Green walls: water consumption & quantity and quality of drain water

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Abstract

Nowadays, more and more buildings with green walls appear in the street scene. To allow plants to grow on a wall, essentially two different system types are used. Within the soil-bound system, the so-called **Green Facades**, plants root in het open ground at the base of the wall and grow on it whether or not supported by a climbing aid. Within wall-bound systems, so called **Living Wall Systems**, plants root in a substrate that is maintained on the wall in one way or another (flower box, geotextile, module,…). Most often, plants in living wall systems depend on an irrigation and fertilization system for their water and nutritional elements.

Although many manufactures are active on the market, each with their own system, still many questions remain on the actual successful and durable implementation of these systems. One of these questions is about their **real water consumption** and the **amount and quality of drain water** (excess of irrigation water coming out of the system) and what can still be done with it.

To answer this question, a **test setup, consisting of nine different living wall systems** available on the market, was built. It was equipped with an **irrigation and fertigation system** allowing an individual program for each wall. A flow logger allowed us to **monitor the water consumption** of each wall individually. Also, the **drain water** coming from each wall was collected for **quantification** and **quality analysis**. Within this analysis part, several parameters were looked at which each have their importance for either storage, reuse or evacuation to the sewer system of this drain water. Within this paper, the results of a first monitoring campaign will be presented.

Keywords
Green Walls, Water Quality, Water consumption, Drain water

1 Introduction

Making facades green is a study subject in full expansion in Europe. Numerous green wall systems, with multiple materials and characteristics, appear on the international and European market and, little by little, in Belgium and Flanders. This increasing interest stems from the many possible benefits that are attributed to green walls. Green walls have the potential to change the view of a building or city from gloomy and gray to lively and green. Besides, green walls might also contribute to the mitigation of the urban heat island effect by preventing the underlying structure from heating up. They also have an acoustic added value, the potency to improve air quality and a positive effect on psychological health. By using different plant species, they also might contribute to biodiversity.

As stated in the abstract, mainly two systems are used for the greening of facades: the soil-bound systems, so-called Green Facades and the wall bound systems, so-called **Living Wall Systems**. This paper only deals with Living Wall Systems. The different systems currently available on the market all display their strengths and weaknesses. Currently there is a lack of scientific information on many aspects of these systems which might hamper their successful and durable implementation. These aspects include proper choice of plants and suitable substrate, maintenance, sustainability (life cycle), influence on air quality,… Therefore, a collaborative research project dealing with these topics was conducted at the Belgian Building Research Institute together with several other research partners. One of the aspects looked at in this project is the **real water consumption** and the **amount and quality of drain water** (excess of irrigation water coming out of the system) and what can still be done with it.

2 Test setup

2.1 General description

To answer these questions a test setup was built including nine living wall systems (see Figure 1). Each wall has a surface of 4m² and are all oriented to the south. As stated before, living walls systems need and irrigation and most of them also a fertigation (injection of fertilizer) system. To allow sufficient flexibility in terms of individual adjustments on timing and duration of the irrigation and individual adaption of the fertigation for each wall, a self-designed and assembled irrigation and fertigation system was installed.

Figure 1 Picture of the test setup including nine Living Wall Systems

A schematic overview of the system is given by Figure 2. The whole test setup is supplied with tap water (A) which is stored in an underground water tank (B) in order to have no direct connection to the tap water system (legal obligation). From there the water is distributed over the system using a pump (C). A digital flow logger (D) allows us to monitor the water consumption of each wall. A digital water timer (E) per wall allows the programming of the start time and duration of in total 6 watering moments per 24 hours. Next, according to the preferences of the manufacture of the green wall, liquid fertilizer from a stock solution (F) can be dosed to the irrigation water using a volumetric dosing pump (G). Before the irrigation water reaches the wall (H), a sample is collected (I) to allow analysis of the initial quality of the water. The irrigation water is distributed within the green wall making use of the system provided by the manufacturer. Different systems are being used by the manufacturers. Some make use of sprinklers/drip lines, while others make use of a capillary system where water is stored in a gutter under the plant modules from where it is absorbed by a textile incorporated in the module. For every wall individually, the excess of irrigation water (so-called drain water) is collected underneath the wall using a gutter and evacuated towards a reservoir (J) allowing quantification of the collected water and sampling for quality analysis.

