Introduction to Water Chain reading materials

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This text has the aim to serve as an introduction to the literature provided for the Water Chain Theme within the WCM course. In the first part the Water Chain Approach will be introduced and explained. The second part focuses on the Urban Water Chain and Urban Water Management. Use is made of different scientific articles on the subject.

Part 1: The Water Chain Approach

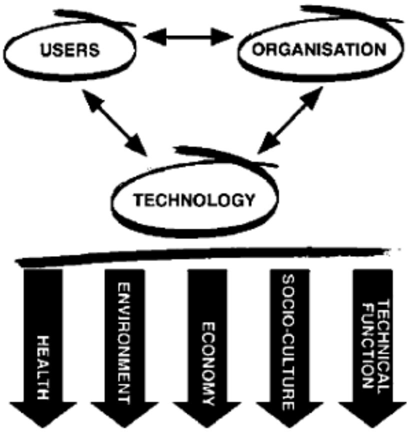
In the course guide of the WCM course there is referred to the water chain approach as follows:
'The water chain approach allows linking different issues such as water supply, the sewage system and wastewater treatment in a logical and stepwise framework. The water chain approach helps to think along the line of the water flow while dealing with water issues which touch different disciplines'. The water chain approach 'would be the most appropriate basis to come to an integrated design of water measures ultimately supporting environmentally safe agricultural production in urban areas and downstream'.
Similarly according to Huibers and van Lier wastewater flow and agricultural use of the (treated) wastewater could be described in a water chain approach. 'In this way, the water is followed along the path from originally fresh water made available for high value domestic or industrial use, leaving these activities as wastewater, being upgraded by treatment facilities and subsequently brought to agricultural fields. The chain approach could help to constructively discuss the technical and institutional issues step by step with due attention to water quality issues and proper management at each point in the chain.'

Objectives of the Water Chain approach

According to Huiber and van Lier the 'overall objective of the chain approach is to effectively use the scarcely resources such as water and nutrients in a sustainable manner with manageable environmental risks.'
According to Hellström *et al.* 'urban water and wastewater systems should – without harming the environment – provide clean water for a variety of uses, remove wastewater from users to prevent unhygienic conditions, and remove storm water to avoid damage from flooding.'
'The main objectives for a sustainable urban water and wastewater system as well as for the majority of any urban infrastructure' 'can be summarized as: (a) moving towards a nontoxic environment; (b) improving health and hygiene; (c) saving human resources; (d) conserving natural resources; (e) saving financial resources.'

Urban Water Chain (UWC) and Urban Water Management (UWM)

In literature most of the time the Water Chain approach is applied on the Urban Water Chain (UWC). The UWC is defined by Bots as 'the infrastructure for the production, distribution and consumption of drinking water and the collection, treatment and disposal of wastewater. Good performance of the water chain is crucial for public health and the environment.' Public interests to be served in Urban Water Management (UWM) are 'public health, reliable drinking water provision, affordable water services, environmental quality' and protection.



Malmqvist and Palmquist introduce ‘a framework of an integrated urban water system that has been equally divided into three subsystems (Fig 1):

- The *organisation* owns, plans, finances and manages the urban water system, and may be public or private, central or local
- The *users* use the water and need to get rid of the waste products
- The *technical system* (pipes, pumps, treatment plants, etc.) supplies the water and takes care of the wastewater.’

Figure 1: Framework of an integrated urban water system (Malmqvist and Palmquist, 2005)

According to Mitchell ‘the principles of Integrated Urban Water Management can be summarised as follows.

1. Consider all parts of the water cycle, natural and constructed, surface and subsurface, recognising them as an integrated system.
2. Consider all requirements for water, both anthropogenic and ecological.
3. Consider the local context, accounting for environmental, social, cultural and economic perspectives.
4. Include all stakeholders in planning and decision making processes.
5. Strive for sustainability, aiming to balance environmental, social and economic needs in the short, medium and long term.’

Part 2: Urban Water Chain

Urban Water Chain interactions with the hydrological water cycle

'Traditionally, the hydrologic cycle has been used to represent the continuous transport of water in the environment (Asano, 1998 from Mitchell *et al.*, 2000). The urban hydrologic cycle comprises water supply, wastewater disposal, and stormwater runoff systems, making up the total urban water system (Mitchell *et al.*, 2000).' In the following paragraphs conceptualisations by different authors of UWC interactions with the hydrological water cycle will be given.

