D1.2 Factsheets on barriers and ways to overcome them

Kati Vierikko, Sonja Koivisto, Jussi Torkko, Iwona Wagner, Pascal Breil, Kinga Krauze, Renata Włodarczyk-Marciniak, Agnieszka Bednarek, Karolina Koprowska & Antti Rehunen

Contents

1. Introduction

The Atenas project is funded within European Union's Water JPI and the research is carried out by European Regional Centre for Ecohydrology of the Polish Academy of Sciences (ERCE PAS), Finnish Environment Institute (SYKE), FPP Enviro (Poland), and National Research Institute for Agriculture, Food and Environment (INRAE) (France). The project aims to contribute to closing the water cycle gap through securing water cycling and the quality of urban runoff by using NBS, but also increasing the resilience of urban systems to dry periods. The ambition is to increase project's impact through triggering learning process among the water users. For that purpose, the project develops real scale demo-sites in a gradient of urban pressures and urban dynamics, to embrace a range of conditions for future applications.

The project has examined critical factors in the planning, implementation and maintenance of nature-based solutions (NBS) in urban water management. The project's deliverable 1.1 includes the examination of critical factors based on ongoing developments in different contexts and using data from research literature, project publications, recent inventories and case study workshops

This deliverable 1.2 presents factsheets on NBS barriers and ways to overcome them. Factsheets include descriptions of ten NBS cases in Finland, Poland and France. Barriers and enablers of NBS are usually rather context-dependent, and therefore they are best exemplified through case examinations. Local factors vary significantly between NBS interventions and they need to be dealt with to understand why NBS have succeeded or failed to attain their objectives. On the other hand, many NBS projects face similar types of problems and can learn from previous experiences.

All factsheets follow a similar format. They present the type, location and scale of NBS. The water management problem the NBS is aiming to tackle is explained, and details are provided on the solutions including the capacity of the solutions. The effectiveness of the NBS is assessed on basis of existing studies and expert knowledge. Life cycle and maintenance are also explained as important attributes of NBS. NBS usually offer also other co-benefits than the water management solutions, and these are mentioned for the cases. In addition to benefits, the factsheets include an assessment of possible disadvantages and related risks. As regards, barriers of NBS, the type of the barrier is stated briefly, and the barrier is explained in detail focusing also on the ways they can be overcome. Alternative solutions for the NBS are included in the factsheets, considering e.g. traditional technical solutions. Enablers for better implementation are presented for several cases. Lastly, additional information, references and web links are provided.

2. Aviapolis – Example of underground stormwater management system

Type: Underground stormwater treatment system combined with meadow vegetation
Location: Immediate proximity to the airport, City of Vantaa, Finland
Scale: Local, managing surface runoff water from the airport area.

Problem: Airport has vast amount of impervious surfaces which proposes a challenge for surface runoff water management. Additionally, the runoff water from the airport contains remnants of antiskid treatment, de-icing fluids and possible oil or sewage leaks that cause stress for organic material and create shortage of oxygen in the waters (Aluehallintovirasto, 2017).

Solution: There are two separate underground systems, one of which handles surface runoff water from the terminal area and the other one from airport ramp (Fig. 4). The runoff water directed to the underground water treatment, is first infiltrated through sediment and biofilm and then distributed evenly to the meadow. The runoff water is aerated so that the above layers of system does not freeze during winter and surface vegetation works as insulation (Aluehallintovirasto, 2017).

After the treatment, the water is released to the brook Veromiehenkylänpuro and during rainy periods the water can be retained in flood basin to prevent flooding. The brook Veromiehenkylänpuro flows to the brook Krakanoja which is prone to floods and a potential spawning area for threatened fish species sea trouts (Finavia, 2019). The entire runoff water treatment system is inclined so that water naturally flows from detainment basin towards underground systems and flood basin, and finally to the brook Veromiehenkylänpuro (Aluehallintovirasto, 2017).

Capacity: Stormwaters from direction of Terminal area are distributed through pipes to a detainment basin, with a capacity of 10 000 m^3, before directing into the underground system. The detainment basin regulates the amount and quality of water in the wetland and retains impurities and sediment. The waters from ramp 8 have a detainment basin underground under the ramp.

Effectiveness: Not functional yet. Supposedly high effectiveness if constructed and maintained properly.

Life cycle and maintenance: The life cycle length depends on how well the maintenance is carried out. If maintained properly and the substances from the airport are not deteriorating the soil, then the life cycle of the structure is longer, and the effectiveness is higher. Attention to harmful substances must be paid while emptying the retention basins and removing the sediments.

Co-benefits: Safety of airport. The underground ponds will not attract birds as an open wetland would, which minimize the risk of birds colliding with departing and arriving aircraft (Aluehallintavirasto, 2017).

Disadvantages / related risks: The maintenance of underground wetlands might be difficult and technically challenging. Harmful substances from the airport might deteriorate the soil in the long run and that might affect the functioning of the structure. Although most of the runoff water containing glycol is gathered separately for special treatment, some remnants will end up in the stormwater system. Furthermore, the banks of the flood basin were quite steep and therefore could be prone to erosion. This could be prevented by planting deep-rooted vegetation on the banks.

Barrier type: Economic, climate, technical
Barrier description: There might be technical challenges in the construction or maintenance of underground system (see more in related risks). In addition, there are little experiences how the system function in Nordic climatic conditions. The maintenance costs of system can be higher than expected.

Alternative solutions: The runoff water from the airport area could also be collected and treated in an off-site treatment plant and directed to stormwater sewers. Other solutions include collecting the de-icing fluids with pads or vacuuming up the concentrated streams of it. Ecologically unsustainable solution would be allowing the untreated runoff water runs freely into a sewer and directing them to nearby brooks without any treatment (Aviationpros, 2020).

Figure 1 and 2. Open-faced stream coming from the airport to the retention basin in construction phase. © Sonja Koivisto

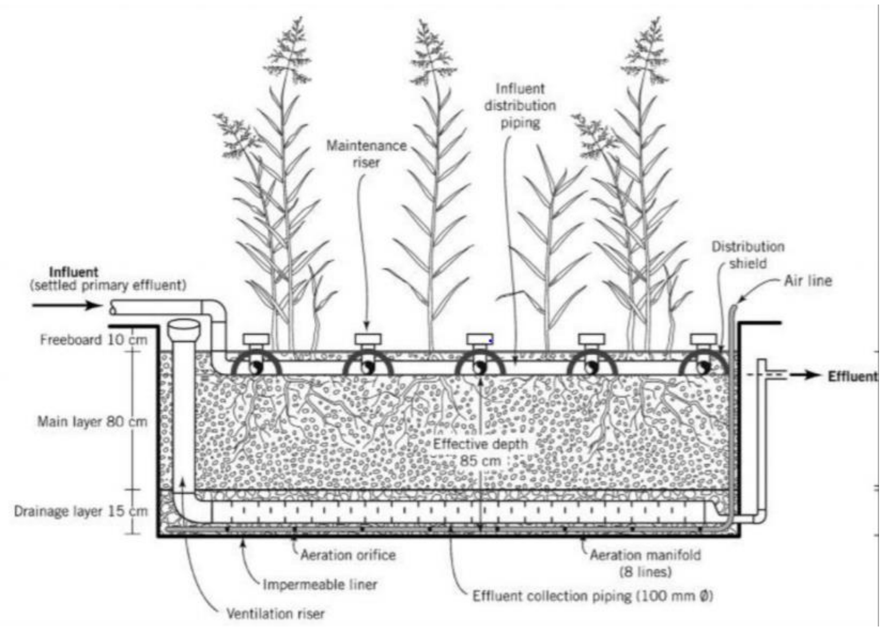


Figure 3. *The vertical structure of the underground water treatment system. (Picture: Finavia/ Sito)*

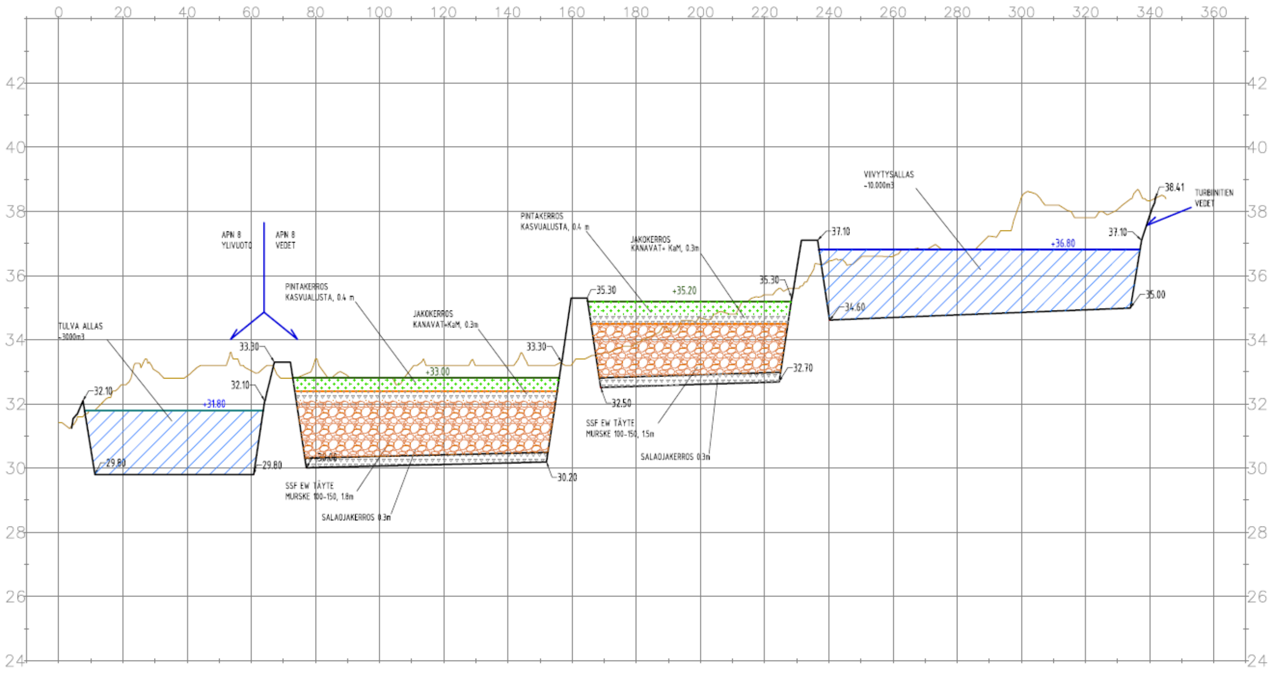


Figure 4. *The urban runoff water treatment system at the Helsinki-Vantaa airport area. From upper right to down left: detainment basin, 1st underground system covered by meadow vegetation, 2nd underground system covered by meadow vegetation and a flood basin for occasional runoff peaks. (Picture: Finavia/ Sito)*

