DELIVERABLE NUMBER D1.4

3D printed rain garden boxes

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D1.4 – Public

3D printed rain garden boxes

VERSION	DATE
03	30-April-2021

ABSTRACT

Deliverable D1.4 “The raingarden boxes will be placed next to the New Wastewater Treatment Plant of Prague. Internal parts will be printed on a 3D printer.

DELIVERABLE ID	WORK PACKAGE	PLANNED DELIVERY DATE
D1.4	WP1	30-April-2021

AUTHORSHIP AND APPROVAL INFORMATION

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1 Introduction

In WIDER UPTAKE, demonstration activities are covered by WP1. These activities ensure the application of water smart solutions in batch/pilot and real scale.

Reclaimed water from the new wastewater treatment plant – **New Water Line (NWL)** of Prague may be used for different purposes *e.g.,* irrigation of green areas and street cleaning, which would contribute to mitigation of heat island effects and reduce dust. The installation of tertiary treatment in Prague would also contribute to reduce the load of nutrients and residual organic contaminants (especially contaminants of emerging concern) to the receiving waters (the Vltava river).

The quality of the reclaimed wastewater must meet the criteria for each water reuse application. Four demonstration units have therefore been designed and constructed. The demonstration units are impervious boxes suitable for flowers, small plants, and bushes. Each box has been equipped with growth media and has hydraulic and filtration capabilities in relation to the drainage area, the outlet/piping system and flow of effluent water. The design has been made in such a way that the raingarden will receive a constant amount of effluent water that will either be used by the plants or filtrated. Excess surface water will be handled by the overflow pipe, the detention chamber, and the flow-restricted outlet.

The raingarden boxes are placed next to the New Wastewater Treatment Plant of Prague. Internal parts have been printed on a 3D printer according to the Storm Aqua's design. Storm Aqua has prepared composition of the growth media according to plants and local climate which has been mixed at the site.

Each box will be irrigated from a different water source to compare the effects of different qualities of feed water:

- Box 1: Water from the river Vltava will be used for comparison with the central wastewater treatment plant (CWWTP) effluent treated to different levels of quality. This will be a reference test as river water is currently used for agriculture irrigation downstream and the City of Prague is also planning to use the river water in a local ZOO.
- Box 2: Treated effluent from the biological stage of CWWTP (effluent from secondary clarifier and phosphorus post-precipitation): this is the current effluent from the "New Water Line" of the CWWTP Prague. This demonstration unit will simulate a direct use of the current effluent without any further treatment as a comparison with Demo units 3 and 4.
- Box 3: Treated effluent from CWWTP plus UV disinfection. The following methods will be studied and compared (both with respect to disinfection efficiency and economic feasibility): UV light, chlorine, and chlorine dioxide, peroxy carboxylic acids.
- Box 4: Treated effluent from CWWTP plus:
    - Membrane filtration and UV disinfection: Membrane filtration in the range of ultrafiltration represents a barrier against bacteria by itself and at the same time produces clear effluent without any particles, which increases the efficiency of UV disinfection.
    - Membrane filtration, UV disinfection, advanced oxidation plus activated carbon sorption: This combination of tertiary treatment processes can produce a water quality comparable to potable. This product can be used in the city water management for the most sensitive uses like spraying the streets in hot summer days.
    - In case of observed problems with salinity, reverse osmosis will be tested as a final step: the effluent after tertiary phosphorus precipitation contains certain residual salinity. In case of long-term use of such water for irrigation there could appear problems with increased soil salinity. Some types of grass used in urban parks or on golf courses are rather sensitive to soil salinity. For such cases, reverse osmosis will be applied for effluent salinity control.

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2 Aim of the experiments

Development and construction of demonstration units of tertiary treatment for reuse of wastewater:

- Demonstration of safe use of treated wastewater for irrigation of urban areas
- Development and application of monitoring and control systems in order to adequately assess the health and quality risks associated with the reuse of treated wastewater and the use of waste as a resource
- Optimization of value chains to quantify the increase in resource efficiency and economic benefits with respect to future applications
- Water for irrigation according to the scheme below

