

Urban River Restoration in China:

Current restoration activities and expectations by the population



Supervised by Karls Matthias WANTZEN

Chuyuan FENG

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Research Director

Karls Matthias WANTZEN

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Author

Chuyuan FENG

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Formation par la recherche, Projet de Fin d'Etudes en génie de l'aménagement et de l'environnement

La formation au génie de l'aménagement et de l'environnement, assurée par le département aménagement et environnement de l'Ecole Polytechnique de l'Université de Tours, associe dans le champ de l'urbanisme, de l'aménagement des espaces fortement à faiblement anthropisés, l'acquisition de connaissances fondamentales, l'acquisition de techniques et de savoir faire, la formation à la pratique professionnelle et la formation par la recherche. Cette dernière ne vise pas à former les seuls futurs élèves désireux de prolonger leur formation par les études doctorales, mais tout en ouvrant à cette voie, elle vise tout d'abord à favoriser la capacité des futurs ingénieurs à :

- Accroître leurs compétences en matière de pratique professionnelle par la mobilisation de connaissances et de techniques, dont les fondements et contenus ont été explorés le plus finement possible afin d'en assurer une bonne maîtrise intellectuelle et pratique,
- Accroître la capacité des ingénieurs en génie de l'aménagement et de l'environnement à innover tant en matière de méthodes que d'outils, mobilisables pour affronter et résoudre les problèmes complexes posés par l'organisation et la gestion des espaces.

La formation par la recherche inclut un exercice individuel de recherche, le projet de fin d'études (P.F.E.), situé en dernière année de formation des élèves ingénieurs. Cet exercice correspond à un stage d'une durée minimum de trois mois, en laboratoire de recherche, principalement au sein de l'équipe Dynamiques et Actions Territoriales et Environnementales de l'UMR 7324 CITERES à laquelle appartiennent les enseignants-chercheurs du département aménagement.

Le travail de recherche, dont l'objectif de base est d'acquérir une compétence méthodologique en matière de recherche, doit répondre à l'un des deux grands objectifs :

- Développer toute ou partie d'une méthode ou d'un outil nouveau permettant le traitement innovant d'un problème d'aménagement
- Approfondir les connaissances de base pour mieux affronter une question complexe en matière d'aménagement.

Afin de valoriser ce travail de recherche nous avons décidé de mettre en ligne sur la base du Système Universitaire de Documentation (SUDOC), les mémoires à partir de la mention bien.

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List of acronyms

BMA	Bangkok Metropolitan Administration
CBCGDF	China Biodiversity Conservation and Green Development Foundaion
COD	Chemical Oxygen Demand
CTMA	Territorial Contract of Aquatic Environment
CURA	Chengdu Urban Rivers Association
ICPR	International Commission for the Protection of the Rhine
IPE	Institute of Public and Environmental Affairs
MEP	Ministry of Environment Protection
MoHURD	Ministry of Housing and Urban-rural Development
NGO	Non-governmental Organization
OECD	Organisation for Economic Co-operation and Development
ONEP	Office of Natural Resources and Environmental Policy and Planning
PPP	Public-Private Partnership
SEPA	State Environmental Protection Administration
TP	Total Phosphorous

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1. Introduction: theoretical basis of urban river restoration

Human societies have been developed with increasing environmental impacts, particularly in rivers (Nilsson C. et al. 2005). Before two Industrial Revolution, agricultural activities including deforestation along the river, channelization of rivers, and damming for irrigation, had steadily impacted the river hydrology, morphology and water quality. The global environmental impacts on the ecosystem were relatively low and restricted locally or regionally (K.M.Wantzen et al. 2016). Later, developing industrialization has supported urbanization. Enormous cities and metropolis have emerged worldwide. The change of land use and human activities along the river has caused an inevitable large scale of pollution and degradation on the ecosystem. For instance, Species living on alluvions in the perialpine zone in Europe were threatened to extinct in the 19th century according to discontinuities of their traces in the alluvial records of hydrogeomorphic systems (Brown et al. 2013).

In fact, rivers of good quality benefit humans and societies. As the river offer water resource for human, it is directly linked with human's health. Humans and biodiversity face similar or same stressors of water security. Thus, protection on the biodiversity of rivers and river restoration directly improve human health (K.M.Wantzen et al. 2016). Besides, during the development of humans' societies along the river, great cultures have been formed worldwide, like that of four early great civilisations: Mesopotamia, Egypt, Indus Valley and Yellow River. Rivers offer a pleasant place for leisure, thinking, and the birth of philosophy. Its unique landscape and fresh air offer people ease in daily life thus its benefits human well-being. Artists get inspirations from rivers and the masterpieces reflect human's dependence on rivers.

Therefore, river restoration in the process of urbanization is essential, taking into account both human's expectations and the river ecosystem.

This article gives a deep view of current river restoration activities in China, especially on river pollution and riparian zone, meanwhile investigates citizens' expectations on urban rivers. Firstly, problems on rivers caused by urbanization are analyzed. Then, the river restoration activities, as well as citizens' expectations, are studied. Last, according to the inadequacy of current activities, suggestions on a more efficient way of urban river restoration are proposed, with reference and comparison of examples worldwide.

2. Materials and methods

To begin with, the literature review on river state and restoration worldwide gives an overall view on the impacts of urbanization on rivers and the values of rivers in cities. This step acts as a theoretical basis of the article. The main work is literature searching and reading while key words are defined like river restoration and urbanization. Search engines used are the Google Scholar and the Web of Science. Lists of references of the articles also help.

In order to conduct research in the context of China, a large quantity of literature and data in China's urban rivers in Chinese as well as in English is studied. The literature is about the problem of rivers caused by Chinese urbanization these decades and current activities in urban river restoration. A part of Chinese literature is found by the search engine CNKI (Chinese National Knowledge Infrastructure). These articles on problems and activities are composed generally after 2010. The keywords during searching are black and odorous water treatment, real estate, River Chief System and PPP. To analyze the disturb of ecological continuum of rivers by exploitation in riparian zone, an example of Fujiang in Mianyang, Sichuan Province is taken, in which there is a close relationship between values of real estate and recreation of rivers. Besides, from the aspect of governance and participation in river restoration, an innovative practice of Chinese environmental governance system, River Chief System, and the

PPP (public-private-partnership) model are studied. The advantages and problems of current activities are rethought.

