Smart Urban Water Grids enabled by Nature Based Solutions

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Highlights

- Current urban water systems (drinking water supply, sewage systems and WWTP) are under threat.
- Nature Based Solutions can balance water supply and demand with water quality fit-for-use in times of climate change
- With extending the current scope and definitions of current intrinsic Nature Based Solutions with inspired NBS, NBS can become an industry standard
- Smart urban water grids connect different urban areas with different supply and demands.
- Rainwater harvesting combined with treatment by gravity is a very NBS solution
- Grey water reuse is an easy solution with large urban water supply impact

Abstract

Centralized water systems in urban areas are under threat. Drinking water supply is worldwide stressed by both an increasing demand and diminishing sources, fouling of sources (salination, micro pollutants and agro/industrial waste) and climate change. Sewage systems are not designed for the heavy rainfalls occurring more often due to climate change and leading to urban flooding's. Centralized waste water treatment has little opportunities for sustainable reuse of water, components and energy. In addition to these challenges diminishing biodiversity and the transfer to green and renewable energy are additional problems which could be treated together with the water problems. A new vision on establishing urban water autarky is presented based on Nature Based Solutions (NBS) addressing all issues. Several cases (drinking water from rain, green roofs, black water treatment for energy recovery and the removal of minor components from waste water) are presented to underline the vision of smart urban water grids for future resilient water systems.

Key words: smart urban water grids, Water from Heaven, grey water reuse, NBS, water resilient, water recycling, water autarky, gray and green roofs

Introduction

Climate change is worldwide having a large impact [IPCC, 2022]. Even in The Netherlands (a delta), during droughts, drinking water is becoming scarce and climate change is adding up to this problem [RIVM, 2021]. Although this seems a bit strange because more water is coming available on earth thanks to the incineration of fossil fuels resulting in CO_2 and water and by increasing temperatures also more water is evaporating resulting in more precipitation with almost drinkable water quality. A pity is that most of this water falling on us, is transported from ashore, to the seas and oceans where it gets salinized. Desalination is of course possible but comes with a high energy price and is no solution for inland areas. At fewer suitable sources, during droughts and high temperatures, water use is rantioned [Helpdesk Water, 2022]. At the same time current drinking water sources (ground and surface water) are falling in quality by industrial and agricultural emissions as well by WWTP effluents.

Another consequence of climate change is sudden extreme rain fall. The capacity of current sewage systems cannot follow the supply resulting in wet feet, with very high economic cost as a result. The city of Copenhagen reported a damage after a cloudburst in 2012 of 800 M€ resulting in a water management plan to avoid these disasters and create water resilience in many cities after this event. More recently (2021) the small city of Valkenburg (the Netherlands) suffered a cloudburst with 2300 houses damaged and 400 M€ loss[NOS, 2021]. So cities are at risk.

Connected at the end of our sewage systems is the waste water treatment plant (WWTP). These are large scale and fully centralized facilities outside the city because of economy of scale advantages, but are now hampering innovations because of:

- Water reuse is cost full because new pipelines returning into the city are necessary
- Useful heat content gets lost by cooling during transport in sewage system
- Useful nutrients (energy intensive chemicals) are destroyed via biological oxidation at high energy (compressor) costs while micro-pollutants are not at all removed
- Organic content is also oxidized without using their intrinsic energy value

Figure 1: Current centralized urban water systems (except canals, etc..)

In Figure 1 we see the three mayor players of our urban water system, drinking water production, sewage system and waste water treatment, which are all under stress.

Figure 2: urban water systems in stress

What if our drinking water production is no longer sufficient, sewage systems are overloaded or the waste water treatment plants are not efficient removing new types of contaminants. Should we look for add-on solutions or shall we introduce new systems that also addresses other challenges like food, energy and biodiversity.

During droughts there is a higher need for water in urban areas, because of higher evaporation rates and need for cooling water, while at the same moment drinking water sources are the most stressed. Past few years (2019, 2020), many drinking water companies in The Netherlands for example reduced the water pressure in the system and people were urged to reduce their water use because of scarcity. [Drinkwaterplatform, 2022]

Summarizing, climate change together with larger water needs are causing stress on all three main urban centralized water systems we need another system.

