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City Blueprints: 24 Indicators to Assess the Sustainability of the Urban Water Cycle

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Abstract Climate change, population growth and increased consumption, coupled with urbanization, are all placing increased pressure on water management. This global challenge can often best be addressed at the local level, e.g. in cities by optimizing the role of civil society. Although there are approaches for assessing the sustainability of countries and cities, there is no dedicated framework for the assessment of the sustainability of urban water management. We have therefore compiled a comprehensive list of indicators (the city blueprint) for this. The city blueprint is proposed as a first step towards gaining a better understanding and addressing the challenges of integrated urban water management (IUWM). City blueprints will enable the IUWM of cities to be compared, and stimulate the exchange of success stories (good practices) between cities to address the enormous IUWM challenges which lie ahead. The city blueprint provides a quick scan and baseline assessment. It comprises elements from a variety of methodologies, such as water footprint, urban metabolism and ecosystem services. The indicators have been subdivided into eight broad categories, i.e. (1) water security following the water footprint approach developed by Hoekstra and Chapagain (2007), (2) water quality, which includes surface water and groundwater, (3) drinking water, (4) sanitation, (5) infrastructure, (6) climate robustness, (7) biodiversity and attractiveness and (8) governance. Experience using city blueprints for the cities of Rotterdam, Maastricht and Venlo (in the Netherlands) have been included as practical

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examples. It was concluded that simplicity (ease of calculation and data availability), transparency and ease of communication makes the blueprint a valuable tool for policy makers, decision makers and resource managers as a first step in the process of understanding, envisioning, developing and implementing measures to transform the water management of cities. The best results are obtained when all the stakeholders are involved and connected right from the start.

Keywords Sustainability · Water management · Climate change · Urban metabolism · Water footprint · City blueprint

1 Introduction

The need for water is growing rapidly and water scarcity is a serious problem in major parts of the world (UNEP 2007). Competing demands for scarce water resources may lead to an estimated 40 % supply shortage by 2030 (2030 Water Resources Group 2009). The relevance of water in terms of water scarcity, water quality, human health and ecosystem services is summarized in Table 1.

There are currently over 300 cities in the world with more than one million inhabitants and 21 mega cities—metropolitan areas with a total population in excess of 10 million people. Approximately 50 % of the human population lives in cities, and by 2030 this will be 60 %. In developed countries this will rise to 82 % by 2030 (UN 2008).

Changes in demography, including the aging population, socio-economic factors, climate change, biodiversity, energy use, water supply and consumption, as well as ageing infrastructures for water supply, distribution and treatment (Ernstson et al. 2010; Cohen 2007; Brown 2009; Deltares 2009) demand a thorough understanding of the various options available for moving towards sustainable cities.

A sustainable society is a society that "meets the needs of the present generation without compromising the ability of future generations to meet their own needs, in which each human being has the opportunity to develop itself in freedom, within a well-balanced society and in harmony with its surroundings" (UN 1987). From an anthropocentric point of view sustainability has been summarized as "improving the quality of life of humans while living within the carrying capacity of supporting ecosystems" (Van de Kerk and Manuel 2008; IUCN, UNEP and WWF 1991).

Different scenarios to improve urban water supply in the context of already well-developed and equipped cities have to be evaluated in respect to different aspects of sustainability, i.e. efficient use of water, energy and non-renewable resources, climate change, safety, biodiversity, green space, recreation, human and environmental health, public participation, compliance with current and future legislation, transparency, accountability and costs (Nederlof et al. 2010; Frijns et al. 2009; Verstraete et al. 2009).

Technologies for Integrated Urban Water Management (IUWM) may include stormwater management and rainwater harvesting, water conservation, water reclamation and water reuse, energy management, nutrient recovery, source separation as well as decentralization of water treatment and use of local groundwater (Deltares 2009; Verstraete et al. 2009; Daigger 2009; Ishaku et al. 2011). Improvements in water retention by using green roofs, porous paving systems, rain gardens and water squares are clear examples of new, climate-proof stormwater management technologies that provide opportunities for conservation and reclamation of water (Daigger 2009; C40 Cities 2010; Charlesworth 2010).

Discussions about IUWM are multi-stakeholder processes (Hein et al. 2006; Philip et al. 2011). This process needs to start with (1) an evaluation of the actual situation involving all

Table 1 Facts about water according to UNEP (2007)

Water scarcity
The per capita availability of freshwater is declining globally. The need for water is growing rapidly and water scarcity is becoming a serious problem in major parts of the world.
If present trends continue, 1.8 billion people will be living in countries or regions with absolute water scarcity by 2025, and two-thirds of the people in the world could be subject to water stress.
Water withdrawals are predicted to increase by 50 % by 2025 in developing countries and 18 % in developed countries.
Water quality
Changes in water quality are primarily the result of human activities on land that generate water pollutants, or that alter water availability.
An estimated 2.6 billion people are without improved sanitation. Pollutants of primary concern include microbial pathogens and excessive nutrient loads.
Important point-source pollutants are microbial pathogens, nutrients, oxygen-consuming materials, heavy metals and persistent organic pollutants.
Major non-point-source pollutants are suspended sediment, nutrients, pesticides and oxygen-consuming materials.
Human health
Human health is the most important issue related to water quality.
Contaminated water remains the greatest single environmental cause of human sickness and death.
Three million people die from water-borne diseases every year in developing countries, most of whom are children under the age of five.
Climate change threatens coastal areas as well as the food security and livelihoods of people in the most vulnerable regions.
Ecosystem Services
The decline in the quantity and quality of surface and groundwater is impacting aquatic ecosystems and their services. This degradation puts many ecosystem services at risk, including the sustainability of food supplies and biodiversity.
More than 1.3 billion people depend on fisheries, forests and agriculture for employment—close to half of all jobs worldwide.
Agriculture accounts for more than 70 % of global water use. Water shortage together with land degradation decreases agricultural productivity, resulting in lower incomes and reduced food security.
Fish is an important protein source, especially in the developing world, providing more than 2.6 billion people with at least 20 % of their average per capita animal protein intake.
Reductions in freshwater discharge and seasonal peak flows caused by damming and withdrawal are lowering downstream agricultural yields and fish productivity, and causing the salinization of estuarine land.
Global marine and freshwater fish catches are declining on a large scale, mostly due to persistent overfishing.

stakeholders, followed by (2) a selection of a water supply and sanitation strategy and an inventory of the technological and non-technological options as future alternatives for the water cycle, where various possible changes in the use of technology, space and several socio-economic scenarios can be introduced, (3) a selection of the measures, including an evaluation of their costs and benefits under different development scenarios and, (4) how to integrate these into the long-term planning of urban investments (Goudie 2009).

As pointed out by the European Environment Agency (EEA), the achievement of EU water policy goals appears far from certain due to a number of past and emerging challenges (EEA 2010). The Blueprint to Safeguard Europe's Water (European Commission 2011) will be the EU policy response to these challenges. It aims to ensure good quality water in sufficient quantities for all legitimate uses. The challenges will predominantly reside in cities (European green city index 2009; Engel et al. 2011). Therefore, we have developed a quick scan for the evaluation of the actual situation in cities, involving all stakeholders, as a first step in the strategic planning process for IUWM (Philip et al. 2011) and refer to it as the city blueprint in the remainder of this paper. The city blueprint is proposed as a first step towards gaining a better understanding and addressing the challenges of IUWM. City blueprints will enable the IUWM of cities to be compared, and stimulate the exchange of success stories (best practices) between cities to address the enormous challenges involved in implementing sustainability (Goudie 2009).

2 Methodology

The strategic planning process for IUWM consists of the development and implementation of a flexible strategy that holistically considers all areas of the urban water cycle as well as its links to other management sectors (Fleming 2008; Goudie 2009; Philip et al. 2011). We propose a heuristic approach and aimed to develop a method that is practical, relatively simple, transparent, easy to communicate and understand for decision-makers and the public in general, and enables the sustainability of IUWM of a city to be assessed in about a week. Our proposal therefore, i.e. the city blueprint, comprises a set of indicators. We have chosen an indicator approach because good indicators are: (a) easy to access, (b) easy to understand, (c) timely and relevant, (d) reliable and consistent, (e) credible, transparent and accurate and, last but not least, (f) developed with the end-user in mind. We decided to include indicators derived from a number of existing approaches as given below.

