3.14 Water Quality – general urban

Project Name: CONNECTING Nature (Grant Agreement no. 730222)

Author/s and affiliations: Stuart Connop[1], D. Dushkova[2], D. Haase[2], C. Nash[1]

[1] SRI - Sustainability Research Institute, University of East London, United Kingdom

[2] Geography Department, Humboldt University of Berlin, Berlin, Germany

Water quality – general urban	**Water Management**
Description and justification	Run-off water in cities represents a threat to water quality by conveying high pollutant loads into receiving water bodies and ground water aquifers. NBS can help manage and improve urban water quality through settlement, filtration, bioretention and phytoremediation. Emerging techniques using remote sensing technology includes using high resolution satellite or airborne optical imagery (visible and infrared), DSM (Digital Surface Model) height information and existing building out- lines maps (footprints) to estimate the percentage of vegetated areas on building roofs and to identify potential green roof sites, providing municipalities with the opportunity to use this data for urban planning decisions in the field of climate modelling, drainage system calculation and biodiversity networks. Recent and planned launches of satellites with improved spectral and spatial resolution sensors should lead to greater use of remote sensing techniques to assess and monitor water quality parameters. Data on the water quality performance of nature-based solutions collected in these ways can be used to: • Quantify the benefits of NBS in terms of stormwater/waterway quality improvement; • Assess any negative impact on water quality of diverting rainwater through NBS; • Calculate total pollution loading being released from an NBS (when combined with flow rate calculations); • Assess compliance with Water Framework Directives; Provide easily accessible data to communities and decision-makers to change perceptions of SuDS.
Definition	Calculating/predicting the change in water quality caused by diverting rainfall or surface water flow through an NBS (e.g., green roof, tree pit, bioretention pond, rain garden, wet woodland, naturalised waterway, etc). Implementing an NBS can result in a positive or negative impact on water quality. This is dependent upon: the quality of water entering the system, the type of NBS, the age of NBS, and the water quality parameters being investigated. Both

	positive and negative impacts of NBS on water quality are of relevance for this indicator. Remote sensing and earth observation approaches are only generally used to provide background/mapping data that can be fed into water quality modelling.
Strengths and weaknesses	**Applied methods:** Robustness of evidence depends upon the precision and accuracy of the method adopted. Frequency and design of sampling is also linked to the strength of evidence. For example, regular sampling may provide long-term and seasonal patterns but may miss significant short-term events such as 'first flush' of urban areas following long dry periods. **EO/RS methods:** Methods can provide robust data, but the range of water quality parameters that EO/RS can provide is limited.
Measurement procedure and tool	*Applied/participatory methods*: Basic measurements of water quality associated with NbS have included: • NO_3, NO_2 and NH_3 (Payne et al., 2014; Batalini de Macedo et al. 2019) • Phosphorus (Bratieres et al. 2008a) • Heavy metals (Blecken et al. 2011; Batalini de Macedo et al. 2019) • Suspended/Sedimentary solids (Hatt et al 2008; Batalini de Macedo et al. 2019, Fowdar et al. 2017) • Micropollutants (such as hydrocarbons and pesticides) (Zhang et al. 2014) • Colour (Batalini de Macedo et al. 2019) • Turbidity (Batalini de Macedo et al. 2019) • Chemical Oxygen Demand (Batalini de Macedo et al. 2019; Leroy et al. 2016) • Biological Oxygen Demand (Fowdar et al. 2017; Leroy et al. 2016) • Pathogens (Bratieres et al. 2008b) • Hydrocarbons (Hong et al. 2006) • Total organic carbon (TOC) and dissolved organic carbon (DOC) (Fowdar et al. 2017) Choice of parameter to measure should be related to issues of water pollution, the type of plant species and substrates used in the bioretention process, physio-chemical processes, and the desired quality of water at the end of processing (Dagenais et al. 2018; Payne et al. 2018, Batalini de Macedo et al. 2019). Sampling can be done using in-situ stormwater sampling equipment (e.g., Teledyne ISCO 6712/7400 (Hong et al.

