Chapter 7
Guide to Green Roofs for Wastewater Treatment: A Vietnam Perspective

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Abstract Green roofs can be defined as "contained" green spaces on top of artificial structures and are considered a nature-based solution to prevent several environmental and socio-economic problems associated with urban sprawl and climate change. A green roof system contains a high-quality waterproofing membrane and root barrier system, a drainage system, filter fabric, a lightweight growing medium, and plants. Green roof systems can be modular layered systems already prepared in trays, including drainage layers, growing media, and plants, or each component of the system can be installed separately on top of the structure. With its inherent strengths, green roofs have been applied more and more widely in urban areas. This chapter shows significant information such as basic elements, pollutant removal mechanisms, and benefits associated with green roofs, as well as offer technical

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instructions to install a green roof system and operation and maintenance procedures that ensure the longevity of the system. Using this guide, the users know how to select the type of plant, prepare materials, etc., to install a green roof system. Besides, the users also get a more comprehensive understanding of implementation and maintenance issues.

Keywords Charcoal · Green roof · Growing media · Nature-based solution · Oyster shells · Vernonia elliptica · Trumpet vine

7.1 Introduction

Green roof is one of the innovative architectural and urban development options based on sustainable development concepts that can be utilized to increase urban green areas, improve environmental quality, and generate sustainable urban development. Additionally, green roof improves building insulation, lowering heating and cooling costs and resulting in cost savings. The structure of green roof system is entirely or partially covered by vegetation and has multiple layers such as waterproofing, drainage, insulation, plant growth, and active plant layers (Shafique et al. 2018). The main components of the proposed green roof system have been illustrated in Fig. 7.1. Green roofs are classified into extensive, intense, and semi-intensive (Fig. 7.2). The differences between these types are designs of vegetation layer. Extensive green roofs are simpler, lighter, and thinner (depth of 60-200 mm) and are usually planted primarily with moss, herbs, and grass. While intensive green roofs have a depth of 150–400 mm and are planted with shrubs and trees (Fernandez-Cañero et al. 2013).

Green roof is a technique that benefits the environment by optimizing energy use, absorption of air pollutants, runoff regulation, controlling the heat island effect, and enhancement of urban ecology. Green roof flora minimizes building heat absorption by reflecting or deflecting solar radiation and evapotranspiration. The

