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WATER QUALITY: ITS PRACTICAL IMPLICATIONS TO SUSTAINABLE DEVELOPMENT IN THE PEARL RIVER DELTA, CHINA

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ABSTRACT

This paper reviews the interactions between water supply, surface water quality, environmental management and sustainable development in the Pearl River Delta. As an economic center of the Pearl River Delta, Hong Kong has to import about 80 % of its potable water from Dongjiang. Ironically, the factories, which are invested by Hong Kong residents are believed to be one of the major sources of water pollution to Dongjiang. The present paper critically reviews this dilemma, and suggests practical solutions for achieving the 'win-win' scenario in water resource management and sustainable development in the 21st Century.

KEY WORDS: Sustainable development, Point and non-point source pollution, Water Resource Protection, Cross-border environmental cooperation.

INTRODUCTION

Water is vital to life. According to historical records, big cities could not be sustainable if inhabitants were not able to find sufficient and adequately clean supplies of drinking water. Hence, water is often the prime limiting factor for the sustainability of a metropolitan or an economic region.

Pearl River Delta (PRD) is located in the southern China covering several highly populated cities like Hong Kong, Guangzhou, Macau and Shenzhen. Similar to other big economic regions in the world, the PRD is facing the challenges of sufficiency in water supply and purity of drinking water. The watershed of Pearl River and its tributaries totals 453,690 km^2 with an annual mean discharge of 333.8 billion m^3. Nevertheless, the main water resource in the delta the Pearl River is unlikely to support over 22 millions population and the fast-growing economy in the South China. Recently, the surge in population and urban development in the PRD has heightened the demand for clean, plentiful water. The rapid increase in population and economic activities, ironically, has simultaneously damaged the water resources by a severe deterioration in water quality.

WATER SUPPLIES IN PRD: THE PRESENT SITUATION

The average water consumption rate in the mainland side of the PRD is 0.344 m^3 $head^{-1}$ day^{-1} (Zhang and Wu, 1999). Comparatively, the annual water consumption rate in Hong Kong is a bit higher, at an average of 0.369 m^3 $head^{-1}$ day^{-1}. These water consumption rates, unfortunately,

are much higher than those of China as a whole (0.15 m^3 $head^{-1}$ day^{-1}), and the daily average of the South China Region (0.239 m^3 $head^{-1}$ day^{-1}). Solely on the basis of calculation, the annual water demand of the PRD is greater than 3.7 billion m^3. This is the typical character of a rapidly growth economic region, which is represented by high water consumption rates due to industrial and commercial usages. Simultaneously, the high water consumption rate in the PRD is an indicator for wastage, due to water-pipes leakage, low awareness in water consumption efficiency and lack of appropriate policies in water resources protection.

Water supply is one of the major challenges to the sustainability of the PRD. As reported, Guangdong is facing the problem of water shortage in the coming decades (Zhang and Wu, 1999; Wang and Zhou, 1999 and Liu, 1999). To this regard, the provincial government is searching for new water resources to support the need of increased population and economic activities in the 21th Century. While Dongjiang is still providing about 800 million m^3 $year^{-1}$ to Hong Kong, the international city is also worried about the sufficiency of potable water supply in the coming decades. Now, potable water is abstracted from Dongjiang, and is transported to Hong Kong through a semi-open channel. An agreement was signed between the authorities of Hong Kong and Guangdong in 1989 to increase the amount of Dongjiang water supply from 660 million m^3 $year^{-1}$ to 1100 million m^3 $year^{-1}$ until 2010. Nowadays, about 80% of potable water in the international city is imported. The unit cost of imported Dongjiang water amounts to HK$3.085 m^3. In 1999, the annual expenditure for buying in potable water totalled HK$ 1.9 billion excluding the cost of more than 151 million HK dollars in treating the imported water to acceptable drinking standards (Hong Kong SAR Legislative Council, 1999).

