SWITCH

SIXTH FRAMEWORK PROGRAMME

Input to deliverable 6.1.5-6 Comparative Analysis of Enabling Factors for Sustainable Urban Water Management

Making urban water management more sustainable: Achievements in Berlin

A case study investigating the background of and the drivers for, sustainable urban water management in Berlin

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Executive summary

This study illustrates why Berlin can be considered as a city on its way to becoming a model for sustainable urban water management. Based on a review of literature and expert interviews, the study describes the historic and current drivers that have influenced this development and fostered research, innovation and practical transformation in Berlin's water sector.

The research concludes that five factors have played a crucial role in establishing Berlin as a unique example in sustainable urban water management. These are: (1) Berlin's historic circumstances after World Water II and until reunification, (2) the high level of financing made available for water management, (3) Berlin's unique administrative status as a national capital, federal state and local government, (4) an ecologically aware Senate as a powerful regulator, (5) a high level of public awareness regarding water issues.

This paper also includes lessons learned from Berlin that can be transposed to other cities depending on the local context. These relate to: *(1) narrowing governance gaps (2) closing the urban water cycle; (3) making integration in water management a reality; and (4) putting demand management into focus*

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1 Purpose of the study

This case study is part of the SWITCH project's Work Package on 'Governance for Integrated Urban Water Management' (WP 6.1.). It has been written to support the deliverable D.6.1.5/6, a 'Comparative analysis of enabling factors of sustainable urban water management'.

The project 'SWITCH – Managing Water for the City of the Future' aims at developing sustainable urban water systems through a combination of research, technological development, demonstration activities and training within a Learning Alliance framework. Learning Alliances are stakeholder platforms designed to break down barriers to information sharing, thus speeding up the process of uptake and innovation.

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Achievements in the direction of sustainable urban water management have been investigated in this case study from two different perspectives: firstly by looking at the city's broader approach to urban water management, and secondly by exploring the adoption of individual technical solutions that have contributed to a more sustainable urban water system.

Berlin has been chosen as a case study because of its self-sufficiency in water supply and its outstanding achievements in many different aspects of managing urban water, including demand management initiatives, stormwater infiltration and the construction of green roofs. These achievements have been explored in more detail taking into consideration the factors that contributed to the development of an integrated approach to water management, including Berlin's unique history, which saw the city divided for more than 40 years following the Second World War.

2 Introduction

Berlin has a unique history of political turmoil. In the aftermath of the Second World War, the city was divided into separate administrative sectors: a western sector controlled by the occupying forces of the United States, Great Britain and France, and an eastern sector controlled by the Soviet Union. With the division of Germany into the German Democratic Republic (East Germany) and the Federal Republic of Germany (West Germany), West Berlin became part of West Germany despite being surrounded on all sides by East Germany.

The construction of the infamous Berlin Wall in 1961 further emphasised the administrative and physical isolation enforced on the western half of the city. This situation came to an abrupt end in 1989 with the destruction of the Berlin Wall and the reunification of the two sovereign states the following year. Berlin was subsequently reinstated as the capital of the new nation.

The isolation of West Berlin created a situation whereby half of the city was reliant on water resources from within its administrative boundaries, forcing the city to adopt a closed water cycle approach. As a result, Berlin is today acknowledged as a forerunner and trendsetter in innovative and holistic urban water management. The city has accumulated considerable expertise in sustainable water solutions, often derived from the necessities of Berlin's isolation over a period of almost 40 years.

Examples of this approach include the following:

- the extraction of water had to occur within the confines of the city's boundaries;
- the quantity of water used for various purposes needed to be minimised;
- the withdrawal of groundwater had to be proportional to replenishment and recharge;
- the city's water bodies had to be protected from pollution as strictly as possible;
- the treated wastewater was useful for boosting the flow rate in the water bodies; and
- the retention of stormwater was a given in order to complement the limitations of the other resources.

(SenStadt, 1998a)

Despite the fall of the Berlin Wall, the city has continued to promote the sustainable use of the city's own resources. In 2000, the Senate passed new legislation requiring all water intended for use in Berlin to be abstracted within its boundaries and to promote a more responsible and sustainable use of its water resources.

Consequently, Berlin became a breeding ground for innovative ideas which were developed and implemented with considerable ease, and has continued to play this role, generating new benchmarks for urban water management elsewhere in Germany and the rest of the world.

Below is a selection of some of the highlights of sustainable technical solutions implemented in the city largely as a consequence of its unique situation.

- Since drinking water in Berlin is obtained solely from groundwater extracted within the city, wells are mostly found in the immediate vicinity of the water bodies where treated wastewater is discharged. Thus, two-thirds of the water extracted actually consists of river bank filtrate or artificially recharged surface water.

- Being fully conscious of the limitations of local water supplies, attempts were made in the 1980s, with increasing success, to influence the use and consumption of water resources by applying economic instruments such as fees and price increases, along with subsidising water-saving gadgets and equipment. According to the Federal Statistical Offices of Germany, in 2007 the per-capita consumption of water in Berlin was estimated to be 112 litres per day as compared to 122 litres for the rest of Germany (Statistisches Bundesamt Deutschland, 2009 & Amt für Statistik Berlin-Brandenburg 2009).

- In order to minimise the pollution of water resources, the City of Berlin has built eight wastewater purification plants that are optimised to the limits of conventional biological treatment and discharge treated wastewater in water bodies within the city's confines. Following technological improvements in nitrate and phosphate removal, pollution has been reduced substantially since the end of the 1980s. In order to reach the clean-up goal of water quality Class II[1] or 'slightly eutrophic' (SenStadt, 1998), further upgrading of the sewage works is planned.