Next, in order to know about citizens' expectations on rivers, scientific research articles, news reports, as well as information on official websites of several institutions and organizations, are studied. The participation of the public on the treatment of river pollution is analyzed with the help of reports composed by NGOs (Non-governmental Organization). By looking through the websites of several NGOs, an overall view of their efforts in river restoration is obtained. The website of information transparency on the treatment of black and odorous water bodies nationwide presents methods and systems to engage the public into river restoration. It also offers the results of annual supervision tours. By studying examples in scientific research articles on the management of the riparian zone, the transformation of citizens' expectations on rivers as well as improvement in the idea of riparian zone management is gained. Besides, examples of riparian zone renaturation in hometown city show citizens' dependence on rivers.

Finally, many successful examples of river restoration activities worldwide are studied. These examples come from research articles and news reports. From these examples, the key to success and restoration idea is analyzed. According to the Chinese context and its inadequacy in current activities, several suggestions have been made to improve the efficiency of urban river restoration.

3. Problems on rivers during urbanization

Since the Reform and Opening Up Policy in the 80s of the last century, fast process of urbanization and increase of cities nationwide have transferred a large amount of natural land to impermeable land where dense infrastructure, factories and residence have been built. In 2016, urbanization rate reached 57.35% with an annual rate of increase around 2% (State statistics Bureau, 2017). It is aimed by government that till the middle of 20s of this century, urban population will take up 70% of total population (OECD, 2015). During the urbanization, more population has migrated to cities with the change of lifestyle and production method. The human activities along the river have greatly changed the morphology, hydrology, water quality and ecosystem of rivers. Meanwhile, it presents a tendency of exploitation from city center to suburban area while continues to invade the riparian zone.

3.1 Huge quantity of urban population increases pressure on rivers

Since the Chinese economic reformed in 1978, there has been continuously large quantities of rural population migrating to cities, speeding the progress of urbanization. However, the continuous source of labors has increased the demand of quantity of potable water and the burden of sewerage system. With the expansion of urban area to the suburban area where there is not yet an adequate sewerage system, the temporal residential constructions sometimes discharge the domestic wastewater directly into the rivers. At the same time, the riparian zone has been gradually occupied by industrial factories and residential buildings due to the convenience of resources and the pleasant river landscape. Thus, in return, the water quality of rivers has been degraded with different levels sometimes even not suitable anymore for living and producing activities. The natural hydrology process of rivers has been affected and the local biodiversity as well as the ecosystem have been disturbed.

3.2 Excessive wastewater and rainwater cause river pollution

Recent decades, black and odorous water pollution has become the highlight of public concern. According to the result of supervision by MoHURD (Ministry of Housing and Urban-rural Development) and MED (Ministry of Environment Protection) in the end of 2016, there were 220 prefecture cities out of 295 nationwide with black and odorous water bodies. Nearly 60%

located in the province Guangdong, Anhui, Jiangsu, Shandong in the east part and the typical industrial province Hubei in the middle part (LIAO Weiling et al. 2017).

The source of pollution mainly exists in three parts: the industrial factories, the combined sewerage system and the non-point pollution in rainfall runoff.

- The industrial factories: Rapidly emergent small industrial factories in the suburban areas take advantage of convenient and abundant water resource along the riverside while ignore the influence of river pollution. Due to the small scale of companies, generally they don't have enough money to purify the industrial wastewater or to enhance the technologies of production process. Thus, quite a quantity of unpurified or not qualified purified wastewater is illegally discharged directly into the rivers with secret outlet pipes.
- The combined sewerage system: In the early years of urbanization, most of the sewerage systems in city are designed as combined style which accumulates and transfers the wastewater and the rainwater together in the same pipes. The problem is that with the increase of urban population, the quantity of wastewater has increased. Due to the monsoon climate in most of the cities and the increasing extreme weather, the capacity of combined sewerage plant can't afford such burden anymore. Therefore, excessive wastewater and rainwater flows directly into rivers rather than get purified in the sewerage plant.
- The non-point pollution in rainfall runoff: Due to the increase of impermeable surface in the city, a large quantity of rainfall runoff especially the runoff at the initial stage flushing the highways and parkings has quite a high concentration of organic materials which need much more oxygen to be decomposed in the river.

3.3 Disturb of ecological continuum of river by exploitation of riparian zone

The riparian zone is composed by the river bed between the low- and high-water marks as well as the terrestrial landscape above the high-water mark where vegetation may be influenced by elevated water tables or extreme flooding and by the ability of the soils to hold water (Naiman et al. 1993). The riparian zone support the biodiversity which in turn assure the ability of self-rebuild and productivity of the ecosystem. Besides, the aquatic plants and trees along the rivers with the root system help to resist erosion, floods and offer fresh air in a more pleasant microclimate. This buffer between the land and the river where natural hydrological process takes place offers habitats to a large diversity of plants and animals and allows the exchange of materials. On the one hand, it supports the biodiversity. Especially, riparian zone is essential to the reproduction of fishes. On the other hand, it's effective for eliminating the excessive nutrients and for slowing down the floods thanks to the biochemical reactions and physical resistance of aquatic plants and trees.

In the context of city, riparian zone is cooler than other parts and offers more pleasant landscape, which are highly persuaded by citizens reluctant to live among narrow ways and noise. They need rivers to respire the fresh air and stay healthy. Thus, there is a popular trend on society that wealth and happiness is partly represented by an apartment with a good view of rivers. In recent decades, merchants take advantage of this common thought and purchase the land of riparian zone to build high-grade residence like the same thing in other metropolitans in the world. For instance, a large part of the riparian zone of the downstream of River Fujiang in Mianyang (Figure 1) beside the developing district in the suburban area has been occupied by real estate exploitation in the recent decade. According to existent research, the market value of real estate is tightly associated with its distance to a lake and a river. If the distance is below 160m, the increase of value reaches 5.9% and this extra value presents a tendency of decrease with a further distance (Nikolaos Karanikolas and al. 2011). The market has greatly contributed to the loss of natural riparian zone. Besides, the government didn't notice the effect to environment. In order to encourage local economic development, much construction of

residence is allowed without further reflection for the long term. Moreover, in order to protect the infrastructure and residence against risks of flood, especially for the main river in the city, quite a lot of parts of river banks have been covered by high concrete dikes. They render the river banks impermeable thus, there are not enough plants and lentic shallow places for fishes to settle in (Figure 2). In fact, The erosion and deposition process of natural river banks creates spacial and temporal habitat heterogeneity (James A. et al. 1995). The interactions between the main channel and adjacent lentic habitats is crucial for the ecosystem of large, undeveloped rivers (Welcomme 1989). Therefore, these concrete dikes block this interaction. They have less impact on diverse habitat than that made of a wide range of stone sizes. By setting back levees and making them more distant from the channel, the ecological values of riparian zone and floodplain can be restored (James A. et al. 1995), approved by examples in Danube in The Czech Republic (Welcomme 1989) and along the lower Mississippi River (James A. et al. 1995). Nowadays, these long dikes built downstream along the River Fujiang in the late years of the last century and have not yet been engaged in the project of restoration of riparian zone.



