

Istanbul: the challenges of integrated water resources management in Europa's megacity

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Abstract Effective integrated water resources management (IWRM) and developments impacting on water resources are recognized as key components of environmentally sustainable development. Istanbul (Turkey) is a very large metropolitan city with a population of approximately 14 million. Istanbul is one of the 23 megacities (metropolitan areas with a population of more than 10 million) in the world and one of the most rapidly growing cities in Europe. The annual population growth is 2.8 %. The population growth in the city is almost twice the overall rate of the whole of Turkey, because of a large in-migration. The present study is a baseline assessment of IWRM of Istanbul and also provides a critical review of Istanbul's future challenges. The assessment is part of an action on water governance (City Blueprints) in the context of the European Innovation Partnership on Water of the European Commission. The City Blueprint indicator approach and process have been applied as first step of gaining a better understanding of IWRM and the challenges ahead. This is done by using well-established and high-quality data sets, a relatively cost-effective online survey and a relatively simple questionnaire. Istanbul has set a good example to the challenges faced in water supply in megacities, where illegal settlements on watershed zones posed a threat to scarce water resources. Despite these enormous efforts, the projected future population growth and climate change in Istanbul will necessitate further major transitions towards sustainable IWRM. This holds for all aspects of the water cycle: water quality, water quantity, water supply and sanitation, coping with extreme weather events (floods and droughts), as well as for the protection of the sources of water, i.e. ecosystem conservation. Istanbul is a place where problems emerge and solutions need to be found. The time window available to do this is rapidly closing. As such, this review of IWRM of Istanbul confirms the conclusions of the World Economic Forum that water

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supply is one of the top three global risks for both the impact and likelihood. Our framework has been applied for nearly 40 cities, and the results for Istanbul are discussed in the broader context of recent initiatives on water governance and smart cities by the European Commission.

Keywords IWRM · Water governance · Water scarcity · City Blueprint[®] · Blue City Index[®]

1 Introduction

Cities are home to many. There are currently more than 400 cities with more than 1 million inhabitants and 23 megacities (metropolitan areas with a population of more than 10 million) mainly in Asia (UN 2012). According to the United Nations (UN), 50 % of people live in cities and by 2050, this will be 67 % (UN 2012). In developed countries, this percentage is even higher (more than 86 %). Global urbanization is taking place at an unparalleled speed. In 1970, there were just two megacities (Tokyo and New York); in 1990, there were ten; in 2011, 23; and by 2025, there will be 37 megacities. Istanbul is one of the 23 megacities on this globe. The UN estimates that between 2011 and 2050, the world population will grow from 7 to 9.3 billion and that the population in cities will increase from 3.6 to 6.3 billion, while the number of people living in rural areas will decline. This means that the growth in the world population will be absorbed by the cities. Together with the migration from rural areas to the cities, during this period more than 200,000 people—a day—will need to find a new place to live in an urban environment. This will be accompanied by strong growth in urban water demands, especially in East and West Africa, Latin America and Asia (Dobbs et al. 2011, 2012).

The availability of sufficient clean and freshwater is a prerequisite for the health, economic development and social well-being of any society. The world's water resources are threatened, however, by increasing demand from growing urban populations leading to groundwater depletion, salt water intrusion, and the deterioration of water quality from pollution and climate change (Hoekstra and Wiedman 2014; Huynen et al. 2013; Van Leeuwen 2013). These threats are placing water increasingly higher on the international agenda. Recently, the World Economic Forum (2014) ranked the ten global risks of highest concern. Four of them are related to water: the food crisis (rank 8), as agriculture accounts to 70 % of the global water use (UN 2014); the greater incidence of extreme weather events (rank 6); failure of climate change mitigation and adaptation (rank 5); and the water crises (rank 3). The United Nations estimates that in 2025 approximately 2 billion people will have an absolute water shortage and that two-thirds of the world population will be affected by water scarcity (UN 2012). Because of the rapid urbanization, cities are the main problem holders (Grimm et al. 2008; Engel et al. 2011; EEA 2012).

Situated where Asia and Europe meet, Istanbul (the largest city in Turkey) has been a city at the centre of life, art and culture for thousands of years. It is a very large metropolitan city with a population of 13.9 million (Turkish Statistical Institute 2013). The city is located in the north-western region of Turkey and has Asian and European parts in the sides of the Bosphorus strait. This waterway connects the Sea of Marmara and the Black sea. The city forms the largest urban agglomeration in Europe and is classified as a megacity (a city with a population over 10 million people). Furthermore, Istanbul is one of

the most rapidly growing cities in Europe. The annual population growth is 2.8 %. The population grew at almost twice the overall rate of the whole of Turkey, because of a large in-migration (Baban et al. 2011; Altinbilek 2006). Hence, water supply and sanitation are of particular concern. The majority of resources are located on the Asian side in contrast to the urban density. Therefore, the water reservoirs are linked, and an integrated system is used with operational flexibility. Furthermore, water from adjacent catchment areas is connected to secure water supply for the city at high cost (ISKI 2013).

