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Sustainable water services and interaction with water resources in Europe and in Brazil

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HESSD

4, 3441–3467, 2007

Water services and water resources in Europe and in Brazil

B. Barraqué et al.

Title Page

Abstract

Introduction

Conclusions

References

Tables

Figures

◀

▶

◀

▶

Back

Close

Full Screen / Esc

Printer-friendly Version

Interactive Discussion

EGU

Abstract

The increasing interaction between large cities and nature makes “urban water” an issue: water resources and water services – including public water supply, sewage collection and treatment, and in large cities, storm water control –, which had become separate issues thanks to the process of water transport and treatment technologies, are now increasingly interfering with each other. We cannot take nature for granted anymore, and we need to protect water resources, if only to reduce the long term cost of transporting and treating water. In this paper, we compare the historical development of water industry technologies in European and Brazilian metropolitan areas, in their socio-economic and political context, tracing it through three “ages” of water technology and services which developed under civil engineering, sanitary engineering, and environmental engineering perspectives: the “quantity of water” and civil engineering paradigm was developed on the assumption that water should be drawn from natural environments far from the cities; in the “water quality” and chemical/sanitation engineering paradigm, water treatment was invented and allowed cities to take water from rivers closer to them and treat it, but also to reduce sewer discharge impacts; finally, the environmental engineering paradigm proposes to overcome the supply side perspective, by introducing demand side management, water conservation, water allocation flexibilisation, and an integrated approach to water services, water resources management, and land use policies.

1 Introduction

Paris is now a world size metropolis, but unfortunately, the Seine has not grown with it! As in other large cities in Europe, we have to re-consider the separation between water management and land use planning. Increasing interaction between large cities and nature gives rise to a reflection on “urban water”: water resources and water services, which had become two separate issues thanks to the process of water transport

HESSD

4, 3441–3467, 2007

Water services and water resources in Europe and in Brazil

B. Barraqué et al.

Title Page

Abstract

Introduction

Conclusions

References

Tables

Figures

◀

▶

◀

▶

Back

Close

Full Screen / Esc

Printer-friendly Version

Interactive Discussion

EGU

and treatment technologies, are now increasingly interfering. We need to protect the resource to reduce transportation and water treatment costs. In Brazil, at least in the large metropolitan areas around Sao Paulo and Rio de Janeiro, there is a growing competition for water resources between water and waste water services and electricity, while the three systems are interdependent. This paper builds upon the similarities and differences between European and Brazilian metropolitan areas.

The invention of piped water systems spread on both sides of the Atlantic at the same time; until the 1930's there was no significant difference in terms of connection rates to both systems, and only central city and privileged areas had domestic connections. And of course sewerage was embryonic, often limited to drainage, with most houses still on cesspools or privies. But, along the 20th century, the richest western European States as well as North America managed to universalise the services, while in Brazil governments at different territorial levels are still striving to do it, in particular concerning sewerage. What made the difference? Is it the wealth of industrialized countries, the technical development conditions, differences in demography or in financing systems, or the difference in the allocation of competences between local, regional and national levels? In this paper we can only sketch how these various factors combined. Over the last century and a half, we can identify three socio-technical systems which successively developed under civil engineering, sanitary engineering, and environmental engineering perspectives. Indeed, these three approaches developed in Europe partly as an answer to sustainability crises. In Brazil, relative abundance of water but also dramatic urban in-migration of poor people made it more difficult. However, in Europe, there are now signs of a new crisis, which might make water services unsustainable. Strangely enough, a "spiralling down" evolution could take place, partly due to the low acceptability of the full cost recovery doctrine and the subsequent prices increase. European water services might then face similar issues as emerging countries. We then imagine that territory could resolve what technology cannot any more, and this is why the above mentioned separation between water services and water resources is increasingly blurred.

Water services and water resources in Europe and in Brazil

B. Barraqué et al.

Title Page

Abstract

Introduction

Conclusions

References

Tables

Figures

◀

▶

◀

▶

Back

Close

Full Screen / Esc

Printer-friendly Version

Interactive Discussion

Water services and water resources in Europe and in Brazil

B. Barraqué et al.

Title Page

Abstract

Introduction

Conclusions

References

Tables

Figures

◀

▶

◀

▶

Back

Close

Full Screen / Esc

Printer-friendly Version

Interactive Discussion

In the early 20th century in both areas, water services were under the responsibility of local authorities. In Western Europe, they were part of local welfare through what is termed *municipalism* (including other public services). Even though upper levels of government would intervene in support of local policies, there was little centralisation, but frequent concentration (joint boards). Conversely in Brazil, water policy was long dominated by the over-powerful hydro-energy sector. Besides, agricultural conversion starting in the 1960's, with no land reform, led to an intense rural to urban migration of very poor people, while local authorities were weak and unprepared. During the military government period starting 1964, water services were centralised at States' level: the program named PLANASA met an initial success in extending water services, but it failed to modernise services into something similar in Europe. Quantities of water used are higher per capita, but quality of services is lower, and is maintained low by lack of self funding capacity: the price of water services is low, because the poorer cannot afford to pay higher prices, and then service remains deficient.

Some European countries are still in an intermediate position between the two models. Portugal and Spain had authoritarian governments until 1974–75, and they ended up with water services lagging behind, but large hydraulic projects developed for the sake of hydroelectricity and irrigated agriculture. Joining the EU allowed for some decentralisation, and more recently, they develop the cooperation between central, regional and local governments. In Brazil there is a debate on decentralisation, but it reveals more confrontation than co-operation.

