenments that are worthy for China to learn. Some of them are summarized as follows.

1) Japan is establishing a sound material-cycle society through changes in business and life styles. A comprehensive legal system for this kind of society was established in Japan. In addition, other supporting measures, such as financial measures, utilization of economic instruments, implementation of research and

promotion of education and science and technology, help Japan to cope with the recent environmental challenges.

2) Japan's excellent environmental technologies changed its socioeconomic system. They are at the highest global standards. This can be reflected by the number of patents registered in Japan which has been on the steady growth. Country by country comparison in the application for patents on environmental technologies also indicate that Japan ranks high in such areas as atmospheric pollution and water quality management, solid waste management and renewable energy. This is a result of the large expenditure invested on research and development (R&D).The environmental expenditure of Japan had been ever as high as 2.0% of its GDP, in which the environmental technologies R&D occupied nearly 10%. This is a key point that China should learn from.

3) Nuclear power station occupies a considerable proportion of electricity. From the table below, it is obvious that nuclear power plant plays an important role in the energy structure (taking nearly 30% of all). This will bring great benefits to environmental protection and is of course a learnable aspect for China.

Table-4.15 Electric power generated (1990~2008) (Adapted from Japan Electric Association, 2011)

Unit: millions of kilowatt-hours

Fiscal year	Total	Hydro	Thermal	Nuclear	Nuclear proportion
1990	857272	95835	557423	202272	23.59%
1995	989880	91216	604206	291254	29.42%
2000	1091500	96817	669177	322050	29.51%
2005	1157926	86350	761841	304755	26.32%
2006	1164110	97340	755084	303426	26.07%
2007	1192771	84234	839029	263832	22.12%
2008	1146269	83504	798930	258128	22.52%

4) Japan’s statistical data was among the most detailed in the world from over 40 years experience accumulation since 1960s when it began its environmental protection. By contrast, China needed to refine the data by developing statistical classifications for exactly further research.

4.4 Critical analysis of U.S.

This chapter is the comparison of environment situation and investment in P.R.C. and U.S.. After discussing the environmental circumstance and trend in the U.S. and comparing the situation of EnvI and policy, we get some enlightenment. However, there are also some limitations for comparison, such the economy gap and employment distribution in industries.

4.4.1 Comparability and Limitation

4.4.1.1 Fundamental condition

The US is the third largest country in the world, in terms of both land area and population, with 9.83 million square kilometers land area and 312 million people. The U.S. economy is the world's largest national economy, with an estimated 2010 GDP of $14.53 trillion (23% of nominal global GDP and over 19% of global GDP at purchasing-power parity).

The U.S. also has a mass of natural resources. Apart from having the world's largest proven reserves of coal, 22.6% of the world's total, the U.S. also holds the 14th largest proven oil reserves and the 6th largest proven natural gas reserves. Other natural resources, such as copper, lead, molybdenum, uranium, bauxite, gold, iron, mercury, nickel, exist in abundance. (Economy Watch, 2010)

Although the population of U.S. is significantly lower compared with India or China, the U.S. has the highest labour force participation rate in the world with 139.396 million employed. The table below shows the distribution of the employment by industry from 2000 to 2009.

Table-4.16 Employment by industry in U.S. (Adapted from the website of U.S. Environmental Protection Agency)

Unit: thousand

	2005	2006	2007	2008	2009
Total employed	141730	144427	146047	145362	139877
Agriculture and related industries	2197	2206	2095	2168	2103
Construction	11197	11749	11856	10974	9702
Manufacturing	16253	16377	16302	15904	14202
Retail trade	16825	16767	16570	16533	15877
Professional and business services	14294	14868	15621	15540	15008
Education and health services	29174	29938	30662	31402	31819
Leisure and hospitality	12071	12145	12415	12767	12736
Other industries	39719	40377	40526	40074	38430

The majority (35.5%) of the labour force's occupations are managerial, professional or technical in nature. A further 24.8% hold sales or office jobs, 22.6% are in either manufacturing, extraction, transportation and crafts, 0.6% are in arming, forestry or fishing, and 16.5% have jobs in other services.

As a main sector of economy of U.S., retailing is credited with leading the economy. This can be reflected from the number of the employment in retail trade.

Agriculture is a major industry in the U.S.. Although the employment numbers of agriculture and related industries are very small, accounting 1.5% of all, U.S. controls almost half of world grain exports. (Lester, 2003)

The U.S. has been the 2nd largest energy consumer in the world since 2010. In addition, it ranks 7th in energy consumption per-capita after Canada and other countries. The majority of this energy is derived from fossil fuels. (Robert, 2011)

The United States is the world's largest manufacturer, with an industrial output of US$2.33 trillion in 2009. Its manufacturing output has been a small part of the entire U.S. economy as compared to other countries. (Greyhill, 2011)

4.4.1.2 Comparability

Economic aspect

As claimed in an international conference hold in Brussels in 2007, GDP is the best-recognised measure of economic performance in the world, often used as a generic indicator of progress. However, the relationship between economic growth as measured by GDP and other dimensions of social progress is not straightforward.

As we know, U.S. is the world’s largest economy. Many key financial and economic organizations in the world reside in the U.S.. The U.S. is home to the world's largest stock exchange, the world's largest gold depository and reserves, and 139 of the world's 500 largest companies, which is almost twice that of any other country. (Economy Watch, 2010)

However, after long-term development, China’s GDP had reached 39798.3 billion Yuan in 2010, at a growth rate of 10.3%. This figure made China to be the second largest economy, exceeding Japan 404.4 billion US dollars, since Japan announced its GDP of 2010(5474.2 billion US dollars)

Social aspect

The employment rate is another important social indicator when comparing the two countries’ performance. Especially, the ‘employment in industry’ can demonstrate people’s life dependence and the economic growth power. Employment rate in industry is 30.5% in year 1980 in the U.S. while it is only a little more than 20% in China during the 10^{th} Five-Year Plan. This indicates both the U.S. in 1970s and China in recent year has the similar reliance on industry.

U.S. had the third largest land area in the world only after Russia and Canada. Its land area is 34.46 thousand square kilometres larger than that of China. This feature obstructs the efficiency of the enforcement of legislations and laws. At the same time, the large amount of population and land area will also pretend to be a hamper in environmental expenditure effectiveness.

4.4.1.3 Limitations

1) The employment distribution in three types of industries which expressed the people living dependence had obviously distinction between P.R.C. and U.S. (Table-4.17). For U.S., the majority of work force is involved in the third industries, which have less pressure on environment than other two kinds of industries. Since the 1970s, the US economy has gradually shifted from producing goods to providing services. The proportion of work force in the third industry increased continuously from 66% in 1980 to 78% in 2005. However, the situation in China is just the opposite. Although the employment proportion in agriculture declined annually, the proportion of employment in the first industry is still a large part. The employments in industry and services have almost equal shares of power. The difference in the employment of industry would be a limitation for comparison.

Table-4.17 Employment in agriculture, industry and services (Adapted from the U.S. Environmental Protection Agency)

Unit: %

	1980	1990	1995	2000	2001	2003	2005
U.S.							
Employment in agriculture	4	3	3	3	2	2	2
Employment in industry	31	26	24	23	23	21	21
Employment in services	66	71	73	74	75	78	78
China							
Employment in agriculture	69	53	48	46	45	49	44
Employment in industry	18	19	21	17	17	21	24
Employment in services	12	10	12	13	13	29	31

2) Although the economic power of P.R.C. has been the second largest in the world and is comparable with that of U.S., in per capita aspects, there is a huge gap between them. This large gap must lead to increasing more difficulties in EnvI in China. Table-4.18 shows the per-capita GDP in P.R.C. and U.S. according to the World Bank database.

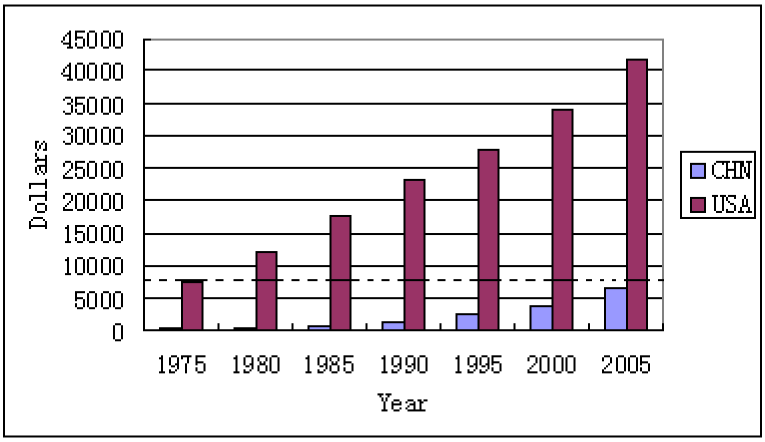
Table-4.18 GDP in per-capita level in U.S. and P.R.C. (Adapted from World Bank database)

Unit: US dollar

Years	Per-capita GDP in U.S.	Per-capita GDP in P.R.C.
1970	5063	–
1975	7583	–
1980	12243	430
1985	17683	780
1990	23185	1300
1995	27813	2460
2000	35273	3690
2005	42664	6571

Chinese GDP per capita (PPP) was 6571.6 dollars in 2005 while that in U.S. was 7583 dollars in 1975, which is a little more than that in P.R.C. (Figure-4.53). Thus, we can only choose the EnvI of U.S. in 1970s to be a comparative body. But nonetheless, as time went by, some definitions of investment and other indicators are altered. Thus caused comparison cannot be done detailed. Besides, data availability was not enough about the U.S..

Figure-4.52 Comparison of per capita GDP between U.S. and P.R.C



4.4.2 Environmental circumstance and trend

4.4.2.1 Ambient air quality

National Ambient Air Quality Standards for suspended particulate matter, sulfur dioxide, oxidants, carbon monoxide and nitrogen dioxide were firstly set by EPA in April, 1971. Non-federal suspended particulate sampling stations increased from approximately 800 in 1969 to over 3,700 in 1974. Data from these stations are periodically submitted to EPA's National Aerometric Data Bank for summarization in annual reports on the nationwide status of air quality.

Figure-4.53 and Table-4.19 describe the distribution of national total emission estimates by source category for specific pollutants in 2008. We can see that electric utilities contribute about 70% of the national SO_2 emissions. Operations related to agricultural occupy over 80% of national NH_3 emissions. Almost 50% of the national VOC emissions are generated from other processes and highway vehicles. About 80% of CO comes from highway vehicles.

