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RESEARCH ARTICLE

Impact of anthropogenic activities on urban stream water quality: a case study in Guangzhou, China

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Abstract Anthropogenic activities are increasingly impacting the quality of urban surface water, particularly in regions undergoing intensive urbanization, such as Guangzhou of South China with a large urban stream network. To examine such impacts, we conducted field sampling on December 24, 2010, May 24, 2011, and August 28, 2011, representative of the low-, normal-, and high-flow periods, respectively. The first sampling was timed immediately after the closing of the 16th Asian Games (November 12–27, 2010) and the 10th Asian Para Games (December 12–19, 2010) held in Guangzhou. Assessments based on a pollution index method showed that the urban streams under investigation were extremely polluted, with direct discharge of untreated domestic sewage identified as the main pollution contributor. In addition, stream water quality around urban villages with high population densities was worse than that within business districts away from the urban villages. Pollution control measures implemented in preparation for the Asian Games were effective for urban streams within the business districts, but less effective for those adjacent to the urban villages. However, short-term efforts may not be able to achieve sustainable urban water quality improvements. In the case of Guangzhou, minimizing or even eliminating direct point-source inputs to the urban streams is perhaps the best option.

Keywords Water quality · Urban stream · Urban village · Anthropogenic activity · Asian Games · Guangzhou

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Introduction

Water quality is considered one of the main factors impacting ecosystems and human health (Kazi et al. 2009), and is affected by a combination of natural and anthropogenic events (Bu et al. 2010; Huang et al. 2011). Rapid economic development and population growth have resulted in deterioration of worldwide water quality (Smith 2003; Ghadouani and Coggins 2011; Ahuja 2014). In particular, water quality in urban rivers or streams is under increasing stress because of fast population growth within metropolitan centers (Pekey et al. 2004; Chang 2005; Singh et al. 2005; Azrina et al. 2006; Duha et al. 2008; Spring 2011; Huang et al. 2012; Furlan et al. 2013). In China, rural-to-urban migration and expansion of urban centers have been under way over the last three decades, creating a number of unprecedented urban water quality issues. The severity of urban water quality has threatened the sustainability of economic growth and maintenance of high quality of life.

A typical example of anthropogenic impacts on urban water quality can be found in the city of Guangzhou, which is the capital of Guangdong Province and is located in the center of the Pearl River Delta (Fig. S1 of the Supplementary material; "S" designates tables and figures in the Supplementary material thereafter). Guangzhou has a total area of 7,430 km^2 and a population of 12.7 million in 2011, and also houses a large watercourse network consisting of 231 streams in the main urban districts, with a total length of 913 km (Qiu et al. 2009). The urban water quality of

Guangzhou has been deteriorating in the past 30 years (Ouyang et al. 2006; Dong and Mei 2008), and has been a great public health concern. Local governments and experts have been striving to take steps toward better water pollution control and environmental management. During the long-lasting process of economic development and urbanization in Guangzhou, a new type of urban neighborhood, called urban village (detailed in the Supplementary material), has emerged; a total of 138 urban villages have gradually formed within the city territory (Liu et al. 2010; Lin and De Meulder 2012). In addition, the 16th Asian Games (http://en.olympic.cn/games/asian/2011-02-11/2125066.html) and 10th Asian Para Games (http://www.ibsa-sports.org/calendar/228/10th-asian-para-games) were held in Guangzhou on November 12–27 and December 12–19, 2010, respectively. A large number of pollution control measures were implemented in preparation for these games, which exerted heavy human interferences with the environment. As a result, Guangzhou could serve as a good case study for understanding the impact of anthropogenic activities on urban stream water quality.

Given the above perceptions, the present study was conducted to (1) examine the urban stream water quality of Guangzhou, (2) analyze the effects of urban villages on the urban streams of Guangzhou, and (3) assess the effects of human efforts to improve urban stream water quality for the Asian Games. The results are expected to be useful for developing effective water pollution control measures and long-term strategies for future water management, which will benefit not only Guangzhou but also other places of China.

