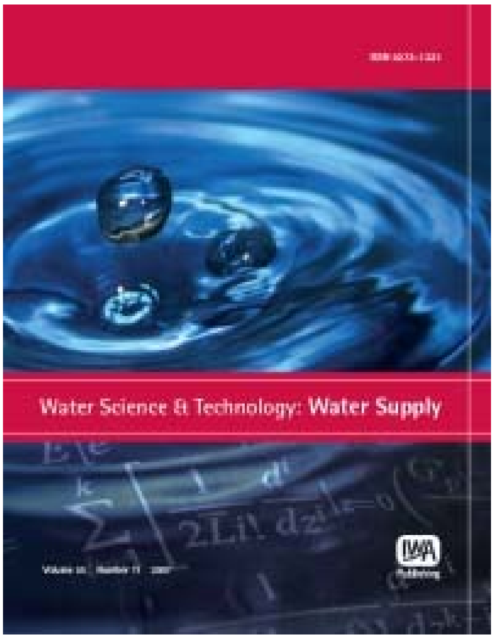
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The City Blueprint of Amsterdam: an assessment of integrated water resources management in the capital of the Netherlands

C. J. Van Leeuwen and R. M. A. Sjerps

ABSTRACT

In this study the sustainability of integrated water resources management in Amsterdam has been reviewed using the City Blueprint approach. The City Blueprint® is 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. In 2006 the various urban water-related services in Amsterdam were brought under one roof, culminating in the country's first water cycle company called Waternet. Waternet is responsible for surface water (rivers, canals, ditches and lakes), groundwater, stormwater, drinking water supply and waste water treatment. The city's unique water cycle approach has proved highly beneficial. Currently Amsterdam is the best performing city of the 30 cities assessed so far. This can be explained by: (1) a long-term vision and a multi-level water governance approach, (2) integration of water, energy and material flows (e.g., struvite production), (3) the entanglement between urban quality and water management, and (4) the transparent communication to and feed-back from customers, i.e., farmers and citizens. Surface water quality and biodiversity remain future challenges.

Key words | Blue City Index®, EIP Water, nutrient recovery, water governance, water management, watershare®

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INTRODUCTION

Amsterdam is the capital of the Netherlands and home to over 800,000 people. Amsterdam and water are intimately connected; the name of the city refers to the adjacent Amstel River, which terminates in the well-known historical canals that run through the city center. The city's aim is to develop as a competitive and sustainable European metropolis in the face of economic, demographic and climate challenges. Amsterdam has a prominent international position in integrated water resources management (IWRM). In the European Green City Index (2009), Amsterdam ranked number one for water. Its water company was the first to deliver piped water in the country (1853) and the first in the world that does not use chlorine in the treatment of its surface water. In 2006 the various urban water-related services were brought under one roof, culminating in the country's first water cycle company called Waternet. Waternet has responsibilities for surface water (rivers, canals, ditches and lakes), groundwater, stormwater, drinking water supply and waste water treatment. The city's unique water cycle approach has proved highly beneficial. In 2014 Waternet took the initiative to recover phosphate (struvite) from waste water, thereby improving its previously reported blue city index (Van Leeuwen 2013).

METHODS

The baseline assessment of cities is based on a method and questionnaire as described by Van Leeuwen *et al.* (2012) and is supplemented with additional information on

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water security, public participation and regional or national estimates for local environmental quality (surface water, groundwater and biodiversity). This information is used to provide a quick scan of IWRM of cities and regions. The assessment includes a City Blueprint®, i.e., a graphical presentation of the scores of 24 indicators to assess the sustainability of IWRM (Van Leeuwen *et al.* 2012). The method has been refined further in a study of the city of Dar es Salaam (Van Leeuwen & Chandy 2013) and, subsequently, in the EU project TRUST (transitions to the urban water challenges of tomorrow), where a more extensive questionnaire was developed (Van Leeuwen & Marques 2013; Van Leeuwen 2013; Van Leeuwen & Bertram 2013). The overall score of the sustainability of IWRM of the city is expressed as BCI (Blue City Index®). The method can only be briefly summarized in this paper (Table 1). Detailed information on the indicators, the data sources, the scoring method and sample calculations for each of the 24 indicators are provided in the City Blueprint questionnaire on the website of the European Innovation Partnership on Water (European Commission 2014a).