Smart urban water grids

When society is considering that the solution is to invest more in local rainfall harvesting to prevent wet feet, we could welcome this and try to combine this to achieve real autarkic urban water systems. These decentralized systems could be buildings, streets, neighborhoods, but could also be urban areas use for different applications like industry, agricultural, parks, sports fields, hotels and other businesses. Another approach could be living with the surplus of water with floating homes, farms, hospitals, offices, hotels, etc… All with their own water demand and rain harvesting potential.

If these were to become autarkic even oceans would become livable.

E.g. the total urban water use of a city like Utrecht in The Netherlands with approximately 350.000 [Utrecht, 2022] inhabitants with an average consumption of 129 l a person a day

[CBS, 2021] is 16,4 Mm^3/a, while the precipitation in this urban area of 99 km^2 at 0,82 m^3/(m^2.a) is 85 Mm^3/a. So we need to organize 16 % of the urban area for rain water harvesting. When we only look at water for consumption and for food preparation only 1,2 % is necessary. An easy target to meet.

So cities can serve themselves for water supply. But demands and supply are different for different areas. For other use in house the additional rain in combination with grey water reuse will be sufficient. How to do this on a sustainable way! And how to balance water supply and demand for each area.

Figure 3: Smart Urban Water grids, a decentralized approach of urban water systems

In figure 3 we see an infographic depicting several waterflows (with different water qualities) in use in an urban area:

- Water for drinking water
- Water for hygiene
- Water for plant crops (with nutrients)
- Water for heating
- Water for industrial processes
- Water (treated waste water) for disposal
- Water for transport and recreation

The idea of the smart urban water grid is that a surplus of water in one area will be supplied to another area with shortages using systems based on decentral and nature based solutions for both storage and quality adjustments

The concept is simple: areas with a surplus of rain-water harvest it and store it and connected to a water supply system to the city for areas in need which can treat the water further to a quality fir-for-use.

Next to rain water we identify waterflows with a potential of using the heat content from industrial sites towards houses and greenhouses.

Water flows with nutrients from WWTP can be forwarded to urban agriculture and used for irrigation. So no new energy intensive production of nutrients are needed.

Industrial water supply is the highest urban challenge. It is the most water stressed urban area. The water consumption per surface area is often more than hundred times larger than the rain fall. In figure 4 an infographic shows all possible water flows on a virtual industrial site. This means that solutions for reducing the external water demand should be not sought externally but preferable internally. The first thing to do is safeguarding the existing water supplies including rain water catchments. Looking at the used waterflows we should focus on the value of their content. Often we can use the heat in plants internally for power production or preheating in reactors or for urban or greenhouse areas. Then we have to look to the reuse of valuable molecules in internal processes followed by converting non-valuable organics into other forms, such as energy (methane). Inorganic molecules can be recovered as nutrients for plants or as minerals for other chemical processing. After removing the minor components a water quality is achieved often fit-for-reuse as process water.