Figure-4.53 Distribution of national total emissions estimates by source categories

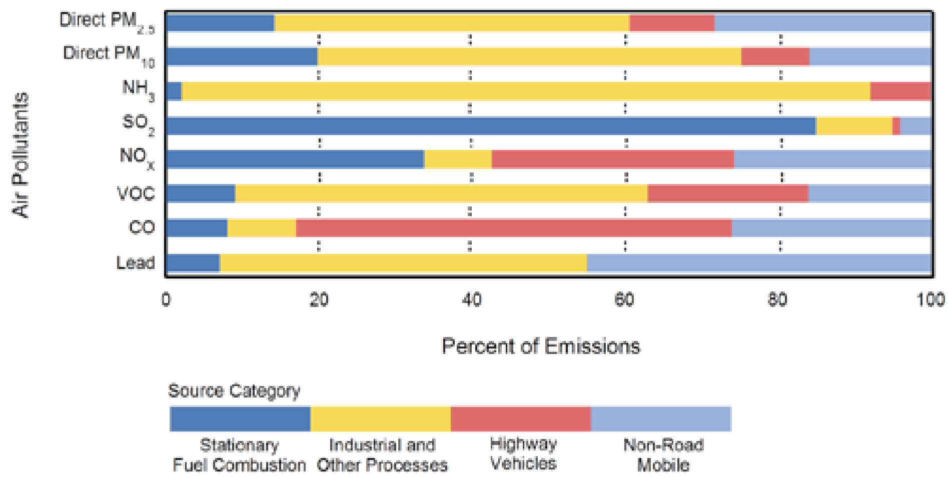


Table-4.19 Selected air pollutant emissions by pollutant and source in 2008 (Adapted from U.S. Environmental Protection Agency)

Unit: thousand tons

Source		NH_3	CO	NO_x	PM_{10}	SO_2	VOC
Total emission		4043	77683	16366	14805	11502	15927
Fuel combustion , stationary sources	Electric utilities	34	699	3033	534	7624	50
	Industrial	16	1216	1838	330	1670	130
	Other fuel combustion	18	3369	727	466	578	1269
Industrial processes	Chemical product manufacturing	22	265	67	39	255	228
	Metal processing	3	947	68	78	203	46
	Petroleum industries	3	355	350	24	206	561
	Other	151	500	418	967	329	404
	Storage and transport	1	115	18	57	4	1303
	Waste disposal and recycling	26	1584	120	288	27	374
Highway vehicles		308	38866	5206	171	64	3418
Off highway		3	18036	4255	304	456	2586
Miscellaneous		3457	11731	260	11540	85	1332

From the figure below, it's very obvious that the air quality exhibited a steady decrease since 1990, with the greatest percentage drop in CO emissions. PM also showed a satisfactory decline from 80ug/m^3 to 50ug/m^3. NO_2 and SO_2 showed the smallest percentage drop for the reason of the expanding car ownership and heavy reliance on electricity.

Figure-4.54 Variation tendency of concentration of selected air pollutants (Adapted from the website of U.S. Environmental Protection Agency)

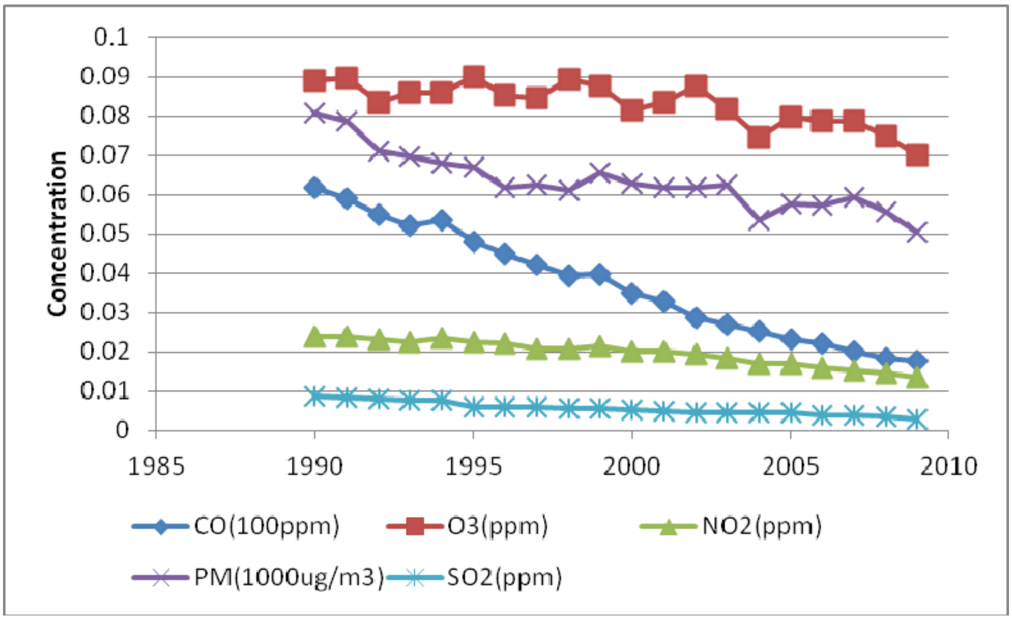


Table-4.54 also gives us a clear impression of the improvement of air quality of U.S. that all the pollutants showed a decrease in different degree.

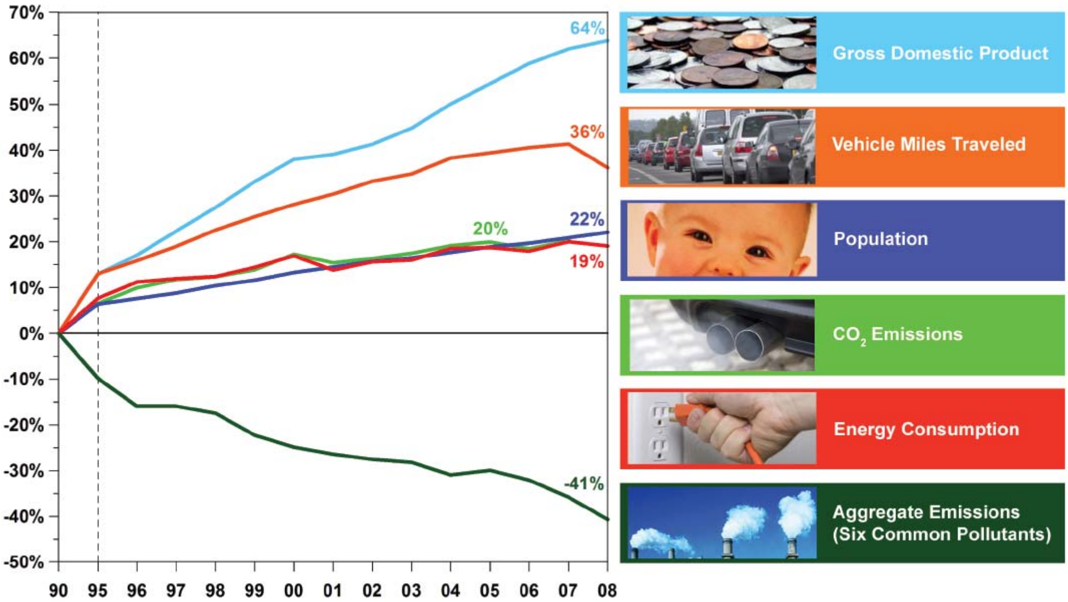
Table-4.20 Change in annual national emissions (1990 vs. 2008) (Adapted from U.S. Environmental Protection Agency)

Unit: thousand tons

Source Category	$PM_{2.5}$	PM_{10}	NH_3	SO_2	NO_x	VOC	CO	Lead
Stationary Fuel Combustion	-773	-813	+43	-10490	-5423	+445	-228	-0.42
Industrial and Other Processes	-343	-217	-446	-731	-144	-3150	-442	-2.80
Highway Vehicles	-213	-216	+153	-439	-4386	-5970	-71389	-0.42
Non-Road Mobile	-17	-24	-28	+85	+474	-76	-3411	-0.27
Total Change	-1346	-1270	-278	-11575	-9379	-8751	-75470	-3.91
Percent Change	-58%	-39%	-6%	-50%	-36%	-35%	-53%	-79%

The aggregate emission of the six common pollutants decreased 41% on average since 1990, as shown in Figure-4.55. With the development of U.S. economy, people drove more miles, and population and energy use increased. These pollution reductions were achieved by the implementation of regulations and voluntary partnerships between government and other non-governmental organizations.

Figure-4.55 Comparison of growth measures and emissions, 1990-2008 (EPA, 2008)



4.4.2.2 Water environment

The 2004 ATTAINS database summarizes the water environment situation in river and streams, lakes, ponds, and reservoirs, bays and estuaries and other waters. Waters are rated for overall use support as follows:

- **Good**: if they fully support all their desgnated uses
- **Threatened**: if they fully support all uses, but exhibit a deterorating trend
- **Impaired**: if they are not supporting one or more designated uses

Table-4.21 shows the water quality in assessed water bodies. We can see over half part of the river and streams and bays and estuaries exhibit 'Good' water quality while 64% of lakes, ponds and reservoirs shows ‘Impaired’ water quality. Although small part of water bodies exhibit ‘Threatened’ quality (i.e. water quality supported uses, but showed a deteriora

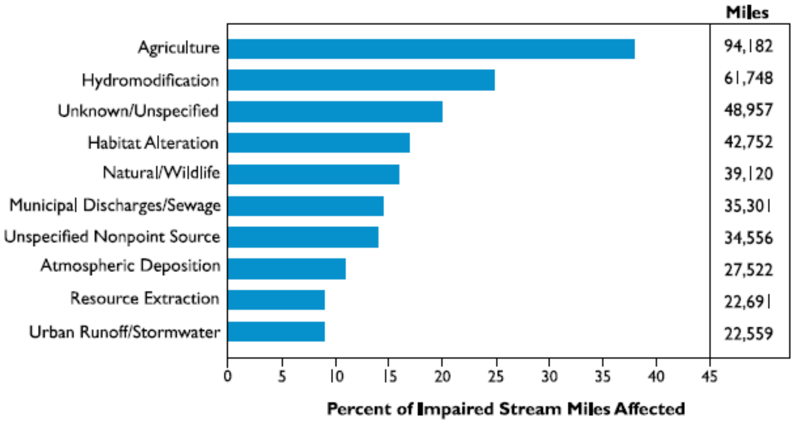
ting trend), it should not be ignored in case of pollution exacerbation. However, the assessed miles, acres and square miles are only part of all, accounting up to 39%, it cannot exactly reflect the whole circumstance of the water quality of U.S.