References

Aviationpros 2020: <https://www.aviationpros.com/home/article/10380603/engineering-runoff-solutions>, citred 20.07.2020

Vesala, E. 2019: Hulevesien hallinnan monikäyttöiset alueet ja vuorovaikutus. <https://aaltodoc.aalto.fi/bitstream/handle/123456789/37931/master_Vesala_Emmi_2019.pdf?sequence=1&isAllowed=y>

Finavia 2019: An underground water treatment system will help Helsinki Airport clean water more effectively <https://www.finavia.fi/en/newsroom/2019/underground-water-treatment-system-will-help-helsinki-airport-clean-water-more>, cited 21.7.2020

Aluehallintavirasto 2017: Helsinki-Vantaan lentoaseman ympäristöluvassa määrätty selvitys koskien laskupurojen kunnostusta, Vantaa https://tietopalvelu.ahtp.fi/Lupa/AvaaLiite.aspx?Liite_ID=3369385

Finavia Oyj 2016: Helsinki-Vantaan laskupurojen kunnostustarpeen selvittäminen

3. The brook Illenpuro – Multiple benefits of stormwater NBS in Kartanonkoski residential area

Type: Stormwater collection, flow deceleration and biofiltration.
Location: The brook Illenpuro, Pakkala district, City of Vantaa.
Scale: Local, surrounding suburb of approximately 4 500 residents. In addition, the drainage basin of brooks consists of a large shopping mall (not shown in the above aerial photo) and other paved infrastructure.

Problem: Suspect to large runoffs with impurities from nearby impervious surfaces.
Solution: Open water flood ponds and banks to collect and hold stormwater, wetland vegetation to filter and deaccelerate water flows. Integrating an urban brook/flood management system to a residential neighborhood. The residential area Kartanonkoski represent a typical "garden city" with diverse and multifunctional public green spaces and with restricted access to motor vehicles. Inner part of the residential area, where the brook runs, is occupied for recreational use. Stormwater NBS with bridges and wetland vegetation are highly integrated to the neighborhood and they are part of the living sphere of the residents.

Capacity: No detailed information available.

Effectiveness: High effectiveness, the vegetation slows down the flowrate and filters the water (Ilmastokestävä kaupunki, 2014).

Life cycle and maintenance: The life cycle of the brook system is long, but it needs continuous management of the vegetation to maintain water areas open. The silt accumulating to the bottom of the ponds needs to be cleaned regularly (Ilmastokestävä kaupunki, 2014). Monitoring of the water quality is needed especially during additional construction and abnormal weather.

Co-benefits: • Biodiversity: Supporting local aquatic species diversity (see Fig. 3), • Ecological: micro-climatic conditions: refreshing park areas with integrated water systems. • Aesthetic: Visually attractive small-water pond.

Disadvantages / related risks: Periodical high levels of stormwater enter the brook. These erode the banks downstream, causing more solid matter to end up to adjoined water systems (Janatuinen, 2011). This especially true for Illenpuro, due to its channel moving through clay and silt soil. The stream flows to Krakanoja brook downstream, which is a new nature reserve. It is vulnerable if high levels of impurities or solid matter manage to reach it. The risk for unwanted impurities is especially real during high rains and flooding, if the vegetation is not able to slow down and filter the flows enough.

Initial waters entering the brook have high levels of impurities. Before sedimentation and filtration, these can be dangerous to the residents. The brook might also need water replacements during dry periods to protect the aquatic vegetation and to prevent smells. The vegetation needs to be planned in a way that its effectiveness remains high during different seasons and weather conditions. Some locals consider the brook as a danger to small children, due to its location in the middle of the neighborhood (VTT, 2010).

Barrier type: Climate, social, technical
Barrier description: • Climate: The conditions met by the brook might change in future due to climate change, which needs to be considered. • Social: Complex and visually attracting NBS systems will raise the area's housing prices, which might in some cases cause eco-gentrification (Haase et al., 2017). • Technical: the system needs capacity to control multiple types of runoff situations during different times of the year.

Alternative solutions: More local systems such as biofilters or rain gardens for each housing complex. This could be composed of block by block biofiltration and delaying infrastructure.

Enablers for better implementation: Lessons learned from other similar projects are that usually more filtering of stormwaters at their source is needed. This could pre-clean the waters to limit the amount of initial impurities entering the brook. More control of the flow levels during increased runoff to limit erosion downstream. The amount and species of the vegetation could be reconsidered, because the current vegetation limits some biodiversity due to its shading and dense nature (Friman, 2016)

Figure 1. One of the ponds integrated to the neighborhood. They collect and hold stormwater to slow down the flowrate © Jussi Torkko

Figure 2. Multiple roaches were present in the ponds. © Jussi Torkko

References

Friman, M. 2016: Aviapoliksen sudenkorentokohteet ja niiden säilyttäminen: Aviapoliksen pienvesiympäristöjen monimuotoisuuden huomiointi kaupunkisuunnittelussa: sudenkorentolajistoon vaikuttavat tekijät, lajien elinympäristöjen säilyttäminen ja parantaminen. HAMK opinnäytetyö. http://urn.fi/URN:NBN:fi:amk-2016061813185

Haase, D., Kabisch, S., Haase, A., Andersson, E., Banzhaf, E., …..Wolff, M. 2017: Greening cities e To be socially inclusive? About the alleged paradox of society and ecology in cities. Habitat International 64, 41-48.

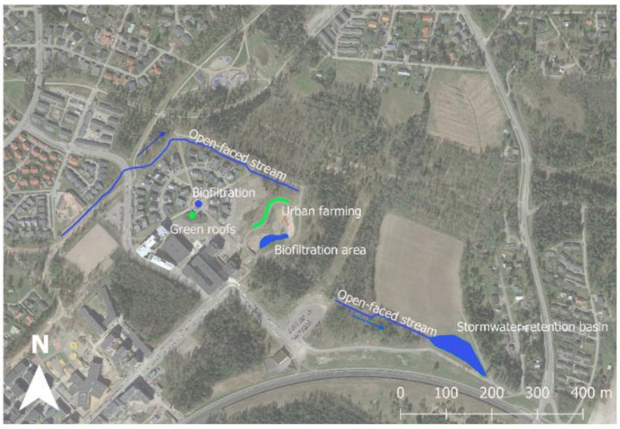
Ilmastokestävä kaupunki 2014: Hulevesien hallintarakenteet ja niiden kunnossapito. https://ilmastotyokalut.fi/files/2014/07/3.2.Hulevesien-hallintarakenteet-ja-niiden-kunnossapito_ty%C3%B6kalu.pdf

Janatuinen, A. 2012: Vantaan virtavesiselvitys 2010-2011.

VTT 2010: Asuinympäristön ominaisuudet ja asukkaan arvot. Kuluttajatutkimusnäkökulman sovellus asuinympäristön koetun laadun tutkimukseen.

4. Kivistö – NBS stormwater management in a new and fast developing residential area

Nature-based solutions for stormwater management in Kivistö



Type: Combination of different NBS elements for stormwater management in Kivistö area: biofiltration, green roofs an open-faced stream that leads to a retention basin
Location: Kivistö newly constructed medium-density residential area, City of Vantaa, Finland
Scale: Regional, NBS structures are located nearby the developing Kivistö residential area (see arrow in the Fig. 1), and construction principles that limit the coverage of impervious surfaces are applied.

Problem: Construction of a new residential area to a place that has previously been covered by forests changes the hydrology of the area by increasing the amount of stormwater that flows to Koivupäänoja stream.

Solution: NBS were integrated into the area already in the planning phase so that the increase in impervious surfaces wouldn't pose problems in stormwater handling and would improve the quality of stormwater. Lots of green space has been left as a park and many of these include open-faced streams which retain and clean water and slow down the flowrate. One biofiltration structure has been integrated into the center of residential buildings built in a circle (Fig. 3). These blocks were planned using a green index as a reference and some of them have green roofs (Sanaksenaho, 2015). Many small-scale nature-based stormwater management systems and urban farming are introduced in neighbourhood and at residental blocks. Construction principles that are applied in the whole area include that every block should have at least 20 meters of continuous green space and only three parking spots can be built in a row on the roadside before a permeable structure in between. Also, parking houses should be 70% covered by green roofs or rooftop gardens (Vantaa City Council, 2015).

Capacity: No detailed information available. Stormwater is meant to be handled by block but if that is not possible, the excess is led to regional retention basin via an open-faced stream (Vantaa City Council, 2015).

Effectiveness: High proportion of the area is paved. Current combination of NBS elements prodives medium effectiveness with the combination of different NBS elements.

Life cycle and maintenance: The life cycle varies by the structure. If maintained regularly, the structures can last long. The open-faced streams need to be monitored for signs of erosion and if erosion occurs, the banks should be replanted or made less inclined to prevent further erosion. The biofiltration area should be weeded and replanted with the original species if it has barren spots and the casing layer should be replaced about every 5 years (Ilmastokestävä kaupunki, 2014). The stream water quality should be monitored, and the stream should be kept clean of trash, sludge and excess vegetation and any erosion on the banks should be prevented. The retention basin should be drained sometimes and sedimented material removed from the bottom (Ilmastokestävä kaupunki, 2014).

Co-benefits: Recreational and aesthetic, integrating open water NBS into the large green space enhances the attractiveness of the area and encourage people to spend time outside. Specialized wetland can absorpt nutrients and purify the water quality of runoff water. Diverse vegetation provides habitats for insects and supports local biodiversity. Urban farming brings the production of food closer to city dwellers and reduces the need for food transportation.