2 The paradigm of water quantity and long distance transfers

In the 19th century, or rather until the Koch and Pasteur discoveries were popularised, hygienists and engineers thought that water should be drawn from natural environments far from the cities. With the industrial revolution and urbanisation, large cities in particular would have to get water from further and further. Typically, in Paris, engineer Belgrand developed a system of transfer from distant sources, which were all more

elevated than the city itself. Thanks to clever hydraulic works including siphons, Paris would get clean water at low operation costs. Yet most cities went on taking water from local wells and from the nearby river (Guillerme, 1988). Indeed, obtaining a water right or a concession on distant water sources requested at least the legal intervention of the national government, who had sovereignty on water resources and their allocation. This created a *de facto* centralisation. Expansion of the new doctrine was also limited by the traditional vision that people should have free access to water resources for their domestic needs. Thus the idea that water should be paid for as a service was not popular, and this vision was supported by the quasi-absence of operation costs. All the expenses were with the installation of the infrastructure, which was paid for by public money.

2.1 The failure of private concessions in Europe...

Yet, in the 19th century private companies imagined that water could be delivered to private residences, including in condominiums, against payment of a bill. In many cities of the time, authorities would consider this as a luxury, and they did not want to get involved. They granted concessions to the companies, which often had to deliver water at a cheap price to fountains and public needs, most of the profit coming from private subscribers of “private” water (Pezon, 2000). Companies were left by themselves to produce and distribute water, having to solve several technological problems (leak control, metering etc.). These initial ventures usually lacked both enough capital and political support to be able to generalise the service. The initial model of the concession in turn suffered distrust between companies and the population. Conflicts developed at the end of 19th century when municipalities became convinced that water supply was not a luxury, but a fundamental public health issue. If operators took water from nearby rivers, it was of bad quality, but they had even fewer financial and legal possibilities to get it from a distance.

Water services and water resources in Europe and in Brazil

B. Barraqué et al.

Title Page

Abstract

Introduction

Conclusions

References

Tables

Figures

◀

▶

◀

▶

Back

Close

Full Screen / Esc

Printer-friendly Version

Interactive Discussion

2.2 ... and in Brazil: the emergence of municipal management

In Brazil, municipal councils and government took on responsibility for developing water and sanitation services starting in the middle of 19th century in response to a catastrophic health situation which struck various towns (Britto, 2006). Yet the embryonic character of the Brazilian state at this time and the limited stage of technical development led to the call for foreign companies, mainly English ones, to build harbours, railways, sewerage, electricity, tramways¹ and telephones throughout Brazil.

In 1857 in Rio de Janeiro, water distribution remained under public administration, but a company, set up with English capital, took over the construction and operation of waste water, thus making the city one of the first in the world to have a system of separate sewers. In São Paulo, water and sanitation services were provided by the *Companhia Cantareira*, a company of Brazilian and British capital created in 1877. Public offices and religious buildings were connected, but residential water supply was still the privilege of an elite. There were no regulatory instruments helping the state control the concessions which lost credibility with the rising concern for public health. By the 1890s, sanitation services were no longer provided satisfactorily by the *Companhia Cantareira*. When its contract ended, the municipal water and sanitation service took over. The same occurred a few years later in Rio de Janeiro, Brazil's capital (until 1960).

The idea that water should be paid as a service was still unthinkable, in part because operation costs were almost nil. All investments were devoted to the infrastructure, especially for water supply, paid for by government revenues. As in Europe, medical thought assumed that cleaner water should be drawn from sources far from the cities. The limited availability of good-quality water was associated with annual epidemics of yellow fever and of other diseases resulting in a significant number of deaths (Rezende

¹ Interestingly, the popular name for tramways in Rio is *bondes*, because they were built by English engineers and funded, as in England, by bonds, i.e. money raised among the city elites.

HESSD

4, 3441–3467, 2007

Water services and water resources in Europe and in Brazil

B. Barraqué et al.

Title Page

Abstract

Introduction

Conclusions

References

Tables

Figures

◀

▶

◀

▶

Back

Close

Full Screen / Esc

Printer-friendly Version

Interactive Discussion

EGU

and Heller, 2002). This situation worsened in the first decades of the 20th century, as sanitation infrastructure failed to expand at the same rate as population, in particular after 1930.

A new notion of sanitation formulated by civil engineers became hegemonic. It was concerned with preparing space for urban expansion through landfills, river channels, flood control, and the elimination of risk areas, where networks of water supply and sewerage were to be installed as well. Saturnino de Brito's plans for Sao Paulo are an example of this idea of integrated urban water management, including the protection of strategic water sources for public supply. However, the largest Brazilian cities – and São Paulo itself – failed to put those plans in practice. This integrated concept of sanitation planning would later be aborted by the new concept of *saneamento básico* (Britto, 2006; see Sect. 2.5).

As in Mediterranean Europe, between 1930 and 1940 (a period known as the *Estado Novo*), the Brazilian welfare state developed under a mixture of authoritarianism and populism. This expansion of infrastructure took place in a new regulatory climate which eventually evolved into a highly centralized system of electric energy regulation and large scale water resources management at federal level. Urban sanitation services partially escaped that model, and from 1940 to 1960, water supply and sewerage often continued to be run by municipal departments, but a “public service” logic dominated and tariff issues were kept on the backstage. Costs were covered by taxes and decreased as consumption increased, fostering waste and losses. In turn, water engineers imagined to meet the demand with quantitative supply side solutions, and they remained influenced by the civil engineering paradigm more than in Europe. This led to a crisis for the allocation of water resources.