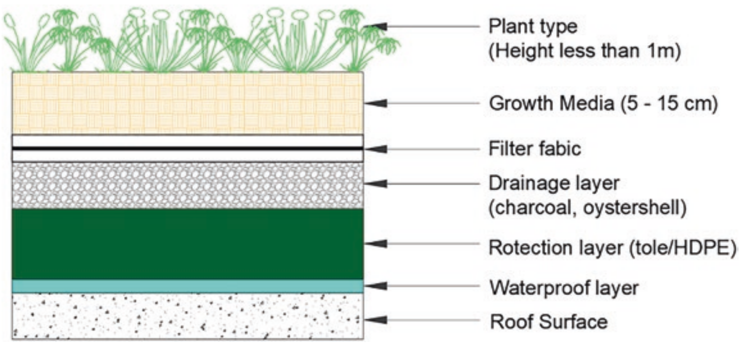

Fig. 7.1 Components of green roof system

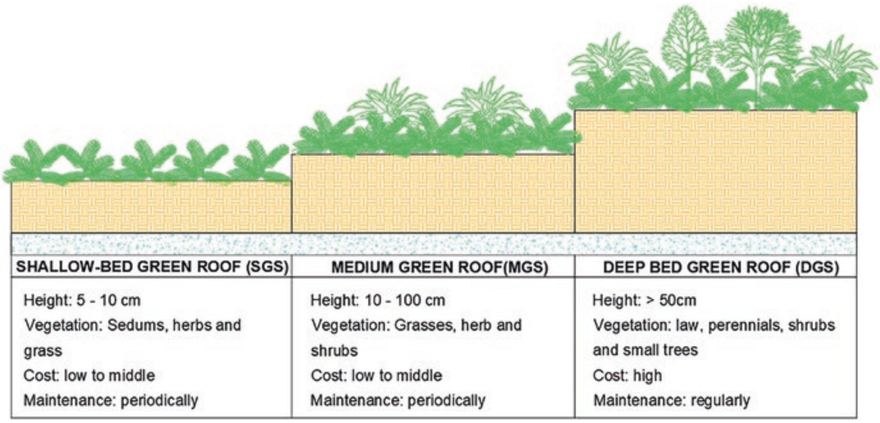

Fig. 7.2 Types of Green roof

growing substrate works as a physical barrier to control proximal temperature and as many drainage layers to keep moisture in the plant. Green roofs with varying substrate depths, drainage networks, and plants function as urban ecosystems on top of conventional roofs; as a result, additional layers are added to the roof surface for better insulation, preventing heat penetration into the building envelope and lowering ambient rooftop temperature. Apart from these benefits, green roofs do not require extra land beyond the building footprint because they are placed on otherwise empty roof space. Building roofs are estimated to cover 80% of impervious surfaces in metropolitan areas. The ability to construct green roofs on existing building roofs without the need to acquire new land area, in addition to their ability to significantly reduce runoff volume and decrease peak discharge, makes green roofs a valuable nature-based solution. They have the potential to absorb hazardous fine dust particles from the air, which can aid in human comfort in heavily developed metropolitan areas. In metropolitan regions, the air generally contains small dust particles, which makes the urban environment unpleasant. Green roofs serve to mitigate air pollution in two ways. To begin, the plants collect tiny air contaminants via stomata. The annual average concentrations of fine particles in the world are measured at 30–55 g/m^3 (PM2.5) and 5–33 g/m^3 (PM10) (Jurado et al. 2023). According to Speak et al. (2012), a green roof with a 19 ha area could eliminate up to 230 tons of PM 2.5 and PM10. This technology also demonstrates that green roofs can assist in decreasing habitat loss in urban settings. Green roofs also encourage urban leisure activities. It encourages animals by enabling them to congregate in green spaces. It aims to convert impermeable surface areas into natural green spaces, which can provide significant environmental advantages in metropolitan settings. Green roofs have a pleasant impact on city dwellers by minimizing air and noise pollution. Green open areas catch the eye and have attempted to bring people together for roof gardening. Green roofs also increase the value of a home. Green roofs can also provide potential for urban agriculture. They can grow many veggies and make civilization self-sufficient in food production: irrigated tomatoes, green beans, cucumbers, peppers, basil, and chives for green roof food production.

Green roof systems have been widely employed nowadays owing to their ecological and economic benefits. A benefit–cost analysis incorporating a social dimension, on the other hand, is still lacking. Thus, quantifiable estimations of their costs and benefits are required to encourage the application of green technologies for sustainable development. The investment costs are determined by a variety of factors, including location, labor costs, green roof type and material, and so on. It is commonly assumed that a green roof does not require frequent irrigation or fertilizer; nevertheless, for the best advantages in drought conditions, watering and fertilization are required. These roofs must also be properly and regularly maintained in terms of plant growth, drainage, and substrate in the systems to extend the used time. In addition, when the installation of green roof systems is improper, there is a great risk of roof leakage and structural failure. As a result, adequate studies should be conducted on various components of green roofs (e.g., weight and storage capacity) to minimize leaks and adverse impacts on structures such as seepage walls and decay walls.

7.2 Instruction for Installing Green Roof Systems

7.2.1 Preparation of Materials

Material layers that support plant growth are considered one of the most important design parameters due to their strong impact on the performance of green roofs in terms of vegetation, physical and biochemical processes, hydrodynamics, wastewater treatment, and other functions. The porous media act as pollutant adsorbents and provide an environment for macrophytes to grow. Soil, sand, and gravel have been commonly used for green roofs; besides, some other materials, as shown in Table 7.1, can be considered. Materials applied in green roofs must be high performance (e.g., lighter, high absorption capacity, long life).

