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Navigating Long-term Uncertainties of Water Management through Megatrends

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Summary

Megatrends like climate change, urbanization, and technological advancements provide crucial foresight for managing future uncertainties in the water sector. They create feedback loops that can amplify or mitigate impacts, especially in environmental and water management contexts. Assessing these trends helps strengthen strategic long-term decision-making by predicting and avoiding damaging knock-on effects or tipping points. Recognizing and responding to megatrends is therefore vital for securing long-term water quality and availability, requiring proactive measures to ensure sustainable water management.

Consequences for you

	Low	Midle	High	Brief explanation
Impact				Potentially profound local and global effects on livelihood
Certainty				Interplay of trends in uncertain future poses risks

Megatrends provide foresight for managing future uncertainties in the water sector. (modified from DALL·E 3)

S = sociaal E = economisch P = politiek T = technologisch E = ecologisch D = demografisch

Background

The future is uncertain and foggy. How to see through this fog? In 2023, *stemwijzer* (a Dutch political test), ChatGPT (a deep learning-based chatbot) and FIFA Women's World Cup (a football competition), were among the top most Googled topics online in the Netherlands. This provides a snapshot of which topics may have been most trendy in that particular year, given what individuals were most driven to look to learn more about. However, how to see far into the future and where are we heading towards? To build more robust, resilient and affordable drinking water systems, the sector needs to stay on top of the short and, most of all, long-term trends while remaining conscious of the uncertainty in future predictions.

Trends can be something that is currently popular or fashionable. Trends can also be a general direction of change. Great challenges, opportunities and trends lay ahead. Human have forever been mystically intrigued by the ability of foresight, being able to tell what the future holds and spot which signals translate to general changes in a particular direction. The ability to forecast tomorrow's weather, predict the outcome of a sports match or guess the wining political party via polls has been the subject intense philosophical and scientific discussions. Harnessing the future to harness the present. When thinking about long-time horizons, many actors have made attempts to delineate the *bigger* trends in our societies, the *megatrends*.

Megatrends

A megatrend may be defined as a "*significant driver of change that is likely to have transformative impact on individuals, organisations and societies (…), typically developing over a period of years or decades, occurring at the intersection of multiple trends*" [1]. Among other foresight approaches such as scenario planning and Delphi method, megatrends are a popular tool for organisations and individuals in exploring uncertain futures [1]. Megatrends can generally be classified and distinguished from other phenomena (e.g., fads, micro-trends, backcasting) using diagnostic tools such as the one depicted in Figure 1.

It is important to recognize the confluence of megatrends, i.e., that these overlap and interact with each other leading to potential feedback loops. These feedback loops may diminish or exacerbate the effects of a certain phenomenon. A simple example of a positive feedback loop is the growth of a population leading to more births and further population growth. A counteracting force to stabilize a population may be the depletion of resources (negative feedback loop). A (re)balance between both are key mechanisms in every ecosystem and human social system. Megatrends are indicative of which underlying feedback loops may be at play, nudging us to one future scenario over another. However, these are very hard to formalize, especially when accounting for knock-on effects leading to rapidly large escalating events which may be irreversible , so called tipping points [2]. Environmental problems sometimes appear suddenly, but most may be foreseen with the support of megatrends' assessment. The same concept may be applied to (drinking) water management and safety.

Megatrends may be seen as pressing for countries like Germany or Belgium; however, The Netherlands may also be indirectly affected, with water reminding us of its unboundedness. A prime example is the impact of water contamination upstream of transboundary rivers, like the Rhine or the Meuse. Over 60% of European rivers are transboundary, flowing through more than one country, which demands good water governance to avoid conflict over limited water resources and socio-economic instability. Emission of pollutants that take place in one country may lead to pollution in downstream countries due to the environmental transportation, this is particularly concerning for persistent and mobile chemicals posing a threat to

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sources of drinking water. Many laws are in place to reduce pollution, yet these may still need to fully mature into tools able to cope with megatrends. The water sector is a key stakeholder but the resilience required to withstand the societal needs will need an integrated approach across sectors and actors to tackle pollution at source.

Sector-specific focus on megatrends

Although there is great commonality between megatrends, it is noticeable that these are categorized and subcategorized differently by different stakeholders [3-11]. Also, the sector which an actor fits in will tend to categorize the areas which are of most relevance to their activity. For example, a life science technology company may identify and categorize megatrends into DNA sequencing in precision medicine, cellular reprogramming and the coupling of data science with the Internet of Things (IoT) [12]. An insurance company may identify megatrends as being asymmetric global population, climate change, renewable energy, globalization, healthcare revolutions, information technology development and economic inequality [13]. An asset management company might find the key issues to be extreme weather and climate change, net-zero carbon economy, labour market, aging population and pandemics [14].

