Implementation of the sponge city: transformation and sustainable model solutions for roofs of the blue-green city

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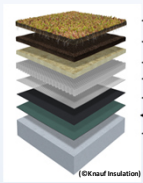
Introduction

The consequences of climate change pose enormous challenges for urban areas. In addition to prolonged heat waves, climate change significantly affects water availability: both heavy rainfall events with flooding and droughts cause considerable damage to buildings, infrastructure, and ecosystems. The sponge city concept offers various advantages in addressing these challenges: besides retaining rainwater, preventing flooding, and relieving wastewater systems, it reduces urban heat island effects through evaporative cooling and mitigates drought. A key component of this concept is the implementation of green roofs. Currently, building materials are used that, due to the leaching of potentially toxic substances in contact with rainwater, may negatively impact the retained water. This water eventually reaches surface or groundwater and can enter drinking water supplies, potentially causing eco- and human-toxic effects. In this research project, building materials used for green roofs will be subjected to leaching tests, and the eluates will be examined using a standardized biotest battery to assess potential negative impacts on the aquatic environment. Furthermore, a scaled-down model roof will be constructed using building materials that have been evaluated as non-(eco)toxic, and the resulting runoff will be analyzed for ecotoxicological effects. In comparison, runoff from existing green roofs will also be examined. The goal is to identify building materials that can be used for roof greening within the sponge city concept without posing ecotoxicological risks.

Hydrotox is leading WP 5 and is conducting exemplary testing of 20 selected construction products for their ecotoxicological potential and assessment of retained water from the model green roofs.

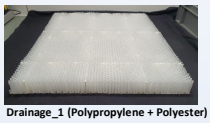


Construction of a model green roof

Test roofs as part of the project

Construction Products

Substrate_1 (Mineral wool fiber)



Drainage_1 (Polypropylene + Polyester)

Protection_1 (Nylon)

Roofing membrane _1 (Flexible polyolefins)

Drainage_4 (Expanded clay)

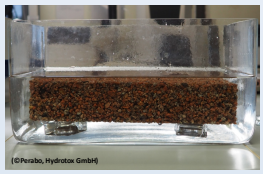
(All: ©Perabo, Hydrotox GmbH)

Methods

Leaching tests

Technical specification DIN CEN/TS 17459
„Determination of ecotoxicity of construction product eluates“ [1]

Monolithic, plate-like or foil-like building products → **Horizontal dynamic surface leaching test (DSLT)** → DIN EN 16637-2



- L/A = 25 L/m²
- Elution with deion. Water (< 5 µS/cm)
- Without agitation
- Eluates after 6 h and 18 h

Granular building products → **Horizontal up-flow percolation test** → DIN EN 16637-3

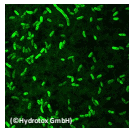
- L/S = 2 L/kg
- Elution with deion. Wasser (< 5 µS/cm)
- Particle size < 4 mm
- Flow rate 1.63 ml/min for columns with 10 cm inner diameter

Biotests

Algae test
ISO 8692
72 h
Raphidocelis subcapitata

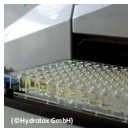
Water flea test
ISO 6341
48 h
Daphnia magna

Luminescent bacteria test
ISO 11348-2
0,5 h
Alliivibrio fischeri



Genotoxicity test

UmuC Test
ISO 13829
4 h
Salmonella typhimurium



Results

The lowest dilution level without effects exceeding the test-specific variability is reported as test result (**lowest ineffective dilution (LID).**

Table 1: Results to be expected from the test battery

Test species	Test standard	Endpoint	Evaluation
Luminescent bacteria (Vibrio fischeri)	EN ISO 11348	Light emission	EC50 (30 min) and LID
Algae (Pseudokirchneriella subcapicata or Desmodesmus subspicatus)	EN ISO 8692	Growth	EC50 (72 h) and LID
Crustaceans (Daphnia magna)	EN ISO 6341	Mobility	EC50 (48 h) and LID
umu-Test with Salmonella typhimurium TA 1535/pSK1002	ISO 13829	Gene induction	Induction rate (24 h)

Table 2: **Ecotoxicity of eluates.** First results are listed, showing conductivity, pH, TOC and LID values for biotests.

Product description	Leaching method	Conductivity (µS/cm)	pH	TOC (mg/L)	Algae LID_A	Daphnia LID_D 48 h	Luminescent Bacteria LID_{15}	UmuC LID_{EU}
Filter_1 (Polypropylene)	DSLT	4,7	6,7	4,27	≤2	≤2	≤2	≤1,5
Protection_1 (Nylon)	DSLT	6,4	6,5	5,52	≤2	≤2	≤2	≤1,5
Drainage_1 (Polypropylene + Polyester)	DSLT	2,4	6,7	0,35	≤2	≤2	≤2	≤1,5
Substrate_1 (Mineral wool fiber)	DSLT	17,2	8,3	1,64	≤2	≤2	≤2	≤1,5
DB_1 (Flexible polyolefins)	DSLT	16,3	7,5	0,67	> 24	≤2	≤2	≤1,5
Drainage_4 (AlZnFe)	DSLT	9,8	6,8	1,36	>6	=4	≤2	≤1,5
Blank_1	DSLT	1,4	7,0	0,19	≤2	-	-	-

Discussion

-Ecotoxic effects in some construction products detected (DB_1 and Drainage_4) → Assessment of ecotoxic effects of construction products installed in green roofs is reasonable and necessary

-No genotoxicity detected → A very positive result, indicating low health and environmental risks

-DSLT limitations → The determination of the liquid/surface ratio reaches its limits when construction products have complex or irregular surfaces

[1] DIN CEN/TS 17459:2023-02 “Construction products: Assessment of release of dangerous substances- Determination of ecotoxicity of construction product eluates”; German Version CEN/TS 17459:2022 https://dx.doi.org/10.31030/3096453

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