2006), ISCO GLS auto-sampler (Lucke and Ncihols 2015), ISCO Model 6712 Portable Sampler (Stagge et al. 2012)). This allows continuous and simultaneous sampling. Where this is not possible, or is prohibited by cost, v-notch weirs installed to monitor flow rate can be used to create a reservoir that can be sampled using a manual sampling technique (Hong et al. 2006). Alternatively, artificial drain/reservoir features can be incorporated into the NbS design from which water samples can be collected (Leroy et al. 2016). Laboratory analysis of each parameter is then carried out based on standardised analytical methods (e.g., Standard Methods for Examination of Water and Wastewater (APHA, 2015)).

An alternative, and more participatory method of monitoring water quality can be achieved through the use of biological indicators to monitor moving or still waterbodies. An example of this is the Biological Monitoring Working Party (BMWP) scoring system (Armitage et al. 1983) or adapted versions of this protocol (e.g., Romero et al. 2017). Samples are typically collected by kick sampling or surber sampling (Everall et al. 2017), providing opportunities for community engagement (including as part of school curricular activities). Wetland plants have also been used as biological indicators of water chemistry in wetland areas (US EPA 2002).

Simulated storm events with artificially created water pollution can be used as a mechanism to validate performance of NbS (Lucke and Nichols 2015). This is of particular value to ensure continuity of performance as the NbS ages/matures.

Remote sensing/Earth observation methods:

Remote sensing and earth observation approaches are only generally used to provide background/mapping data that can be fed into water quality modelling. However, some remote sensing techniques are emerging. Methods for delivering this include:

a) In general:

The remote sensing technology uses high resolution satellite or airborne optical imagery (visible and infrared), DSM (Digital Surface Model) height information and existing building out- lines maps (footprints) to estimate the

	percentage of vegetated areas on building roofs and to identify potential green roof sites. The new remote sensing technology provides municipalities with the opportunity to use this data for urban planning decisions in the field of climate modelling, drainage system calculation and biodiversity networks. According to Ritchie et al. (2003), remote sensing techniques can be used to monitor water quality parameters (i.e., suspended sediments (turbidity), chlorophyll, and temperature). Optical and thermal sensors on boats, aircraft, and satellites provide both spatial and temporal information needed to monitor changes in water quality parameters for developing management practices to improve water quality. Recent and planned launches of satellites with improved spectral and spatial resolution sensors should lead to greater use of remote sensing techniques to assess and monitor water quality parameters. Integration of remotely sensed data, GPS, and GIS technologies provides a valuable tool for monitoring and assessing waterways. Remotely sensed data can be used to create a permanent geographically located database to provide a baseline for future comparisons. The integrated use of remotely sensed data, GPS, and GIS will enable consultants and natural resource managers to develop management plans for a variety of natural resource management applications. In addition, Massoudieh et al. (2017) developed a modelling framework to predict the water quality impacts of urban stormwater green infrastructure systems. Shi et al. 2017 demonstrated links between urban water quality and different landuse patterns that could be used to predict improvements in water quality. For further information, see: Connecting Nature Environmental Indicator Metrics Review Report
Scale of measurement	**Applied methods:** Implementation is typically on a component or site level. It can be scaled-up to much larger scales through replication. However, it is more typical to model the impacts of up-scaling once results have been obtained that can be fed into the model. **EO/RS methods:** Typically used on medium/large scale monitoring as resolution of satellite imagery can create a barrier to monitoring smaller scale areas.

Data source	
Required data	Required data will depend on selected methods, for further details on applied and earth observation/remote sensing metrics refer to Connecting Nature Environmental Indicator Metrics Review Report
Data input type	Data input types will be depend on selected methods, for further details on applied or earth observation/remote sensing metrics refer to Connecting Nature Environmental Indicator Metrics Review Report
Data collection frequency	Data collection frequency will be depend on selected methods, for further details on applied or earth observation/remote sensing metrics refer to Connecting Nature Environmental Indicator Metrics Review Report
Level of expertise required	**Applied methods:** Some expertise required for installation of equipment and/or sampling methodology. Expertise required for sample analysis depends on the level of automation of the sampling equipment (e.g., in stream dataloggers carry out sample analysis automatically). Samples taken may require specialist analytical methods, these are typically carried out through an accredited laboratory. Data analysis/interpretation against statutory guidelines can be very basic once systems are in place. **EO/RS methods:** Data processing expertise is needed.
Synergies with other indicators	**Applied methods:** There are synergies in relation to measuring flowrates as such data is necessary for calculating total pollutant loads over time. BMWP scoring can be linked to biodiversity indicators. Improved water quality can have correlations with nature, health and social value of a waterway. **EO/RS methods:** Synergies with other water management and blue space area indicators.
Connection with SDGs	SDG3, SDG4, SDG6, SDG8-SDG12; SDG14-SDG17: Clean water supply; Links to environmental education; Clean water; Job creation; Social equality in relation to water quality; Sustainable urban development; More sustainable water management; Improved water quality (for life below water); Improved water quality (for life on land); Environmental Justice; Opportunities for collaborative working
Opportunities for participatory data collection	**Applied methods:** Opportunities are available for a participatory process, particularly in relation to carrying out visual inspection of water (e.g., in relation to combined sewage overflow occurrences and water sampling (Farnham et al. 2017; Jollymore et al. 2017). Water quality analysis can be linked to local schools/universities, especially through schemes that use BMWP methodologies to monitor