Disadvantages / related risks: Considering the structures in Kivistö, the banks of open-faced stream had experienced some erosion which is not good for the structure. Erosion is also a risk in the biofiltration areas if barren spots are not replanted with the original perennials. The open-faced stream and the retention basin were a bit smelly during the site visit, so the water quality could be improved, and less organic material should end up in there. On the bottom of the stream, there is probably too much vegetation and sludge (see picture 1) which prevents the water flowing as planned and the stagnant water starts to smell during rainless periods (Ilmastokestävä kaupunki, 2014).

Barrier type: Planning and financial

Barrier description: The widespread use of NBS structures should be considered already in the planning phase. This restricts the way they could be integrated into an existing neighbourhood due to the existing water structures and lack of free space. NBS can also take up quite a lot of space and in central areas of the city, the opportunity cost of that space might be too high. On top of the opportunity cost of an alternative use for space, the NBS structures also cost, so the city must be ready to invest in NBS.

Alternative solutions: The usual solution would be to direct the stormwater to stormwater sewers.

Enablers for better implementation: More biofiltration areas before the water end up in the open-faced stream could reduce the nutrition load and smell in the stream and in the retention basin. Also, regular weeding as maintenance for the open-faced stream should be carried out.

Figure 1. Murto stormwater basins. Smaller in the front and larger wetland area on the background. Stormwaters from Kivistö are directed here via a stream. In the future, the field on the background and surroundings is planned to provide housing for 2000 people which will increase the amount of stormwaters. The neighbourhood identity would be built around urban farming and sustainable stormwater control (City of Vantaa, 2020). ©Sonja Koivisto

Figures 2, 3 and 4. Open-faced stream on the left, city gardening in the middle and biofiltering on the right. © Sonja Koivisto

Additional information

General plans of Murto stormwater basin <https://www.vantaa.fi/instancedata/prime_product_julkaisu/vantaa/embeds/vantaawwwstructure/108053_Murronpuiston_hulevesisaltaan_yleissuunnitelmaselostus.pdf>

References

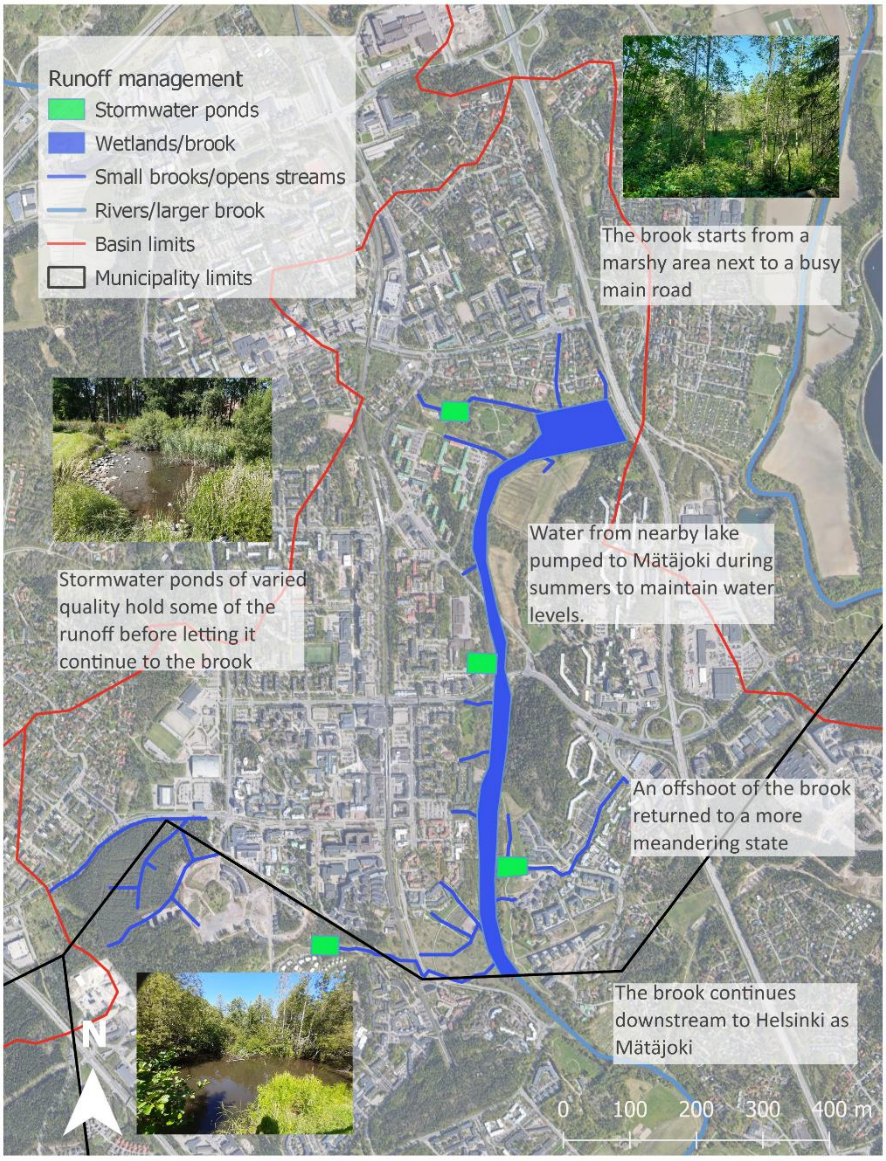
Sanaksenaho, V. 2015: Viherkertoimen käyttö Kivistössä. <https://www.vantaa.fi/instancedata/prime_product_julkaisu/vantaa/embeds/vantaawwwstructure/122722_kaupsu_Viherkertoimen_kaytto_Kivistossa.pdf>

Vantaa City Council 2015: Kivistön kaupunkikeskus 1. <https://www.vantaa.fi/instancedata/prime_product_julkaisu/vantaa/embeds/vantaawwwstructure/133187_kaupsu_230800_selostus.pdf>

City of Vantaa 2020: Kivistön turkoosikehän asemakaava. <https://www.vantaa.fi/instancedata/prime_product_julkaisu/vantaa/embeds/vantaawwwstructure/149458_232900_Kiviston_Turkoosikeha_asukastilaisuus_esitys_2020-01-30.pdf>

Ilmastokestävä kaupunki 2014: Hulevesien hallintarakenteet ja niiden kunnossapito < https://www.ymk-projektit.fi/suunnitteluopas/files/2014/07/3.2.Hulevesien-hallintarakenteet-ja-niiden-kunnossapito_ty%C3%B6kalu.pdf>

5. The urban brook Mätäjoki – an example combined natural and human constructed NBS



Type: Combined NBSs of natural brook with restoration and man-made stormwater ponds
Location: Upper section of the brook Mätäjoki, City of Vantaa, Finland
Scale: Regional, an approximately 3 km long section of the brook Mätäpuro in Vantaa. The brook habitat varies from open channel to a more closed wetland system. The catchment area (basin limits in the upper figure) covers built, heavily paved areas but also agricultural meadows and natural like urban forests.

Problem: Handling and taking advantage of increasing urban runoffs in a way that doesn't disturb the natural ecosystem of the brook and adjacent habitats and surrounding vegetation.

Solution: The slowing flow of meandering brook with wetland vegetation improves holding capacity and delay mechanism for runoffs. Stormwater ponds delay and hold urban runoff before distributing it to the brook. Restoration of the smaller channels into natural conditions.

Capacity: No detailed information.

Effectiveness: Relatively high.

Life cycle and maintenance: The brook itself is a natural ecosystem and with proper care along with active monitoring of the habitat's status, and maintaining dense and natural structure of surrounding vegetation the NBS can last as long as required. Maintenance is needed for stormwater ponds (cleaning and digging up accumulating sediments). Drastic changes in the flow rate of Mätäpuro are minimal, due to its wetland type characteristics being able to stabilize excess runoffs. It has a wide catchment area, because it used to be the channel for the area's main river of Vantaanjoki, before it diverged to a different channel due to post-glacial rebound (Ruth, 2004). Increased runoff from the new paved areas can be used to balance the water levels in the brook during the dry season. This is done to improve the flow rate and quality of water. Previously the water levels have been controlled by pumping water from the nearby lake of Silvola (Ruth, 2004). Returning the channels to a meandering state delays runoff creates ponds and substrate for wetland vegetation, which together with aquatic vegetation increases local biodiversity (Vantaa Kaupunkisuunnittelu, 2010)

Co-benefits: • Recreational: Greener/bluer infrastructure, refreshing nature areas next to tightly constructed residential areas. • Biodiversity protection: Provides suitable habitats such as flood meadows for groves, rare birds and insects (Vantaan kaupunki, 2017). Increased flowrate is important for local trout. The environment connected to the creek provides habitat for endangered beetle species (*Hylochares cruentatus*) in Vantaa.

Disadvantages / related risks: The brook is sensitive to water quality changes. Increase of runoffs brings the risk of more impurities reaching the brook, even when filtrating measures and considered. Many of the runoff structures located in parks around the brook are decades old and are not up to modern standards. During dry seasons they also cause a smell disturbance. Increased construction around the brook might affect its nature values. There are industrial areas around the brook which places a risk on its ecosystem. For example, in 2013 a solvent leak from a nearby factory killed most of the brook's aquatic life downstream (MTV national news, 2020).

Barriers
Barrier type: Land use, political, recreational
Barrier description: Using wetlands as an NBS to handle runoff requires, which might conflict with other planned land uses. The runoff infrastructure leading to the wetlands requires maintenance and refurbishing. Political will is needed for keeping the wetlands as first and foremost an important nature area, instead of a waste water dumping ground.

Alternatives: Leading the runoffs straight to the brook and wetlands, to let them handle the cleaning process. Would have drastic effects on the habitat's quality. Creating alternative pathways for the runoffs to reach their discharge point. Would also have drastic effects, due to the wetlands heavily leaning on runoff to maintain suitable levels of water

Enablers for better implementation: Modern runoff filtering before running the water to the brook system.