Materials and methods

Field sampling

Water samples were collected from 17 streams and two man-made lakes throughout the main districts of Guangzhou, i.e., streams of Xinshi (R1), Shijing (R2), Tangxia (R3), Chebei (R4), Shen (R5), Ruibao (R6), Liwan (R7), Haizhu (R8), Donghao (R9), Shahe (R10), Liede (R11), Wu (R12), Huangpu (R13), Shiliugang (R14), Xilu (R15), Beihao (R16), and Huadi (R17) and Baiyun Lake (L1) and Haizhu Lake (L2) (Fig. S1). Streams of R1 to R6 are located around urban villages, whereas other sites are within business districts and away from urban villages.

Sampling was conducted on December 24, 2010, May 24, 2011, and August 28, 2011, representative of the low-, normal-, and high-flow periods, respectively, during neap tides and approximately 1 h before the intra-day low tides to avoid tidal influences (Ni et al. 2008). Water was taken from 0.5 m below the air–water surface, middle of the water column, and 0.5 m above the sediment bed, with a stainless-steel submersible pump to constitute one composite sample. Composite lake water samples were also collected at the approximate centers of Baiyun and Haizhu lakes using the above procedures. During each sampling cycle, water was pumped for 5 min before actual samples were collected into pre-cleaned white polyethylene plastic barrels, which were rinsed three times with field water beforehand. At the same time, nitric acid (HNO_3) was added to samples upon collection till pH <2 for measurement of heavy metals. All the samples in plastic barrels were cooled with ice in foam boxes and then transported to the laboratory where they were processed within 24 h.

Sample analysis

Physicochemical parameters pH, dissolved oxygen (DO), chemical oxygen demand (COD_{cr}), 5-day biochemical oxygen demand (BOD_5), total nitrogen (TN), and total phosphorous (TP) were measured in the present study. In addition, eight heavy metals, i.e., arsenic (As), selenium (Se), cadmium (Cd), chromium (Cr), nickel (Ni), copper (Cu), lead (Pb), and zinc (Zn) were also selected for assessments.

Water samples were filtered with a vermicular system, and total suspended solids were retained by GF/F glass fiber filters (Whatman International, Maidstone, England). A portion (5 mL) of filtrates for every sample was used for measurement of heavy metals with an Agilent 7700x ICP-MS (Santa Clara, CA, USA). Values of pH and DO were recorded in situ using a multi-parameter water quality monitoring instrument (YSI, Yellow Springs, OH, USA), which was calibrated prior to use. Contents of COD_{cr}, BOD_5, TN, and TP were determined with standard method procedures (Chinese State Environment Protection Bureau 2002). In addition, water samples not analyzed immediately were stored at 4 °C in darkness.

Data analysis

The National Surface Water Environment Quality Standards of China (GB3838-2002) (Table S1) were used for water quality assessment. In addition, a more comprehensive assessment tool, i.e., pollution index (PI) (Zhao et al. 2010) based on water pollution classification criteria (Table S2), was also used to derive integrated assessment results. The value of PI was estimated by

$$\mathrm{PI} = \frac{1}{n}\sum_{i=1}^{n}\frac{Ci}{Si} \qquad (1)$$

where C_i and S_i are the measured and standard values of the ith parameter and n is the number of parameters used. In the present study, DO, COD_{cr}, BOD_5, TN, and TP were the assessment parameters, whereas Grade III values of the National Surface Water Environment Quality Standards of China (GB3838-2002) were used as the water quality standards.

Similar application has been reported in previous studies (Ouyang et al. 2006; Zhao et al. 2010). All statistical analyses were executed with SPSS 18.0 (Chicago, IL, USA).

Quality assurance and quality control (QA/QC)

Two bottles (~20 L each) of purified water were carried to the sampling sites and left open during each sampling period. These samples, labeled as field blanks, were processed in the same manner as the field samples. Procedural and laboratory blanks were also processed with each batch of less than 15 samples. Besides, a standard solution was analyzed for every 15 samples to monitor possible instrument shifts for heavy metals. The concentrations of heavy metals were calibrated with internal standards (Sc, Ge, Rh, In, and Bi at 1 mg L^{-1}). The detection limits for As, Se, Cd, Cr, Ni, Cu, Pb, and Zn were 0.02, 0.02, 0.005, 0.33, 0.02, 0.49, 0.46, and 0.91 μg L^{-1}, respectively. All the samples were analyzed in triplicate and the average of three measurements was reported as the final result.