Table 7.1 Characteristics of media used in green roof systems

Medium	Diameter (mm)	Density (kg/m^3)	Porosity (%)	References
Cobble	80–100	270	49	Sheng et al. (2007)
Oyster shell	200–500	250	88	Li et al. (2010)
Coconut Shell	10–20	600–800	15–25	Parjane and Sane (2011)
Charcoal	9–10	180–220	38	Vo et al. (2018)
Ceramsite	8-15	1130-1150	50-60	Cheng et al. (2014)
Mussel shell	90–140	2620	87–89	Geng et al. (2022)

7.2.2 *Plant layers*

Plants, or macrophytes, cover the material layer's surface and create a green space. The root system of the plant may help with physical filtration, avoid clogging, absorb nutrients and metals, and serve as media for microorganisms that are linked to it. It has been demonstrated that plants have a substantial impact on how green roof systems remediate pollutants.

According to Table 7.2, the mentioned plant species suitable for green roofs should have the following characteristics: easy to grow, thriving in harsh conditions (rain/storm in winter and high temperature in summer), capable of treating wastewater, having a long life, and good coverage (green area).

Table 7.2 Characteristics of selected plants

Names	Characteristics
Vernonia elliptica	
	• Perennials, vines, climbers, grown for foliage, evergreen. • Height of plants: 60–120 cm. • Length of leaves: 6–10 cm long. • Density: 46 plants/m^2.
Campsis radicans	
	• High-climbing, aggressively colonizing woody vine. • Fairly heat, cold, drought tolerance, no serious insect or diseases. • Height range from 6 to 12 m, flowers can grow up to 8 cm long; leaves grow up to 10 cm in length. • Density: 28 plants/m^2.
Tristellateia australasiae	
	• Climber, vine and liana. • Fast-growing for fences, pergolas, trellises, and vertical greening of buildings. • Be trained as ground cover; suitable for gardens, parks, or roadsides.
Hedera helix	
	• Evergreen perennial climbing vine that attaches to bark of trees, brickwork, and other surfaces by root-like structures that exude a glue-like substance to aid in adherence.

7.2.3 Design Parameters

The selection of acceptable plant species and substrates as growing materials, the evaluation of the best hydraulic parameters, and the establishment of optimum operating conditions all contribute to the optimization of the removal processes in natural-based solutions. It is crucial to determine the best design parameters for green roofs in order to achieve high levels of pollutants removal while making optimum use of the available space. However, high hydraulic loading rate (HLR) values, on the other hand, speed up filtration and will slow down hydraulic retention time (HRT), which will reduce the amount of time the wastewater will be in contact with the microbial biofilm and plant roots. So, it is anticipated that the removal of pollutants will be reduced by excessive HLR (especially with the pollutants that are more easily washed out). Table 7.3 lists the key parameters for each study in terms of substrate, plants, and operational factors (HLR, organic loading rate (OLR), and HRT), differentiating between pilot and laboratory studies. Thereby, the optimal design value for HLR is in the range of 1.6–5.0 $m^3/m^2/d$ and OLR is 480–1500 $gCOD/m^2/d$.

Table 7.3 Design parameters of a green roof system

Size	Area (m^2)	Media	Design parameters HLR ($m^3/m^2/d$)	OLR ($gCOD/m^2/d$)	HRT (h)	References
Pilot-scale		Soil, sand, small rock	2.60–4.00	300–600	23–30	Vo et al. (2018)
Pilot-scale		Soil, sand, small rock	3.40	490	NA	Van et al. (2015)
Pilot-scale	0.72	Clay, coco coir; sand	1.00	60	0.2–0.7	Masi et al. (2016)
Pilot-scale		Sand, organic soil, LECA, PLA	1.60	120	91.2	Zapater-Pereyra et al. (2016)
Lab-scale	3.50	Sand, coarse sand, gravel	0.05–0.11	5.7–15.4	96–48	Fowdar et al.(2017)
Pilot-scale	2.64	Sand	–	10.2	24	Chowdhury and Abaya (2018)
Pilot-scale	2.50	Soil, sand, rocks, gravel	2.47–4.03	210–280	NA	Vo et al. (2018)
Pilot-scale	1.08	Charcoal, oyster shell, Gravel	1.60–5.00	480–1500	72–24	In case study at HCMUT (Vietnam), 2021