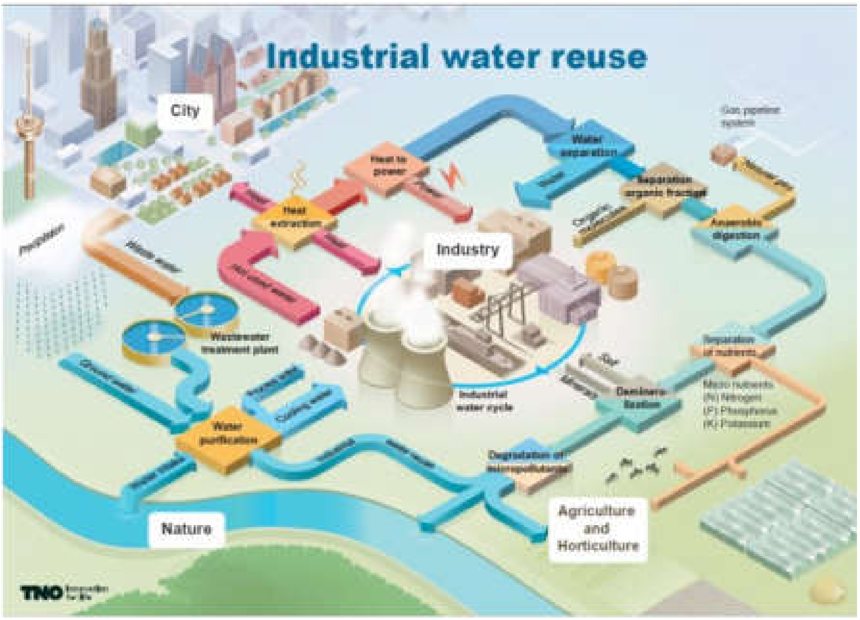

Figure 4, An overview of possible water flows on an industrial site.

Nature Based Solutions (NBS)

Nature Based Solutions are defined by the EU as: “ solutions that are inspired and supported by nature, which are cost-effective, simultaneously provide environmental, social and economic benefits and help build resilience. Such solutions bring more, and more diverse, nature and natural features and processes into cities, landscapes and seascapes, through locally adapted, resource-efficient and systemic interventions” [EC, 2022] Where do Nature

Based Solutions come in the picture and how do they relate to water efficient systems like smart urban water grids? Figure 4 shows such an highly integrated smart urban water grid, in this case also applied at industry. To meet the different requirements on both quality and quantity, solutions as treatment and buffering of the water are needed. The technology here fore can be assisted by Nature or Nature can be assisted by Technology inspired on nature. At last this transformation end where both meet each other. NBS solutions are commonly also hybrid systems, using the best of all worlds as explained in the following cases:

Case 1: Drinking or process water from Rain (Water from Heaven)

Water from Heaven is a patented [Jansen, 2016] and prize winning concept for decentral and sustainable producing drinking water [ref]. It is a so-called Nature Based Solution thanks to the natural occurring rain and naturally occurring gravity as the only energy source while also no chemicals are used. This concept can contribute significant to energy savings for drinking water production, because current drinking water production is energy intensive processing with 1,5 PJ/a for the Netherlands alone [ref].

The principle is very easy as demonstrated in Figure 5 . After flowing of the roof the rain water is harvested in tanks large enough to deal with high rainfalls. The collected water is purified from nutrients, bacteria and viruses, minor components by a biofilter and an UF membrane before storing to overcome droughts. Just before consumption a final UF membrane removes possible bacteria resulting from after growth.