Results and discussion

Occurrence of the target analytes

Concentrations of DO, COD_{cr}, BOD_5, TN, and TP in urban streams of Guangzhou were in the ranges (mean) of 0–6.0 (2.7), 16–97 (42), 5.1–49 (19), 4.7–28 (13), and 0.24–5.3 (1.1)mg L^{-1}, respectively, while pH values ranged from 6.7 to 7.7 (7.1) (Table S3). Specially, higher concentrations of COD_{cr}, BOD_5, TN, and TP appeared in the urban streams around urban village, with the average values of 59, 29, 18, and 2.1 mg L^{-1}, respectively. The lowest concentration (0 mg L^{-1}) of DO and highest values of COD_{cr}, BOD_5, TN, and TP (97, 49, 28, and 5.3 mg L^{-1}, respectively) were observed in R3, indicating that R3 was the most polluted stream in the region. In addition, values of COD_{cr}, BOD_5, TN, and TP in the man-made lakes were in the ranges of 20–25 (23), 7.1–9.0 (7.8), 6.2–8.8 (7.3), and 0.19–0.36 (0.28) mg L^{-1}, generally lower than those in the urban streams.

In addition, concentrations of As, Se, Cd, Cr, Ni, Cu, Pb, and Zn were in the ranges (mean) of 1.4–38 (4.7), 0.19–15 (1.7), 0.02–5.2 (0.34), 0.44–11 (2.0), 2.1–65 (12), 1.2–139 (16), 0.61–34 (3.7), and 2.5–338 (37)μg L^{-1}, respectively, which were slightly greater than those in man-made lakes, i.e., 1.5–5.3 (3.1), 0.68–4.2 (1.4), 0.02–0.15 (0.06), 0.38–2.7 (0.92), 4.8–26 (13), 1.6–7.5 (4.3), 0.67–2.9 (1.4), and 2.7–21 (8.9)μg L^{-1} (Table S3). However, the concentrations of As, Se, Cd, Cr, Ni, Cu, Pb, and Zn within the urban villages were in the ranges (mean) of 1.6–38 (6.2), 0.19–15 (1.8), 0.02–5.2 (0.43), 0.44–11 (2.3), 2.6–65 (12), 1.2–139 (22), 0.74–34 (5.2), and 4.2–338 (56)μg L^{-1}, respectively, which were comparable to those in the urban streams not around urban villages, i.e., 1.4–7.9 (3.9), 0.33–9.1 (1.6), 0.02–2.8 (0.30), 0.52–5.5 (1.8), 2.1–28 (12), 1.2–86 (12), 0.61–18 (2.8), and 2.5–86 (27)μg L^{-1}, respectively.

Generally, COD_{cr} concentrations in the urban streams of Guangzhou were greater than those in rivers of the Pearl River Delta (Fan et al. 2010), Jinshui River (Bu et al. 2010), Qiantang River (Su et al. 2011), Yangtze River (Müller et al. 2008), and Songhua River (Wang et al. 2013) of China, Gomti River (India) (Singh et al. 2005), Fuji River (Japan) (Shrestha

Table 1 Concentration range (mean value) of selected water quality parameters in worldwide rivers