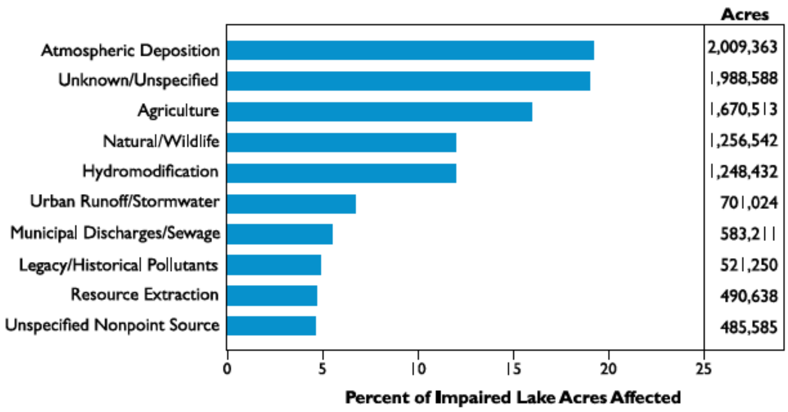
Table-4.21 Water quality in assessed water bodies (Adapted from National Water Quality Inventory: Report to Congress, 2010)

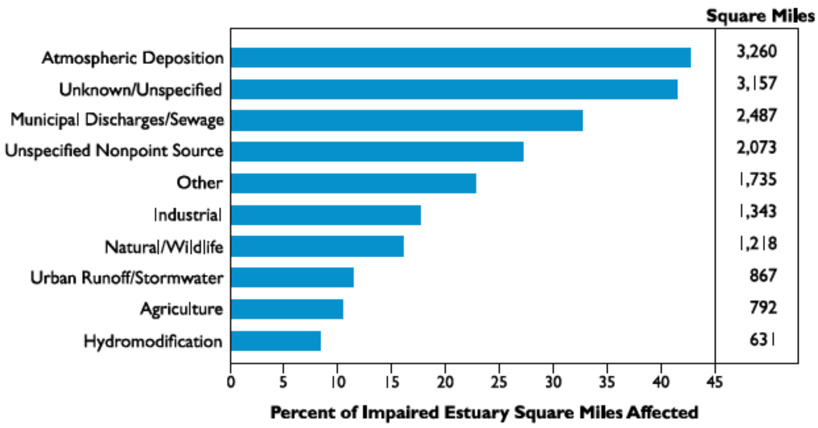
Water source	Assessed amount	Percentage of the total	Percentage of waters assessed		
			Good	Threatened	Impaired
River and streams	563955 miles	16%	53%	3%	44%
Lakes, ponds, and reservoirs	16230384 acres	39%	35%	1%	64%
Bays and estuaries	25399 Square miles	29%	70%	1%	30%

From Figure-4.56, it is obvious that Agriculture activities, such as crop production, grazing, and animal feeding operations, impaired near 40% of the assessed stream. And the Hydromodifications, such as water diversions, channelization and dam construction, and Unknown or unspecified sources occupied the second and third place, respectively. As for lakes and bays, the atmospheric deposition which can bring pollutants such as mercury from distant locations such as industrial centers, was the top one source of lakes and estuary.

Figure-4.56 Top ten sources of impairment in assessed water bodies







According to the analysis above, we can see the over situation of water quality of U.S. was satisfactory. However, there are still a large part of impaired water bodies which are not supporting one or more designated uses. Agricultural operations and atmospheric deposition are the most important ones among the top ten water pollution sources.

4.4.2.3 Solid waste environment

U.S. generated 243 million tons of municipal solid waste in the year 2009 which is 8 million tons less than that generated in 2008. Except composting, 61.3 million tons of MSW were recycled with a tiny decline of 0.5 million tons from 2008. The tons of recovery of food scrap and yard trimmings for composting were 20.8 million tons in 2009. The recovery rate for recycling (including composting) was 33.8% in 2009, up from 33.4 percent in 2008. Although the numbers recycled and composted dropped in 2009, the tons generated also decreased resulting in an increase in the recycling rate. (Table-4.22 and Figure-4.57)

Table-4.22 Generation, Recovery, Composting, Combustion with Energy Recovery, and Discards of MSW in U.S., 1960 – 2009(Adapted from MSW in U.S.:2009 facts and figures, 2009)

Unit: million tons and %)

	Generation		Recovery for recycling		Recovery for composting		Total materials recovery		Combustion with energy recovery		Discards to landfill	
1960	88.1	100	5.6	6.4	Neg.	Neg.	5.6	6.4	0	0	82.5	93.6
1970	121.1	100	8.0	6.6	Neg.	Neg.	8.0	6.6	0.4	0.3	112.7	93.1
1980	151.6	100	14.5	9.6	Neg.	Neg.	14.5	9.6	2.7	1.8	134.4	88.6
1990	208.3	100	29.0	14.0	4.2	2.0	33.2	16.0	29.7	14.2	145.3	69.8
2000	242.5	100	53.0	21.9	16.5	6.7	69.5	28.6	33.7	13.9	139.4	57.5
2005	252.4	100	59.3	23.5	20.6	8.1	79.9	31.6	31.6	12.5	140.9	55.9
2007	255.0	100	63.1	24.8	21.7	8.5	84.8	33.3	32.0	12.5	138.2	54.2
2008	251.0	100	61.8	24.6	22.1	8.8	83.9	33.4	31.6	12.6	135.6	54.0
2009	243.0	100	61.3	25.2	20.8	8.6	82.0	33.8	29.0	11.9	131.9	54.3

Figure-4.57 MSW generation rate, 1960-2009

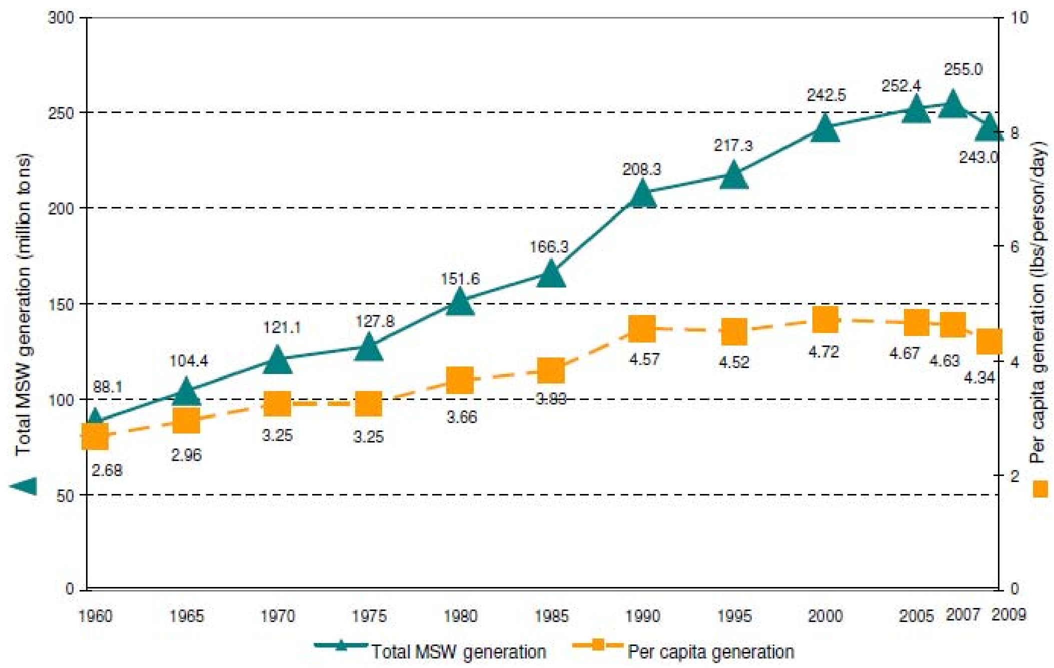


Figure-4.58 MSW recycling rate, 1960-2009

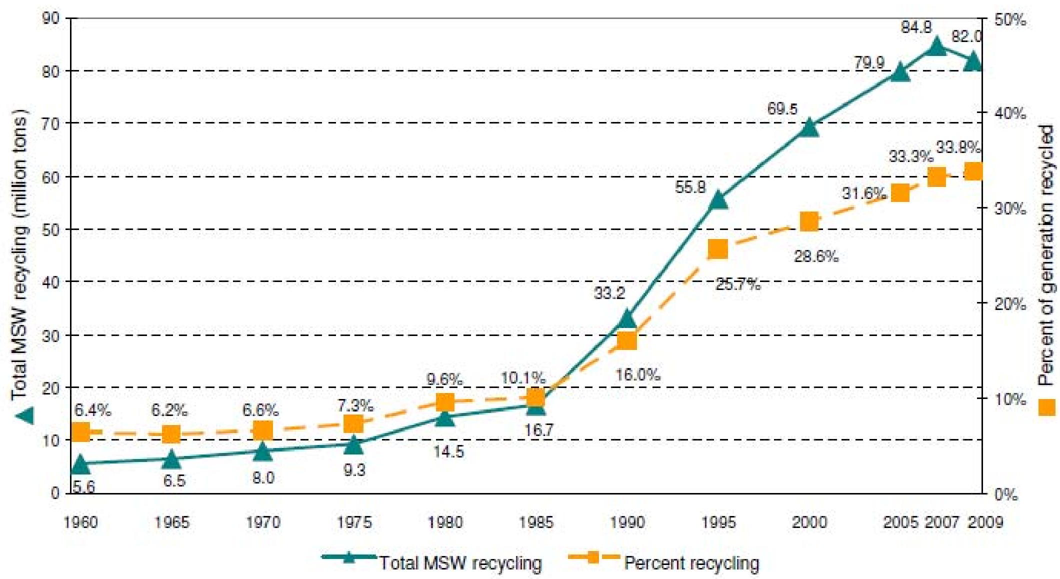
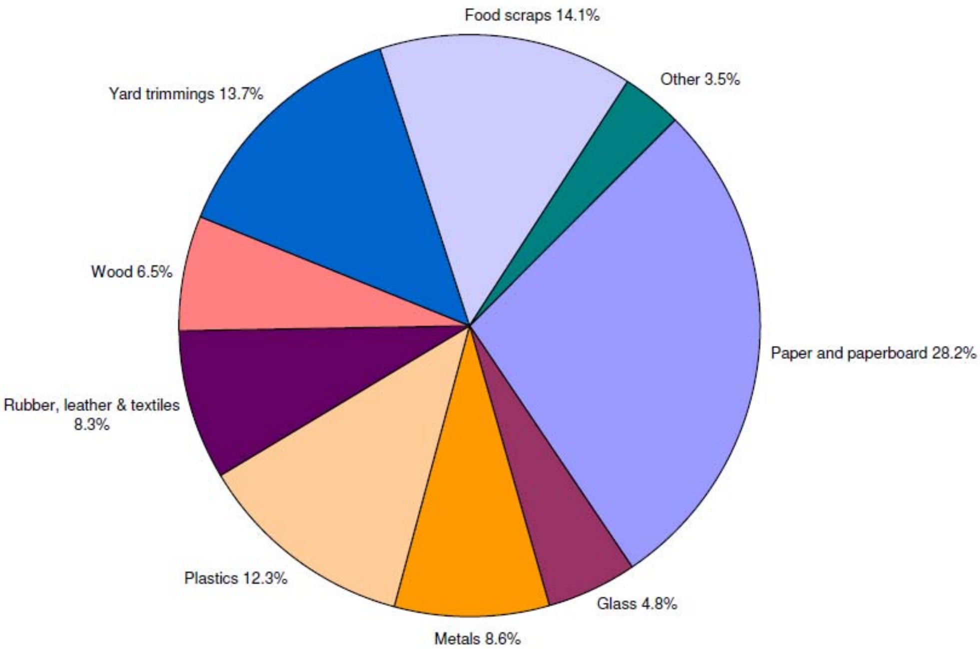