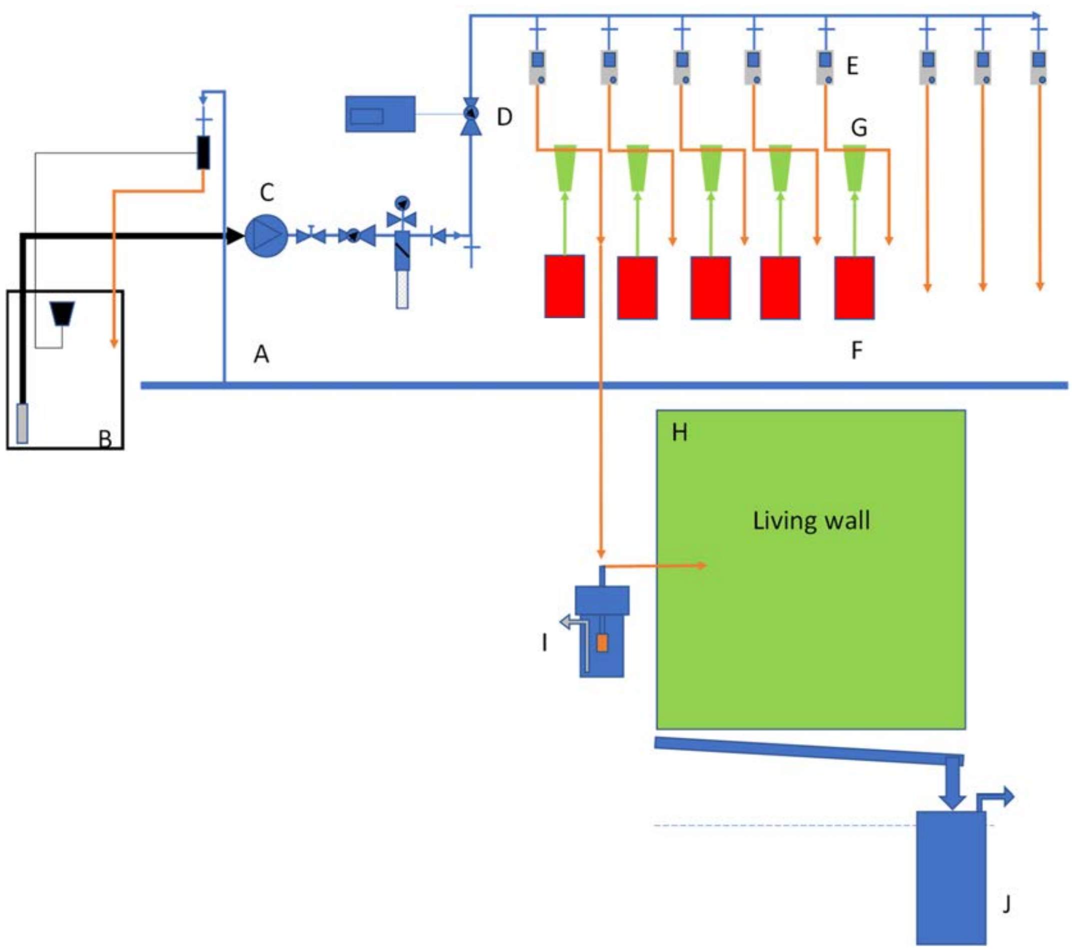

Figure 2 Schematic overview of the irrigation and fertigation system

2.2 Settings and sampling campaigns

The irrigation program for each wall is based upon recommendations of the manufacturer. We then optimized it to achieve a balance between sufficient humidity of the plant substrate on the one hand, and minimization of the amount of drain on the other hand.

Regarding fertigation, two main systems were applied based on the preferences of the manufactures. For some systems, once a year solid fertilizer was administered directly at the base of the plant (further called discontinuous fertigation). For the other systems, liquid fertilizer was administered continuously at low dose (0.5g/l final concentration) to the irrigation water. Two different types of fertilizer were used based upon the preferences of the manufacturers.