2.1 Water Footprint

The water footprint (WF) shows the extent of water use in relation to people's consumption (Hoekstra and Chapagain 2007). WFs are modified ecological footprints and account for the scarcity and sustainability of renewable water resources (Hoekstra and Chapagain 2007; Hoekstra et al. 2009; Notovny 2010). According to Jenerette and Larson (2006) the water resources are affected by four comprehensive factors: (1) population, (2) per capita water use, (3) climate change, and (4) allocations for water conservation. In their analysis of the WF of nations Hoekstra and Chapagain (2007) concluded that the four major direct factors determining the WF of countries are: (a) volume of consumption which is related to the gross national income, (b) the water-intensity of the consumption pattern (e.g. high versus low meat consumption), (c) climate (water requirement per unit of crop) and (d) agricultural practices (water use efficiency). The concept has been internalized by companies where they use WF to account for water (KPMG 2010; Morrison et al. 2010). WF shows wide variation throughout the world (Hoekstra and Chapagain 2007; Jenerette and Larsen 2006). Some of the largest footprint concentrations are in Southeast Asia. The Middle East region also has several cities with large footprints. The water footprint approach provides a transparent and communicable insight into the global water scarcity problem in general, and the enormous challenges facing cities in particular. The WF concept has therefore been included in our set of indicators for the sustainability of IUWM.

2.2 Urban Metabolism

Urban metabolism (UM) can be defined as “the sum total of the technical and socio-economic processes that occur in cities, resulting in growth, production of energy, elimination of waste” (Kennedy et al. 2007). It provides a means of understanding the sustainable development of cities by drawing an analogy with the metabolic processes of organisms.

UM describes the inward and outward flow of energy and various materials such as carbon, water, nutrients and pollutants. There are strong parallels: "cities transform raw materials, fuel, and water into the built environment, human biomass, heat and waste" (Decker et al. 2000). Increasing metabolism implies greater loss of farmland, forests, and species diversity. This approach can be used to compare flows in a variety of actual and possible future urban water cycle systems (Barles 2010; Kane and Erickson 2007). Kennedy et al. (2007) concluded that the vitality of cities depends on the spatial relationships with the surrounding hinterland and global resource webs. The UM approach is transparent and inputs, dynamics, services and outputs can be measured. UM is a broader concept than WF as it also encompasses WF.

2.3 Ecosystem Services

Ecosystem services (ES) include provisioning services (e.g. food and water), regulating services (e.g. flood and disease control), cultural services (e.g. spiritual, recreational and cultural benefits), and supporting services (such as nutrient cycling). ES maintain the conditions for life on earth (UNEP 2007) and are the benefits people obtain from ecosystems (Millennium Ecosystem Assessment 2005a, b; Costanza et al. 1997; de Groot et al. 2002; Liu et al. 2010). This forms the cornerstone of the Convention on Biological Diversity (CBD). According to the CBD the ecosystem approach is a strategy for the integrated management of land, water and living resources that promotes conservation and sustainable use in an equitable way. It may help to reach a balance in the three objectives of the CBD: conservation, sustainable use, and the fair and equitable sharing of the benefits arising out of the utilization of genetic and natural resources. Ecosystem services and goods are collectively called ecosystem services (Fig. 1).

The ES concept seems a useful way to assess drivers of change in the interests of human well-being. This concept can help to understand and manage societal expectations regarding sustainable provision of various goods and services (Fig. 1). It provides a flexible measure of the quality of the "ideal" system—from the human perspective—and a better understanding of the trade-offs between these goods and services as exemplified in Fig. 2. Agriculture accounts for more than 70 % of the global water use (FAO 2011) and many people also depend on fish as a source of protein. There are many human needs that compete for water (Fig. 2). Not only agriculture, livestock breeding, and wood production, but also power supply, which is directly related to water in the case of hydropower generation, or as a source for cooling water in case of other energy sources (e.g. coal, oil, gas and nuclear power). Other competing activities for water are drinking water, nature (biodiversity), recreation, industry (e.g. the food processing industry as well as the chemical and pharmaceutical industries).

The strength of the ES approach is the demonstration that ecosystems do not provide infinite resources and that choosing one ES may affect other services, thereby showing how the trade-offs inherent in such choices impact certain functions of ecosystems. Special attention was devoted to the economics of ecosystems and biodiversity by calculating the economic value of changes in ES as a result of policy changes and depicting the global cost to society of the impoverishment of biodiversity and ecosystem services (TEEB 2009, 2010).

2.4 Indicators

At the Millennium Summit in September 2000 the largest gathering of world leaders in history adopted the UN Millennium Declaration, committing their nations to a new global

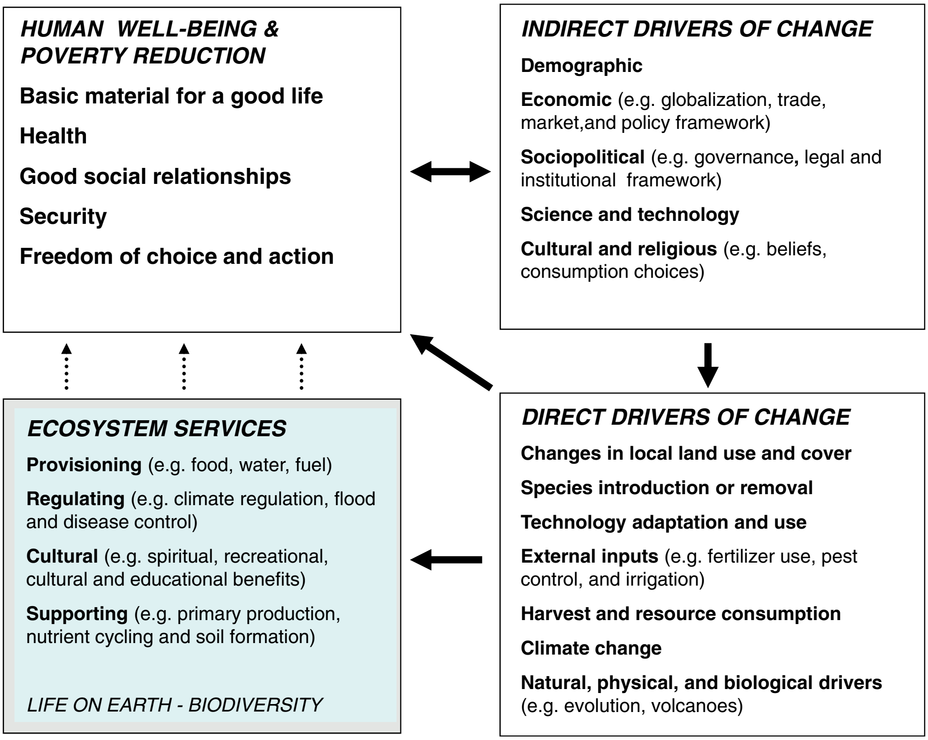

Fig. 1 Ecosystem services and drivers of change according to UNEP (2007) and the Millennium Ecosystem Assessment (2005a). *Bold arrows* indicate strategies and interventions

partnership to reduce extreme poverty and setting out a series of time-bound targets, with a deadline of 2015. Many of these Millennium Development Goals (UN 2010) are directly or indirectly linked to water. Indicators for the assessment of countries have also been developed. An example, the Sustainable Society Index (SSI), is shown in Fig. 3. The advantage of the SSI is threefold: (1) the rationale behind the indicators is given, (2) all input data and calculation methodologies are published, and (3) results are published in a transparent and attractive manner. Results are currently available for 151 countries (Van de Kerk and Manuel 2008; Sustainable Society Foundation 2010). The SSI index is based on 24 indicators (Fig. 3) which can be subdivided into three broad categories: the social dimension (people; human well-being), the environmental dimension (planet; environmental well-being) and the economic dimension (profit; economic well-being). The SSI is transparent, straightforward, and easy to calculate and to communicate and has been accepted as a tool by a variety of international organizations.