Figure-4.57 and Figure-4.58 show constant increase of both generation and recycling of MSW in U.S., especially after the year 1985. The recycling rate increased very quickly decreases after 1985 which is the effects of environmental management and investment. However, they also exhibit a decrease in MSW generation and recycling from 2007 to 2009. That means the state of the economy has a strong impact on consumption and waste generation. Waste generation increases during times of strong economic growth and decreases during times of economic decline.

A breakdown, by weight, of the MSW materials generated in 2009 is provided in Figure-4.59. It is obvious that paper and paperboard possess the largest component of MSW generated (28.2%), food scraps and yard trimmings were the second (14.1%) and third (13.7%) largest component, respectively. Metals, plastics, and wood each constituted between 6% and 13% of the total MSW generated. The others share the rest 25% of the MSW generated in 2009.

Figure-4.59 Materials Generation in MSW in 2009 (before recycling) (Adapted from the website of U.S. Environmental Protection Agency)



4.4.3 Environmental policy and investment

4.4.3.1 Environmental policy

The environmental policy went through two stages that are government control period and market mechanism period.

In the government control period in 1970s, environmental problems in U.S. are treated by mandatory direct control method, including promulgation of laws, formulation of emission standards and mandatory installation of pollution treatment equipment.

After 1980s, the environmental policy in U.S. went into the second stage, in which the government strengthened the incentives and coordination effects of market. Since then, environmental governance had been partially replaced by means of economic regulation of the market. Green Tax Policy and Marketable Pollution Permits are good examples of government's economic interventions. U.S. Federal Government regards environmental industry as high-tech industry which is promoted in this period.

4.4.3.2 Environmental investment

Environmental protection has become the focus of public and government in the late 1960s. Based on the strong economic base, developed capital markets and perfect environmental management laws and regulations, the United States established a relatively sound EnvI and financing system which can be summarized into two categories: government and market mechanism investment and financing.

A substantial regulatory framework to manage the environmental problems in the U.S. started with the Clean Air Act of 1970 (Elliott and Regens, et al, 1994).

The U.S. conducted the Pollution Abatement Costs and Expenditures (PACE) survey in 1973 (Becker and Shadbegian, 2007). This is the most comprehensive source of information on manufacturing's capital expenditures and operating costs associated with pollution abatement in the U.S.

The following tables show the Federal investments for pollution control and abatement from 1970 to 1980 and the Chinese EnvI in the early 21th century. By comparison, we can see that although the EnvI in China is still very little compared with that of U.S., the growth trend of Chinese EnvI is more obvious.

Table-4.23 Federal obligations for pollution control and abatement 1970 to 1980 (U.S. Office of Management and Budget, 1981)

Unit: millions dollars

MEDIA OR POLLUTANT	OBLIGATIONS (liabilities, contracts and other commitment entered into requiring the payment of money by the government.)							
	1970	1973	1974	1975	1976	1978	1979	1980
Total(1)	1070	4545	4176	6103	6465	5370	7961	8701
Water	677	3730	3455	5179	5492	3922	6212	6597
Air	189	461	490	348	334	456	517	576
Land	35	61	40	57	66	132	122	141
Living things, materials, etc.	169	293	191	519	573	860	1110	1287
GDP(2)(billion $)	NA	NA	NA	159.6	NA	NA	NA	276.7
(1)/(2)				3.8%				3.01

Table-4.16 Chinese Investment Completed in the Treatment of Pollution (Adapted from the website of National Bureau of Statistics of China)

(Unit: billion Yuan)

MEDIA OF POLLUTANT	OBLIGATIONS (liabilities, contracts and other commitment entered into requiring the payment of money by the government.)					
	2004	2005	2006	2007	2008	2009
Total(1)	191.0	238.8	256.8	338.8	449.0	452.5
Industrial water	10.56	13.37	15.11	19.61	19.46	19.89
Industrial air	14.28	21.3	21.3	27.53	26.57	28.54
Industrial solid waste	2.26	2.73	2.74	1.83	1.97	2.36
GDP(2)(billion Yuan)	16039	18321	21192	25730	30067	34050
(1)/(2)	1.19%	1.30%	1.21%	1.32%	1.49%	1.33%

Figure-4.60 and Figure-4.61 illustrate the investment tendency in U.S. and P.R.C. By contrast it can be seen that although the EnvI ratio in P.R.C. is rising at a high speed, it lags far behind that of U.S.. The EnvI ratio in U.S. had reached 2.6% of GDP in 2000. However, in the year 2008, China's EnvI ratio only achieved 1.49% of GDP. The American investment level (0.9%) in 1972 had almost attained the investment level (1.02%) in China in 2000. Of course, the dominant position of U.S. benefits from its high developed economy and civic environmental awareness.

Figure-4.60 Scale of environmental investment and investment ratio in U.S. (1972~2000)

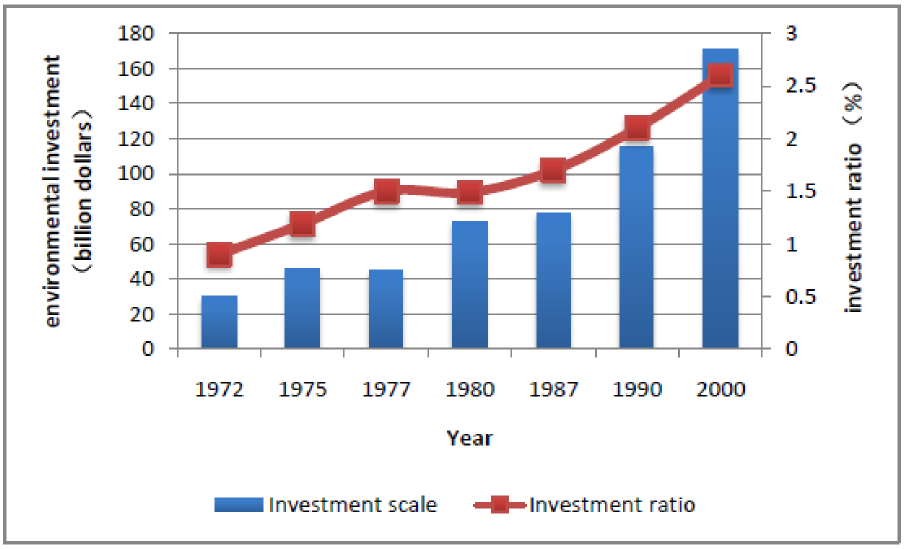
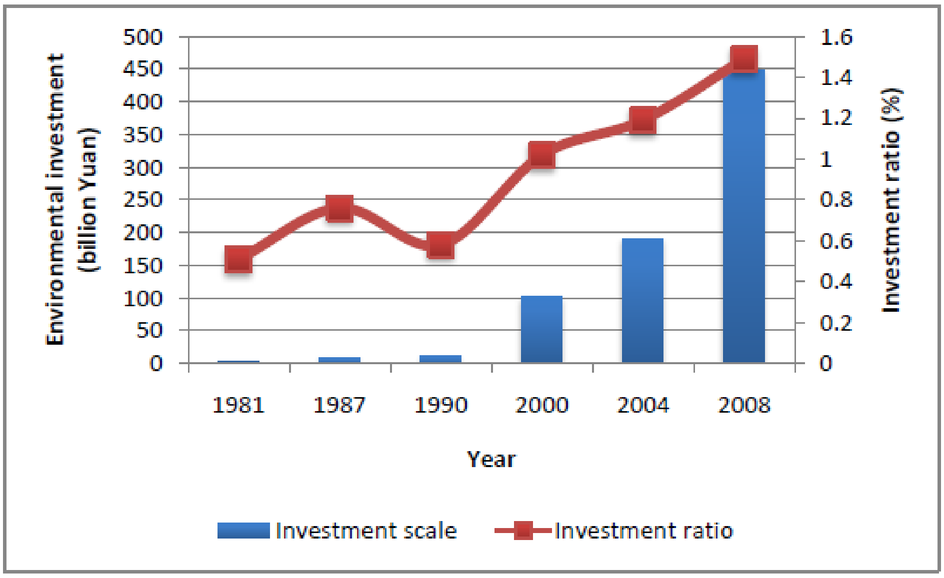


Figure-4.61 Scale of environmental investment and investment ratio in P.R.C.

(1981~2008)



4.4.4 Learnable aspects and cooperation opportunities

After analyzing and comparison of the related contents of EnvIs in U.S. and P.R.C., we can get some conclusions and recommendations. Some of them are the common problems in the two countries and some situations in U.S. are good examples that are worth learning by the Chinese government.

There are some similar political problems that hamper the efficiency of environmental programs both in U.S. and P.R.C: (1) the EPA often lacks authority compared with some important industrial ministries. (2) Fragmented bureaucratic complexity delays the implementation of environmental policies. (3) Environmental funding for enforcement is usually inadequate (4) Corruption often provides counterproductive options to compliance (Fryxell and Lo, 2002).

