CHAPTER 11

Air Pollution Status and Challenges Ahead in the Greater Pearl River Delta Region*

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CHAPTER SUMMARY

This chapter describes current air pollution conditions in the Greater Pearl River Delta (GPRD) region and illustrates how urbanization and industrialization have led to dramatic air quality degradation. In addition, it shows how the long-distance transportation of ozone precursors along the East Asian coast and from the Southeast Asian subcontinent contributes to ozone enhancement in the GPRD. Limited air quality data in the GPRD has become the main obstacle for scientists addressing air pollution problems there. Also, the unclear interpretation of the Air Pollution Index in the Chinese mainland conceals the urgency of these problems from the public.

INTRODUCTION

The Greater Pearl River Delta (GPRD) is located on the southeast coast of China and includes nine cities in Guangdong province (Guangzhou, Shenzhen, Zhuhai, Foshan, Jiangmen, Dongguan, Zhongshan, Huizhou, Zhaoqing), Hong Kong, and Macau.[1] The GPRD is one of the most developed regions in China. These nine cities in Guangdong have been recognized as the Pearl River Delta (PRD) economic zone since 1978, and it is now one of the most important manufacturing centers in the

[1] Department of Foreign Trade and Economic Cooperation of Guangdong Province. http://www.thegprd.com/index.asp.

world. From 1980 to 2004, the annual GDP (gross domestic product) growth rate in the PRD was 16.24 percent, which was about 70 percent more than the growth rate of the rest of China.[2] Since the 1970s,[3] Hong Kong has surpassed Shanghai as an international financial center. It now has the second-largest stock market in Asia and ranks eleventh among the world's trading economies.[4] Relying on tourism, Macau's GDP per capita reached $28,436 in 2006, ranking first in the GPRD.[5]

[2] http://www.investhk.gov.hk/pages/1/67.html

[3] http://www.chinavalue.net/Media/Article.aspx?ArticleId=16086

[4] http://www.hketo.ca/abouthk/international.html

[5] http://www.investhk.gov.hk/pages/1/67.html

Along with the growth of GDP, the GPRD has seen substantial increases in population, energy consumption, and the number of vehicles on the road. Within only 42,648 km², four major cities—Guangzhou, Shenzhen, Hong Kong, and Macau—coexist with more than 54 million permanent residents and a huge influx of migrants. With the dramatic industrialization and urbanization of the past thirty years, environment degradation in the region is significant. Air pollution, as the most observable and crucial environmental problem in the GPRD region, is a concern for local people, government officials, entrepreneurs, and even the global community. High pollutant concentration and low visibility have been affecting local people's living conditions and health.

These challenges are even more difficult to address because three different governments with separate institutions coexist in the GPRD region: the People's Government of Guangdong Province; the Government of the Macau Special Administrative Region; and the Government of the Hong Kong Special Administrative Region (HKSAR). This unique situation makes the allocation of responsibilities and cooperative policy-making more complex. In addition, increasing emissions in the GPRD are possibly affecting downwind areas over the Pacific Ocean, including the West Coast of the United States, so the GPRD's emissions are a concern for countries far beyond China's borders.

This paper will address the current air pollution status in the GPRD and explore its affiliation with regional and global pollutant emissions. The aim is to provide a comprehensive scientific background for policymakers to address air quality degradation in the GPRD.

AIR POLLUTION STATUS IN GPRD REGION

The air pollution status in the GPRD region is quite complex and very different from most U.S. and European cities. Because the GPRD region has had a relatively short but intensive developmental history, London-type smog problems, mainly caused by coal combustion, and photochemical smog problems, mainly caused by vehicle emissions, coexist in this region (Wang et al. 2005). In addition, industrial emissions, biomass burning, and biogenic emissions in rural areas add more complexity to air pollution control. These conditions make it necessary to research the many reactions among different pollutants while exploring emissions of each pollutant individually.

Particulate matter

Particulate matter is considered to be the most crucial air pollution problem in the GPRD region because of its high concentration and great impact on human health.