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: 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

RESULTS

The baseline assessment

The results of the baseline assessment based on the completed TRUST questionnaire together with some additional information are summarized in Tables 2–4 and Figure 1. Table 2 provides the general information for Amsterdam, whereas Table 3 summarizes the key data for the drinking water and waste water system. Based on the Food and Agriculture Organization (FAO) Aquastat database, the total renewable water resources (TRWR) available for the Netherlands is 91 km^3/year (FAO 2014). Only 11 km^3/year is from internal (national) sources leading to a dependency ratio of almost 88%. This is also reflected in the low score for water self-sufficiency. The TRWR per capita is 5,478 m^3/year. Most of the water withdrawal in the Netherlands is from industry (9.3 km^3), followed by municipalities (1.25 km^3) and agriculture (0.07 km^3). In the Netherlands, the total withdrawal per capita per year is relatively low, i.e., 639 m^3 which is 11.7% of TRWR (Table 1). The surface water quality is reasonable, but shallow groundwater quality and biodiversity of surface waters is poor (Table 4 and Figure 1).

Drinking water

Drinking water is prepared from lowland surface water sources (88%) and borehole sources (12%) and there is 100% population coverage. The total water consumption

Table 2 | Basic data for Amsterdam

Resident population (×1,000)	811
Household occupancy	1.95
Supply area (drinking water) km^2	287
Catchment area (waste water) km^2	269
Annual average rainfall (mm)	847
Daily average air temperature (°C)	10.1
Population density (inhabitants/km^2)[a]	400
TRWR per capita (m^3/year)[a]	5,478
Total freshwater withdrawal as % of TRWR[a]	11.7

[a]National data according to FAO (2014).

Table 3 | Key data for drinking water and waste water for Amsterdam

Drinking water		Waste water	
System input volume (million m^3/year)	36.14	Number of properties connected (×1,000)	777
Population coverage	100	Collected sewage (m^3/inhabitant/year)	87
Authorized consumption (million m^3/year)	46.6	Length of combined sewers (km)	523
Consumption m^3 per person per year	50	Length of stormwater sewers (km)	1,669
Service connections ×1,000	409	Length of sanitary sewers (km)	866
Water losses (m^3) per connection per year	5	Waste water treated (million m^3)	80.97
Water losses (%)	5.4	Total sludge produced in STPs (ton DS/year)	20,734
Quality of supplied water	100	Sludge going to landfill (ton DS/year)	0
Average water charges (€/m^3)	€ 1.30[a]	Sludge thermally processed (tons DS/year)	20,734
Mains length (km)	3,098	Sludge disposed by other means (ton DS/year)	0
Average age of the water supply system (year)	35.6	Energy costs (million €)	1.136
Number of mains failures/year	26	Average age of the sewer system (year)	28
Mains failures per 100 km	0.839	Sewer blockages/year	573
Asset turnover ratio	0.389	Sewer blockages per 100 km	18.7

[a]VAT excluded.

(50 m^3 per person per year) is very low and leads to a very high score for water efficiency (Table 4). The quality of the supplied water is excellent (Table 3 and Figure 1). The total transmission and distribution mains length is 3,098 km and has an average age of 26 years. The number of mains failures in the water supply system is very low (0.839 per 100 km) and so are the water losses (5.4%).