Hong Kong is still able to support about 20% of its domestic water supply. Of the about 500 kilometers of streams in Hong Kong, however, most of them are very steep and shallow near the coastal areas. Since 1852, Hong Kong has built several reservoirs for storage of rainwater for domestic supply. Hong Kong has also developed several world-class water treatment plants to purify water. As reported, Hong Kong is able to maintain its drinking water quality at WHO standards (HKSAR Legislative Council 1999). In the near future, Hong Kong still needs to rely on potable supply from Guangdong and so drinking water remains one of the limiting factors to the sustainability of Hong Kong as well as other parts of the PRD.

On the basis of calculation, less than 5% of the annual discharge of the Pearl River has been abstracted for potable and industrial purposes. In view of this, the present challenges to water supply can be overcome by proper enhancement in water resource planning and management. Nevertheless, due to hydraulic and distribution constraints the freshwater resources cannot be maximally used. As discussed later on, water supply in the PRD is further threatened by the problems of pollution.

THE WATER QUALITY DETERIORATING TREND

Due to increased social and economic activities in recent years, there is an obvious trend of water quality deterioration in the main stream as well as tributaries of the Pearl River (Zhang and Wu, 1999; Wang and Zhou, 1999 and Hui and Ho, 1999). Increasing concern over the health and epidemiological impacts has being raised by the general public (Citizens Party, 1999). According to statistics (Guangdong EPB 1999), about 51.5% of the monitored river sections in Guangdong Province were rated as Class III - Class V of the State Water Environmental Quality Standards (SWEQS) in 1998. That is, not more than half of the water resources in the Guangdong Province achieve Class I and Class II standards of the SWEQS, which are the environmental objectives for water 'suitable for potable supply after adequate treatment' (Guangdong EPB, 1999). As revealed, all the river sections draining through the urban and town areas of the PRD were classified as Class IV or Class V of the SWEQS (Guangdong 1999). Although the water quality in the river sections of upper Xejiang, northern Dongjiang and Shende showed an improving trend, other sections of the lower Pearl River remained unsatisfactory in environmental quality. The major deteriorating water quality parameters include: BOD, ammonical-nitrogen, fluorides, petroleum materials and faecal coliforms (Guangdong EPB, 1999). Hence, water contamination in the PRD is mainly related to domestic

sewage discharges and agricultural activities (such as animal husbandry) in the watershed. Contamination from industrial sources is generally under control, but risks of illegal discharges and further deterioration should not be overlooked.

Water quality deterioration in the lower sections of Dongjiang is confirmed by Hui and Ho (1999) and Ho and Hui (2000). Of their nine sampling locations at the main stream of Dongjiang, high level of BOD_5 and ammoniacal nitrogen, together with fairly low level of dissolved oxygen, were recorded in the river sections near Weizhou, Tangxia, Shangpu and Yantian. While the levels of organic pollution at Qiaotou, Sima and Matan were not obvious due to natural dispersal and dilution, the near to the urban areas of Weizhou and Shenzhen the higher the level of water contamination. As evident from the high levels of coliform bacteria in water samples, domestic sewage and animal husbandry are the major sources of pollution in the middle and lower sections of Dongjiang.

It is noteworthy that for most of the sampling locations, deteriorating trends in ammoniacal nitrogen and *E. coli* have been recorded since 1996.

Another survey on the river sediments by Ho and Hui (2000) confirmed the presence of trace amount of PCBs, PAHs and HCHs in surface (<10 cm) sediments (Fig.1). Moreover, apparently high levels of copper and zinc were found in Weizhou, where an industrial locality is surrounded by densely populated areas. While the levels of hydrocarbons and heavy metals were slightly decreased from Qiaotou to Matan due to natural dilution and dispersal, the levels of sediment contamination resumed in the river sections near Shenzhen. This suggests that industrial pollution is mainly related to the newly developed commercial and industrial areas. Therefore, higher priority of water pollution control should be given to these highly populated economic zones.