Figure 2. The surrounding vegetation of the brook is partly naturally developed and dense, blocking visual connection to the stream © Jussi Torkko

Figure 3. *Water levels in the constructed ponds running to the main water system is low during summer, leading to appearance of bottom layer. © Jussi Torkko*

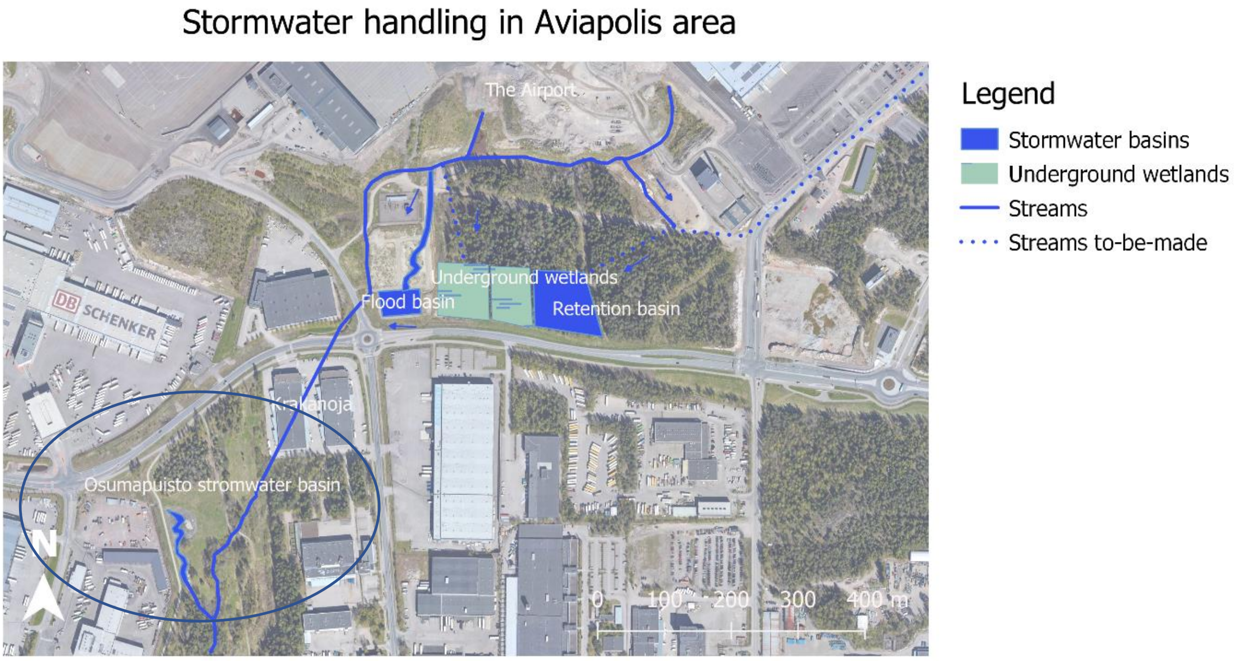
References

Ruth, O. 2004: Kaupunkipurojen hydrogeografia kolmen esimerkkivaluma-alueen kuvastamana Helsingissä, Vantaan kaupunkisuunnittelu 2010: Kaivoksela 3B

Vantaan kaupunki 2017: Mätäojan luonnonsuojelualue

MTV national news 2020: https://www.mtvuutiset.fi/artikkeli/likaista-kaupunkipuroa-kunnostetaan-lohijoeksi-matajoen-padosta-tehdaan-luonnonmukainen-koskipaikka/7880728#gs.bczfgy.

6. Osumapuisto stormwater basin – Example of public private partnership NBS



Type: Stormwater pond and flood meadow in public green space
Location: City of Vantaa, Finland, mostly industrial areas, quite close to the airport
Scale: Local scale

Problem: Osumapuisto retention basin gets its water from industrial areas and parking lots, mostly from west from Osumakuja. Surrounding areas are constituted of high proportion ofimpervious surfaces such as big roads, parking and industrial areas. Therefore, the runoff might contain impurities. The area needs more permeable surfaces so that the stormwater can be managed, retained and cleansed better. Runoff from this catchment area will end up in Krakanoja brook (also known as Veromiehenkyläpuro here upstream), which floods easily.

Solution: A private company could not fulfill the requirements for stormwater prevention or local management within their property, so they made a deal with City of Vantaa to finance the construction of retention basin in the park owned by the city. The basin will hold the stormwaters from the company-owned lands and nearby streets before releasing them to Krakanoja brook via a small, open channel. This is to regulate the amount and quality of water in Krakanoja which the sea trouts can climb in fall (Jormola et al., 2017). In flood situations, the water will flood to the surrounding meadow, which is slightly inclined towards Krakanoja brook (Jormola et al., 2017).

Capacity: No detailed information available. The flood meadow has a big holding capacity and will decease flooding downstream and increase flood control (Jormola, 2019).

Effectiveness: Moderate effectiveness. Some waters flow straight to Krakanoja brook, so they don't go through the structure.

Life cycle and maintenance: The stormwater retention basin should be easy to clean. The basin located in the park Osumapuisto where runoff water eventually flows, the basin should have solid bottom layer to withstand digging of accumulated sediment. The basin needs to be cleaned of trash and the entry and exit pipes need to remain open, free of items blocking it, and not frozen. There is a special need to take care that the small open channel to Krakanoja brook does not get clogged by a branch or trash. Sludge should be removed from the basin annually so that it will not flow away from the basin in flood situations. The life cycle of the structure is long. (Ilmastokestävä kaupunki, 2014)

Co-benefits: • Aesthetic: restored water pond attracts citizens • Ecological: improves the quality of the water • Biodiversity: provides habitats for water-dependent species such as dragonflies.

Disadvantages / related risks: Since the open channel which connects the retention basin to Krakanoja brook is so small, there is a risk that it can get clogged with tree branches or trash. In case of flood, the structure doesn't necessarily clean the water but simply retains it and some water infiltrates in the meadow and some overflows to Krakanoja brook. During continuous rains, if the retention basins cannot hold all the water, Krakanoja would still flood and the water quality might reduce.

Barrier type: Policy and land-use planning
Barrier description: The park is owned by the city of Vantaa and needs approval and situating the stormwater retention system there needs commitment of the city officers. Sometimes there are no green spaces or other free spaces available nearby where nature-based stormwater solution could be situated. In a more densely built industrial or residential area, where the competition for land is harder, it can be hard to get enough space for a reasonable cost unless incorporated very well into an existing park structure.

Alternative solutions: The common solution would be to direct the stormwater in a pipe to the closest brook or river, maybe untreated. The untreated water would contain suspended matter from the streets and parking lots. The retention basin and flood meadow flatten the flood peaks by holding the water and parts of it are infiltrated into the ground.

Figure 1. Stormwater retention pond and meadow for occasional flooding. © Sonja Koivisto

References

Jormola J., Vienonen S. & Ristimäki M. 2017: Vesihuoltoverkostojen tila ja riskien hallinta (VERTI) Rankkasateiden hallinta ja hulevedet Maanpäällisten hulevesien hallintakeinojen edistäminen. Työpaketti 6.

Jormola J. 2019: Uutta tietoa hulevesien käsittelyrakenteiden toimivuudesta vesistöjen kannalta.

Ilmastokestävä kaupunki 2014: Hulevesien hallintarakenteet ja niiden kunnossapito <https://www.ymk-projektit.fi/suunnitteluopas/files/2014/07/3.2.Hulevesien-hallintarakenteet-ja-niiden-kunnossapito_ty%C3%B6kalu.pdf.

7. Sequential Sedimentation Biofiltration System (SSBS) – for stormwater purification

Figure 1. Sequential Sedimentation Biofiltration System, part of a hybrid system purifying stormwater runoff from a street in Lodz, Poland, before its disposal to recreational reservoirs at the Bzura River. SSSB implemented within LIFE08ENV/PL/000517 Project EH-REK „Ecohydrologic rehabilitation of recreational reservoirs 'Arturowek' (Łódź) as a model approach to rehabilitation of urban reservoirs". © T. Jurczak.

Type: Purification of stormwater at the stormwater sewage outflows to different types of freshwater ecosystems (rivers and reservoirs), at different land use configurations and limitations, and purification of waters in small urban stormwater-fed rivers.

Location: City of Łódź, Poland, in various locations on the rivers of Sokołówka and Bzura with its recreational reservoirs, and in the City of Radom on the rivers of Mleczna and Cerekwianka.

Scale: Regional; handling rain falling from urban catchments of different scales and land use types.

Problem: Small urban (natural and stormwater) catchments are strongly affected by intensive land use, often of high development rates and low permeabilities. Thus stormwater runoff often transports high pollutants loads, which negatively affect ecological processes in urban freshwaters. Pollution control and land use management can seriously lower the loads, the rest must be handled at the stormwater sewage outflows. Conventional measures for stormwater sewage outflows would usually include oil and grit separators or sedimentation ponds. The efficiencies of pollutant removal for those measures, especially for total suspended solids, are very high and can reach as much as 98%, however the concentrations of dissolved nutrients leaving the separators is still high as for freshwater ecosystems, especially small urban rivers or reservoirs. These can be removed by biological treatment methods such as constructed wetlands. Biological water treatment processes require however require considerable land area, which is often difficult to locate in urban areas. Therefore systems with high efficiency of nutients removal per area unit are needed (Szklarek et al. 2018, Jurczak et al 2018, 2019).

Solution: SSBS consists of three zones: • intensive sedimentation zone (with surface flow) - sedimentation process in this zone takes part by water retention time or can be enhanced by additional lamellar structures, which reduce energy of the inflow and control areas of sedimentation; • intensive biogeochemical processes zone (with subsurface flow) made of limestone and optionally covered by coconut mat - an area of additional filtration function and phosphates adsorption; • biofiltration zone (with surface flow) - a wetland zone with native plants, in which the water flow direction and length f the water flow path may be further increased by additional flow barriers. • SSBS can be constructed on its own, as a separated system. It can be also preceded by engineered devises, such as oil and grit separators, establishing a hybrid (i.e. linking engineering and natural processes) system; • SSBS can be constructed on the stormwater sewer outflows, directly in the river or in the reservoir (“instream”) or on a “by-pass” of the river.