2.3 Water supply, hydropower and large water transfers in Brazil

The first major water transfers in Brazil were to produce electric energy for the metropolitan regions of São Paulo and Rio de Janeiro, with later impacts on urban water supply. The expansion of drinking water needs in Greater São Paulo entered

Water services and water resources in Europe and in Brazil

B. Barraqué et al.

Title Page

Abstract

Introduction

Conclusions

References

Tables

Figures

◀

▶

◀

▶

Back

Close

Full Screen / Esc

Printer-friendly Version

Interactive Discussion

into conflict with the hydropower sector (Formiga-Johnsson and Kemper, 2005) The Guarapiranga and Billings reservoirs were built for power generation purposes in the 1920s and 1930s, respectively. For decades, the Alto-Tietê – Cubatão Complex diverted a large volume of water from the Tietê and Pinheiro rivers into the Billings reservoir (with a capacity of 1 km³) for use by the Henry Borden hydropower plant, located in the state's coastal area, in another river basin. As had occurred in the late 1940s with the Guarapiranga reservoir, in the 1970s, the water in the Billings reservoir began to be requisitioned to supply Greater São Paulo. But sanitation infrastructure in São Paulo had failed to expand at the same rate as the population, resulting in severe pollution of these rivers and, consequently, of the Billings reservoir. Although engineers and politicians have repeatedly recognized the precariousness of both drinking water supply systems, priority for this complex was always given to hydropower generation (Keck, 2002). Pressures from environmental groups increased, however, and the 1989 state constitution changed the priority for use of the Billings Reservoir to urban supply. Since 1992, pumping into Billings has been suspended altogether, except when required for severe flood control. However, tensions continue since plans to increase energy production by pumping water from the Tietê and Pinheiros Rivers have always been on the electricity company's agenda. After a major drought in 2000 which culminated in a national level energy crisis the following year, a special license was granted to transfer an outflow of up to 4 m³/s to meet an emergency power demand; there are also projects for cleaning up the Pinheiros river so that it would be possible to use it as in the past, while meeting environmental regulations. Today, the main function of the Guarapiranga reservoir is to supply water to São Paulo city. One isolated part of the Billings reservoir supplies some municipalities of Greater São Paulo, including São Paulo city itself.

Conversely, the dominance of large water transfers for hydropower purposes was beneficial for Greater Rio de Janeiro's water supply needs (Formiga-Johnsson et al., 2007). After World War II, the largest transfer in the country in terms of water volume was designed to generate electricity for the Rio de Janeiro Metropolitan area. Located

Water services and water resources in Europe and in Brazil

B. Barraqué et al.

Title Page

Abstract

Introduction

Conclusions

References

Tables

Figures

◀

▶

◀

▶

Back

Close

Full Screen / Esc

Printer-friendly Version

Interactive Discussion

Water services and water resources in Europe and in Brazil

B. Barraqué et al.

Title Page

Abstract

Introduction

Conclusions

References

Tables

Figures

◀

▶

◀

▶

Back

Close

Full Screen / Esc

Printer-friendly Version

Interactive Discussion

in the middle stretch of the Paraíba do Sul river², immediately downstream from the main industrial area of the basin, this transfer diverts two-thirds of the average flow of the river (up to 160 m³/s) and the entire flow of one of its tributaries, the Pirai River (about 20 m³/s), into a system of hydropower reservoirs known as the Sistema LIGHT. The outflow provides over six times more water to the Guandu River than that river's natural average flow, eventually turning it into the main water source for domestic users in the metropolitan region of Rio de Janeiro (RMRJ) and many important industrial users. Indeed, although Light's hydroelectric plants remain in operation today, electricity production plays a minor role, while water supply is crucial for 8 million inhabitants of RMRJ.

Large water transfers have been widely used for more than 50 years, and continue to be common practice in Brazil. But the mobilizations against the Alto-Tietê diversion in São Paulo and recently against the contentious São Francisco project have demonstrated that centralized supply sided solutions for water based development are getting more difficult to carry out in Brazil.

2.4 A transition toward the second paradigm in Europe: municipal management

In Europe, the tradition of local water services management was kept, following the trend set in England: water supply and sewerage were generalised earlier than on the continent; the skill of “mechanics” allowed for innovation, in an overall context of decentralisation and rise of what should be termed municipalism (rather than municipal socialism as depicted in France, or as water and gas socialism as derided in the UK itself). Indeed, “welfare state” and central government involvement in the economy were anticipated by at least two generations of municipal welfare policy in England, followed by other cities in Europe.

With the emergence of a middle class and of qualified working class, also came the

² The Paraíba do Sul river basin is federal, since shared by the states of São Paulo, Minas Gerais and Rio de Janeiro.

savings banks, which would eventually loan at cheap rates for local welfare achievements. Municipal bonds were found attractive by the public, and on top of this the Government would subsidise projects. Direct management generalised, private concessions were not renewed and even terminated. But overall, in Britain, the idea prevailed that water services should be covered by local taxation, i.e. by rates proportional to the renting value of the house. This proved to have important redistributive effects and played a significant role in the acceptance of domestic supply.

Glasgow was one of the first European cities to reach this temporary equilibrium: in the middle of 19th century, it took over the water company, made the needed investment to connect the whole population, and at the same time, thanks to government grants, built an aqueduct to tap clean water from Loch Katrine, some 55 km away. “The official opening by Queen Victoria on an appropriately wet autumn day in 1859 was an event of enormous significance for Glasgow (. . .) Loch Katrine was unquestionably the prime municipal showpiece for the city, combining the wonders of Victorian technology with the nurturing quality of pure Highland water” (Maver, 2000).

However in Britain, there was not so much water available, and many cities had to take it from rivers; so they had to invent some form of purification, and first filtration; then, the overall *problematique* of water quantity could be partly replaced by a quality one. But the first type of approach remained dominant in the New World, and was extended in the rest of the world after the Second World War, due to the co-occurrence of International Financing Institutions offering cheap money, and of various forms of support for National Governments’ intervention in infrastructure provision (Keynesian or socialist). The American federal government’s involvement in large hydraulics offered a long lasting example. Interestingly enough, it also remained dominant in European dictatorships: importance of central and regional policies, and the reduced role of municipalism, maintained a low priority on water services. Besides large hydraulic projects of the 1950’s and 60’s were increasingly devoted not to cities, but to electricity and irrigated agriculture which was then associated with development. Today, still, many States in developing countries base their water policy on large water transfers, so as to

Water services and water resources in Europe and in Brazil

B. Barraqué et al.

Title Page

Abstract

Introduction

Conclusions

References

Tables

Figures

◀

▶

◀

▶

Back

Close

Full Screen / Esc

Printer-friendly Version

Interactive Discussion

indirectly subsidise the production of irrigated cash crops to integrate in the world market. This is even the case in Spain (Barraqué, 2000). In some cases the safe yield has been passed, and the present crisis offers the possibility to check the unsustainability of these past policies. California, which has become indeed the “largest artificial river basin in the world”, thanks to huge State and Federal funded infrastructure, is a leader in experiencing this need for change.

