CEST 2023

18th International Conference on Environmental Science and Technology

Athens, Greece, 30 August to 2 September 2023

Water-wise approaches for circular cities – lessons learned from Amsterdam.

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Abstract Under a constantly changing world, the environmental costs of increasing urbanization and associated water challenges, prioritized the circular economy on political agendas. Simultaneously, water-wise-cities initiatives, seeking sustainable and resilient communities, started to emerge. Synergies between these two concepts are, however, poorly explored in the literature. They can be influenced by legislation, stakeholders' perceptions and associated networks, among others. Driven by the work of the project *Water-wise Cities* from the International Water Association, this article builds a conceptual model merging the principles of circular cities and the principles of water-wise cities. This model is then applied in the case of Amsterdam, by assessing current circular economy strategies and related municipal policies to understand how cities are adopting circularity while becoming water-wise. The assessment used a brief content analysis of the current circular initiatives and how these can be part of a transition into a water-wise city. The developed conceptual model has proven to be able to identify the key areas where further intervention is needed to attain a circular and water wise city. The study displayed a water-wise community where many collaborative networks between public administration entities, entrepreneurs and citizens are in place, which create a robust potential for synergetic urban initiatives. Within the water sphere, their focus is mainly on flood risk management and resilient infrastructures, while lesser attention is given to circularity concerns. However, a few circular actions are identified in the water-sensitive design and the regenerative water approaches dimensions, such as the decentralization of wastewater treatment systems, the reuse and recovery of organic residues and the integration of water-sensitive nature-based solutions. Legislation and project upscaling constrains were identified as barriers hindering opportunities to mainstream circular solutions. Overall, there is still room for developments in the basin connected cities' dimension.

Keywords: circular city, conceptual model, policy, water-wise city

1. Introduction

Urban areas of the world are expected to absorb all the population growth over the next decades (Prendeville *et al*., 2018; Williams, 2021). Increasing urban development generates environmental, social and economic challenges, prioritising the establishment of political and social commitments towards the sustainable management of natural and non-renewable resources (e.g., water). This is supported by the Circular Economy (CE) model, which has gained momentum in the past decade, among scientists and practitioners, such as the Ellen MacArthur Foundation (Giezen., 2018). With CE on the top of worldwide political agendas, circular cities (CC) have started to emerge, approaching circularity as an instrument to reconfigure unsustainable urban features and better prepared them for upcoming climate challenges (Prendeville *et al*., 2018).

Water's shortage problems, uneven distribution, and seasonal variability are some of the major challenges faced by countries worldwide. These challenges call for water-wise solutions (e.g., water circularity approaches), as water resources are increasingly under pressure and its systems interconnect with all sections of society and industry (EMF & ARUP., 2018). More recently, new studies have been refocusing the initial product & waste-centric CE model, giving water a more central role (EMF & ARUP., 2018; Fidélis *et al*., 2021). In parallel, the International Water Association has been working towards the conceptual definition and robust framework of a water-wise city (WWC), providing a set of principles and building blocks to guide practitioners towards

successful transitions (IWA, 2015). This project already counts with the enrolling of several worldwide cities committed to this transition to become more water-wise, as is the case of the Dutch city of Amsterdam. As a pioneer in implementing circular systems, the city of Amsterdam aims at becoming 100% circular by the year of 2050 (Circle economy *et al*., 2018). Thereby, the city has been making considerable efforts to improve urban water management through a commitment in the CE and water-wise policy arena (Williams, 2021; Prendeville et al., 2018). Such commitments, concerning popular city concepts, require the use of complete definitions and an adequate integration of its goals and principles in roadmaps (Miranda *et al.*, 2022)

Effective transitions also demand robust and flexible frameworks for the evaluation of long-term performance of strategic interventions. As the application of circular principles into urban initiatives often fall short in adequately considering impacts on water resources (Miranda *et al*., 2022), this study builds a conceptual framework based on the principles of CC and the principles of WWC to understand how cities are adopting water-wise solutions while becoming circular. For that purpose, the city of Amsterdam is taken as a case study for the screening of urban initiatives. A better perception of the interconnections between these two conceptual frameworks and how these are being considered in the design of urban initiatives may work as a driver to the implementation of water-wise solutions in circular cities.