	water quality in waterways. Automated dataloggers offer less opportunity for such participation with participation limited to observing and processing the data produced. There are also opportunities for stewardship of equipment or nature-based solution, etc. **EO/RS methods:** Limited opportunities for participation
Additional information	
References	**Applied methods:** Armitage, PD, Moss, D, Wright, JF and Furse MT (1983) The performance of a new biological score system based on macro-invertebrates over a wide range of unpolluted running-water sites. Water Research 17, 333-347. Batalini de Macedo, M, Ambrogi Ferreira do Lago, C and Mario Mendiondo, E (2019) Stormwater volume reduction and water quality improvement by bioretention: Potentials and challenges for water security in a subtropical catchment. Science of The Total Environment 647, 923-931. Blecken, G-T, Marsalek, J and Viklander, M (2011) Laboratory study of stormwater biofiltration in low temperatures: total and dissolved metal removals and fates. Water, Air, Soil Pollution 219, 303-317. Bratieres, K, Fletcher, TD, Deletic, A and Zinger, Y (2008a) Nutrient and sediment removal by stormwater biofilters: A large-scale design optimisation study. Water Research 42(14), 3930-3940. Bratieres, K, Fletcher, TD, Deletic, A, Alcazar, L, Le Coustumer, S and McCarthy, DT (2008b) Removal of nutrients, heavy metals and pathogens by stormwater biofilters. 11th International Conference on Urban Drainage, Edinburgh, Scotland, UK, 2008. Davis, A, Hunt, W, Traver, R and Clar, M, (2009) Bioretention technology: Overview of current practice and future needs. Journal of Environmental Engineering 135, 109–117. Dagenais, D, Brisson, J and Fletcher, TD (2018) The role of plants in bioretention systems; does the science underpin current guidance? Ecological Engineering 120, 532-545. Everall, NC, Johnson, MF, Wood, P, Farmer, A, Wilby, RL, Measham, N (2017) Comparability of macroinvertebrate biomonitoring indices of river health derived from semi-quantitative and quantitative methodologies. Ecological Indicators 78, 437-448. Farnham, DJ, Gibson, RA, Hsueh, DY, McGillis, WR, Culligan, PJ, Zain, N and Buchanan, R (2017) Citizen science-based water quality monitoring: Constructing a large database to characterize the impacts of combined sewer overflow in New York City. Science of The Total Environment 580, 168-177.

Fowdar, HS, Hatt, BE, Breen, P, Cook, PLM and Deletic, A (2017) Designing living walls for greywater treatment. Water Research 110, 218-232

Hatt, BE, Fletcher, TD and Deletic, A (2008) Hydraulic and pollutant removal performance of fine media stormwater filtration systems. Environmental Science & Technology, 42 (2008), pp. 2535-2541

Hong, E, Seagren, EA and Davis AP (2006) Sustainable oil and grease removal from synthetic stormwater runoff using bench-scale bioretention studies. Water Environment Research 78, 141-155.

Jollymore, A, Haines, JH, Satterfield, T and Johnson, MS (2017) Citizen science for water quality monitoring: Data implications of citizen perspectives. Journal of Environmental Management 200, 456-467.

Leroy, M-C, Portet-Koltalo, F, Legras, M, Lederf, F, Moncond'huy, V, Polaert, I and Marcotte, S (2016) Performance of vegetated swales for improving road runoff quality in a moderate traffic urban area. Science of The Total Environment 566–567, 113-121.