Figure 1. Dense residence along the downstream of the River Fujiang in Mianyang, Sichuan (Source: Google)

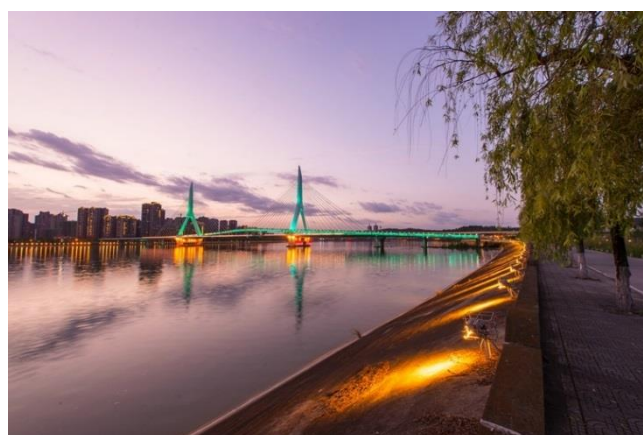


Figure 2. Concrete dike of the downstream of the River Fujiang in Mianyang, Sichuan (Source: Google)

On the one hand, these years, local governments have got more and more interested in constructing leisure area in the riparian zone since the idea *City Betterment* was proposed by the Central City Work Conference in 2015 and promoted nationwide after the first project *City Betterment and Ecological Restauration* was lauched in Sanya, Hainan Province in 2016 (YANG Lu, 2018). Mainyang lauched the project of *Sanjiang Hu* wetland park in order to reserve habitats for wilde birds in 2016 (Sichuan Observer, 2019). On the other hand, the real estate companies tend to settle green land around residence to increase the value of residence and to attract consumers. However, in some place, the green lands are still separated from the

rivers by concrete barriers like steps or dikes where the riparian ecosystem is still not allowed to develop (Figure 3).

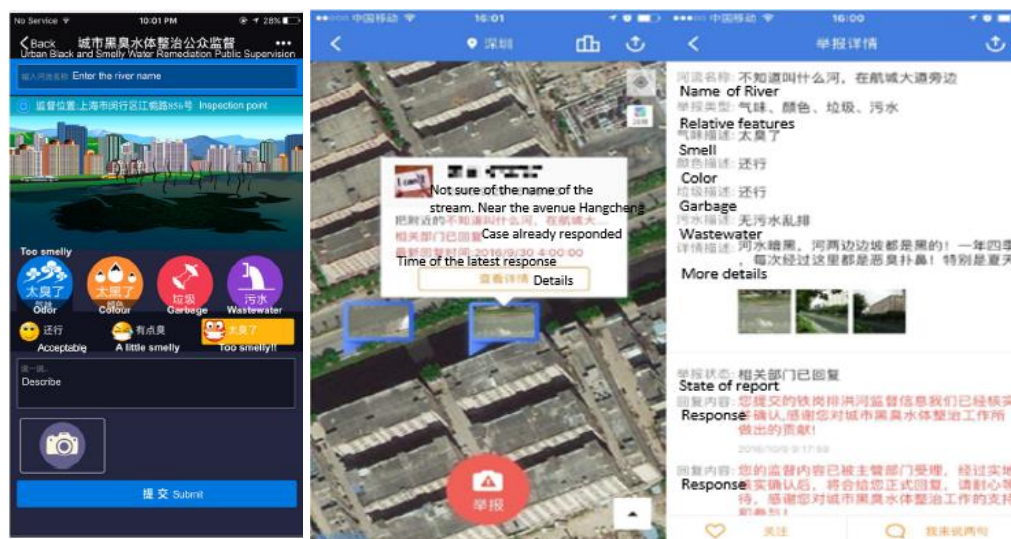


Figure 3. Artificial green land around the residence beside the downstream of the River Fujiang in Mianyang, Sichuan (Source: Google)

4. Citizens' expectations on the urban rivers

4.1 Public participation in the treatment of black and odorous pollution

Since the nationwide Urban Black and Odorous Water Information Platform was built by MoHURD and MED in 2016, citizens have actively participated in the the process of river restoration by reporting the river issues such as river pollution nearby their residence (see an example in Figure 4). Via the application of BlueMap and Wechat (Figure 4) on the mobile phone where the data of rivers are interconnected, it's allowed to locate a visually polluted river on the digital map, to attach the photos, and to give comments on its situation (color, smell, existence of garbage or not, existence of illegal outlet pipes or not). Besides, citizens can also call the environmental protection reporting hotline to report the polluted rivers. The reports of



citizens need to be responded by the local government within seven days after the fieldwork of preassessment on the river. At the same time, the reported cases are shown on the applications with program of treatment, the deadline as well as the name of the supervisor.

Figure 4. platform on Wechat(left) and on BlueMapwith an in Shenzhen (right) (Source: Angel Hsu, 2019)

The public has shown a great passion in revealing the polluted rivers around them which directly affect their feelings outside doors in daily life. Until 16th October 2016, there were totally 2550 cases nationwide received from the public. (A number of environmental NGO including CURA et al. 2016) Just from August, there were 704 cases added and the average number in 2016 was around 700 cases per quarter (Hsu Angel et al. 2019). The statistics show an uneven distribution in space of reported cases (Figure 5). The most cases were reported in Beijing (30%), followed by Hunan Province (17%) and Shandong Province (12%). There was no case reported in Ningxia Province, Qinghai Province and the autonomous region Tibet in the north-west (Association of environmental NGO, 2016). The difference can be caused by multiple factors like unbalanced industrialization and levels of income in different provinces (X.Yu, 2014), the awareness of environmental protection and so on. The North-east part like Shandong Province and the middle part like Hunan Province have been subjected to comparatively severe industrial pollution. The factors causing varying degrees of public participation remain to be studied.