[1] River classification standard as developed by the Federal Ministry for the Environment, Nature Conservation & Nuclear Safety (Umwelt Bundes Amt). http://www.umweltdaten.de/publikationen/fpdf-l/3045.pdf

- Due to the high level of urbanisation in Berlin, a large quantity of polluted stormwater needs to be collected and treated. The operation and maintenance of such infrastructure is a vast and expensive process. For this reason, innovative concepts for collecting and treating stormwater at source, such as retention soil filters to purify polluted stormwater from separate sewers, were adopted early,.

For a long time, Berlin has also been a city where many landmark projects in service water use have been executed. A few examples are:

- The famous DaimlerChrysler Potsdamer Platz, where rainwater is collected from 19 buildings over an estimated 32,000 m^2 area and is then stored in a 3,500 m^3 rainwater basement tank. It is later used as service water, i.e. for toilet flushing, the watering of green areas and also the replenishment of an artificial pond.
- The GSW[2] Housing settlement in Lankwitz that collects rainwater for use as service water and saves up to 2,650 m^3 of high quality drinking water per year.
- The Institute of Physics in Berlin-Adlershof that showcases the collection of rainwater to irrigate a facade greening system, which acts as an air-conditioner for the building by generating an evaporative cooling effect.

[2] GSW - Gemeinnützige Siedlungs- und Wohnungsbaugesellschaft Berlin mbH

3 Berlin – a brief overview

Berlin is the capital city and one of the 16 federal states, or Bundesländer, of Germany. Home to 3.4 million inhabitants, plus an additional one million within the wider conurbation, it is the largest city in Germany and one of the most populated cities in Europe.

Berlin has an area of 899 km², 38 km from north to south and 45km from east to west. Around one third of the city's territory is composed of forests, parks, gardens, rivers and lakes. The city has an impressive waterscape and is characterised by several large streams, both natural and man-made. It also has numerous lakes, ponds and pools encompassed within its urban environment.

Climate

Located in north-eastern Germany, Berlin is geographically embedded in the European plains and has a temperate seasonal climate. It has warm summers, with average high temperatures of 22 to 25° C and lows of 12 to 14° C. Berlin has cold winters, with average high temperatures of 4° C (39° F) and lows of -2 to 0° C (28 to 32° F). Spring and autumn are generally chilly to mild. Berlin has an annual precipitation of 600 mm with moderate rainfall throughout the year. Light snowfall occurs mainly from December through March.

Political structure

The municipality of Berlin is a decentralised body divided into 23 districts, or Bezirke. The districts have between 50,000 and 300,000 inhabitants and carry responsibility for local politics and their own administration. Unlike independent municipalities, they do not have financial autonomy but are allocated funds by the City Government: the Senate of Berlin. The Senate acts as the main authority for the City as a whole which is divided into different administrative departments (comparable to Ministries in other German Länder).

Berlin's executive body is the Senate of Berlin (Senat von Berlin). The Senate of Berlin consists of the Governing Mayor (Regierender Bürgermeister) and of up to eight senators holding ministerial positions, one of them holding the official title "Mayor" (Bürgermeister) as deputy to the Governing Mayor. The Governing Mayor is simultaneously Lord Mayor of the City (Oberbürgermeister der Stadt) and Prime Minister of the Federal State (Ministerpräsident des Bundeslandes).

<u>Economy</u>

Berlin is today a celebrated world city of culture, politics, media and science. The city is also one of the most visited tourist destinations in Europe. Berlin's economy is primarily based on the service sector, encompassing a diverse range of industry, media corporations, and congress and convention venues.

In 2009, the number of employed persons in Berlin was 1.6 million, out of which more than 47 % were employed in finance and trade and,40% by the service sector; only 8 % were employed by industry and the rest were employed by construction and agriculture sector (Amt für Statistik Berlin-Brandenburg, 2009).

In addition, Berlin is a centre of environmental research and technology, and a great number of businesses are engaged in environment-related activities. Four hundred companies with 13,000 employees are directly involved in environmental protection (engineering offices, and producers and distributors of environmental technology). Furthermore, Berlin is a stronghold of scientific research, with approximately 100 companies involved in measurement and analytical activities, approximately 80 eco-research institutes (including universities), and 45 public administrations and authorities in charge of environmental matters (Lanz & Eitner, 2005).

Due to reunification-related expenditures, Berlin as a German state has accumulated more debt than any other city in Germany, with the recent estimate (31st Dec 2009) being 59 billion Euro (Amt für Statistik Berlin-Brandenburg, 2009).

4 Water resources and services in Berlin

Berlin is located in a relatively dry area of Germany with an annual precipitation of 600mm. The rivers Spree and Havel flow through Berlin as chains of regulated slow-flowing lakes (average 34.7 m^3/s), and the flow is further reduced during summer. Thus the rivers do not act as a major source of water supply for the city.

Berlin can however make extensive use of the groundwater aquifer underlying the city. Formed during the last ice age over 10,000 years ago and part of the Berlin-Warsaw glacial valley, the valley stratum consists of sand gravel, marley, till and clay and provides good quality groundwater for almost all of Berlin's potable use.

Main water users

In Berlin, domestic consumption is the highest use of water, making up 72% of total water consumption. Industrial and commercial utilities consume around 15% and the rest is supplied to the surrounding areas. The following table gives a brief estimate of water consumption by various sectors in 1992, 2000 and 2008.

