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Assessment of the urban water cycle in Antwerp (BE): The City Blueprint Approach (CBA)

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ABSTRACT

The City Blueprint Approach (CBA) is applied to assess the urban water cycle and sustainability in Antwerp, Belgium. Using two complementary frameworks. The Trends and Pressures Framework (TPF) assesses the city's main social, environmental, financial and governmental challenges based on 18 indicators. The City Blueprint (performance) Framework (CBF) deals with the adequacy of the city's water management, based on 24 mostly-quantitative indicators. The Blue City Index is the geometric mean of the performance-based indicators in the CBF. Our analysis of the TPF identified five major indicators reflecting *concern* for the urban water cycle of Antwerp: *Water Scarcity, Flood Risk, Water Quality, Air Quality (all environmental concerns) and the Unemployment Rate*. Antwerp experiences periodic flooding accentuated by sea level rise. Water abstraction rates compared to available water resources reflects water scarcity of ~33%. The fraction of surface water bodies not achieving 'good' ecological status exceeds 90% due to hydromorphological modifications, diminished ecological functioning, and chemical contaminants. Mean air quality in the city exceeds air quality standards several days per year. The CBF framework identifies 4 indicators reflecting 'poor' performance for the urban water cycle of Antwerp: *GW quality, stormwater separation (CSOs), age of the sewer system and quantity of green space.* Less than 25% of the groundwater bodies are of good chemical and/or quantitative status in the Scheldt river basin. The city currently has only limited stormwater separation sewers; separating CSOs is costly. The average age of the sewer system in Flanders is between 25 and 49 years, 66 years old in Antwerp. Sewers are replaced after ~75 years of service, making water infrastructure a main area of concern. Antwerp's green space (~17%) is being expanded promoting cooling in warm periods, improves social cohesion and well-being of citizens, and reduces the risk of urban flooding. Having a Blue City Index of 6.2/10, Antwerp ranks amongst the top 20 cities performances (>70 cities). The CBA identifies pressures acting upon the city and its performance on water sustainability in Antwerp. Analyzing the CBF creates opportunities in enhancing water sustainable development.

1. Introduction

The growth in the extent and population of cities worldwide has increased substantially during the 21st Century (Baptista et al., 2018). By 2050, 87% of the global population is predicted to live in urban areas leading to major challenges in sustainable water management. The rate of urban growth rate is >2% per annum evaluated for 1998–2015 (UN-Habitat, 2016). Climate change combined with urban growth will challenge the availability and safe-guarding of water quality. Sea level rise in combination with more intense and frequent flooding events form a threat to environment, biodiversity and human health and economy.

Progress has been made in tackling urban water challenges within Europe. Significant progress has been made in access to clean drinking water and treatment of wastewater from households and industries

Abbreviations: SDG, Sustainable development Goals; WFD, Water Framework Directive; GW, Groundwater; RBMP, River Basin Management Plan; WWT, Wastewater Treatment; WaSH, Water Sanitation and Hygiene; EC, European Commission; UNESCO, United Nations Edicational, Scientific, and Cultural Organization; IHP, International Hydrological Program; IWA, International Water Association; EEA, European Environment Agency; VMM, Flemish Environmental Agency (Vlaamse Millieumaatchappi).

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(Baptista et al., 2018). Between 2010 and 2015 over 1 million people gained access to basic sanitation facilities (WHO Europe, 2019). Within the European Region, regional differences exist in urban waste water treatment (EEA, 2017). In the northern EU countries over 80% of the population are connected to waste water treatment plants of which 70% are tertiary facilities since 1995. For Central Europe (including BE) the connection rate is >97% of which 75% encompasses tertiary treatment. Connection rates have increased over the last decade to 70% in southern and eastern EU (EEA, 2017). The percentage of the population connected to urban waste water treatment ranges from 30 to 99% in Southern Europe. In Eastern Europe the connection rate to urban waste water treatment ranges from 70 to 85%. South-Eastern European countries have connection rate between 48 and 87% (EEA, 2017). Further expansion of municipal wastewater treatment continues to advance within the EU and especially for N and P removal (EEA, 2018).

Substantial quantities of wastewater are discharged into EU rivers following treatment. Wastewater reclamation and reuse is one method to sustain water resources and is a priority of the EU (Triollet et al., 2018; EEA, 2018). Currently 1 billion m^3 of treated urban waste water is reused annually in the EU, but corresponds to only 2.4% of treated urban wastewater effluent, and less than 0.5% of the annual EU freshwater withdrawals (EEA, 2018). Properly treated wastewater is most used for agricultural irrigation and artificial groundwater recharge (Drewes et al., 2017). Since 36% of water use in Europe is attributed to agricultural irrigation and more than 70% of water abstractions go to agriculture, water reuse can enhance water sustainability (Drewes et al., 2017). The future challenge for wastewater reuse is to convince society that reclaimed and reused wastewater is environmentally safe and does not endanger human health and not compromising local groundwater, surface water or soil qualities (Drewes et al., 2017).

1.1. Belgium

Th main challenges for Belgium in implementation of EU environmental policies are improving air quality, reducing water pollution derived from urban wastewater and agricultural sources, and managing the Natura2000 network towards a favorable conservation status (European Commission, 2019). To tackle these issues effective coordination across policies (surface and ground waters, climate change, agriculture) is needed within a system of multi-level governance. Between 2017 and 2019 progress was made in reducing emissions impacting air quality but city-wide air quality still exceeds limit values due to intensive road traffic. Progress has also been made in the water quality sector where now all agglomerations comply with the Urban Wastewater Treatment Directive (European Commission, 2019).

1.2. Urban water cycle

Integrated Water Resources Management (IWRM) is a major focus since impacts on the environment and health are recognized by the UN, EC and UNESCO. The latter addressed the role of water in urban areas and the effects of urbanization on the urban hydrological cycle in the International Hydrological Program (IHP) (Marsalek et al., 2006; Makarigakis and Jimenez-Cisneros, 2019). An integrated approach to water management is needed for complete understanding of the urban water cycle its components and anthropogenic impacts.

The analysis of urban water management provides unifying concepts for addressing climatic, hydrologic, land use, engineering and ecological issues in urban areas (Marsalek et al., 2006). The hydrologic cycle describes inputs, storage/transformations and circulation of water between biosphere, atmosphere, lithosphere and hydrosphere. The hydrologic cycle is modified by urbanization, industrialization and population growth, leading to a more complex urban environment. The urban water cycle provides a conceptual basis for studying water balances, and performance essential to integrated water resources management. The main sources of water are precipitation, flowing streams and municipal water supply. The water for DW is often imported from outside the urban area or catchment, and reflects local water demands and their management, including water from rivers and lakes and withdrawals from aquifers (Marsalek et al., 2006). In Flanders 29.9 million m^3 drinking water was imported in 2015, mostly coming from the Walloon region, France and The Netherlands (Vlaamse Milieumaatschappij, 2017b). Municipal water flows through different pathways leading to internal transformations, distribution of various uses and loss due to leakage and seepage (Marsalek et al., 2006). Precipitation is subject to hydrologic abstractions such as interception, infiltration and depression storages. The wastewater is collected and treated before being discharged into the rivers or used as water for aquifer recharge and irrigation.

1.3. Research objectives

The city of Antwerp is the 2nd largest Belgian city with 520,504 inhabitants (2017). Water resources in Antwerp are subjected to major pressures from social, economic, environmental and governmental activities.