Contamination from agricultural chemicals, as evident from the HCHs levels in river sediments, worth concerns. Widespread use of agricultural chemicals and increased soil erosion in recent years are considered the main sources of these contaminants. It should be noted that water quality deterioration in the PRD is not only related to 'point-source' discharges, but also related to increases in 'non-point-source' contamination

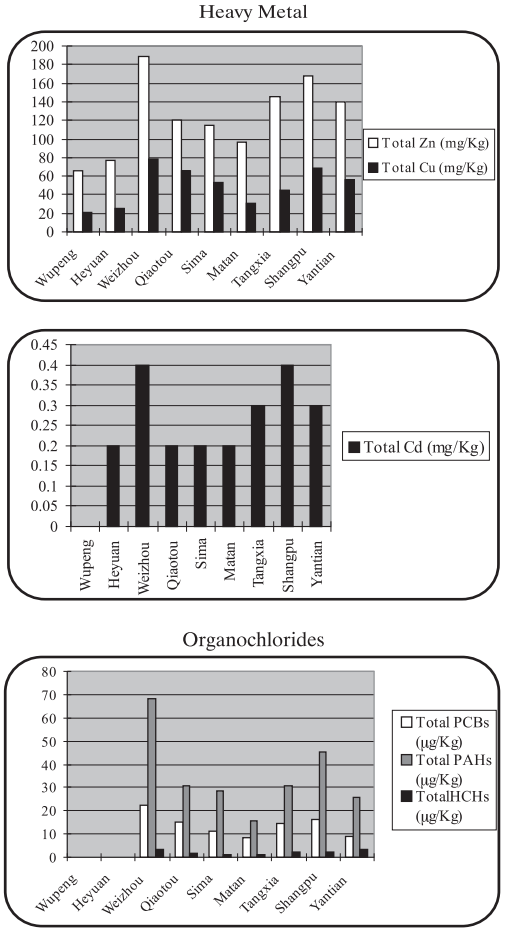

Figure 1. The results of Chemical analysis of Dongjiang sediments

recently. Ho and Hui (2000) confirmed this argument by comparing satellite images from early nineties to 1999.

ENVIRONMENTAL CONTROL MEASURES: A REVIEW

Environmental legislation

Water quality deterioration in the PRD may not attribute to the lack of environmental enthusiasms of the provincial and SAR governments. According to Government reports (Guangdong EPB, 1999; HKEPD 1999), various measures of environmental protection have been intensively implemented since the late eighties to maintain water quality for potable supply and ecological conservation. However, both the Provincial Government and the SAR Government recognized that resources were not sufficient for meeting the challenges from rapid increase in population and economic activities.

Table 1. Quantity of wastewater discharge in Guangdong
(Sources: Statistical Bureau of Guangdong, 1991, 1996-98; Smil and Yushi, 1998; Citizens Party, 1999 and Oriental Daily News, 20 September 1999)

	1990	**1995**	**1996**	**1997**
Total volume of wastewater discharged (million tons)	2512	3816.5	3714	4189
Overall Domestic Sewage	1100 (44%)	2124 (56%)	2122 (57%)	2935 (70%)
Estimated Domestic discharges from Dongjiang watershed	ND	ND	ND	686.2 (16.3%)
Overall industrial effluent	1402 (56%)	1692.5 (44%)	1592 (43%)	1263 (30%)
Estimated industrial discharges at Dongjiang watershed	ND	ND	ND	69.85 (1.7%)
Total volume of COD emission in wastewater (10,000 tons)	69.50	112.36	106.30	95.16
Overall rate of industrial wastewater treatment (%)	56.80	77.08	80.21	85.30
Estimated rate of industrial treatment in Dongjiang watershed (%)	ND	ND	ND	<10%
Rate of industrial wastewater recovered (%)	NA	43.41	49.79	45.0
Rate of industrial wastewater meeting discharge standards (%)	47.08	56.34	57.73	56.7
Total Number of wastewater treatment facilities	3336	10 347	10 391	5 259