By contrast, we can also get some enlightenment as follows:

(1) The effects of market mechanism should be paid much attention to because they

have been powerful complements for environmental laws and policies in U.S.. The market mechanism should be a powerful complement to government control mechanism in P.R.C. to alter the situation that the government financial investment accounts for the major parts of environmental protection investment.

(2) Pollution control at the beginning of the production line should be more emphasized than terminal treatment of pollution. Promoting cleaner production is a global trend.

(3) Environmental protection industry should be vigorously developed.

(4) Environmental tax helps to finance for environmental remediation, so the system of environmental taxing in P.R.C. needs further development and refining.

(5) The cost of enterprise's pollution control in U.S. is basically financed and invested by themselves. However, enterprises in China have not been the real investors compared with the complex environmental investment structure of U.S.. The enterprises should get rid of the subsidiary position in the government departments and should be independent on the environmental protection.

In general, the U.S. has a more completed environmental protection system including the legislation frame work, monitoring framework and plenty investment. China should learn from U.S. to improve the environment protection system in all respects.

4.5 Critical analysis of Germany

This section discusses the environment situation and investment Germany. After comparing the trend of environmental quality and situation of environmental policy and investment, we get some conclusion and learnable aspects to refer to.

4.5.1 Comparability and Limitation

4.5.1.1 Fundamental condition

Germany is the most populous member state and the largest economy in the European Union, with 81.8 million inhabitants. It is one of the major political powers of the European continent and a technological leader in many fields. It has the largest national economy in Europe, the fourth largest by nominal GDP in the world (3,309,669 millions of dollars), and the fifth largest by PPP in 2009. It is also the world's second largest trader both in terms of imports and exports. (The World Bank, 2010).

The service sector contributes approximately 71% of the total GDP, industry 28%, and agriculture 0.9%. The distribution of labor force by occupation in 2005 is as follows: agriculture 2.4%, industry 29.7%, services 67.8%. (The World Factbook, 2011)

Like most countries, Germany relies primarily on fossil fuels as energy source. About 40% of energy consumption in Germany comes from petroleum. About 30% comes from domestic coal deposits. Natural gas provides about 17% of energy consumed, and nuclear energy about 10%. Other sources of energy, such as hydroelectric, solar, or wind-powered electric power plants, are relatively insignificant. (Eric, 1995)

4.5.1.2 Comparability

Economic aspect

As mentioned before, Germany is the one of the most developed countries in the world, with the fourth largest GDP and fifth largest GDP per capita. Among the world's 500 largest companies measured by revenue in 2010, the Fortune Global 500, 37 are headquartered in Germany.

From Table-4.62, it can be seen that the trend of German GDP increased with fluctuation. It reached 2500 billion U.S. dollars in 1996 and then decreased until 2003 when it started to rise again. However, the GDP of P.R.C. is increasing continuously and it caught up with the 1996's level of Germany in 2007.

Figure-4.62 GDP in Germany and P.R.C., 1991~2010 (Adapted from Trading Economics, 2011)

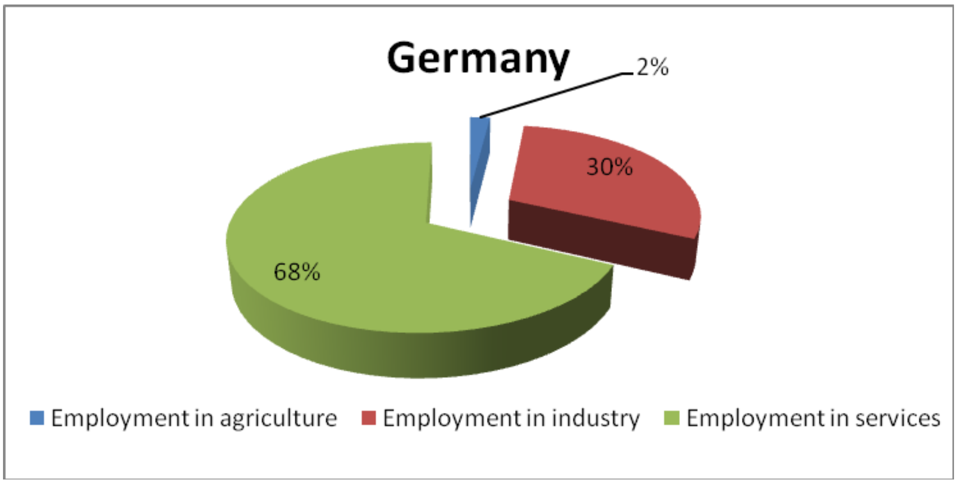
Unit: billion dollars

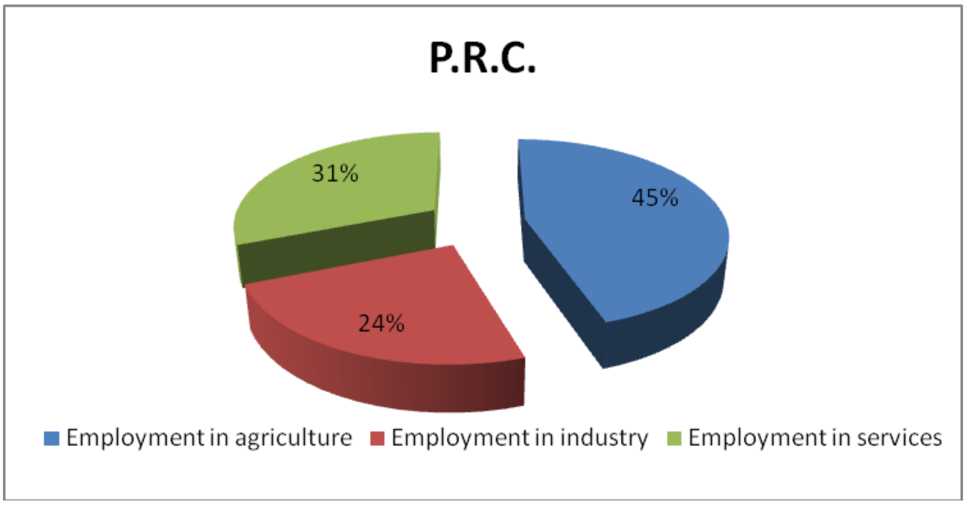
Social aspect

Germany is a densely populated country in Europe with 229 inhabitants per square kilometers. China had the average population density of 139.6 inhabitants per square kilometers, and even higher density in south and east coastal regions. The environmental pollution was spatially concentrated in Germany because of the population distribution was unevenly (OECD, 2001). And so it is with China whose east coastal regions were also the main objective areas on pollutant treatment.

The employment distribution by industries in these two countries is another reason for comparison. The employment percentage of industry can reflect the development of industry, which plays an important role in the waste generation. Figure-4.63 makes a comparison between Germany and P.R.C.

Figure-4.63 Employment percentage by industry in three categories (2005)





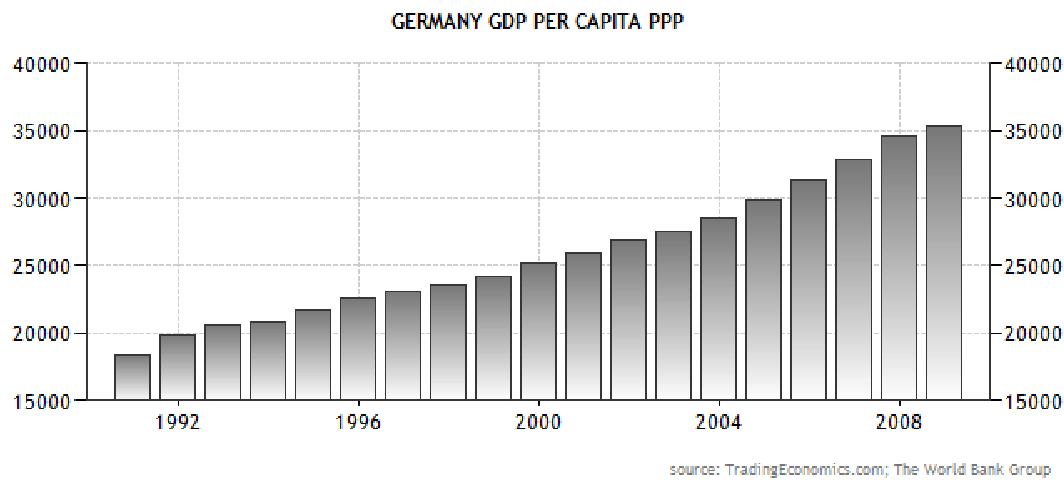
By contrast, we can get a direct impression that although the German employment percentage in services is much higher than P.R.C., the employment percent in industry of the two countries are nearly the same. The treatment and management of industry waste in the two countries can be a factor to be compared and used for reference.

4.4.1.3 Limitations

1) Although the economic power of P.R.C. has surpassed Germany in 2007, taking the population into consideration, the GDP per capita in China is far behind Germany.

Figure-4.64 GDP in per-capita level in P.R.C. and Germany (Trading Economics, 2011)

Unit: US dollar



From this figure, we can find the huge gap of economy in terms of GDP per capita in China and Germany. The GDP per capita in China was about 6000 dollars in 2009 while it reached 35000 dollars in Germany in the same year which was almost 6 times more than that in China. Because the GDP per capita has the better representation of development level and human living conditions, the large gap could bring some irrational matters for comparison. It would have led some challenges to the environmental protection expenditure.

2) Environmental education is another aspect for the limitation of comparison. As we know that environmental education has been a key concern in Germany for many years. No matter in school or in company, environmental education has been promoted.

Environmental education in schools has been developed for years. Environmental issues are involved in most subjects in schools. The curricula are developed by each federal state subject-wise and can differ from state to state quite dramatically. (Rachael Dempsey, 1999) However, schools in P.R.C. haven't offered enough environmental related courses which are only offered for college students who major in environment-related disciplines.

In addition, many companies and institutions offer environmental education in Germany. These institutions consist of adult education, nature and environment centers, consumer councils, conservation and other environmental protection organizations, museums, and even zoos and botanical garden. By contrast, the environmental education in the P.R.C. is not offered such widely and frequently.