The overall objective of this research is to assess the urban water cycle of Antwerp applying the City Blueprint Approach, assess how water resources are managed and propose sustainability improvements. This investigation leads to a baseline assessment of the urban water cycle in Antwerp. Specific objectives are to construct the calculational frameworks for indicator development applying the most credible 'local' data sources to construct the (TPF) Trends and Pressures Framework (18 indicators) including a new environmental indicator "Air Quality Index" for Antwerp, to construct the (CBF) City Blueprint performance Framework for Antwerp for indicator development, to analyze the indicators from TPF and CBF and assess the urban water cycle in Antwerp for water sustainability.

Since Europe's water management occurs at the river basin scale, this study places Antwerp in the context of the Scheldt River Basin. The CBA consists of three complementary frameworks related to pressures and trends acting upon the city, water resources management (performance) and governance. The City Blueprint approach will result in increased understanding of IWRM of Antwerp (Koop and Van Leeuwen, 2015). To obtain a credible assessment of Antwerp's urban water cycle, the most credible 'local' data are used when available; otherwise, river basin, regional and/or national data support indicator scores. A new indicator, 'Air Quality Index', is introduced as a significant pressure within urban management and governance.

City Blueprints have been completed for more than 70 cities worldwide (https://www.watershare.eu/tool/city-blueprint) through 2019. Recently, the CBA has been successfully applied to 32 major Chinese cities to assess the efficiency, effectiveness and capability of IRBM (Chang et. Al., 2020). The CBA makes possible the inter-comparison of cities' performance as a component of IWRM and the City Blueprint of Antwerp will be compared with other cities worldwide.

1.4. Water resources management in the Scheldt river basin

The Flanders region of Belgium consists of two main river basins: The Scheldt River Basin and the Meuse River Basin. The RBMPs contain ground and surface water characteristics, land use, hydrologic budget, abstractions, measures taken, and socio-economic, political and environmental conditions and flood risk management in the region. (Coördinatiecommissie Integraal Waterbeleid, 2016).

Pressures acting upon the water resources of Flanders are abstraction for drinking water production, agricultural irrigation and industrial cooling. Pressures on groundwater systems are mainly due to abstraction for agricultural activities and drinking water production (Coördinatiecommissie Integraal Waterbeleid, 2016). Sea level rise attributed to a warming climate increases pressure on coastal areas and nearby rivers exposing people and ecosystems to a higher flood risk (Willems, 2015). Over 220, 000 people within Flanders are exposed to floods with a return period of 1000 years and 11,000 people reside in the high flood probability area (Coördinatiecommissie Integraal Waterbeleid, 2016).

Water pricing in Flanders is based on the principle of full cost recovery (Coördinatiecommissie Integraal Waterbeleid, 2016). This implies that the costs for wastewater treatment, public drinking water production and distribution, and infrastructure investment are fully charged to its users. This imposes a system with respect to equality and fairness where every user pays a fair amount in the form of a tax (Coördinatiecommissie Integraal Waterbeleid, 2016). Major users and polluters of water are obligated to contribute more than minor users (EEA, 2013). This implies not all operation costs are recovered directly, but the complete set of costs is totally recovered through general taxation (Coördinatiecommissie Integraal Waterbeleid, 2016).

Governance and multilateral coordination of the Scheldt River is accomplished by members of the Scheldt Treaty 2002, an ensemble of institutions regarding the implementation of the WFD for the Scheldt river basin district in France, Federal State of Belgium and the Netherlands and three Belgian regions of Wallonia, Brussels Capital Region and Flanders. Coordination of activities in the Scheldt RB occasionally encounter difficulties since several regional entities are involved (Coördinatiecommissie Integraal Waterbeleid, 2016).

The WFD has the overall objective for all Member States to achieve 'good' ecological and chemical status of water bodies by 2027 (1st target 2015). Pressures of high population density, dense networks of transportation, intense agricultural activities and expanding urbanization increases challenges on water resources in the Scheldt river basin. In previous decades surface waters received a wide range of substances leading to decrease surface water quality (Coördinatiecommissie Integraal Waterbeleid, 2016). Less than 60% of the surface waters in Flanders achieve 'good' chemical quality status (Coördinatiecommissie Integraal Waterbeleid, 2016). Of all water bodies, 58% are classified as heavily modified based largely on hydromorphological pressures. Thirty four out of 42 groundwater systems in Flanders attain good quantitative status and 9 out of 42 attain good chemical status leading to 8/42 groundwater systems achieving overall 'good status'.

2. Methods

2.1. City Blueprint approach (CBA)

The aim of the City Blueprint Approach (CBA) is to assess the sustainability of the urban water cycle developing quantitative indicators of efficiency and sustainability. Data to support indicator calculations are available on different spatial scales and from a variety of country, river basin and urban sources. The CBA is a diagnostic tool to assess the pressures and performance of the urban water cycle (Fig. 1). The CBA aims to enhance the transition towards water-wise cities by city-to-city learning and sharing best practices (Koop and Van Leeuwen, 2015). The CBA – Fig. 1 - consists of three complementary frameworks, dealing with trends and pressures on which urban IWRM has no or little influence and an IWRM performance framework (Koop and Van Leeuwen, 2015).

The introduction of six governance indicators of the World Bank (2016) in the Trends and Pressures Framework (TPF) allows for a broader assessment of the city's main social, environmental, financial and governance challenges (Table 2) and is based on a total of 24 (sub)indicators. The trends and pressures framework (TPF) permits setting of city priorities in the social, environmental, financial and governance categories of specific cities (Koop and Van Leeuwen, 2015). The TPF provides the context in which water managers may gain insights on limitations and windows of opportunity for IWRM.

The City Blueprint (Performance) Framework deals with the adequacy of the city's water management assessing 7 categories subdivided into 24 indicators as provided in the results and discussion section (Table 3). Each indicator is scored ranging from 0 (poor performance) to 10 (good performance) and displayed in a spider web diagram. The CBF is now based on 24 indicators divided over seven main categories: (i) basic water services, (ii) water quality, (iii) wastewater treatment, (iv) water infrastructure, (v) solid waste (vi) climate adaptation and (vii) plans and actions.

In some cases, only national data are available to calculate the indicator score. To assess the urban water cycle in Antwerp in a rigorous way, we utilized the most credible 'local' data sources (see Supplementary Material). The CBA makes use of publicly available data available on a national scale, making the City Blueprint less city-specific (Koop and Van Leeuwen, 2015). Water resources management in Flanders (Belgium) occurs on the river basin level and Antwerp is imbedded in the Scheldt River Basin. Upstream activities from different sectors influence the status and behavior of the water bodies and activities downstream. Therefore, an assessment of the Scheldt river basin and Antwerp within its boundaries is needed to capture a complete picture of Antwerp's IWRM. The indicators of the TPF and CBF are derived from a defined framework (see Supplementary Material). Indicators of the TPF vary from 0 to 10, reflecting 'no concern' and 'great concern', respectively. In the CBF the score of 0 reflects 'poor performance' in IWRM and a score of 10 reflects 'best' performance.