Examples of indicators for sustainable cities include the European common indicators (European Commission 2001), the sustainable cities index (Australian Conservation Foundation 2010; Forum for the future 2010), the European green city index (2009), and the global city indicators (Global city indicators facility 2008). All these indicator frameworks are very generic and do not specifically address the urban water cycle. There are many similarities between the broader indicator frameworks. Quite often about 20 indicators (“the magic 20”) are used (Bell and Morse 2003) and there are many links between the thematic indicators (UNEP 2007). Simplicity is what matters, as it is important to realize that a pragmatic approach is

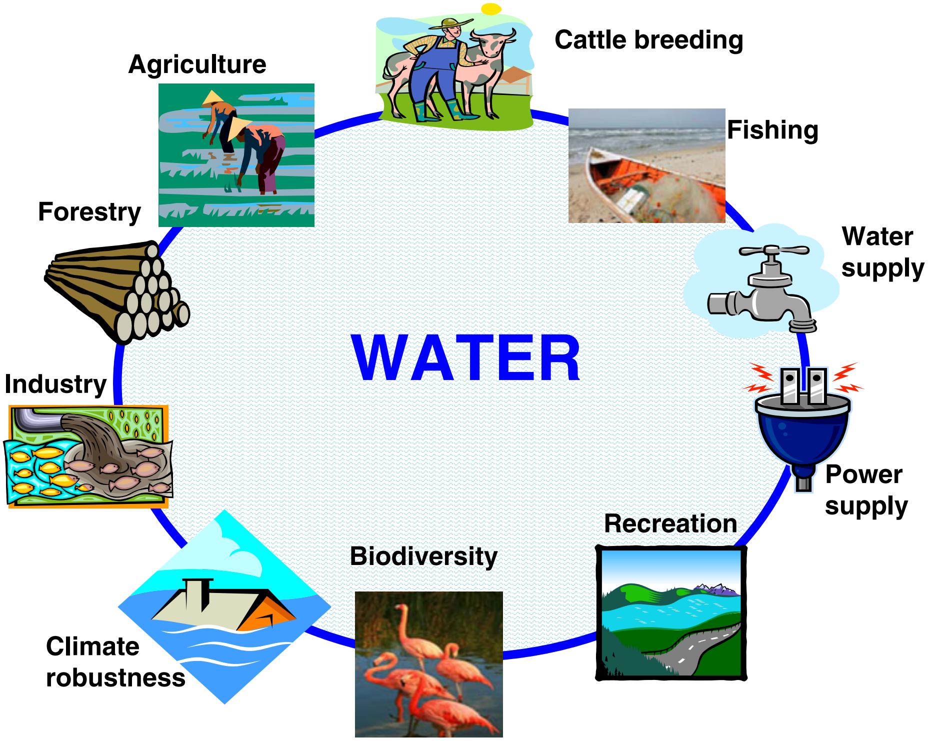

Fig. 2 Ecosystem services demonstrate that competing needs for water lead to trade-offs in practice

needed because of the general lack of data (Australian Conservation Foundation 2010; Forum for the future 2010).

Examples of dedicated frameworks for drinking water and wastewater have been provided by the European Benchmarking Co-operation (EBC 2010). This dedicated set of mainly quantitative indicators is very useful but it lacks the broader context of cities, sustainability and governance.

3 The City Blueprint: A Proposal for a Set of Indicators for the Urban Water Cycle

Based on the evaluation of policy documents, publications on IUWM and an analysis of practical methods as described above, three main conclusions were drawn:

- Despite the global challenges of water security and urbanization which will predominantly affect cities (Engel et al. 2011), a dedicated set of indicators for IUWM is currently lacking.
- Existing country, city and water utility indicator frameworks (e.g. Sustainable Society Foundation 2010; European green city index 2009; EBC 2010) are either too general or too specific for the evaluation of IUWM.
- IUWM can best be addressed at the local level optimizing the role and expertise of civil society (European green city index 2009; Goudie 2009).

Based on these documents (e.g. Brown et al. 2009; Daigger 2009; EEA 2010; EBC 2010; European Commission 2011; European green city index 2009; Goudie 2009; UN 2008;

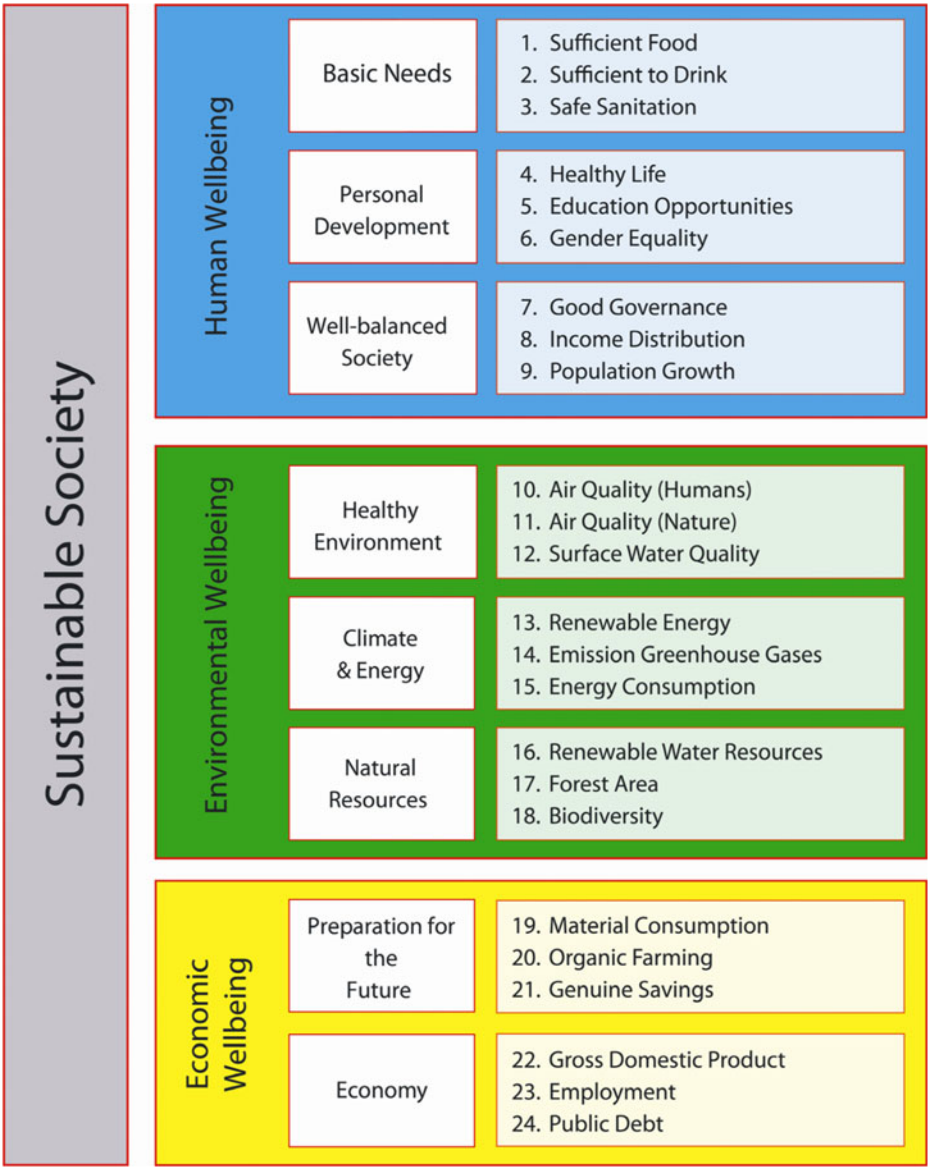

Fig. 3 The indicator framework of the Sustainable Society Foundation (2010)

UNEP 2007; Van der Steen 2011; 2030 Water Resources Group 2009), the following decisions were taken:

1. City blueprints should comprise: water security, water quality, drinking water, sanitation, infrastructure, climate robustness, biodiversity and attractiveness, as well as governance.
2. A quantitative approach is the preferred option in which expert panel scores can also be included.
3. Indicators for city blueprints need to be scored on a scale between 0 (serious concern) to 10 (no concern).