4.5.2 Environmental circumstance and trend

4.5.2.1 Ambient air quality

In accordance with the Gothenburg Protocol and the 'Directive on National Emission Ceilings', Germany determined to engage in reducing Nonmethane Volatile Organic Compounds (NMVOC) emissions to 995 thousand tons by 2010, which means that the 2007 emission levels must still be reduced by a further 285 thousand tons (22 %). In the ‘Nationales Programm zur Verminderung der Ozon -konzentration und zur Einhaltung der Emissionshöchstmengen’ (National Programme for Ozone Concentration Reduction and for the Adherence to Maximum Emission Levels) in 2007, some appropriate reduction measures were proposed for NO_x, NH_3, SO_2, and NMVOC for the solvent sector and road transport.

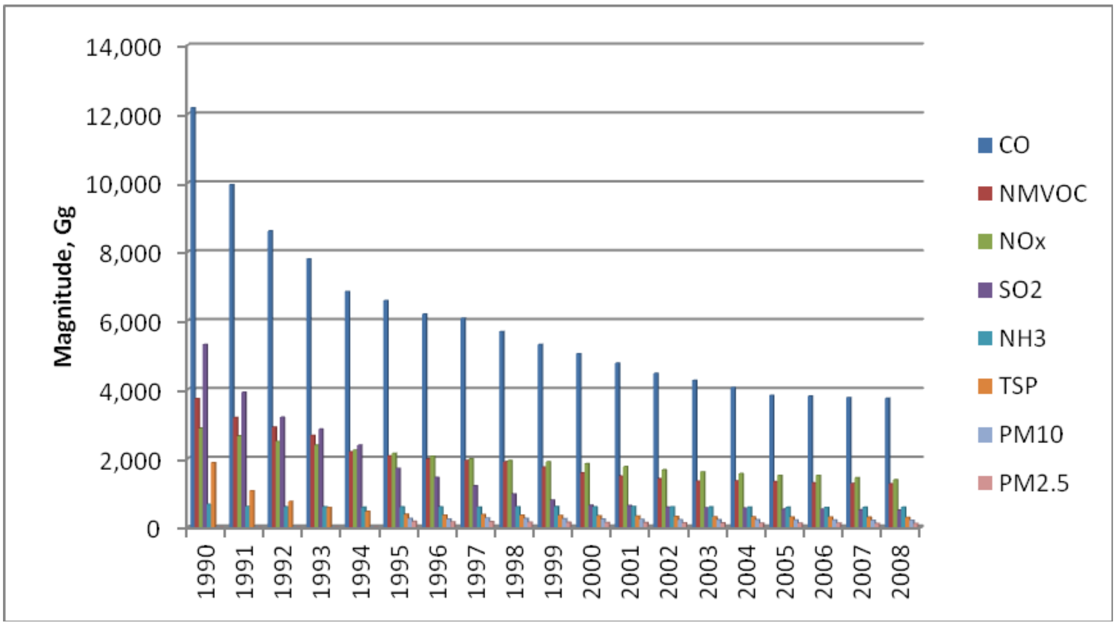
The air quality in terms of general air pollutants is listed in Table-4.24. The data about PM_{10} and $PM_{2.5}$ was recorded since 1995. If we plot the data on the figure we can find almost all the pollutants showed a decrease since 1990, especially CO and SO_2. For CO, the total amount experienced the largest drop from 12178Gg in 1990 to 3741Gg in 2008. The emission of SO_2 also witnessed a most obvious decline in aspects of percentage, that is, the amount of SO_2 dropped to 498Gg in 2008 which is 9.4% of the amount in 1990 (5311Gg). Thus, we can say the air quality in Germany has been improved in a large extent.

Table-4.24 Atmospheric emission trend for Germany since 1990(Adapted from website of Umweltbundesamt)

Unit: Gg

	CO	NMVOC	NO_x	SO_2	NH_3	TSP	PM_{10}	$PM_{2.5}$
1990	12,178	3736	2877	5311	671	1874	0	0
1991	9,949	3186	2654	3921	607	1061	0	0
1992	8605	2913	2494	3197	592	750	0	0
1993	7,792	2671	2385	2852	595	574	0	0
1994	6844	2193	2239	2386	581	461	0	0
1995	6582	2076	2149	1713	591	375	254	172
1996	6193	1984	2067	1447	596	356	239	160
1997	6074	1943	1984	1203	588	372	270	163
1998	5684	1902	1938	964	594	353	254	150
1999	5310	1746	1908	791	599	344	246	144
2000	5039	1580	1846	637	594	331	237	137
2001	4771	1484	1763	632	606	322	231	134
2002	4473	1409	1668	585	594	312	223	128
2003	4264	1339	1605	570	589	303	217	125
2004	4062	1349	1563	555	588	304	217	123
2005	3829	1328	1503	524	581	296	211	119
2006	3807	1295	1509	532	578	297	211	119
2007	3763	1273	1442	506	581	292	207	113
2008	3741	1267	1380	498	587	287	203	110

Figure-4.65 Atmospheric emission trend for Germany since 1990

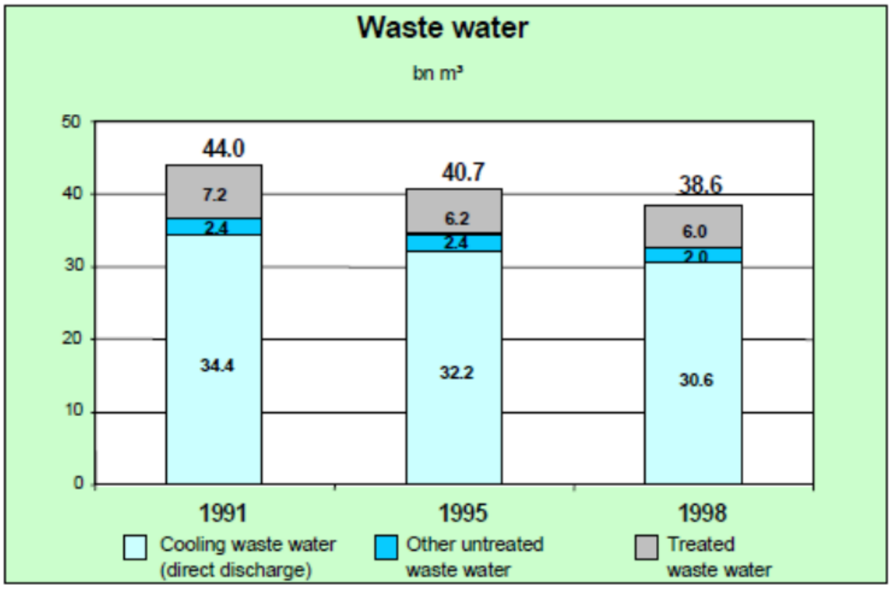


This achievement on pollution control in Germany has been mainly due to implementation of environmental policies. Over 80% of Germany's total reduction of SO_2 emissions has been achieved in New Lander. In addition, these achievements have also resulted from economic restructuring and well developed environmental management.

4.5.2.2 Water quality

Parallel to the decline of air pollutants, wastewater discharge also experienced a decrease in the 1990s. The discharge of wastewater consists of less than 6 billion m^3 treated water and 2 billion m^3 untreated wastewater (Figure-4.66). The volume of wastewater fell by 12.3% (5.4 billion of m^3) from 1991 to 1998.

Figure-4.66 Wastewater source distribution



Source: Water Framework Directive, Umwelt Bundes Amt,2009

We can also see above average declines were recorded for the discharge volumes of treated (-16.8%) and untreated wastewater (-15.7%). The quantity of discharged cooling wastewater was dropped by 9.2% from 33.4 in 1991 to 30.6 in 1998.

4.5.2.3 Solid waste environment

Due to a substantial increase in industrial production and private consumption, waste generation grew rapidly at the beginning of the 1970s when waste was mainly disposed of in 50 000 small dumpsites. Then, they attracted a number of interests and more and more advanced waste management facilities were built (European Environment Agency, 2009).

Policies of limiting landfilling were introduced by Germany and other European countries in the 1990s. Measures consist of schemes for collection of packaging waste, biowaste and waste papers. As a result, Germany has already recycled a reasonably large proportion of municipal waste (approximately 40 %) by the year 1995.

Table-4.25 Development of waste quantities in Germany (Adapted from Federal Statistical Office and Federal Environment Agency, 2007)

	Quantity of waste (1000 tons)			
	2002	2003	2004	2005
Total	381262	366412	339368	331889
Municipal waste	52772	49622	48434	46555
Mining industry rubble	45461	46689	50452	52308
Building and demolition waste	240812	223389	187478	184919
Waste from production and industry	42218	46712	53005	48106

From Table-4.25, it can be seen that more than 330 million tons of waste are generated in Germany annually. The statistics in the table shows that the total waste quantities dropped slightly from 2002 to 2005. That’s because of the recessionary economic situation in the construction industry which leads to a reduction in the quantity of building and demolition waste. However, we can find the building and demolition waste still occupied the largest part (55.7% in 2005) of solid waste. On the other hand, municipal waste quantities also decreased at rate of 12% from 2002 to 2005. However, with the improvement of human living condition, the task of avoiding waste, ensuring its environmentally friendly and economically efficient management presents Germany with ever-increasing challenges.

4.5.3 Environmental policy and investment

4.5.3.1 Environmental policy of Germany

High levels of innovation

Environmental expenditure for research and innovation is above average. It seems that the adjunctive environmental protection facilities, such as incineration plants and wastewater treatment plants, are becoming less popular compared with integrated solutions like the cleaner production processes. As a result, knowledge-intensive methodologies, scientific research, planning and consulting services are playing an important role.