Istanbul has always faced water scarcity in its history due to its distant location to drinking water resources (Saatci 2013). The city kept growing, and the need for water increased accordingly (Baban et al. 2011). In recent years, Istanbul has been suffering from drought, especially in 2006, with the lowest rainfall being recorded in the last 50 years (ISKI 2013). It is estimated that the frequency of extreme events, such as droughts and intense rainfalls, will be increased due to the climate change. It is expected that one of the main impacts of climate change will be water scarcity in the Mediterranean Region. Therefore, effective strategies and adaptation plans have been developed including water saving campaigns, transfer of water from adjacent basins and reuse of treated wastewater (Baban et al. 2011; ISKI 2013).

The present study provides a baseline assessment of integrated water resources management (IWRM) of Istanbul as case study of the Mediterranean area. It is part of an action on water governance by the City Blueprint Action Group in the context of European Innovation Partnership on Water of the European Commission (European Commission 2014). Until now, nearly 40 cities have been assessed and the results for 30 cities have been published as interim report on the website of the City Blueprint Action Group (Van Leeuwen and Sjerps 2014; European Commission 2014). Istanbul is the only megacity (a city with more than 10 million inhabitants) assessed so far, and its performance on IWRM is critically analysed and so are its future challenges on environmental management.

2 Methodology

A set of indicators, i.e. the City Blueprint[®], has been developed to assess the sustainability of IWRM. The City Blueprint comprises a set of 24 dedicated indicators divided over eight categories, i.e. water security, water quality, drinking water, sanitation, infrastructure, climate robustness, biodiversity and attractiveness and governance including public participation (Van Leeuwen et al. 2012). The indicators are scored on a scale between 0 (very poor performance) to 10 (excellent performance). General information about the indicators, sources of information and limitations of the City Blueprint approach are provided by Van Leeuwen and Chandy (2013) and Van Leeuwen (2013). The methodology is shortly summarized in Table 1. Detailed information about the 24 indicators, the data sources, the scoring methods and sample calculations for each of the 24 indicators an extensive City Blueprint questionnaire is provided on the website of the European Innovation Partnership on Water (European Commission 2014). A critical discussion about the strength and limitations of the City Blueprint methodology is also provided in Van Leeuwen (2013).

The City Blueprint[®] covers a broad range of aspects and can be used as a first step to benchmark IWRM in cities (Philip et al. 2011; Van Leeuwen and Chandy 2013). It is a baseline assessment and part of a strategic planning process and provides the framework that facilitates the shift to more integrated policies, governance structures, practices and choice of technology for more sustainable water management (Fig. 1; Philip et al. 2011; Brown et al. 2009). More specifically, the City Blueprint can be applied: (1) to

Table 1 Short summary of the City Blueprint method

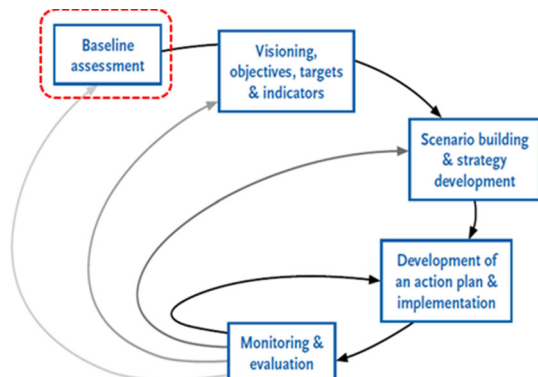
Goal	Baseline assessment of the sustainability of IWRM
Indicators	Twenty-four indicators divided over eight broad categories: <ol style="list-style-type: none"> 1. Water security 2. Water quality 3. Drinking water 4. Sanitation 5. Infrastructure 6. Climate robustness 7. Biodiversity and attractiveness 8. Governance
Data	Public data or data provided by the (waste) water utilities and cities based on a questionnaire for IWRM
Scores	0 (concern) to 10 (no concern)
BCI	Blue City Index [®] , the arithmetic mean of 24 indicators which varies from 0 to 10
Stakeholders	Water utility, water board, city council, companies, NGOs, etc.
Process	Interactive with all stakeholders involved early on in the process

communicate a city's IWRM performance and exchange experiences, (2) to select appropriate water supply and sanitation strategies and (3) to develop technological and non-technological options as future alternatives for the water cycle, where several possible changes in the use of technology, space and socio-economic scenarios can be introduced. This should finally lead to: (4) a selection of measures, including an evaluation of their costs and benefits under different development scenarios, and how to integrate these in long-term planning on urban investments.

The collection of information for Istanbul was carried out by the authors. Feedback was asked from several stakeholders (representatives of municipalities, water utilities, wastewater utilities and water boards) on the preliminary assessment. A site visit was made to Istanbul to drinking water production and wastewater treatment facilities as well as to the bioremediation site in the Golden Horn of Istanbul (Altinbilek 2006). Final reporting was done in an interactive manner with the stakeholders.