Detailed information for the calculation of all indicators (see Supplementary Material) include: Indicator identity, definition, method of calculation on normalized scale of 0–10, sources of data supporting indicator development, the indicator score on a scale of 0–10, and the

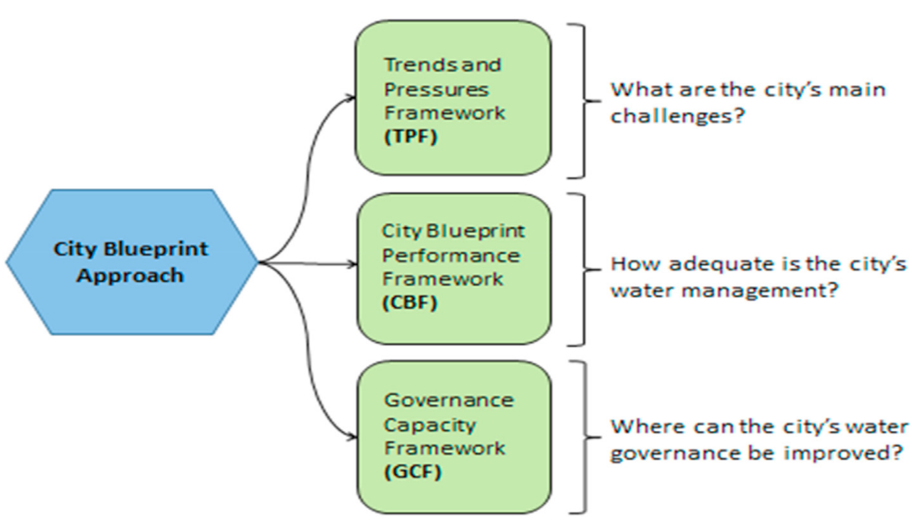

Fig. 1. The City Blueprint Approach divided in its three complementary frameworks (https://www.watershare.eu/tool/city-blueprint/).

'degree of concern'. The geometric mean of the CBF indicators provide the Blue City Index. The scores of all indicators are provided in spider diagrams to present a 'global' view. After completion of the TPF and CBF, additional analysis is provided on specific indicators reflecting 'a degree of concern'.

2.2. Site characterization

Antwerp lies within the Scheldt River Basin crossing three national borders. The Scheldt river flows from France through Belgium and discharges to the North Sea via the Netherlands (Fig. 2). The river length is 350 km of which half lies within Flanders territory (Coördinatiecommissie Integraal Waterbeleid, 2016). The area of the Scheldt river basin is 36 500 km^2, of which 12 026 km^2 is within Flanders (Coördinatiecommissie Integraal Waterbeleid, 2016). The land in the Scheldt river basin is flat and low stream velocities are typical (Coördinatiecommissie Integraal Waterbeleid, 2016). The area is densely populated and strongly urbanized with a dense network of transportation routes (Coördinatiecommissie Integraal Waterbeleid, 2016). Industrial sites such as the Port of Antwerp act as a major user and polluter of (water) resources (Coördinatiecommissie Integraal Waterbeleid, 2016). Almost half of the river basin is used for intensive agriculture, using pesticides and fertilizers which impact ground and surface water bodies. Widespread connected green areas are scarce (Coördinatiecommissie Integraal Waterbeleid, 2016).

The city of Antwerp had 520,504 legal inhabitants in 2017 representing an increase of 13.7% compared with 2005, and growing faster than other cities in the Flemish Region (Statistiek Vlaanderen, 2018). The city of Antwerp has a population density of 2582 persons/km^2 (Statistiek Vlaanderen, 2018).

The climate in Antwerp (Belgium) is temperate maritime with cool summers and moderate winters, classified as Cfb in the Köppen-Geiger climate classification (Climate-Data.org, 2019). Average precipitation in Antwerp is 778 mm and average temperature is ~10 °C (Climate-Data.org, 2019). July is the hottest month and January being the coldest with average temperatures of 17.4 °C and 2.4 °C, respectively (Climate-Data.org, 2019). Precipitation is distributed over all months (Climate-Data.org, 2019).

2.3. Data sources

The CBA makes use of credible publicly available data at the most 'local' scale (Koop and Van Leeuwen, 2015). Previous City Blueprints utilize data on national scale (Koop and Van Leeuwen, 2015). In this study we used the best local data sources to make the TPF more robust and rigorous. A full description of the data sources used and indicator calculation can be found under the section "SuppMat I: Trends and Pressures Framework". For the CBF indicators, national data sources are also used and contrasted to 'locally available data. A trade-off is made between identifying mostly national sources of information and applying the most appropriate data needed to achieve a city-specific assessment of the urban water cycle. As a result, data were sought from the Scheldt RBMP (Coördinatiecommissie Integraal Waterbeleid, 2016), Flanders-specific sources and Antwerp-specific sources (e.g., VMM, Aquafin, Water-Link).

3. Results and discussion

3.1. Trends and pressures framework of Antwerp (TPF)

The TPF of Antwerp describes the major pressures acting upon the city, identifies limitations and opportunities for urban water management and describes potential priorities for policy makers in urban planning. The trends and pressures within the TPF cover social, financial, environmental and governmental aspects of the city. These four major categories are subdivided into 24 standardized indicators and sub-indicators as displayed in Table 1, modified after Koop and Van Leeuwen (2015).

The Air Quality Index is a new indicator in the TPF given its relevance as a major environmental and health pressure in European cities, as well as a governance indicator of the World Bank (2016). The calculated indicator score and the degree of concern for the TPF are also given in Table 1. The indicator scores are noted in Table 2 to simplify the presentation of the CBA-TPF, are discussed in detail below, and an example calculation is given here.

3.1.1. Biodiversity

Principal: Measure of the biodiversity of aquatic ecosystems in the city. A low indicator score is given where biodiversity is good.

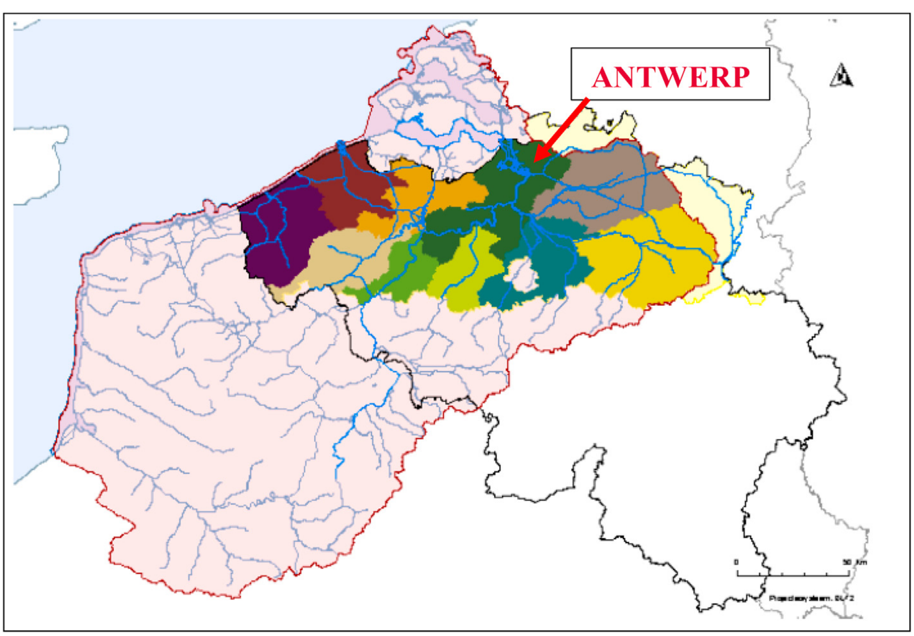

Fig. 2. The Scheldt river basin with Antwerp located in Flanders territory (Coördinatiecommissie Integraal Waterbeleid, 2016). Dark black line: Belgian territory; colored areas: sub basins of the Scheldt river basin.