Figure 5. Uneven distribution in space of reported cases (Source: Association of environmental NGO, 2016)

Apart from individuals, the environmental NGOs which take the largest part of civil society in China (Ewot & Rollins, 2011) have greatly dedicated effort into environmental assessment and share of research results. IPE (Institute of Public and Environmental Affairs), the cooperative creator of BlueMap with the MoHURD and MEP, collects the government reports on environmental supervision on the water and air quality. Additionally, it integrates the research results of environmental protection departments of different levels of local governments on the digital map and makes them more comprehensible. Moreover, it compiles the supervision of enterprises' impact on the environment conducted by local government. Meanwhile, the NGOs based on cities like CURA (Chengdu Urban Rivers Association) and on river basins have worked together and composed the *Synthesis of treatment and supervision on black, odorous rivers* where there is a table of the cases accomplished with the result of treatment and the cases abandoned as well as a presentation of investigation process by organizations. These NGOs, composed by ecologists, sociologists, engineers and enthusiastic ordinary citizens have offered expertise and labor to help address the inadequacy of local government.

The initiative of treatment of black and odorous water bodies is a typic example of how E-participation (participation in process involved in government and policy-making by information and communication technology) favors the public-generated transparency defined

as data that people or their organizations produce to directly monitor, demand or drive change on issues that affect them (Hsu Angel et al. 2019). The willing of citizens on getting involved in restoration activities is crucial for the success (Palmer et al. 2014). For a long time, under the top-down administrative system in China, the public can hardly participate in the decision making. This innovation in the treatment of river pollution via internet platform shows the placation level of citizen participation¹ in environmental affairs has been achieved. Besides, the supervision from citizens addresses the implementation gap between the local government and the central government for decades especially in the environmental problems, in which the local government generally show more interests in economic development without a perspective in the long term.

4.2 Change of expectation on the urban rivers: from safe water quality to pleasant riparian zone

In the last century with the development of industrial factories along the riverside, some rivers in China were heavily degraded by toxic materials, which have caused damage to human's health and security of society. Local citizens in the industrial zones beside rivers have never stopped protesting against the companies who inject the polluted water into rivers. Their effort has led to focus of media in a wide range of society that the factories were forced to close. Daishan Huo, a journalist who was borne in Henan Province along the River Huaihe, shows the great impact of individual's expectation on the river restoration (CBCDGF, 2016). The River Huaihe is one of the main tributaries downstream the River Yangtze with a watershed of 270 000 square kilometers. In the 90s, the pollution from industrial factories was observed and aimed to resolve by the central government. However, by the time of deadline in 1997, the pollution was left existent and most parts of river were below the quality Nivea V²(). There was an informational gap between local and central government where the real situation of the River Huaihe was hidden. Local habitants still suffered from the pollution and many cancer cases emerged in the villages along the riverside. Seeing friends and neighbors dying of cancer, Huo resigned and dedicated himself totally to reveal the real situation of the river. He has taken a huge number of photos on the foamy river and outlet pipes. During his investigation, he has visited and interviewed many residents in the villages suffering from cancer. His photographs were published on media and became the highlight of critics. Moreover, he didn't stop his steps of offering water purifying devices to the villages and settling sewerage plants along the riverside. His activity was supported financially by MEP and donation from society. Meanwhile, nearly 280 not qualified enterprises causing pollution were forced to close in the following years. In 2003, due to his passion and impact, the NGO Guardian of the River Huaihe was established and now it has changed into a scientific research center for ecological environment of the watershed Huaihe (CBCDGF, 2016).

The river pollution cannot ever be ignored. In the 21st century, with the development and application of water science and technology in China, more and more qualified sewerage plants have been built in smaller cities. River pollution is not as heavy as before while most of the urban rivers appear a pleasant illusion. As study shows there is a significant decrease of industrial wastewater as well as a 15.59% COD reduction from 2004 to 2015 in 40 cities in the Yangtze River Economic Belt³ (SHE et al. 2019). However, the industrial factories tend to

¹ Allows citizens to advise but retains for power holders the right to judge the legitimacy or feasibility of the advice (Arnstein, Sherry R. 1969)

² In China, the surface water quality is classified into Grades I to V by the Ministry. Grades I to III are suitable for domestic use, while Grades IV and V are not suitable for human contact, and for agriculture use (MEP, 2002)

³ It covers 2.05 million square kilometers, stringing up 11 provinces and municipalities from west to east, with Sichuan, Guizhou, Yunnan and Chongqing in the upstream, provinces of Hubei, Hunan and

move to suburban areas where environmental supervision is not enough compared to cities.

At the same time, with the economic development and enhancement of living standard of citizens, they tend to buy a second house or to invest in real estate. In 2003, the real estate was defined as one of the main support of economic development and was encouraged nationwide. (the State Council, 2003) A huge amount of land along the river has been exploited by real estate company and has been occupied by residence and commercial buildings as river offers special values like fresh air and green land in riparian zone. In the example of Mianyang, Sichuan Province, the economic developing zone in suburban area has been exploited in the latest decade beside the downstream of the River Fujiang. (Figure 6) Its riparian zone nearly 5km long has been largely occupied by real estate exploitation. Local citizens enjoy the view of large surface of river from these residences and can have a walk, ride bikes and go fishing in the artificial green land. However, these narrow bands are not large enough between highway and concrete dikes (Figure 7).



Figure 6. Distribution of city centers in design along the riverside in the economic developing zone (Source: the official site internet of Lingdi Group)



Figure 7. Narrow green band between the dike and the highway downstream the River Fujiang, Mianyang, Sichuan Province (Source: Google)

Citizens are always looking for a larger natural green land in the city to have some leisure. In fact, on the other side of the bank, a wasteland in riparian zone was restored into the Xiaojian Wetland Park for citizens not only in this zone but also arriving from other parts of the city (Figure 8) . Their expectations are supported by the policy of an environment-friendly way of urbanization in riparian zone these years. In the case of Mianyang, the green land between the river and the previous water wall has become the most popular leisure area in the last decade. The riparian zone stretches around 4.5 km long, located in the center of city and upstream of the economic developing zone (Figure 9). Different kinds of activities can be discovered here: walking, jogging, fishing, rest, flying kites, dancing and so on. On the water walls, there are beautiful wall paintings of typical natural landscape and the cultural tourist sites. Citizens can have a clearer impression of the city by these art works during the joyful time beside rivers. Meanwhile, the red-billed gull has become a highlight scenery in the city and appreciated by citizens (Figure 10). The seasonal immigrating aquatic bird chooses this natural riparian zone as well as natural islands in the River Fujiang as its habitat and live a peaceful life with humans in the city.