Table 1: Water consumption in Berlin with respect to various sectors, Source Berliner Wasserbetriebe

Parameters	Unit	2008	2000	1992
Inhabitants	Million	3.4	3.39	3.47
Total consumption	Million m^3	192.8	207.6	270.9
Domestic consumption	Million m^3	140.7	152.9	174.5
Commercial and Industrial consumption	Million m^3	29.7	23.0	40.0
Consumption by other customers	Million m^3	18.8	33.5	54.0
Consumption by surrounding areas	Million m^3	3.6	3.2	2.4
Domestic consumption per person/day	Litres	112.1	121	138

Water supply

In principle, the Berlin Water Works or Berlin Wasserbetriebe (BWB) – the water utility in Berlin – relies exclusively on groundwater for its water supply operations. The raw water is extracted from depths of between 30 and 170 metres through 800 deep wells and is then transported to the waterworks. In 2009, the BWB abstracted approximately 205 million m^3 of raw water for its supplies (BWB, 2010).

Raw water is obtained through a combination of bank filtered water, artificially infiltrated rain water and ground water. Figure 1 gives a rough estimate of the various components of the water cycle in Berlin.

Six wastewater treatment plants discharge 227 million m^3 of treated wastewater per annum into the Havel and Spree rivers. This quantity contributes to the volume of surface water available and helps replenish groundwater resources via bank filtration, (BWB, 2010). It is estimated that more than two thirds of the groundwater withdrawn for water supply contains bank filtrated water, partly originating from Berlin's wastewater treatment plants and artificially recharged surface water (Pawlowski.L 2007 & Jekel &

Heinzmann, 2003). Water supply is thus indirectly recycled from treated wastewater discharges and infiltrated rainwater.

As the water abstracted is less than what is discharged, a balance between withdrawals and replenishment is maintained and the solution is thus considered to be a sustainable one.

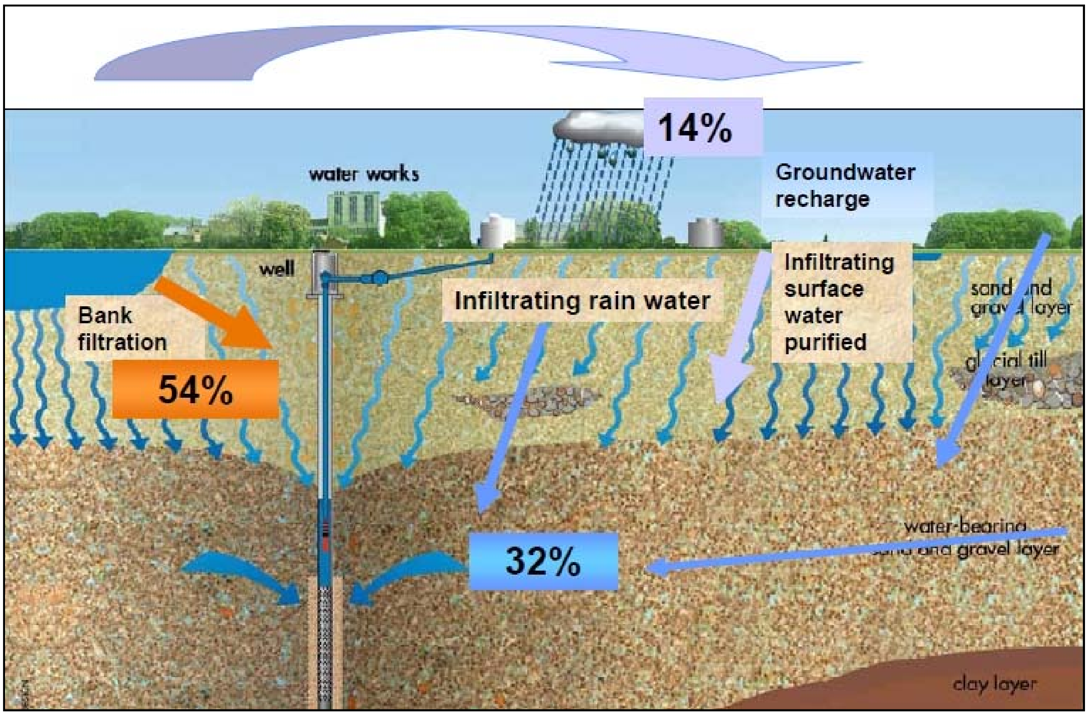

Figure 1: Drinking water quantity in Berlin, 2004 (Pawlowski.L 2007)

In 2009, the nine waterworks of the BWB produced on average 585,000m³ of drinking water per day. This water is supplied to 3.4 million inhabitants in 279,000 household connections as well as to industry and trade (BWB, 2010). The overall withdrawal of raw groundwater in Berlin has been reduced by 45% from 1989 to 2008. In 1989, 378 million m³ of water was withdrawn as compared to 205 million m³ in 2008. The reasons attributed to this reduction in consumption are lowered domestic demand as well as the relocation of industry out of Berlin. Figure 2 shows the constant reduction in water consumption from 1989 to 2008 (SenStadt.2009).