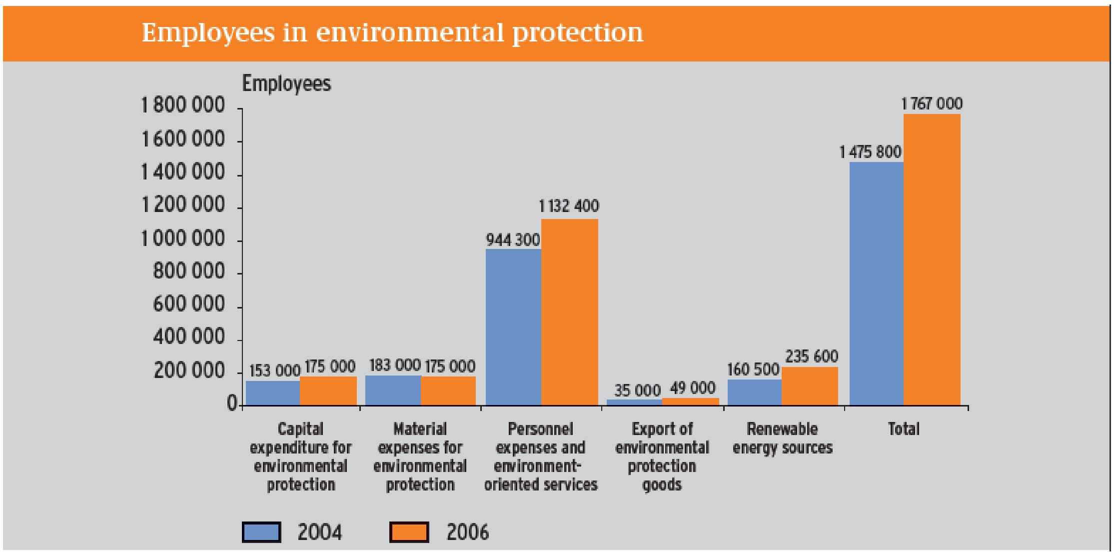
Patent application is one of the most important indicators for innovation levels. In fact, Germany holds the highest share (21%) of annual patents registered with the European patent office in renewable energies in the European Union. Therefore, Germany’s environmental protection industry has been playing a leading role for many years.

Green markets

Green jobs are booming in all key green markets in aspects of energy efficiency, sustainable water management, sustainable mobility, energy generation, resource and materials efficiency, waste and closed cycle management. This global green markets have already created nearly 1000 billion euro in 2005. It is estimated that profits from these environmental industries will double by 2020.

Booming green markets must lead to the increase of employment in environmental protection. Employment in this area has risen continuously in Germany over the past few years, most recently from 1.5 million jobs in 2004 to about 1.8 million in 2006. From Figure-4.67 we can see the biggest increases occurred in the area of renewable energies whose employment rose by 46.8% from 2004 to 2006 and the trend continues. The second largest increase happened in area of personnel expenses and environmental oriented services with a growth rate of 19.9%. According to latest estimates, approximately 278,000 people worked in the renewable energy sector in 2008 (Umwelt Bundes Amt, 2009).

Figure-4.67 Employees in environmental protection in Germany (Adapted from the website of Umwelt Bundes Amt, 2009)



Environmental taxation

By paying a higher price, companies and households are forced to think of the environmental protection and change of their habits and customs. Therefore, the use of environmental taxes and fees that helps to effectively meet the ecological challenges that come from energy and resources consumption. Since the introduction of ecological tax reform in 1999, consumption of fuels decreased annually by 3 %, after having been on the rise for decades. Table-4.26 exhibits the environmental tax revenue from 2000 to 2010. (Umwelt Bundes Amt, 2009)

Table-4.26 Revenues from environmental taxes and fees (Adapted from the website of Umwelt Bundes Amt, 2009)

Unit: EUR mn

	2000	2003	2006	2007	2008	2009	2010
Energy tax	37826	43188	39916	38955	39248	39822	39838
Motor vehicle tax	7015	7336	8937	8898	8842	8201	8488
Electricity tax	3356	6531	6273	6355	6261	6278	6171
Wastewater charges	5384	5020	4582	4474	-	-	-
Waste charges	4871	4164	3961	3955	-	-	-
Total revenue	58453	66239	63669	62636	-	-	-

4.5.3.2 Environmental investment in Germany

Being different from China, EnvI in Germany consists of three parts of sources that are investment from production industries, government expenditure and expense from privatized public enterprises. Their EnvIs are listed in Table-4.27. We can see the investment from privatized public enterprises occupies the largest part of all and its percentage is increasing year by year, from 49% in 2000 to 59% in 2006. The investment from production industries and government experienced a steady decline since 2000.

Table-4.27 Environmental protection investment in Germany (Adapted from Economy and Use of Environmental Resources, Edition 2010)

Unit: EUR mn

Environmental domain	2000	2003	2004	2005	2006	2007
Production industries	7070	7250	6780	6500	6310	6640
Waste management	1380	1360	1290	1270	1430	1450
Wastewater management	2490	2740	2520	2410	2400	2470
Noise abatement	180	220	160	160	170	190
Protection of ambient air	3020	2930	2820	2670	2310	2530
Government	9550	8360	8020	7760	7860	7690
Waste management	4170	3630	3490	3570	3590	3470
Wastewater management	5220	4560	4320	4030	4130	4080
Noise abatement	120	150	190	150	120	120
Protection of ambient air	30	20	20	20	20	20
Privatized public enterprises	16080	17940	19240	19550	20050	19540
Waste management	7540	8520	8850	9740	10070	10430
Wastewater management	8540	9430	10390	9810	9970	9110
Total investment	32700	33550	34040	33810	34220	33870

In addition, an increasing number of foundations in Germany supported environmental research, development. Among them, The Germany Federal Environment Foundation, established in 1990, with the capital of nearly 1.53 billion EUR is one of the biggest foundations in Europe. It supported over 3300 projects spent at least 0.77 billion EUR during the 1990s.

Since the middle of 1980s, annual expenditure on pollution abatement and control (PAC) in Germany has reached 1.5% of GDP. About 50% of total PAC expenditures are invested to wastewater treatment, 40% to solid wastes and the rest 10% is related to air pollution abatement.

Except for the environmental protection research and technology innovation, a large proportion of the investment was used for the construction and management of the fixed assets for environmental protection. Table-4.28 illustrates the number of these fixed assets from 1991 to 2000. It is clearly that both of the total amount and number of facilities in each aspect showed an obvious increase.

Table-4.28 Gross fixed assets for environmental protection (Adapted from the website of the Federal Statistical Office 2002, 2003)

Unit: Euro mn

Year	Total	Waste disposal	Water protection	Noise abatement	Air quality control
1991	205690	12530	164240	3860	25060
1992	212960	13800	168950	4090	26120
1993	221310	15450	174340	4310	27210
1994	228800	16540	179530	4520	28210
1995	235280	17270	184160	4710	29140
1996	240280	17910	187930	4880	29560
1997	243890	18410	190600	5030	29850
1998	245880	18650	192630	5200	29410
1999	246930	18740	194060	5430	28710
2000	248150	18820	195750	5630	27950

4.5.4 Learnable aspects and cooperation opportunities

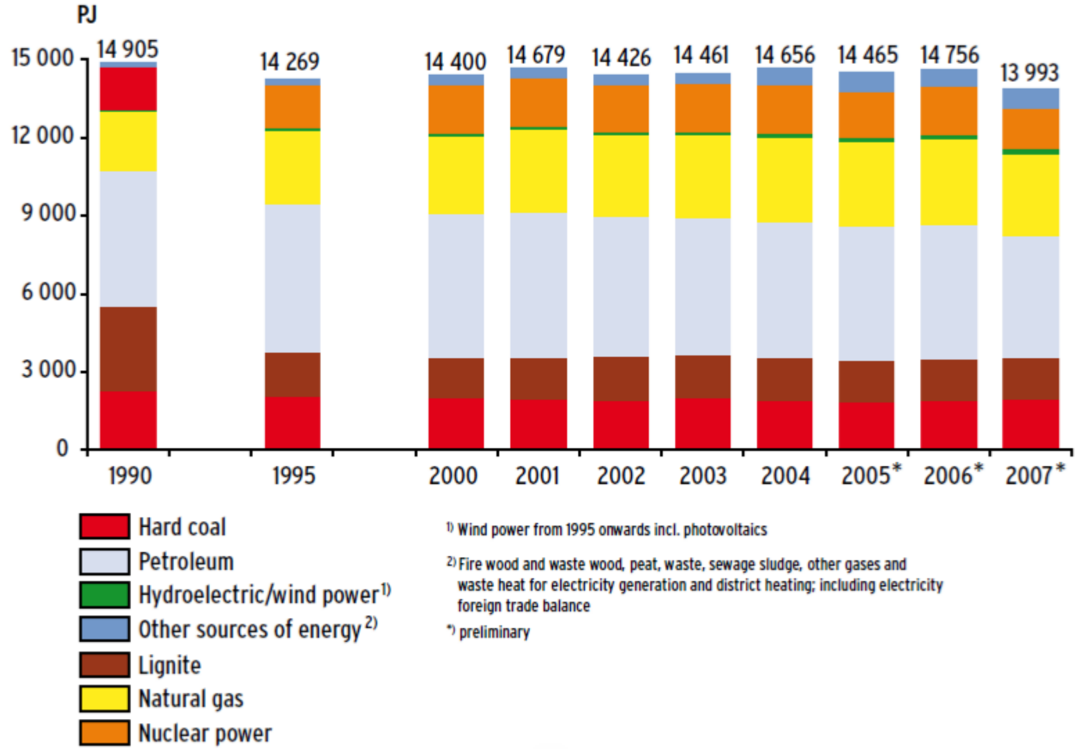
By contrast, we can find some conclusion and learnable aspects from the EnvI of Germany.

1) Germany has established a well developed institutionalization of environmental education. The definition and recommendations for environmental education are importantly emphasized in schools and universities. They have developed different school organizations and systems for environmental education and various curricula for environmental education which are not uniform for the entire country. And the ecological culture at school is dynamic and continuous renewal (Rachael, 1999). China should learn from German experiences on the environmental education and establish its own environmental education system by legislation and regulation to improve the civil environmental awareness and knowledge which are important for the environmental protection work.

2) The booming of green markets in Germany is a very successful experience for China to learn. Green market not only creates a number of job opportunities, but also helps the government to improve and protect the environment. As a result, private investment took the largest part of EnvI. Introduction of marketable mechanism will share the pressure of environmental improving targets. In addition, competition mechanism of market will improve the investment efficiency of environmental protection.

3) Last but not least, another advantage of Germany is the energy supply structure, which has a high usage of clean energy such as natural gas, nuclear power, hydroelectric and wind power. The clean energy production occupies more than 40% of the total energy supply since 2000. As a result, the emission is decreased obviously and the environment protection expenditure is cut down. Thus, China should transfer the investment on thermal power station to other power plant using clean energy gradually.

Figure-4.68 Primary energy consumption in Germany according to energy source (Adapted from Energy Balances Working Group, 2009)



4.6 Overall analysis and discussion

As the analysis shown in the former chapter, we have attained dedicated conclusion between each country and China. The overall comparison is necessary to carry out to study the future direction which China government would reference.