4. Calculations and scoring of the indicator values need to be relatively easy.
5. Data must be easily obtainable from public sources.
6. Results need to be interpreted and communicated relatively easily, not only to experts but to politicians and the public too, preferably in one graphic image such as a spider web, without the need for an in-depth knowledge of the applied methodology.

Based on these criteria we propose that 24 indicators be included in the city blueprint. These indicators are summarized in Table 2.

Water Security As shown in Table 1, water resource overuse is a global problem, especially in large cities (Hoekstra and Chapagain 2007; Notovny 2010; Jenerette and Larsen 2006; Engel et al. 2011). While the per capita use in some parts of the world is almost 650 l per person per day, millions of the world's poorest subsist on fewer than 20 l per person per day (Notovny 2010). Information on water scarcity or water resource overuse by cities may be estimated with the methods used to calculate WF for countries. We have proposed including the total water footprint (indicator 1), water scarcity (indicator 2) and water self-sufficiency (indicator 3). Although the parameters developed by Hoekstra et al. (2009) and Hoekstra and Chapagain (2007) are used to describe water footprints in countries, these national data provide a good indication of water footprint for cities, provided that the geographical variation within the country does not vary greatly.

Water Security Surface water and groundwater quality is a requirement for human and ecological health and can be based on many chemical and biological indicators. Besides the biological oxygen demand or dissolved oxygen concentration and concentrations of nutrients and suspended solids, the water quality assessment can be refined by also looking at persistent and non-persistent organic pollutants and heavy metals. City blueprints need to include relevant microbial risks too as these may arise from surface water and rainwater (Sterk 2008; Fewtrell and Kay 2008; Vinjé et al. 2007; De Graaf et al. 2007a). The scoring for surface water quality (4) and groundwater quality (5) for European cities can be based on obligatory reporting under the WFD (European Commission 2000) and the Groundwater Directive (European Commission 2006).

Drinking Water Risk assessment calculations assume that an average adult ingests approximately 2.0 l of water per day (Van Engelen et al. 2007). For the sustainable production of drinking water it is essential to rethink current practices and implement strategies to improve the threshold, coping, recovery and adaptive capacities of cities (De Graaf et al. 2007a, b) through more efficient water delivery infrastructures (e.g. reduce losses due to system leakages), reduce excessive use, enhance quality and reduce the vulnerability of the water supply with backup water supply facilities, multi-source water supply and the reuse of water. We have proposed five indicators for drinking water (Table 2): potable water supply service (6), water system leakages (7), water efficiency (8), consumption (9) and drinking water quality (10).

Sanitation Wastewater is a source of water, soil and air pollution that may impact human health and the environment (Van der Poel et al. 2007). Access to improved sanitation is a key challenge as many children in the world still die because of microbial pollution which is often linked to inadequate sanitation (Table 1). Effective wastewater collection and sewage treatment plants are required. Furthermore, new technologies may lead to a better use of energy (energy recovery) of waste streams (Frijns et al. 2009; Verstraete et al. 2009) and

Table 2 Proposed indicators for the city blueprint (N = national scale; L = local scale; QN = quantitative; QL = qualitative)

Indicator	Rationale and methodology	Description
Water security		
1. Total water footprint	Sustainable development of a city, region or country (N,QN)	Total volume of freshwater that is used to produce the goods and services consumed by the community (Hoekstra et al. 2009; Hoekstra and Chapagain 2007)
2. Water scarcity	Measure of providing water security (N,QN)	Ratio of total water footprint to total renewable water resources (Hoekstra et al. 2009; Hoekstra and Chapagain 2007)
3. Water self-sufficiency	Sustainable development of a city, region or country (N,QN)	Ratio of the internal to the total water footprint. Self-sufficiency is 100 % if all the water needed is available and taken from within own territory (Hoekstra et al. 2009; Hoekstra and Chapagain 2007)
Water quality		
4. Surface water quality	Requirement for human and environmental health (L,QN)	Assessment of the water quality preferably based on international standards for e.g. microbial risks, nutrients, BOD and organic/inorganic micro-contaminants (European Commission 2000)
5. Groundwater quality	Requirement for human and environmental health (L,QN)	Assessment of quality preferably based on international standards for e.g. microbial risks, nutrients, BOD and organic/inorganic micro-contaminants (European Commission 2006)_
Drinking water		
6. Sufficient to drink	Requirement for the development of an individual (L,QN)	Percentage of city population, with potable water supply service (UN 2007; Sustainable Society Foundation 2010; Global city indicators facility 2008)
7. Water system leakages	Distribution efficiency (L,QN)	Percentage of water lost in the distribution system (European green city index 2009)
8. Water efficiency	Use efficiency (L,QL)	Assessment of the comprehensiveness of measures to improve the efficiency of water usage (Jenerette and Larsen 2006)
9. Consumption	Current drinking water consumption (L,QN)	Domestic water consumption per capita (liters/day) (Global city indicators facility 2008)
10. Quality	Requirement for the development of an individual (L,QN)	Percentage of drinking water meeting the WHO water quality guidelines or the EU Drinking Water Directive (Sustainable Society Foundation 2010; Global city indicators facility 2008; European Commission 1998; EBC 2010)
Sanitation		
11. Safe sanitation	Requirement for the prevention and spread of diseases that would severely hamper a person's development (L,QN)	Percentage of city population served by wastewater collection and treatment (UN 2007; Sustainable Society Foundation 2010; European green city index 2009; Global city indicators facility 2008)
12. Sewage sludge quality	Measure of the use of resources (L,QN)	Percentage of sewage sludge that can be safely used in agriculture based on organic/inorganic micro-contaminants (Fewtrell and Kay 2008; Vinjé et al. 2007; De Graaf et al. 2007a, b)
13. Energy efficiency	Measure of the use of resources (L,QL)	Assessment of the comprehensiveness of measures to improve the efficiency of wastewater treatment (UN 2007; European green city index 2009)

Table 2 (continued)

Indicator	Rationale and methodology	Description
14. Energy recovery	Measure of the use and depletion of resources (L,QN)	Percentage of wastewater treated with techniques to generate and recover energy (Frijns et al. 2009; Verstraete et al. 2009; Daigger 2009)
15. Nutrient recovery	Measure of the use and depletion of resources (L,QN)	Percentage of wastewater treated with techniques to recover nutrients, especially phosphate (Frijns et al. 2009; Verstraete et al. 2009; Daigger 2009; Cohen 2007)
Infrastructure		
16. Maintenance	Measure of maintenance (L,QN)	Percentage of infrastructure for wastewater collection, distribution and treatment younger than 40 years (RIONED 2010)
17. Separation of wastewater and stormwater	Measure of the use of resources (L,QN)	Percentage of separation of the infrastructures for wastewater and storm water collection (Tredoux et al. 1999; UN 2007; Sustainable Society Foundation 2010; EBC 2010)
Climate robustness		
18. Local authority commitments	Requirement for the development of people (L,QL)	Assessment of how ambitious and comprehensive strategies and actual commitments are on climate change (Australian Conservation Foundation 2010; Forum for the future 2010; European green city index 2009; Global city indicators facility 2008)
19. Safety	Requirement for the development of people (L,QL)	Assessment of measures taken to protect citizens against flooding and water scarcity, including sustainable drainage (Deltares 2009; Nederlof et al. 2010)
20. Climate-robust buildings	Measure of sustainability of heating and cooling of buildings (L,QL)	Assessment of energy efficiency for heating and cooling, including geothermal energy (Charlesworth 2010)
Biodiversity and attractiveness		
21. Biodiversity	Requirement for perpetuating the function of nature (L,QN)	Biodiversity of aquatic ecosystems according to the WFD (European Commission 2000)
22. Attractiveness	Requirement for quality of life for residents in cities (L, QL)	Water supporting the quality of the urban landscape as measured by community sentiment within the city (Costanza et al. 1997; European green city index 2009)
Governance		
23. Management and action plans	Measure of participatory, adaptive, coordinated and integrated management (L, QL)	Measure of local and regional commitments to adaptive, multifunctional, infrastructure and design for IUWM as demonstrated by the ambition of the action plans and actual commitments (European green city index 2009; Fleming 2008; Brown and Farrelly 2009)
24. Public participation	Measure of local community strength and willingness (N,QN)	Proportion of individuals who volunteer for a group or organization as a measure of local community strength and the willingness of residents to engage in activities for which they are not remunerated. Public participation is an indicator of stakeholder equity in the planning process (Brown 2009; Brown and Farrelly 2009; European green city index 2009; EFILWC 2006)

nutrients or other basic materials from these waste streams (materials recovery), such as phosphate (Cohen 2007). Organic farming, assuming the use of sewage sludge as a fertilizer for agricultural land, is important and can be expressed as a percentage of the sewage sludge that can actually be used as fertilizer in agriculture. Often the high loads of heavy metals and persistent organic pollutants may hinder the use of contaminated sewage sludge as fertilizer on agricultural land (Daigger 2009; Traas and Van Leeuwen 2007; Van Engelen et al. 2007). We have proposed five indicators for sanitation: safety (11), sewage sludge quality (12), energy efficiency (13) as well as energy (14) and nutrient recovery (15).