Lucke, T. and Nichols, PWB (2015) The pollution removal and stormwater reduction performance of street-side bioretention basins after ten years in operation. Science of The Total Environment 536, 784-792.

Payne EG, Fletcher TD, Russell DG, Grace MR, Cavagnaro TR, Evrard V, Deletic A, Hatt BE, Cook PL (2014) Temporary storage or permanent removal? The division of nitrogen between biotic assimilation and denitrification in stormwater biofiltration systems. PloS One, 9 (2014), p. e90890

Payne, EGI, Pham, T, Deletic, A, Hatt, BE, Cook, PLM, and Fletcher, TD (2018) Which species? A decision-support tool to guide plant selection in stormwater biofilters. Advances in Water Resources 113, 86-99.

Romero, KC, Del Río, HP, Villarreal, KC, Anillo, JCC, Zarate, ZP, Gutierrez, LC, Franco, OL and Valencia, JWA (2017) Lentic water quality characterization using macroinvertebrates as bioindicators: An adapted BMWP index. Ecological Indicators 72, 53-66.

Stagge, JH, Davis, AP, Jamil, E and Kim, H (2012) Performance of grass swales for improving water quality from highway runoff. Water Research 46 (20), 6731-6742.

U.S. EPA (2002) Methods for Evaluating Wetland Condition: Using Vegetation To Assess Environmental Conditions in Wetlands. Office of Water, U.S. Environmental Protection Agency, Washington, DC. EPA-822-R-02-020.

Zhang, K, Randelovic, A, Page, D, McCarthy, DT and Deletic, A (2014) The validation of stormwater biofilters for micropollutant removal using in situ challenge tests. Ecological Engineering 67, 1-10.

	EO/RS methods: Boelee E. et al. (2017) Overcoming water challenges through nature-based solutions. Water Policy (2017) 19 (5): 820-836. https://doi.org/10.2166/wp.2017.105 Kumar D (2015) Remote Sensing based Vegetation Indices Analysis to Improve Water Resources Management in Urban Environment. Pages 1374-1380 in G. S. Dwarakish, editor. International Conference on Water Resources, Coastal and Ocean Engineering. Ritchie J., Zimba P.V, Everitt J.H. (2003) Remote Sensing Techniques to Assess Water Quality. Photogrammetric Engineering and Remote Sensing 69(6). DOI: 10.14358/PERS.69.6.695. Massoudieh, A, Maghrebi, M, Kamrani, B, Nietch, C, Tryby, M, Aflaki, S, Panguluri, S (2017) A flexible modeling framework for hydraulic and water quality performance assessment of stormwater green infrastructure. Environmental Modelling & Software 92, 57-73. Shi, P, Zhang, Y, Li, Z, Li, P and Xu, G (2017) Influence of land use and land cover patterns on seasonal water quality at multi-spatial scales. CATENA 151, 182-190.

3.15 Total Suspended Solids (TSS) content

Project Name: CLEVER Cities (Grant Agreement no. 776604), GrowGreen (Grant Agreement no. 730283) and UNaLab (Grant Agreement no. 730052)

Author/s and affiliations: Laura Wendling[1], Ville Rinta-Hiiro[1], Maria Dubovik[1], Arto Laikari[1], Johannes Jermakka[1], Zarrin Fatima[1], Malin zu-Castell Rüdenhausen[1], Peter Roebeling[2], Ricardo Martins[2], Rita Mendonça[2], Saioa Zorita[3]

[1] *VTT Technical Research Centre Ltd, P.O. Box 1000 FI-02044 VTT, Finland*

[2] *CESAM – Department of Environment and Planning, University of Aveiro, Campus Universitário de Santiago, 3810-193 Aveiro, Portugal*

[3] *TECNALIA, Basque Research and Technology Alliance (BRTA), Mikeletegi Pasealekua 2, 20009 Donostia-San Sebastián, Spain*

TSS content	**Water Management**
Description and justification	Total Suspended Solids (TSS) are solids in water that can be trapped by a filter. TSS can include a wide variety of material and can have adsorbed pollutants. High concentrations of suspended solids can affect the health and productivity of the aquatic life. TSS and turbidity are simple indicators of water quality. Sources of TSS include, e.g., sediment runoff from agricultural fields, logging activities, construction sites, roadways, waste discharge, or