Table 1
The modified Trends and Pressures Framework, indicators and sub-indicators, indicator scores and the results for the city of Antwerp. Scores range from 0 (no concern) to 10 (great concern).

Category	Indicators		Indicator score	Degree of concern
SOCIAL	Urbanization rate		2.9	Little concern
	Burden of disease		2	No concern
	Education rate		3.9	Little concern
ENVIRONMENTAL	Water scarcity	Fresh water scarcity	7	Concern
		Groundwater scarcity	2.5	Little concern
		Salinization and seawater intrusion	7.5	Concern
	Flood risk	Urban drainage flood	8.5	Great concern
		Sea level rise	0	No concern
		River peak discharges	10	Great concern
		Flood risk due to subsidence	5	Medium concern
	Water quality	Surface water quality	3.4	Little concern
		Biodiversity	10	Great concern
	Heat risk	Heat island	4.9	Medium concern
	Air Quality	YACAQI	6.6	Concern
FINANCIAL	Economic pressure		2.6	Little concern
	Unemployment rate		8.5	Great concern
	Poverty rate		0	No concern
	Inflation		3.8	Little concern
GOVERNANCE	Voice and accountability		0.5	No concern
	Political Stability		3.7	Little concern
	Government effectiveness		1.5	No concern
	Regulatory quality		1.3	No concern
	Rule of law		1.2	No concern
	Control of corruption		1	No concern

Table 2
Summary of Trends and Pressures Framework indicators of concern or great concern for Antwerp.

Category	Indicators		Degree of concern
Environmental	Water scarcity	Fresh water scarcity	Concern
		Salinization and seawater intrusion	Concern
	Flood risk	Urban drainage flood	Great concern
		River peak discharges	Great concern
	Water Quality	Biodiversity	Great concern
	Air Quality	YACAQI	Concern
Financial	Unemployment rate		Great concern

Data were obtained from the EEA (2016) - http://www.eea.europa.eu/data-and-maps/figures/proportion-of-classified-surface-water/proportion-of-classified-surface-water/image_original.

Table 3
The City Blueprint Framework for the city of Antwerp - categories, indicators and scores.0 (low performance) to 10 (high performance).

Category	Indicator	Score
Basic water services	Access to drinking water	10
	Access to sanitation	9.9
	Drinking water quality	10
Water Quality	Secondary WWT	10
	Tertiary WWT	10
	Groundwater quality	2.1
Wastewater treatment	Nutrient recovery	10
	Energy recovery	10
	Sewage sludge recycling	6.4
	WWT energy efficiency	8
Water infrastructure	Stormwater separation	0.3
	Average age sewer	0
	Water system leakages	7.6
	Operation cost recovery	3.6
Solid waste	Solid waste collected	8.9
	Solid waste recycled	9.4
	solid waste energy recovered	8.8
Climate adaptation	Green space	0.6
	Climate adaptation	8
	Climate-robust buildings	8
Plans and actions	Management and action plans	8
	Water efficiency measures	10
	Drinking water consumption	10
	Attractiveness	10

Calculation method: The data from the EEA on 'percent of classified waters in less than good ecological status' was used as shown in this the high-resolution version available via the above link. In Flanders more than 90% of waters are of less than good ecological status or potential resulting in an indicator score of 10 (EU scale), and consequently of Great Concern (from Supplementary Material).

Grouping all (sub-)TPF indicators in major indicator categories (Fig. 3), provide a holistic view of the individual areas of concern. The indicator score for each of the major indicators are shown ranging from 0 (no concern) to 10 (great concern) and are depicted in Table 1: *Flood risk, Water Quality, Unemployment rate and Air Quality* are the four major indicators of **concern** or **great concern** to the city of Antwerp. Except for unemployment rate, these indicators all belong to the environmental category.

Fig. 4 shows the results presenting each indicator of the TPF separately (i.e., no lumping of sub-categories). This is done to assess how each sub-indicator contributes to the average indicator score. (Sub-) Indicators of concern or great concern are the following and represent the biggest pressures on the city of Antwerp: *fresh water scarcity, river peak discharges, urban drainage floods, salinization and seawater intrusion, biodiversity, air quality and unemployment rate*. These indicators are all part of the environmental dimension except for the financial indicator *unemployment rate*. Social (and most of the financial) and governmental aspects range from no concern up to medium concern.

Seven indicators result in scores reflecting **concern** or **great concern** (Table 2). All of these are environmental indicators of the TPF, except for the unemployment rate which is a financial indicator. These seven parameters further discussed below are: *'Fresh water scarcity', 'Salinization and seawater intrusion', 'Urban drainage flood', 'River peak discharges', 'Biodiversity', 'Air Quality' and 'Unemployment rate'*.

3.1.1.1. Fresh water scarcity. The freshwater scarcity indicator is defined as fresh surface and ground water resources abstracted as a percentage of the total renewable resources. For Belgium this percentage (2008–2012) is 32.8% yielding an indicator score of 7 meaning fresh water scarcity is of **concern**. Reducing losses within the distribution system, capturing water more efficiently, and water reclamation and reuse are major steps to be taken in Flanders (Coördinatiecommissie Integraal Waterbeleid, 2016). These measures increase water use efficiency and hopefully result in a decreased abstraction rates, reducing the pressure on surface and

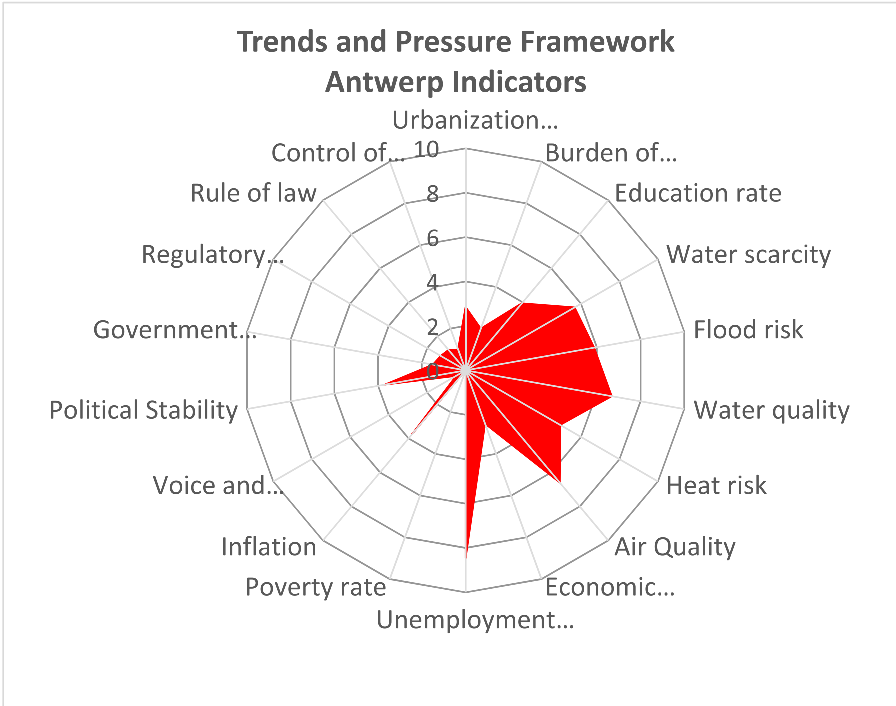

Fig. 3. Spider chart diagram of the Trends and Pressures Framework for Antwerp – indicator scores ranging from 0 (no concern) to 10 (great concern).