7.2.4 A Case Study in Ho Chi Minh City

7.2.4.1 Design Parameters

Two pilot-scale green roof systems are located on the roof of a building at Ho Chi Minh City University of Technology (10°46′31.3″N, 106°39′35.2″E). Therefore, green roofs are exposed to fully natural tropical conditions such as rain, sunlight, and wind. Each system consists of two modules with the same dimension of 1800 × 300 × 170 mm (length × width × height) (Fig. 7.3). The media in a module were arranged as follows: a charcoal layer (length × width × height = 1680 × 300 × 80 mm) on the top and an oyster shell layer (length × width × height = 1680 × 300 × 40 mm) on the bottom. The mass density of charcoal and oyster shells used in this study was 323 and 476 kg/$m^{3,}$ corresponding to the weight in each module of 13.0 and 9.6 kg. Additionally, the module was allocated marginally with layers of rock 1 × 2 inch on either vertical side, which are equal in size (length × width × height = 300 × 60 × 120 mm). *Vernonia elliptica* and *Campsis radicans* were planted in two separate green roof systems with densities of 55 and 37 plants/m^2 and an average initial height of 70 cm.

7.2.4.2 Instruction for installing the green roofs

The installation process of the system is shown in Fig. 7.4. Details are as described below:

Step 1. Select charcoal and oyster shells and wash and dry them

- Caculate the volume of charcoal and oyster shells required.
- Carry out the preliminary processing: rinse with clean water to remove the dirt from the charcoal and oyster shells. Then let them dry out in the sun.
- Weigh to determine the dry weight of charcoal and oyster shells to be placed into the system.

Step 2. Plant selection. Wash the soil and put the plant in a pot to be adapted to tap water.

Selected plants are brought back from the field or a nursery, and the soil from the root is removed. Wash the roots with clean water and then put them in a pot in order to be adapted to the water environment for about 1–2 days before putting them into the green roof system.

Step 3. Installation of the tray, pump, pipe, and electrical systems.

- Install pipes that connected the inlet tank, wastewater pump, and modules.
- Install the electrical system to operate the pump.

Step 4. Adding oyster shell to the tray

- Calculate the weight of oyster shells that need to be put into the system.
- Weigh and place the oyster shells into the green roof system to the required height.