Particulate matter has very broad health effects for all populations, but the respiratory and cardiovascular systems are predominantly affected. Finer particles tend to have a stronger impact on health. Particles with diameters less than 10 µm (PM_{10}) can enter the respiratory tract and increase respiratory symptoms and disease, while particles with diameters less than 2.5 µm ($PM_{2.5}$) can more easily penetrate the lungs, decrease lung function, alter lung tissue and structure, and even lead to premature death (Zheng et al. 2000). In the GPRD, $PM_{2.5}$ accounts for a very high percentage of particulate matter, up to 70.4 percent of PM_{10} (Cao et al. 2003).

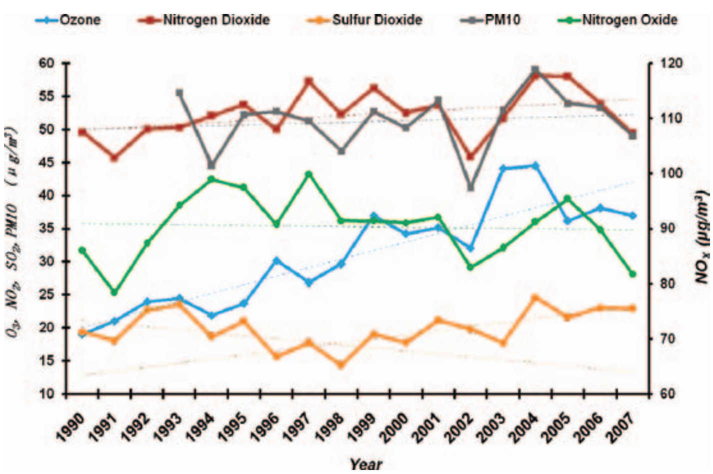
Guangzhou has the one of the highest annual average PM_{10} concentrations in this region, ranging from 73 to 99 µg m^{-3}. Even though this range is below the Chinese National Ambient Air Quality Standard of 100 µg m^{-3} for urban and residential areas, it is still much higher than the standard of 20 µg m^{-3} that is suggested by the World Health Organization's air quality guidelines (AQGs) (WHO 2006). Shenzhen and Hong Kong have lower annual average PM_{10} concentrations—around 50 µg m^{-3}—which are still more than double the concentration suggested by AQGs.

Some components of particulate matter, such as toxic metals, can have great health impacts on humans, but this data is generally not available for the GPRD beyond Hong Kong. While Hong Kong's annual average of toxic metals in PM_{10} was under the safety limits (Lee et al. 1999), more research should be done for the rest of the GPRD region.

Ozone

Since 1990, ozone concentration in Hong Kong has continued to increase (Figure 1), while little data is available for the rest of the GPRD region. In October 1995, daily average ozone concentration exceeded 80 ppbv (parts per billion by volume) for at least five days (Zhang et al. 2008b). The highest hourly ozone average in the GPRD increased from 142 ppbv between October and December 2001 to 179 ppbv between October and November 2004 (Zhang et al. 2008a). In the downwind southern PRD, the 8-hour mean ozone concentration reached 116±16 ppbv in 2004, which is higher than 100 ppvb suggested by the WHO AQGs (WHO 2006).

Figure 1 Trends in major air pollutant concentrations in urban Hong Kong (central/western, 1990-2007)



The year-to-year change in ozone concentration also depends on weather patterns. For example, when rainfall was very low in 2004, ozone concentration soared dramatically. Ozone concentration also has obvious seasonal patterns: fall and spring always have higher ozone concentrations (Wang et al. 1998). Anthropogenic VOCs (volatile organic compounds) and NO_x are also important control factors (Huang et al. 2005), and on-road vehicles and power plants are reported to be the main sources (Chan et al. 2002; Lee et al. 2002).