The overall score of the sustainability of IWRM of the city is expressed as Blue City Index (BCI). The BCI is the arithmetic mean of the 24 indicators comprising the City

Fig. 1 Function of the City Blueprint (red box) in the strategic planning process for IWRM according to SWITCH (Philip et al. 2011)



Blueprint and has a theoretical minimum and maximum of 0 and 10, respectively (Table 1).

3 Results

3.1 Water resources of Istanbul

Trend analysis of temperature, precipitation, natural stream flow and evapotranspiration for the last 50 years showed that Istanbul has become warmer and drier (Sen 2010). Also, it was found that changes in precipitation or temperature could incur significant impact on the frequency and amount of hydrologic extremes like floods and droughts. Basic information from a variety of sources is summarized in Table 2.

The annual rainfall in Istanbul is 734 mm (ISKI 2013) and is considerably higher than the average for Turkey (Table 2). Water supply and sanitation are the responsibilities of the public utility Istanbul Su ve Kanalizasyon Idaresi (ISKI) or Istanbul Water Works and Sewerage Administration (IWWS) created in 1981. Information on water and wastewater services has been reported by Altinbilek (2006), Baban et al. (2011), Patan (2012) and ISKI (2013). According to Patan (2012), Istanbul supplies 1353 million m³/year water mainly from surface water reservoirs. Use of groundwater is not common, constituting only a small fraction of the overall consumption, compared to the other sources. Groundwater accounts for approximately 30 million m³/year (Baban et al. 2011). Uncontrolled settlement and over-abstraction have diminished groundwater levels and led to salt water intrusion in coastal areas. The decline in the water table due to unsustainable abstraction ranges from 30 m to as much as 150 m in some areas (WaterWiki 2015). Surface water, more than 97 % of all of Istanbul's drinking water, is collected in six drinking water reservoirs. Several reservoirs are located on the European side (Terkos, Alibeyköy, Büyükçekmece, Sazlıdere Reservoirs and Istranca Rivers) and three on the Asian side (Omerli, Darlık and Elmari reservoirs). The water systems consist of dams, reservoirs, water treatment plants and pipelines. Key figures for Istanbul's water infrastructure are given in Table 3.

Currently there are 15 dams with 17,808-km water network in Istanbul (ISKI 2013; Patan 2012; Bekiroglu and Eker 2011). One of the most important water resources of

Table 2 Basic data for Istanbul and Turkey

Resident population (million) of Istanbul ^a	13.9
Household occupancy of Istanbul ^b	3.9
Annual average rainfall (mm) in Turkey ^c	593
Daily average air temperature (°C) of Istanbul ^d	15.0
Population density Turkey (inhabitants/km ²) ^c	98
Population density Istanbul (inhabitants/km ²) ^a	2666
Total renewable water resources per capita (m ³ /year) in Turkey ^c	2860
Total freshwater withdrawal as % of the annual renewable water resources in Turkey ^c	18.9

^a Turkish Statistical Institute (2013)

^b Saatci and Akpınar (2007)

^c FAO (2014)

^d Turkish State Meteorological Service (2013)

Istanbul province is Ömerli Watershed (at the Asian side), which provides about 32 % of the total freshwater supply (Baban et al. 2011; Tezer et al. 2012). System integration has been applied to provide operation flexibility, and water is pumped from one reservoir to another according to the need of area. The use of groundwater is negligible, constituting only a very small portion of the overall consumption, compared to the other sources (Baban et al. 2011).

The reservoirs are exposed to pollution from settlements without adequate sanitation. Water quality is theoretically controlled by conservation zones around the reservoirs. Regulations in these zones limit construction and industrial activities with increasingly strictness closer to the reservoirs. However, there is little enforcement of these regulations in the face of rapid and often unplanned urbanization (Wikipedia 2013). Nutrient control is necessary as a result of eutrophication. This is a primary issue in the reservoirs and linked to population density and percentage urban land use within the watershed (Baykal et al. 2000).

3.2 Drinking water

Access to water supply and sanitation in Turkey is high. The joint monitoring programme for water supply and sanitation (WHO 2013) estimated that the urban population had 100 % access to an improved water source in 2011. In rural areas, where a third of the population lives, 99 % has access to an improved water source. ISKI provides water to Istanbul through 17,808-km drinking water network (ISKI 2013). For Istanbul, the score for indicator six, sufficient to drink, is ten (Table 4).

The water obtained from the reservoirs is treated by filters and chlorination before supply to Istanbul. The treated water meets the criteria for drinking water. Pipelines, however, can cause the distributed water to taste badly as a result of the solution of metals. According to a 2004 survey, 35 % of customers stated that they drink water from the tap, up from only 10 % in 2000. During that period, water quality had improved due to network repairs and the completion of new drinking water treatment plants.