Figure 8. Xiaojian Wetland Park downstream the River Fujiang, Mianyang, Sichuan Province (Source: Google)



Figure 9. Riparian zone in the center of the city Mianyang, Sichuan Province (Source: Google)



Figure 10. Red-billed gull in Mianyang, Sichuan Province (Source: Google)

In conclusion, from the late years of last century to the recent years, citizens' expectations on the river have gotten higher and higher, from a safe water quality to the pleasant riparian zone, reflecting the essential role of urban rivers in citizens' daily life. During this process, it is proved that public's force can influence the river restoration and defense the general interest of the society. The previous and present cases encourage citizens to continue to protect their living environment.

5. Current activities for solving the problems

5.1 Treatment of the black and odorous rivers

Affected by the black and odorous water pollution, the programme Ten Water Rules (Action Plan for Preventing and Treatment of Water Pollution) has been launched by the state council nationwide with intermediate targets since 2015. It's aimed to enhance the water quality of watersheds and deal with the black and odorous water pollution in the cities. As defined in the programme, by 2020, the proportion of black and odorous water bodies in prefecture cities will be reduced to a maximum of 10%. The water quality of at least 70% of the seven main basins should reach Grades III. By 2030, There will be almost no black and odorous water bodies in prefecture cities. The water quality of at least 75% of the seven main basins should reach Grades III. The aquatic ecosystem will be preliminarily successfully restored (State Council, 2015).

The core of the treatment of the polluted rivers is based on three steps. The most basic step is to identify and eliminate the sources of pollution along the rivers. The second step is to purify the polluted water and silt in channels. The last but essential part is to restore the ecosystem of rivers (LIAO Weiling et al. 2017).

5.1.1 *Identification and elimination of the sources of pollution along the rivers*

The sources of pollution are diverse and scattered. There are illegal outlet pipes of factories and injection of domestic wastewater. Meanwhile, excessive polluted water from the combined sewerage system runs directly into rivers during extreme rainstorm weather under the monsoon climate in China. Local governments share the huge task of dealing with sources with the public who act via new media and hotline platform.

In order to eliminate the sources from factories, on the one hand, wastewater from outlet pipes is accumulated and transported to nearby sewerage plants. On the other hand, factories who inject not qualified purified water get pollution discharge tax or even forced to close according to the Environmental Protection Tax Law (GUO Xiaolin, 2018). As for the sewerage system, separated systems for wastewater and rain is in progress. With the help of green lands, wetlands and storage tanks in the idea of *Sponge City* in reducing the rainfall-runoff, the burden of sewerage system and non-point pollution have been reduced (SHI Guoqi et al., 2019).

5.1.2 *Combined technologies of treatment*

The physical and chemical purifying methods have obvious effects in the short term but not adequate for restoring the river ecosystem in the long term. Therefore, they should never be used alone without biochemical technologies. For example, introducing clean water from nearby water bodies or sewerage plants can enhance the hydrological dynamic of rivers but it risks transport pollution downstream. Aeration machine in the river can bring quite a large amount of oxygen but it can't restore the ecological function of producing oxygen.

It's essential to take into account the river ecosystem during the treatment of water quality. Biochemical technologies favorable for the restoration of ecosystem have been proved effective in many cases. They are based on bio-degradation of micro-organisms as well as adsorption, assimilation of local aquatic plants in reducing organic materials, heavy metal and excessive nutrients (LIAO Weiling et al., 2017). In the biomembrance process, thanks to the large surface of the fixed medium placed in water, the pollutants can be absorbed more efficiently by the microorganism. Meanwhile, plants can be placed in riparian zones and on floating islands in the river.

For instance, in Nanjing, Jiangsu Province, combined technologies have got success in restoring rivers on the island. The Island Jiangxinzhou is situated in the River Yangtze in the southeast of Nanjing. On the island, there is a large number of channels totally 40 km long accompanied by wetlands. Due to inadequate sewerage systems, a part of domestic wastewater from villages as well as wastewater from farmlands was discharged into the rivers. Most of the river banks were covered with concrete dikes, presenting a lack of aquatic plants. Before treatment, the water quality of the rivers was below the Grade V. In the project, aeration machines were used to offer oxygen while biomembrance devices were placed in the rivers. Moreover, concrete dikes were removed while aquatic plants were settled in riparian zone according to their adaptability and functions. Later, as the water quality got better, a quantity of local aquatic animals was introduced in order to restore the river ecosystem. After six months of treatment, COD, TP, $\text{NH}_3\text{-NH}_4^+$ have decreased by 44.2%, 45.8% and 38.3% with water quality of the Grade III (HUANG Boping et al. 2016). As a result, the rivers are not black and odorous anymore while the river ecosystem is on the way of getting better.

5.1.3 *Annual nationwide supervision tour*

Every year, a series of supervision teams composed of MEP and MoHURD choose certain prefecture cities to investigate the treatment of black and odorous rivers. In 2018, 70 cities were chosen out of 295: 36 prioritized cities and other cities along the River Yangtze (WANG Qian, GAO Hongjie, 2019). During the supervision tour, methods and results of treatment are investigated while potential black and odorous water bodies are examined. Besides, information transparency and public voice via media are evaluated. Later, a journal of inspection on black and odorous water bodies, accessible by the public, is issued on the official site (Publication of information on the nationwide treatment of black and odorous water bodies).

Several unignorable problems are recognized in the current treatment of black and odorous river pollution. Sometimes, the project doesn't take into account whole watershed and riparian zones. Thus, the success is limited and pollution comes again after treatment. Besides, in some cases, incorrect measures like landfilling of channel with soil and use of flocculation agent reveal ignorance and perfunctory attitude of local governments. Furthermore, the separation of sewerage system and rain system still needs to be continued nationwide.

5.1.4 *Conclusion*

It's a long-term process to resolve the problem of black and odorous water bodies. A large amount of financial defense and qualified experts on ecological restoration is essential.

Nowadays, there are many scientific researches on biological technologies some of which has been proved effective via experiments and application. However, the financial expense on treatment of river pollution is too much expensive. It's estimated that the treatment expense per kilometer of river reaches 35 to 45 million. Until 2017, the general length of black and odorous rivers is about 5596km nationwide (LIAO Weiling et al. 2017). Thus, for some local governments, certain qualified technologies can't be adopted. Thus, the more superficial methods are chosen to pass the inspection while polluted rivers still affect citizens' daily life. The current situation reveals that for government, it's essential to cooperate with qualified scientific teams and social capital in river restoration.

Moreover, the annual supervision tour really urges treatment of river pollution. However, in practice, only a quater of prefecture cities is engaged in investigation. Thus, the public supervision by individuals and NGOs is crucial.