Jong schematizes 'the relationship between the water chain, the water system and the environment' (Fig 2). The water system is defined as 'the totality of surface water and groundwater, which belong together to the natural environment'. Figure 2 shows that 'the water chain consists of three components: drinking water supply (production and distribution); the sewage system (collection and transport of wastewater); and wastewater treatment.' 'This diagram shows among other things the multiple links between the water chain, the water system and the environment (including its other, non-wet aspects). The water chain makes contact with the water system both at its inflow and outflow ends. The 'raw material' for drinking water is surface water or groundwater. After consumption by private households and industry, drinking water is generally discharged into the sewage system. After purification of wastewater in treatment stations, the effluent is discharged into the surface water.' 'Rainwater can enter the water system or the water chain in various ways. It can fall on surface water or enter groundwater via the soil (these are both components of the water system). If it falls on a paved or metalled surface, it can end up in the sewer (part of the water chain) unless the region in question has its own storm drainage system separate from the general sewage system.'

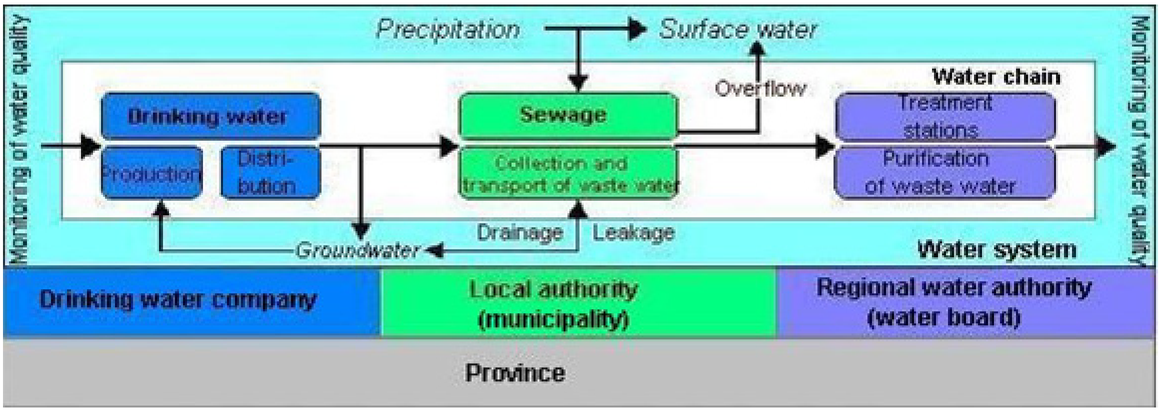


Figure 2: The water system and water chain in Dutch water and environmental legislation

Figure 3 links the UWC and the interactions with the surrounding water system (Bots, 2008).

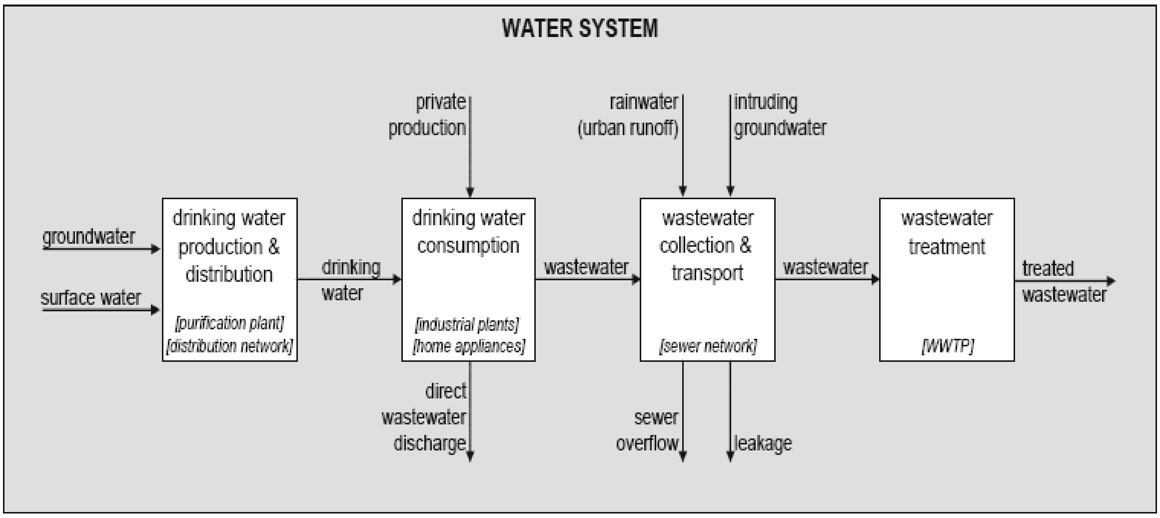


Figure 3: Schematic representation of the urban water chain (Bots, 2008)

'The urban water chain is a subsystem of the water system that comprises surface water and groundwater, and their relations with the soil and the atmosphere (evaporation and precipitation). The arrows in Fig. 1 denote the pertinent relations between the four links and the water system:

- Groundwater and surface water are extracted for large scale production of drinking water, but also for production on a smaller scale by industry and private persons (wells).
- Wastewater may be discharged directly (without treatment) to surface water or (via septic tanks) to groundwater, but is usually collected and transported (via the sewer network) to a wastewater treatment plant (WWTP), where pollutants are removed before the water is discharged to the surface water.
- Untreated wastewater may still flow out of the sewer system due to leaks, or when a peak in wastewater causes the sewer system to overflow. When part of the sewer network lies below groundwater level, ground water may enter through leaks, lowering the system's wastewater transport capacity.
- Rainwater running off hard surfaces (roads, roofs) enters the chain when it is led to the sewer network. Depending on the network architecture and the pollution of the runoff, rainwater and wastewater can be collected and transported separately to avoid sewer overflow and the ensuing pollution of groundwater and surface water.'

Imbe *et al.* give a schematic impression of the hydrological water cycle in urbanized areas (Fig 4). 'The cycle is classified into the following three flow systems.

1. Natural water cycle such as precipitation, evaporation, runoff, discharge and permeation.
2. Artificial water cycle such as water supply and sewerage including treatment processes.
3. Artificial water control systems such as rainwater storage and infiltration facilities.

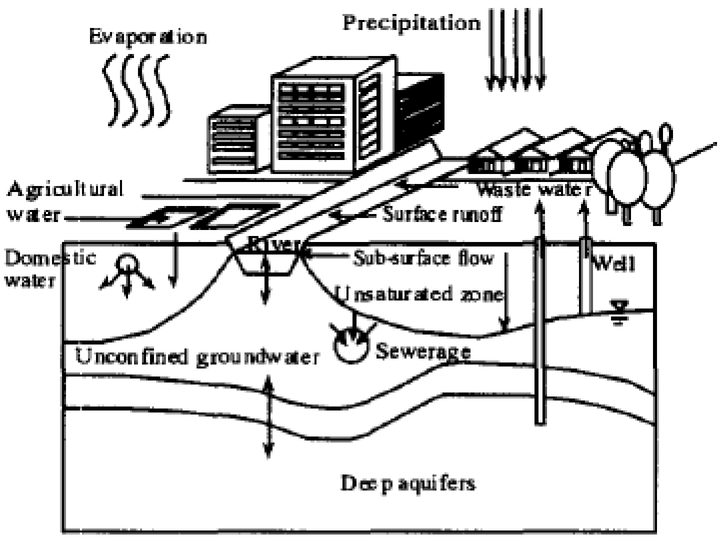


Figure 4: Schematic impression of hydrological water cycle in urban areas (Imbe *et al.*, 1997)

Impacts of urbanization on aquatic environments

In figure 5 impacts of urbanization on aquatic environments are schematized.