The non-revenue water, as a percentage for total distributed water, for whole Turkey, is 59 % (IBNET 2013). Istanbul has substantially reduced water loss in the distribution network in a successful programme (Altinbilek 2006). The percentage water loss has been

Table 3 Characteristics of Istanbul's water and wastewater system (ISKI 2013; Patan 2012)

Population served (million)	13.6
Total area served (km ²)	5461
Total number of customers (million)	5.1
Total length of potable water pipes (km) by the end of 2012	17,808
Total length of wastewater pipes (km) by the end of 2012	16,454
Annual yield of water resources (million m ³ /year)	1353
Average daily water supply (million m ³ /day)	2.25
Capacity of drinking water treatment plants (million m ³ /day)	4.40
Volume of water reservoirs (million m ³)	1.35
Capacity of wastewater treatment plants (million m ³ /day)	3.11
Power consumption by ISKI (million kwh/year)	932
Number of staff (31-12-2012)	7496
Budget 2012 (million €)	1312
Investment 2012 (million €)	590

Table 4 City Blueprint scores of the city of Istanbul

No.	Indicator	Score	No.	Indicator	Score
1	Water footprint	6.3	13	Energy efficiency	5.0
2	Water scarcity	5.2	14	Energy recovery	1.0
3	Water self-sufficiency	7.9	15	Nutrient recovery	0.0
4	Surface water quality	5.8	16	Average age sewer system	5.0
5	Groundwater quality	4.0	17	Infrastructure separation	7.0
6	Sufficient to drink	10.0	18	Climate commitments	4.0
7	Water system leakages	7.6	19	Adaptation strategies	4.0
8	Water efficiency	5.0	20	Climate-robust buildings	3.0
9	Drinking water consumption	8.9	21	Biodiversity	6.3
10	Drinking water quality	9.0	22	Attractiveness	7.0
11	Safe sanitation	9.5	23	Management and action plans	5.0
12	Sewage sludge recycling	0.0	24	Public participation	0.5

reduced from more than 50 % loss prior to 1994 to 34 % in 2000 by the public utility ISKI. The most recent annual report (ISKI 2013) provides a 24 % water loss ratio. This leads to a score for water leakage of 7.6 (Table 4).

An indication for drinking water consumption can be obtained from Table 5. With an annual supply of 952.5 million m³ and a population size of 13 million, an average annual consumption of 73.24 m³/person is obtained. This is in line with the annual water consumption per head in Istanbul of 68.63 m³ as reported for Istanbul in the European green city index (2009). The drinking water consumption of 68.63 m³/cap/day leads to a score of 8.9 (Table 4).

3.3 Wastewater

In urban areas in Turkey, 97 % of the population has access to improved sanitation facilities, compared to 75 % in rural areas (WHO 2013). In Istanbul, there are 41 wastewater treatment plants. The quantity of wastewater treated is 1119 million m³/year. About 73 % of treated wastewater goes through pre-treatment, and 27 % is treated in advanced biological and biological treatment plants. Wastewater reuse is taking place at a very moderate scale with a volume of 750,000 m³/year (ISKI 2013). The Marmara Sea, which is a semi-enclosed sea, is subject to eutrophication due to low regeneration of water and discharge of significant amounts of land-based pollutants. Therefore, almost all of biologically treated wastewaters having higher effluent quality are discharged to the Marmara

Table 5 Drinking water supply–demand and deficit of Istanbul according to Bekiroglu and Eker (2011)

Year	Population (million)	Demand m ³ /year (million)	Supply m ³ /year (million)	Supply deficit m ³ /year (million)
2005	11.3	1298.0	762.0	473.2
2010	13.0	1635.5	952.5	682.0
2020	16.5	1798.5	1190.6	607.9
2030	17.7	1929.3	1488.3	441.0

Sea. The less advanced treated wastewaters are discharged to the Bosphorus Strait towards the Black Sea in the North. The Black Sea has a much greater assimilative capacity than the ecologically more sensitive Marmara Sea (Baban et al. 2011). The effects of wastewater treatment systems discharged into the Bosphorus, the Marmara Sea and the Black Sea are controlled by water quality monitoring (Haci and Askin 2008).

In Istanbul, the share of wastewater treated increased from 9 % in 1993 to 95 % in 2004 (Coleman et al. 2009). Therefore, safe sanitation (indicator 11) has been scored with 9.5. In Istanbul, the total daily volume of wastewater treated is an impressive 3 million m³. Also the total length of the sewers is enormous (Table 3). In principle, the sewer system consists of separate sanitary sewers and storm water drains. However, in reality, there are illegal cross-connections so that untreated wastewater reaches the storm water drains and contributes to the pollution of drinking water reservoirs. Therefore, the score for infrastructure separation (indicator 17) becomes seven (Table 4).