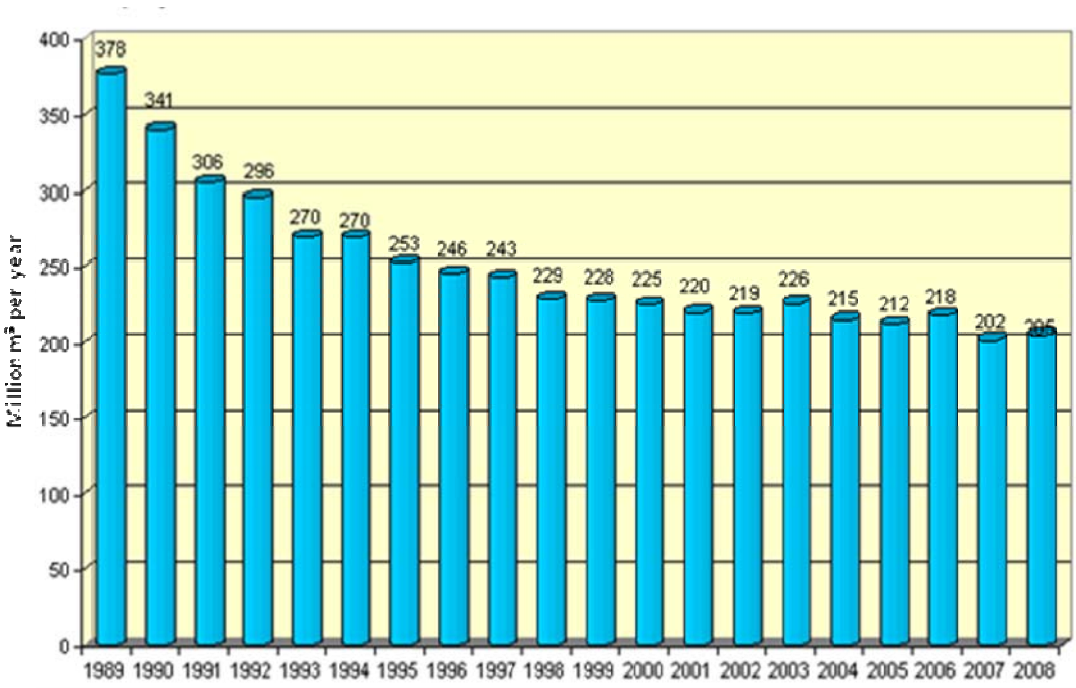

Figure 2: Reduction of water consumption in Berlin (Stadtentwicklung Berlin 2009)

<u>Micropollutants</u>

It is estimated that 54% of the groundwater withdrawn for water supply contains bank filtrated water, partly originating from Berlin's wastewater treatment plants (Pawlowski.L 2007). Although optimised to the limit in biological treatment for wastewater, the wastewater treatment plants have not been equipped to control micro contaminants derived mainly from domestic pharmaceutical waste. Micro-pollutants pose considerable risk as the effluents from wastewater treatment are discharged in the same rivers which are used for bank filtration; this water is subsequently withdrawn for water supply by the BWB (Lanz & Eitner, 2005).

Despite the threat of micropollutants, the quality of water in Berlin exceeds the requirements of the German drinking water ordinance and is considered to be generally good. However, at the time of writing, the ordinance had not attempted to regulate micro contaminants in its water supply regulations (Interview with Dr. Lanz).

<u>Polluted stormwater</u>

Repeated fish kills have been observed in the Spree and Havel in Berlin after heavy rainfall events. This is mainly caused by untreated waste- and rainwater discharges from the wastewater treatment plants into the rivers.

After heavy rainfall events the intake capacity of the mixed-sewage systems in the city are insufficient to handle the quantities of rainwater as well as untreated wastewater and, as a result, the excess is discharged into the Spree and Havel without any pre-treatment. This untreated stormwater can contain pollutants like nitrates, heavy metal and hydrocarbons washed away from impervious areas like roads and pavements and poses considerable threat to the ecology of the rivers. This is predominantly the case for the inner city of Berlin where the mixed sewer systems were built during the 1950s.

Changing the sewer system to one where stormwater is separated from domestic and industrial waste would require considerable investment from the state. As of 2009, no plans had been drawn up to tackle the problem (SenStadt, 2009a).

Groundwater pollution

As of 1998 it was estimated that 40% of groundwater reserves are threatened by contamination, mainly by some 5,500 abandoned industrial and waste disposal sites. The main problems cited here are heavy metals, phenols, hydrocarbons and ammonium. Areas around wells where drinking water for the city is abstracted have been assigned protected status in an attempt to prevent pollution of the source. (SenStadt, 1998)

5 Main players in urban water management in Berlin

The main institutions involved in water management in Berlin are the Senate, the water utility, research organisations, universities and NGOs. The following paragraphs present the key competencies of the various institutions.

The Senate Department for Health, Environment and Consumer Protection or **Senatsverwaltung für Gesundheit, Umwelt und Verbraucherschutz** (**SenGUV**) is responsible for water resources management, resource protection, river ecology and stormwater drainage. As a department it is also responsible for representing public interests in water management and formulating related water regulation for Berlin. Alongside this, the department issues permits for all kind of water uses, like wastewater discharge, stormwater discharge and groundwater abstractions. It also oversees the implementation of the European Union Water Framework Directive for the state of Berlin.

The Senate Department for Urban Development or **Senatsverwaltung für Stadtentwicklung** (**SenStadt**) is responsible for city planning and development. Key competencies are road construction and the construction and maintenance of rivers and trenches. It is also involved in integrating the planning of the different environmental strategies involving themes like energy, water, green spaces, building materials and waste.

The Berlin Water Works or **Berliner Wasserbetriebe** (**BWB**) is the sole water utility in Berlin and is responsible for the operation of the drinking water supply, wastewater treatment and drainage system (sewerage and stormwater). The organisation is partly privatised: 50.1% of the shares are owned by the City Senate and 49.9% by the multi-utility companies Veolia and RWE. BWB also owns the water supply and wastewater system (excluding the stormwater system which is owned by the city). The decision to partly privatise the BWB in 1999 was made for two reasons: firstly, to help address a severe deficit in the public finances of the city of Berlin; and secondly due to a strong liberalisation discourse in Germany in the 1990s which was readily taken up by key political actors in Berlin. The Berlin water utility and its municipal gas and electricity suppliers GASAG[3] and BEWAG[4] were privatised in the late 1990s following the liberalisation discourse.

The **Kompetenzzentrum Wasser Berlin** (KWB) is a non-profit organisation responsible for the required research in the field of water management in Berlin. It is owned by BWB, Veolia, Berlinwasser and the City of Berlin. The KWB prepares and carries out major research projects with the financial support of shareholders and funding from the European Union.