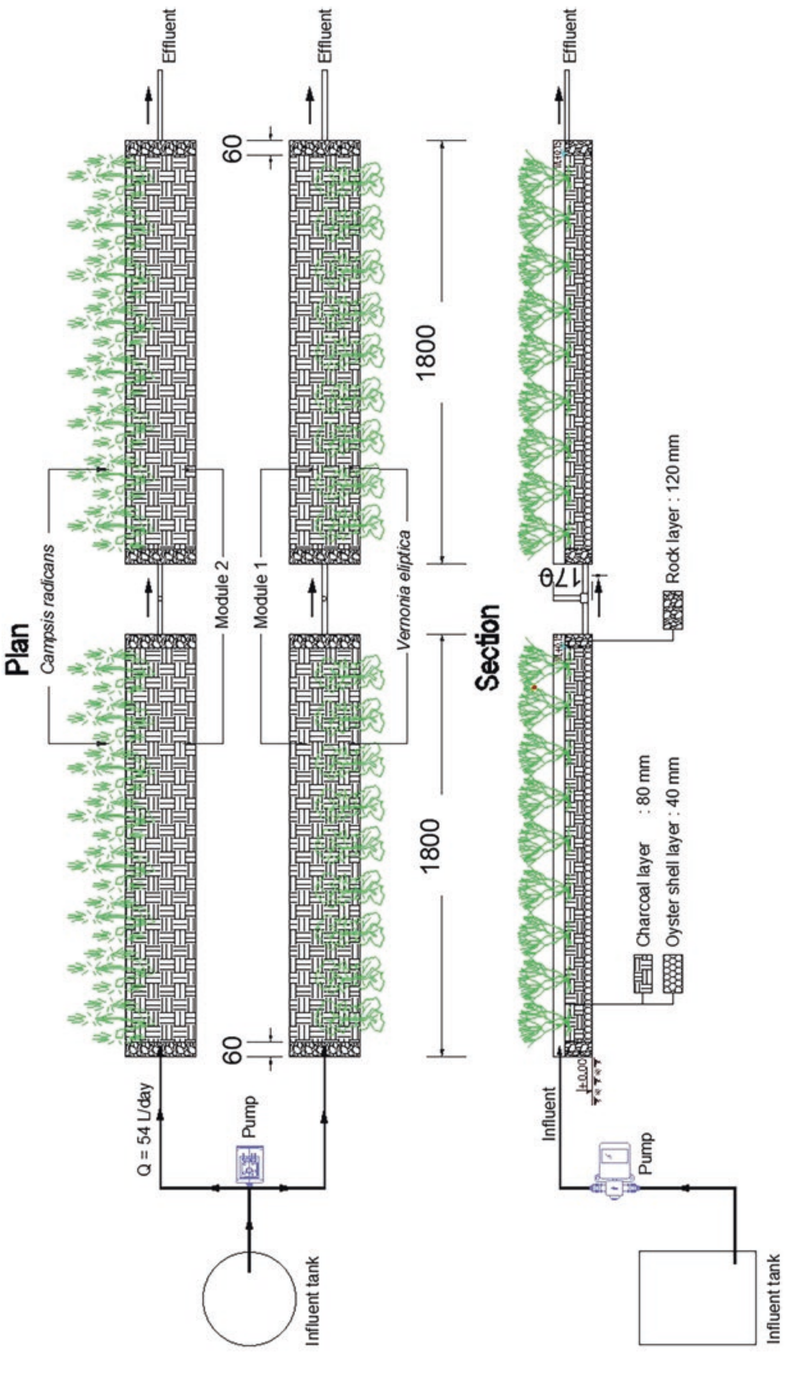

Fig. 7.3 Schematic diagram of the green roof system

Fig. 7.4 Green roof system installation process

Step 5. Adding charcoal to the tray

- Calculate the weight of charcoal that needs to be put into the system.
- Weight and place the charcoal on top of the oyster shell layer to the required height.

Step 6. Adding rocks to the tray

- Calculate the weight of rock that is needed to be placed into the system.
- Place the rocks on both ends of each module to the specific height.

Step 7. Adding plants in the green roof system

– Place the plants in the tank at a specified density. The distance between the two plants is about 20 cm.
– After stabilizing, turn on the pump to bring the wastewater to the system with the calculated flow rate.

Figure 7.5 shows the green roof systems after installing completely.

7.2.4.3 Experiment Set-up

The green roof systems were operated under the conditions shown in Table 7.4. Besides, Table 7.5 shows the water quality of the influent and effluent of the systems.

Fig. 7.5 Green roof systems at Ho Chi Minh University of Technology

Table 7.4 Operational condition of green roof system

Stages	HLR (m^3/m^2/day)	OLR (gCOD/m^2/d)	HRT (h)	Q (L/d)	Biomass growth (g/d)	
					Wet biomass	Dry biomass
Adaption	0.9	20	144	14	4.43[a] 0.29[b]	1.02[a] 0.13[b]
HLR1	1.6	115	72	17	8.69[a] 0.82[b]	2.10[a] 0.13[b]
HLR2	5.0	345	24	54	11.65[a] 1.65[b]	2.10[a] 0.27[b]

Note: a: *Vernonia elliptica*; b: *Campsis radicans*

Table 7.5 Characteristics of influent and effluent of green roof system

No.	Parameters	Unit	Concentration (Mean ± SD)	
			Influent	Effluent
1	pH	–	6.8 ± 0.2	7.2 ± 0.4
2	Turbidity	NTU	46 ± 15	3.0 ± 2.0
3	TSS	mg/L	52 ± 14	5.0 ± 2.0
4	COD	mg/L	335 ± 35	30 ± 13
5	NH_4^+-N	mg/L	21 ± 12	3.0 ± 0.8
6	TP	mg/L	2.0 ± 0.8	1.0 ± 0.4

7.3 Operation and Maintenance

Everyone involved in a green roof project benefits from routine upkeep. The achievement of the designer's objective, maximizing the ecosystem services offered by the roof, and safeguarding the owner's investment all depend on it. A green roof can be made to require little upkeep, but this is uncommon. Failure to manage a green roof will frequently conceal issues that eventually have unforeseen effects, which may include the death of the majority or all targeted plants. That might nullify any warranties that still apply. Regular maintenance will increase the lifespan of the roofing materials, lessen the frequency and severity of leaks, and lower ownership costs in addition to supporting healthy plants.