2.5 A transition toward the second paradigm in Brazil: the development of *saneamento básico*

By the mid 1950’s, a new concept, “basic sanitation” (*saneamento básico*), began to guide service management Brazil. This concept refers exclusively to water supply services and to the collection and treatment of waste water, unlike the broader concept of the previous period, when sanitation was associated with wider sanitary conditions for urban development and the integration of urban infrastructure.

Under the new perspective, water supply and sewer services were both considered essential services within the urban sanitation sector. They should be under the control of public administration but autonomously managed by specific agencies which would run the two systems together. Planning and management were expected to rely on modern engineering techniques and entrepreneurial models. System maintenance and expansion would be financed by user fees which would vary according to consumption levels. The idea of self-sufficiency, alongside the creation of municipal autarchies, i.e., of autonomous companies owned by the government, began to spread. These ideas fundamentally differentiated the *saneamento básico* approach from other services such as garbage collection and flood control, which continued to be financed by taxes and stayed under the purview of ordinary municipal agencies.

Municipal management also gained autonomy through the development of independent agencies and self-financing mechanisms. Services began to expand into the suburbs. However, since the health situation had improved, federal and state levels of government preferred to devote public resources to productive infrastructure (energy,

Water services and water resources in Europe and in Brazil

B. Barraqué et al.

Title Page

Abstract

Introduction

Conclusions

References

Tables

Figures

◀

▶

◀

▶

Back

Close

Full Screen / Esc

Printer-friendly Version

Interactive Discussion

transport) than to local sanitation. Under-funding and rapid urban growth finally resulted in a pattern of centre-periphery segregation: most of the suburbs, distant from the centre, and inhabited predominantly by low income groups, were poorly served. In addition, in these areas the urbanisation process often took place without planning or public control; the infrastructure layout was not thought out in advance, leading to a growing deficit. Conditions were made worse by irregular urban land occupation. For example, squatter settlements, or *favelas* located in areas improper for settlement (wetlands, flood risk areas, and agriculture or environmental conservation areas) were not allowed to receive public infrastructure which, indeed, was often technically unfeasible.

3 The paradigm of water treatment

In North West Europe, industrialisation and urbanisation led to a quicker crisis of the “civil engineering age”: as cities grew in population, water would eventually be fetched from further and further, and this would generate conflicts with communities deprived from their resources. Besides, for reasons of political conflicts related to the centralisation *versus* decentralisation issue, cities would eventually become reluctant to depend on central governments’ legal and financial support.

3.1 Drinking water plants and sewage treatment plants in Europe

Once Pasteur and Koch found water contamination was a major cause of diseases in the 1880’s, even distant and pure water would eventually need to be treated. This is how sanitary engineering developed to complement civil engineering and solve the first crisis of water services. Because direct medical action upon waterborne diseases was uneasy, it was decided that water should be filtered (end of 19th century), and later disinfected (chlorination, ozone or activated carbon, around World War I). But then, taking surface water just upstream from cities would induce economies of scale, and would save a lot of investments. Typically, in Paris a 30 years’ debate started in 1890

Title Page

Abstract

Introduction

Conclusions

References

Tables

Figures

◀

▶

◀

▶

Back

Close

Full Screen / Esc

Printer-friendly Version

Interactive Discussion

about an aqueduct from Geneva Lake which would “solve all the City’s water quantity problems forever”. The project was discarded after the First World War for geostrategic reasons, but indeed it had become useless after the inauguration, in 1902, of the slow filtration plant in Ivry, operating with Seine water just upstream from Paris; filtration gained support after a typhoid epidemics in 1899, which was found to be due to the contamination of the Loing springs; yet these then were the furthest and supposedly cleanest water sources for the city.

However, treating water would induce a serious rise in operation costs, which are usually more visible to the public and to the city councils. Then the idea spread that services could be at least partly covered by bills. It was certainly also an important change for the public, and charges were initially limited to cover operation and maintenance. Slowly however, delivery of pressure water within the homes changed status, from a luxury good to a commodity, and made water billing normal. In Europe, only Britain (and the Republic of Ireland) kept until recently the ancient charging system based on rateable housing values (but also many municipalities in the U.S., like New York, and in Canada).

Covering an ever larger fraction of the costs by bills increased the self financing capacity of water services which improved their sustainability, and in many continental countries, it was decided to pass on the sewerage charges in the drinking water bills, despite the compulsory character of sewer connection, which would normally imply coverage of the costs by local taxes. Sewage treatment (and sometimes also collection) also became a commercial service. Eventually, increased self financing capacity reinforced the legitimacy of local authorities as services providers, or at least organisers. But, in order to achieve economies of scale, it was often needed to develop the joint efforts of neighbouring communes. Usually, central governments allowed and supported the creation of joint boards of municipalities, to bring the institutional, the technical and the management scales closer to each other.

In turn, this innovation in both plants (water and waste water) supported the development of new territories and of new relationships between politics and expertise,

Water services and water resources in Europe and in Brazil

B. Barraqué et al.

Title Page

Abstract

Introduction

Conclusions

References

Tables

Figures

◀

▶

◀

▶

Back

Close

Full Screen / Esc

Printer-friendly Version

Interactive Discussion

between elected representatives and engineers. In several countries, citizens pay a water bill to a private company which is owned by a joint board of municipalities, sometimes involving a regional level institution (Barraqué, 1995)

3.2 *Saneamento básico* and centralisation of services in Brazil

5 The “water treatment paradigm” began to emerge in Brazil only in the 1970s, with the implementation of the *saneamento básico* concept and, above all, the generalization of urban water supply. In those years, the country underwent a period of great transformations, with intense industrial development, demographic explosion and accelerated urbanization. The political situation also underwent deep changes after a military regime took power in 1964.