VOCs

As the precursors of ozone on the ground level, VOCs are critical air pollutants, especially in urban areas (Liu et al. 2008). From 2001 to 2006, the composition of VOCs in the GPRD region changed dramatically: propane concentration increased to nearly 50 percent in both urban (Guangzhou) and rural (Dinghu) areas; isoprene and ethyne decreased by 47 percent and 78 percent, respectively; and benzene concentrations in cities (Guangzhou) reached 20 ppb due to industrial emissions, compared to 16.25 μg m^{-3} (about 5 ppb) by the UK Air Quality Objectives.[6]

[6] http://www.airquality.co.uk/archive/standards.php

The change in VOC composition at different sites provides vital insight into the sources of pollutants. For example, the similar changes in VOC spectrum for urban and roadside atmospheres indicate that VOC emissions in the city are mainly due to fuel combustion in vehicles. VOC composition can further indicate the fuel structure of vehicles: ethylene, acetylene, and other light alkenes are attributed to local emissions from gasoline-powered vehicles, while propane is mainly contributed by Liquefied Petroleum Gas (LPG) fuel (Box 1).

SO_2 and acid rain

Since 1999, few trends could be observed for acid rain in most of the GPRD region. Guangzhou, which is located at the center of the second largest acid rain region of China, has been suffering from frequent and intense acid rain for several decades. From 1999 to 2005, acid rain accounted for 63 to 91 percent of rain days every year, with the annual average pH values ranging from 4.4 to 4.8. The occurrence of acid rain in Hong Kong remains steady, with the annual average pH around 4.6. Acid rain occurrences in Shenzhen have increased from 33 percent in 1999 to 81 percent in 2005, while the annual average pH values have decreased from 5.1 to 4.6 (Chan and Yao 2008). These acid rain events are mainly caused by the oxidation of SO_2, though the ratio of another acidic species, NO_{3-}, has been increasing.

To deal with the acid rain problem, the government of Guangdong province has taken efforts to reduce SO_2 emissions, especially emissions from power plants, which account for 32.9 percent of SO_2 emissions (Wang et al. 2005). An execution plan for de-sulfurizing power plants in Guangdong Province was promoted in 2003, and a slight decrease of SO_2 concentration in Guangdong and Shenzhen was observed in 2005 (Chan and Yao 2008). However, the SO_2 concentration in Guangzhou, 77 μg m^{-3}, was still higher than the Chinese National Ambient Air Quality Standards for urban and residential areas. SO_2 concentration in Shenzhen and Hong Kong are around 27 μg m^{-3}, much lower than the standard.

Box 1: A Lesson from LPG Fuel

In 2003, in order to reduce dust emissions from vehicles and improve urban air quality, the Guangdong government started to encourage replacing diesel light buses and taxis with LPG versions by offering incentives.[a]

With 2 billion RMB invested by the government, LPG was quickly adopted by switching the engines of existing vehicles. By the end of 2007, about 6,400 buses and 16,000 taxis had been changed to use LPG, which accounted for 80% of buses and 100% of taxis in Guangzhou.[b] However, the many problems that came to light during this dramatic change have revealed that LPG is not necessarily an economical, environmental, and safe way to improve urban air quality.[c]

LPG in Guangzhou faces the dual challenge of high economic costs and limited fuel resources. Even though the government has spent a lot on the transition to LPG vehicles and subsidized the LPG fuel price, most of the bus corporations have been suffering from debts since they adopted LPG. In addition, LPG fuel in Guangdong is highly dependent on imports. With the drastic increase of LPG in the vehicle fuel structure from nearly zero percent to 14.2 percent within only five years,[d] pressure will increase on the limited LPG resources, as well as the price.

In addition, without careful design, new engines are not efficient enough to burn all of the LPG. Sometimes the fuel can be seen leaking out of the vehicles. As a result, even though on-street dust has been reduced, propane—one of the reactive VOC species—has been found in increasing amounts, which could potentially lead to even more serious O_3 problems in the region.

[a] Key points of the Pearl River Delta Regional Air Quality Management Plan. www.epd.gov.hk/epd/english/environmentinhk/air/prob_solutions/files/plan_english.pdf.
[b] http://www.ycwb.com/2008-01/16/content_1757848.htm
[c] http://house.people.com.cn/GB/6779543.html
[d] 2000-2006 Almanac of Guangzhou

Visibility deterioration

Deterioration of visibility in the whole GPRD region is the most observable air pollution problem among the general public. The number of hazy days—visibility less than 10 km and relative humidity less than 80 percent—in Shenzhen has soared from 6 in the 1980s to 164 in 2006. In Hong Kong, the percentage of hours with low visibility—visibility less than 8 km and relative humidity less than 80 percent—has increased from about 4 percent in the 1990s to about 15 percent in 2006. Although the number of hazy days in Guangzhou decreased from 1997 to 2001, the number increased significantly from 65 in 2001 to 144 in 2004 (Wu et al. 2007).