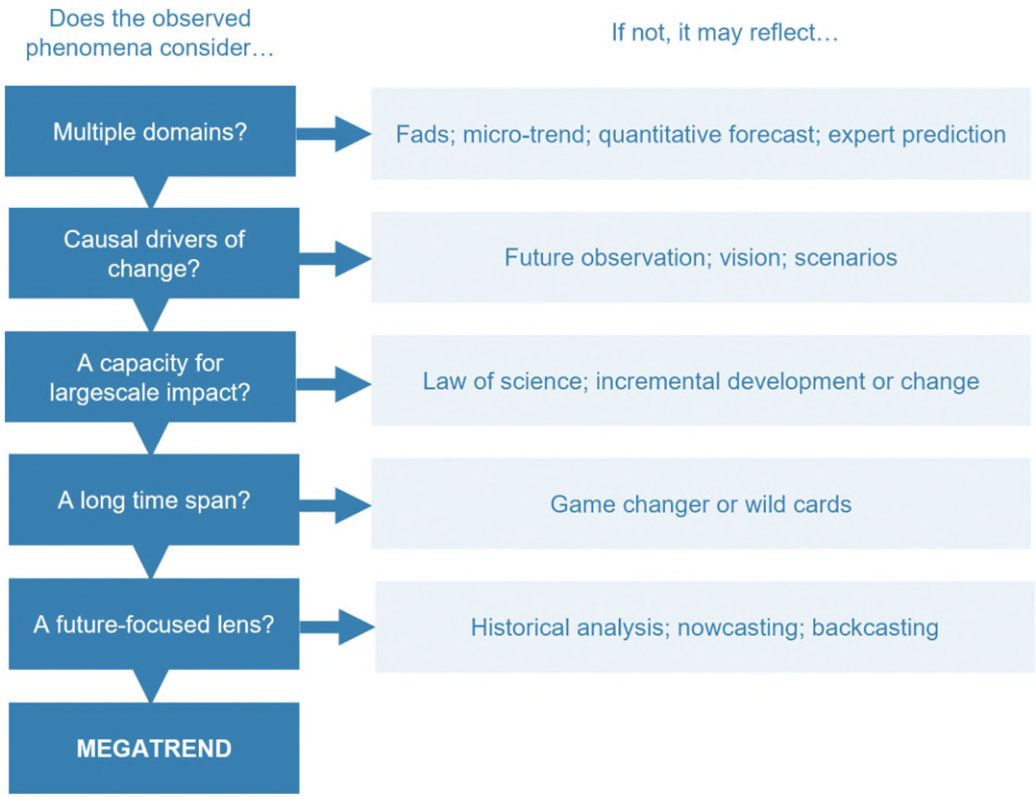

Figure 1. A diagnostic tool for classifying observed phenomena as a megatrend. (sourced from [1]).

The water sector is no exception in the temptation to focus their attention on trends directly related to water-reliant systems. For example, it has been proposed that climate, resources, technology and society are the

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megatrends outlining the biggest issues the water sector is facing [15]. Others have identified population growth, urbanization and climate change as most relevant megatrends exerting pressure in renewable water resources and the way in which they are used [16]. Other determinant trends were said to be water reuse, forever chemicals (e.g. PFAS), solar desalination, AI, SaaS and digital twins [17]. More recently, authors claimed that there was no doubt that the megatrend of this century is the acceleration of digital and innovative ways to manage water [18]. Some disagreement in the degree of relevance and prioritization of megatrend among experts and practitioners continue [19]. This lack of coherence and consistency has recently been studied for the first time since the inception of the concept 40 years ago [1]. In fact, the surprising majority of studies do not report the methods and approaches used in identifying megatrends (e.g., trend identification, survey, desktop research, consultation, personal opinions). This further reveals the lack of a consensual definition and approach in identifying megatrends which restricts one's ability to make comparisons between megatrend studies, track the evolution of megatrends over time and test the accuracy of these approaches. Nonetheless, megatrends continue to be perceived as valuable tools that can be used to improve our foresight, while building the right frameworks on how to best respond to upcoming trends and threats to water quality and quantity.

Megatrends in water quality

The world as we know it keeps on changing, rendering the future of local and global water governance more challenging than ever [20]. Water is a uniquely interlinking factor across megatrends and with it, the water sector occupies a unique position in curbing the challenges that ensue with water as a common good at its core [21]. In can be understood without much creativity that water relates to all megatrends one way or another. Based on the (gray) literature available, it seems acceptable to claim that 6 topics appear to be most recurrently identified as megatrends: environment, urbanization, demography, governance, and technology.