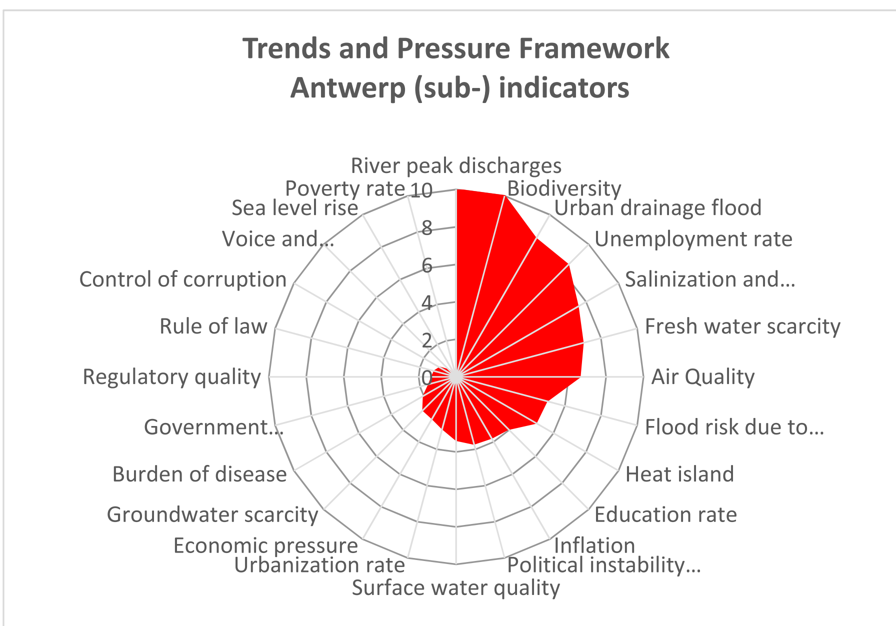

Fig. 4. Spider chart diagram of individual indicators of the Trends and Pressures Framework scored from 0 (no concern) to 10 (great concern).

groundwater bodies. Water use has decreased ~10% over the last ten years, lowering the demand side and possibly affecting the supply side similarly (Vlaamse Milieumaatschappij, 2017b).

3.1.1.2. Salinization and seawater intrusion. This indicator represents the vulnerability of a city to seawater intrusion and salinization of the soil and the score is estimated based on the Scheldt RBMP and 'Geopunt' data. The scoring is based on two separate indicators: 1. Seawater intrusion and 2. groundwater salinization. The highest of the two sub-indicator scores provide the overall indicator score. In this case seawater intrusion scores a 7.5 given that the coastal zones and docks of the Antwerp port are prone to seawater intrusion (Coördinatiecommissie Integraal Waterbeleid, 2016). In combination with tidal movement bringing salt water closer to the city, this indicator is reported as of **concern** to the city of Antwerp. Groundwater salinization receives a score of 5, being of medium concern to the city since it lies within the boundaries of an area with groundwater layers prone to natural salinization. No other specific information on groundwater salinization in Antwerp was found.

3.1.1.3. Urban drainage flood. The urban drainage flood indicator is fraction of the urban soil that is sealed, leading to a risk of flooding with intensive rainfall. In Antwerp, 64% (2017) of the urban area is sealed, leading to an indicator score of 8.5. Future plans for expanding green and blue space are promising. For example every citizen of Antwerp should in the near future live within 400 m of green space and reducing the soil sealing (Rooman, 2013). This conversion of the soil from sealed to green space will reduce the indicator score. Urban drainage flood is of **great concern** to the city of Antwerp.

3.1.1.4. River peak discharges. River peak discharges is a measure of the vulnerability of the city to flooding if sea level (or river peak) rises by 1 m. More than 95% of the city of Antwerp will be flooded if the Scheldt river level increases by 1 m and thus Antwerp falls within the highest category of **great concern**. This indicator covers only environmental conditions, and protection measures such as dams and dikes are not considered. As a response to this issue, the city has developed a masterplan currently being implemented to renovate the dikes and raising them to 9.25 m TAW (reference level Belgium) (Antwerpenmorgen.be, 2019).

3.1.1.5. Biodiversity. The biodiversity indicator for aquatic ecosystems is the percentage of waters with less than 'good' ecological status (EEA, 2016). For Flanders, ~90% of the waters are of less than 'good' ecological status or potential meaning biodiversity is of **great concern** to the city of Antwerp. This indicator score is not likely to improve in future perspectives since achieving good ecological status is based on the one-out-all-out principle (Coördinatiecommissie Integraal Waterbeleid, 2016). However actions are being taken to protect surface and groundwater quality; some threshold values will never be reached since 103 out of 177 registered water bodies are classified as heavily modified (Coördinatiecommissie Integraal Waterbeleid, 2016).

3.1.1.6. Air quality. The Air Quality Index (AQI) was introduced as a new indicator to the TPF since air pollution is now a focus in urban environmental management and a major pressure. The calculation is based on the YACAQI index developed by the European Regional Development Fund of the EU. Based on annual 24-h averages of core air quality parameters (NO_2, PM_{10}, $PM_{2.5}$, O_3, SO_2 and Benzene) the city of Antwerp scores 6.6 out of 10 meaning **concern** to the city of Antwerp. The data used for this indicator derive from the urban area only. Large differences may exist between the urban area of Antwerp and the port of Antwerp, where air pollution is even a bigger concern. Measuring air quality within the city itself is a recent evolution. Low-emission zones and car-free zones are implemented within the city to reduce the possible harm of air pollution to the citizens.

3.1.1.7. Unemployment rate. Unemployment rate is the only non-environmental parameter that is of concern or great concern to the city of Antwerp. This indicator is defined as the percentage of the total labor force without a job. In Flanders the average unemployment rate is 6.4% while the city of Antwerp exhibits an unemployment rate of 13.7%, which is the highest unemployment rate within Flanders municipalities. Unemployment rates in cities are often higher than rural areas. This results in an indicator score of 8.5 or **great concern** to the city of Antwerp (Statistiek Vlaanderen, 2018).

3.1.1.8. Heat island effect. The heat island indicator is based on two sub-indicators - the number of combined tropical nights (>20 °C) and hot days (>35 °C), and the percentage of green and blue area. The arithmetic mean of the two sub-indicator scores is taken as the overall score on heat island effects. The projected number of combined tropical nights and hot days in Belgium is 2, leading to a sub-indicator score of 0.4 or no concern. The percentage of green and blue urban area of Antwerp is 17.8% (2006) leading to a sub-indicator score of 9.44 or great concern. As a result, the overall indicator score for heat island is 4.92 indicating **little concern** to the city of Antwerp. Recent warmer than average day and night temperatures in BE suggest that this level of concern may increase.

In conclusion the main finding (Table 2) from the TPF is that environmental pressures (Water Scarcity, Flood Risk, Water Quality and Air Quality) are the biggest concerns to the city of Antwerp, while for the other categories only the Unemployment rate is of great concern.

3.2. Water management performance in Antwerp – City Blueprint framework (CBF)

The City Blueprint (Performance) Framework deals with the adequacy of the city's water management assessing 7 categories subdivided into 24 indicators as provided in the results and discussion section (Table 3). Each indicator is scored ranging from 0 (poor performance) to 10 (good performance) and displayed in a spider web diagram. The CBF is now based on 24 indicators divided over seven main categories: (i) basic water services, (ii) water quality, (iii) wastewater treatment, (iv) water infrastructure, (v) solid waste (vi) climate adaptation and (vii) plans and actions.