7.3.1 Operational Protocols

7.3.1.1 Starting Up of the System

The domestic wastewater is collected and transferred to an influent tank with a volume of 80 L before being pumped into the green roof system through two separate lines. After about 2 months, when the plants had grown up, pruning and collection of pruned biomass was carried out. Replacement of new plants is not required unless the plants have not grown well or died.

7.3.1.2 Operational Parameters

For the influent wastewater of the green roof system, many researches with different operational parameters have been conducted, and Table 7.6 shows the allowable ranges of those parameters.

Besides those water parameters, regularly monitoring cleaning of the system and measuring parameters to see if they are consistent with the indicators stated on the

Table 7.6 Some operational parameters of green roof and wetland roof systems

	Operational parameters				
Type	HLR (m^3/ha/d)	OLR (kg/ha/d)	NLR (kg TN/ha/d)	HRT (h)	References
GR	160–500	48	–	76.8–240	In the case study at HCMUT (Vietnam), 2021
WR	260–400	30–60	15–39	23–30	Vo et al. (2018)
WR	340	36	21	18	Thanh et al. (2014)
WR	340	49	22.5	–	Van et al. (2015)
WR	160	12	5	91.2	Zapater-Pereyra et al. (2016)
WR	247–403	21–28	9–13	–	Vo et al. (2018)

equipment label or not (2 times a week) in order to promptly detect possible causes that could lead to broken equipment and other parameters such as current, voltage, insulation, and noise also need to be recorded for evaluation.

– The noise level for devices submerged in liquid is 70 dB. For equipment installed on open surfaces, the noise level should not exceed 80 dB.
– Allowable insulation for electrical equipment in low voltage grid is <1 MΩ.
– The allowable voltage rise should not exceed 10% of the voltage stated on the equipment label and the voltage drop should not exceed 2A/100 V.
– The current should not exceed the current indicated on the label of the equipment.

7.3.2 Maintenance

Maintenance considerations should be incorporated into the design process of the green roof system, with emphasis placed on identifying potential maintenance issues early on. Maintenance personnel must be prepared to conduct regular inspections and understand that green roofs require a different approach than traditional grade-level landscapes. It is important to maintain a balance between the health of the growing media and the plants to ensure the longevity and effectiveness of the green roof system.

7.3.2.1 Equipment Maintenance

To ensure proper operation of the machine, it is important to check that the input power supply voltage matches the rated voltage of the machine. Regularly cleaning the suction and discharge nozzles is also crucial, as these areas are prone to becoming dirty or blocked, potentially causing the pump head to malfunction. If the water does not flow properly, it may be due to a loose suction head, allowing air to enter and prevent water flow. In such cases, the air release button can be turned by hand to discharge the air and then screwed back on. It is important to avoid exceeding the allowed flow limit by adjusting the flow control knob, as excess tightening may cause damage to the machine. Regular cleaning of the equipment is also recommended to ensure optimal cooling and heat dissipation. Table 7.7 shows some pump failures and solutions to fix them.

7.3.2.2 Caring Plants and Harvesting Biomass

To ensure the optimal growth of plants on the green roof system and maintain its aesthetic appeal, regular care and periodic pruning is necessary. Weeds should be cleared from the system every two months to promote the growth of the plants. Dead plants should be replaced with new ones. Trimming the plants and clearing weeds will require using ladders or chairs to climb to the roof, so it's important to