Determination of the water balance (in & out) and quality analysis was done during one-week lasting sampling campaigns. During this period the water consumption (flow logger), the amount of drain water (weighing of the collected drain water) and the water quality according to different analysis parameters were determined (see point 4). **Two sampling campaigns were launched before fertilization was applied** in order to have an idea about the influence of the wall itself on the water quality. Next, **two sampling campaigns** were launched **after the startup of fertilization** and having respected an equilibration period. These serve to have an idea about the influence of fertilization on the drain water quality.

4 Analysis parameters

As Figure 3 illustrates several water quality parameters have been analyzed on the collected water samples. These parameters were selected based on their importance for at least one of the final destinations of the drain water being either drainage to the sewer system, storage & reuse, and reuse for plant nutrition. The results for the parameters given in bold will be presented in this paper.

All chemical parameters, including Chemical and Biological Oxygen Demand (COD/BOD), were quantified using appropriate analysis kits from Hach and by making use of a DR6000 spectrophotometer.

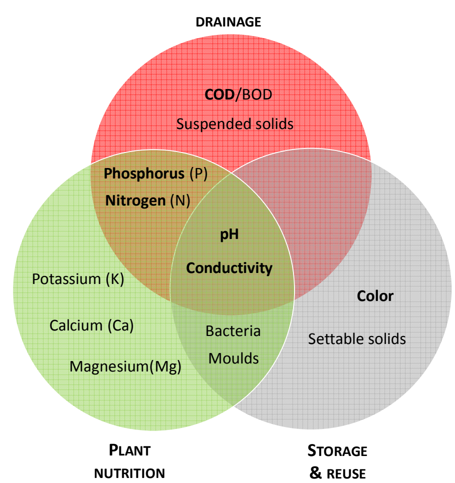

Figure 3 Overview of the water analysis parameters

3 Results

The following paragraphs will describe the results as far for the drain water quality, the water consumption and drain water quantity for seven green walls. Two additional walls were recently installed for which no results are yet available. For the drain water quality, the results of the campaigns before and after startup of the fertilization are described (see § 2.2).

Remark: The commercial names of the different systems are replaced by a code. Within this code the first letter is an O or I standing for the type of substrate, either ***O****rganic or* ***I****ntert. The second letter is a T or t standing for a* ***T****hick or a* ***t****hin system structure. The number of + signs behind are an indication of the quantity of substrate in the system.*

3.1 Drain water quality

Figure 4 contains a series of graphs showing the results of the analysis parameters for the drain water for seven living wall systems as discussed below. The light grey bars show the results without fertilization (influence of the system itself), while the dark grey bars show the results with fertilization (additional influence of fertilization). The shaded bars give the results for the reference samples including tap water and the irrigation water (with fertilizer) as supplied to the different walls. For systems with discontinuous fertilization (dc) the results for the drain water should be compared to the values of the tap water to have an idea about the influence of the green wall. For systems with continuous fertilization (c) the results for the drain water must be compared to the corresponding irrigation water.

pH and conductivity:

For the systems with **discontinuous fertilization** (dc): comparison of the **pH** values of the drain water with the pH of the tap water used to irrigate these systems indicate no major influence of the fertilization or the system on the pH of the drain water (see Figure 4 A).

For the systems with **continuous fertilization** (c): the addition of fertilizer to the tap water results in a pH decrease for the irrigation water (shaded bars Figure 4 A). However, this does not result in an obvious decrease of the pH of the drain water for these systems. This indicates that both systems with organic and inert substrate have a buffering capacity.

Regarding the **conductivity** (measure for dissolved ions), the systems themselves and **discontinuous fertilization** seem to have a limited effect on this parameter (see Figure 5 B). When fertilizer (soluble inorganic salts) is added to the tap water this obviously results in an increase of the conductivity of the irrigation water. This also results for systems with **continuous fertilization** in an increase of the conductivity of the drain water, indication that at least part of the fertilizer administered to the walls is not taken up by the wall and ends up in the drain water.