ND: No data

Both governments have developed effective pollution control legislation in tackling water pollution. For examples, Hong Kong first implemented its Water Pollution Control Ordinance in 1986. Now, all (ten) water control zones are gazetted and regulated by licenses and prosecution. In the Guangdong side, the Pearl River Delta Water Protection Regulations were enacted in 1998 to protect the water resources in the PRD. Besides, in 1998 the provincial government implemented the Guangdong Province Environmental Protection Enforcement and Supervision Methods, the Guangdong Province Environmental Protection Regulating Documents Filing Methods and the Guangdong Province Environmental Protection Inspection and Enforcement Methods to strengthen the various regulatory measures. All of them help to protect and restore the water resources in Guangdong in a longer term.

Although very strict environmental legislation are being implemented in the past decades, the trend of environmental improvement is not as obvious as expected. This is also an outcome of the generally 'command and control' approach in water quality management (Ho, 1997 and Yan *et al*., 1997) and the lack of environmental awareness among the general public. It is worth the two governments to consider further measures to step up their programs in 'polluters pay' and environmental education/campaigns.

Municipal wastewater treatment

Domestic sewage remains the major source of water pollution. As shown in Table 1, Guangdong government is enthusiastic in upgrading its sewerage and sewage treatment facilities. The total vol-

ume of wastewater discharge in Guangdong had almost doubled from 1992 to 1997. Regrettably, more than 80% the sewage generated by Guangdong Province only received preliminary to primary level treatment before discharge. For the Dongjiang watershed, for example, only 6.4% of domestic discharges and not more than 10% of industrial effluents have received higher-level treatment before discharged.

As discussed, Guangdong Province is committed to upgrading its sewage treatment facilities but the provincial government is constrained by the lack of financial support and generally low environmental awareness among the general public.

For the Hong Kong side, 6.4% and 9.0% of the watercourses in New Territories were classified as 'vary bad' and 'bad' respectively on the basis of the Dutch Water Quality Index (HKEPD, 1999). Further improvement of river water quality relies on upgrading the sewerage systems and the full implementation of the Strategic Sewage Disposal Scheme (SSDS).

Industrial wastewater treatment

The towns and villages of the PRD are dominant with small scale, labour intensive industries. For Guangdong Province, the total industrial discharge in 1997-8 was 1.177 billion m^3. Out of them, 89.2% were treated before discharged into nearby water-bodies. This reflects the environmental efforts of the Guangdong authorities. Unfortunately, the compliance to industrial wastewater treatment regulations was only 61.6% in 1997-8, indicating the urgency in upgrading industrial treatment facilities in the coming years. The major polluting industries in the PRD include: chemical and biochemical products manufacturing, petrochemicals, printed circuit board, bleaching, dyeing, pulp and paper, pharmaceuticals, electroplating and food processing (Guangdong Statistical Bureau, 1998).

According to field investigations, chemical contaminations in Dongjiang are closely associated with small-scale factories located along the river banks (Hui and Ho, 1999 and Ho and Hui, 2000). The level of effluent treatment in these small factories is usually very primitive. Similar to the Dongjiag watershed, environmental law compliance in the central areas of Guangzhou, Fushan, Shenzhen and Dongguan are relatively poor (Guangdong EPB 1998, 1999). Therefore, one of the great challenges to the Guangdong Province is to strengthen its ability in law enforcement and industrial control. Priority should not only being given to factories in big cities, but also small-scale industries in towns and villages.

For the Hong Kong side, there is a need to continue its present efforts in tackling illegal discharges and improving sewage treatment facilities, although most of the manufacturing industries in the international financial center have been moved to the PRD.