Table 7.7 Some common pump failures and remedies

No.	Problem	Causal	Solutions
01	Pump is not working (not rotating)	There is no incoming power supply	Check the power supply, power cable
02	The pump is working but there is a rattling noise	The power source loses phase to the motor Impeller is clogged with hard objects The gear box is missing oil, grease, and possible wear Large foreign objects are trapped into the pump chamber or screw	Check and repair the power supply Remove rigid objects from the impeller Check and add, or change new oil Check for cleanliness
03	The pump works but does not pump the water	Reverse rotation The opening and closing valve is clogged, or damaged The pipe is clogged; Haven't opened the valve yet Tearing of pump diaphragm	Reverse rotation Check for damage and fix it, if damaged, replace the valve with a new one Check for any head loss and repair it Open valve Other changes
04	Pump flow is reduced	Stuck in the impeller, valve, pipeline The water level has dried up The power supply is incorrect Deteriorated equipment	Check and solve again Turn off now Check the power supply Wash and clean with soap or special solution

exercise caution to avoid damaging the plants' root system and to prevent falls (Fig. 7.6).

Remarks: The operation and maintenance processes must be recorded in the equipment monitoring table and equipment history (date of maintenance, number of times the maintenance is carried out, what accessories have been changed, and include their specifications for the ease of follow-up maintenance).

7.3.2.3 Troubleshooting

The purpose of this section is to present a quick guide to the operator in the event of problems and to provide solutions. To fix a problem, one must first understand the system well. Operators need to know the following in order to troubleshoot:

- The role of each part in the system.
- Principles of the processes in the system.
- Unusual factors and phenomena and ability to identify them.
- Options available when a fault occurs.

In essence, to recognize when an abnormal condition arises, it is crucial to understand how the process functions under normal circumstances. Table 7.8 shows some problems in a green roof system.

Fig. 7.6 Taking care and pruning the green roof system

Table 7.8 Some problems that could occur in a green roof system, their causes, and possible solutions

Problem	Cause	Check or monitoring	Solution
No water in the inlet manifold	Pump is turned off/broken	Pipe is clogged/ broken	Clean pipes/remove broken pipes and replace with new pipes
Increase in pollutant concentration at the outlet	Hydraulic loading is too high (overload)	Flow rate	Reduce flow rate
Overgrowth of algae	Low coverage of plant Low hydraulic load	Plant density Flow rate	Increase plant density Intercropping with other crops Increase the flow rate
Yellow leaves, slow growth	Low pH Lack of nutrition	pH adjustment Adjust the water inlet distribution line	Adjust the pH at the inlet stream by adding $NaHCO_3$ Install additional water distribution pipes from the start to the end of the tank
No effluent	Turned off/broken	Pipe is clogged/ broken	Unclog/unblock Replace the new pipe

To ensure effective green roof maintenance, it is recommended to plan preventive maintenance visits rather than reactive ones. This requires a sound understanding of plant physiology and weed life cycles. Along with addressing common roof problems, the maintenance crew should inspect the waterproofing and other components to ensure their proper functioning. Optimal plant establishment during the first year or two can greatly reduce the long-term maintenance required for extensive roofs, unless a pre-vegetated installation method is employed. A well-designed program should be developed that includes plant establishment and ongoing maintenance requirements.

7.4 Conclusions

This chapter presents comprehensive guidelines for the construction, installation, and maintenance of green roof systems designed to treat septic tank effluents originating from households, institutions, and various facilities. Notably, these green roof systems offer a cost-effective solution with a small footprint, making them an economically viable choice. The replication of such systems carries the potential to mitigate the long-standing issue of septic tank effluent discharge into canals—a prevalent problem in numerous countries. This not only promises substantial improvements in canal water quality but also stands to enhance the overall well-being of nearby communities and bolster biodiversity by fostering healthier aquatic ecosystems. To fully realize these benefits, future endeavors must address several critical aspects, including (i) establishment of governance structures and policies tailored to the application of green roof systems in diverse settings, (ii) cultivation of awareness and community engagement, along with mechanisms for financial participation, (iii) retrofitting of existing septic tanks to divert effluents toward green roof systems, and (iv) design and integration of novel sanitation solutions within buildings, enabling the collection and distribution of wastewater to these green roof systems. By addressing these key elements, we can harness the potential of green roof systems as a sustainable and ecologically sound nature-based solution to wastewater treatment in urban environments.