As for the TPF, an example calculation is given for Stormwater separation: Water infrastructure. Details of all indicator calculations are provided in Supplementary Material:

Stormwater separation: Water infrastructure:

Principal: A measure of the proportion of the wastewater system for which sanitary sewage and storm water flows are separated. In principal, a separate system is better than a combined system as extreme weather events may lead to sewer overflows into surface water. These sewer overflows are a major source of pollution. Also flooding vulnerability is larger if stormwater separation ratio is low. A lower Indicator score is given where the proportion of combined sewers is greater.

Data obtained from.

The total length of sewer system in Antwerp: (Water-Link, 2017b).

The Water-Link states that there is little stormwater separation in Antwerp's sewer system (Van Maercke and Rosso, 2015).

https://water-link-jaarverslag.be/#kerncijfers.

Calculation method.

A. Total length of combined sewers managed by the utility (km)
B. Total length of stormwater sewers managed by the utility (km)
C. Total length of sanitary sewers managed by the utility (km)

$$\text{Indicator score} = \frac{\boldsymbol{B}+\boldsymbol{C}}{\boldsymbol{A}+\boldsymbol{B}+\boldsymbol{C}} \times 10$$

Total length of sewers = 2500 km

Stormwater separation is rare in Antwerp and most of the sewers are combined (Van Maercke and Rosso, 2015). New sewer projects within the city boundaries are being checked whether stormwater separation could be implemented but with the extensive cost of these projects, has not often been put into practice. Therefore, the indicator score is assumed to be **0**, and of **Great Concern.**

Following the calculation of each indicator of the CBF (Table 4), a spider web diagram (Fig. 5) provides a holistic view on the city's water resources management.

Basic water services are adequately provided in Antwerp with most indicator scores close to 10. Water Quality indicators 'Secondary WWT'

Table 4
Summary table of CBF: main areas of concern.
Indicator scores range between 0 (poor performance) to 10 (good performance).

Category	Indicator	Score
Water Quality	Groundwater quality	2.1
Water infrastructure	Stormwater separation	0
	Average age sewer	2.2
Climate adaptation	Green space	0.6

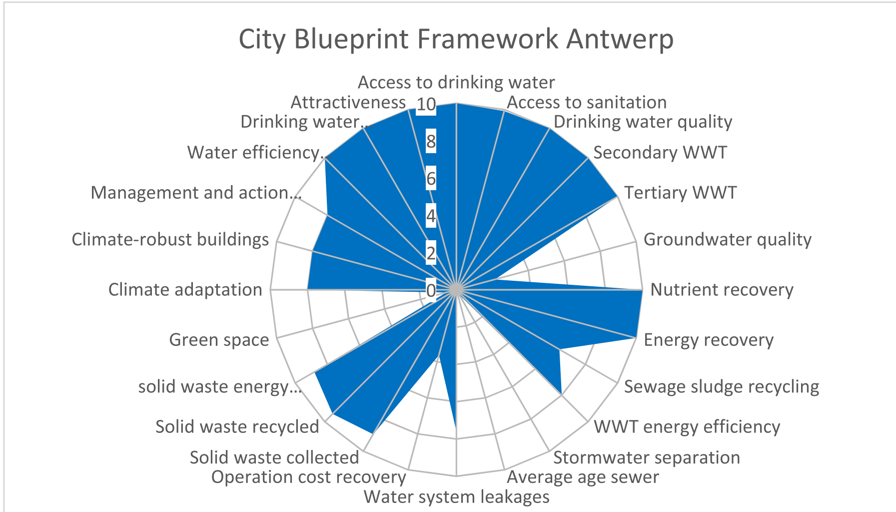

Fig. 5. City Blueprint of Antwerp based on 24 performance indicators. The range of scores varies from 0 (center of the circle; low performance) to 10 (periphery of the circle; high performance).

and 'Tertiary WWT' are of no concern to Antwerp because 100% of the city's waste water is equipped with secondary and tertiary treatment. 'Groundwater quality' is an indicator of main concern with an indicator score of 2.1, since only 9 out of 42 groundwater bodies attain 'good chemical status'. Wastewater treatment indicators 'Nutrient recovery' and 'Energy recovery' score positively, since all of Antwerp WWTP's are equipped with tertiary treatment and all sludge is used for biogas production. 'Sewage sludge recycling' scores are 6.4 for Antwerp and 4.6 for Belgium. This difference is due to the % of secondary WWT coverage - 100% for Antwerp and 72% for Belgium. 'WWT energy efficiency' scores 8 since energy efficiency in WWT facilities is reflected in the Scheldt RBMP and in local reports of Aquafin, with governmental subsidies available to implement strategy and action plans.

Flanders' water infrastructure (sewers) has an average age of 25–49 years old (66 years old in Antwerp) and nearly all sewer systems are combined (CSOs). No stormwater sewers distinct from CSO currently exist within the city of Antwerp and therefore the indicators 'Stormwater separation' and 'Average age sewer' yield indicator scores of 0.3 and 0, respectively. Antwerp's water distribution system loses ~12% of distributed water due to leakage, thus performing well on 'Water system leakage'. The 'Operation cost recovery' ratio from Water-Link was 1.05 in 2017. The small excess in annual operational revenues compared to annual operating costs making some funds available for investments in water services. Because this excess is small, the indicator score is 3.6.

Flanders is one of the top-ranking EU regions in handling solid waste. 194.8 kg/cap/year of solid waste is collected in Antwerp of which 65.6% is recycled and 30.3% is incinerated to recover energy, resulting in good performance on the solid waste indicators 'Solid waste collected', 'Solid waste recycled' and 'Solid waste energy recovery'.

Climate adaptation in cities is gaining needed attention and a necessity in RBMPs. Strategic plans to adapt to climate change and increase sustainable urban development are well described within official documents on RB scale, national, regional and city-level scale (Coördinatiecommissie Integraal Waterbeleid, 2016); Vlaamse Overheid, 2018); (District Antwerpen, 2019)). Subsidies to implement these plans are available. The indicator score for 'Climate adaptation' and 'Climate-robust buildings' is 8 reflecting good performance. Green space is a major area of concern as Antwerp has 17.8% green and blue area, resulting in an indicator score of 0.6 reflecting poor performance.

The recognition of the importance of governance is reflected in plans and actions. For the Scheldt RB multiple management and action plans are provided in the Scheldt RBMP. Subsidies are available for their implementation but progress is not reported annually. Therefore 'management and action plans' score 8 for the CBF. The RBMP also consists of vision notes and action plans to improve water efficiency in the city. Regulations exist on different spatial scales and act as guidance towards transitioning to become more water efficient e.g. water saving measures in taps and other sanitary. Subsidies are available and annual reports on the progress exist, already being in place for at least three years. Therefore 'water efficiency measures' scores 10. In Antwerp on average 40.26 m^3/cap/year of water is consumed, leading to an indicator score of 10 on 'Drinking water consumption', since it is lower than the previous minimum from Rotterdam (45.2 m^3/cap/year). Lastly the city recognizes the importance of proximity to the Scheldt River/Estuary for economic growth, tourism, social cohesion and recreation. Information is provided in annual progress reports on implementation of several action plans where water plays a dominating role in the well-being of citizens. Therefore 'Attractiveness' attains the score of 10.