3.4 Surface water quality

Considering the geographical status of Istanbul with a sloping topography formed by several hills and valleys, natural landscape forming processes such as soil erosion, sediment mobilizations, transport and deposit of mass movements are potential threats to the drinking water supplies and reservoirs (Uyguner 2009). The Bosphorus has been used as a garbage dump for centuries. The sea strait is much polluted, and floating rubbish is a common sight alongside many of Istanbul's waterfront neighbourhoods (Lehtinen 2013). Massive population growth—together with rapid industrialization—has put increasing pressure on the Bosphorus. The main problem, however, is not the rubbish thrown in the Bosphorus, but the sewage water pumped into it. Almost all of biologically treated wastewaters having higher effluent quality are discharged to the Marmara Sea, whereas pre-treated wastewaters are discharged to the Bosphorus strait (Baban et al. 2011).

The Golden Horn Estuary is a 7.5-km-long, 200- to 900-m-wide horn-shaped body of water that connects the Alibeykoy and Kagithane Rivers to the Bosphorus Strait. The Golden Horn Estuary supported thriving fisheries. From 1950s, unauthorized chaotic urbanization due to massive immigration, rapid and unregulated industrialization and inadequacy of sewage disposal resulted in thick layers of anoxic sediment, toxic bacteria, strong hydrogen sulphide odour and ecologically unliveable conditions (Perez et al. 2013; Coleman et al. 2009). The evidence of industrialization has been found in deep sediments of the Golden Horn, due to the poor circulation and massive contaminant absorption. For example, the two major sources of anthropogenic metals, especially zinc, copper and lead, were discharges from an iron and steel plant starting in 1948 and metalwork industries commissioned in 1959 (Coleman et al. 2009). In 1985, there were 700 industrial sites and 2000 businesses on the banks of the Golden Horn producing a smell that caused great discomfort to the people living in the area (Altinbilek 2006). The Istanbul Metropolitan Municipality and ISKI began a major environmental rehabilitation project in 1994. This rehabilitation project, which has been one of the world's largest estuary cleaning projects, has cost a total of US\$653 million. While once the biological life in the water of the Golden Horn was extinct, 33 different species of fishes are now observed in the estuary. The value of the coliform bacteria per 100 ml is 1000, while it was as much as 350,000 in 1998. The estuary is now open to swimming, rowing and navigation (Fig. 2). The Golden Horn Environmental Protection Project was awarded First Prize in the Metropolis Award in 2002 (Altinbilek 2006).



Fig. 2 Golden Horn, after its major clean-up (Photo by C. J. van Leeuwen)

The undertaken efforts were largely successful in revitalizing the area through dramatic water quality improvement. Consequently, the estuary is once again inhabitable for aquatic life as well as amenable to local resource users and foreign visitors, and Istanbul has regained a lost sense of cultural identity. The score for surface water quality, using national data for Turkey from the Environmental Performance Index (2010), is 5.8 (Table 4). However, water pollution in Istanbul and its reservoirs is still relevant (Saatci 2013), and a more realistic local score for surface water quality in Istanbul would be approximately 4.

3.5 Groundwater quality

The bedrock of Istanbul consists of many types of rock: sandstone, limestone and quartz from Palaeozoic, Cenozoic age together with quaternary sediments. The Palaeozoic rocks consist of coastal shallow-marine clastics and carbonates, deep-marine shales and limestones and constitute the basement formation of the area. Groundwater quality, not in the area of Istanbul, but in the western European part of Turkey (Trace region), was studied by Özler and Aydın (2008). Chemical and microbial pollution was evident, and in some of the samples, the values exceeded the limits set by the European and Turkish drinking water directives. The high number of indicator microorganism which was present in the samples reflects the poor quality of water being used by these communities served by groundwater. Groundwater pollution in Turkey is caused by natural (salt water intrusion, geothermal water, discharges from contaminated lakes and streams and dissolution of minerals) and anthropogenic sources. The major anthropogenic sources are as follows: agricultural pesticides and fertilizers, mining waste products, industrial waste, on-site septic tank systems and pollution from poorly constructed wells (Baba and Tayfur 2011). In large cities, such as Istanbul, groundwater is also contaminated by leakage from sewers. Standardized information on groundwater quality is hardly available (Van Leeuwen 2013). Based on this scarce information, a provisional score of 4 has been assigned to groundwater quality in Istanbul.

3.6 City Blueprint of Istanbul

Cities vary considerably with regard to the sustainability of the IWRM (Van Leeuwen and Sjerps 2014). The variability has been captured in the Blue City Index[®]. In 30 cities and

regions reported so far, the BCI varied from 3.5 to 8.0 (Fig. 4). Cities with BCIs >7.5 are as follows: Amsterdam, Berlin, Hamburg and Malmö. Cities with BCIs lower than five are as follows: Kilamba Kiayi (Angola), Belém (Brazil) and Dar es Salaam (Tanzania). Also Malta had a low BCI score. The final result of the City Blueprint analysis of Istanbul is shown in Fig. 3 and Table 4. The BCI of Istanbul is 5.3. This is an average score compared to the range of BCI values observed for the other cities and regions (Van Leeuwen and Sjerps 2014). This is shown in Fig. 4, where the BCIs of 30 cities and regions have been plotted against government effectiveness, one of the governance indicators of the World Bank (2012).