This deterioration is caused by the coexistence of multiple pollutants, which also makes it difficult to determine the key control elements. Extremely hazy days are associated with high concentrations of aerosols, which are the solid or liquid form of particles suspended in the atmosphere (Wu et al. 2007). However, a multiple linear regression analysis, which was conducted to determine the relations between pollutant concentrations and monthly reduced visibility in Hong Kong, shows different results: monthly reduced visibility has little relation with PM_{10}, which is supposed to be the main cause of visibility degradation. Meanwhile, monthly reduced visibility is highly correlated with SO_2 and O_3. Thus, the complex chemical composition of the atmosphere in the GPRD region requires further research to understand the internal mechanisms and determine a control strategy.

EMISSIONS AND AIR POLLUTION: REGIONAL AND GLOBAL

As the variety and emission intensity of air pollutants increase continuously, the impact of emissions is no longer limited to a local area. The long-distance transportation of pollutants and precursors has enlarged the impact radius of local emissions to a regional and even global scale. Consequently, in order to improve air quality in the GPRD effectively, it is not enough to just understand the association between local emissions and pollution conditions. Rather, more attention should be paid to the regional transportation of essential pollutants and precursors.

The Hong Kong paradox

The Hong Kong government has been putting a great deal of effort into controlling regional smog and street-level air pollution, and local emissions of sulfur dioxide, nitrogen dioxide, and PM_{10} have been dramatically reduced (Figure 2). In 1990, annual emissions of SO_2, NO_x, and PM_{10} were about 140,000 tons, 180,000 tons, and 12,200 tons respectively. After sixteen years, the emissions have been reduced to 70,000 tons, 100,000 tons, and 6,000 tons, respectively.

After cutting local emissions almost in half, better air quality should be expected. However, the impact of these drastic reductions was rarely reflected by the local air pollutants concentration (Figure 1). On the contrary, the percentage of poor visibility days even actually increased dramatically since the 1990s (Figure 3). If not local emissions, what is dominating the continuous degradation of air quality in Hong Kong?

Could it be attributed to emissions from Guangdong Province? Though many researchers and Hong Kong citizens complain about this, it is not necessarily true. The GPRD region is dominated by East Asian monsoons, and about 70 percent of the winds in Hong Kong are from the ocean or the northeast part of Guangdong, which is less industrial than the PRD. In fact, the wind blew directly from Guangzhou/Shenzhen—a highly developed region in Guangdong—to Hong Kong for less than ten days out of the year. Thus, even though the airmass from Guangzhou/Shenzhen is full of pollutants, the direct transportation of this dirty airmass to Hong Kong is infrequent.

Figure 2 Trends in pollutant emissions in Hong Kong (1990-2006)