Worldwide rivers	COD	BOD_5	TN	TP	Reference
Urban streams (Guangzhou, China)	16–97 (42)	5.1–49 (19)	4.7–28 (13)	0.24–5.3 (1.1)	The present study
Rivers in Pearl River Delta (China)	1.0–7.7	0.25–23		0.04–0.67	Fan et al. (2010)
Jinshui River (China)	0.65–4.4 (2.0)	0–4.6 (1.5)	0.01–4.4 (0.5)	0.03–4.3 (0.06)	Bu et al. (2010)
Qiantang River (China)	1.1–13 (3.3)	0–8.4 (2.1)		0–0.69 (0.11)	Su et al. (2011)
Yangtze River (China)			1.4–3.5 (2.0)	0.04–0.22 (0.08)	Müller et al. (2008)
Songhua River (China)	15–73 (29)	2.6–23 (7.4)		0.14–1.6 (0.45)	Wang et al. (2013)
Gomti River (India)	2.6–76 (20)	0.8–36 (8.4)	3.0–5.5(3.9)	0.06–0.49 (0.27)	Singh et al. (2005)
Han River and its tributaries (Korea)	3.7–51 (17)	2.1–96 (28)	3.0–27 (12)	0.1–39 (1.2)	Chang (2005)
Langat River (Peninsular Malaysia)	52–233 (127)	1.3–2.6 (1.8)			Azrina et al. (2006)
Rivers in Juru River basin (Malaysia)	36–85 (59)	1.3–6.1 (4.1)			Al Shami et al. (2011)
Pisuerga River (Spain)	0.7–10 (3.9)	1.5–6.5 (3.2)			Vega et al. (1998)
Chillan River (Central Chile)	1.2–189 (16)	0.9–64 (5.2)			Debels et al. (2005)
Pardo River (Brazil)	2.0–64 (17)	1.1–11 (4.3)	1.3–13 (4.3)	0.52–7.5 (2.2)	Da Silva and Sacomani (2001)
Fuji River (Japan)	2.0–4.6 (3.0)	0.74–3.1 (1.7)			Shrestha and Kazama (2007)

COD chemical oxygen demand, *BOD_5* 5-day biochemical oxygen demand, *TN* total nitrogen, *TP* total phosphorous (unit, mg L^{-1})

Table 2 Pollution index in the urban streams of Guangzhou through the sampling period

Site[a]	December 24, 2010[b]	May 24, 2011[b]	August 28, 2011[b]	Mean
R1	9.59	12.3	11.5	11.1
R2	6.83	5.86	4.75	5.81
R3	15.5	15.2	8.44	13.1
R4	10.2	7.86	6.54	8.18
R5	11.8	7.64	6.70	8.72
R6	9.93	11.5	7.61	9.67
R7	2.61	4.07	2.04	2.91
R8	4.57	4.02	3.57	4.06
R9	2.70	4.67	3.01	3.46
R10	3.17	6.64	4.37	4.72
R11	3.33	7.50	4.57	5.13
R12	5.62	3.96	2.98	4.19
R13	4.32	7.26	4.03	5.20
R14	4.02	2.94	2.48	3.15
R15	4.01	5.25	3.50	4.25
R16	5.37	6.89	4.31	5.53
R17	4.56	3.87	2.81	3.75
L1	4.24	3.29	2.75	3.43
L2	4.74	3.74	3.08	3.85

[a] The sampling sites are labeled as Xinshi (R1), Shijing (R2), Tangxia (R3), Chebei (R4), Shen (R5), Ruibao (R6), Liwan (R7), Haizhu (R8), Donghao (R9), Shahe (R10), Liede (R11), Wu (R12), Huangpu (R13), Shiliugang (R14), Xilu (R15), Beihao (R16), Huadi (R17), Baiyun Lake (L1), and Haizhu Lake (L2)

[b] December 24, 2010, May 24, 2011, and August 28, 2011 were representative of the low-, normal-, and high-flow periods, respectively

and Kazama 2007), Han River and its tributaries (Korea) (Chang 2005), Pisuerga River (Spain) (Vega et al. 1998), Chillan River (Central Chile) (Debels et al. 2005), and Pardo River (Brazil) (Da Silva and Sacomani 2001), but lower than those in Langat River (Azrina et al. 2006) and five rivers in the Juru River basin (Al Shami et al. 2011) of Malaysia (Table 1). In addition, concentrations of BOD_5 in the present study were only lower than those in Han River and its tributaries of Korea (Chang 2005), while concentrations of TN and TP were similar to those in Han River and its tributaries. On the other hand, concentrations of TN were higher than those in Jinshui River (Bu et al. 2010), Yangtze River (China) (Müller et al. 2008), Gomti River (India) (Singh et al. 2005), and Pardo River (Brazil) (Da Silva and Sacomani 2001). Finally, concentrations of TP were higher than those in the rivers of the Pearl River Delta (Fan et al. 2010), Jinshui River (Bu et al. 2010), Qiantang River (Su et al. 2011), Yangtze River (Müller et al. 2008), Songhua River (Wang et al. 2013), and Gomti River (Singh et al. 2005), but lower than that in Pardo River (Da Silva and Sacomani 2001). All these results indicated that the levels of the water quality parameters in urban streams of Guangzhou were at the high end of the global range.