Table 4 | Scores for the 24 indicators of the City Blueprint for the city of Amsterdam

Nr.	Indicator	Score	Nr.	Indicator	Score
1	Water footprint	6.9	13	Energy efficiency	10.0
2	Water scarcity	7.4	14	Energy recovery	10.0
3	Water self-sufficiency	0.5	15	Nutrient recovery	10.0
4	Surface water quality	7.3	16	Average age sewer system	7.2
5	Groundwater quality	6.1	17	Infrastructure separation	8.3
6	Sufficient to drink	10.0	18	Climate commitments	8.0
7	Water system leakages	9.5	19	Adaptation strategies	10.0
8	Water efficiency	10.0	20	Climate-robust buildings	7.0
9	Drinking water consumption	9.8	21	Biodiversity	1.0
10	Drinking water quality	10.0	22	Attractiveness	9.0
11	Safe sanitation	10.0	23	Management and action plans	7.0
12	Sewage sludge recycling	10.0	24	Public participation	7.7

Waste water

The waste water system is a collection, transport and treatment system. The percentage of the population covered by adequate waste water collection and treatment is nearly 100%. There is a system of combined sewers, sanitary sewers and stormwater sewers. The separation of this infrastructure is 82.8% (score 8.28; Figure 1). The average age of the sewer system is 28 years and the number of sewer blockages per 100 km is relatively high (18.7). The energy costs for the waste water system are 1.1 million € (Table 3). Waste water is effectively used to recover energy. Recently Waternet introduced a new nutrient recycling facility to treat waste water for the City of Amsterdam and other communities, which produces 1,000 tonnes of struvite ($MgNH_4PO_4{\cdot}6H_2O$) on an annual basis. This process is based on the addition of magnesium chloride ($MgCl_2$) to digested sludge during aeration with compressed air and formation of struvite. The plant treats approximately 2,000 m^3 sludge per day. The investment costs were € 4 million, while the expected savings are € 400,000/year (Van Der Hoek *et al.* 2013). Struvite will be used for

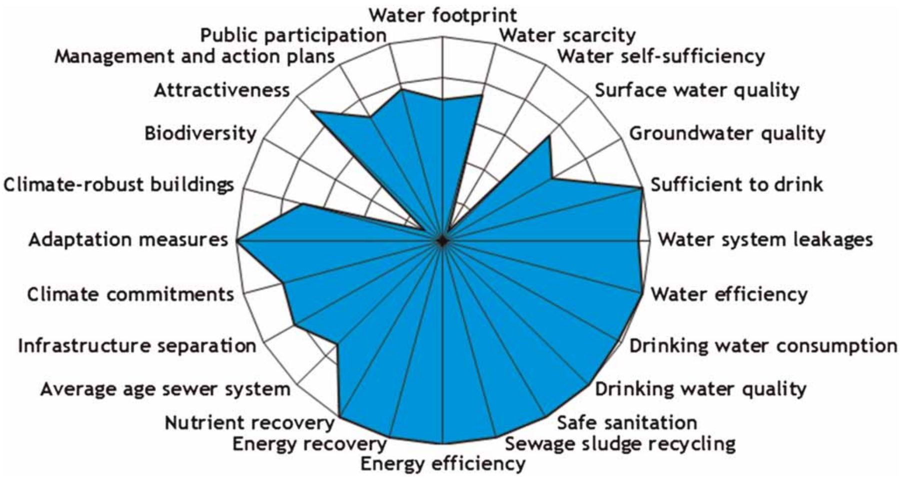

Figure 1 | City Blueprint of Amsterdam. The range of the scores varies from 0 (center of the circle) to 10 (periphery of the circle). Further details are provided in the text and supporting information (European Commission 2014a). The BCI (Blue City Index) is 8.0.

non-agricultural purposes, among other things as fertilizer for sports fields and parks. So the current phosphate recovery is 100%. As a result of a national law related to the pollution of sewage sludge by heavy metals and other persistent pollutants, the application of sewage sludge in agriculture is forbidden and all sewage sludge is thermally treated, which leads to a score of 10 for indicator 12 (Table 4).