Capacity: The capacity of SSBS differs for different catchments and must be each time recalculated for the receiving flows and type of the catchment. Sizes of SSBS tested in Poland were: • (a) SSBS on the Sokołówka river (cleaning part of the high-flowing water directed to the SSBS directly from the stream by a “by-pass system”): 1040 m2 (Fig. 2; Szklarek et al. 2018); • (b) SSSB capturing and purifying stormwater runoff from a street, before its disposal to recreational reservoirs at the Bzura River: 425 m2 (Fig. 1; Jurczak et al. 2018); • (c) SSSB purifying water of the Bzura river at its inflow to a reservoir: 1200 m^2 (Fig. 3.; Jurczak et al. 2019); • (d) SSSB (hybrid systems) purifying stormwater from a stormwater sewage outflows from a small sealed catchment. Due to lack of adequate space on land, the engineered part of the hybrid system (separators) are located on land, while SSBS part of the system directly in the reservoir (“instream”): 100 m^2 and 150 m^2 (Fig. 4; Jurczak et al. 2018).

Effectiveness: High effectiveness. Efficiency of SSBS in pollution removal differ depending on their parameters, e.g.: • (a) reduced TSS by c.a. 60% and TP y c.a. 37% (Fig. 2; Szklarek et al. 2018); • (b) reduced TN by c.a. 71 % and TP by c.a. 67% (Fig. 1; Jurczak et al. 2018); • (c) reduced nutrients (TN and TP) by c.a. 57% and TSS by c.a. 91.3% (Fig. 3.; Jurczak et al. 2019); • (d) reduced nutrients (TN and TP) by more than 80% and TSS by c.a. 90% (Fig. 4; Jurczak et al. 2019).

Life cycle and maintenance: The life cycle is unknown, most likely long. The systems were implemented in the years 2011 to 2013 and are still functioning correctly. Maintenance includes cleaning of separators of the hybrid systems, removal of sediments from sedimentation zones and removal part of the vegetation in the autumn to avoid decay and nutrients internal loads and stimulate nutrients assimilation by intensive vegetation growth.

Co-benefits: • Biodiversity: provides additional habitats for vegetation and water fowls, crates “novel ecosystems”; • Aesthetics: may create visually attractive area supporting ecosystem services in different cities management zones (Krauze and Wagner, 2019); • Hydrological: mitigates floods and droughts through river water small retention; • Climate mitigation: contributes to CO_2 sequestration by vegetation.

Disadvantages / related risks: • Improper management of the systems after its construction may limit its effectiveness. Lack of, or delay in removal of sediments and vegetation mismanagement may lead to water quality deterioration in the SSSBS and in the protected waterbodies.

Barrier type: Planning

Barrier description: The space at the stormwater sewage outflows to the waterbodies may be limited, and instream purification systems can be considered in such situations.

Alternative solutions: Traditional measures include separators only, which leads to high nutrients loads transported from the stormwater sewage outflows to freshwater ecosystems. There is no conventional good solutions for the river instream purification.

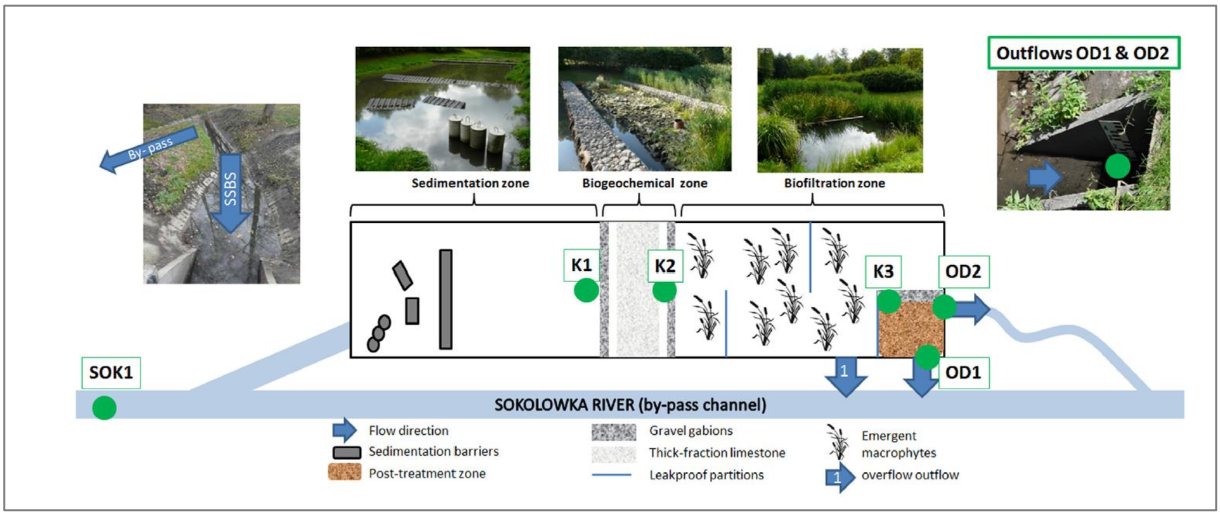


Figure 2. SSBS on the Sokołówka river, Poland, cleaning part of the high-flowing water directed to the SSBS directly from the stream by a "by-pass system". EU SWITCH Project (Szklarek et al. 2018).

Figure 3. SSSB purifying water of the Bzura river at its inflow to a reservoir ("insream"). LIFE08ENV/PL/000517 Project EH-REK. © T. Jurczak.

Figure 4. Hybrid system (separators and SSSB) purifying stormwater from at the outflow of stormwater sewage from a small sealed catchment. Due to lack of adequate space on land, the engineered part of the hybrid system (separators) are located on land, while SSBS part of the system directly in the reservoir ("instream"). Before (on the left) and after construction (on the right). LIFE08ENV/PL/000517 Project EH-REK. © T. Jurczak.

References

Szklarek, S., Wagner, I., Jurczak, T., Zalewski, M. 2018. Sequential Sedimentation- Biofiltration System for the purification of a small urban river (the Sokolowka, Lodz) supplied by stormwater. Journal of Environmental Management (205): 201-208

Jurczak, T., Wagner, I. Wojtal-Frankiewicz, A., Frankiewicz, P., Bednarek, A., Łapińska, M., Kaczkowski, Z., Zalewski, M. 2019. Comprehensive approach to restoring urban recreational reservoirs. Part 1 – reduction of nutrient loading through low-cost and highly effective ecohydrological measures. Ecological Engineering (131): 81-98

Jurczak, T., Wagner, I., Kaczkowski, Z., Szklarek, S., Zalewski, M. 2018. Hybrid system for the purification of street stormwater runoff supplying urban recreation reservoirs. Ecol Eng (110): 67-77

Krauze, K., Wagner, I. 2019. From classical water-ecosystem theories to Nature Based- Solutions - contextualizing Nature-Based Solutions for sustainable city. STOTEN (655): 697-706

8. Denitrification barriers for nitrogen removal from groundwater

Figure 1. Location of barrier - Czarnocin Reservoir. Project GEOFIBRUS „ Development of model geofibrous, biodegradable fold of biological nitrogen and phosphorus pollution remediation to in the affected areas of the agricultural landscape" (No N R14 0061 06/2009) National Centre for Research and Development; 2009-2012; *property rights:* P.404407

Figure 2. Location of barrier – Orla River, Łaszczyn Village (Rawicz). Project: RPWP.01.02.00-30-0010/17-00" Development and optimization of an innovative method for reducing significant scattered and area pollution in rural areas". Wielkopolska Regional Operational Programme 2014-2020 priority axis 1. Innovative and competitive economy. Action 1.2 Amplification the innovation potential of Wielkopolska companies).

Challenge: Runoff from agricultural or nitrogen polluted areas:

- increased possibility of nitrates outflow in groundwaters from the catchment
- with a high level of fertilization
- high rate of infiltration in poor sandy soil

Approximately 50% of N coming from fertilisers is not taken up by plants and is going to deeper soil layers and to the groundwater

Sometimes illegal discharges of urban waste water into fields overlap with unused fertilisers from the agricultural catchment area.

NBS and their targets: Due to activation of the denitrification process in the barrier the load of nitrogen in groundwater leaching from the agricultural catchment will be decreased (transformed to N_2). The barrier can be part of the ecotone zones, increasing their efficiency, especially during winter time or in area of the absence of free space it can function under the ground - independently in groundwater and surface water contact areas (coastal zone). This solution doesn't cause any degradation of the landscape.

The most effective sources of carbon in activation of the denitrification process in the barrier are: lignite, harl flax, oat straw and pine sawdust and the mix of those.




Type: Runoff of groundwater, polluted by nitrogen, through denitrification barrier:

- possible leaching from the cesspools
- high rate of infiltration in poor sandy soil
- increased possibility of nitrates outflow from the catchment

Location: Czarnocin reservoir- agriculture part of catchment; Orla River – underground barrier decreasing outflow from the catchment, Łaszczyn Village (Rawicz), Poland

Scale: Local, barriers along the banks of rivers and water bodies

Problem: Groundwater contaminated with nitrogen, especially high concentrations of nitrites and ammonia, negatively affects the biological life of the aquatic ecosystems into which they are discharged and contribute to their eutrophication. The problem is the identification in the catchment scale the area/red points with the high nitrogen outflow and finding the optimal locations for denirification barriers.

Solution: Denitrification barriers are decreasing the nitrogen level in groundwaters leaching from the catchment and consequently decreasing level of eutrophication of freshwater ecosystem.

Capacity: The capacity of denitrification barrier can be adjusted to its depth. Important factors are: availabity of organic carbon, nearly anaerobic condition and high groundwater level and high level of barrier moisture.

Effectiveness: High effectiveness – above 50 % of reduction of nitrogen in groundwater flowing through the barrier. Very important is the fact, the this biotechnology is "working" also during the winter time – thanks to microbiological activity in the barrier.

Life cycle and maintenance: The life cycle is most likely long (not calculated yet, but more than 10 years). After implementation in the catchment denitrification barrier doesn't need any maintenance or activity.

Co-benefits: Denitrification barrier for nitrogen removal is a holistic solution which provides not only removal of high amount and toxic N forms in the groundwater flowing through it, but additionally increases the caries value of the soil, soil moisture and vegetation biodiversity.

Disadvantages / related risks: One of the potentially biggest problem is the extreme drought and the large reduction of groundwater layers in the catchment area. This may result in the flow of nitrogen-contaminated groundwater under the denitrification barrier, so that they will not be sufficiently cleaned by microbiological processes occurring in the barrier.