Color

Measurement of the color of the drain water indicates that most of the systems cause to a greater or lesser extent discoloration of the water. Addition of fertilizer does not result in a discoloration of the irrigation water, neither does the feeding of this fertilized irrigation water to the green walls cause an increased discoloration of the drain water (Figure 4 C). This means that the observed discoloration is mainly coming from the system itself. Especially green wall systems with a thick structure and a large quantity of organic substrate cause a clear discoloration of the drain water. Upon comparison of the apparent color (data not shown) and true color measurement results, it becomes clear that this discoloration largely results from dissolved impurities.

Chemical oxygen demand

In general, green wall systems and fertigation (= inorganic salts) are found to have a limited effect on the COD value of the drain water, except for the ticker systems with a large quantity of organic substrate (Figure 4 D). This might hamper stable storage of the drain water for later reuse.

Plant nutrition: nitrogen, phosphorus and potassium

The systems themselves and discontinuous fertilization do not have a clear influence on the nitrogen content of the drain water (see Figure 4 E). However, addition of fertilizer to the tap water results in an increased nitrogen content of the irrigation water, which in turn results in an increased concentration in the drain water. Since this concentration is lower than that of the corresponding irrigation water at least part of the nitrogen is taken up by the green wall. Anyhow, a considerable amount still flows out, which certainly makes reuse of the drain water from plant nutrition perspective worth considering.

Besides nitrogen, fertilizers also contain a source of phosphorus and potassium. As can be seen from Figure 4 F, the addition of fertilizer logically results in an increase in the phosphorus content of the irrigation water. Unlike with nitrogen, this does not result in a strong increase in the phosphorus content in the drain water. The findings for potassium (not shown) are quite similar to those of nitrogen.