Environmental quality

In this study changes have been made compared to previous work. First of all, the lack of harmonized information for environmental quality (surface water quality, biodiversity of surface water and quality of shallow groundwater) for the 30 cities assessed so far, led to the use of national data as published by the European Environment Agency (EEA 2010) and in the Environmental Performance Index (Environmental Performance Index 2010). For surface water quality use was made of the 2010 Environmental Performance Index Water Quality Index (Environmental Performance Index 2010). The EPI uses three parameters measuring nutrient levels (dissolved oxygen, total nitrogen and total phosphorus) and two parameters measuring water chemistry (pH and conductivity). These parameters were selected because they cover issues of global relevance (eutrophication, nutrient pollution, acidification and salinization) and because they are the most consistently reported. The score for surface water quality, using the EPI score of the Netherlands is 73.2/10 is 7.3 (Table 4).

DISCUSSION

Governance gaps

The world's environmental challenges have intensified. There has been a rapid deterioration across many environmental domains, and in some cases, breaching of safe planetary boundaries with respect to environmental issues, such as water (Hoekstra & Wiedman 2014). In many cases this is related to bad water governance practices (OECD 2011). Seven major governance gaps have been defined by the Organisation for Economic Cooperation and Development (OECD) (Table 5). This multi-level framework can also be used to review IWRM at the local and regional level. The strength of IWRM in Amsterdam is the result of a strong focus on water governance. These gaps are limited or absent in the city of Amsterdam. Amsterdam shows high commitments to sustainable solutions on almost all aspects of the water cycle: water efficiency, losses as a result of drinking water leakages, sanitation as well as energy and nutrient recovery from waste water. This is based on both strong implementation of improvement plans as well as a long-term vision (City of Amsterdam 2009, 2010). Waternet has adequate funding, clear objectives (City of Amsterdam 2009, 2010), skilled staff, coordinates all aspects of IWRM in an integrated manner, and is involved in external collaboration with governmental organizations, non-governmental organizations (NGOs) industry and private companies and

Table 5 | Key co-ordination gaps in water policy (OECD 2011)

Administrative gap	Geographical 'mismatch' between hydrological and administrative boundaries. This can be at the origin of resource and supply gaps
Information gap	Asymmetries of information (quantity, quality and type) between different stakeholders involved in water policy, either voluntary or not
Policy gap	Sectoral fragmentation of water-related tasks across ministries and agencies
Capacity gap	Insufficient scientific, technical, infrastructural capacity of local actors to design and implement water policies (size and quality of infrastructure, etc.) as well as relevant strategies
Funding gap	Unstable or insufficient revenues undermining effective implementation of water responsibilities at subnational level, cross-sectoral policies and investments requested.
Objective gap	Different rationales creating obstacles for adopting convergent targets, especially in case of motivational gap (referring to the problems reducing the political will to engage substantially in organizing the water sector)
Accountability gap	Difficulty in ensuring the transparency of practices across the different constituencies, mainly due to insufficient user's commitment, lack of concern, awareness and participation

national and international research organizations. Furthermore, they clearly communicate with their customers, i.e., the citizens of Amsterdam. Furthermore there are no questions regarding who is accountable for IWRM. In fact, Amsterdam is well embedded in local, regional, national and international collaboration. The good performance on IWRM for Amsterdam is also reflected in the City Blueprint scores which are relatively high and vary from 7 to 10. These results are in line with information provided in the European Green City Index (2009), where Amsterdam ranked number one for water. Furthermore, Amsterdam scores low in carbon dioxide emissions, good in clean and efficient energy use as most of the heat is produced by the Waste and Energy Company, by converting biomass and biogas derived from waste and sewage into heat and electricity (European Green City Index 2009).