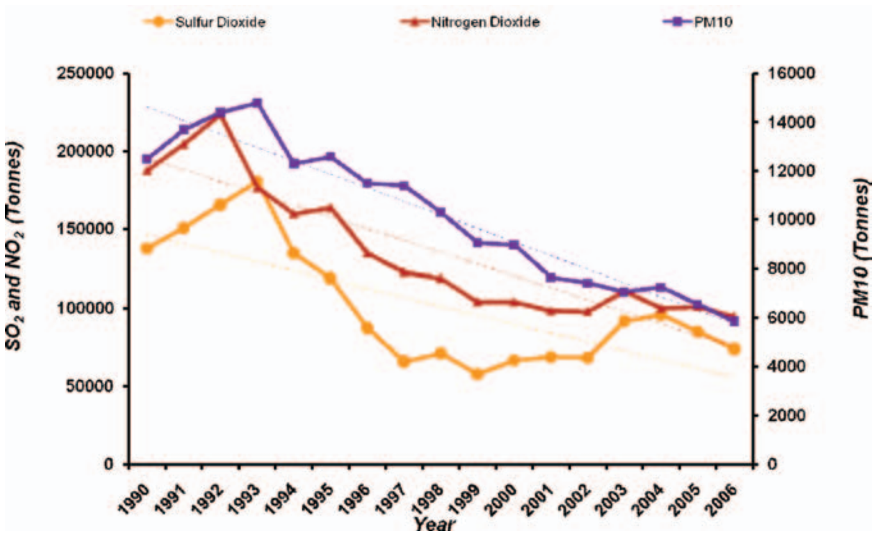
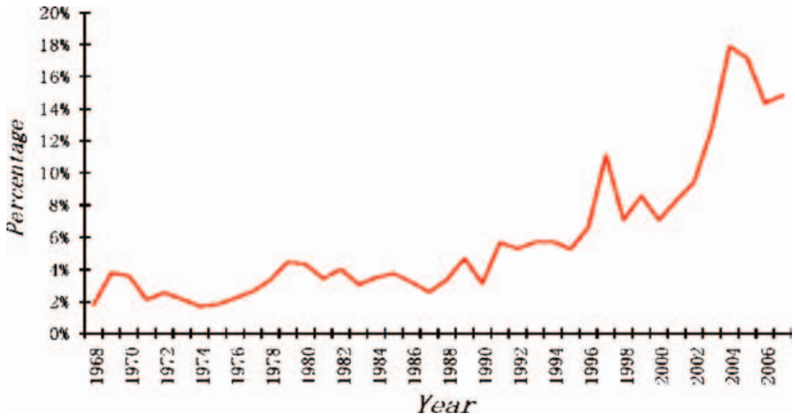


Figure 3 Trends in reduced visibility at the Hong Kong Observatory (1968-2007)



Source: Chan and Yao 2008

> *"In terms of air pollution, if you just conduct local control you will not be successful."*
>
> –John C.Y. Chan

Even if the impact from Guangdong Province is included, the dominant factor for air degradation in Hong Kong is still missing. To identify it, air mass transportation on a continental scale should be considered. With this reasoning, the increasing ozone concentration along the East Asian coast indicates that the impact of emissions from continental scale may be a crucial factor.

Ozone increases along East Asian coast

If the landmass upwind of Hong Kong is considered, all of the East Asian coast could be included in the source area. According to backward trajectory calculations, about 21 percent of the airmass is from the east coast pathway. Correspondingly, obvious increases of ozone concentration along the East Asian coast, such as Taiwan and Japan, have been reported (Chou et al. 2006; Lee et al. 1998). The annual average of daily maximum 1h ozone concentration increased about 2.6 percent yr^{-1} in Taiwan for the period of 1994-2003 and increased 2.5±0.6 percent yr^{-1} at Okinawa, Japan, for the period of 1989-1997 (Chou et al. 2006).

A possible hypothesis is that ozone precursors are transported and accumulate from north to south along the East Asian coast. Under this hypothesis, two factors could be explained: (1) the fastest rate of ozone increase was observed upwind of the GPRD region. This may be caused by the transportation of ozone precursors from the north. (2) when the airmass is transported from north to south, the higher ozone concentration tends to be formed in Hong Kong than that in Taiwan and Japan because of the higher temperature and radiation in Hong Kong.

Biomass burning in Southeast Asia

In Hong Kong, most ozone enhancement cases occur from February to early May, which corresponds to the period when biomass burning is most intensive in Southeast Asia. Biomass burning includes forest fires, grassland fires, agricultural waste burning in the field, and domestic biofuel use for cooking and heating. These fires are often initiated by humans, such as burning vegetation for land clearing, but biomass burning may also start naturally, such as the case of fires induced by lightning.[7]