10 The military regime decided to set up a new operation and regulation structure for the water and sanitation sector based on the concept of “basic sanitation” (*saneamento básico*). PLANASA – the National Plan of Basic Sanitation or *Plano Nacional de Saneamento Básico* – was launched in 1971 with the goal of making investments more rational and of significantly developing the system within 10 years. To achieve these objectives, administrative centralisation at the state level was considered to be of utmost importance. Centralisation would also allow for cross subsidization. In the state of Rio de Janeiro, a new State Water Company created in 1975, CEDAE, would become responsible for almost all municipalities of Rio de Janeiro state. In São Paulo state, SABESP was created in 1973, absorbing various regional companies. Despite the emphasis on expanding the network, however, the new companies were pushed to operate as if they were private companies, leading them to give priority to higher profits and rapid returns.

25 Even though the 1967 Federal Constitution continued to give municipalities the responsibility for providing water services, the new policy reduced the role of local government to signing concession contracts to the state companies. Handing over the concession to state companies was the only way to be given access to the new financing structure. Most municipal governments did not question the new model for many

Water services and water resources in Europe and in Brazil

B. Barraqué et al.

Title Page

Abstract

Introduction

Conclusions

References

Tables

Figures

◀

▶

◀

▶

Back

Close

Full Screen / Esc

Printer-friendly Version

Interactive Discussion

years. Indeed, the predominance of state water companies became a justification for denying that they had responsibility for matters related to water supply and sanitary sewers.

In terms of the quality of the infrastructure systems and of the urban environment itself, the consequences of this new approach were disastrous. As argued by Silva, infrastructure networks must be planned in accordance with vectors of city growth (Silva, 2004). However, the State Companies of Sanitation have rarely considered local plans, unless, of course, they coincided with their own. On the other hand, the way *saneamento básico* was defined – giving priority to evidently essential systems, such as water and sewerage, but excluding drainage and solid residue collection, and delaying sewage treatment – generated critical situations in terms of flooding and water resources pollution.

In this period, the need to integrate water resources management and water and sewerage services began to become apparent. Environmental agencies were created to control pollution and localized integrated water management initiatives were adopted in Greater São Paulo, though with few practical results. These experiences, however, were important precursors to the emergence of a new water services paradigm, in which water resources protection and water quality recuperation become unavoidable.

In 1986, a profound institutional crisis led to the extinction of PLANASA. Its initial success in water access coverage is obvious, and was largely a result of the vitality of the Brazilian economy between 1967 and 1980: high growth rates allowed social security and retirement funds to finance ever larger housing and urban infrastructure. However, investments concentrated on water supply, while critics have noted that sewerage was left aside, especially waste water treatment. Water supply is cheaper and can easily be charged for, producing better returns on investment than waste water collection and treatment, which must be done collectively and at high cost. In addition, the portion of the population able to pay for the real price of services was too small to guarantee self-sustainability, as originally planned. As a result, PLANASA invested more in wealthy urban areas while connection deficits in poor municipalities and, in

Water services and water resources in Europe and in Brazil

B. Barraqué et al.

Title Page

Abstract

Introduction

Conclusions

References

Tables

Figures

◀

▶

◀

▶

Back

Close

Full Screen / Esc

Printer-friendly Version

Interactive Discussion

particular, in areas of irregular land use did not decrease.

The management model of the state companies was dominated by a supply logic, based on the belief in the inexhaustibility both of resources and of the technical capacity to expand water supply systems and infrastructure. Indeed, water transfers continue to be necessary in Greater São Paulo, since most water bodies there have been heavily polluted. This so-called “relative water scarcity” – caused by inadequate water quality – led the Alto-Tietê basin to import water from neighbouring basins in the 1970s (Formiga-Johnsson and Kemper, 2005). Water diverted from the Piracicaba and Capivari basins to the Cantareira System currently supplies half of the total water in Greater São Paulo. A new major conflict has risen recently: rapid population and economic growth in the Piracicaba basin increased significantly local water demand as well as the level of pollution of its rivers. After an intense and lengthy mobilization that started in the 1980s, the Piracicaba basin only recently obtained more flexible operating rules for the Cantareira system, which now must ensure minimum water quality conditions in the Piracicaba basin. This conflict and the movement around it also greatly influenced the state reform of water resources management that occurred during the 1990s, which in turn strongly influenced the adoption and implementation of national level integrated water management policies in the 1990s. In the end, drinking water quality is not very good, and sewage treatment is lagging behind: Brazil has to meet the third paradigm issues, while it has not yet met those of the second one.

4 The third paradigm of water services

However, the sustainability of the European model might be challenged in the near future: how is it possible to maintain a good service quality on the long run, even once everybody is connected, if full cost recovery is imposed?

In France like in other northern European countries, it was decided to have sewerage paid within the water bills. But in the same period, water supply itself became a mature business, i.e. it had to face the issue of renewing ageing infrastructure with-

Water services and water resources in Europe and in Brazil

B. Barraqué et al.

Title Page

Abstract

Introduction

Conclusions

References

Tables

Figures

◀

▶

◀

▶

Back

Close

Full Screen / Esc

Printer-friendly Version

Interactive Discussion

Water services and water resources in Europe and in Brazil

B. Barraqué et al.

Title Page

Abstract

Introduction

Conclusions

References

Tables

Figures

◀

▶

◀

▶

Back

Close

Full Screen / Esc

Printer-friendly Version

Interactive Discussion

out any more subsidies. We hypothesize that European municipalism had to adapt in various ways, but chiefly through returning to legal private status, so as to be able to depreciate the assets and to make renewal provisions, which was difficult under public accounting. In turn, adopting depreciation and provisions meant another rise in water bills. As a result, today an increasing number of large water users (industry, services) either quit or change their processes or fight their leaks. This explains the recent stagnation and even decrease in volumes sold (Barbier, 2000). In some countries even domestic consumers have reduced their demand, through changing fixtures, different garden design, and also with rainfall storage or other alternative sources of water for non drinking uses. Yet this demand reduction ultimately worsens the already fragile financial balance of collective services.