4 Discussion

4.1 Methodological aspects

The City Blueprint[®] is an effective and efficient manner to benchmark cities with regard to the sustainability assessment of their IWRM. The ultimate aim is to establish a network (learning alliance) of cities to share their best practices to improve the sustainability of IWRM in their city/municipality/region (European Commission 2014). These learning alliances are needed because the challenges in cities are important and urgent. Istanbul is no exception. The City Blueprint method is a baseline study and not a refined or comprehensive study on, e.g. asset management or water resources planning. Advantages and limitations of the baseline assessment approach have been discussed previously (Van Leeuwen et al. 2012; Van Leeuwen and Chandy 2013; Van Leeuwen 2013). To put the results for Istanbul in context, it is important to highlight these limitations of the City Blueprint approach:

1. The City Blueprint is a baseline assessment.
2. It is a snapshot or static picture. The City Blueprint does not provide a trend analysis.

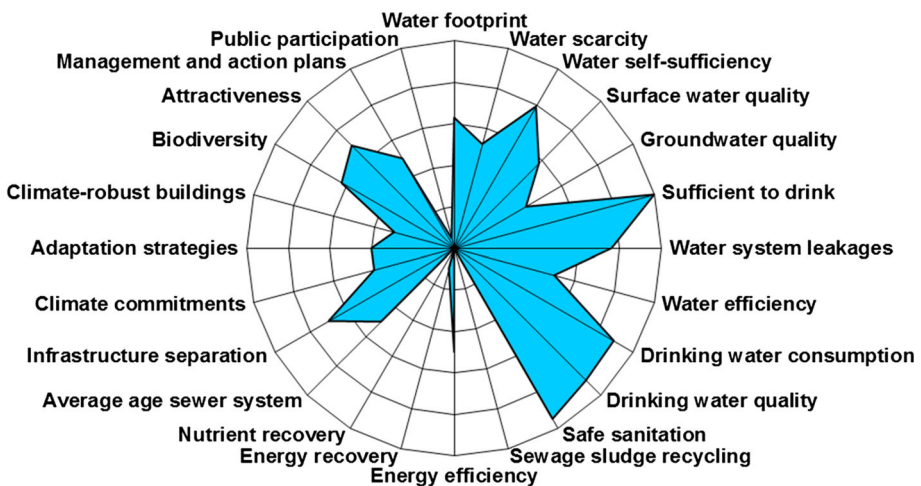


Fig. 3 City Blueprint of Istanbul. The BCI (Blue City Index) is 5.3

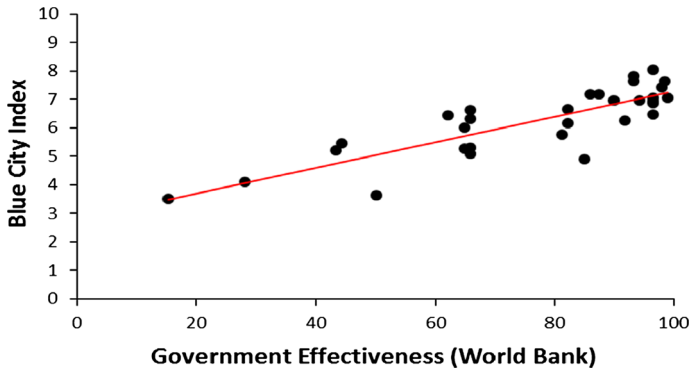


Fig. 4 Relation between the BCI and government effectiveness for 30 cities and regions

3. Local data are often not available for voluntary participation, surface water and groundwater quality, biodiversity of surface water and all water security parameters (Van Leeuwen 2013). The consequence is that estimates are made on the basis of regional/national data, and therefore, local environmental quality may actually be worse. Detailed information on the sources of information and the scoring is provided in the City Blueprint questionnaire (European Commission 2014)
4. Part of the scoring is subjective (e.g. attractiveness) and depends on stakeholder input.
5. The 24 indicators of the City Blueprint do not include economic indicators, but in the case of Istanbul a more extensive analysis has been carried out (see Table 3).
6. Care should be taken not to interpret the scores as the absolute truth. In fact, the discussion on the scoring of the City Blueprint with stakeholders shows that the City Blueprint is not so much a blueprint but more a discussion platform to start transitions, as shown in Fig. 1.
7. Indicators are not weighed, because the approach is a baseline assessment and the priority that can be attached to each of the indicators is per definition subjective (Van Leeuwen 2013). Furthermore, it is the responsibility of the local authorities and stakeholders to set priorities.

A major revision of the City Blueprint assessment framework will take place in the Horizon 2020 project BlueSCities (European Commission 2014), with the aim to include solid waste. The review is also carried out to provide a better separation between the local IWRM performances in cities and the ‘context’ of cities, i.e. the social, environmental and financial trends and pressures in countries. Istanbul will be one of the case studies in this project.