5.2 Innovation of the River Chief System

The river chief system appeared for the first time in the process of dealing with eutrophication in the Lake Taihu in Wuxi, Jiangsu Province. After primary success, the system was adopted by other provinces. Until October 2016, 8 provinces had adopted the system in whole city and county while other 25 provinces in part of their territory (KONG Fanbin et al., 2018). By the end of 2018, a four-level structure of province, city, county and town nationwide nation has realized the implementation of the river chief system.

For each level of government, the river chief is the main leader or the main responsible of relative departments. The river chief office (except the level town) charges execution of chief's decisions. There are plenty of duties of river chief which demand the comprehension of theories mainly in four basic domains. The main duties are protection of water resources, management of river banks, prevention and treatment of water pollution, restoration of aquatic environment and ecosystem, implementation of water law. These duties include every aspect of protection of rivers so that it's essential for the river chief to learn about professional theories before making decisions. The four domains of theories are the hydrology, water resource, river ecosystem and water law (ZUO Qiting et al. 2017).

The innovation of river chief system exists on three points:

- The river chief can cooperate with different relative departments on the management of rivers and avoid the buck-passing and or low effect among the departments
- The river chief of higher-level should supervise and examine the implementation of duties of the river chief of a lower level so that the coherence of management on rivers in a province is assured. The award and punishment following the examination encourage the river chief of a lower level to work actively.
- As for the upstream, downstream and river banks situating in several adjacent administrative territories, the duties of river chief are separated clearly.

The river chief system has gotten gradually more and more success these years. After 8 years in 2015, for the 15 main rivers running into the lake Taihu in Jiangsu Province, the water quality has risen to the Grade IV from V and the degree of eutrophication was greatly decreased. The water quality of the Lake Taihu also achieved grade IV (KONG Fanbin et al. 2017).

The river chief system breaks out the administrative barrier among different departments of local government so that it makes local government more active and more effective in river restoration. The significant innovation is that the information platform on the internet where states of rivers and works of river chiefs are shared is in the process of construction. This platform allow upstream and downstream to know each other better. Besides, on the *Conference of River Chiefs*, all river chiefs come to identify works under each's responsibility and to arrange work plans together. (Research and Formation Center of the River Chief System, 2018)

However, though the river chief system has emerged for more than a decade, the degree of implementation nationwide presents a large variation. The main deficiency exists in lack of legislation to define the authorities, the duties and the supervision on river chief (KONG Fanbin and al. 2017). If the system is just supported by administrative suggestions by the central government like *Views on the Overall Implementation of the River Chiefs System* (2016), the efficiency of river chief will be limited and the supervision will not enough be realized. Moreover, river restoration of the whole watershed is expected. Nowadays, the duties of river chiefs are defined according to administrative territory. The exchange of information among the river chiefs in the same watershed should be reinforced for the cooperation of river restoration in the long term. Besides, as the four main domains of theories are crucial in river restoration, only depending on the river chief is not enough. Thus, technologies and effort of scientific researched team, as well as environmental companies, should be integrated in.

5.3 PPP (Public-Private Partnerships) in urban river restoration

The PPP model was born in Great Britain and then got popular and adopted worldwide. Though there are several definitions of PPP, the core is a cooperation between government and private companies. Both sides offer together public services with different resources while undertaking together risks. The government side supervises the private companies and the later ones earn revenue according to the contract and the result of work (YANG Jingjing, 2019).

Before the 80s in the last century in China, the treatment of urban water pollution is charged by local government alone, having low effect and huge financial burden in the long term. Before PPP was used in the treatment of water pollution, it had already been used and got success since the 90s in other domains of public utilities like communication, transport and energy. Gradually, PPP has been introduced to the domain of water like service of water purification by the French company Veolia. The legislation of PPP has got more and more adequate and encouraged its application. These decades, PPP in the treatment of black and odorous water bodies is still on the way of developing. Before, Government generally financed nearly 90% of total defense on project while only 10% was afforded by private companies and NGOs (YANG Jingjing, 2019). In the Action Plan for Preventing and Treatment of Water Pollution in 2015, social capital is encouraged to participate in the public affairs of water pollution. Soon, the more specific guide has been published by the central government. Nowadays, there is a large quantity of research on the application of PPP in urban river restoration.

The benefit of PPP in river restoration exists in taking advantages of each other which can be concluded in three parts:

- Abundant financial support in the long term of construction and maintenance from private companies eases the burden of huge defense on river restoration and assures the continuation conduct of the project.
- Experts and devices are offered by private companies to assure scientific reasonability, efficiency and feasibility. Government can take advantage of the market to choose more qualified teams while the role of government transfers from execution to supervision.
- Thanks to the legislation of PPP in public utilities and administrative support from local government, the investment of private companies on the use of territory is decreased as well as tax and loan. Besides, the companies are paid by the government according to the result of project.

A typical example of PPP in Nanning, Jiangxi Province shows the success and problem in the application. There are 18 rivers in Nanning of which 155km present different degrees of black and odorous pollution. In the beginning, the local government resorted to environment investigation companies as well as the habitants to review the current state of rivers in the city. Then, faced with the complexity of technologies of the project and on cooperation, the local government consulted qualified legal advisers and experienced the scientific research team of

Tsinghua University. With the effort of consultant teams, advice and notice on technologies in the project were given to the potential cooperative companies. Besides, through exchange of ideas with the consultant teams, the object of restoration project based on several phases was decided. The definitive companies were selected through the public bidding procedure. In the contract of the PPP between local government and companies, the total investment reaches 1.23 billion yuan of which 93% is supported by the private side (YANG Jingjing, 2019). The duration of contract is 15 years, composed of five years to attain the object of water quality and 10 years of maintenance of water quality. The duties of private companies include field survey, concept and execution of project as well as maintenance. The progress of work has been examined by the local government every year and the companies have been paid according to the result.

In the project, the main problem comes from inadequate cooperation among the different departments of the local government which sometimes share the same duties and pass the buck to each other confronted with problems. Another point is that the separation of responsibilities and cooperation between the government side and the private side need to be enhanced. In conclusion, communication between different parts is essential in order to assure the efficiency of the project.