The Urbanization megatrend suggests that human will continue to convey into highly dense populated areas increasing local and regional water demands above the surrounding ecosystem capacity to retain and sustain good groundwater and surface water, which will further exert pressure over drinking water management [22, 23]. The Demography megatrend suggests that the galloping population growth worldwide, with regional human migration differences also induced by environmental trends [24], will increase the number of persons to feed meaning an ever increasing reliance on safe and quality water for basic needs such as drinking water, hygiene, food, and energy. Furthermore, risk remains that communities may become increasingly compartmentalized leading to inequalities in terms of access to good education, health, housing, employment, and, not least, disparities in access to high quality water [25, 26]. In fact, law dictates that vulnerable and marginalized groups are paid particular attention. The Governance megatrend suggests that accelerating water stress will demand from policymakers appropriate legislation to minimize the threat of water scarcity and water quality, followed by adequate water governance approaches to handle with the challenges associated with disputes about water usages between sectors and states [27], particularly in transboundary **waters** such as in the Netherlands [28]. The Technology megatrend suggests that digitization and technological development will play a critical role in society, as it has already been for a few years now. Take for example, the role of digitalization (i.e., the availability of actionable information through digital systems) to manage and allocate water resources, and to increase system efficiency to make the best use of available water [29]. Other interesting examples are green hydrogen production and computer chips which require extremely purified water. Also, for the manufacture of digital systems, critical raw materials are necessary. In turn, during the extraction of these metals and minerals mining-related emissions of hazardous substances can further compromise the quality of the aquatic

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environment [30-33]. The Environment megatrend suggests that climate warming leads to higher incidence of extreme weather, including heat waves and droughts, depleting water resources. An impact is expected on water availability and water quality, due to pollution, wildfires, extreme precipitation, microbiological responses to higher temperatures and, finally, demand due to significant shifts in human migration. Additionally, heavy showers will overwhelm wastewater treatment infrastructure, causing pollutants ending up in the environment due to effluent disposal and combined sewer overflows, thus potentially compromising drinking water sources [28]. An estimated 69% of Europeans consider pollution to be the main threat to water, with pharmaceuticals and cosmetics composing 92% of the toxic load in wastewaters [34]. The environmental degradation is unsurprisingly a megatrend which continue to demand the water sector's full attention. In fact, a recent study warns that only 3 out of 40 future risks pose an existential threat to humans, two of which are environmental degradation and disasters [35]. When asked about the most severe global risks to humanity in the long-term, most experts agree that environmental risks, such as extreme weather events, critical changes to Earth systems, biodiversity loss, ecosystem collapse and natural resource shortages, outweigh economic, geopolitical, societal and technological risks [36].

Megatrends for better and timely actions

With increasing number and magnitude of disasters threatening our waters, more drastic responses are required. Scrutiny of polluting activities and the adverse impacts in human health and the environment is increasing. In fact, 78% of Europeans think that current measures are not enough to address current water problems. For example, due to heavy contamination, Mar Menor, Europe's largest saltwater lagoon, became the first EU ecosystem to be recognized as a legal person in 2022, now enjoying a unique protected status to prevent pollution. Similar discussions regarding Dutch water bodies are taking place [37]. Freshwater is also an essential resource. What would be impact of such deliberations to businesses and other water-dependent corporate activities? What can the water sector do? How to deal with the insights underlying megatrends?

Megatrends do not offer a set of metrics on which a bullet-proof assessment and management of water can be devised. Instead, megatrends are useful strategic tools to help us narrow down the future from infinite possibilities to a more restricted possibility space (see Figure 1). However, these trends often describe plausible systemic changes in the future for which short/mid-term measures are of little use. The water sector should aspire to be, like water in nature, a unifying element in society. A diverse set of actions may be taken. For example, it must stay engaged with all stakeholders (in)directly involved in the use and protection of the water cycle through dialogue and expert knowledge exchange. This dialogue is particularly relevant with policy makers (e.g., support better policy including regulation), polluting critical actors (e.g., co-design best practices to prevent over extraction of water, encourage reuse and halt harmful emissions) and consumers (e.g., raise awareness about water footprint). The water sector should increasingly adopt effective measures in the transition to low-emission energy sources needs. These would relate to reduce carbon footprint, reduce waste, digitize for total asset visibility and efficient system wide demand management, preventive maintenance. In an uncertain future, the water sector can play a key role in shifting important actors from a short-term mindset to strategic long-term thinking. Ultimately, it is a matter of adaptation to foreseen changes and, more challengingly, of adaptability to unforeseen ones.