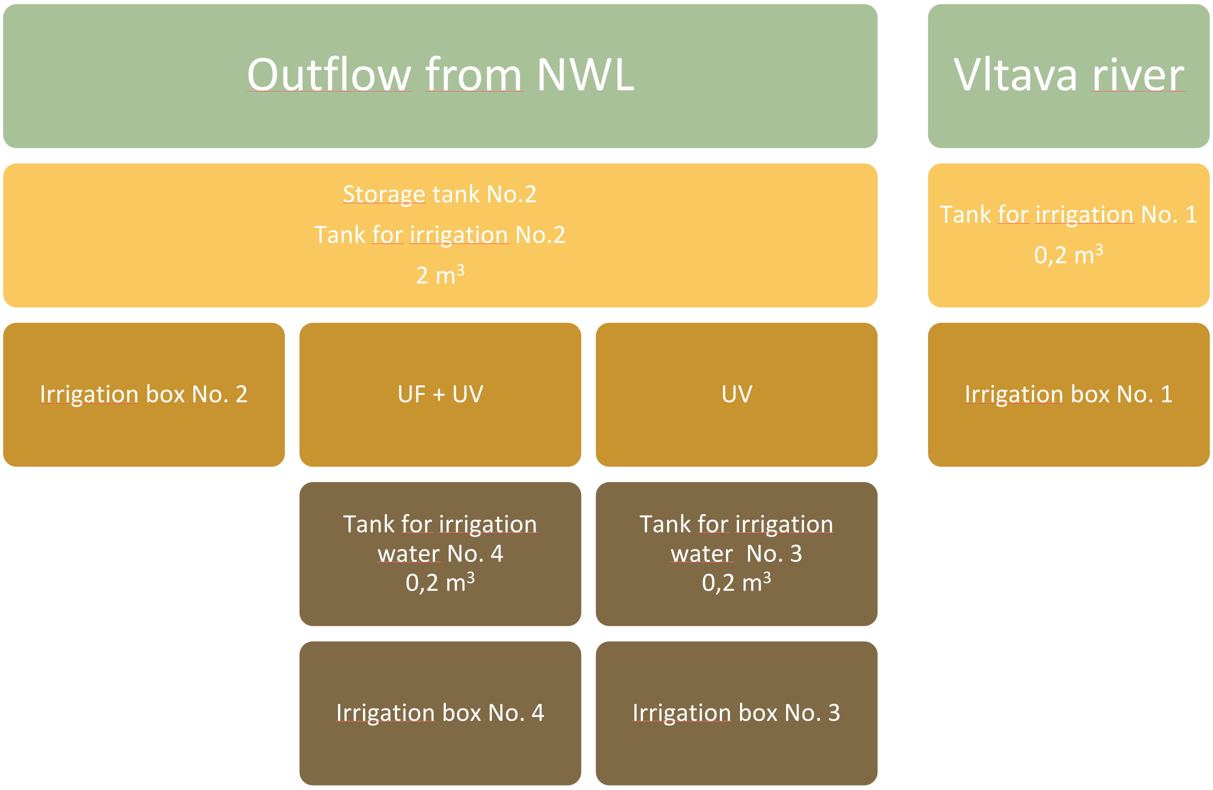

Figure 1: Irrigation block scheme

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3 Source of the water

For comparison of the influence from water quality, two main water sources – river Vltava and outflow from NWL, have been chosen.

3.1 River Vltava

Vltava river is flowing around the island where the NWL and the experimental boxes are installed. The place location is downstream of Prague meaning that all the flushes from Prague will end in the irrigation water.

3.2 Prague WWTP - NWL

The source from NWL will be used for three different boxes with additional cleaning.

3.2.1 NWL description

A workshop held at UCT Prague in April 2019, before start of WIDER UPTAKE, was devoted to modern wastewater treatment plants. EWA chose Prague as the venue of the workshop because the City of Prague in September 2018 started trial operation of a new "water line" of the Central Wastewater Treatment Plant. This new line is exploiting several processes and operations which are still not common in large wastewater treatment plants, e.g., chemically enhanced primary treatment, cascade D-N activated sludge process with in-situ bioaugmentation of nitrification bacteria or tertiary phosphorus precipitation. The design and construction of the plant had to deal with the requirement of the city to protect the new plant from floods comparable to the historical disastrous flood in 2002. This new facility will help the city to meet the effluent limits according to the 91/271/EEC directive on one side and on the other side it will enable the reconstruction and upgrade of the existing Central Wastewater Treatment Plant built in the 1960s.

Besides listening to the lectures on the Prague project and on the newest trends and challenges in wastewater treatment plant design the workshop participants had the chance to see the technology of the New Water Line completely hidden in a concrete containment.

The project is divided into two parts, which will occupy a total of 400,000 m^2 and require 500,000 m^3 of concrete: a complete overhaul of the existing treatment plant on the island of Císařský Ostrov, as well as the addition of independent treatment facilities – dubbed the "New Water Line" – which will incorporate mechanical and biological processing with an additional chemical treatment system. The new technology introduced will bring the facilities in line with the European Council emissions guidelines for "sensitive areas". Once improvements are completed, the plant will utilise the updated infrastructure to conduct 40% of all water treatment, while the new line will be responsible for the remaining 60%.
Solution ULMA

The construction of the new line is divided into four work zones:SO04, SO06, SO09, and SO10. The magnitude of these areas, not only in size but in the complexity of the operations involved, requires them to be considered as independent projects, each with its own construction manager, worksite coordination, etc.