4.2 Istanbul’s future perspectives for water scarcity and droughts

Based on the typology of cities as proposed by Van der Steen (2011), Istanbul can be categorized as a city with a moderate rainfall pattern, affected by climate change. The BCI of Istanbul is 5.3 and demonstrates that despite the enormous investments in IWRM of Istanbul, many aspects of Istanbul’s water cycle can still be improved (Fig. 3; Table 4). This holds especially for sewage treatment (73 % consists only of pre-treatment), sewage sludge recycling, energy recovery and nutrient recovery. Therefore, Istanbul can also be categorized as a city with potential for reuse of treated wastewater (Van der Steen 2011).

The City Blueprint of Istanbul (Fig. 3) provides a static picture (a snapshot) of IWRM. To put the results in more perspective, future population growth in Istanbul, as well as water supply and demand information, needs to be considered, as well as climate change. It is estimated that the frequency of extreme events, such as droughts and intense rainfalls, will increase (Bekiroglu and Eker 2011; Patan 2012; EEA 2012). It is also expected that one of the main impacts of climate change will be water scarcity in the Mediterranean Region (Baban et al. 2011). Bekiroglu and Eker (2011) have studied drinking water supply–demand and deficit in Istanbul (Table 5) and demonstrated water shortages.

In a study of Baban et al. (2011), water demand did not exceed water supply. In recent years, Istanbul has been suffering from drought, especially in 2006, with the lowest rainfall being recorded in the last 50 years (Baban et al. 2011; ISKI 2013). ISKI, using a scenario of a 2 °C temperature increase by 2030, estimated that the city's water supply may decline by as much as 14 % over the next two decades because of higher evaporation from reservoirs. This is where habitat conservation comes in too. Bekiroglu and Eker (2011) correctly emphasize the importance of forested areas of Istanbul to drinking water supply, because most of the drinking water reservoirs are located in these areas. Recently, this has been highlighted in a short and impressive video as contribution to the fifth International Architecture Biennale Rotterdam (Kartaler 2012).

In addition to the water resources from the local reservoirs, water is transferred from the Melen Basin (180 km in eastern direction) with high costs. This project was set up to increase the water resources capacity and fulfil the increasing water of the region of Istanbul. The Melen project shall provide an annual volume of 1180 million m³ of water to fulfil the water requirement until 2040 (Patan 2012). In this way, the total water resources capacity of Istanbul will increase. As a result, the water shortage in Istanbul will be postponed for a while due to the new water resources constructed at high cost, but the need for more sustainable solutions remains crucial as one of the main impacts of climate change will be water scarcity in the Mediterranean Region. This is why ISKI explores other water resources for Istanbul (Patan 2012). These and other sustainable solutions, including water saving campaigns and reuse of treated wastewater, are under way (Baban et al. 2011; EEA 2012).

4.3 Policy implications for IWRM and water governance

IWRM requires integration at multiple levels, including those between the natural and social sciences, between scientists and managers, and between stakeholders and policy makers (Ison et al. 2011; Holzkaemper et al. 2012). Presenting information that is understandable to all parties can increase transparency and awareness, and this is an explicit goal of our City Blueprint assessment framework (Van Leeuwen 2013). IWRM is closely linked to ecosystem services as the sustainable allocation of water between agricultural, industrial and domestic use, and all other uses are a major challenge (Liu et al. 2013; Van Leeuwen et al. 2012). The ecosystem services approach is part of our City Blueprint approach (Van Leeuwen et al. 2012). Habitat conservation to protect these ecosystem services, as emphasized by Bekiroğlu and Eker (2011) and Kartaler (2012) for Istanbul, is crucial. In that respect, our case study of the megacity Istanbul demonstrates that water is one of society's critical assets and that major and urgent attention is needed to preserve these assets (Costanza et al. 1997; Hoekstra and Wiedmann 2014; Van Leeuwen 2013; World Economic Forum 2014).

An important conclusion from our previous work on 11 cities (Van Leeuwen 2013) is that the best performing cities (cities with a high BCI) are those with ambitions to make the

urban water cycle more sustainable. These cities have an active population with a high Voluntary Participation Index (EFILWC 2006). Generally, these cities and regions are in countries with greater prosperity, i.e. a high GDP and high government effectiveness (Fig. 4). These conclusions were recently reconfirmed in our interim report for 30 cities (Van Leeuwen and Sjerps 2014).

According to the United Nations Development Programme (UNDP 2004), 'water governance encompasses the political, economic and social processes and institutions by which governments, civil society and the private sector make decisions about how best to use, develop and manage water resources'. The main obstacle for IWRM is adequate water governance. This has been highlighted in a report of the Organization for Economic Cooperation and Development where seven clear governance gaps have been described. This can provide a simple framework for cities to analyse these gaps and to improve their IWRM (OECD 2011). Recently, the UNDP has published a guidance document on water governance (UNDP 2013), which will be useful for cities too.