Non-point-source pollution

Agriculture remains an important component of the economy in Guangdong Province. As discussed above, agricultural runoff is one of the major sources of 'non-point' chemical contamination. A report by the Citizens Party (1999) stated that from 1986 to 1989, the market of chemical fertilizers in China increased by 40% (quoted from Smil and Yushi, 1998). It was estimated that more than 170, 000 ton $year^{-1}$ (142,000 ton in wet season and 30,000 ton in dry season) of total inorganic nitrogen (TIN) were discharged into the Pearl River through surface runoff and soil erosion.

Similar to other countries which are affected by severe soil erosion and surface runoffs, water quality deterioration in the PRD are also closely associated with intensive transport development, housing estates construction and deforestation. The tree coverage rate in Guangdong amounted to 56.6% in 1998. In recognition of the loss of tree coverage in the urban and suburb areas, Guangdong Province has implemented an intensive program in tree-planting in the PRD as well as other parts of the Province. Only in 1998, 22.9 million hectares of land in Guangdong were restored for tree-planting and prevention of soil erosion. This indicates the severity of soil erosion and the efforts of land protection in the past decades.

WATER QUALITY MANAGEMENT AND SUSTAINABLE DEVELOPMENT IN THE PRD

Sustainable development policies

Academics and government officials recognize that water quality management in the PRD should be reviewed and planned under the scope of sustainable development (Hills *et al*., 1998; Ho and Man, 1998; The Policy Address of the Chief

Executive of HKSAR, 1999 and Guangdong EPB 1999). The conceptual components of sustainable development as we comprehended include:

(1) Finding ways to increase prosperity and improve the quality of life while reducing overall pollution and waste;
(2) Meeting our own needs and aspirations without doing damage to the prospects of future generations; and
(3) Reducing the environmental burden we put on our neighbors and helping preserve common resources.

Practically, sustainable development should be implemented on the basis of:

(1) an integrated approach in social, economic and environmental developments,
(2) widespread public participation and community actions,
(3) equity,
(4) attractive environmental incentives, (such as the Polluters Pay Principle and environmental taxes), and
(5) win-win scenarios among different stakeholders.

As discussed, water is vital to life and is closely related to the sustainability of Hong Kong and the other parts of the PRD. Taking Dongjiang as an example, over 50% of the polluting industries in the Dongjiang watershed are invested by Hong Kong residents (personal research based on the Statistic Year Books, published by the Guangdong Statistic Bureau 1991-1998). Ironically, the contaminated water of Dongjiang is abstracted and imported to Hong Kong for the residents' consumption. In light of this, it is not only the responsibility of the Guangdong government, but also that of the Hong Kong residents to ensure the healthy status of the water system. It is an urgent need to protect the water resources in Guangdong such that the status of 2nd Class Standards of SWEQS can be properly maintained. In particular, the general public should be educated on efficient use of water and appropriate methods in ecological conservation. Moreover, industrial and business sectors should develop their corporate environmental culture and environmental management systems to enhance environmental performance.

Undoubtedly, government officials should take the lead in formulating and implementing sustainable development policies. A joint government body, namely the Hong Kong - Guangdong Environmental Protection Liaison Group, has been established since 1990 to deal with cross border, collaborative environmental issues. However, during the past years, the Liaison Group had produced only limited progress on conservation of the Chinese White Dolphin, air quality monitoring in the PRD and environmental management of Deep Bay. Resource deployed to deal with drinking water quality is obviously insufficient. Recently, increased voices have been evolved from politicians and green groups (Citizens Party, 1999; Green Power, 1999 and Green Peace, 1999) for establishing a higher level inter-governmental body to look after matters in sustainable development in the PRD. In response to this, a 'Joint Working Group on Sustainable Development and Environment Protection' between Hong Kong SAR and Guangdong Province was initiated by the SAR Chief Executive's 1999 Policy Address. We have a high expectation on the Joint Working Group and hope that Hong Kong SAR and Guangdong Province could step up their environmental measures in protecting water resources in the PRD. We also expect that more discussions will be taken to streamline the environmental law and environmental management systems between the two economically inter-dependent areas. It is anticipated that a unified body should be established in the near future to combat problems of unplanned land development, wastewater treatment and purification of potable water.