2. Conceptualizing a Circular city and a Water-wise city

With different focuses and complexity levels, several CE models and frameworks have been developed (Prendeville *et al*., 2018). Aiming to a more Circular European Economy, the RESOLVE framework, from EMF (2015), outlines definitions, principles and metrics for CE, focusing on mobility, food systems and built environment sectors. According to the work of the authors, CE is based on the following three principles: i) preserve natural capital by controlling finite stocks and balancing renewable resource flows; ii) optimise resource yields by always circulating products components and materials in use at the highest utility, in both technical and biological cycles and iii) design out negative externalities (EMF., 2015). These principles can be translated into six business actions, compiled in the RESOLVE framework – regenerate (e.g., shift to renewable energy and materials; regenerate the health of ecosystems), share (e.g., reuse and share products; improve design and durability), optimize (e.g., increase performance and efficiency of products; reduce waste), loop (e.g., keep materials in closed loops), virtualize (e.g., increase digitalisation of services) and exchange (e.g., application of new technologies) (EMF., 2015). Further exploratory studies (Prendeville et al., 2018) have used this framework to understand how cities are approaching CE as a strategy and towards a better conceptualization of CC. According to the authors, a CC 'is a city that practices CE principles to close resource loops, in partnership with the city's stakeholders (citizens, community, business and knowledge stakeholders), to realize its vision of a future-prof city' (Prendeville et al., 2018, p.187). Furthermore, Williams (2021) explores the concept and features of CCs through the process of circular development and its synergistic benefits in European cities implementing circular projects.

The IWA principles for water-wise cities foster an urban water management with higher awareness of limited resources, increased city densification and future uncertainties. The 17 principles are divided in the following four levels of action: i) regenerative water services; ii) water sensitive urban design; iii) basin connected cities and iv) water-wise communities (IWA, 2015). The first level of action is focused on regenerative water systems, including five principles related with the replenishment, reduction, reuse, recovery and recycling of water, nutrients and energy, therefore intimately linked to the principles for water circular economy (EMF & ARUP., 2018). The second level of action is focused on water sensitive urban design, including four principles related with the integration of urban planning and urban water management, namely with the designing of resilient spaces that are sensitive to water. The third level of action focuses on cities that are connected by water basins, including three principles reinforcing the need for a higher security and protection of shared water resources and preparedness for extreme events. The fourth and last level of action focuses on water-wise communities, including 5 principles that call for stakeholders' awareness, shared responsibilities and water-wise networking approaches, essential to foster the first three levels of action (IWA., 2015; Gustavsson *et al*., 2009).

Among the several contributions gathered from the reviewed literature, the abovementioned two conceptual frameworks for CE and for WWC are worth of further exploratory assessment. In the present study, we gather and merge these binding steps towards the conceptualization of circular cities and water-wise cities. The aim is to understand how a synergistic relation between these two concepts (yet poorly explored in the literature) may help in the identification of key areas where further intervention is needed to attain a city that is both circular and water wise.

3. Research Methodology

This study aimed to understand how cities are adopting water-wise approaches while becoming circular. This entails, at first, to understand the interconnections between the conceptualization of a circular city and a water-wise city and then, the study of circular initiatives in place to explore how these interconnections are being applied at the city scale. The methodology is divided into two main methodological steps: i) building a conceptual model for a circular and water-wise city and ii) testing the conceptual model through the assessment of current urban initiatives, using the city of Amsterdam as a case study. The methodological approach is depicted in annex 1, figure 1.

3.1. Building a conceptual model for a circular and water-wise city

In the first methodological step, a conceptual model was built to integrate the interconnections between the conceptualization of a circular city and a water-wise city. Salient scientific and grey literature on these two

research topics was reviewed, aiming at the identification of main goals and principles for these two different city concepts. The development of this conceptual model was supported by the work of (EMF and Williams) on the field of circular cities and by the work of IWA, (2015) on the field of water-wise cities. Main goals and principles were identified and studied to understand their conceptual interconnections. Afterwards, the different principles were merged, to propose a set of principles to a circular and water-wise city.