4.4 The blueprint to safeguard Europe's water resources

Freshwater constitutes only about 2 % of the water on the planet, and competing demands may lead to an estimated 40 % global water supply shortage by 2030 (2030 Water Resources Group 2009). The Blueprint to Safeguard Europe's Water is the European Union (EU) policy response to these challenges (European Commission 2012). It aims to ensure good quality water in sufficient quantities for all legitimate uses. Cities are concentrated centres of production, consumption and waste disposal that drive land change and a host of global environmental problems and are highly dependent on other cities and hinterlands to supply materials (including water), energy, and to dispose waste (Grimm et al. 2008; Bai 2007). Unfortunately, the blueprint to safeguard Europe's water resources fails to highlight the importance of cities as the challenges and solutions regarding sustainable water use will predominantly reside in cities and regions (European green city index 2009; Engel et al. 2011; UN 2012; UNEP 2012). Recently, the European Commission has implemented European Innovation Partnerships. EIPs aim to speed up innovations that contribute to solving societal challenges, enhance Europe's competitiveness and contribute to job creation and economic growth. EIPs help to pool expertise and resources by bringing together public and private actors at EU, national and regional level, combining supply- and demand-side measures. In 2013, the European Commission decided to set up an EIP on Water, and the City Blueprint Action Group on water governance has been one of the first action groups selected by the European Commission (2014).

4.5 Europe's need for smarter cities and communities

More than two-thirds of the European population lives in urban areas. Cities are places where both problems emerge and solutions are found (European Commission 2011). In order to develop sustainable cities, IWRM needs to be further integrated. According to the European Commission (2013), smart cities are cities that focus on ICT, energy and transport. Unfortunately, this policy currently excludes amongst other things, water, wastewater, solid waste, housing and climate change adaptation. According to the EIP Water City Blueprints Action Group, it is not coherent, but fragmented, and may lead to many missed opportunities for cities (European Commission 2014). With the urgency of the water governance crisis, it is time that we simply cannot afford to lose (2030 Water Resources Group 2009; Van Leeuwen 2013). The initiative of the European Commission

on smart cities is welcomed, but needs to be transformed into a practical coherent long-term European Urban Agenda, e.g. an EUA-2050, with cities and based on the needs of cities. This is a top priority because an active civil society (with the inclusion of companies) is probably the most important driver for change towards sustainability in cities (EFILWC 2006; European green city index 2009; Fleming 2008). According to the City Blueprint Action Group, such an initiative may also lead to a better visibility and better image of Europe for the European citizens, which is a political priority for Europe after the 2014 elections for the European Parliament (European Commission 2014). An Urban Agenda with the focus on cities is even more needed in the rest of the world, where the challenges for IWRM are much greater and more urgent than for Europe (Dobbs et al. 2011, 2012). Thus, there is a need to move towards smarter cities:

1. Smarter cities are cities with a coherent long-term social, economic and ecological agenda,
2. Smarter cities are water-wise cities that integrate, amongst other things, water, wastewater, energy, solid waste, transport, ICT, climate adaptation and nature to create an attractive place to live
3. Smarter cities implement a circular economy (EMF 2014), focus on social innovation (Science Communication Unit 2014) and, last but not least, greatly improve on governance (OECD 2011).

Globally, we need regional platforms to exchange best practices between cities. The water sector is crucial but needs to reframe and to refocus radically (Van Leeuwen 2014).

5 Conclusion

The results of the baseline assessment of IWRM of Istanbul (Table 4; Fig. 3) confirm the conclusions provided in earlier studies (Altinbilek 2006; Uyguner 2009; Baban et al. 2011; Saatci 2013). Istanbul has set a good example to the challenges faced in water supply in megacities, where illegal settlements on watershed zones posed a threat to scarce water resources (Saatci 2013). Nevertheless, despite the enormous efforts of ISKI to provide adequate solutions for IWRM of Istanbul today, the projected future urbanization and population growth together with climate change will necessitate further major transitions towards a more sustainable IWRM for tomorrow. This holds for all aspects of the water cycle: water quality, water quantity, water supply and sanitation, coping with extreme weather events (flood and drought), as well as the protection of the sources of water, i.e. ecosystem conservation (OECD 2013; Bekiroğlu and Eker 2011). The time window available to do this is rapidly closing (2030 Water Resources Group 2009). These challenges for Istanbul are captured in an impressive video (Kartaler 2012). Our case study of IWRM in Istanbul confirms the conclusions of the World Economic Forum (2014) that water supply is one of the top three global risks for both the impact and likelihood.

In Europe, it is necessary that the European Commission takes the lead in the development of a practical coherent long-term European Urban Agenda, an EUA-2050, with cities and based on the needs of cities. Globally, we need regional platforms to exchange best practices between cities. The water sector is crucial but needs to reframe and to refocus radically (Van Leeuwen 2014). Fortunately, cities are not passively waiting but are already taking promising initiatives, e.g. by sharing their best practices and experiences (C40Cities 2014).

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