Barrier type: Planning, spaces, financial

Barrier description: • Sometimes the lack of the adequate free spaces available or lack of the permition of land owners can be a limitation;

Alternative solutions: Traditional plant buffer zone that decreases nutrients and decreases their load to open water and their eutrophication.

Additional information:

Project GEOFIBRUS „ Development of model geofibrous, biodegradable fold of biological nitrogen and phosphorus pollution remediation to in the affected areas of the agricultural landscape ” (Nr N R14 0061 06/2009) National Centre for Research and Development; 2009-2012; ***property rights:*** **P.404407**

Project: RPWP.01.02.00-30-0010/17-00 ”Development and optimisation of an innovative method for reducing significant scattered and area pollution in rural areas”. Wielkopolska Regional Operational Programme 2014-2020 priority axis 1. Innovative and competitive economy. Action 1.2 Amplification the innovation potential of Wielkopolska companies)

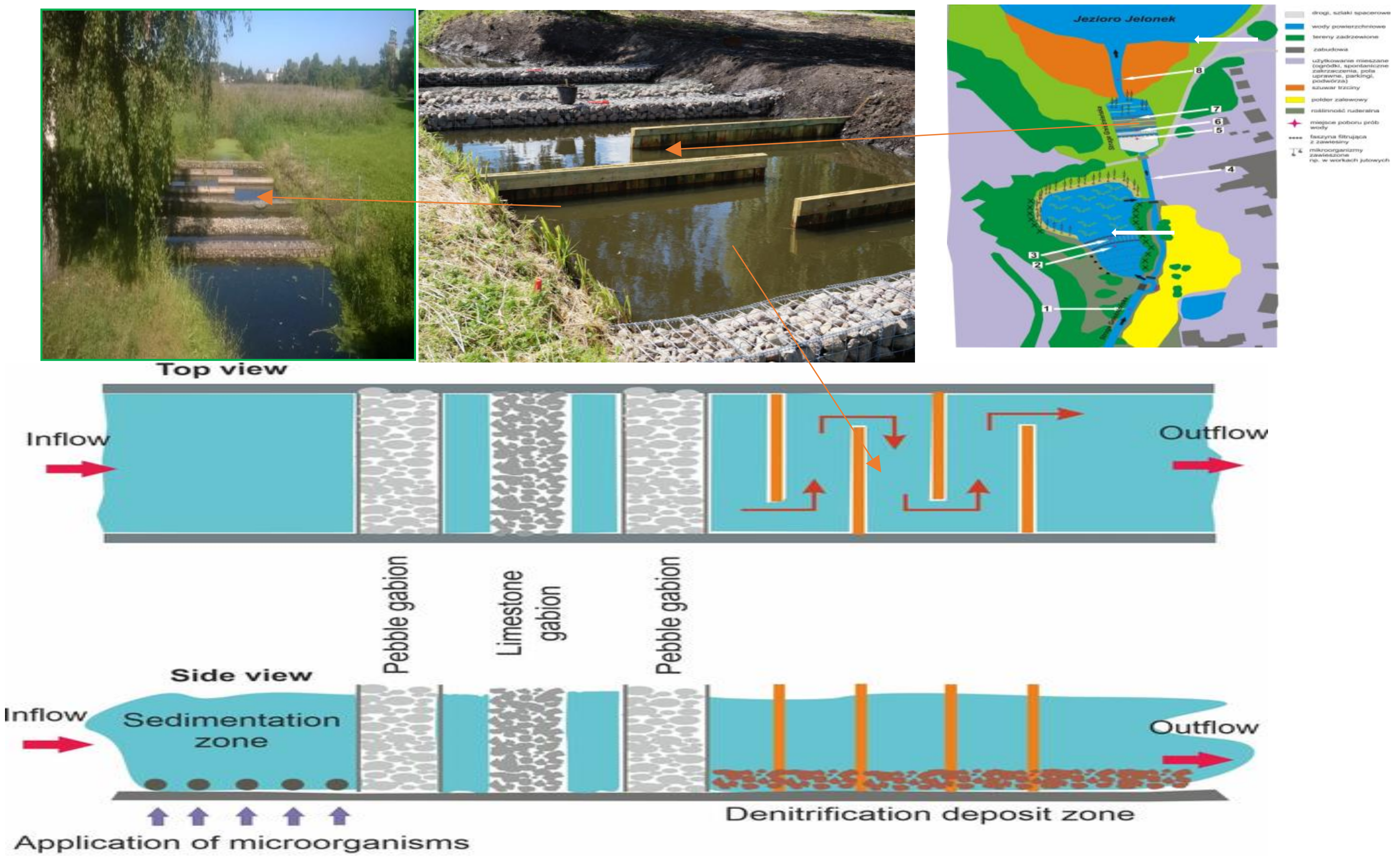
References

Izydorczyk K, Michalska-Hejduk D, Frątczak W, Bednarek A, Łapińska M, Jarosiewicz P, Kosińska A, Zalewski M. 2015. Strefy buforowe i biotechnologie ekohydrologiczne w ograniczaniu zanieczyszczeń obszarowych (Buffer zones and eco-hydrologous biotechnologies in reducing area pollution) ERCE PAN, ISBN 978-83-928245-1-0

Bednarek A., Szklarek S., Zalewski M. 2014. Nitrogen pollution remowal from area of intensive farming – comparison of varius denitrification biotechnologies. Ecohydrology & Hydrobiology 14 132–141.

Bettina Holsten, Agnieszka Bednarek, Annegret Fier, Nicola Fohrer, Goswin Heckrath, Heinrich Hoper, Cindy Hugenschmidt, Charlotte Kjergaard, Bjorn Krause, Norbert Litz, Andreas Matzinger, Dagmar Orlikowski, Cecile Perillon, Matthias Pfannerstill, Pascal Rouault, Walter Schafer, Michael Trepel, Marek Ubraniak und Maciej Zalewski. 2012. Potenziale für den Einsatz von Nährstoff- Filtersystemen in Deutschland zur Verringerung der Nährstoffeinträge in Oberflächengewässer. HyWa 56. Heft 1, 4-15.

9. Denitrification zone in Sedimentation Biofiltration System (SBS) for nitrogen removal from contaminated storm water



Picture1-3. Sedimentation Biofiltration System located in Gniezno, Poland (Struga Gnieźnieńska/Jelonek Lake) (construction: Mikronatura Środowisko Sp. z o.o., project GEKON2/O3/267948/21/2016 Development and implementation of a method of lake reclamation and surface water protection based on natural biological technologies using useful microorganisms; property rights: P.422056 29/06/2017)

Type: Runoff of storm water, polluted by nitrogen, through SBS system:

- possible leaching from the cesspools
- high rate of infiltration in poor sandy soil
- increased possibility of nitrates outflow from the catchment

Location: City of Gniezno, Poland

Scale: Local, in small rivers collecting rainwater

Problem: Rainwater heavily contaminated by nitrogen, especially high concentrations of nitrites and ammonia, negatively affects the biological life of the aquatic ecosystems into which they are discharged and contributes to their eutrophication. The problem is, that during extremely high rainfall events and rapid flows of rain water through the SBS, the retention time of rainwater in the denitrification zone is too short what limits its microbiological efficiency.

Solution: Activation of the denitrification zone in SBS decreases the nitrogen level in waters flowing through the system and consequently protects water ecosystem against eutrophication

Capacity: The capacity of denitrification zone can be adjusted to the size of the SBS. Important factors are: retention time – prefered for optimising the process is min. 5 days, nearly anaerobic condition and high availabity of organic carbon.

Effectiveness: High effectiveness – above 70 % reduction of nitrogen in storm waters flowing through the denitrification zone in SBS.

Life cycle and maintenance: The life cycle is most likely long (not calculated yet, as the technology is only 4 years old now), and will depend on the quality of maintenance of SBS. Maintenance of SBS includes: after winter cleaning and technical check, and removal of part of vegetation at the late autumn to avoid vegetation decay and further water quality deterioration. The denitrification zone, inside the SBS system doesn't need any maintenance.

Co-benefits: Denitrification zone for nitrogen removal in Sedimentation Biofiltration System (SBS) is a holistic solution which provides not only onsite stormwater management and biodiversity improvement, but also a meeting place for residents to play and enjoy. Located in public space, it creates an area for climatic and ecological education for children and awareness rising for adults, promoting sustainable behaviors. It helps in water scarcity handling by gradual distributing retained rainwater during dry weathers for greenery watering, while minimizing expenditure for tap water use for greenery watering. It increases ecological connectivity by creating resting place for birds and insects and upgrades urban space quality and aesthetics.

Disadvantages / related risks: Risk of water spilling/local flooding from SBS in densely developed areas. Denitrification zone for nitrogen removal in Sedimentation Biofiltration System (SBS) should be equipped with emergency outflow, to avoid flooding during extreme rains.

Barrier type: Planning, Cultural, Financial

Barrier description: • Sometimes lack of adequate free spaces available nearby can be a limitation; • Safety issues must be taken into consideration when the Sedimentation Biofiltration System (SBS) is placed in public space, therefore fencing of the area and placing adequate information and warnings must be considered;

Alternative solutions: Traditional measures include transporting stormwater to pounds or to the sewage system, without any biological sub-treatment, which increases their nutrient load and eutrophication of open water.

Additional information:

Sedimentation Biofiltration System location Gniezno, Poland (Struga Gnieźnieńska/Jelonek Lake) Construction: Mikronatura Środowisko Sp. z o.o., project GEKON2/O3/267948/21/2016 Development and implementation of a method of lake reclamation and surface water protection based on natural biological technologies using useful microorganisms; property rights: P.422056 29/06/2017)

NBS details:
http://proenv.pl/projekty/gekon/

Mikronatura Środowisko Sp. z o.o.

ul. Wachowiaka 8 B
60-681 Poznań

10. Green bus stops – example of onsite stormwater capturing by urban furniture

Picture 1. Green Bus-Stop in the city of Białystok, Poland (developed and implemented by FPP Enviro, Poland).

Type: Onsite capturing of rainfall and stormwater runoff from pavements by green roofs and vegetated retention-infiltration box of a bus stop shelter, as well as by other connected, optional elements such as tree-trench, infiltration trench, infiltration well, swale or green space.