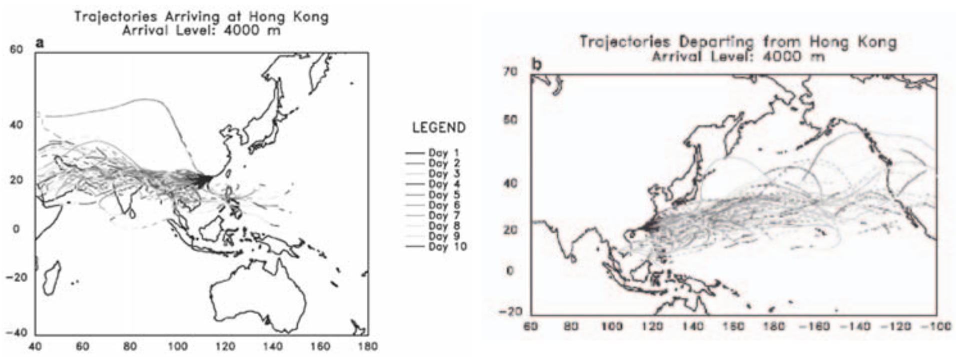
[7] http://earthobservatory.nasa.gov/Features/BiomassBurning/

The amount of burning is highly related to the location, season, and human activities. The severity of forest and grassland fires initiated by natural causes is determined by lightning, precipitation, and temperature. Crop residue burning, on the other hand, is determined by agricultural practices (Streets et al. 2003). India, Thailand, Laos, Cambodia and Vietnam are the major contributors of biomass burning in Southeast Asia, and these burning activities show obvious seasonal patterns. For example, in 1998 and 1999, the number of fires gradually increased starting in January, reached a peak in March, and then dropped dramatically in May. This period accounts more than 80 percent of the total fires annually.

During the same period, huge enhancement of ozone and aerosols could be observed in South China, even in the Tengchong, a remote mountain site in Yunnan. In addition, the enrichment of a biomass burning tracer, CH_3Cl, could be observed in the ozone-rich airmass (Chan et al. 2003). The results from a ten-day backward trajectory model show that before reaching the GPRD region, the airmass traveled across Southeast Asia from west to east, passing through regions with intensive biomass burning activities, such as India, Myanmar, and southwest China (Figure 4). Therefore it is believed that ozone enhancement in the GPRD in spring results from the intensive biomass burning activities in the Southeast Asia subcontinent.

Forward trajectories (Figure 5) also suggest that the emission of air pollutants in GPRD could affect the air quality on the other side of the world in a short time. In fact, pollutants from biomass burning in Southeast Asia, enhanced by local emissions from the GPRD region, can make the journey across the Pacific Ocean and reach North America within ten days. Thus, the transcontinental transportation of air pollutants makes it possible for local emissions to have a drastic impact around the world.

Figure 4 Ten-day (a) backward air trajectories reaching Hong Kong and (b) forward trajectories departing from Hong Kong at 4 km during ozone enhancement events from October 1993 to September 1999



Source: Chan et al. 2003

DATA AVAILABILITY, DATA QUALITY, AND INTERPRETATION

Even though the world has been paying close attention to China's air pollution issues, few people can get access to detailed air quality data. Data availability, as well as data quality, has become the biggest barrier for scientists and the public to understand China's air pollution problems.

The Chinese government has tried to be more open with information on the condition of China's environment, especially since the "Regulation on Government Information Openness" was approved in 2007. Daily air quality forecast data for sixty-nine important cities has been available online since 2005. These forecasts include the maximum and minimum Air Pollution Index (API), primary pollutants, air quality levels according to China's Ambient Air Quality Standards, and descriptions of the "Air Quality Situation."[8] In addition to the data published online, citizens can request more information by submitting application forms to the environmental protection agency within the local or central government, and the agency should respond within fifteen workdays.[9]

Some provincial governments have also launched initiatives to establish regional monitoring networks and publish the results online. In the case of the GPRD, the Guangdong Provincial Environmental Protection Monitoring Centre (GDEMC) and

[8] http://www.sepa.gov.cn/quality/airforecast/air_forecast.php

[9] http://www.gov.cn/flfg/2007-04/20/content_589673.htm

the Environmental Protection Department of the Hong Kong Special Administrative Region (HKEPD) have been working together to establish a PRD Regional Air Quality Monitoring Network since 2003. In this network, sixteen automatic air quality monitoring stations, including three regional stations, measure SO_2, NO_2, O_3, and PM_{10} continuously. The measurements are controlled by a set of quality assurance and quality control (QA/QC) operating procedures developed by the two governments. Monthly maximum and minimum hourly averages for all of the network's monitored pollutants have been reported to the public since 2005.[10]

[10] http://www.gdepb.gov.cn/gsgg/200710/t20071026_49978.html

Box 2: Manufacturers: Move or Stay?