5.4 Ecologies restoration of riparian zone

These decades, urbanization has been faced with the degradation of riparian zone and habitants' expectation of a pleasant place for leisure along the riverside. These years, integrating ecologic restoration in urbanization is supported by policies and included in the strategy of urbanization. In 2015, the requirement of quality and efficiency for urbanization was proposed in the Central City Work Conference. The idea of urbanization *City Betterment* of which the goal is to make people living in the city more convenient, more comfortable and better has been promoted nationwide after the project *City Betterment and Ecological Restauration* was launched in Sanya, Hainan Province by the MoHUD in 2016 (YANG Lu, 2018). Since then, restoration of ecologic values of riparian zone and preservation of local culture along the river have got more and more emphasis (YANG Lu, 2018). The ecologic values of riparian zone are the base for human's activities and conservation of locale culture along the riverside.

The practices of restoration of riparian zone generally adopted in China are based on four parts: Change of the land use along the riverside, restoration of the morphology of river banks, reintroduction of aquatic plants and trees, association with adjacent water bodies.

- Change of the land use along the riverside exists in reducing farmland, aquacultural pond and temporal residential constructor in riparian zone. Since the land use is changed, most of pollution sources are eliminated.
- Restoration of morphology of river banks is basic for the restoration of ecosystem. Channelized riverbanks covered with rocks and concrete act as a barrier for aquatic, amphibious animals and birds so that the biodiversity has been greatly decreased. The core of restoration of morphology is to render banks to gentle slope or several terraces in a sinuous form covered with plants. The natural morphology of river banks also allows pertinent speed and depth of current, essential for other creatures in the river.
- Reintroduction of aquatic plants and trees aims to offer a place of reproduction, feeding, shelter and habitat for aquatic animals, amphibians and birds. The floating, emergent, submerged plants as well as a composition of plants on the higher banks are settled to restorer the riparian zone.
- Association with adjacent water bodies is adopted on a larger scale to enhance the hydrological dynamic and immigration of animals in riparian zone. The adjacent water bodies can be natural or artificial, wetlands or rivers.

The restoration of riparian zone should meet the demand for flood control in the city. For

example, on the island of Baxizhou in Changsha, Hunan Province, several terraces of river banks covered with proper composition of aquatic plants are settled as the first line of defense. The second brand is composed of herbs, bushes and trees of local species on the higher bank and flood plain. The third defense line exists in distributing flood by artificial and natural wetlands in the water bodies (JING Yunfeng et al. 2018). The park on the island allows citizens to have close contact with the nature.

As for a river with huge width in cross-section, a combination of plant engineering and civil engineering is suggested in order to protect the river banks from erosion by strong hydraulic washing force. For example, in Nanjing, Jiangsu Province, the width of downstream of the Yangtze River reaches 1.1 to 3.5km. The banks are covered with concrete dikes like in many other cities. In the suggestion, the foot of banks protected by gabions filled with rocks can resist the erosion of current while allowing creatures to settle down in the interspace. The banks protected by geotextile and plants can resist the erosion of current as well as the erosion of rainfall-runoff. Besides, beaches along the riverside present little biomass and biodiversity at the moment. It is suggested to remain them and reconnect them with riparian zone (CHEN Hui et al. 2018).

In order to reserve enough land for restoration of riparian ecosystem, activities and constructors along the riverside need to be controlled. In the example of the River Gaoluo situated in the village of the city in Wuhan, Hubei Province, the private aquacultural pond along the river have been transferred into wetland where the aquaculture is banned. An area of 30 meters wide beside the river is reserved for constructing gentle slope after removing the temporary constructions. Surface of some parts of river have been broadened with artificial islands settled in order to increase variety of habitats (TANG Xuehu, 2019).

Ecologic restoration in riparian zone in the city always meets difficulties with other land use along the riverside due to limit from society and economy. There is a quantity of researches on the width of riparian zone based on composition of plants. Corresponding widths are defined for different ecological services, for example, water and soil conservation as well as prevention of river pollution. The largest width below 80 meters is for filtering the pollutions (LI Linying et al. 2013). However, the creatures living in riparian zone need far more land than that. As habitat for birds, the width reaches 150 to 170m, which contains 90% of habitats of birds (Wenger S. 1999). Therefore, the choice of width in restoration of riparian zone should take into account the need of creatures while consulting the corresponding width from research.

Restoration of riparian zone in a larger longitudinal scale in the city depends on classification of functions of urban districts. In the example of the River Suzhou in Shanghai, the west part in suburban area is designed to preserve large surface of natural environment and to support the local biodiversity. The upstream in this district is connected with wetland and green land. The middle part is mainly the residential district with walk pass in riparian zone along the river. Besides, several parks are connected with the river. The east part at the intersection with the River Huangpujiang is highly exploited as commercial center (CUI Haijie, 2019). In this district, the riparian zone is much more limited and its restoration is more like landscape design with less regards to ecologic value. Thus, the suburban area with more nature land should be preserved for decreasing the burden of rivers in the city.

6. Suggestions to improve river restoration activities

6.1 Reinforce the PPP model in the River Chief System

Faced with the inadequacies and advantages of the River Chief System and the PPP models explained in the previous phrases, it is observed that the two methods can be integrated with

each other in river restoration, offering advantages of one side to make up the inadequacies of the other side.

On the one hand, the sources of river pollution come from different human activities and land use charged by different responsible departments of local government. Some of their duties are overlapped so that they tend to pass the buck among each other. Without a definitive person acting as the medium, the companies easily get confused by the administrative regulation so that projects are postponed. Fortunately, the river chief can efficiently cooperate with different departments so that the private companies can save time to concentrate more on the conduction of the project.

On the other hand, it is a huge burden for local government to afford continuous defense on river restoration. Even though there are experts consulted during the decision of projects, the conduct of project and scientific maintenance in long term need adequate experts and professional devices. Private company of higher quality is selected during bidding process with the effort of market, which in return encourages the companies to get more qualified.

In conclusion, the cooperation of two methods can combine administrative efficiency of government with the financial and technical support of the society.

6.2 Encouragement of participation of citizens

It is proved by enormous cases that the most effective assurance of project exists in efficient cooperation with stakeholders. Otherwise, project risks to be postponed or abandoned. During the treatment of black and odorous water bodies as well as the ecologic restoration of riparian zone, many sides of stakeholders are affected in a positive or negative way. As for farmers, close of aquacultural ponds decreases their income. Besides, some farmlands along the riverside lacks adequate sewerage system. As for industrial companies, huge quantity of industrial wastewater with high concentration of organic or even toxic materials needs quite a lot expense of purification. It is a huge burden that can even lead to the break down of small companies. Besides, enhancement of manufacturing technologies in order to discharge less wastewater also needs money and experts. Restoration and protection of river is a general interest for citizens. Good quality of river and pleasant environment along the riverside bring benefits to everyone. The problem is that sometimes the long-term nuisance is ignored by the habitants or producers who just persuade convenience or a lower cost. Thus, different sides of stakeholders are strongly suggested to get involved in the process of river restoration. Moreover, in return, consensus of citizens makes them more active and spontaneous in favoring the projects.