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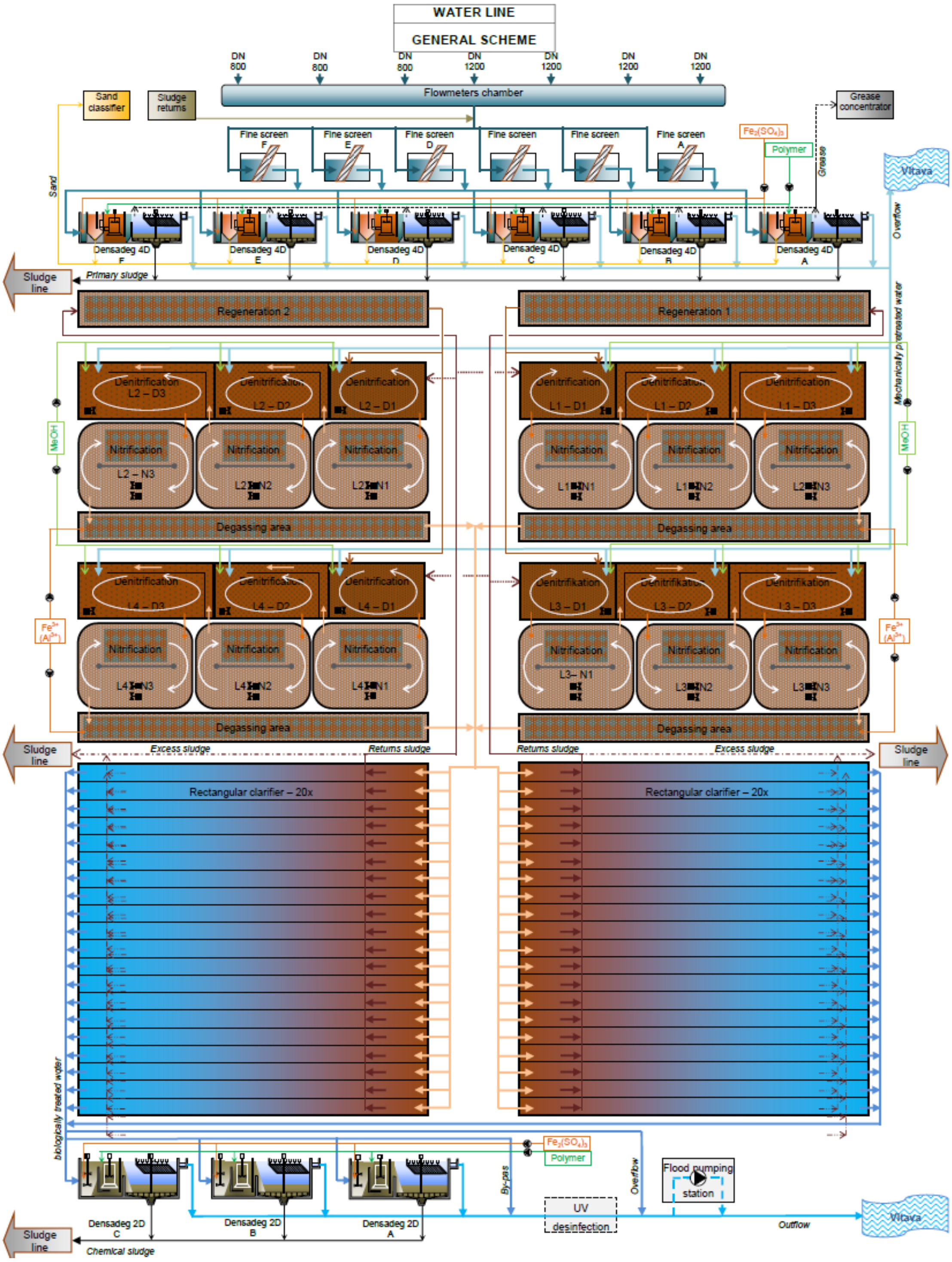

Figure 2: technological scheme of the NWL

The Czech ULMA team provisioned pre-assembled systems, thus saving assembly and erection time on-site. These systems will remain on the worksite throughout the entire construction process. ULMA offers pre-assembly services as a way for clients to cut costs and increase the profitability of their projects.

The sheer size of this project, not to mention the diversity of tasks required, demanded specific solutions for each of the four work zones. The technologies at work and the continual circulation of water

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necessitate extremely precise execution of the geometry, finishing, and the entire pouring process. The MK System – ENKOFORM VMK for vertical applications and ENKOFORM HMK for horizontal applications – was used to build more than 30 specialised structures. Moreover, the walls, measuring more than 12 m in height, were formed in a single pour using ORMA Panel Formwork reinforced by MK Walers.

Close and constant cooperation between the customer and the ULMA team has been critical to the completion of the project in accordance with the established criteria and deadlines. ULMA's comprehensive solution includes the continuous on-site assessment. Specialised technical personnel from every department were present to assist in material delivery, systems erection, and other critical tasks.

Safety considerations formed a vital part of this project. ULMA demonstrated its commitment to guaranteeing safety throughout the entire construction process by provisioning all safety systems required.

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4 Construction of boxes

Four identical boxes have been built for plants growing irrigated by different water sources. Four different type of the wate r will irrigate the sets of three boxes. The reason for the different type of the water is to compare the influence of the water for plants, soil, and ground water. The four sets boxes are identical and have three compartments to compare the influence on different type of the plants. The soil is the same in all boxes.