The Technical University of Berlin (**TU Berlin**) runs the Centre for Water in Urban Areas and provides innovative and advanced technological solutions for future-oriented urban water management. The centre also provides consultation services to large infrastructure projects in Berlin. Its core fields of activity are water

[3] Berliner Städtische Gaswerke
[4] Berliner Städtische Elektrizitätswerke Akt -Ges

recycling and reuse, analysis of persistent chemicals and economic assessments in urban water management.

Although they do not have a direct influence in the decision making process, **NGOs** in the water sector in Berlin are becoming increasingly influential as more discussion forums are being set up, like the Berliner Wassertisch (Berlin Water Table). Lobbying for more social justice, NGOs like the Grüne Liga (Green League) and NABU[5] have been active in campaigning against the privatisation of water facilities in Berlin. Water issues are widely discussed in civil society and continue to be an important topic of the public debate.

6 Drivers of change for sustainable urban water management in Berlin

Historic events have to some extent shaped Berlin's water management priorities and strategies. At the height of the Cold War from the 1950s to the late 1980s essential amenities for an isolated West Berlin were being supplied by or via East Germany. But events after the Berlin blockade[6] severely disrupted the relations between the Allies and the Soviets, such that on the 3rd July 1952 negotiations on the price for water supply broke down. The authorities in West Berlin, assuming that they could provide the required water quantities from the wells within the city's borders, shut off the water supplies coming into West Berlin from the East (Moss, 2004). In the following weeks, several districts in West Berlin were left without water and emergency supplies had to be established via temporary pipelines and tankers. This event revealed the vulnerability of West Berlin in terms of its water resources and three weeks later negotiations were re-opened to set an amicable price for water supply into West Berlin (Merritt 1968 as quoted in Moss 2004).

In the following years the authorities in West Berlin concentrated on increasing water supply capacity to make West Berlin more self-sufficient and secure in terms of water availability. Their first priority was to reduce West Berlin's dependency on the East, therefore extensive infrastructure plans were drawn up, funded and completed in the coming years. Innovative techniques aimed at increasing drinking water reserves were

[5] Naturschutzbund Deutschland

[6] The Berlin Blockade (24 June 1948 – 12 May 1949) was instigated by the Soviet Union to blocked railway and road access to the sectors of Berlin under Allied control.

implemented, notably extensive forms of groundwater enrichment by bank filtration and rainwater infiltration. Extensive programmes on reducing leakages in pipelines and reducing domestic water consumption were undertaken, and by 1978 West Berlin waterworks had increased its supply capacity by 227% compared to 1949 (Bärthel 1997 as quoted in Moss 2004).

Although the political situation completely changed after 1989, a reunited Berlin has managed to keep a cautious attitude towards the city's water management. The reunification of Germany reinstated Berlin as the country's capital and large development projects were planned in consideration of a population increase. The city also received considerable financial support for the reunification. This opportunity provided a unique testing ground for innovative ideas to be put into practice in the form of large-scale development projects not only in water management but also in the field of ecological construction (SenStadt, 2010 b).

In the late 1970s, Berlin also experienced a high demand for environmentally-friendly living from its citizens and this helped initiate an urban greening campaign by the city administration. Although intended to improve urban biodiversity and reduce soil sealing in densely populated areas, the campaign indirectly affected the city's water management strategies by reducing hydraulic stress on drains and improving replenishment of groundwater (Ngan, 2004).

By the late nineties – after reunification – Berlin had the possibility to source water from the neighbouring state of Brandenburg. But in a decisive move, the SenGUV passed an ordinance ensuring that all water consumed by the city should be abstracted within its boundary and made sure that a closed-water-cycle approach was adhered to. The ordinance was also in part established by the Senate to keep the existing water supply and wastewater infrastructure functional and protect the workers of BWB from unemployment. To counter the over-abstraction of water, the senate also levied a charge of € 0.31 / m^3 on the service provider BWB (Lanz & Eitner, 2005). Thus, by creating a system of check and balance, the city administrators ensured the sustainability of the city´s water resources.

7 Sustainable solutions adopted in Berlin

7.1 Bank filtration in conjunction with wastewater reclamation

Riverbank filtration is the process of collecting water from wells or infiltration galleries located near the bank of a river. In this process the river water is allowed to pass through the riverbed/bank into the aquifer, thus the riverbed/bank acts as a natural filter that removes most organic particles and pathogenic microorganisms (Water Resource Research Centre, 2000). Although bank filtration has been used before elsewhere in Germany, city administrators in Berlin have extensively applied this technology in conjunction with wastewater reclamation[7] and artificial aquifer recharge in West Berlin, thus boosting the city´s groundwater resources.

Prior to the Berlin blockade, West Berlin imported 34.6% of its water from the East and the limited availability of fresh water became an immediate concern to the authorities. Thus large groundwater infiltration projects at Lake Tegel, Jungfernheide and Spandau were implemented on an emergency basis. Also, treated wastewater from West Berlin was pumped back up-stream to replenish surface water which in turn recharged aquifers, replacing the quantity of water withdrawn from the city's groundwater sources (Lanz & Eitner, 2005).

The key institutions involved in providing the required intervention in water supply and wastewater management were the Senate, the utility managers, infrastructure planners and city administrators (Moss 2004). The infrastructure required for the programme proved to be very capital-intensive and total investment in the wastewater reclamation system alone from 1950 to 1989 came to 3,800 million USD (Bärthel, 2003 as quoted by Moss 2004).

The total cost of infrastructure was not reflected in the fees levied to the consumers in West Berlin, but the amount was covered by the federal government in the form of subsidies to the West Berlin authorities. The citizens of Berlin paid water fees equal to other West German cities. The ease and availability of funds from the federal

[7] Reclaimed water is former wastewater that has been treated to remove solids and certain impurities to be used for non potable use or to recharge groundwater aquifers

government seemed to have played a major role in providing the much needed investment in West Berlin's water supply and reuse infrastructure.