In addition, water suppliers have a harder time to comply with the drinking water standards (DWS) all the time at reasonable costs. Drinking water criteria tend to privilege a traditional “no-risk” strategy at the expense of economic considerations. But the multiplication of criteria is slowly bringing the situation into over-complexification: chlorination by-products give cancer (Okun, 1996). There are many other examples: eventually the media can report a growing proportion of people receiving non-complying water, even though the treatment is improving on the long run. To lower the risk of being unable to make it, along with local, national and European authorities, water supplies turn to a new strategy: water resources protection. That is part of environmental engineering.

4.1 Some features of environmental engineering as paradigm of the third age

Originated in sanitary engineering in the U.S., environmental engineering aims at protecting not only populations from negative environmental factors, but also global and local environments from potentially dangerous human activities. Of course, knowledge of natural processes was an important issue, but programs also focussed on urban issues and technical systems (Barraqué, 1993). The common characteristic of the two first paradigms is to focus on supply-side solutions, while environmental approaches

have to consider “demand side”. While economists would equate the term with market prices, environmental engineering considers that demand and supply are not independent like in a market, but inter-related. Thanks to the concept of environment, we have learnt that sometimes causes act on consequences not linearly, but exponentially, and that supply and demand are not really independent, but interacting. This is what we call the “network effects”.

Until recently, however, systems called “infrastructure” were hidden from the people, while offering more freedom, as time and space saving devices. Besides, it was not the infrastructure, but the plot of built or buildable land, which provided political legitimacy. City aldermen and elected representatives were competent on issues like valorisation/devalorisation of urban land, and they did not know much about the systems. Conversely, early sanitary engineers were convinced that public health was a too important issue to be negotiated with either landowners or their tenants, and they preferred to impose connection to systems located under public space. The choice of the *Tout-à-l’égout* in Paris is typical (Dupuy and Knaebel, 1982). In turn, people became ignorant of the importance of systems: “out of sight, out of mind” and NIMBYism characterise the public’s attitude and is at odds with a conservation attitude (Melosi, 1981). Operators had no interaction with the public and with demand side problems: they just had to match the demand with more or less invisible infrastructure and that was it.

With our “systemic” eyes of today, we can see how the municipalist model comes to a crisis. Sewer systems were designed bigger and bigger to accommodate increasing volumes of stormwater, because planning regulations seldom include limitations on soil imperviousness. Since urban services are finally meeting diseconomies of scale, demand side is at last considered as a potential rationalisation.

This leads to redefine the very notion of “operator”; if supply and demand interact permanently, the traditional separation between supply-side and engineers, and demand-side and elected representatives, is blurred. A direct contact with the public is necessary, so as to get away from coarse linear and overoptimistic projections for the

Water services and water resources in Europe and in Brazil

B. Barraqué et al.

Title Page

Abstract

Introduction

Conclusions

References

Tables

Figures

◀

▶

◀

▶

Back

Close

Full Screen / Esc

Printer-friendly Version

Interactive Discussion

demand. Going further: getting the users of the system to use it more efficiently, and alleviate the negative network effects. This implies a significant change in governance: in the end the new grid-based systems operator is a complex mix of people and institutions who can only master the networks effects when they interact. Sharing information becomes crucial to succeed when a growing number of institutions interact to provide the water services.

4.2 The case of Paris region

Any large metropolis offers a very complex institutional situation: communes are responsible for water services, but they cannot anymore do it alone: for historical reasons, Paris city has its own water services, and relies for half of its needs upon distant springs and aquifers, but the other half comes from rivers. Suburban communes are almost all part of large joint boards (the largest one, SEDIF, serves 4 million inhabitants in 144 communes), to rationalise their services (large plants treating surface water) and to build a better balance of power with the private operators; only one commune has a municipal water supply, Saint-Maur.

Since the system relies heavily on rivers, it was decided after World War II to build three upstream reservoirs to sustain the low flow in the summer. The first was built through central government funding, taking advantage of an important winter flooding in 1952. But the two next ones were funded by Agence de l'eau Seine Normandie, i.e. by levies paid in water bills. This new responsibility of water users in funding dams led them to discard a project for a fourth reservoir³. And it was a good idea, since drinking water demand is now on a slight but steady decline. Clearly, the major issue remains drinking water quality, and since the treatment plants are now within the urbanised area,

³This fourth reservoir was planned by mayor J. Chirac's experts, but it was abandoned for the same reasons (we must and can purify the water anyway, said the giant water supply companies, and the probability to have a dramatic scarcity is very low); plus the fact that Paris water demand went down by 16% between 1990 and 1998 (Cambon-Grau, in Barbier, 2000); after a pause, demand is now reducing again.

Water services and water resources in Europe and in Brazil

B. Barraqué et al.

Title Page

Abstract

Introduction

Conclusions

References

Tables

Figures

◀

▶

◀

▶

Back

Close

Full Screen / Esc

Printer-friendly Version

Interactive Discussion

the big metropolis is dependent on better protection of both surface water resources (from upstream cities, agriculture and industry) and groundwater (from agriculture).