Infrastructure Cities have many different infrastructures for heating, drinking water supply, groundwater cooling, wastewater, stormwater and surface water. Research is taking place to see if some of these infrastructures can be combined which may lead to cost savings and a reduction of material use. Currently, stormwater in urban areas is a relatively clean source which is not yet used for drinking water production. Instead it is converted to wastewater in combined sewer systems (De Graaf et al. 2007b). Stormwater could be used as an alternative source of water (UNEP 2008; Tredoux et al. 1999) as well as reduce the volume and material consumption of sewage water systems. This becomes even more relevant in the context of water scarcity and how cities organize and implement their climate robustness. Stormwater can also lead to sanitary sewer overflow (SSO) whereby untreated sewage is discharged into the environment before reaching treatment facilities. Separation of these systems would be a more sustainable way as it would lead to better surface water quality and enhance the efficiency of the wastewater treatment process. Maintenance of infrastructures for wastewater collection and treatment (RIONED 2010) is a high priority too. Maintenance costs increase with the age of the infrastructure and especially when this exceeds 40 years (RIONED 2010). Therefore, we have proposed two indicators for the infrastructure: (16) maintenance of the wastewater infrastructure and (17) separation of infrastructures for wastewater and stormwater collection.

Climate Robustness Reducing vulnerability to climate change is another challenge that cities face. Multi-source water supply (surface water, groundwater, stormwater, drinking water and wastewater) in the event of drought is just one of the options. Higher dikes, increased river capacity, emergency plans, financial instruments are other approaches (Vinjé et al. 2007). Sustainable drainage devices such as green roofs and walls, water squares, rain gardens, constructed wetlands, filter strips, swales, vegetated porous paving systems and street trees are examples that can play a role in improving the retention capacity of cities and reducing the urban heat island effect (Charlesworth 2010; Lafortezza et al. 2009). Green buildings are important as well. Climate-robust cities are both water-robust and heat-robust (Deltares 2009). We have proposed three indicators for climate robustness: (18) local authority commitments, (19) safety and (20) climate-robust buildings.

Biodiversity and Attractiveness Biodiversity is a pre-requisite for perpetuating the function of nature in all its aspects and is therefore linked to all other aspects (UNEP 2007). A city's attractiveness is determined by a wide range of elements (Australian Conservation Foundation 2010). Many countries are implementing various measures to enhance their cities' attractiveness based on their own history, cultural heritage, and landscape excellence. The proximity to green space in an otherwise dense urban area has a positive impact on perceptions of health and well-being, certainly in times of intense heat stress (Charlesworth 2010; Lafortezza et al. 2009). It has been recommended that green space adapted for climate change by providing access to water and shade should become national policy (Lafortezza et al. 2009). Minx et al. (2010)

proposed green space access (green space to which the public has access in square meters per capita) and recreational land (proportion of land area for recreational, sports and leisure activities) as indicators for green space and accessibility. Similar proposals have been made by the EEA (EEA 2010). For IUWM, the focus should be on biodiversity in aquatic ecosystems. In fact, together with the reporting that has to be provided in the context of the WFD (European Commission 2000), biodiversity should also be reported. We therefore propose two indicators: (21) biodiversity according to the WFD and (22) attractiveness.

Governance Governance is a socio-political issue (Fleming 2008). Good governance is a necessary condition for the development of all people in freedom and harmony within the framework of national and international legislation and regulations (Brown and Farrelly 2009). Governance means that explicit choices have to be made in the trade-offs. This can be quantified by (a) green action plans (an assessment of how ambitious and comprehensive strategies to improve and monitor performance are), (b) green management (an assessment of how environmental issues are managed and the commitment to achieving international environmental standards) and (c) public participation (as the role of citizen involvement and behavioral change in achieving healthy urban communities and environments is one of the key elements) (Brown 2009; Brown and Farrelly 2009; European green city index 2009; EFILWC 2006). Therefore we have proposed two indicators for governance: (23) management and action plans and (24) public participation.

4 Results

4.1 The City Blueprint of Rotterdam

The city blueprint of Rotterdam is shown in Fig. 4 and further details of the calculations for the Rotterdam city blueprint are provided in the supporting information. Because data for the city of Rotterdam on aspects like water footprint, water scarcity and water self-sufficiency were not available (indicators 1–3 in Table 2), use has been made of the work of Van Oel et al. (2009) who provided information for the Netherlands. Although this may be a suitable approach for small countries such as the Netherlands, more refinement may be necessary for large countries with significant differences in e.g. soil conditions, hydrology and climate.

In order to interpret the overall city blueprint in a relatively straightforward manner, the scoring system was converted to a scale of 0 (a very poor performance needing further attention by managers and politicians) to 10 (an excellent performance which requires no further attention). In some cases, this necessitated modification of the original data. For instance, the total water footprint of the Netherlands is 2300 m^3/year/person (Van Oel et al. 2009). This value is scored as a percentage of the maximum total water footprint, i.e. 2483 m^3/year/person in the USA. This is 93 % or 9.3 on a scale of 0–10. In order to convert this high score into a "concern" score for managers and politicians, this score was transformed to $10–9.3=0.7$. In other words, the total water footprint in the Netherlands is very high, which is a concern and this is now reflected in a low score of 0.7. A similar approach was applied for three other indicators in the city blueprint, i.e. water scarcity, water self-sufficiency and water system leakages. This is explained in more detail in the supporting information.

The spider web presentation of the calculations provides a quick scan of the concerns, which in the case of the city blueprint for Rotterdam are the total water footprint, water self-sufficiency, sewage sludge quality, nutrient recovery, energy recovery and biodiversity. Groundwater quality may also be an issue due to insufficient information (preliminary score of 6). As the water security

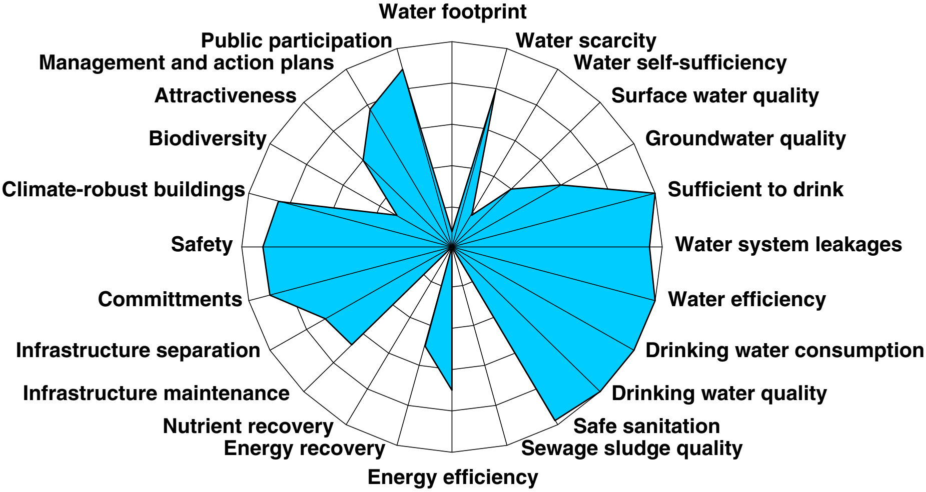

Fig. 4 The city blueprint of Rotterdam based on 24 indicator scores. The range of the scores varies from 0 (center of the circle) to 10 (periphery of the circle). Further details are provided in the text and supporting information

parameters were estimated on the basis of information for the Netherlands (Van Oel et al. 2009) and Rotterdam greatly depends on the rivers Meuse and Rhine, it is only natural that water security and water quality issues can only partly be dealt with by the city of Rotterdam and also need to be addressed at national and international levels (Klauer et al. 2011).