3.2. Testing the conceptual model - assessment of water-related circular initiatives in Amsterdam

The developed conceptual model was tested by assessing current urban circular initiatives in Amsterdam. The identification of such initiatives was performed using a brief content analysis and is supported on similar studies (Fidélis *et al.*, 2021). For the case of Amsterdam, the following CE strategies and related municipal policies were assessed: i) 'Municipal policy for the circular economy – lessons learned from Amsterdam' (Circle Economy *et al.*, 2018); ii) 'Amsterdam Circular 2020-2025 Strategy' (Gemeente Amsterdam., 2020); and iii) 'Circular Amsterdam – city circle scan' (Circle Economy *et al.*, 2016). After the screening of circular initiatives, water-related initiatives were assessed using the developed conceptual model.

4. Results

This section describes the results from: i) the development of a conceptual model for a circular and water-wise city and ii) the screening of circular initiatives for the city of Amsterdam, testing the developed conceptual model for water-related initiatives.

4.1. A conceptual model for a Circular and Water-wise city – goals and principles

A conceptual model was built by studying the interconnections between the concepts and principles of a circular city and a water-wise city, also integrating the CE RESOLVE framework, to attain the principles for a circular and water-wise city. The first part of our analysis, that focused on the study of the underlying principles of circular cities and water-wise cities, shows a conceptual synergy between both city concepts. The need to regenerate urban ecosystems, to reduce waste by increasing efficiency and closing resource loops and to increase resilience of natural systems to protect urban populations are transversal concerns in the three analysed frameworks. However, the RESOLVE and the CC frameworks seem to be more 'material-centric'. Hence, we can see that from a broader city concept (CC) to a narrower one (WWC), a WWC integrates circular principles, especially focusing its application on their water agenda, through water sensitive spatial planning and integrative river basin management. The conceptual model is presented in figure 1 and the respective principles are systematized in annex 2 table 1.

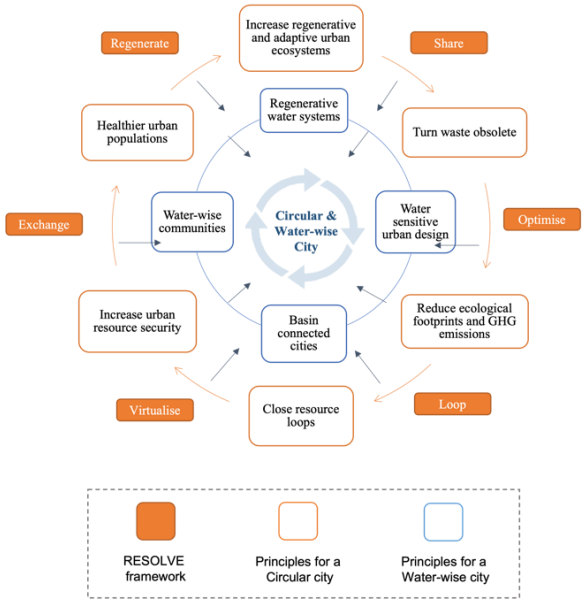

Figure 1. Conceptual model for a circular and water-wise city. Adapted from: EMF, Williams and IWA (REFS).

4.2. How water-wise is the Circular City of Amsterdam? Testing the conceptual model.

This paper gathered a set of circular initiatives and studied their assimilation of principles for a circular and water-wise city. From the analysis of CE strategies and municipal policies for the city of Amsterdam, a set of 13 circular initiatives were selected. The performed content analysis also allowed the identification of major areas of intervention, drivers for success and barriers (mainly legislative barriers and project upscaling constrains) to CE implementation. The collected circular initiatives approach the following areas of intervention: knowledge instruments, circular public procurement, legislation, spatial planning, business support, food & organic waste streams, consumer goods, built environment, organic residual streams and water. The set of initiatives are described in detail in annex 2, table 2. Only one initiative was more directly related to water and was therefore further assessed, as presented in annex 2, table 2. Different types of initiatives were found, many engaging a variety of stakeholders in knowledge sharing, test of circular solutions, identification of opportunities and creation of synergies. Common concerns include the creation of markets for circular products, the necessary support to sustain changes in these market conditions and a flexible collaboration between public and private entities to support entrepreneurs in the implementation of circular business.