3.2.1. *Basic water services*

Equal access to safe and affordable drinking water is a human right according to SDG6 'Clean water and sanitation' (SDGS.be, 2019). Human health must be safeguarded by providing water for which the quality complies with regulatory standards. In Europe and Belgium major investments have been made to improve the access to safe drinking water and sanitation (Coördinatiecommissie Integraal Waterbeleid, 2016).

All Belgians have access to safe drinking water (WHO and Unicef, 2013). In Antwerp >99% of the population have access to proper sanitation facilities (Vlaamse Overheid, 2019). Tap water in Flanders is consistently monitored and complies with strict quality standards (Vlaamse Milieumaatschappij, 2017b). In Flanders ~99.6% of the samples (N = 10.499) of DW conformed with the norms (Vlaamse Milieumaatschappij, 2017b). The city of Antwerp provides basic water services and high quality DW to its inhabitants and aims to further optimizing these services.

3.2.2. *Water quality*

Without connection to proper wastewater treatment facilities conventional pollutants enter (surface) water bodies, reducing water quality and impacting ecosystem health (Coördinatiecommissie Integraal Waterbeleid, 2016). Access to WWT in Flanders has increased substantially in recent decades (Coördinatiecommissie Integraal Waterbeleid, 2016). The connection to WWT has increased from 30% in 1990 to 52% in 2000, to 79% in 2012. Additional projects are planned to increase this rate in the future (Coördinatiecommissie Integraal Waterbeleid, 2016). In Antwerp all wastewater treatment facilities offer secondary and tertiary WWT (European Commission, 2017a). Groundwaters in the Scheldt RB experience high abstraction rates for irrigation, drinking water production and commerce. Groundwater quality is impacted by adding nutrients and polluting substances into the system via runoff and infiltration (Coördinatiecommissie Integraal Waterbeleid, 2016). Out of 42 groundwater bodies within the Scheldt RB, 9 attain 'good' chemical status (Coördinatiecommissie Integraal Waterbeleid, 2016). This groundwater quality issue is recognized by the authorities and regulations are in place to improve the current status (Coördinatiecommissie Integraal Waterbeleid, 2016). Based on the one-out-all-out principle and the intensity of agriculture, improvement of groundwater quality 'status' remains a major challenge.

3.2.3. Wastewater treatment

Requirements for the collection and treatment of urban wastewater have been set in the Urban Waste Water Treatment Directive (UWWTD) to protect the environment from adverse effects of wastewater discharges (European Commission, 2017b). The ambition to meet these requirements remain challenging since proper governance, investments and adequate competences are needed (European Commission, 2017b). Tourism, depletion of key resources, changing socio-economic situations and increased societal demands for 'cleaner' waters increase pressures to safeguard the environment though wastewater treatment (European Commission, 2017b). The four major WWTP's in Antwerp provide tertiary treatment to incoming wastewater, removing nutrients and producing sludge, which is digested and used to generate biogas (European Commission, 2017a). The generation of biomass to recover energy is mainly done to decrease the volume of the produced sludge. Costs of transporting and disposing sludge greatly outweighs the benefits from energy recovery. Reducing the volume of produced sludge and recovering energy is the most optimal treatment method given the circumstances in Antwerp. The WWTP's in Antwerp receive sludge from all over the province of Antwerp and the rest of Flanders making it difficult to describe what portion is generated by Antwerp itself.

Incoming wastewater also originates from surrounding municipalities. In total 163 000 t of dry sludge was generated in Belgium in 2014 of which >26 000 t was used as soil amendments in agriculture, and 78 000 t was incinerated (European Commission, 2017a). Several projects are ongoing to increase WWT energy efficiency in the future such as installing new blowers and mixers (Aquafin, 2019). Governmental subsidies are available for further implementation of these plans (Coördinatiecommissie Integraal Waterbeleid, 2016).

3.2.4. Water infrastructure

Most Belgian cities find their origins in Medieval times. During the 19th and 20th Century's the first water distribution and sewer systems were constructed (Van Maercke and Rosso, 2015) as CSOs. In the 20th Century environmental and human health concerns lead to slow transitions to better sanitation, wastewater collection and transport out of the city and first steps in cleaning waste water (Van Maercke and Rosso, 2015). At the end of the 20th Century and early 21st Century, additional segments of the population were connected to WWTP's, but the old infrastructure was still in place (Van Maercke and Rosso, 2015). Present water infrastructure in Flanders and Antwerp is 'outdated' and new sewers are on average being replaced after 50–75 years of service (Vlaamse Milieumaatschappij, 2018). Implementing stormwater separation is costly, since the current combined systems lie beneath Antwerp's buildings and roads. More attention is fixed today in preventing water leakage, currently 12.1% annually in Antwerp (Vlaamse Milieumaatschappij, 2017a). The operation cost recovery ratio is of major importance in evolving towards more efficient and sustainable water infrastructure, since the excess of revenues compared to the costs may lead to more investments. For Water-Link this ratio is 1.05, covering all the costs but not generating a significant excess of revenues to be invested (Water-Link, 2017).

3.2.5. Solid waste

Belgium is the top ranking EU country in recycling packaging waste at ~80% in 2011 (L'Hoost et al., 2014). The province of Antwerp is the 9th efficient region in Europe in waste recycling (L'Hoost et al., 2014). In Belgium citizens are obliged to sort their waste according to the type which is then separately collected and processed (OVAM, 2016). Raising awareness and governmental implementation of strict regulations for reducing waste production leads to the efficient performance of Antwerp in solid waste collection and recycling (OVAM, 2016). In Antwerp 65.6% of the solid waste is recycled and 30.3% is incinerated with energy recovery (OVAM, 2016).

3.2.6. Climate adaptation

Green space within cities offers many advantages to citizens, healthier ecological functioning, and enhanced social cohesion space is used for leisure and relaxation (Rooman, 2013). The importance of green space within the city of Antwerp is recognized and described in 'Groenplan Antwerpen' (Rooman, 2013); Antwerp contains 17.8% green and blue area (EEA, 2012). Strategy and action plans to improve green space within the city are being implemented (Rooman, 2013). New or renovation projects within the city may not reduce existing green area; urban designers and planners aim for increasing green space as in the 'Nieuw Zuid' project (District Antwerpen, 2019). Legal frameworks are constructed with measures for climate adaptation and increase sustainable development of the city (Stad Antwerpen, 2012). Applying green roofs and harvesting rainwater has been widely promoted within Flanders cities and society is willing to invest in sustainable development (Vlakwa, 2018). Action and strategy plans also exist in protecting citizens from natural hazards (Vlaamse Overheid, 2018).

3.2.7. Plans and actions

The Scheldt RBMP contains strategy and action plans which are executed by municipalities and regions in Flanders (Coördinatiecommissie Integraal Waterbeleid, 2016). Improving water efficiency is one of the main objectives in current urban IWRM (Vlaamse Overheid, 2019). The city of Antwerp invests in bringing its citizens in closer contact with the water ((District Antwerpen, 2019) (Rooman, 2013);). Guided tours on the Scheldt river, to museums next to the water with exhibitions related to water resources in the city and gentrification of the beach area next to Scheldt are currently being implemented by Antwerp. Antwerp increases awareness amongst its citizens as to water sustainability which is reflected in low drinking water consumption. In Antwerp the average drinking water consumption is 40.26 m^3/person/year, lower than the so far assessed minimum of Rotterdam (45.2 m^3/person/year) (Water-Link, 2018).