Location: City of Białystok and City of Radom, Poland - in various locations in the streets of central, densely developed districts of the city.

Scale: Local; handling rain falling on the roof of the Green Bus-Stop and stormwater runoff from part of the surrounding pavements; not taking extra space comparing to initial situation (replaces existing urban furniture – traditional bus stops). Size of the standard Green Bus-Stop shelter: length ca. 5.4 m, width ca 1.9 m, however size can differ for individual design. Size of the surrounding sidewalk area possible to drain with the standard design: up to 160 m^2, can differ in individual design.

Problem: Most impermeable areas in cities are those of streets and pavements in the central, densely developed parts of the city. This is also where bringing blue-green infrastructure and nature-based solutions is most problematic, because of compact underground infrastructure and densely developed and build-up surfaces. Additionally, the runoff contains several types of pollution, which transfers through the city surfaces and sewage systems to the natural environment. In these parts of cities, the living environment for plants and people is often difficult, because of instable water conditions (usually dry, with temporal flooding) and temperatures (urban heat island).

Solution: Green Bus-Stop is a piece of innovative, urban-street, stormwater capturing furniture, which can be incorporated into dense city areas and does not require additional space. Opposite to traditional bus stops, Green Bus-Stop serves several functions, using the same space. Aside from being a shelter for the passengers to wait for the next connection, it retains stormwater and provides extra green space for people and nature with all the related ecosystem services. Stormwater is retained in several ways: each bus-stop is covered with a plant-based green roof underpinned with a water retention layer; during dry weather, the water is used by the plants and evaporated, making space for the next fallout; the excess of the water from the roof flows down to the vegetated retention-infiltration box in the back of the shelter. The box collects also stormwater from the surrounding sidewalk. The vegetated retention-infiltration box supports climbing plants which grow on the wall at the back of the construction, creating additional green space. The excess water from the vegetated retention-infiltration box can be further used locally by nearby green areas, trees, or other stormwater NBSs connected to the Green Bus-Stop water system, or be drained to the sewage system.

Capacity: Green roof of the Green Bus-Stop retains even up to 90% of the annual stormwater falling on its surface. In its standard design version, it can catch up to 180 L of rain during one-time rain event. The capacity of the vegetated retention-infiltration box can vastly differ in its capacity, storing in its standard design version ca 100 L of water. Additional water retaining elements can included e.g. tree-trench system (storing in the City of Radom additional c.a. 470 L of stormwater) and infiltration well (storing in the City of Radom additional c.a. 370 L of stormwater). Other NBSs are also possible to connect, according to the space availability.

Effectiveness: Medium; Green Bus-Stops capture mostly water falling on the roof of the shelter; High effectiveness may be achieved in case of draining additional space from the neighboring pavements.

Life cycle and maintenance: The life cycle is most likely long (not calculated yet as the technology is only 2 years old now), and may depend on the quality of maintenance. Green Bus-Stops needs regular maintenance and conservation of the technical construction of the shelter (2-4 times a year overall, visual, technical check; cleaning according to the needs, at least once a year, after the winter season and salt application on the roads). Additional maintenance is needed for the green elements and water conveyance system (especially downspouts, which must be revised for their effectiveness of water flow).

Co-benefits: Aside of help in minimizing local flooding and stormwater sewage systems overloads, the Green Bus-Stop contribute to urban heat island mitigation. It does so by providing new green patches in densely developed parts of the city and supplying them with retained stormwater, which by evaporation cools and humify the air. The temperature of the green roof of the Green Bus-Stop can be lower even by 10°C, comparing to the traditional metal roofs. It therefore can be more friendly to the passengers with respiratory system disorders, children, elderly and other sensitive groups. Green Bus-Stop supports local urban biodiversity by providing a green "stepping stone" for insects and birds. It is also more friendly to birds by limiting their collisions with the glass of the traditional bus stops. The bus stops contributes to CO_2 sequestration, builds awareness for stormwater and climate behaviors and upgrades urban space.

Disadvantages / related risks: Installation of Green Bus Stops should take place in spring, summer or late summer only, otherwise proper establishment of green roof is not possible. There is a need for very intensive watering (even twice a day) for the first six weeks after installation of the green roof. Later, watering may be needed only occasionally, in case of dry and high temperature conditions continuing for longer than 3 weeks. In case of Green Bus-Stops collecting stormwater from additional space from pavements, no salt or no other de-icing agents which can be harmful to the plants should be applied on these pavements in winter. In order to drain additional area, adequate slopes of the surrounding pavements must be assured.

Barrier type: Technical, Planning, Organizational, Administrative

Barrier description: • It is not possible to install green roof on a regular shelter. A special construction is needed to safely support extra weight of water, snow and vegetation on the roof and to allow water flow between the elements of the construction; • In some cities or districts, barriers may be related to visual requirements / identification guidelines and special permissions from relevant city units (e.g. city council, city architect) may be needed; • Implementation of the Green Bus-Stop may require temporal change in the public transport or traffic organization, e.g. organizing temporal bus stop for the time of Green Bus-Stop installation (2-3 days); • Maintenance of Green Bus-Stop may be assigned individually in each case to a respective city unit. Road departments are usually responsible for maintenance of bus shelters and road infrastructure, however do not have greenery maintenance in their responsibilities. Cooperation for cost and responsibility sharing with green facilities departments may be considered as solution - Green Bus-Stops may be categorized as green facilities, thus part of the maintenance cost can be covered by the budget for maintenance of green areas and assigned to greenery departments.

Alternative solutions: Stormwater from the bus stops in densely developed city areas is usually disposed directly to the road and then, through road drains, to the sewage systems. Alternatively, underground stormwater storage may be considered.

Picture 2. Green Bus-Stop in the city of Białystok, Poland (developed and implemented by FPP Enviro, Poland).

Picture 3. Green Bus-Stop with the excess of water directed to tree-trench in the city of Radom, Poland (developed and implemented by FPP Enviro, Poland).

Additional information:

Green Bus-Stops were invented, developed and built in Radom within a project LIFE-RADOMKLIMA-PL (LIFE14CCA/PL/000101) "Adaptation to climate change through sustainable management of water of the urban area in Radom city", co-financed by the European Union and the National Fund for Environmental Protection and Water Management in Poland.

http://zieloneprzystanki.pl/en/home

http://www.chronmyklimat.pl/projekty/eko-lokator/aktualnosci/zielone-przystanki-retencjonujace-wode-opadowa-w-radomiu-element-zielonej-infrastruktury-i-zagospodarowania-wod-opadowych

https://www.youtube.com/watch?v=iqxAFxy14f0&index=5&t=0s&list=PLg0xKDFc6_G0fOjT2ikl-9JUwT1ls1oEC

http://bialystok.naszemiasto.pl/artykul/zielone-przystanki-na-placu-nzs-w-bialymstoku-czy-cos,5079469,artgal,t,id,tm.html

https://www.bialystok.pl/pl/wiadomosci/aktualnosci/zielone-przystanki-w-bialymstoku.html
http://bialystok.wyborcza.pl/bialystok/7,35241,24651152,dwa-zielone-przystanki-w-bialymstoku-na-dobry-poczatek.html

11. Climapond – biological pond for roof stormwater retention and infiltration and biodiversity support


Picture 1, 2. Climapond in the Public Kindergarten No 16 in the city of Radom, Poland (construction: FPP Enviro, Poland within an EU project LIFE-RADOMKLIMA-PL, LIFE14CCA/PL/000101; property rights: P.419910, 20/12/2016).

Type: Onsite stormwater capturing from roofs by retention-infiltration ponds, supporting local biodiversity, connected to raingarden with infiltration trench and emergency outflow to sewage system.

Location: City of Radom, Poland, in various locations in public space, in districts of the city with mixed landuse.

Scale: Local; handling rain falling from roofs of buildings.

Problem: Roofs are one of the critical elements of urban space, contributing to excessive runoff, resulting in local flooding and stormwater systems overload. At the same time, during dry weather, surrounding green areas dry fast and require using tap-water for their watering which generate high maintenance costs. Dry period also destroy biodiversity causing deterioration of vegetation, simplification of plants communities and water shortage to small animals (e.g., birds, insects). Also, lack of open water elements in cities have negative impact on microclimate, urban heat island and quality of life. Local capturing roof water can be a game changer in stormwater onsite management and climate adaptation for cities.

Solution: Climapond re-introduces concept of a village pond as a stormwater capture method in urban areas. It collects stormwater from nearby roofs and creates a semi-natural habitats for animals and plants and thus supports biodiversity. In the design process, ecological requirements are considered at the same level as water and technological aspects. The hydraulics of the inflowing water is controlled by an innovative inlet device that minimizes disturbances to biodiversity even during heavy rains. Part of the inflowing water is retained in the pond all year round, to assure safe habitat for plants and animals, improve microclimate and mitigate high temperatures. Some of the water infiltrates into the surrounding ground through designated infiltration areas, providing water to the surrounding greenery in periods of dry weather and emptying space for the next rainfall. The system is designed in collaboration with biologists and landscape architects. Emergency outflow keeps the area safe in case of excessive rains. Climapond design is protected by property rights (P.419910, 20/12/2016).

Capacity: The capacity of Climapond can be adjusted to the size of the roof from which stormwater is to be captured. The minimum space requirement for the Climapond retaining water from the roof area of c.a. 225 m^2 together with the surrounding vegetation (buffering belt) around it, is about 25 m^2. Additional space may be needed to connect downspout to the Climapond inlet device and to combine Climapond with other stormwater facilities.

Effectiveness: High effectiveness. Elements properly scaled to the size of the roof can retain 100% of stormwater with zero outflow to the sewage system.

Life cycle and maintenance: The life cycle is most likely long (not calculated yet, as the technology is only 4 years old now), and will depend on the quality of maintenance. Maintenance includes after winter cleaning and technical visual check, and removal of part of vegetation at the late autumn to avoid vegetation decay and water quality deterioration.