In a context of circularity, and based in the set of documents analysed, initiatives directly targeting water are residual. The focus for water is mainly related with maintaining the security and increasing resilience of infrastructures (e.g., improving flood risk management), and less attention is given to water circularity concerns. However, in the case study of Buiksloterham the dimensions of water-sensitive design, regenerative water approaches and water-wise communities are well reflected by the robust coverage of circular and water-wise principles (annex 2, table 2). An example of these is the decentralization of wastewater treatment systems, the reuse and recovery of organic residues and the

integration of water-sensitive nature-based solutions in a collaborative atmosphere (Circle Economy *et al*., 2016; Gemeente Amsterdam., 2020).

5. Discussion and Conclusions

The challenges of increasing urbanization led many cities towards paving their way to become more circular and water-wise. This study proposes and tests a conceptual model for a circular and water-wise city, through the study of circular initiatives in Amsterdam, assessed through content analysis of CE municipal policies. The development of the conceptual model entailed, at first, the study of the underlining principles of the RESOLVE framework (EMF., 2015), the principles for CC (Williams, 2021) and the principles for WWC (IWA, 2015). Findings show that the practical application of CE in cities is challenging and often narrowed to materials and products, giving water a more peripheral role. This is also referred in the literature exploring the embeddedness of water concerns in CE national action plans (Fidélis *et al.,* 2021). Our study shows several interconnections between the models of CCs and WWCs. These conceptual similarities have been referred in the literature (Miranda *et al.,* 2022), namely showing that in the framework for water-wise cities, water plays a central role, while following the rationale of CE model. According to the work of Miranda et al., (2022) the study of definitions of several city concepts (among which including CC and WWC) unveiled different but complementary approaches to water and circularity principles. So, merging these two conceptual frameworks may create opportunities in the implementation of circular solutions more adequately focused on addressing urban water problems.

Through the test of our conceptual model, we were able to identify key intervention areas for CE implementation. The screening of circular initiatives shows that within the water sphere, initiatives are few and focused mainly on flood risk management and resilient infrastructures, while less attention is given to circularity concerns. This is surprising in a city where the urban metabolism is dominated by water flows and port-related throughput of fossil fuels (Voskamp *et al*., 2017). Nonetheless, the assessed water-related initiative (annex 2, table 2) covers a great variety of circular and water-wise principles in the dimensions of water-sensitive design, regenerative water approaches and water-wise communities, but leaving room for improvements in the basin connected cities' dimension. The screening of circular initiatives also showed a variety of collaborative networks between public administration entities, entrepreneurs and citizens, fostering opportunities for synergetic urban initiatives. This is evinced by the knowledge exchange and space for mutual learning created in several initiatives, where the municipality also plays a crucial role. According to the contributions from Gustavsson (2009), cooperative network creates opportunities for the development of innovative ideas, new technologies, higher investment attractiveness and fosters change in citizen attitudes and behaviour. Hence, the collaborative nature of Amsterdam's initiatives constitutes a key driver for success in their path to become circular, also reinforced in studies assessing circular cities (Prendeville *et al*., 2018; Williams., 2021). However, legislation and project upscaling issues are still hindering the implementation of circular solutions.

This study only assessed a limited set of CE strategies and related municipal policies, potentially not including other relevant circular initiatives in place. Nevertheless, Amsterdam's important steps towards circularity makes the case for a realistic and profitable scenario of a circular city, where local policy enables the acceleration of circular activities, providing the necessary foundation for the development of circular practices. However, there is great potential and conditions for the development of circular and water-wise initiatives. Yet, in a city where water plays such a central role, Amsterdam's circular initiatives still show room for improvements in their water-wise potential. Future studies could assess a wider set of CE strategies for the identification of circular initiatives and test the developed conceptual model for other circular cities.