In view that Guangdong is short of financial resources in building more wastewater treatment plants, the comparatively wealthy Hong Kong should consider mechanism in injecting money and facilities in assisting the Guangdong government for advance environmental infrastructures. The most recent case is that the Legislative Council of Hong Kong SAR approved a HK$2,364 million loan to Guangdong for building a closed water duct in protecting the environmental quality of imported water. The loan will be drawn in eight payments, one in every six months, and the Guangdong government shall repay the loan in 20 annual installments of HK$118,200,000 each, starting from the commissioning of water quality improvement project or year 2003, whichever is the earlier. This project is a good example of cross-border cooperation and 'win-win' scenario in sustainable development. While Hong Kong has an enormous stake in protecting

the Dongjiang watershed, Guangdong is able to reduce its financial constraints by the injection of the no-interest loan. We deeply hope that this cooperative relation can be extended to solve the other common concerns of environmental protection in the PRD.

Public participation is an essential component for sustainable development. Academics argued the need for establishing a platform for public consultation on common environmental interest in the PRD (Hills *et al*., 1998 and Ho and Man 1998). In order to absorb views from various professionals, stakeholders and the general public, it is a priority job for the two governments to explore the possibility of establishing a cross-border, public consultation body like the SAR's Advisory Council on the Environment (ACE).

Technical strategies

To enhance efficient use of water resources, the following technical strategies are recommended:

1. Reduce water consumption: mainly through imposing higher water consumption rate in Guangdong Province and the sewage charges in both places.
2. Reduce agricultural water consumption, and the associated soil erosion: mainly through the introduction of advanced irrigation system. As noted, this would reduce water consumption for a maximum of 20% and would prevent further contamination by soil runoff (Liu, 1999).
3. Development of Environmental Management System (EMS) in corporations: this will improve corporate culture in environmental quality, energy and water efficiency, environmental auditing and reporting, ecolabeling and environmental impact assessment.
4. Separation of water supply and drainage systems: this is able to help improving water quality in the Guangdong Province (this policy is being implemented in Hong Kong SAR).
5. Reuse of 'grey water': this is able to increase water reserve and to prevent further water quality deterioration in the lower streams.
6. Integrated river management system: this complies with the 'integrated approach' in sustainable development. In particular, the water system can be better managed for potable abstraction, agriculture, aquaculture, passive recreation and drainage purposes through innovative environmental planning.
7. Implementing Sustainability Impact Assessment (SIA): the present project-based and strategy-based EIA should be extended in to cover widespread ecological impact assessment (i.e. more than a checklist of affected habitats and species), social impact assessment, health impact assessment, environmental risk assessment, and policies impact assessment. In essence, an integrated approach should be taken to integrate ideas in economic development, transport, housing, community development and social justice during feasibility and planning stages.

SUMMARY

The present paper reviews the causes and effects of water resource damage in the PRD. By the use of examples in Dongjiang in particular, it is revealed that water quality deterioration is closely related to insufficiency in environmental protection facilities, malfunctioning of wastewater treatment facilities, poor compliance in environmental law, lack of environmental awareness, lack of environmental planning and coordination and, the generally short of money in implementing environmental measures. With an insight over sustainable development, the present paper suggests 'win-win' scenarios to be established between Guangdong and Hong Kong. The recent example is the allocation of loan to Guangdong for building a water drain of Dongjiang. Towards the 21st Century, more cooperative relations should be established between the governments of Guangdong and Hong Kong. Besides, advanced technological solutions and environmental management strategies should be introduced under the lights of widespread public participation and sustainability impact assessment.

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