Participation of citizens in river restoration has been widely adopted by other countries worldwide and has gotten positive effects. For instance, in the late years of the 19th century in Germany, ecologic restoration of riparian zone of the River Emscher began. In the beginning, Only the committee EG, consulted by government, participated in the designing of project while the force of citizens protested against the project. Later, in the continuous programmes on the river, private companies, scientific research teams, users of the river have been allowed to participate in the project offering financial support, technical support and public consensus. The programme of river restoration has attained much more attention and help from the public. The power of citizens has become the main factor of successful conduct of project and gradually become the strong point in the making of decisions (WANG Min, 2019).

Another example comes from the decision making of CTMA (Territorial Contract of Aquatic Environment) based on five years by a syndicate of rivers (institution working with local government and charging affairs of rivers). Since the cooperative research team authorized by the syndicate completes prospection and offers a programme of river restoration based on five years, there should be a conference for negotiation between citizens, research team, syndicate

and local government. The programme and technologies are presented as well as the general interest. The voices of citizens are obligated to be taken into account during making the decisions. This method favors the comprehension of each other between citizens and local government and enhances the trust in local government.

Meanwhile, the lack of communication between citizens and local government causes discredit of each other. In the example of promenade project along the River Chao Phraya in Bangkok, Thailand, the promenade road of 7km long on both sides of the river of 400m wide accompanied with greenland parks was designed to be built. The ONEP (Office of Natural Resources and Environmental Policy and Planning) considered that there was no need for environmental impact assessment. In fact, the nuisance to ecosystem of riparian zone was ignored. The design and construction were started without consulting citizens or academic teams. In the project, 280 households were relocated and historic heritages were affected on the Rattanakosin Island. Its concrete dikes blocked contact between the river and the riparian zone. A local heritage conservation group suggested to downsize and change the style of promenade but it was ignored by BMA (Bangkok Metropolitan Administration). With the continuous protesting from several academic teams, the project has been ceased for many times till now (Nation Thailand, 2018).

So far, China has had successful experience in engaging citizens in the discovering and supervision of black and odorous water bodies. Therefore, in order to make more progress, it is suggested to invite citizens into the process of decision, execution, supervision and evaluation of the river restoration. The conduct can be a conference, interview and quiz. During the conference, local government and cooperative companies who conduct the project explain the general interest, the current situation of river, existent activities and the programme of the project. Users of river propose their expectations and problems. Research teams offer professional advice. The proposition of ideas and negotiation is favorable for obtaining a result with the most satisfaction. In this way, the project gets more support from the public as well as more scientific reliability.

6.3 Association of administrative districts in the scale of watershed

The topographic watershed is defined as the zone accommodating surface water and delimited by the crest line of mountains. (just surface water is taken into account while ground water left aside) Each river has its own watershed while the watershed of main stream includes several smaller watersheds of tributaries (KONG Fanbin et al. 2017). In a watershed, the ecosystem of aquatic environment presents adherence and coherence while river problems of different parts are similar.

Generally, a watershed can include parts of several adjacent administrative districts like towns, counties, cities and provinces. River restoration in each district has impact on the upstream or downstream parts of the whole watershed. Thus, regarding the watershed as a unity in the management of water bodies is the efficient principle approved in domestic and abroad. Since the 90s of the last century, the concept *Integrated Water Bassin Management* has spread with support of the United Nations, NGOs and natural scientists for water ressource management. The principle is based on effective cooperation among the adjacent local governments. Thus, Association of administrative districts in river restoration helps to cooperate efforts in different parts of watershed to restorer the whole river ecosystem.

For instance, in the project of the Comarca River Park in Pamplona, Spain, since 1990, treatment of river pollution and restoration of riparian zone has been conducted by the consortium of nine riparian communities and later by the federation of municipalities of Pamplona in a larger scale of watershed (Elise FERLAY, 2019). So far, the riparian zone of 33km along the River Agra has been transferred into river park and another 70km is under

construction. Besides, there are also examples of cooperation among countries on river restoration of watershed (Mancomunidad Comarca de Pamplona (b) 2012). In 1950, in order to protect and restore the River Rhine from water pollution, five countries as Swiss, France, Luxembourg, Germany and Netherlands in the Rhine watershed established the ICPR (International Commission for the Protection of the Rhine) (KONG Fanbin et al. 2017). The members determine the objectives and measures together. So far, the commission has achieved the well-known 'Rhine Action Programme' (1987-2000) and work on the 'Rhine 2020', also known as 'Programme on the sustainable development of Rhine'. It plays a leading role in the restoration of river ecosystem of the Rhine watershed (Rhine 2020).

7. Conclusion

As the process of urbanization in China still presents an increase today, it is essential to rethink the values of rivers in order to prevent water pollutions and decrease damage to river ecosystem. So far, many environmental problems especially in rivers become the highlight of society. Citizens have presented high dependence on rivers as well as strong expectation on river restoration.

According to worldwide research, examples and Chinese experience, urban river restoration is based on three steps: treatment of river pollution, restoration of ecosystem and renaissance of local river culture. The restoration programme always takes long term and huge effects.

Therefore, different sides of stakeholders are suggested to participate in the restoration process while offering their advantages and support. Finally, the effect of river renaturation depends on cooperation in watershed.

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Research Director:
Karl Matthias WANTZEN

Chuyuan FENG
PFE/DAE5
IMA
2018-2019

Urban River Restoration in China:

Current restoration activities and expectations by the population

Abstract

This research aims to inspire the thinking of during river restoration in the process of urbanization, how to take into account both human's expectations and the river ecosystem. It is based on the context of China. The fast urbanization in China has degraded rivers since decades while the problems like black and odorous river pollution and loss of the ecological continuum of rivers has disturbed citizens' daily life. Citizens look forward to the good quality of rivers as well as a pleasant natural riparian zone. Nowadays, river restoration has got more and more emphasis during urbanization with its values observed again by citizens and government. In the article, current practices and initiatives are presented, supported by projects realized or on progress. The advantages and inadequacies are analyzed while suggestions are proposed by consulting river restoration examples worldwide.

Keywords: river restoration, citizens' expectations, local government, black and odorous rivers, riparian zone