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Annex 1

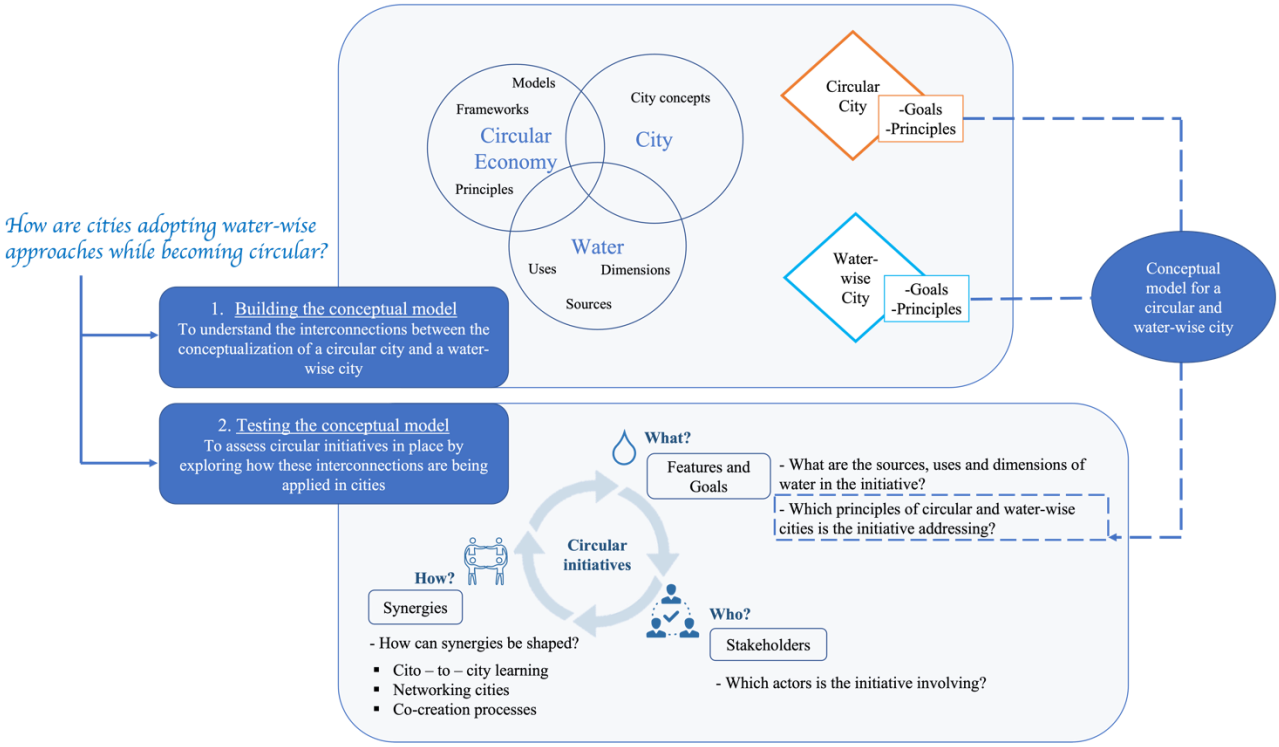

Figure 1. Methodological approach.

Annex 2

Table 1. Principles for a Circular and Water-wise city. Adapted from IWA, 2015; Williams., 2021; ARUP)