The situation is even more complex concerning sewage collection and treatment. The initial scheme at the end of 19th century was to collect all waste water and some of the rainfall and to convey this water downstream (combined sewers at the time), where it would be spread on sewage farms. The large interceptors were built and operated by central government staff at the *département* (county) level. But with the growth of the city, there was not enough space, and sewage works with biological treatment were built in Achères just before World War II. Stormwater would overflow directly in the river. With the rise of environmental policy though, it was found that Achères, the second largest sewage works in the world, had a severe impact on the Seine down to the estuary: there was not enough space to fully stabilise pollution. Besides, stormwater was increasingly found to be heavily polluted: the post war choice of separate sewers allowed to see it. After several years of intense debate between the many stakeholders involved, it was finally decided to break the linear scheme of engineer Belgrand: taking water upstream and discharging it all downstream. The construction of modern and innovative sewage works upstream from Paris in Valenton, and the enlargement of smaller sewage works, will reduce waste water arriving in Achères by 30%, which would allow treating it better. Stormwater is increasingly collected and stored before treatment either in the sewage works after the storms, or sent to a couple of special treatment plants.

The resulting institutional set up is quite complex: suburban communes are in charge of street sewers, the three *départements* of the inner ring around Paris city are in charge of larger interceptors and of the stormwater control policy. Together with Paris city, they formed the SIAAP (Syndicat Interdépartemental d'Assainissement de l'Agglomération Parisienne), an inter-county board for running the largest interceptors and the sewage treatment plants. In the outer ring, there are some inter-communal joint boards which operate at the level of catchments of small tributaries, and which combine sewage collection and treatment and protection of the aquatic environment.

Water services and water resources in Europe and in Brazil

B. Barraqué et al.

Title Page

Abstract

Introduction

Conclusions

References

Tables

Figures

◀

▶

◀

▶

Back

Close

Full Screen / Esc

Printer-friendly Version

Interactive Discussion

Projects benefit from the financial support of the Agence de l'eau. This implies an unprecedented need for multilevel governance, and it is a very sensitive issue in the region and in the country: the Agences de l'eau cannot fund available stormwater control, unless one can prove that quantity management has a positive impact on quality.

5 And symmetrically, communes are not sufficiently encouraged to reduce runoff from their territory, e.g. by subjecting building permits to detention constraints.

Now it is clear that the new water services policy needs to turn towards demand management, and we argue that this indeed means to develop citizens' participation. And as a matter of fact, several institutions like the SIAAP, the city of Paris and some
10 suburban *départemental* councils have recently set up consultative bodies to share information with citizens and NGOs.

4.3 Towards the third paradigm in Brazil

In Brazil, the environmental engineering paradigm develops basically because problems related to water supply and, above all, sewage treatment and collection developed into major challenges. Intense urban and industrial growth during the second half
15 of the last century means that the dominant water issue in the Alto-Tietê Basin – where Greater São Paulo is located – is the struggle to balance water demand and availability. Ultimately, it is a tremendous challenge to provide water for nearly 18 million people in a highly urbanized area. Rapid urbanization has had intense impacts on water sources
20 and water quality and has developed a complex web of interests and issues around water, involving sectoral policies, inter-basin transfers, and others (Formiga-Johnsson and Kemper, 2005). The same problem can be observed in the Rio de Janeiro Metropolitan Region, although less intensely: that city's main source of drinking water – the Guandu river, which receives waters diverted from the Paraíba do Sul river basin – has
25 become severely polluted in recent decades, requiring the Guandu water treatment station to use enormous quantities of chemical products to make the water collected potable. Water services universalisation remains a challenge, especially with respect to sewage treatment and collection: investments increased substantially in the 1990s,

Water services and water resources in Europe and in Brazil

B. Barraqué et al.

Title Page

Abstract

Introduction

Conclusions

References

Tables

Figures

◀

▶

◀

▶

Back

Close

Full Screen / Esc

Printer-friendly Version

Interactive Discussion

but deficits remain important.

Indeed, São Paulo and Rio de Janeiro and their metropolitan areas illustrate a generalized problem in Brazil's large cities, the resolution of which will require the integration of the two main dimensions of water management in metropolitan areas: water resources management and environmental sanitation management. This is what the new policy starting in the early 1990s develops: it is based on intrinsic concepts of the environmental engineering paradigm such as demand side management, water conservation, water allocation flexibilisation, and an integrated approach of water services, water resources management, and land use policies. In Greater São Paulo, the water resources policy has gone even further, addressing the issue of headwaters protection from urban sprawl, one of the most serious water-related problems of the basin (and the most difficult to resolve). Initiated in the mid-1970s and revised in 1997 (State Headwaters Law 9.866/97), this new approach also represents a remarkable departure from São Paulo's traditional sectoral approach to water quantity and quality, which separated the management of water from its environmental aspects, especially water pollution and land use. However, the implementation of such policies will likely face significant difficulties, since reaching the proposed goals depends on the capacity and will of municipal authorities to improve their urban regulations so as to guarantee the control and monitoring of land use in the sub-basins.

But this also implies to develop new forms of multi-level governance: the predominant management model is still based on the delegation of services to state-owned sanitation companies, unlike other Latin American countries that have recently undergone major privatization in the area. By the year 2000, 71% of the 5.507 Brazilian municipalities had delegated their responsibility for water and sewage services to state leveled companies; 28% had their own municipal agency, and only 1% had handed over services to private companies (63 concessions in all). However, in 2006, a new regulatory framework law passed in congress, defining new operating rules for sanitation services; and in 2007 additional legislation creates participatory management bodies at municipal level, encourages new territorial scales of service management

Water services and water resources in Europe and in Brazil

B. Barraqué et al.

Title Page

Abstract

Introduction

Conclusions

References

Tables

Figures

◀

▶

◀

▶

Back

Close

Full Screen / Esc

Printer-friendly Version

Interactive Discussion

(see below) and gives municipalities more control over services (“program contracts”). The law returns to and broadens the integrated sanitation vision of the early 20th century, now called *saneamento ambiental* and including water supply, sewage collection and treatment, solid waste and urban drainage.

5 Besides, the creation of River Basin Committees has created a new multisectoral articulation that has challenged the sectoral logic of sanitation management that prevailed until the 1990s. Even a river whose waters are limited to a single municipality will normally flow into another river, probably in another municipality. A waste water treatment problem becomes a water resources one, just like in France when the Agences de l’eau were invented.