In conclusion, Antwerp performs in general well on IWRM; however, water infrastructure, green space and groundwater quality are the major areas of concern. Action and Management plans exist and are updated frequently to make a transition towards sustainable urban planning and design as well as towards a more water efficient environment. Belgium is one of the top-ranking EU countries in solid waste collection and recycling with Antwerp in the top 10 provinces in the EU. Table 4 shows the main areas of concern on IWRM performance in Antwerp; Groundwater quality, Stormwater separation, Average age sewers and green space.

3.2.7.1. Comparison of the blueprint city index of Antwerp with other cities. The Blue City Index is the geometric mean of the CBF indicator scores. For Antwerp a Blue City Index of 6.2 is obtained, placing it in the top 20 of the 70+mcities that have been assessed using the CBA.

Due to rapid urbanization, effects of climate change and population growth in cities worldwide, a transition towards 'water-wise' cities is necessary (IWA, 2016). This ambition encourages collaborative action with a shared vision by stakeholders and governments in finding solutions for sustainable water management (IWA, 2016). The CBA has been applied to over 70 cities worldwide, exposing strengths and weaknesses in urban IWRM performances. Combining the results from the City Blueprint and intercomparing the BCI may lead to sharing best practices among cities and collaboration in tackling IWRM issues.

The integrated overview of the management performances within the urban water cycle lead to the possibility of intercomparing cities (Van Leeuwen et al., 2017). The audience of concern is the multi-sectorial decision-makers of urban areas such as city planners, regional water authorities, municipalities, water utilities, and waste managers, as well as the key policy makers. Of over 70 cities assessed by the CBA, Amsterdam currently performs best with a BCI of 8.3 (Van Leeuwen and Sjerps, 2015). The strong performance on IWRM in Amsterdam – and the Netherlands-is the result of a strong focus on water governance. Amsterdam depicts commitments to sustainable solutions on all parts of the water cycle (e.g. water efficiency, reduction of leakage losses, sanitation and energy and nutrient recovery from wastewater) (Van Leeuwen and Sjerps, 2015). The same commitments are present in Antwerp's water governance and management practices. Leakage losses in Antwerp (~12%) are higher than in Amsterdam (~5%) but still acceptable by EU criteria, and water infrastructure is a main area of concern in Flanders (Van Leeuwen and Sjerps, 2015). The Flemish government has set clear objectives towards increasing water efficiency and implementing management plans (Coördinatiecommissie Integraal Waterbeleid, 2016).

Kortrijk is the other Belgian city assessed by the CBA (Vlakwa, 2017). Short- and long term management and action plans exist for Antwerp, while lacking for Kortrijk (Vlakwa, 2017). Water infrastructure for Kortrijk is similar to Antwerp, lacking stormwater separation and having old sewer systems (Vlakwa, 2017). Antwerp performs better in waste generation and collection, climate adaption and water efficiency measures compared to Kortrijk (Vlakwa, 2017). Kortrijk on the other hand has a higher percentage of green space, (Vlakwa, 2017). Comparing the city of Kortrijk with Antwerp is not straightforward, since the city of Kortrijk is much smaller, having a population of ~76.000 in 2017 or approximately 6 times less (Statistiek Vlaanderen, 2018). Different pressures act upon the two cities e.g. lower population growth in Kortrijk, more green space, longer distance from the sea and lower unemployment rate ((Vlakwa, 2017); (Statistiek Vlaanderen, 2018)).

A positive correlation is observed between the best performing cities (high BCI) and worse performing cities (low BCI) in terms of GDP per capita, ambitions of local authorities IWRM sustainability, voluntary participation and governance indicators (Van Leeuwen and Sjerps, 2015).

Cities performing well on these aspects correlate positively with the BCI, while cities experiencing high pressures tend to have a lower BCI (Van Leeuwen and Sjerps, 2015).

4. Conclusions

Water demand across Europe has steadily increased over the past 50 years, mostly due to population growth, agriculture and general economic progress leading to an overall decrease in renewable water resources per capita by 24% across Europe. The urban water cycle is increasingly under pressure from high rates of urbanization, climate change (availability, quantity, scarcity, floods), water abstractions, and waste generation and transport activities. In 2050, cities will host more than 80% of global population with associated challenges to urban water sustainability. In Belgium, ~98% of EU citizens reside in urban areas (2016) in contrast to 74% (2018) of the European population. Cities concentrate production, consumption, and waste disposal that drive land use change, pressure on water supplies and numerous health and environmental issues.

In this study, we apply the City Blueprint Approach (CBA) to assess the urban water cycle and water sustainability of the city of Antwerp, Belgium located in the Flanders region and the largest municipality of Belgium. The City Blueprint Approach is a diagnostic tool to assess the pressures and performance of the urban water cycle. The CBA consists of three complementary frameworks. The Trends and Pressures Framework (TPF) assesses the city's main social, environmental, financial and governmental *challenges* based on 18 indicators. The City Blueprint (Performance) Framework (CBF) deals with the adequacy of the city's water management, based on 24 mostly quantitative *indicators* divided over seven main categories.: (i) basic water services, (ii) water quality (iii) wastewater treatment (iv) water infrastructure, (v)solid waste (vi) climate adaptation and (vii) plans & actions. The Governance Capacity Framework (GCF) assesses where governance can be improved to sustain the urban water cycle (not addressed in this analysis). The Blue City Index is the average of the performance-based indicators in the CBF.

New in the application of the CBA is the study of the urban water cycle of Antwerp, the development of a new indicator based on air quality (AQI), use of the most 'local' data sources to support indicator development, and the placement of the urban water cycle of Antwerp in the context of the water resources management of the Scheldt River Basin.

Our analysis of the TPF identifies five major indicators reflecting degrees of concern from medium **concern** to **great concern** for the urban water cycle of Antwerp: Water Scarcity, Flood Risk, Water Quality, Air Quality (all environmental concerns) and the unemployment rate. The city of Antwerp suffers from periodic flooding accentuated by sea level rise. Water abstraction rates in the RB yield a water scarcity of ~33%. The fraction of surface water bodies not achieving 'good' status exceeds 90% due to hydro-morphological, ecological and hazardous chemical elements. Mean air quality within and without the city boundaries exceeds air quality standards (health) several days per year. The unemployment rate in Antwerp is 3x the Flanders/BE rate.

Our analysis of the City Blueprint (Performance) Framework identifies 4 indicators reflecting **poor performance** for the urban water cycle of Antwerp: GW quality, stormwater separation, age distribution of sewer system and quantity of green space in city. Less than 25% of the groundwater bodies are of good ecological status or potential, not likely to improve in the future based on classification criteria and the one-out-all-out principle. The city currently has only limited stormwater separation sewers and implementing it in new water infrastructure projects is very costly. The average age of the sewer system in Flanders lies between 25 and 49 years old, being 66 years old in Antwerp. Sewers are on average replaced after 75 years of service, making water infrastructure a main area of concern. With only ~17% of Antwerp's surface being green area, management plans have been created and are being implemented, since green space is recognized to have many benefits, e.g., cooling effects in warm periods, social cohesion and well-being of citizens.

With increasing pressures from urbanization, population growth and climate change, cities must make a transition towards becoming more water efficient. The City Blueprint Approach offers insights on pressures acting upon the city and the performance on the sustainability of IWRM in Antwerp. Analyzing the CBF creates opportunities to improve sustainable development. The focus on performance will enhance city-to-city learning if cities share best practices and knowledge amongst each other, as this is the ultimate goal of the EIP Water Action Group.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

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