7.2 Green roofs

A green roof is a conventional roof that is covered with a layer of vegetation planted over a waterproofing membrane. Green roofs provide several advantages for buildings, such as absorbing rainwater, providing insulation, creating a habitat for wildlife, increase humidity and helping to lower urban air temperatures and combat the heat island effect (Köhler, M., 2003).

The introduction of green roofs in Berlin formed, along with community gardens and green facades, part of an urban development project which was aimed at increasing the green spaces in high density districts in Berlin (Ngan, 2004). In the 1970s, researchers from the Technical University of Berlin were experimenting with green roofs in the city with respect to an ecological approach. Green roofs seemed to provide multiple benefits like water purification, runoff delay as well as increasing urban biodiversity. It proved to be an approach effective to address a large number of problems in Berlin.

At the same time, there was also a growing demand from the citizens for a more environmentally-friendly standard of living. This motivated the landscape planners in the city administration (SenStadt) to follow up on the research made on green roofs and to implement them through the city's urban plans during 1984 to 1994 (Ngan, 2004). The urban development programme was aimed at mitigating the following concerns:

- Hydraulic stress on existing stormwater drains.
- Lack of humidity and excess warming of the surrounding areas.
- Decrease of flora and fauna due to inadequate green spaces.
- High degree of soil sealing in densely populated areas.
- Inadequate replenishment of groundwater which resulted from rapid draining of rainfall run-off into the drains.

Through the greening programme, approximately 65,750 m² of green roofs were installed. Berlin's residents received 25 to 60 Euros /m² in subsidies for their investment in green roofs. Direct financial incentives were a common practice throughout from the 1980s until the 1990s. The incentives were gradually reduced and a more voluntary approach to green roofs was adopted as Berlin faced economic deficits (Köhler, 2003, sited in Ngan 2004). In spite of the reduction in incentives, 14% of all new urban development in Berlin are installed with green roofs (Köhler, 2003).

7.3 Sustainable rainwater management

Sustainable rainwater management for artificial groundwater recharge is an important part of water resources management in the Berlin area. With an average precipitation of 600 mm/a, the natural groundwater recharge rate of up to 200 mm/a is not sufficient to maintain groundwater resources for the city. The public water companies have established three groundwater recharge plants in order to increase groundwater quantities. The collected surface water is discharged in the vicinity of groundwater abstraction wells, into shallow earthen basins, ponds, or pits for percolation into the groundwater. By infiltrating rain water the remaining deficit of groundwater is thus attenuated (interview with Dr. Pawlowski, Jekel & Heinzmann, 2003).

In 2000 the SenGUV - under the Berlin Water Act - introduced the 'rainwater management at source' strategy. The strategy promotes disconnection of rainfall runoff collected by impervious surfaces to urban drainage systems and provides infiltration at source. Two main reasons led to the promotion of this system: first, the increase of rainwater infiltration and, second, the economic benefit associated with reducing infrastructural and operational costs that are linked to treating polluted rainwater at a centralised location (SenStadt, 2007 & interview with Dr Seiker).

In recent years, rainwater harvesting, retention and use as service water[8] has gained popularity in Berlin. Many new commercial centres as well as residential areas in Berlin have installed innovative concepts in stormwater retention and reuse.

7.4 Demand management

From an economic perspective, high levels of water use would require ever-increasing and expensive investments in the water system infrastructure needed to collect, deliver and dispose of water. Realising this, the water authorities in West Berlin introduced a water demand management strategy to curb per capita consumption during the 1980s (interview Dr. Pawlowski).

[8] Water used for non potable purposes like toilet flush, gardening and car washing.

The initiation of the strategy was taken up by Bewag (the West Berlin water utility prior to privatisation), and, after its privatisation, the Berlin Wasserbetriebe became instrumental in implementation. The demand management strategy mainly focused on the following measures:

- Higher tariffs for water to encourage customers to adopt a more economical use of water.
- Effective publicity campaigns and well-organised public relations and instructions for water saving (in the 1980s first in West Berlin, later in the 1990s in the former Eastern sector of Berlin).
- Temporary subsidies for the purchase and installation of water saving equipment.
- Strong efforts to diminish leakages and losses due to pipe breakages.

As a result of such measures, the overall consciousness of water related-issues in Berlin tangibly improved. In addition, there were also numerous technological innovations implemented in the field of leakage detection in pipes to reduce losses in water supply. The result was that Berlin's pipe breakage rate was reduced to 0.05 to 0.1 damages per kilometre per year as compared to 0.2 to 0.25 damages per kilometre per year in a span of ten years.
These measures have succeeded in reducing Berlin's per capita water consumption from 250 to 112 litres/ person/ day. In total the consumption of water for the whole city has dropped by 45% in the last twenty years (Heinzmann, 2003).

8 Conclusions and lessons learned

8.1 Conclusions

To answer the question "why" it has been possible to implement sustainable solutions in water management to such a great extent in Berlin, five factors have been identified as the most relevant ones in the course of this study: (1) Berlin's historic circumstances after World Water II until reunification; (2) the high level of financing made available for water management; (3) Berlin`s administrative structure as a national capital, federal state and local government; (4) an ecologically-aware Senate as a powerful regulator; (5) a high level of public awareness in water issues.

(1) Historic circumstances: As an island state within the German Democratic Republic ('Eastern Germany') from 1949 to 1990, the West Berlin authorities were compelled to be innovative in the way they managed the city's water resources. Historic events like the Berlin blockade in 1948/49 had forced the city authorities to look for a self-sufficient solution to the city's water supply needs, as well as to find efficient ways of dealing with the wastewater generated in Berlin. The city planners had to come up with innovative synergies within the various aspects of water management to cope with the daily water needs of Berlin and, arguably, they tried to adopt a closed water cycle approach in the city's water management practices.