10 The “ideal scale” for sanitation services management is currently in debate in Brazil, opposing defenders of the *municipalista* option and those who support regionalized management at the level of state governments. A third option is now emerging: intermunicipal articulation through consortia formed at the river basin or sub-river basin level and the formulation of an inter-sectoral management model. Such intersectorality is necessary to deal with the fundamental questions related to water management that Brazilian cities are confronting. The consortia, whose structure has been recently regulated by federal law, have been conducting service management planning and regulation and interacting in an integrated manner with the Basin Committees, the most important bodies for mediating conflicts among public actors and civil society. They may be a viable alternative for building the intersectorality that is so necessary. However, since they are a form of voluntary and cooperative intermunicipal organization, creating consortia requires breaking with the fragmented vision that characterizes city management today, typically ridden with party politics and competition among cities. In this respect, the ABC Consortium and the Alto Tietê Committee, both in the Metropolitan Region of São Paulo, point to new, alternative paths and deserve further study.

Water services and water resources in Europe and in Brazil

B. Barraqué et al.

Title Page

Abstract

Introduction

Conclusions

References

Tables

Figures

◀

▶

◀

▶

Back

Close

Full Screen / Esc

Printer-friendly Version

Interactive Discussion

5 Conclusions

In Europe, urban water services were increasingly run separately from the issues of water resources allocation, thanks to the innovation of water works and sewage treatment plants. Today it becomes preferable to combine technology and land use based solutions for a better sustainability of water services, rather than just technological solutions. Increasingly, in Germany, the Netherlands, and to a lesser degree in Denmark and France, utilities or their organising authorities develop contracts with farmers, to obtain a reduction of fertilizers and pesticides' use, through appropriate compensation for the corresponding loss of revenues (Brouwer et al., 2003). This policy is criticised by some economists and ecologists together, who argue that the polluters and not the victims should be the payers. Other economists just acknowledge that it is an efficient policy, and probably the only one, at least during a phase of "social learning" (Salzman, 2005).

A new intelligence of the limits of urban technology, also means extending the services to new areas with alternative technologies, e.g. decentralised sewerage systems: in most rural areas, and in low density suburbs, it is economically unreasonable to connect everybody to a sewer. Advances in soil biology make septic tanks better than small treatment plants, if properly operated. What we need to invent then is a service in-between the costly and heavy traditional centralised sewerage system, and the full self reliance of rural people. Even in water supply, there are a lot of flexible alternative technologies which could be used safely provided there were an appropriate institutional set up.

Beyond the generalisation of commercial management and water billing by public institutions, a striking institutional evolution in Europe is concentration of services at an upper than local level of Government. In Great Britain regionalisation and removal of local authorities' control took place 15 years before privatisation. In the Netherlands there remains only 13 water supply companies, and less than 30 water boards (in charge of large sewers and sewage works). In Italy, communal water services are merged into

HESSD

4, 3441–3467, 2007

Water services and water resources in Europe and in Brazil

B. Barraqué et al.

Title Page

Abstract

Introduction

Conclusions

References

Tables

Figures

◀

▶

◀

▶

Back

Close

Full Screen / Esc

Printer-friendly Version

Interactive Discussion

EGU

new integrated boards (water and sewer) organised at the level of ATOs (optimal territories) which usually correspond to the provinces. In Portugal, the Government pushes communes to join large mixed boards where the National water company holds half of the shares and they have the other half. In a way, Brazil is undergoing reverse processes: since former centralization was associated with a non democratic regime, a lot of people, and in particular left wing parties, advocate for a re-municipalization of water services. Some even mix up decentralisation and privatisation, because many State water companies are held in distrust.

The picture is then largely blurred: in developed countries there is good tap water, but people have been brought to ignore quasi everything about their services, so they cannot make a difference between water resources and water from the tap. Conversely, in developing countries part of the population has to rely on untreated water resources. Unfortunately, in the global debate about privatization, there is a tendency to amalgamate water resources and water services, and also developed countries and developing ones, for the sake of fighting globalisation and related markets: people advocate that water should be public and free for the poor. The worst is that in large metropolitan areas in the whole world, water as a resource, water services and other services like electricity have to be integrated and request intergovernmental solutions plus public participation.

The expression “three engineering paradigms for water industry” should not be understood as replacing each other in a sequence: some projected water transfers are still quite necessary and sustainable. And cities will go on needing water and sewage works. But new land use based solutions will help; they request new approaches and larger interdisciplinarity. Our comparative approach helps developing a good vision of what is at stake in water services provision today: a need for social sciences in what we call “hybrid forums”, where stakeholders are confronted to scientific or technical issues within the scientific community, and can eventually build up alternative and innovative “advocacy coalitions” to lead more sustainable water policies (Sabatier, 1993). We should therefore mobilise enlarged interdisciplinarity in environmental engineering.

Water services and water resources in Europe and in Brazil

B. Barraqué et al.

Title Page

Abstract

Introduction

Conclusions

References

Tables

Figures

◀

▶

◀

▶

Back

Close

Full Screen / Esc

Printer-friendly Version

Interactive Discussion

May be the most important is to give engineers a socio-economic and institutional culture of their action, to help them accept the consequences of the new motto: integrated and participatory water management. In France the PIREN – Seine project offers a good example of what can be done in that direction.

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HESSD

4, 3441–3467, 2007

Water services and water resources in Europe and in Brazil

B. Barraqué et al.

Title Page

Abstract

Introduction

Conclusions

References

Tables

Figures

◀

▶

◀

▶

Back

Close

Full Screen / Esc

Printer-friendly Version

Interactive Discussion

EGU

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Water services and water resources in Europe and in Brazil

B. Barraqué et al.

Title Page

Abstract

Introduction

Conclusions

References

Tables

Figures

◀

▶

◀

▶

Back

Close

Full Screen / Esc

Printer-friendly Version

Interactive Discussion