Relevance

Many water and environmental issues are often noticed by scientists, but due to political and situational conditions, actions are forfeited. These latent risks later emerge as "sudden" or "unexpected" crises, with some stakeholders claiming surprise to avoid blame [38]. Even the COVID-19 pandemic was predicted in general terms,

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though not in its specifics. The water sector should strive to be better prepared and proactive in addressing problematic megatrends from a water perspective.

Megatrends can help the water sector to better anticipate changes that will (re)shape the strategic landscape. The relevance of megatrends dependent on multiplicity of large scale implication for society. What changes if we recognize drivers to be megatrends? An important consideration is how actors such as drinking water companies can be better prepared for, learn about and take advantage of the opportunities that megatrends offer [39, 40]. It is worthwhile to remember that whereas forecasting estimates a future fact (e.g., number of people connected to the drinking water distribution network), foresight interprets this fact (e.g., that this increased degree of connection will lead to a healthier population) [41]. Regardless of how trends are classified as megatrends, it is increasingly agreed that the future of water and how local and global issues incumbent upon our reliance on water will be very different from the past. Water management will change more during the next 20 years compared to the past 100 years [42].

A matter of critical importance is the quality of water which is dependent on the societies ability to keep it free of contamination by chemicals. Chemical water quality and health are thus tightly interlinked. Large numbers of chemicals reach the market every year and many are increasingly found in surface water and groundwater in the Netherlands and across the globe, despite major efforts by water managers. These contaminants include industrial chemicals, pharmaceuticals, cosmetic products, pesticides, biocides, solvents, detergents, microplastics, nanoparticles and many other.

Water may be strictly argued to not be a finite resource. However, this would miss the point that there is a finitude to its usability either in space (e.g., dried river) or in time (e.g., groundwater with slow natural degrading contaminants and long residency of transformation products). Putting into context and reducing water to our human dimension, water resources are effectively as “finite” as our inability to use it sustainably. This unsustainable exploitation of natural resources underly key concepts such as Planetary Boundaries and Earth System Boundaries [43-45]. Identifying and prioritizing megatrends provides (drinking) water companies an opportunity to reflect and take a closer look at its overall water strategy based on newly acquired knowledge on elusive interlinked driving forces and mechanisms.

In conclusion, there is not ‘one-size-fits-all’ solution to water challenges across regions, particularly considering the plethora of stakeholders involved in a sector which is often highly capital-intensive and monopolistic [46]. The future is uncertain but we wish to secure our collective well-being the safety and quality of water must be secure by acknowledging the trends and have all actors to take sharp action to bend the trend (e.g., setting caps on the water footprint per river basin or groundwater aquifer) [40, 47, 48]. It seems in the best interest of the water sector to assimilate the foresights offered by megatrends, as to fully account for long-term economic, social and/or environmental impacts it bears from the activities of other stakeholders (externalities) [49].

Addressing water issues as purely engineering or technical challenges misses the centerpiece: the people behind these issues and quality water as a human right. How is society evolving? How are people’s behaviors changing? How are underlying cultural values affecting community behavior and policy decisions? How can we influence policy to prioritize long-term, large-scale benefits for water and environmental improvement over short-term gains? How can we avoid our incompetence and shortsightedness from manifesting in derogations? Decisions made for purely political reasons need to be replaced with bolder decisions that surpass political cycles and have long-lasting impacts on institutions responsible for implementing strategic water planning. Additionally, the economic incentive to reduce water

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demand is mostly non-existent compared to other commodities. The water sector can play a strong role by becoming more actively involved in policymaking and decision-making concerning all megatrends with water as a centerpiece. Governance innovations able to tackle chemical water quality issues at the source seem to be increasingly more critical than sole reliance on technological innovations at the end of the drinking water supply, if society has higher hopes for now and future generations.

The present is always now, but so is the future. The planet does not have a water problem, it's humans that have a problem managing it. Planning for the future in a changing climate and under varying degrees of uncertainty requires one to consider all plausible scenarios [50], including catastrophic ones triggered by tipping points [51]. Tipping points in physical as well as social systems provide a great source of uncertainty in future projections. Furthermore, a discussion of megatrends in the context of TUNA conditions (Turbulence, Uncertainty, Novelty, and Ambiguity) could be useful. It is a tremendous challenge to fully embrace uncertainty into long-term thinking and forecasting, but it also offers opportunities to prepare for the unforeseeable megatrends with flexibility, adaptability and constant vigilance.

More information

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