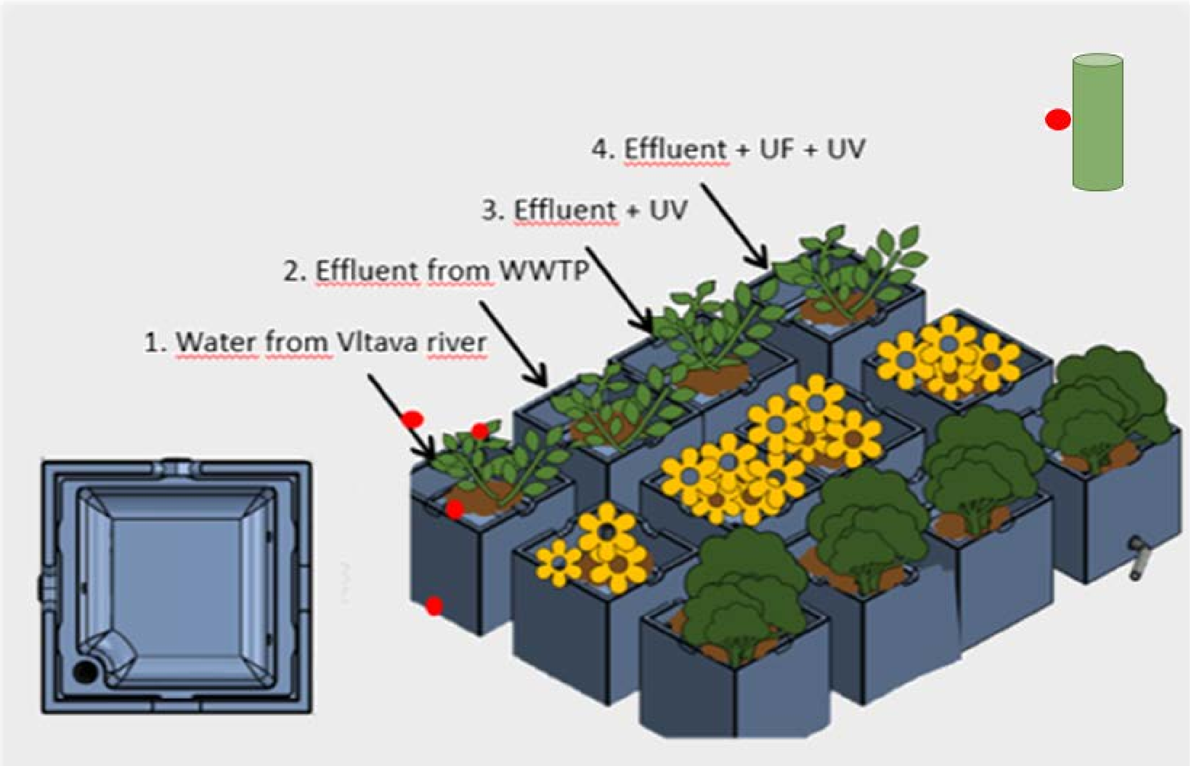

Figure 3: Illustration for the boxes and the different water qualities that will be used for feed water

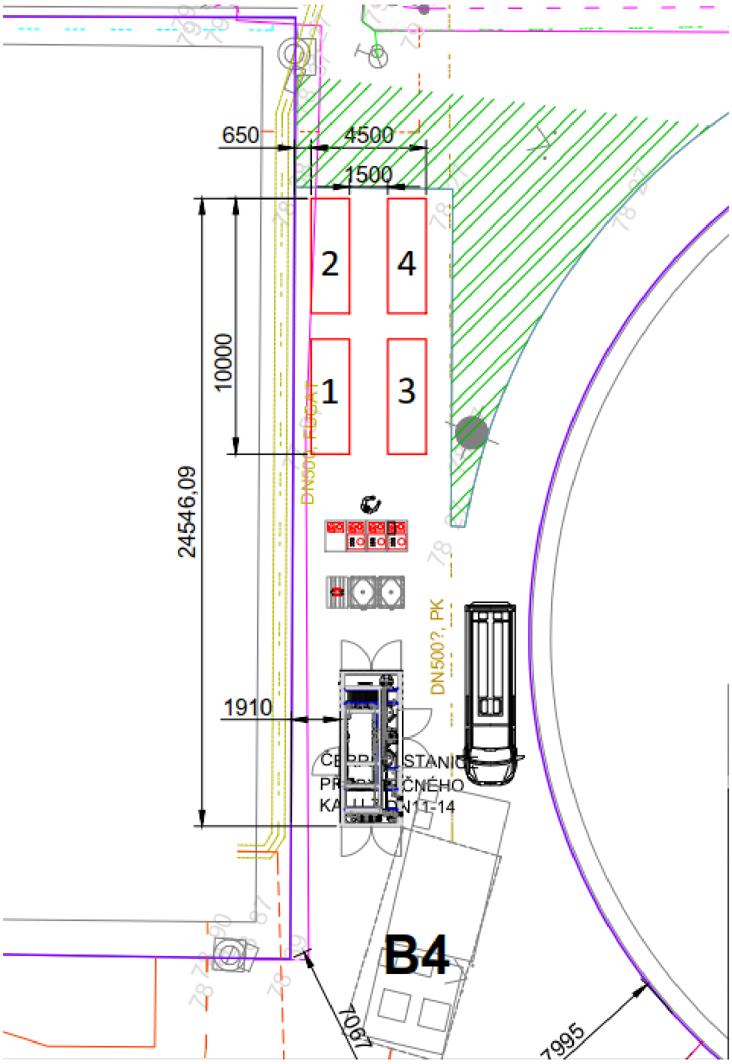

Figure 4: Scheme showing placement of the container with water treatment and measuring equipment and the 4 rain garden boxes.