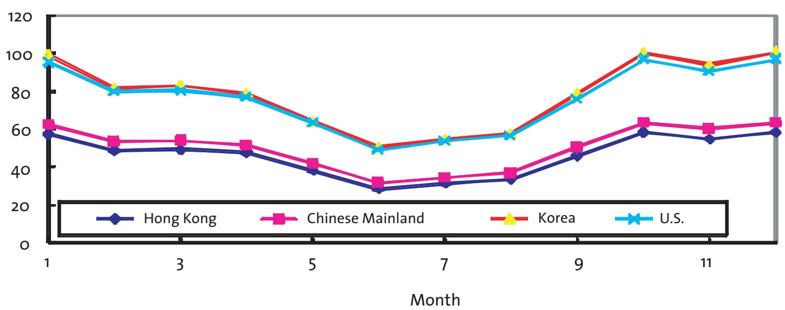
In order to improve air quality in the GPRD, emissions regulations in the region became much tougher than in most parts of China, especially more remote areas such as southwest China. Thus, many heavily polluting manufacturers could not afford to survive in the GPRD and moved to southwest China, where they have been welcomed in order to help with the development of the local economy.

By moving some of the most heavily polluting manufacturers to southwest China, local pollutant emissions within the GPRD could ideally be better controlled. However, the impact of the pollution from those manufactures is far from being eliminated. Through the same pathway demonstrated in Figure 4(a), emissions from southwest China can still affect the air quality in the GPRD. As a result, the situation in the GPRD may actually get worse, since southwest China has a strong desire for a booming economy and little incentive to control pollution, and thus emissions there tend to be much more severe. In addition, as manufacturers are scattered in remote areas, it is becoming more difficult to impose regulations on them.

However, detailed air quality monitoring data is still difficult to access in most parts of China, especially less developed areas. Without the permission of the local and central governments, data related to air pollution cannot be accessed, used, or published. Most of the local governments still treat air quality data as confidential and regulate it strictly. Thus, although more observation sites have be established nationwide, data from these sites still cannot be easily accessed by citizens, scientists, or even the other governments in the region. These restrictions might quell public blame temporarily, but they have killed initiatives and regional cooperation on the air pollution problem. Lack of information makes it very difficult for researchers to find an effective air pollution control strategy, especially in the context of increasing impacts from regional emissions.

Figure 5 Spatial distribution of the PRD Regional Air Quality Monitoring Stations

Figure 6 The monthly variations of PM-API in four different API systems in a general station of Hong Kong (2005-2007)



Most data published online is rough and veils the severity of the air pollution situation in China. For example, API values that are reported are usually not bad at all. Why does China's API provide a better image of China's air quality than what is happening in reality? Two facts are usually overlooked: (1) China has a very different API calculation system from those used in Korea and the United States. With the same air pollutant concentration, the PM-API numbers from different calculation systems do not match (Figure 6). The results from the Chinese mainland and Hong Kong systems are much lower than the results from the American and Korean systems (Figure 6); (2) The interpretation methods of API values in the Chinese mainland are different from those used in Hong Kong and the United States. The interpretation of the API number in the Chinese mainland is called the "Air Quality Situation," with categories such as Excellent, Good, Light Pollution, Low-level Pollution, Severe Pollution, etc. Hong Kong interprets API as "Air Pollution Level," while the United

States interprets it as "Levels of Health Concern." Hence, with an API number between 50-100, the interpretation in the Chinese mainland is that the Air Quality Situation is "good," while the rating would be a "high air pollution level" in Hong Kong and "moderate health concern" in the United States.