Table-4.29 Overall comparison among China, India, Japan, U.S. and Germany

Country	Economic Structure (% of GDP)			GDP (bil. $)	GDP per capita ($)	EnvI (bil. $)	Env. Exp. Percentage of GDP (%)	Per capita Env. Inv. ($)
	Agriculture	Industry	Service					
China	10.9	48.6	40.5	4991	4284	66.38	1.33	51.06
India	17.5	19.9	62.6	1430	1182	-	-	-
Japan	1.6	23.1	75.4	5049	39756	95.93	1.9	755.36
U.S.	1.0	20.5	78.5	14510	40989	464.31	3.2	1311.61
Germany	0.9	27.1	72.0	2182	40512	39.276	1.8	727.33

4.6.1 Adjustment of the economic structure

According the data listed in the table, India and the developed countries have a high GDP ratio for the service sector in the economic structure compared with China. In China, the industry sector, which generates most of the pollution, occupies the 48.6% of the total GDP. As a result, the environmental cost and economic loss are larger than other country from the source. In order to improve the environmental situation, the first task is to reduce the pressure from industry. In next decades, China should make efforts in adjusting the economic structure, developing the service productivity and enlarging the ratio of service sector.

Since a long time, energy structure is a hot issue of the economic development of China. On the one hand, energy industry is the basic industry of the national economy of China. The health development of energy industry has been a material base of sustainable development of society and economy. On the other hand, the production and use of energy is the main source of environmental pollution. Coal is the main part of China's energy consumption structure. The increasing energy consumption and the undue dependence on fossil fuel lead to the fast increase of green house gas. Therefore energy saving and improvement of efficiency of energy has been an inevitable choice to safeguard national energy security and keep sustained economic growth.

4.6.2 Enlargement of total environmental investment

As the table reflects, both the environmental expenditure ratio and the per capita environmental expenditure of China are much lower than the developed countries. At present, China also faces some environmental problems that have been faced by some developed countries in different historical periods. So, even if the EnvI reaches the level of other countries in the corresponding period of history, it is difficult to solve China's environmental problems (Fang, 2006).

The study results of some international organizations and economic experts show that, when a country's EnvI accounts for 1% to 2% of GDP, it can basically control the development of environmental pollution. Significant improvement in environmental quality will occur only when a country's EnvI account for 3% to 5% of GDP (Cheng, 2005).

From the data, China has not yet reached such a level as the developed countries. Hence, China should keep on increasing the EnvI in next decades by innovating the existing investment and financing mechanism, and by broadening the investment channels for environmental protection.

The EnvI ratio is a key factor that affects the investment benefits and environmental quality. Neither too low ratio nor too high proportion could bring damage to EnvI. If the ratio is too low, the effects of investment cannot be obvious and environmental situation cannot be improved effectively. However, if the ratio is too high and it is beyond the tolerance range of economy, it will impede the economic growth and affect the sustainable development of EnvI.

Table-4.30 Calculation for the environmental expenditure increasing

YR	GDP	Env.Inv. (10% growth)	Ratio (%)	Env.Inv. (11% growth)	Ratio (%)	Env.Inv. (12% growth)	Ratio (%)	Env.Inv. (13% growth)	Ratio (%)	Env.Inv. (14% growth)	Ratio (%)
2009	4991.00	66.38	1.33	66.38	1.33	66.38	1.33	66.38	1.33	66.38	1.33
2015	8441.29	117.60	1.39	124.16	1.47	131.02	1.55	138.20	1.64	145.70	1.73
2019	11484.28	172.17	1.50	188.48	1.64	206.17	1.80	225.33	1.96	**246.09**	**2.14**
2020	12403.02	189.39	1.53	209.21	1.69	230.91	1.86	254.62	2.05		
2021	13395.27	208.33	1.56	232.23	1.73	258.61	1.93	**287.73**	**2.15**		
2024	16874.18	277.29	1.64	317.60	1.88	**363.34**	**2.15**				
2025	18224.11	305.01	1.67	352.54	1.93						
2028	22957.13	405.97	1.77	**482.14**	**2.10**						
2030	26777.20	491.23	1.83								
2035	39344.49	791.13	2.01								
2036	42492.05	870.24	2.05								
2038	49562.73	**1052.99**	**2.12**								

As showed in Table-4.30, assuming the GDP growth in China keep at 8%, if the environmental expenditure is growing at 10%, by the year 2038 the ratio will reach 2.12%. By the year 2028 the expenditure ratio will reach 2.10% with the annual growth of 11% while 2.15% will be achieved by 2024 if the growth keeps at 12%.

And with the growth of 14%, the investment ratio is looking forward to reach 2.14% of GDP in the year 2019.

According to the data, the higher growth leads to earlier reaching year. However, when the investment growth is higher than 12%, the acceleration effect is diminished and it could bring adverse impacts on EnvI. Hence, the EnvI growth of 12% is suitable considering both the loading of economy and development speed.

From the U.S. experience, China should encourage more EnvI from the non-governmental organizations in order to further enlarge the amount and raise the positivity for environment protection.

4.6.3 Reasonable distribution of the investment

According to the experience of India, Japan, U.S. and Germany, China should have a strict plan for the investment distribution. Learning from the present environmental status and the experience of Japan and Germany, China should invest more in the research and development of environmental technologies such as promotion of environmental industry patents registration, and China also should develop clean energy in order to reduce pollution from the source and improve the treatment efficiency and the emission generation.

5. Overall conclusion and suggestion

With the in-depth analysis of the current environmental status and economic structural conditions in China, as well as the comparison of the public EnvI situations between the P.R.C. and India, Japan, the U.S. and Germany, it may be arrived at a number of conclusions and recommendations as follows.

5.1 Overall conclusion

(1) Find a suitable environmental investment in P.R.C.

Take China's environmental situation and economic power as well as the investment situation in developed countries into consideration, EnvI in the P.R.C., including the government public spending and commercial involvement (on BOT basis) should be increased to a level of 2% of the annual GDP in the future (EnvI level of U.S. in 1990). Lessons from India, which is of similar population size and population density, and the relatively successful experiences from Japan and Germany, which play the similar roles of global manufacturing hub, also demonstrated that the environmental expenditure amount should be continued to increase to this level. This proportion can be achieved in the year 2031 at an EnvI growth rate of 12%.

(2) Establish a set of effective market mechanism

In the U.S., the effects of market mechanism should be paid much attention to because they have been powerful complements for environmental laws and policies. The market mechanism should be a powerful complement to government control mechanism in P.R.C. to alter the situation that the government financial investment accounts for the major parts of environmental protection investment. The booming of green markets in Germany is a very successful experience for China to learn. Green market not only creates a number of job opportunities, but also helps the government to improve and protect the environment. As a result, private investment took the largest part of EnvI. Introduction of marketable mechanism will share the pressure of environmental improving targets. In addition, competition mechanism of market will improve the investment efficiency of environmental protection.

(3) Enhance the investment on research and development

EnvI in China should be distributed more in environmental technology research and development in order to improve on the treatment efficiencies. Japan's excellent environmental technologies changed its socioeconomic system. They are at the highest global standards. Compared with other countries, Japan ranks high in the application for patents on environmental technologies in such areas as atmospheric pollution and water quality management, solid waste management and renewable energy. The environmental expenditure of Japan had been ever as high as 2.0% of its GDP, in which the environmental technologies R&D occupied nearly 10%.

(4) Encourage the private environmental sectors

EnvI sources should be enlarged to private and commercial communities. The private and commercial input in the U.S. took 1/6 in 1972 and continued to increase to 1/3 in recent years. In China, government investment takes up the most part of total environmental expenditure and the enterprises are in the subsidiary position in the government departments. As well as in Germany, the private investment took the most part of its total investment in the environment, and it has been demonstrated that the entire system has been ultra efficient. Back to China, it can be carried out in a similar manner, by encouraging commercial involvement on a BT (build and transfer), BOT (build, operate and transfer), or even BOO (build, operate and own) basis to attract potential commercial investors to participate in municipal environmental protection. This would undoubtedly lessen the financial load of the government, and improve the operation and management efficiency, and speeds up the development of the environmental protection sector and its relevant technology.

(5) Accelerate clean energy development

Energy sources in China should be altered to clean and renewable energy as soon as possible. The renewable energy was used in more and more extent in other developed countries in recent years, including Germany and Japan. Nuclear power station occupies a considerable proportion (almost 30% of electricity generation) of electricity in Japan. Clean energy, such as natural gas, nuclear power, hydroelectric and wind power, occupies more than 40% of the total energy supply in Germany since 2000. Biological fuels, solar energy, hydropower, and arguably nuclear power, are on a good start in the P.R.C., and this should be strongly encouraged in order to catch up with the developed countries in a relatively short period of time.

(6) Establish a material-cycle society

Reduce, reuse and recycle (3R) are important measures to treat and manage solid waste in nowadays. Establishment of material-cycle society can solve the waste problem fundamentally and can help China to cope with the recent environmental challenges. Japan is establishing a sound material-cycle society through changes in business and life styles. A comprehensive legal system for this kind of society was established in Japan. Meanwhile, Germany has demonstrated that treating the pollution sources was more important and more effective than treat effluent pollution in a communal treatment works, and this will be more economically and technically efficient.

(7) Reinforce environment protection education and propaganda

Germany has established a well developed institutionalization of environmental education which has been a key concern for many years. The definition and recommendations for environmental education are importantly emphasized in schools and universities. Various school organizations and systems for environmental education and different curricula for environmental education have been developed. China should learn from German experiences on the environmental education and establish its own environmental education system by legislation and regulation to improve the civil environmental awareness and knowledge which are important for the environmental protection work.

(8) Improve the quality of environmental statistics

Japan‘s statistical data was among the most detailed in the world from over 40 years experience accumulation since 1960s when it began its environmental protection. Therefore, Chinese government need to classify and refine the statistical data as detailedly as possible. The detailed data make it possible that the future environmental research could be conducted more accurately and efficiently. And this may need more investment on relevant technology and labour employment.

5.2 Recommendations

By the analysis of China's environmental and economic situation and comparison with the specific countries, this dissertation provides how much total EnvI amount should be achieved and presents some other pertinent enlightenment.

Further research could be done according to the investment directions on how much investment should be undertake in each direction, namely atmospheric, hydrospheric and lithospheric aspects.

The EnvI financing channel and investment benefits were also not been discussed in this paper.

Besides, when the environmental quality becomes better in P.R.C., weather the EnvI should be increased further or not in order to balance the economic development is another problem that warrants further research works.

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