Spatial and seasonal variability of water quality parameters

A comparison with the National Surface Water Environment Quality Standards of China (GB3838-2002) (Table S1) indicated that 33 % of DO, 41 % of COD_{cr}, 61 % of BOD_5, 100 % of TN, and 76 % of TP values exceeded the acceptable thresholds for Grade V water quality (2, 40, 10, 2, and 0.4 mg L^{-1}, respectively). On the other hand, the levels of the target heavy metals were all below the acceptable thresholds for Grade V water quality. In fact, 98 % of all heavy metal concentrations were even lower than the thresholds for Grade II water quality. In addition, all the samples had PI values

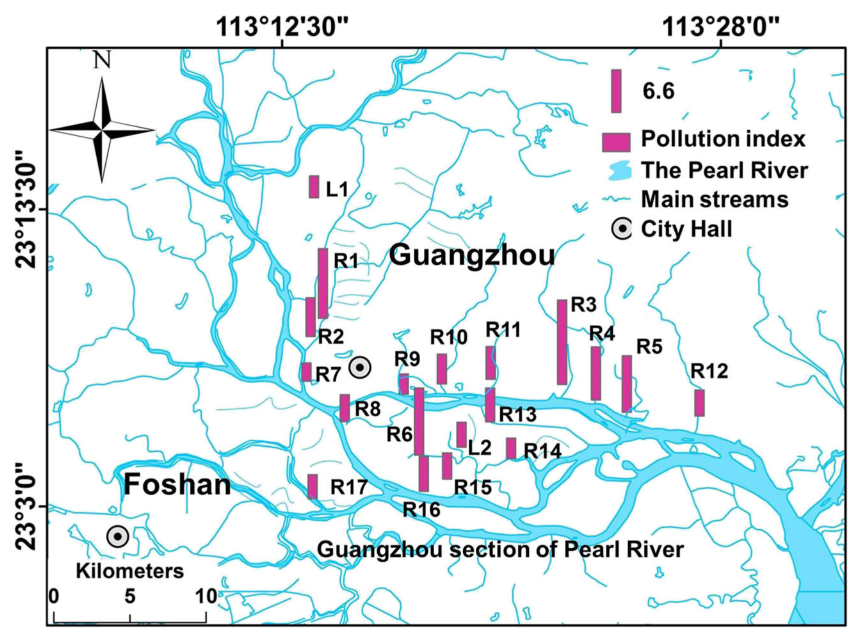

Fig. 1 Spatial distribution of pollution index on water quality of urban streams in Guangzhou, China. Streams: Xinshi (*R1*), Shijing (*R2*), Tangxia (*R3*), Chebei (*R4*), Shen (*R5*), Ruibao (*R6*), Liwan (*R7*), Haizhu (*R8*), Donghao (*R9*), Shahe (*R10*), Liede (*R11*), Wu (*R12*), Huangpu (*R13*), Shiliugang (*R14*), Xilu (*R15*), Beihao (*R16*), Huadi (*R17*); lakes: Baiyun Lake (*L1*), Haizhu Lake (*L2*)

greater than 2.0 (Table 2), the highest threshold of the water pollution classification criteria (Table S2), suggesting that the urban streams under investigation were extremely polluted. Furthermore, the annual mean value (9.43) of PI for sites R1–R6 within urban villages was more than twice that (4.21) for other sites (R7–R17; Fig. 1), reflecting stronger impacts of anthropogenic activities on urban stream water quality within urban villages than those distant from urban villages. On the other hand, water quality in the man-made lakes (mean value of PI, 3.64) was better than that in the urban streams (mean value of PI, 6.05).