4.2 The City Blueprints for Maastricht and Venlo

Based on the publication of the city blueprint for Rotterdam (Van Leeuwen et al. 2011), KWR Watercycle Research Institute was asked to provide city blueprints for another two cities. These Dutch cities, Maastricht and Venlo, are situated along the river Meuse in the province of Limburg. A different approach was taken however. Rather than collecting information ourselves, as in the case of the city of Rotterdam, the stakeholders (representatives of municipalities, water utilities, wastewater utilities and water boards) were asked to complete a questionnaire in an interactive manner. The assessment and evaluation of Maastricht and Venlo were done in an interactive and interdisciplinary manner (Table 3) taking a bottom-up approach (Van Pelt and Swart 2011) in accordance with the principles and management strategies of the implementation challenge approach (Table 4). Not surprisingly, the results of the scoring were quite similar to those of Rotterdam, as all three cities are in the same country, situated on the same downstream water bodies (Klauer et al. 2011), with many similarities for most indicators.

5 Discussion

5.1 Needs and Goals

Imbalances between availability and demand, the degradation of groundwater and surface water quality, intersectoral competition, interregional and international conflicts, are all bringing water issues to the fore (UNEP 2007). IUWM cooperation between water policy

Table 3 Steps in the interactive assessment of city blueprints

Step 1	Orientation. Preliminary discussion about the scope, goals, selection and roles of the different stakeholders, mutual expectations and preliminary project plan (time, methodology, financial aspects, etc.).
Step 2	Project plan. Clear description of mutual expectations, time path, roles and responsibilities of all stakeholders formulated in a SMART manner. Mutual agreement on two persons who will coordinate the work on behalf of the city (city coordinator) and the neutral facilitator (project leader).
Step 3	Invitation. Formal invitation to all stakeholders by the city coordinator and project leader.
Step 4	Methodology. Explanation and discussion of the indicator methodology, questionnaire, scoring process and methodological limitations.
Step 5	Collection of information per indicator on the basis of a questionnaire. This also provides for a division of the work among the stakeholders, managed by the city coordinator.
Step 6	Draft city blueprint. The draft city blueprint is drawn up by the project leader and based on the responses provided in step 5.
Step 7	Discussion of the preliminary results among all stakeholders.
Step 8	Setting priorities and proposals for follow-up actions and implementation (managed by the city coordinator).
Step 9	Final report (project leader).
Step 10	Presentation to managers at city or provincial council level and follow-up.

makers, policy implementers and researchers is necessary to be able to deal with the technical, economic and socio-political challenges we currently face (Table 1; Ison et al. 2011; Godden et al. 2011). The focus on cities is crucial as cities will play a pivotal role in the challenges facing us (Engel et al. 2011).

City blueprints enable the IUWM of cities to be compared, and will stimulate the exchange of success stories between cities in order to address the challenges that lie ahead. The process of comparing cities and highlighting best practices in cities as in the case of the C40 cities initiative, is the ultimate goal as communication with all stakeholders, public participation and implementation are what matters (Brown 2009; European green city index 2009; C40 cities initiative 2010). Transforming cities to become water aware will require a

Table 4 Principles and practices of implementation challenges (VROM 1992)

Principles
Take the initiative
Emphasize outcomes
Seek consensus
Be reasonable
Maintain credibility
Practices
Devise a clear organizational mission
Identify conflicting attitudes and interests
Establish effective two-way communication
Develop options for mutual gain
Devise the criteria for the evaluation of success together
Use neutral parties for facilitation
Shape public perception though use of the media
Plan for monitoring and renegotiation

major social and technical overhaul of conventional approaches (Brown et al. 2009). Fleming (2008) made this very clear: “Ultimately the design, function and sustainability of cities are a function of aspiration, imagination and choice, which is why sustainability is more a socio-political than an environmental issue. We will get what we will choose as a society, whether through passive inaction or proactive design.”

Public participation is a key issue, not only in the design of cities but also in IUWM. The engagement of individuals with the societies around them, i.e. the strength of civil society in the city, is closely linked to environmental performance. As stated in the report of the European green city index (2009), about three-quarters of the existing technological changes that would help London to meet its long-term carbon reduction targets depended on the decisions of citizens or companies, not of governments. In other words, the individual decisions of cities’ inhabitants collectively are more powerful than their governments’ ability to intervene. This is underscored by the relationship between voluntary participation in organizations (based on the average number of voluntary organizations, such as religious groups, trade unions and sports, professional or charitable bodies that people in cities belong to) and a city’s environmental performance (EFILWC 2006; European green city index 2009).

5.2 The Indicators

Despite the many challenges in the implementation planning and engineering of sustainability (Goudie 2009), there is no clear set of indicators to asses the sustainability of the urban water cycle. Only recently a long list of indicators was published (Van der Steen 2011). We therefore developed the city blueprint: a set of 24 indicators that enable a quick scan to be made of the sustainability of the urban water cycle. This quick scan or baseline assessment is an initial collection and analysis of information to gain up-to-date knowledge on water issues, the urban water system, main actors and legal and institutional frameworks relevant for water management (Philip et al. 2011). For the purposes of scope, simplicity, transparency and ease of communication, preference was given to the indicator approach. In this respect, the city blueprint approach is identical to the approach of the European green city index (2009), but with a more specific focus on the sustainability of the urban water cycle (Siemens 2011).

The choice of indicators for the city blueprint is by definition subjective. There are many options for other indicators and a variety of methods to quantify them. For example, we deliberately left out the economic indicators at this stage of IUWM, but this information is available (EBC 2010). We have not addressed salt water intrusion due to groundwater overexploitation, although this may be relevant in many countries (EEA 2010). However, we have addressed the energy efficiency of wastewater treatment, although this is only a relatively small fraction of the total use of energy in the water cycle. So the proposed 24 indicators are subjective and by no means exhaustive and need to be further discussed and developed in a process of learning-by-doing. Undoubtedly, there will never be a perfect set of indicators for IUWM. Nevertheless, the production and use of the indicators for the city blueprint will provide a better way to serve the needs of all stakeholders seeking to improve water management.

Ideally, the following aspects (per indicator) need to be clarified in advance: 1) goal, 2) principle, 3) criterion, 4) indicator, 5) reference value per indicator (Van Cauwenbergh et al. 2007), methodology for calculation or assessment, 7) data requirements and 8) data availability. In order to predict the advantages of the technological and governance interventions it is also important to know: 9) the possible interventions including their descriptions, 10) their costs and 11) their consequences for each indicator. Once accepted, a clear set of indicators, with a transparent methodology and data requirements will support decision-making for IUWM. It should be noted that this is probably the more rigorous, traditional scientific approach.

5.3 Further Development: Learning-by-doing

Our goal was to address the most important challenges documented in the scientific literature, in policy documents and in views from the water sector. This city blueprint is a first step. It is a proposal and intended as a practical tool to facilitate changes in the understanding and practices of stakeholders in complex situations (Ison et al. 2011). The tool has been designed to facilitate the first step in IUWM (Philip et al. 2011; Goudie 2009), i.e. evaluation of the actual situation by involving all stakeholders. Further discussions to refine and improve the indicators and to gain acceptance by all stakeholders is key (Van Leeuwen 2007; Hegger et al. 2011). Therefore the next steps should include:

(1) Further multi-stakeholder discussion and dialogue to refine the proposal as presented in Table 2 and to decide on: (a) the spatial scale, (b) the indicators and their reference values, (c) the appropriate data, methodology and tools to quantify them.
(2) Case studies to implement and test the tool following a learning-by-doing approach. The preliminary scoring of the city of Rotterdam is provided in Fig. 4. This exercise confirmed the data limitations issue (Morrison et al. 2010) and highlighted the need to present the results in a comprehensive manner.
(3) A comparison of cities using this indicator approach. This will require a clear questionnaire and expert panel process (European green city index 2009; Global city indicators facility 2008).
(4) A book, website or other means of communication to attract the attention and involvement of the public, companies and public authorities about the best practices and successes in IUWM (C40 Cities 2010), to explain the win-win opportunities and convince stakeholders of the benefits of integrated approaches for the well-being of citizens. This is a top priority because an active civil society is probably the most important driver for change towards sustainability in cities (EFILWC 2006; European green city index 2009; Fleming 2008). The climate-proof adaptation strategy of Rotterdam is an example of how to implement and communicate this (C40 Cities 2010).