(2) Financing available: It is estimated that Berlin was able to spend a sum of 3,800 million USD from 1950 to 1989 on investments in its wastewater reclamation and reuse infrastructure. This high level of financial commitment was necessary for Berlin to provide a stable water management system. The much-needed investment for such infrastructure was borne by the federal government and the actual costs were never reflected in the fees charged to the inhabitants of Berlin. This emphasises the financial subsidies that were offered to the authorities in West Berlin by the federal government.

Post unification saw Berlin re-instated as the national capital, which symbolically and materially changed the status of the united city. The city was turned into a vast construction site, while many "prestige projects" in water management were implemented. These projects are now exhibition sites for many of the innovative trends and technologies in water management.

(3) *Berlin`s administrative structure as a national capital, federal state and local government*: The proximity of the three pillars of administration - i.e. of a national capital, federal state as well as a local government - provides for a unique advantage for the governance of water, wherein (a) all agencies (national, federal and local) dealing with water are closely related to each other; (b) the challenges in water management receive quicker attention and the

required interventions are implemented in a shorter time span; (c) regulators in the water sector can act as independent authorities, giving them more flexibility in operations.

(4) *Senate as a powerful regulator:* Since water was perceived to be a scarce resource in the past, water management was given a lot of attention socially, financially and politically. Interestingly, after the reunification of Berlin, water scarcity was no longer a problem and there were ample possibilities for transporting water into Berlin from the neighbouring state of Brandenburg. But this was avoided, and Berlin still follows the same techniques of water abstraction, reclamation and reuse as in the past. Why this is so is a puzzling question. Some reasons pointed out by the interviewees state that the Senate in Berlin acts as a very powerful regulator in environmental protection and is very proactive in introducing environmentally-friendly solutions. Within the Senate some civil servants have been ecologically conscious, charismatic and influential leaders who steered and directed the discourses in Berlin's water management. Many of the senators have also been involved in teaching at universities in Berlin, thereby closely linking science and policy making, which has proved beneficial for Berlin's water management.

(5) *Public awareness in water issues:* Given the urban character of Berlin, environmental issues in the city were, and predominantly still are, related to urban life. Therefore, problems relating to housing, transport, urban restructuring, clean air, waste disposal, clean water, protection of parks and green areas have received highest attention. Furthermore, water issues in Berlin gained an important boost in public awareness during the 1980s, when environmental activism gained momentum. Specific awareness-raising campaigns such as *Denk mal über Wasser nach (Think about water)* became popular through advertisements and effective public relations. These campaigns were usually tailored for specific purposes like reduction in water consumption; however, they have also generally led to a higher sensitisation of the inhabitants of Berlin regarding key issues of water in the city.

Of course, the above list of reasons for Berlin's achievements in the water sector is not exhaustive, and it would also not be adequate to consider them in separation. Instead, it is rather essential to understand how they combine and interact with each other to influence and shape development in a direction that could be termed sustainable water management.

8.2 Lessons learned

Considering the above mentioned five unique factors that have influenced sustainable water management practices in Berlin, some lessons that can be learned and transcribed into effective strategies for other cities committed to moving towards more sustainable water management policies and practices are described below.

1. Narrowing governance gaps

Berlin´s administrative setting is as an example where the national, federal and local administrative structures are the same. Such a structure can provide an ideal setting to tackle local situations and problems. In such a set-up, laws and policies are directly related to a city context rather than a sub-national one and provide an effective framework for urban water management considering the local conditions. It is however important to state that directives or ordinances made in such a localised set-up should not adversely affect regional or upstream/downstream situations and attention should be paid to the harmonisation of local and regional strategies.

In Germany, administrative structures similar to Berlin exist in the free states of Hamburg and Bremen. It would thus be interesting to study the progress in water management in these cities in comparison with Berlin.

2. Closing the urban water cycle

The case of Berlin demonstrates that it is possible for a city to be self-sufficient and self-sustaining in maintaining its water resources by applying the required technical and policy measures.

Depending on geological and climatic conditions, a closed water cycle approach can be realised at urban level. At the same time, this requires the adjustment of certain laws and ordinances and a high level of political, technical and financial commitment from a city's administration.

3. Making integration in water management a reality

Berlin has been able to combine several aspects of land-use planning, nature conservation as well as water management in an integrated manner. Although the integration of multiple sectors leads to complexity, it also provides improved benefits to the city as a whole. A few examples from Berlin's integrated solutions which could be transferable to other cities are:

- Infiltration of stormwater is prioritised so that groundwater sources can be replenished.
- Green roofs and green facades are introduced to improve urban biodiversity as well as reduce and control stormwater runoff in a city.
- Wastewater treatment and disposal is managed to support bank filtration such that the city's water reserves are balanced.

4. Putting demand management into focus

Effective demand management strategies in Berlin have resulted in reducing the city's overall water consumption by 50% over a span of twenty years. These strategies that can be a model for other cities, focused on four aspects:

- making water users pay an appropriate price for the services offered;
- launching major awareness-raising campaigns;
- temporarily subsidising water saving equipment;and
- diminishing leakage and losses in the water supply network more vigorously.

9 List of interviewees

1. Dr. Klaus Lanz. International Water Affairs, Hamburg, Germany.
2. Dipl.-Ing. Ludwig Pawlowski. Kompetenzzentrum Wasser Berlin gemeinnützige GmbH, Berlin, Germany.
3. Dr. Timothy Moss. Leibniz-Institut für Regionalentwicklung und Strukturplanung e.V. Erkner, Germany.
4. Dr. Heiko Seiker, Ingenieurgesellschaft Prof. Dr. Sieker GmbH, Hamburg, Germany.