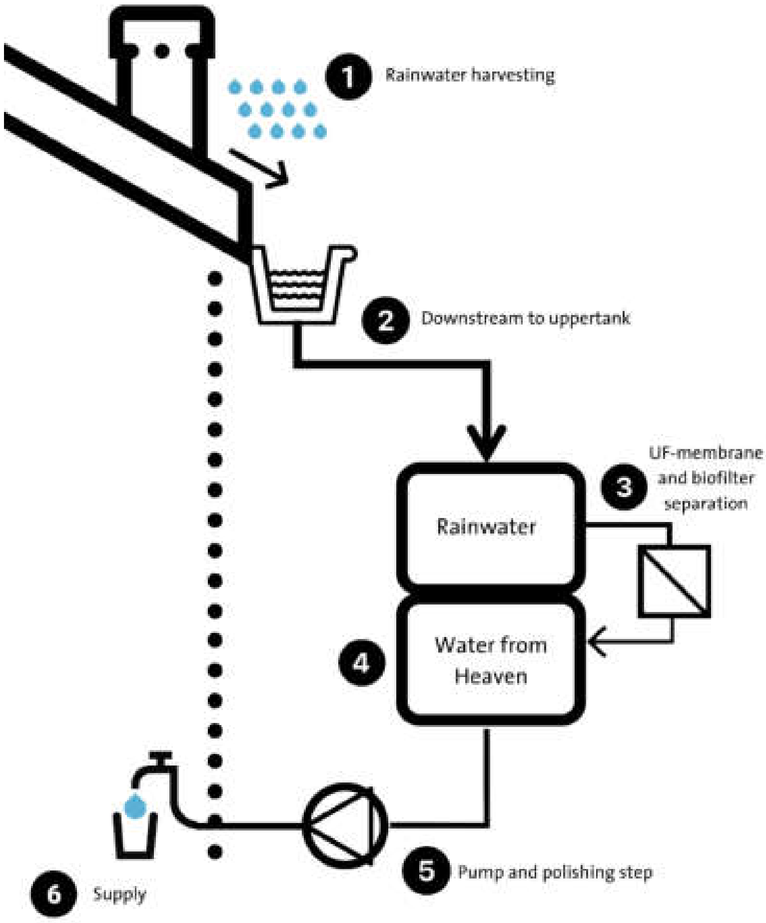

Figure 5, Water from Heaven scheme.

The water quality of Water from Heaven is recently certificated as Dutch drinking water by Kiwa.

Case 2: Hybrid green and grey roofs for food, power, drinking water production and biodiversity

In cities we are used to a multiple usage of the scarce space available. An excellent example of this is the flexible module of a green roof and gray roof currently under design. The green roof covers a horticultural greenhouse and receives enough daylight for vegetables and fruit. The plants are dripped with treated grey water as explained in NBS case 4. A percentage of the glass roof provides power produced by integrated solar panels. At the same time, rainwater is collected by the glass roof and treated as explained in NBS case 1 to supply the system of urban drinking water.