5.4 The Process

The various options for arriving at sustainable IUWM come at a price. Savings can be achieved by thinking in terms of longer term investment rather than short-term expenditure (Goudie 2009). Decisions that concentrate only on identifying the risk to a system may not effectively assess sustainability. Sustainability is not just about managing risks but also about managing and living with change (preparedness and adaptability). Cities that do not adapt to changes in the available water resources may suffer greatly, as in the case of the Sahel countries and parts of Australia where governments have been forced to consider the problem of evacuating some small towns. The same is true for the cities of Rotterdam, Maastricht and Venlo, where the risks of flooding and spatial development are inextricably linked and show that the rate and ease of change or adaptation are very important (C40 cities 2010).

Integration is most successful when there is a process of interaction rather than a one-way delivery of knowledge on the doorstep of the policy maker (Ison et al. 2011). In this respect, the multi-stakeholder approach to problem formulation (Van Leeuwen 2007), assessment and evaluation of IUWM as applied for the cities of Venlo and Maastricht was much more effective, as it underlined the connectivity between the technical, economic and socio-political processes (Ison et al. 2011; Godden et al. 2011). It was indeed a quick scan and a concrete step towards sustainability implementation planning (Goudie 2009; VROM 1992).

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References

Australian Conservation Foundation (2010) Sustainable Cities Index. Ranking Australia's 20 largest cities in 2010. Melbourne, Australia

Barles S (2010) Society, energy and materials: the contribution of urban metabolism studies to sustainable urban development issues. Environ Plan Manag 53:439–455

Bell S, Morse S (2003) Measuring sustainability: learning from doing. Earthscan Publ, London

Brown P (2009) The changing face of urban water management. Water 21(2):28–29

Brown RR, Farrelly MA (2009) Delivering sustainable urban water management: a review of the hurdles we face. Water Sci Technol 59:839–846

Brown RR, Keath N, Wong THF (2009) Urban water management in cities: historical, current and future regimes. Water Sci Technol 59:847–855

C40 Cities (2010) Climate Proof Adaptation Strategy of Rotterdam. New York

Charlesworth SM (2010) A review of the adaptation and mitigation of global climate change using sustainable drainage in cities. J Water Climate Change 1:165–180

Cohen D (2007) Earth audit. Cover story. New Scientist 194(2605):34–41

Costanza R, d'Arge R, de Groot R, Farber S, Grasso M, Hannon B, Limburg K, Naeem S, O'Neil R, Paruelo J et al (1997) The value of the world's ecosystem services and natural capital. Nature 387:253–260

Daigger GT (2009) Evolving urban water and residuals management paradigms: water reclamation and reuse, decentralization, and resource recovery. Water Environ Res 81:809–823

De Graaf R, van de Giessen N, van de Ven F (2007a) Alternative water management options to reduce vulnerability for climate change in the Netherlands. Nat Hazards 5:407–422

De Graaf RE, van de Giessen NC, van de Ven FHM (2007b) The closed city as a strategy to reduce vulnerability of urban areas for climate change. Water Sci Technol 56:165–173

De Groot RS, Wilson MA, Boumans RMJ (2002) A typology for the classification, description and valuation of ecosystem functions, goods and services. Ecol Econ 41:393–408

Decker H, Elliott S, Smith FA, Blake DR, Sherwood Rowland F (2000) Energy and material flow through the urban ecosystem. Annu Rev Energy Environ 25:685–740

Deltares (2009) Land and water management in the urban environment. Utrecht, The Netherlands

EBC (2010) European Benchmarking Co-operation. Learning from international best practices. 2010 water & wastewater benchmark. Leiderdorp, The Netherlands

EEA (2010) European Environment Agency. The European Environment. State and Outlook 2010. Synthesis. Copenhagen, Denmark

EFILWC (2006) First European quality of life survey: participation in civil society. European Foundation for the Improvement of Living and Working Conditions, Dublin. http://www.eurofound.europa.eu/publications/htmlfiles/ef0676.htm. Accessed 21 February 2011

Engel K, Jokiel D, Kraljevic A, Geiger M, Smith K (2011) Big cities. Big water. Big Challenges. Water in an urbanizing world. World Wildlife Fund. Koberich, Germany

Ernstson H, van der Leeuw SE, Redman CL, Meffert DJ, Davis G, Alfsen C, Elmqvist T (2010) Urban transitions: on urban resilience and human dominated ecosystems. Ambio 39:531–545

European Commission (1998) Council Directive 98/83/EC of 3 November 1998 on the quality of water intended for human consumption. Official Journal of the European Union L 330/32

European Commission (2000) Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000 establishing a framework for Community action in the field of water policy. Official Journal of the European Union L 327/1

European Commission (2001) European Common Indicators. Towards a local sustainability profile – European common indicators; Methodology sheets. http://ec.europa.eu/environment/urban/pdf/local_sustainability_en.pdf. Accessed 20 February 2011

European Commission (2006) Directive 2006/118/EC of the European Parliament and of the Council of 12 December 2006 on the protection of groundwater against pollution and deterioration. Official Journal of the European Union L 372/19

European Commission (2011) A Blueprint to safeguard Europe's Waters. Brussels, Belgium. http://ec.europa.eu/environment/water/blueprint/index_en.htm Accessed 21 December 2012.

European green city index (2009) Assessing the environmental impact of Europe's major cities. A research project conducted by the Economist Intelligence Unit, http://www.siemens.com/press/pool/de/events/corporate/2009-12-Cop15/European_Green_City_Index.pdf. Accessed 20 February 2011

FAO (2011) The state of the world's land and water resources for food and agriculture. Managing systems ant risk. Summary report. Food and Agricultural Organization. Rome, Italy

Fewtrell L, Kay D (2008) Health impact assessment for sustainable water management. IWA Publ, London

Fleming N (2008) Understanding 'what's really going on' as a basis for transforming thinking, action and our cities. Paper presented at Enviro 08 Australasia's Environmental & Sustainability Conference & Exhibition, Melbourne, Australia

Forum for the future (2010) The sustainable cities index. Ranking the 20 largest British cities. http://www.forumforthefuture.org/files/Sustainable_Cities_Index_2010_FINAL_15-10-10.pdf. Accessed 20 February 2011

Frijns J, Hofman J, van Wezel A (2009) Water as energy carrier: climate mitigation and renewable energy options in the water sector. Proceedings IWA Water & Energy Conference, Copenhagen, Denmark

Global city indicators facility (2008) Global City Indicators Program Report. Preliminary report. http://www.cityindicators.org/Deliverables/Final%20Indicators%20Report%203_21_08_4-23-2008-924597.pdf. Accessed 20 February 2011

Godden L, Ison RL, Wallis PJ (2011) Water governance in a climate change world: appraising systemic and adaptive effectiveness. Water Resour Manage 25:3971–3976

Goudie D (2009) The emergent science of engineering and sustainable urban environment. Water Air Soil Pollut 9:469–484

Hegger DLT, Spaargaren G, van Vliet BJM, Frijns J (2011) Consumer-inclusive innovation strategies for Dutch water supply sector: opportunities for more sustainable products and services. NJAS-Wageningen J Life Sci 58:49–56

Hein L, van Koppen C, de Groot RS, van Ierland EC (2006) Spatial scales, stakeholders and the valuation of ecosystem services. Ecol Econ 57:209–228

Hoekstra AY, Chapagain AK (2007) Water footprints of nations: water use by people as a function of their consumption. Water Resour Manage 21:35–48

