

PAPER • OPEN ACCESS

Urban Rainwater Management Tools

To cite this article: M Teichmann *et al* 2020 *IOP Conf. Ser.: Earth Environ. Sci.* **444** 012052

View the [article online](#) for updates and enhancements.

You may also like

- [Whole-process Risk Identification of Urban Rainwater Resource Utilization and Construction of Evaluation Index System in Loess Plateau Region](#)
Li Qin, Chengxiang Ma and Yunxiao Mu
- [A Review of Researches on Plant Configuration and Decontamination Efficiency of Rain Gardens in China](#)
P.L Zhou, J.Q Han and H.X Zhang
- [Rainwater Harvesting System \(RWHS\) for buildings: A mini review on guidelines and potential as alternative water supply in Malaysia](#)
Siti Fairuz Juiani, Chun Kiat Chang, Choe Peng Leo *et al.*



ECS
The
Electrochemical
Society
Advancing solid state &
electrochemical science & technology

DISCOVER
how sustainability
intersects with
electrochemistry & solid
state science research

Urban Rainwater Management Tools

M Teichmann¹, D Kuta¹ and N Szeligova²

¹VSB – Technical University of Ostrava, Faculty of Civil Engineering, Department of Urban Engineering, 17. listopadu 2172/15, 708 00 Ostrava – Poruba, Czech Republic

²Karvina City Authority, Department of Spatial Planning and the Environment, Frystatska 72/1, 733 24 Karvina, Czech Republic

Abstract. The paper deals with the state of solution of rainwater management in the urbanized area. The paper describes development and basic principles of rainwater management, analysis of current state, climate change and last but not least, possible ways of rectifying and streamlining the current, nowadays inconvenient, facilities with an emphasis on their easy sustainability.

1. Introduction

Due to the global climate change caused by the occurrence of extreme meteorological phenomena in the Czech Republic, today's urbanized areas are facing a drought on the one hand and an enormous amount of torrential rainwater on the other. These extreme climatic situations bring water scarcity, drought, heat waves and flash floods, all of which have a significant impact not only on the quality of life of the population, but also on the functionality of the infrastructure, natural ecosystems, etc. , where it is further enhanced by an ever-increasing degree of urbanization. Especially the cumulative rainfall water, which arises as a result of insufficient natural infiltration of these waters into the subsoil, is most active here. Urbanized environment of settlements is usually made up of enormous number of impermeable areas, which are often uncontrolled due to urbanization, causing overflow of sewer system, sewage treatment plants, distribution of smaller watercourses and subsequent, increasingly frequent, lightning floods. For these reasons, it is necessary to streamline the management of rainwater, which has become an inevitable activity in recent years due to the changing climate environment and adaptation to it. Although some basic ways of water management are known to mankind today, their logical use in practice so that they operate in a complex way and with a link to their surroundings is still absent.

2. Current state of solution in the Czech Republic

From the current state of knowledge of this issue and the current state of approach to rainwater management in urbanized areas in the Czech Republic and abroad, the main four obstacles to this issue in the Czech Republic have been defined [1]:

- **legislation** - non-conceptual approach in introducing rainwater management into Czech legislation, which can lead to distrust in the whole system,
- **technical regulations** - at present, technical regulations concerning rainwater management are intended only for water managers,
- **awareness-raising** - Rainwater management as one of the appropriate tools for adaptation of cities to climate change is not systematically promoted among the professions that are closely concerned,
- **communication and cooperation** - there is no interdisciplinary communication and cooperation.



Rainwater Management (RM) objects must be designed to become a natural part of the environment in which they are applied, as they are mostly realized on the surface and directly affect the appearance and use of the site. It is important to set the objects sensitively into the surrounding environment and determine the priorities and benefits that we expect from the measures. Not to limit RM only to a tool designed to 'alternative' land drainage, but to use it as an effective means of adapting cities to climate change with all the opportunities it offers. Existing Technical Regulation TNV 75 9011 Rainwater management, which is currently the only official basis for designing RM objects, is too one-sided (water management) and the objects it defines are not easy to apply in conditions that are not modelled (ie enough space, new development, flat surface, etc.) [1]. When designing the infiltration device, it is important to take into account the potential pollution of rainwater as shown in Table 1.

Table 1. Indicative classification of precipitation water pollution in terms of pollution by soluble substances, heavy metals and hydrocarbons [2].

Type of drainage area		Degree of pollution of rainwater
Roofs	Vegetation	Low
	Made of inert materials	
	With untreated area up to 50 m ²	
Road	For pedestrians and cyclists	Medium
	Low traffic parking	
	Low communication	
Roofs	With untreated area up to 500 m ²	Medium
Road	Intermediate parking lots	
Road	Medium traffic	
Roofs	With untreated area over 500 m ²	High
	High Frequency (all)	
	Warehouse areas	
Road	Agricultural areas	High
	Parking of trucks and machines	

3. Basic division into primary and secondary Rainwater Management objects

The existing system of demarcation of objects and equipment of RM, which is specified in the technical regulation, is difficult to grasp for the needs of branches outside water management. Therefore, the work listed in the above-mentioned standard has been categorized in a way that should better reflect the dual nature of the measures and allow a wider use of the RM system and its benefits for the urbanized environment.