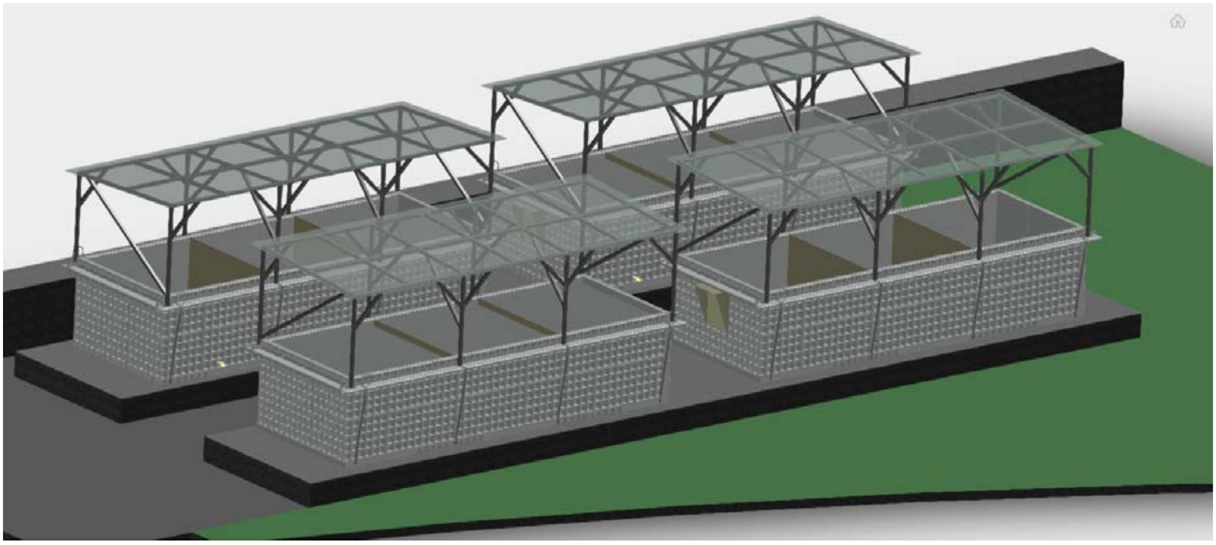

Figure 5: Visualization of irrigation boxes construction

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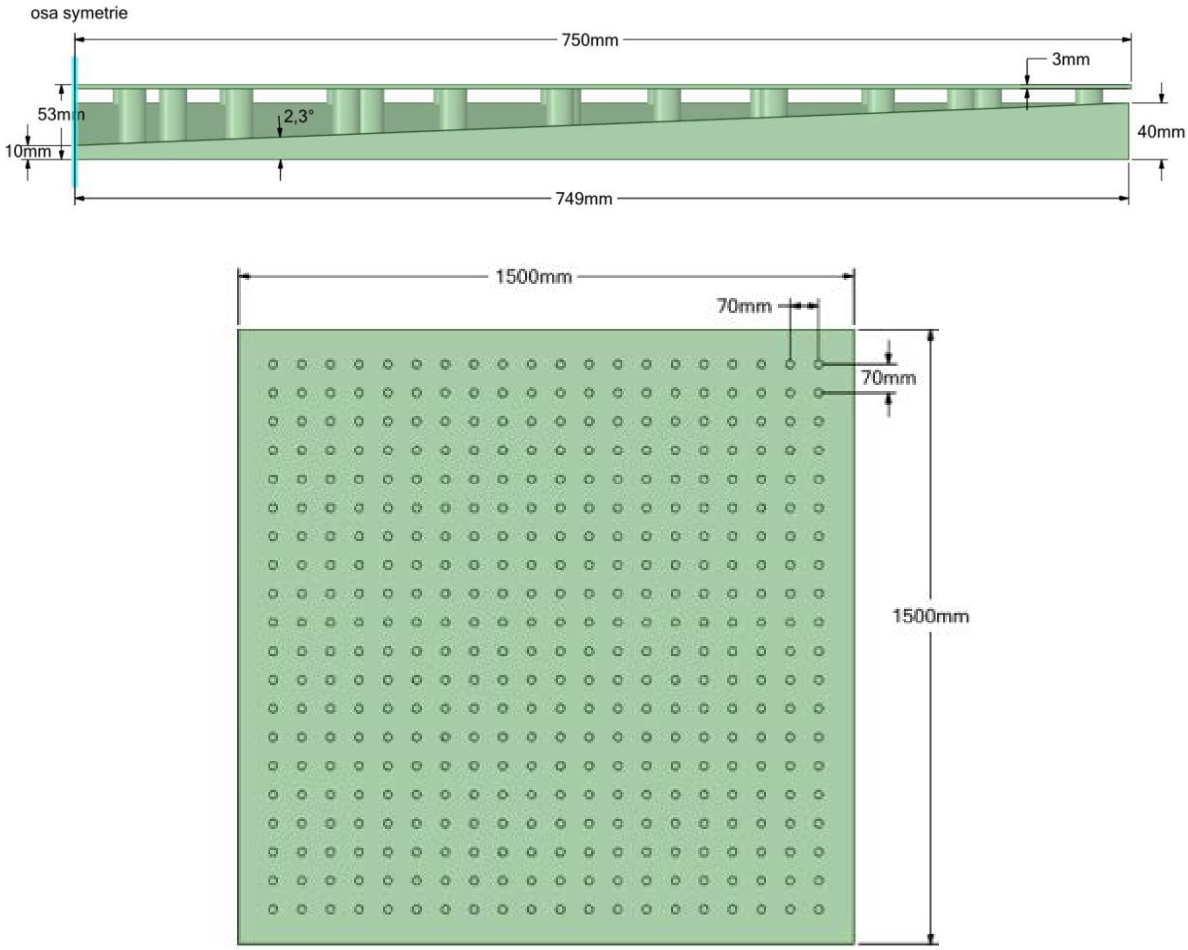