Hoekstra AY, Chapagain AK, Aldaya MM, Mekonnen, MM (2009) The Water Footprint Manual. Setting the Global Standard, 2009. Water Footprint Network, Enschede, The Netherlands

Ishaku HT, Majid MR, Johar F (2011) Rainwater harvesting: an alternative to safe water supply in Nigerian rural communities. Water Resour Manage. doi:10.1007/s11269-011-9918-7

Ison R, Collins K, Colvin J, Jiggins J, Roggero PP, Seddaiu G, Steyaert P, Toderi M, Zanolla C (2011) Sustainable catchment managing in a climate changing world: new integrative modalities for connecting policy maker, scientists and other stakeholders. Water Resour Manage 25:3977–3992

IUCN, UNEP and WWF (1991) Caring for the Earth. A Strategy for Sustainable Living, 1991. http://coombs.anu.edu.au/~vern/caring/caring.html, Accessed 20 February 2011

Jenerette GD, Larsen L (2006) A global perspective on changing sustainable urban water supplies. Global Planet Change 50:202–211

Kane M, Erickson JD (2007) Urban metabolism and payment for ecosystem services: history and policy analysis of the New York city water supply. Ecol Econ 7:307–328

Kennedy CA, Cuddihy J, Engel-Yan J (2007) The changing metabolism of cities. J Ind Ecol 11:43–59

Klauer B, Rode M, Schiller J, Franko U, Mewes M (2011) Decision support for the selection of measures according to the requirements of the EU Water Framework Directive. Water Resour Manage. doi:10.1007/s11269-011-9944-5

KPMG (2010) Sustainable Insight. Accounting for Water. http://www.kpmg.com/Global/en/IssuesAndInsights/ArticlesPublications/sustainable-insight/Documents/sustainable-insights-oct-2010.pdf, Accessed 20 February 2011

Lafortezza R, Carrus G, Sanesi G, Davies C (2009) Benefits and well-being perceived by people visiting green spaces in periods of heat stress. Urban Forestry Urban Greening 8:97–108

Liu S, Costanza R, Farber S, Troy A (2010) Valuing ecosystem services. Theory, practice, and the need for a transdisciplinary synthesis. Ann NY Acad Sci 1185:54–78

Millennium Ecosystem Assessment (2005a) Ecosystems and human well-being: synthesis. Island Press, Washington

Millennium Ecosystem Assessment (2005b) Ecosystems and human well-being: wetlands and water synthesis. World Resources Institute, Washington

Minx J, Creutzig F, Medinger V, Ziegler T, Owen A, Baiocchi G (2010) Developing a pragmatic approach to assess urban metabolism in Europe. Report to the European Environment Agency. Stockholm Environment Institute, Stockholm, Sweden

Morrison J, Schulte P, Schenck R (2010) Corporate water accounting. UNEP & The CEO Water Mandate. Oakland, USA http://www.unep.fr/shared/publications/pdf/WEBx0164xPA-CorporateWaterAccounting.pdf, Accessed 20 February 2011

Nederlof MM, Frijns J, Groenedijk M (2010) Cradle to cradle drinking water production: sense or nonsense? Proceedings IWA Water &Energy Conference, Amsterdam

Notovny V (2010) Footprint tools for cities of the future: moving towards sustainable urban water use. Water 21(8):14–16

Philip R, Anton B, van der Steen P (2011) SWITCH training kit. Integrated urban water management in the city of the future. Module 1. Strategic planning, ICLEI, Freiburg, Germany

RIONED (2010) Factual information on sewage systems in the Netherlands 2009–2010. Stichting Rioned, Ede, The Netherlands. http://www.riool.net/riool/binary/retrieveFile?instanceid=20&itemid=61&style=default. Accessed 20 February 2011 (in Dutch)

Siemens (2011) Website green city index. http://www.siemens.com/entry/cc/en/greencityindex.htm Accessed 21 December 2012

Sterk G (2008) Microbial risk assessment for pluvial urban flooding. Dissertation, Technical University, Delft, the Netherlands

Sustainable Society Foundation (2010) The Sustainable Society Index 2010. The Hague, The Netherlands

TEEB (2009) The Economics of Ecosystems and Biodiversity for National and International Policy Makers – Summary: Responding to the Value of Nature. Geneva, Switzerland http://www.teebweb.org/LinkClick.aspx?fileticket=I4Y2nqqIiCg%3D. Accessed 20 February 2011

TEEB (2010) The Economics of Ecosystems and Biodiversity: Mainstreaming the Economics of Nature: A synthesis of the approach, conclusions and recommendations of TEEB. Geneva, Switzerland

Traas TP, Van Leeuwen CJ (2007) Ecotoxicological aspects. In: Van Leeuwen CJ, Vermeire TG (eds) Risk assessment of chemicals. An introduction, 2nd edn. Springer, Dordrecht, pp 281–356

Tredoux G, King P, Cave L (1999) Managing urban wastewater for maximising water resource utilisation. Water Sci Technol 39:353–356

UN (1987) Our Common Future. World Commission on Environment and Development. New York UN (2007) Indicators of sustainable development: Guidelines and methodologies, third edition, New York

UN (2008) World Urbanization Prospects: The 2007 Revision Population Database. New York http://esa.un.org/unup/. Accessed 20 February 2011

UN (2010) The Millennium Development Goals Report. New York

UNEP (2007) Fourth Global Environment Outlook: Environment for Development. Geneva, Switzerland

UNEP (2008) Every drop counts; environmentally sound technologies for urban and domestic water use efficiency. Geneva, Switzerland

Van Cauwenbergh N, Biala K, Bielders C, Brouckaert V, Franchois L, Garcia Cidad V, Hermy M, Mathijs E, Muys B, Reijnders J (2007) SAFE – a hierarchical framework for assessing the sustainability of agricultural systems. Agric Ecosyst Environ 120:229–242

Van de Kerk G, Manuel AR (2008) A comprehensive index for a sustainable society: the SSI-the Sustainable Society Index. Ecol Econ 66:228–242

Van der Poel P, Brooke D, Van Leeuwen CJ (2007) Emissions of chemicals. In: Van Leeuwen CJ, Vermeire TG (eds) Risk assessment of chemicals. An introduction, 2nd edn. Springer, Dordrecht, pp 37–72

Van der Steen P. (2011) Application of sustainability indicators within the framework of strategic planning for integrated urban water management. Sustainable Water Management in the City of the Future. UNESCO-IHE, Delft, The Netherlands

Van Engelen JGM, Hakkinen PJ, Money C, Rikken MGJ, Vermeire TG (2007) Human exposure assessment. In: Van Leeuwen CJ, Vermeire TG (eds) Risk assessment of chemicals. An introduction, 2nd edn. Springer, Dordrecht, pp 195–226

Van Leeuwen CJ (2007) Introduction. In: Van Leeuwen CJ, Vermeire TG (eds) Risk assessment of chemicals. An introduction, 2nd edn. Springer, Dordrecht, pp 1–36

Van Leeuwen CJ, Frijns J, Van Wezel A, Van De Ven, FHM (2011) Twenty-four indicators to asses the sustainability of the urban water cycle. H_2O 13:35–38 (in Dutch)

Van Oel PR, Mekonnen MM, Hoekstra AY (2009) The external water footprint of the Netherlands: geographically-explicit quantification and impact assessment. Ecol Econ 69(1):82–92

Van Pelt S, Swart RJ (2011) Climate change risk management in transnational River basins: the Rhine. Water Resour Manage 25:3837–3861

Verstraete W, Van de Caveye P, Diamantis V (2009) Maximum use of resources in domestic “used water”. Resource Technol 100:5537–5545

Vinjé J, Altena SA, Koopmans MPG (2007) The incidence and genetic variability of small round-structured viruses in outbreaks of gastroenteritis in The Netherlands. Infectious Diseases 176(5):1374–1378

VROM (1992) The implementation challenge. Managing environment development trade-offs. Ministry of the Environment (VROM), The Hague, The Netherlands

2030 Water Resources Group (2009) Charting our water future. Economic framework to inform decision-making. West Perth, USA. http://www.mckinsey.com/App_Media/Reports/Water/Charting_Our_Water_Future_Full_Report_001.pdf. Accessed 20 February 2011