Seasonally, water quality was generally the best during the high-flow period (mean value of PI, 4.90) (Table 2), apparently due to the dilution effects by precipitations. However, water quality was better during the low-flow period (mean PI, 6.36) than during the normal-flow period (mean PI, 6.91), probably because strict management measures were still tightly reinforced right after the 16th Asian Games and 10th Asian Para Games held in November 12–27 and December 12–19, 2010, respectively (our first sampling was conducted on December 24, 2010). More discussions about the effects of the pollution control measures in preparation for these games will be presented later.

Evolving patterns of pollutant input sources in Guangzhou

Rapid economic development in Guangzhou has resulted in a substantial increase of population (Fig. 2a), as farmers have flocked into the city to seek high-income jobs. Consequently, the amounts of wastewater (domestic sewage and industrial effluent combined) generally increased during the same period (Fig. 2b). At the same time, the capacity of wastewater treatment has greatly lagged behind the population increase (Dong and Mei 2008). As a result, large amounts of untreated wastewater have been directly discharged into urban streams. Existing data suggested that the amounts of industrial wastewater discharged have generally declined during the last 20 years, despite a spike in 2008 (Fig. 2b). It is interesting to note that the capacity of industrial wastewater treatment has continuously increased during the same time period (Fig. 2c). Therefore, the amounts of untreated industrial wastewater are expected to decrease at a fast pace, and in fact industrial discharge may have become an insignificant source of pollution to urban streams. Because Cd and Pb are known markers of chemical and tannery plants (Owen and Sandhu 2000) and electronic industries (Pekey 2006), the low levels of these metals in the present study (below the Grade II thresholds of China) suggested that industrial wastewater may have become an insignificant contributor to the pollutant loads in urban streams of Guangzhou. A previous study conducted in 2009 (Luo 2011) also obtained lower concentrations of heavy metals (As, Se, Cd, Cr, Cu, Pb, and Zn) in four urban streams (R3, R4, R11, and another stream of Dongpu) than the Grade II standards of China, further corroborating the above-mentioned conclusion. On the other hand, another previous study (Gao 2007) implied that water pollution in the Guangzhou section of Pearl River (Fig. S1) was mainly derived from domestically discharged wastewater. All these results appear to support the notion that domestic wastewater has become the main source of pollution in urban streams of Guangzhou.