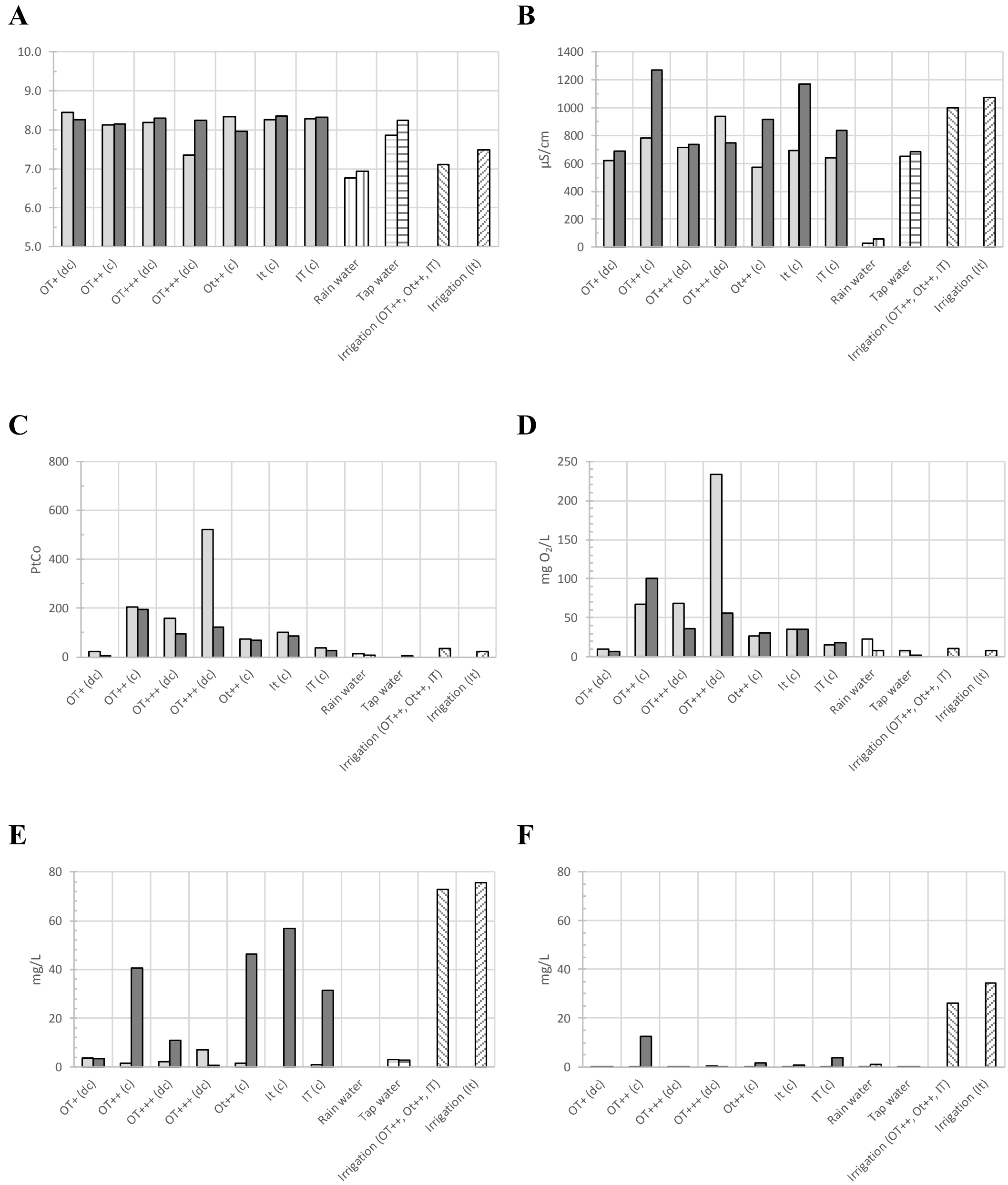

Figure 4 Graphs presenting the results for different analysis parameters including pH (A), Conductivity (B), True color (C), Chemical Oxygen Demand (COD) (D), Nitrogen (E) and Phosphorus (F) in the drain water, reference water samples (rain water and tap water) and the irrigation water (tap water including fertilizer) as supplied to the indicated walls. dc = discontinuous fertilization (compare to tap water), c = continuous fertilization (compare to appropriate irrigation water, shaded bars). Light grey: campaign without fertilization, Dark grey: campaign with fertilization.

3.2 Water consumption and drain water quantity

Regarding the water consumption and the amount of drain, strong differences are observed between the different systems. Some systems need a large water supply (drain + consumption), but also consume most of this supplied water (= have small quantity of drain water). These are typically the thicker systems with a large amount of organic substrate. Other systems are found to consume only a fraction of the water supplied (have relatively high drain water quantity). This includes the systems with an inert substrate or a thin structure with a moderate amount of organic substrate or systems with a small amount of organic substrate.

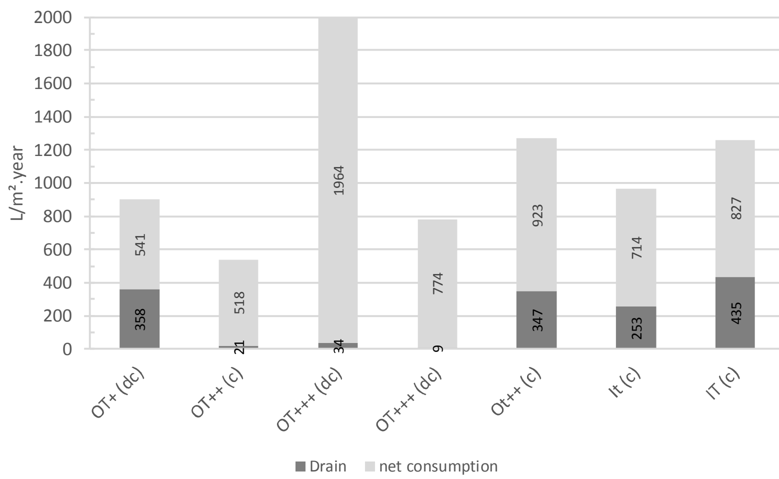

Figure 5 Water supply (drain + consumption), net water consumption (light grey) and drain water quantity (dark grey) in L/m².year

4 Conclusions

Based upon the above results, we can conclude that the systems themselves have an influence on several water quality parameters including pH, color and COD. Except for the influence on pH, this especially holds true for the thicker systems with a large quantity of organic substrate. Discontinuous fertilization has nearly no influence on the quality of the drain water. Continuous fertilization on the other hand, has a strong impact on the conductivity and the nitrogen & potassium content of the drain water. Regarding the amount of drain water and the water consumption a large variety can be observed between the different systems. Some of them have a great potential for optimization/improvement. Further research will have to confirm our observations and give insight in their evolution in time.

5 Presentation of Author(s)

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