Co-benefits: Climapond is a holistic solution which provides not only onsite stormwater and biodiversity management, but also a meeting place for residents to play and enjoy. Located in public schools, it creates an area for climatic and ecological education for children and awareness rising for adults, promoting sustainable behaviors. It provides services of microclimate regulation and cooling (urban heat island mitigation) as well as CO_2 sequestration. It helps in water scarcity handling by gradual distributing retained rainwater during dry weathers for greenery watering, while minimizing spending for tap water use for greenery watering. It increases ecological connectivity by creating resting place for birds and insects and upgrades urban space quality and aesthetics.

Disadvantages / related risks: • Quality of water in Climapond: high density and diversity of vascular plants should be maintained, to maintain low trophy of the water and minimize the risk of algal blooming; • Maintenance: Climaponds may be categorized as green facilities, thus maintenance cost can be covered by the budget for maintenance of green areas of the city; • Risk of water spilling/local flooding in densely developed areas: Climapond is equipped with emergency outflow to the sewers, to avoid flooding during extreme rains.

Barrier type: Planning, Cultural,

Barrier description: • The space at schools or kindergartens is owned by the city and needs cooperation, commitment and approval of the city officers and the educational unit management; • Sometimes lack of adequate free spaces available nearby can be a limitation; • Safety issues must be taken into consideration when the Climapond is placed in public space, therefore fencing of the area and placing adequate information and warnings must be considered; • Water must be checked for its quality to make sure that it is safe for the children to play around.

Alternative solutions: Traditional measures include transporting stormwater to the sewage system, which enhances drought in the area and lowers its attractiveness. Water can be also freely distributed to grasslands, however in such measure, biodiversity support and space upgrading aspects are much less pronounced and the risk of uncontrolled spilling is higher.


Picture 3, 4. Climaponds in living area in the city of Aarhus, Denmark (construction: Amphi Consult Denmark, FPP Enviro, Poland).

Additional information:

Climapond in Radom was constructed within a project LIFE-RADOMKLIMA-PL (LIFE14CCA/PL/000101) "Adaptation to climate change through sustainable management of water of the urban area in Radom city", co-financed by the European Union and the National Fund for Environmental Protection and Water Management in Poland. Climaponds are protected by property rights: P.419910, 20/12/2016.

NBS details:

https://stateofgreen.com/en/partners/klimaspring/solutions/biowater/

https://klimaspring.dk/prejekter-og-projekter/biowater

AmphiConsult Germany, Neu Darchau: fb@amphi.dk, ++49(0)176-29127747
AmphiConsult Denmark, Copenhagen: lb@amphi.dk, ++49(0)176-29127747
FPP Enviro, Poland, Warsaw: fpp@fppenviro.pl, ++48 662 025 199

NBS in application

https://portalkomunalny.pl/radom-uczy-jak-zatrzymac-wode-wiecej-o-deszczowce-w-tym-tygodniu-na-konferencji-w-gniewie-374926/

http://www.radom.pl/page/4,aktualnosci.html?id=10189

12. Porous Ramp – Amplification of the self-purification capacity of small urban watercourses to counterbalance pressure of storm water pollution inputs

Figure 1. Periurban landscape were porous ramp are build (locations indicated by red bars).

Figures 2 and 3. Implementation phases of a porous ramp: left- stony ramp shaping across the Ratier little river, right – sand accumulation acting as biofilter upstream the porous ramp after 8 months of functioning.

Type: Ramp system consisting of rollers.

Location: Small peri-urban river in the city of Lyon.

Scale: Sub-basins (30 km2) exposed to numerous urban discharges during rainy weather.

Problem: The flooding and bad water quality caused by stormwater.

Solution: This device causes the accumulation of sand upstream for about thirty metres and 0.3 m thick. The combination of the accumulated sand and the porous ramp favours the infiltration of water and its horizontal movement in the sand. The same is true for the pollution produced by urban rainy weather discharges (RUTP). The less mobile deep sand matrix allows the development of bacterial biofilms that biodegrade the organic matter brought in by the RUTPs. The water leaving the porous ramp is purified. The ramp shape means that the watercourse is not completely blocked to allow aquatic species to circulate. The system is ideally placed at the exit of a bend in the watercourse to amplify the natural deposition process. The biodegradation processes alternate between oxidation and microbiological reduction with the water level. The processes of dilution of pollutants and mechanical renewal of the sand take place during floods. These alternations are regulated and influenced by natural hydrology. Here we amplify the natural biodegradation process by ecological river engineering. The shape of ramp makes it possible to maintain a minor channel to ensure the continuity of circulation of aquatic species. It is necessary to choose an expansion zone without stakes or to create more sills of lower height. Agreement must be reached with fishing associations so as not to impact breeding areas.

Capacity: The results obtained on a xeperimentary pilot site over several years of observation showed Variations per m3 of sand: 67 m cumulated sand, distributed in three constructed weirs, with 0.6m depth and occupying the width of the bed (1.2 m).

COD mg/L	NH^{4+} mg/L N	NO^{2-} mg/L N	NO^{3-} mg/L N	PO_4^{3-} mg/L
-0.038	-0.011	-0.003	0.087	-0.008

E.g.: for 100m3 of sand we obtain a COD reduction of 3.8 mg/L under the condition of a flow in this medium.

Effectiveness: It depends on the shape and position of the porous ramp in the longitudinal and cross profile of the watercourse. This conditions the flow circulation in the sand stock and the residence time, which should not be too short. It is also necessary that the accumulated volume of sand, the biofilter, is sufficient for the organic load to be treated. The transit time depends on the cumulative length of sand and the average slope of the river bottom.

Life cycle and maintenance: The sand massif is self-sustaining by alternating phases of deposition and erosion with the natural flooding of the watershed. However, sand banks may become vegetated when morphogenic floods do not occur for two or three years in a row. In this case it is necessary to scrape the vegetation, which favors the clogging of the sandbank and limits the infiltration of water. It is therefore necessary to monitor this point to ensure the effectiveness of the device. The minimum size of the pebbles is calculated in principle to withstand the tensile forces of the centennial flood. It can also happen that a major flood, greater than a centennial flood, may wash away the sill. In this case, it must be rebuilt.

Co-benefits: In principle, the system is placed in small water courses heavily impacted by urban runoff. The blocking and biodegradation of pollution by the sandbanks makes it possible to protect the quality of the water downstream while providing minerals useful for other biogenic cycles. The quality of the more important watercourses is protected and the biomass produced is favored. These dispoitives have natural limits. Their function is to treat the overflows of the unitary networks. Any excess pollution must be reduced at the source. It is therefore a device that warns about the limits of biodegradation in watercourses.

Disadvantages / related risks: The design must be based on a precise hydraulic study so as not to create flooding problems. Clogging can occur due to lack of morphogenic floods. Plants can then settle and encourage the river to overflow. The surface of the sandbank must then be scarified and the nascent vegetation removed. The device must not create an obstacle to the movement of aquatic species. The porous ramp must not significantly influence the overflowing water line. The creation of sandy beds is considered unsuitable for the reproduction of poisons.

Limits of application: This type of device is suitable for rivers that carry sand or fine gravel and are subject to seasonal flows. This mainly concerns headwater rivers with a local slope of at least 1/100.

Barrier type: Environmental and social

Barrier description: • Social: Shared use of the watercourse. The opposition comes from fishermen, with whom it must be agreed not to install the device in fish spawning areas. • Environmental: The device should not be installed in an area where the overflow of the river creates a risk of flooding.

Alternative solutions: In principle, stormwater spillways should only operate about twenty times a year to limit impacts on the receiving aquatic environments. With urban sprawl, the saturation of unitary networks in wet weather produces many more overflows. Sewerage networks should be of good capacity and in good condition. The current solution is to disconnect rainwater from the combined sewerage system to infiltrate it or return it to a watercourse after settling or biofiltration.

Figure 4. Porous Ramp System in the Ratier River - Equipped with wooden sticks upstream to monitor the formation of the sand biofilter. (Construction: Green Style, INRAE Designer, Owner: SAGYRC - Syndicat fluvial France).

References:

Wagner I., Breil P., 2013. The role of ecohydrology in creating more resilient cities Ecohydrology & Hydrobiology 13 (2013) 113–134.

13. Summary

In the following table seven NBS cases are summarized identifying a) different types multifunctionality, co-benefits and ecosystem services and b) barriers and risks. In the table 1 means that the factors is identified significant in the case and 0 means it is not.

Nature-based solution in urban water management					Multifunctionality/ co-benefits/ ecosystem services							Barriers and risks										
Country	City	Name	Type	Key solution	Aesthetic	Education	Biodiversity	CC adaptation/mitigation	Environment	Recreational	Safety	Biodiversity	Environmental	Economic	Climate change	Cultural	Information	Political	Planning	Practical	Social	Technical
Finland	Vantaa	Aviapolis	Underground stormwater treatment system combined with meadow	Managing surface runoff water from the airport area	0	0	0	1	1	0	1		1	1	1	0	1	0		1	0	1
Finland	Vantaa	Kartanon-koski	Stormwater collection, flow deceleration and filtration	Managing surface runoff water from housing and commercial area	1	0	1	1	1	0	0		1	0	1	0	0	0		0	1	1
Finland	Vantaa	The brook Mätäjoki	Example combined natural and human constructed NBS	Urban runoff control	1	1	1	1	1	1	0	0	0	1	0	0	0	1	1	0	1	0
France	Lyon	Porous Ramp	Ramp system consisting of rollers	Amplification of the self-purification capacity to counterbalance pressure of storm water pollution inputs	0	0	0	1	1	0	0	1	1	0	0	0	1	0	1	0	1	0
Poland	Gniezno	Struga Gnieźnieńska/ Jelonek Lake	Sedimentation Biofiltration System (SBS)	Nitrogen removal from contaminated storm water	0	1	1	1	1	0	1	1	1	1	1	0	1	0	1	1	1	1
Poland	Lodz	Bzura River	Sequentional Sedimentation Biofiltration System	Purifying stormwater runoff from a street	0	0	1	1	1	0	0											
Poland	Łaszczyn Village (Rawicz),	Czarnocin reservoir & Orla River	Denitrification barriers for nitrogen removal from groundwater	Decreasing the nitrogen level in groundwaters leaching from the catchment and consequently decreasing level of eutrophication of freshwater ecosystem	0	1	1	1	1	0	1	1	1	1	1	0	1	0	1	1	1	1