Figure 6: Drainage system placed in the bottom internally in the boxes

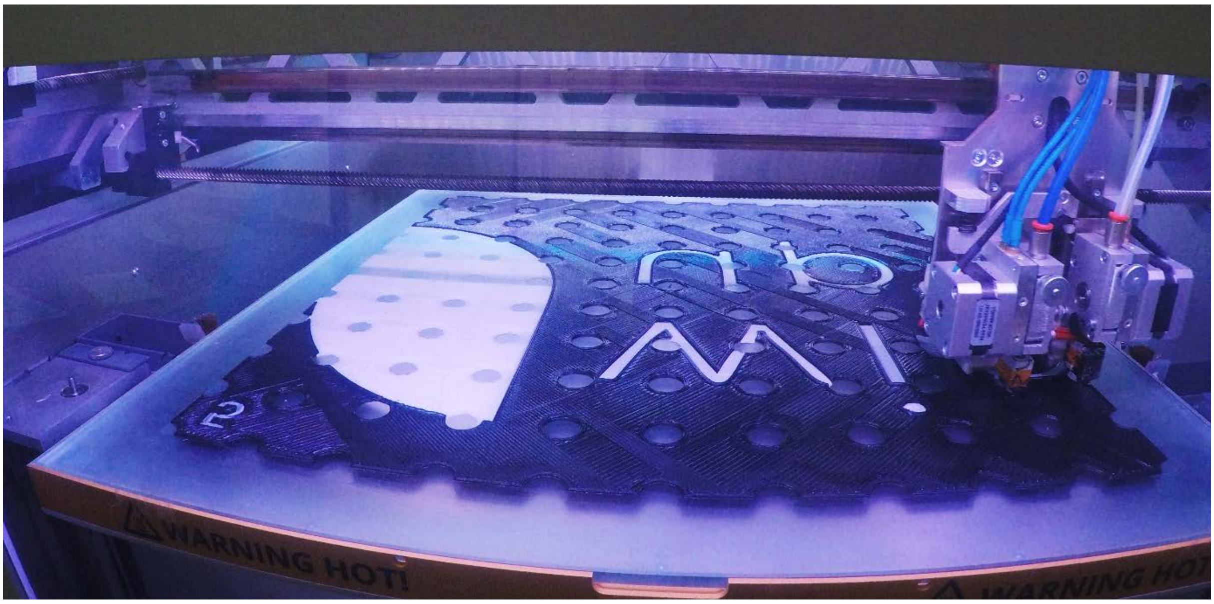

Figure 7: 3D printing of the perforated internal inner drainage layer of the boxes

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Figure 8: 3D printed inner drainage layer


Figure 9: Soil and grave layers in the boxes

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Figure 10: Irrigation system and support structure for roof over the boxes

Figure 11: Overall picture of the experimental boxes

Experimental field (Figure 11) from left:

- Container with filtration and measurement equipment
- Storage tanks with pumps and flow measurement
- Four (4) rain garden boxes with support structure for a roof

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4.1 Plants

The boxes consist of three different parts for planting different types of the plants. The size of the boxes (4 pcs) will be 4.5 m x 1.5 m divided into 3 parts of 1.5 m x 1.5 m.

- Lawn:
    - The area is 9 m^2 and due to the situation, it is necessary to use a carpeted lawn. For normal use, a park is used, which is in the park and in the gardens and can withstand the load, or a playground, which is on an even greater load, but needs more care (more pruning and more frequent mowing, as there is a different composition of grasses requiring maintenance). In our opinion a park is the best choice.
    - This area requires about 11 m^2, due to cuts. Unfortunately, the dimensions of the carpets are not known but there are several sizes (depending on the growing room)

- Plants:
    - Perennials will be planted in a 0.3m x 0.3m clip, which is based on 25 pcs per 1.5 x 1.5 m box and is needed for 4 boxes, ie about 102 perennials
    - 17 x Geranium sanquineum "Ankums pride"
    - 17 x Hemerocalis ,, Stela D oro “
    - 17x Salvia nemorosa "Caradona"
    - 17 x Echinacea purpurea ,, Primadona Deep Rose “
    - 17 x Coreopsis verticullata ,, Grandiflora
    - 17 x Heuchera sanquinea ,, Leuchtkáfer “

- Shrubs:
    - Plant 0.5 -0.6m apart and thus 9 plants per 1.5 x 1.5m box and it is necessary for 4 boxes, ie 3 shrubs
    - 12 x Ulmus pumila
    - 12 x Carpinus betulus
    - 12 x Ligustrum vulgare ,, Lodense “

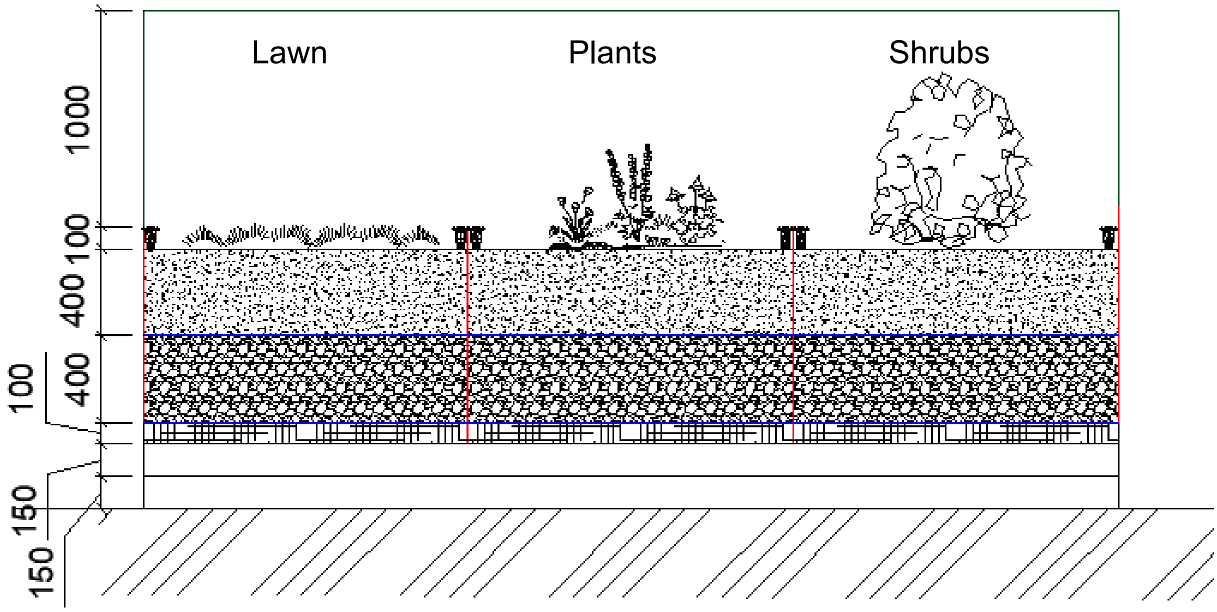

Figure 12: Layers and composiution of the boxes

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5 Water source preparation

Water from river Vltava and from outflow from NWL will be used for boxes 1 & 2 without any treatment. For the boxes 3 & 4 additional treatment were used according to Figure 1 which was placed in the container (Figure 13).