A. Regenerative and circular water approaches
A1. Improve resource efficiency, allocation and management
- e.g., reduce the amount of water and energy used
A2. Close resource loops (turn waste obsolete)
- e.g., water and nutrient reuse, recover, recycle (within internal operations or to external applications)
A3. Apply a systemic approach to water integrated with other urban services
- e.g., circular food systems and construction
A4. Replenish waterbodies and their ecosystems
- e.g., return water to the river basin
B. Water sensitive urban design
B1. Foster regenerative and adaptive urban ecosystems
- e.g., enable regenerative water services; reduce ecological footprint; reduce urban greenhouse gas emissions; modify and adapt urban materials to minimize environmental impact
B2. Enable adaptive reuse of spaces and pop-up activities
- e.g., design urban spaces to reduce flood risks
B3. Increase the integration of blue green infrastructures
- e.g., enhance liveability with visible water
C. Basin connected cities
C1. Increase urban resource security towards healthier urban populations
- e.g., prepare for extreme events (plan to secure water resources and mitigate droughts)
C2. Protect the quality of water resources
- e.g., Bioremediation of contaminated sites
D. Water-wise Communities
D1. Empowered citizens
D2. Professionals aware of water co-benefits
D3. Transdisciplinary planning teams
D4. Policy makers enabling water-wise action
D5. Leaders that engage and engender trust

Table 2. Amsterdam's circular initiatives.

Circular Initiative	Intervention area	Features and Goals
Cirkelstad (Circle Economy *et al.*, 2018)	Knowledge instruments	Circular living lab approach: network of public and private stakeholders committed to waste reduction; frequent meeting labs to knowledge exchange
Procurement of circular office furniture (Circle Economy *et al.*, 2018)	Circular public procurement	Reuse and circular production: reuse of furniture to other purposes or disassembled for making new products at the end of their lifetime
Yes-Yes stickers (Circle Economy *et al.*, 2018)	Legislation	Paper waste reduction: system of mailbox stickers to avoid the delivery of unaddressed mail
Circular development Port-City area (Circle Economy *et al.*, 2018)	Spatial planning	Physical space to test circular solutions and close resource loops: Circular material use in new living units; integration of blue-green infrastructures to increase adaptability of spaces
Amsterdam circular challenge (Circle Economy *et al.*, 2018)	Business support	Business support through Financial and non-financial resources: turn residual flows from companies into products
Tuinen van West (Gardens in West) (Gemeente Amsterdam., 2020)	Food & organic waste streams	Experimental Garden: public educational laboratory for local food production, biomass, soil, fertilization and biodiversity; foster short food chains and a sustainable food system
Amsterdam Made (Gemeente Amsterdam., 2020)	Consumer goods	Community of manufacturing companies: knowledge sharing to reduce the use of raw materials; turn industry more circular
Hub in the Dutch Circular Textile Valley (Gemeente Amsterdam., 2020)	Consumer goods	Knowledge sharing of sustainable and social textile manufacturing with other worldwide textile regions: creation of a global ecosystem for circular textiles
Buiksloterham (Gemeente Amsterdam., 2020)	Built environment	Circular city district: former industrial area transformed into a circular city district for living and working; hub of circular research, experimentation and innovation opportunities; smarter use of materials, close loops and use of local and renewable energy sources
Sustainable canal banks (Gemeente Amsterdam., 2020)	Built environment	Renovation and replacement of canal banks with circular concrete
Greenmills-cluster (Circle Economy *et al.*, 2016)	Organic residual streams	Alliance between six companies: Central bio-refinery hub; optimised cascading (reuse) of organic residual streams
Cluster AEB – Waternet (Circle Economy *et al.*, 2016)	Organic residual streams	Industrial cluster: incineration of dry sewage sludge; biogas production; energy and heat recovery
Buiksloterham (Circle Economy *et al.*, 2016)	Water	Decentralised wastewater management: local recovery of heat, energy and resources; separation of wastewater types; local valorisation of streams

Table 3. Circular initiative assessment.

Circular Initiative	What, How and Who?
Buiksloterham (Circle Economy *et al.*, 2016; Gemeente Amsterdam., 2020)	Features and Goals - Former industrial area transformed into a circular city district for living and working; hub of circular research, experimentation and innovation opportunities; smarter use of materials, close resource loops and use of local and renewable energy sources; decentralised wastewater management with local recovery of heat, energy and resources; separation of wastewater types for reuse; local valorisation of streams - Circular and water-wise principles: A (1-3); B (1,2); C2; D (1-5)
	Stakeholders - Private companies; water utilities; municipality; civil society; researchers
	Synergies - Strong network approaches and co-creation processes