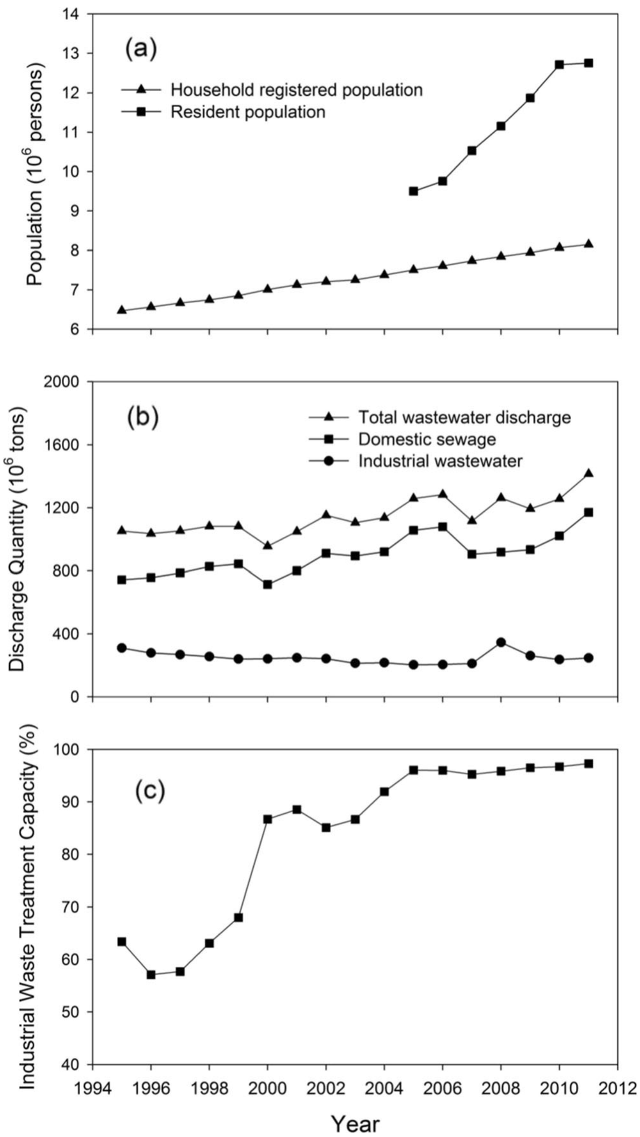

Fig. 2 Variance curves of **a** population; **b** wastewater discharge quantity; **c** treatment rate of industrial effluent of Guangzhou City from 1995 to 2011

Greatly adding to the urban water quality problem is the formation of urban villages throughout Guangzhou where migrant workers are concentrated (Yang 2004; Shen et al. 2006; Lau and Chiu 2013), due to affordable housing and convenience to work places. Population density is usually much higher in urban villages than in any other residential areas of the city (Liu et al. 2010). For example, approximately

70 % of the migrants live in the 138 urban villages of Guangzhou, comprising about 40 % the total urban population, although the urban villages occupy only 20 % of the total urban area (Lin and De Meulder 2012).

Within urban villages, the high population density has created a shortage of public facilities. As such, domestic sewage is mostly discharged directly to nearby streams because of poorly constructed and insufficient drainage systems and municipal pipe networks (Liu et al. 2010). All these well explain why sites R1–R6, which are located around some urban villages, i.e., Xinshi, Shijing, Tangxia, Chebei, Qianjin, and Ruibao, respectively, had worse water quality than other sites (R7 to R17; Fig. 1). For comparison, the population densities for these urban villages were 16,900, 9,200, 37,700, 23,200, 14,900, and 31,300 persons/km^2, respectively, much higher than the average population density (2,890 persons/km^2) of urban Guangzhou in 2011 (Statistical Bureau of Guangzhou 2013).

Effects of anthropogenic events on urban water quality as exemplified by the Guangzhou Asian Games

Urban water quality is often sensitive to human activities (Moglia et al. 2012). The 16th Asian Games (November 12–27, 2010) and 10th Asian Para Games (December 12–19, 2010) hosted by Guangzhou presented a rare opportunity for assessing the effects of human interferences on urban water quality. As part of the preparation work for hosting these games, the government of Guangzhou had invested 48.6 billion RMB from January 1, 2009 to June 30, 2010 on wastewater disposal and stream remediation projects to improve the aquatic environment. The effectiveness of this effort can be assessed via a comparison of the results in the first and second sampling periods (December 24, 2010 and May 24, 2011) (Table 2). Overall, the mean PI value (6.36) in samples collected from the first sampling was slightly smaller than that (6.91) in samples collected from the second sampling (Table 2), reflecting improvements in the water quality prior to the Asian Games despite a spatial difference of the effectiveness. In addition, the PI value for the third sampling was smaller than that for the second sampling (Fig. 3), probably attributed to the dilution effects of precipitations.

Moreover, the effects of the Guangzhou Asian Games on urban stream water quality can also be analyzed with a comparison of the results from a previous study conducted in 2009 (Luo 2011) and those from the present study for three urban streams (R3, R4, and R11; Fig. 3). Figure 3 shows that the PI values for R3 and R4 in 2009 were 8.99 and 10.1, respectively, but elevated to 15.1 and 10.2 right after the 10th Asian Para Games, probably due to continuous anthropogenic influences around the urban villages of Tangxia and Chebei despite the local government's efforts in implementing a series of control measures. Because of the dilution effects of precipitations during the wet weather season, the PI values of R3 and R4 were smaller in samples collected on May 24 (15.2 and 7.86) and August 28, 2011(8.44 and 6.54) than those collected in December 2010 (15.5 and 10.2). For R11, the PI value decreased from 8.93 in 2009 to 3.33 in December 2010 (Fig. 3), partly reflecting the positive outcome of the control measures enforced during the Asian Games. However, a spike in PI value (7.50) for the second sampling (May 24, 2011) illustrated the softened enforcement of pollution control measures and stream remediation projects as the Asian Games were concluded, despite the larger amount of precipitations for the second sampling period (199.5 mm in May 2011) than the first sampling period (25.2 mm in December 2010) (Statistical