Figure 13: Container with water preparation and measurement equipment

5.1 Sources of water

Four sets of boxes have four different water sources:

1. **Water from river Vltava** – this represent classical water source. Because the boxes are under Prague it means all combined sewer overflow will influence this
2. **Water from effluent from NWL** – we want to proof that this water can be sufficient for most of the irrigation cases
3. **Water from effluent from NWL with UV disinfection** (Figure 16) – this type of the water is the same as previous one but without biological pollution (bacteria and viruses)
4. **Water from effluent from NWL with UV disinfection and microfiltration** (Figure 14) – the finest type of filtration to compare it. We expect that less pollution will lead to low growing potential.

The connection and water preparation are done according to the flow diagram and measurement scheme for the water treatment processes inside the container shown in Figure 18, in the next section.

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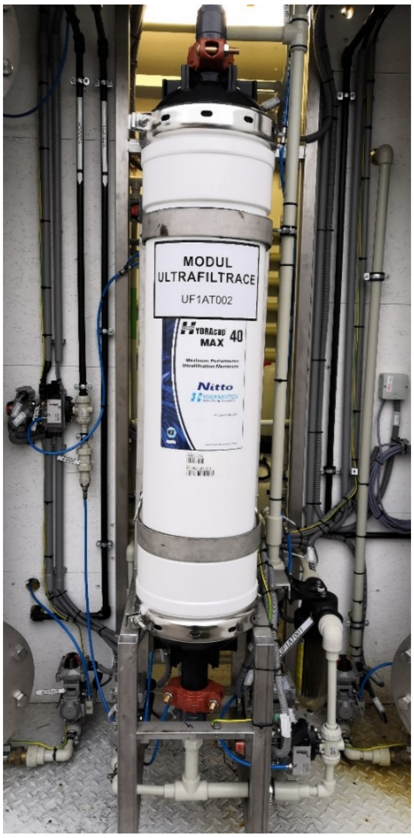

Figure 14: Ultrafiltration

Figure 15: Pumping station

Figure 16: UV disinfection

Figure 17: Inside of container with equipment

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6 Monitoring equipment

Monitoring equipment is designed according to needs of experiment which is the pollution division from the source to the soil, plants, and ground water. The monitoring of listed parameters (Table 1) will be online, and data will be automatically uploaded to the database (WP2) for evaluation according to legislative requirements. Some more measurement will be added later according to database needs to evaluate risk online.

For the complete evaluation of the influence we will also have sets of offline measurements, because not all probes are available for the online measurement. Data will also go to the database, but it will be uploaded manually.

Table 1: Overview of measurement parameters, legislative requirements, and on-line sampling points

Parameter	Online measurement	Lagislative requirements					Sampling points for online measurement									
		ČSN ISO 20761, tab. 6	European directive (WW reuse)	401/2015 Sb. (Cze)	ČSN 75 7143	57/2016 Sb. (Cze)	Frequency	Vltava river	Effluent NWL	Effluent NWL + UV	Effluent NWL + MF + UV	Balancing tank	Influent on boxes	Effluent from boxes (filtrate)	Soil in the boxes	Air
Q	☑						1 x /hour	☑	☑	☑	☑		☑			
T	☑				☑		1 x /hour	☑	☑	☑	☑	☑	☑	☑	☑	☑
pH	☑	☑			☑		1 x /hour	☑	☑	☑	☑	☑	☑	☑	☑	
BOD5	x	☑	☑	☑		☑										
Humidity	☑						1 x /hour								☑	☑
Conductivity	☑															
TDS or conductivity	☑	☑					1 x /hour	☑	☑	☑	☑	☑	☑	☑	☑	
TDS	☑					☑										
COD nebo TOC	-	☑														
COD_{Cr}	x			☑		☑										
TOC	☑															
$N\text{-}NH_4^+$	☑	☑		☑		☑										
$N_{tot.}$ or $N\text{-}NO_3^-$	-	☑														
$N_{tot.}$	x			☑		☑										
$N\text{-}NO_3^-$	☑															

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Ptot.	☑	☑		☑		☑										
Turbidity or TSS	☑	☑														
Turbidity	☑		☑				1 x /hour	☑	☑	☑	☑	☑	☑	☑		
TSS	☑		☑	☑	☑		1 x /hour	☑	☑	☑	☑	☑	☑	☑		
Indicator bacteria	x	☑														
Residual chlorine	☑	☑														
PCB	x				☑											
E. Coli	☑		☑			☑										
Legionella	x		☑													
Intestinalí nematodes	x		☑													
Coliform bacteria	☑				☑											
Fecal coliform bacteria	x				☑											
Enterococci	x				☑	☑										
Patogene mikroorganisms, salmonellas	x				☑											
Clostridium perfringens - spores/ spores-producing sulfatereductive bacteria	x		☑													
Infectious states of parazites of humans and domesticated animals	x				☑											
Colifages	x		☑		☑											
Tests of germiations on plant seeds	x				☑											
Total volume activity except tritium	x				☑											
Radium 226	x				☑											
Uranium	x				☑											
Na^+: (Ca^{2+} + Mg^{2+})	x				☑											