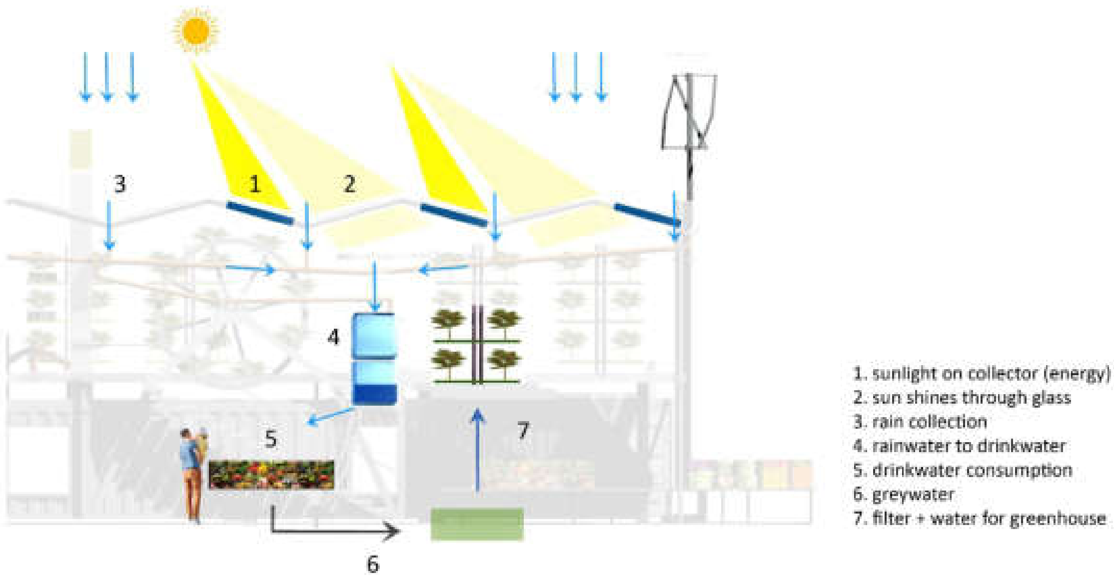

Fig. 6 Multi roof: water and energy harvesting in glass roofs above a green roof

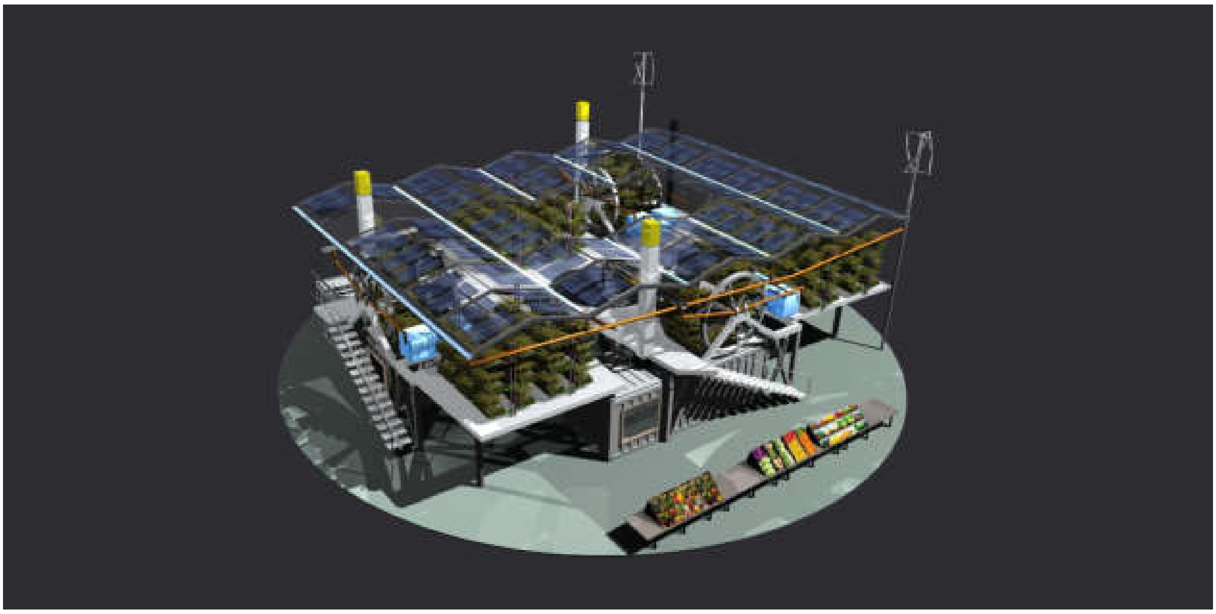

Fig. 7 Multi roof: water and energy harvesting in glass roofs above a green roof

Link for further reading: https://hansmoor.nl/

Case 3: Energy from black water

Faeces separated from grey water streams and residues from our food processing (kitchen and black water) can be anaerobic digested in a so-called Membrane Bio Reactor (MBR) producing methane, a most wanted energy source in house for heating and cooking. The heat content of the waste water can be used in a heat pump to increase the Coefficient of Performance (COP) of the system by lifting the lower temperature of the source of heat compared to ground water temperature. An example of such a technology is being developed by the Dutch company DeSaH BV, which develops sustainable innovations that can be used cost-effectively within the (decentralised) water chain. See figure 8 below.