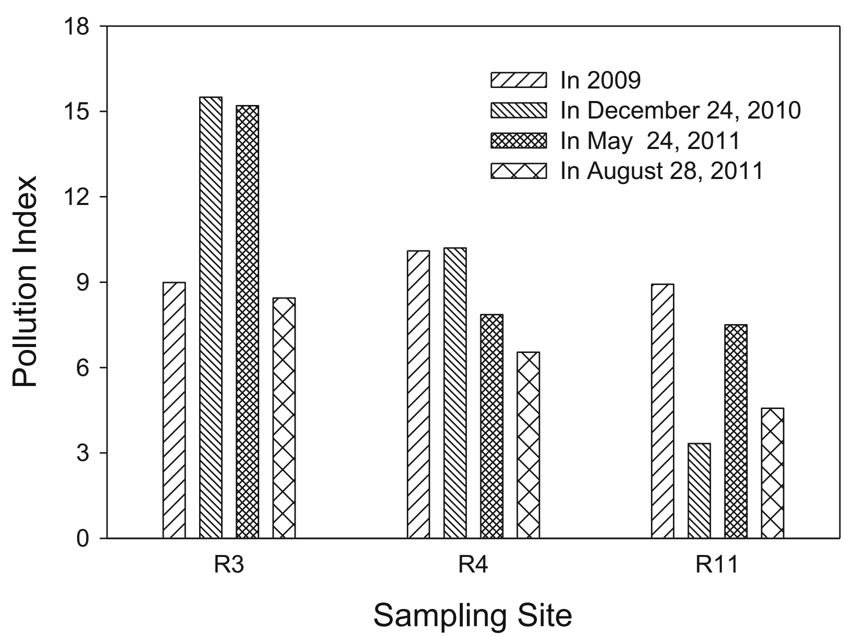

Fig. 3 A comparison of water quality from a previous study conducted in 2009 (Luo 2011) and those in December 24, 2010, May 24, 2011, and August 28, 2011, respectively (representative of the low-, normal-, and high-flow periods) from the present study for three urban streams (Tangxia, *R3*; Chebei, *R4*; Liede, R11), reflecting the effectiveness of the 16th Asian Games and 10th Asian Para Games on urban water quality

Bureau of Guangzhou 2013). This was consistent with the above-stated results, further reflecting the spatial difference in the effectiveness of the Asian Games.

Apparently, the stream water quality has been improved within the business districts but not around the urban villages after the completion of the remediation projects in preparation for the 16th Asian Games and 10th Asian Para Games. Hence, stream water quality around the urban villages will be the key target for any future remediation projects for the local water management agencies.

Conclusions and perspectives

Most urban streams of Guangzhou under investigation were extremely polluted. Domestic sewage was considered as the main contributor of pollutant loads in urban streams. Particularly, densely populated urban villages with poor wastewater collecting systems have become a major source of contamination to the urban streams in Guangzhou and should be dealt with in future water quality improvement programs. In addition, short-term remediation efforts tailored for a specific event such as the Asian Games may not be sustainable if effective management measures are not continuously and rigorously enforced.

Maintaining good water quality in urban streams is greatly beneficial for Guangzhou as the city has been striving to build itself into an international metropolis. In addition to the need to deal with the large number of issues associated with the urban villages, an integrated technical scheme proposed to rehabilitate the urban water environment of Guilin City in Southwest China (Pei et al. 2013) may be adopted in Guangzhou. This scheme uses clean water to flush polluted streams, enforces water pollution control by eliminating endogenous sources and intercepting extraneous contaminants, and implements ecological restoration measures. In the present study, water quality in the man-made lakes was better than that in the urban streams. Hence, use of man-made lake water to flush polluted streams, especially during the dry weather season, is a viable approach to the improvement of urban stream water quality in the future. Ultimately, minimizing or even eliminating any point-source discharge is the best option in managing urban streams.

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