Table 1 Interpretations of the API in Hong Kong, the Chinese mainland, and the United States

API system of HK		API system of Chinese mainland		API system of U.S	
API	Air Pollution Level		Air Quality Situation		Levels of Health Concern
0-25	Low	0-50	Excellent（优）	0-50	Good
26-50	Medium				
51-100	High	51-100	Good（良）	51-100	Moderate
101-200	Very High	101-150	Light pollution（轻微污染）	101-150	Unhealthy for Sensitive Groups
		151-200	Low-level Pollution（轻度污染）	151-200	Unhealthy
201-500	Severe	201-250	Medium-level Pollution（中度污染）	201-300	Very Unhealthy
		251-300	Medium Level-severe Pollution（中度重污		
		301-500	Severe Pollution（重度污染）	301-500	Hazardous

Even if all the air quality data could be accessed freely, the quality of the data is another crucial concern. Because air pollution has not been included in the top issues on most local governments' agendas, and most of the detailed data is concealed from the public, there is little incentive for monitoring stations to stick to or improve quality assurance and quality control operating procedures. In addition to the absence of public oversight, financial support for more advanced equipment and experienced technicians is also urgently needed. In short, the Chinese government still has a long way to go to improve the quality and availability of data for the general public.

> *Technicians are considered "blue collar" workers. Few well-educated people are willing to become a technician for their permanent job.*
>
> –John C.Y. Chan

In closing, though many measures have been taken to tackle air quality degradation, the GPRD region still faces great challenges. How can they provide enough energy for ongoing industrialization and urbanization while preventing the public from exposure to toxic air pollutants? How can they evaluate the impact of local and upwind emissions? How can they collaborate with upwind provinces and countries to limit emissions of ozone precursors? These tough problems still remain in this region.

In order to tackle these challenges, scientists must work closely with governments to build a high-quality, long-term monitoring network, determine the critical areas and pollutants for a cohesive control strategy, and evaluate the appropriateness of control measures proposed by the government. Meanwhile, entrepreneurs, NGOs (non-governmental organizations), and citizens should be encouraged to participate in these efforts. Increasing air quality information transparency should be the first step for the government to move forward.

DISCUSSION

In the lecture, current scientific findings on the air pollution situation in the GPRD were summarized, and some lessons and experiences from previous and current pollution control practices were discussed. The questions of how to make good use of current knowledge and how to move forward to improve air quality in the GPRD region became the key points in the discussion session.

In order to tackle these questions, scientists and policy makers should work together. This cooperation requires efforts from both sides. On one hand, scientists should state the scientific facts clearly and comprehensively to draw the attention of policymakers, while applicable scientific research should be conducted to develop and evaluate solutions. On the other hand, policymakers should learn to live with both the findings and occasional uncertainties of science. Uncertainties are inherent to science and can make science difficult for policymakers to utilize. However, that should not be used as an excuse for denying suggestions for vital policymaking. Strategies with a long-term vision should be made based on risk analysis. Strategies without vision and careful analysis may lead to another situation like the LPG fuel dilemma in Guangzhou. One of the practical ways to encourage cooperation is to have more scientists involved in policymaking procedures.

Public participation should also be encouraged to help with environmental protection. Environmental protection used to be the obligation of the government, but that is no longer the case today. Citizens and corporations have been increasingly affected by environmental degradation. For instance, children's health has been threatened, and real estate corporations have lost customers. In other words, there are many stakeholders besides the government who have an incentive to support and work for environmental protection. They should be used more effectively. Government should gradually increase the transparency of air quality data and policy making procedures to build up public confidence and encourage public participation in decision making.

Finally, regional cooperation is vital because the impact of transboundary transportation has become increasingly important. It is no longer possible to control the degradation of air quality in Hong Kong by restricting local emissions. Although Hong Kong and Guangdong Province have initiated cooperation on air pollution monitoring, there are more challenges ahead for this process in other fields and on a larger scale: (1) For most governments, the priority of air pollution control is still very low, so the incentive for intergovernmental cooperation is not strong enough, unless economic benefits are provided. (2) The obligations of pollution control are difficult to determine. Research on transboundary transportation is still preliminary; reliable and quantitative analysis is expected. At this point, although people are drawing attention to the impact of transboundary pollution, few effective rules have been established. More actions should be taken to foster a more constructive conversation between governments, allowing them to tackle their air pollution issues together.

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