10 References

Amt für Statistik Berlin-Brandenburg (2009). Die kleine Berlin–Statistik, Statistics Office Berlin-Brandenburg, Berlin. Germany. Retrieved on 22.12.2010, from: http://www.statistik-berlin-brandenburg.de/produkte/kleinestatistik/kBEst_m-engl.pdf

Bärthel, H. (1997): Wasser für Berlin: Die Geschichte der wasserversorgung. Verlag für Bauwesen. Berlin, Germany.

Berliner Wasserbetriebe (2010). Key technology and operation data (2005 to 2009). Retrieved on 15th June 2010 from: http://www.bwb.de/content/language2/html/1107.php

Heinzmann, B. (2003). Measures to minimize water consumption and water losses - Case study of Berlin. Berliner Wasserbetriebe, Germany, Retrieved on 05.10.2010 from: http://www.bvsde.paho.org/bvsacd/cd63/measures.pdf

Jekel, M., & Heinzmann, B. (2003). The Research Project “Natural and Artificial Systems for Recharge and Infiltration (NASRI)”, its Relation to the Specific Water Management Challenges of Berlin and the International Relevance, Conference Wasser Berlin 2003. KompetenzZentrum Wasser Berlin, Germany. Retrieved on 02.02.2011 from: http://www.kompetenz-wasser.de/fileadmin/user_upload/pdf/veranstaltungen/kongress/Jekel_NASRI_Overview.PDF

Köhler, M. (2003). The Green Roof Tradition in Germany: the Example of Berlin. Handbook: Green roofs. Earthpledge, New York.

Lanz, K., Eitner,K. (2005). Water Time case study – Berlin. International Water Affairs, Hamburg, Germany.

Merritt, R.L. (1973): Infrastructural Changes in Berlin. Berlin Between Two Worlds. Boulder / London, Westview Press, pp.153-175

Moss, T. (2004). Geopolitical upheaval and embedded infrastructure: Securing energy and water services in a divided Berlin. Working paper, Erkner,Leibniz-Institute für Regionalentwicklung und Struktureplanung. Retrieved on 14th June 2010 from: http://www.irs-net.de/downloads/infrastructures.pdf

Ngan,G. (2004). Green Roof Policies: Tools for Encouraging Sustainable Design, Landscape Architecture Canada Foundation, Ottawa, Canada.

Pawlowski.L (2007). Historical Overview on Water Management in Berlin, IInd International Water Conference (IWC) Berlin, 12 - 14 September 2007. Retrieved on: 18 june 2010, from:
http://www.iwc-berlin.de/cgi-bin/brain_connector.pl?action=Navbar.CreatePage;2x&navbar_action=0,61000000005&SessionId=anonym

SenStadt. (1998). The ENVIBASE-Project handbook. Senatsverwaltung für Stadtentwicklung, Berlin. Retrieved on 13th June 2010 from: http://www.stadtentwicklung.berlin.de/archiv_sensut/umwelt/uisonline/envibase/handbook/water2.htm

SenStadt. (2001) c. Water Conservation Districts (Edition 2001). Senatsverwaltung für Stadtentwicklung , Berlin. Retrieved on 22th June 2010 from: http://www.stadtentwicklung.berlin.de/umwelt/umweltatlas/edb211_04.htm#D4

SenStadt. (2004 a). Quality of Surface Waters (Chemistry). Senatsverwaltung für Stadtentwicklung, Berlin. Retrieved on 21th June 2010 from: http://www.stadtentwicklung.berlin.de/umwelt/umweltatlas/eia201.htm

SenStadt. (2004 b). Dwell Time of Seepage Water in the Non-Saturated Zone. Senatsverwaltung für Stadtentwicklung , Berlin. Retrieved on 21th June 2010 from: http://www.stadtentwicklung.berlin.de/umwelt/umweltatlas/ed216_01.htm#top

SenStadt. (2007). Innovative water concepts, service water utilisation in Buildings. Senatsverwaltung für Stadtentwicklung, Berlin, Germany.

SenStadt. (2009). Water Conservation Districts and Groundwater Use. Senatsverwaltung für Stadtentwicklung , Berlin. Retrieved on 14th June 2010 from: http://www.stadtentwicklung.berlin.de/umwelt/umweltatlas/edd211_01.htm#A2

SenStadt. (2009a). Management of Rain and Wastewater (Edition 2009). Senatsverwaltung für Stadtentwicklung , Berlin. Retrieved on 12th June 2010 from: http://www.stadtentwicklung.berlin.de/umwelt/umweltatlas/edb209_01.htm#top

SenStadt. (2010) b. Development of Urban Green Space in United Berlin since 1990. Senatsverwaltung für Stadtentwicklung , Berlin. Retrieved on 22th June 2010 from: http://www.stadtentwicklung.berlin.de/umwelt/stadtgruen/geschichte/en/stadtgruen/gesamtberlin_1990/index.shtml

Statistisches Bundesamt Deutschland (2009): Per capita water consumption in 2007 dropped to 122 liters per day, Press release from 02.10.2009 Nr.377, Federal Statistical Office Germany, Wiesbaden, Germany. Retrieved on 22.12.2010, from: http://www.destatis.de/jetspeed/portal/cms/Sites/destatis/Internet/DE/Presse/pm/2009/10/PD09__377__322,templateId=renderPrint.psml

Water resource research center (2000). Concept of Bank Filtration, University of Hawaii at Manoa, USA. Retrieved from: http://www.wrrc.hawaii.edu/bulletins/2000_08/filtration.html on 02.02.2011