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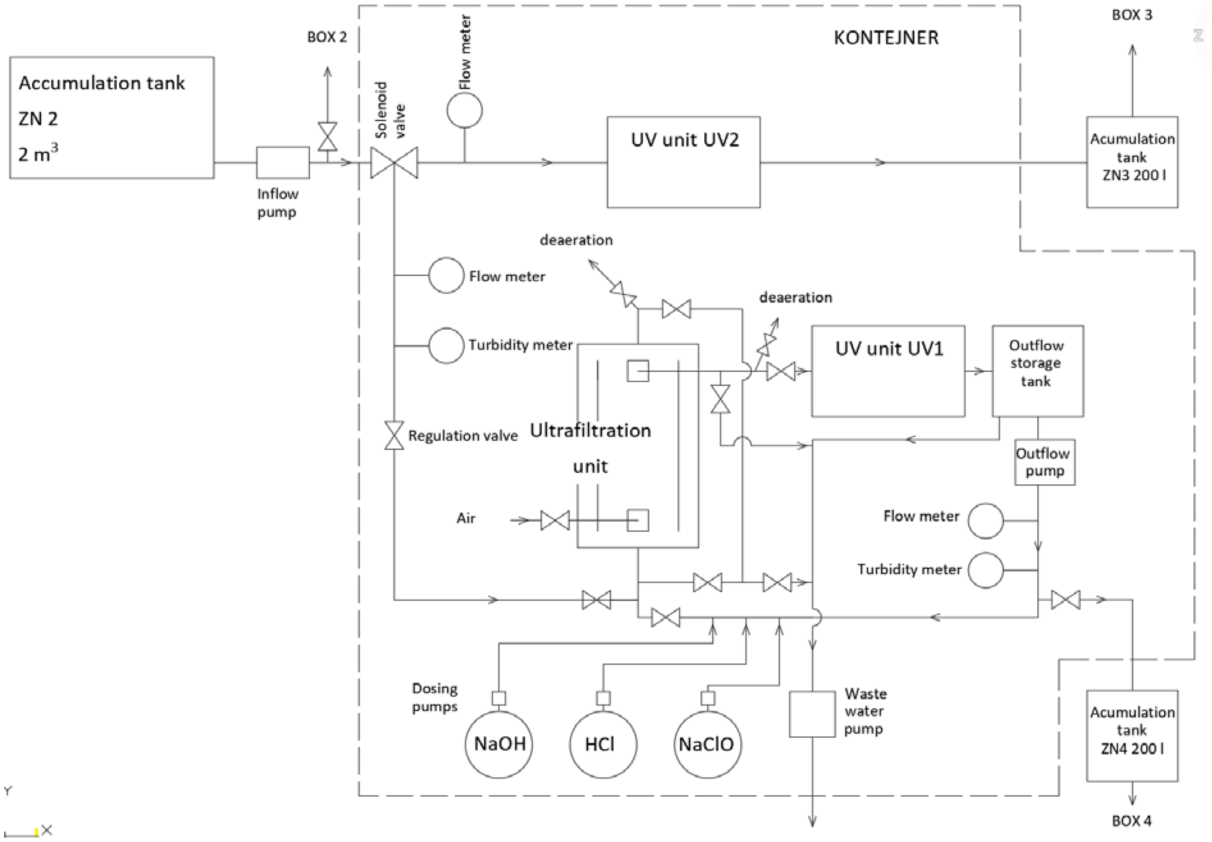

Figure 18: Flow diagram and measurement scheme for water treatment processes inside the container

6.1 Measured and transmitted quantities – online measurement

6.1.1 Flow

- Flow meter between tank ZN1 and box 1, measuring the flow of river water for irrigation
- Flow meter between tank ZN2 and box 2, measuring the flow of treated wastewater for grouting
- Flow meter between tank ZN3 and box 3, measurement Q cleaned and disinfected wastewater for grouting
- Flow meter between tank ZN4 and box 4, measurement Q cleaned, treated (UF) and disinfected o.v. for watering

6.1.2 Soil temperature and humidity

- Soil moisture and temperature sensor CS650-DS, located in the lawn section
- Soil moisture and temperature sensor CS650-DS, located in the perennial section
- Soil moisture and temperature sensor CS650-DS, located in the bush section
- All three sensors located in box 4 (can be changed).

6.1.3 Temperature and humidity

- Relative humidity and air temperature sensor RVT13 / RK, located on the mast near the container.

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6.1.4 Turbidity

- Turbidity of raw water = turbidity of stream 2
- Turbidity of treated water = turbidity of stream 4

- Technological quantities (in connection with possible occupancy of channels for transmission may be shortened)
- Level in the storage tank (contains cleaned, treated and disinfected o.v. - stream 4)
- Flow behind the storage tank (at stream 4)
- Raw water inlet flow (inlet to the container for treatment on the UF membrane and disinfection)
- Pressure, output from ultrafiltration
- Pressure, inlet for ultrafiltration
- Transmembrane pressure (difference of the previous two quantities)
- Immediate power consumption of the entire device

6.1.5 Binary quantities

- Lawn section irrigation solenoid - open / closed
- Perennial irrigation solenoid - open / closed
- Shrub section irrigation solenoid - open / closed
- (All monitored solenoids for box 4; can be changed)

- Accumulation tank outlet pump (current 4) - off / on
- Dry cleaning of the UF membrane - the relevant open / closed pneumatic valve
- Ultrafiltrate outlet from the membrane module - corresponding open / closed pneumatic valve

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7 Conclusions

This document summarizes the activities carried out establish the demonstration plant for irrigation of green urban spaces e.g., irrigation of raingarden boxes with different plants, with wastewater treatment plant effluent after polishing treatment.

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