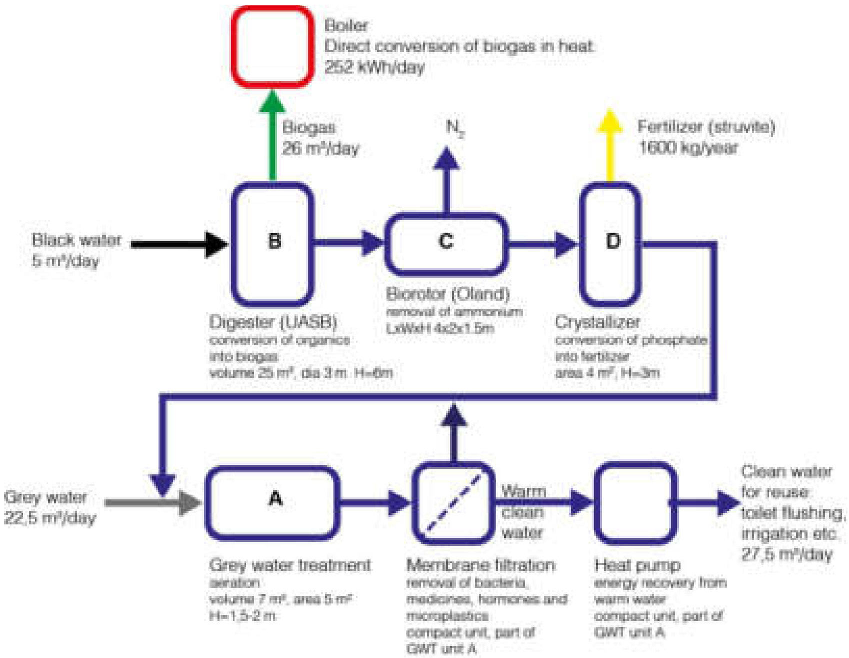

Figure 8 Technology concept for purifying black water and recovering water and energy [DeSaH, 2022]

Link for further reading: https://desah.nl

Case 4: Waste water treatment added with the prevention of the emission of antibiotics and pharmaceutical Residues

Smart and hybrid NBS Water Treatment processes could also very well be an effective measure to remove micropollutants. Emissions of micro-pollutants such as crop protecting agents (CAPs), PFAS and also pharmaceuticals and medicine residues cause an emerging threat to the environment since standard WTTPs are not suited to remove these. One of the important challenges, especially in a smart urban water grid is to reduce the emission of pharmaceuticals at sources such as health institutes like hospitals and elderly homes. The emission of antibiotics also contribute to antimicrobial resistance (AMR), rendering current health treatments worthless and simple infections can lead to severe consequences. Grey water treatment and reuse are common use all ready.

According to the WHO, AMR is one of the greatest threats to health and food safety [WHO, 2022]. It is increasingly evident that antibiotics, resistant micro-organisms, and their resistance genes are spreading invisibly through water. It is important that we tackle AMR effectively in water too. Antibiotics and other medicines will continue to play a key role in our everyday lives, therefore the demand for technologies to reduce AMR in water will increase on a global scale. By investing in sustainable innovative technological solutions for AMR now, we can avoid paying the costs of the damage that AMR and other drug residues will cause to our society. Removal of micro-pollutants from emissions effluent is state of the art technology with processes like adsorption processes and advanced oxidation. All current processes form however a relatively costly operations because of the low concentrations present. Intrinsic NBS however are hardly suited to remove very recalcitrant micro-pollutants such as antibiotics.

By implementing hybrid solutions consisting of both intrinsic NBS solutions like constructed wetlands (using helophytes), vermifilters (using worms) etc.. with inspired NBS deliver best of both worlds. So called polishing technologies based on oxidation like ozonization and other advanced oxidation processes are not specific or selective and also interact with the natural occurring organic material (NOMs) in the effluent. Hybrid NBS combinations of both therefore combine best of both worlds and are now under increasing attention for further development. When NOM content is effectively removed by NBS, oxidation technologies like ozonization are very effective to remove medicine residues [STOWA, 2022].

Link for further reading: White paper Dutch consortium for removal of antibiotics and medicine residues from water, https://www.amr-insights.eu/wp-content/uploads/2021/08/Whitepaper_Removal-of-Antibiotics-from-Water-Urgent.pdf

Conclusions

Smart urban water grids are an solution for current centralized systems. It can make cities climate and water resilient and even autarkic when water supply and demand are balanced even during droughts thanks to storage facilities.

Nature based solutions are key to reach such a balanced system, but ask to organize the city water flows.

Nature based solutions not only provide water solution but can at the same time contribute to energy, food and biodiversity nexus.

For industry these solutions are helpful to minimize risk of no-water supply during drought or shortages by climate change

The concept of smart urban water grids is new and innovative and, however promising, it requires various and vast research and demonstration options. This is for example illustrated by the newly started academic research poject Aquaconnect [WUR.]

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