Transparency and sharing of information

Most of the data for the baseline assessment of Amsterdam have been collected and provided by Waternet (Van Leeuwen & Marques 2013). Utilities in general obtain a lot of information on their water and waste water services and their input into the baseline assessment is very time-consuming, both for the utility and for the scientists who gather these data in order to provide baseline assessments of IWRM. Some of this knowledge is collated and held by water management actors including the utility operators and the different levels of environmental authorities; all of which may have their own distinct reference points and definitions (EEA 2014). Benchmarking networks collect data from their members related to a number of technical and economic parameters used for performance comparison and discuss improvement opportunities. The data policies for the benchmarking networks are defined by the members and results are often presented in anonymous or aggregated form where the individual plants/utilities cannot be identified directly and the underlying data are considered confidential (EEA 2014). In order to meet the enormous water challenges in the next decades (Van Leeuwen 2013) this policy needs to change. Utilities, and certainly utilities paid by the taxpayers, need to be transparent and accountable. These asymmetries of information (quantity, quality, type, scale and confidentiality) between different stakeholders is one of the key co-ordination gaps in (water) policy (Table 5). Fortunately, Waternet sets the example of providing transparent information and feed-back on IWRM and is currently exploring ways to further optimize this (Schaap & Poortinga 2014).

The performance of Amsterdam in an international context

Cities vary considerably with regard to the sustainability of their IWRM (Van Leeuwen 2013). The variability has been captured in the Blue City Index, the arithmetic mean of 24 indicators comprising the City Blueprint with a theoretical minimum score of 0 and a maximum score of 10. In 30 cities and regions assessed so far, the BCI varied from 3.5 to 8.0 (Van Leeuwen & Sjerps 2014). Cities with BCIs greater than 7.5 are Amsterdam, Berlin, Hamburg and Malmö. Cities with BCIs lower than 4 are Kilamba Kiaxi (Angola) and Belém (Brazil), whereas Dar es Salaam (Tanzania) and Malta have BCIs below 5.0.

This assessment confirmed conclusions from a previous study in which the BCI was positively correlated with the Gross Domestic Product per person, the ambitions of the local authorities regarding the sustainability of the IWRM, the voluntary participation index and the governance indicators according to the World Bank (Van Leeuwen 2013). An example of the correlation between BCI and government effectiveness is shown in Figure 2. The Pearson correlation coefficient is 0.84 and is highly significant ($p < 0.0005$).

Based on the scores for Amsterdam, biodiversity may need further attention. Upstream pollution of surface waters may hinder Amsterdam to further improve biodiversity and surface water quality. This needs to be solved at provincial and (inter)national levels. The recent action to recover phosphate (struvite) from waste water puts Amsterdam on top of the ranking of the 30 cities assessed so far (Van Leeuwen & Sjerps 2014).

CONCLUSIONS

An important result from this study is that the variability in sustainability of IWRM among cities offers great opportunities for short-term and long-term improvements, provided that cities share their best practices. This is the ultimate goal of our EIP Water Action Group as cities can learn from each other (Van Leeuwen 2013; European Commission 2014b). Amsterdam has a lot to offer in this respect, for example:

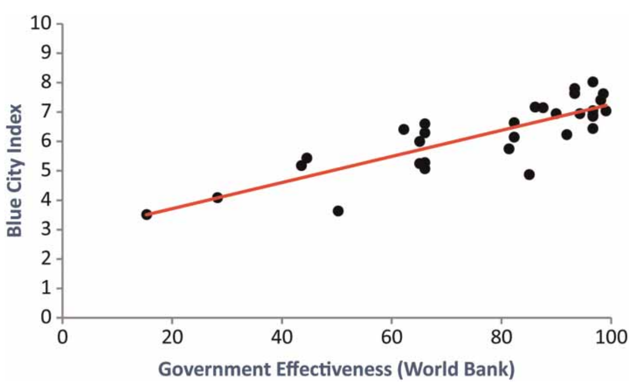

Figure 2 | The relation between the BCI and government effectiveness for 30 cities (Van Leeuwen & Sjerps 2014).

1. A multi-level water governance approach which makes Amsterdam currently the best performing city with a BCI of 8.0.
2. Integration of water, energy and material flows (e.g., struvite production).
3. Living with water (the entanglement between urban quality and water management, e.g., in the WATERgraafsmeer program).
4. Transparency in sharing information to its customers, i.e., farmers and citizens. Many utilities do not provide transparent information and this is a major bottleneck in overcoming the water governance crisis we currently face (OECD 2011; EEA 2014).

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