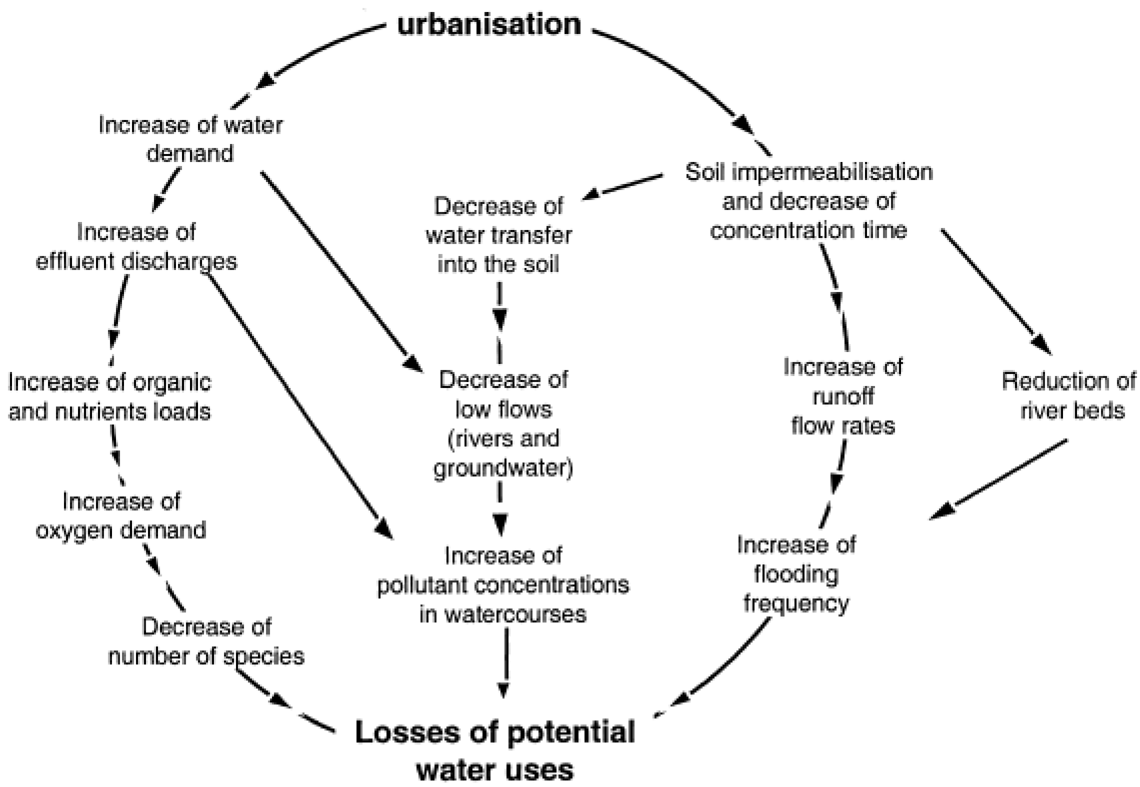


Figure 5: Impacts of urbanization on aquatic environments (Bertrand-Krajewski, 2000 from Chocat, 1997)

Example of interfering in Urban Water Chain

Pahl-Wostl gives an example about how urine separation at household level will influence the UWC (Fig 6).

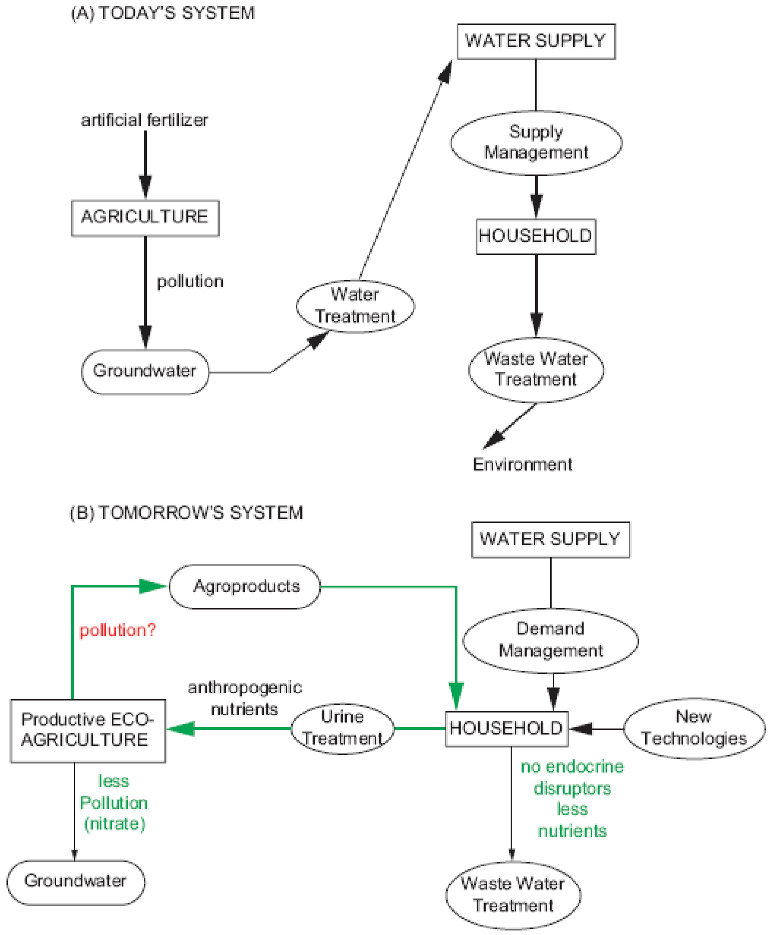


Figure 6: Comparison of today's (A); and tomorrow's (B) system with urine separation regarding the flows of nutrients, drugs and hormone active substances in a combined urban rural setting (Pahl-Wostl, 2005)

Figure 6 shows 'a comparison of the current and the new technology from a system perspective emphasizing the establishment of an urban rural link. In today's system urine is treated in the wastewater treatment plant. Nutrients and endocrine substances, remnants of drugs enter the aquatic environment. The role of endocrine substances in the aquatic environment is a controversial theme. Presumably they have a negative effect on the reproductive capacity of fish and thus on the aquatic ecosystem as a whole (Burkhardt-Holm and Studer, 2000). Conventional agricultural production is resource intensive and uses too much fertilizer that may pollute the groundwater. The groundwater has to be purified to be utilized for drinking water in the households. In the new system urine is separated at the household level. It is converted to fertilizer to be used in ecological farming.
Hence, the nutrient cycle will be closed. Less polluting substances (drugs, endocrine disruptors) will enter the aquatic environment. The new technology leads to considerable water savings. A potential risk is given by the use of urine derived fertilizer for ecological farming.'

References

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