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References

Cheng, Y., Fan, W., & Guo, L. (2014). Coking wastewater treatment using a magnetic porous ceramsite carrier. Separation and purification technology, 130, 167–172. https://doi.org/10.1016/j.seppur.2014.04.030

Chowdhury RK, Abaya JS (2018) An experimental study of greywater irrigated green roof systems in an arid climate. J Water Manag Model 2018:1–10. https://doi.org/10.14796/JWMM.C437

Fernandez-Cañero R, Emilsson T, Fernandez-Barba C, Herrera Machuca MÁ (2013) Green roof systems: a study of public attitudes and preferences in southern Spain. J Environ Manag 128:106–115. https://doi.org/10.1016/j.jenvman.2013.04.052

Fowdar HS, Hatt BE, Breen P, Cook PLM, Deletic A (2017) Designing living walls for greywater treatment. Water Res 110:218–232. https://doi.org/10.1016/j.watres.2016.12.018

Geng B, Li Y, Liu X, Ye J, Guo W (2022) Effective treatment of aquaculture wastewater with mussel/microalgae/bacteria complex ecosystem: a pilot study. Sci Rep 12(1):2263. https://doi.org/10.1038/s41598-021-04499-8

Jurado X, Reiminger N, Maurer L, Vazquez J, Wemmert C (2023) On the correlations between particulate matter: comparison between annual/monthly concentrations and PM10/PM2.5. Atmos 14(2). https://doi.org/10.3390/atmos14020385

Li J, Wai OWH, Li YS, Zhan J, Ho YA, Li J, Lam E (2010) Effect of green roof on ambient CO2 concentration. Build Environ 45(12):2644–2651. https://doi.org/10.1016/j.buildenv.2010.05.025

Masi, F., Bresciani, R., Rizzo, A., Edathoot, A., Patwardhan, N., Panse, D., & Langergraber, G. (2016). Green walls for greywater treatment and recycling in dense urban areas: a case-study in Pune, Journal of Water, Sanitation and Hygiene for Development, 6(2), 342–347. https://doi.org/10.2166/washdev.2016.019

Parjane SB, Sane MG (2011) Performance of grey water treatment plant by economical way for Indian rural development. Int J ChemTech Res 3(4):1808–1815

Shafique M, Kim R, Rafiq M (2018) Green roof benefits, opportunities and challenges – a review. Renew Sust Energ Rev 90:757–773. https://doi.org/10.1016/j.rser.2018.04.006

Speak AF, Rothwell JJ, Lindley SJ, Smith CL (2012) Urban particulate pollution reduction by four species of green roof vegetation in a UK city. Atmos Environ 61:283–293. https://doi.org/10.1016/j.atmosenv.2012.07.043

Thanh BX, Hai Van PT, Tin NT, Hien VTD, Dan NP, Koottatep T (2014) Performance of wetland roof with Melampodium paludosum treating septic tank effluent. Desalin Water Treat 52(4–6):1070–1076. https://doi.org/10.1080/19443994.2013.826323

Van PTH, Tin NT, Hien VTD, Quan TM, Thanh BX, Hang VT, Tuc DQ, Dan NP, Van Khoa L, Le Phu V, Son NT, Luong ND, Kwon E, Park C, Jung J, Yoon I, Lee S (2015) Nutrient removal by different plants in wetland roof systems treating domestic wastewater. Desalin Water Treat 54(4–5):1344–1352. https://doi.org/10.1080/19443994.2014.915767

Vo TDH, Bui XT, Nguyen DD, Nguyen VT, Ngo HH, Guo W, Nguyen PD, Nguyen CN, Lin C (2018) Wastewater treatment and biomass growth of eight plants for shallow bed wetland roofs. Bioresour Technol 247(September 2017):992–998. https://doi.org/10.1016/j.biortech.2017.09.194

Zapater-Pereyra M, Lavrnić S, van Dien F, van Bruggen JJA, Lens PNL (2016) Constructed wetroofs: A novel approach for the treatment and reuse of domestic wastewater. Ecol Eng 94:545–554. https://doi.org/10.1016/j.ecoleng.2016.05.052

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