In practice, we encounter the fact that it is very difficult, even impossible to apply RM measures in meeting the criteria and design parameters given by TNV 75 9011 Rainwater management - such as maintaining the prescribed ratio between reduced A_{red} drainage area and A_{vsak} infiltration area, abilities of the designed object (A_{red} is determined according to CSN 75 9010), frequency of congestion of the retention volume of objects expressed by periodicity p (in most cases retention objects with regulated outflow are expected to have five years of precipitation with the most unfavourable intensity) surface retention volume of the retention volume of T_{pr} objects (for objects with controlled outflow the empty time should be less than 24 hours, for infiltration objects the empty time is governed by CSN 75 9010) and the infiltration outflow for the infiltration device Q_{vsak} . Problems with the location of objects are in most cases in the existing buildings. Therefore, the article proposes the division of measures into so-called primary and secondary measures [3].

Primary measures and objects. Objects are designed according to the criteria and design parameters of the relevant standards. The definition of conditions for the application of primary measures may be

part of the urban drainage master plan. Based on the standard, primary objects can include objects used for infiltration without and with controlled outflow and retention objects with controlled outflow. Namely, these are infiltration holes with surface water supply, infiltration tanks, infiltration trenches with surface area inflow, infiltration trenches with subsurface inflow, infiltration trench - controlled drainage, infiltration trench with subsurface inflow and controlled drainage, dry retention rainwater tank), retention rainwater reservoir with storage space and artificial wetland [4].

Secondary measures and objects. There are support measures that may not meet all the criteria and parameters of standards, as set out in the regulations, allowing a more creative approach to their design and bringing the issue closer to other disciplines that will be able to better grasp it. It is primarily used to reduce or prevent precipitation. They can be designed separately or in series and complemented with primary measures. They can be dimensioned for collisions of lower periodicity and intensity than prescribed by the standard, so they are smaller in size and act as a buffer zone for the first rainfall. They are suitable for application in more complicated conditions, eg in existing buildings. Based on the standard, secondary objects include surface infiltration (surface infiltration without retention space), unpaved surfaces, permeable paved surfaces, vegetation roofs and gravel roofs and objects for accumulation and use of rainwater.

4. Primary measures - objects and equipment

The gaps and bioretency objects (rain gardens) are shallow grassy terrain depressions with a horizontal bottom (see Figure 1). If the drainage point is not in the plane and the bottom of the passageway cannot be flat, the object is divided into several units, which are separated by dikes.

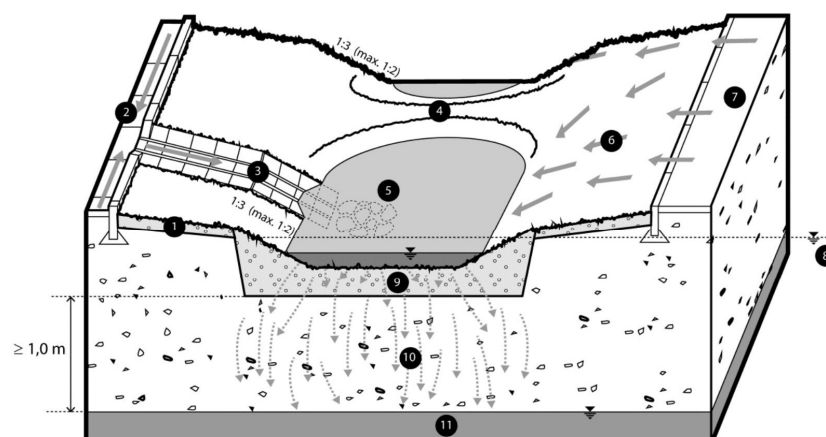


Figure 1. Wicking pattern with surface water supply (1 – Fuzzing; 2 – Road with curb; 3 – Inflow through reinforced channel; 4 – Earth dam; 5 – Stone throw; 6 – Flat inflow; 7 – Recessed curb road; 8 – Max. retention level; 9 – Grassy humus layer of the passageway; 10 – Permeable soil environment; 11 – Max. underwater level) [2].

They are mainly used to contain the design rainfall and slow down the precipitation runoff from the drainage area. After retention in the above-ground part, the water is further filtered through the topsoil layer either into the underground trench or, under suitable soaking conditions, directly into the subsoil. Another equally important benefit in terms of water regime is the support of natural evapotranspiration of steam back to the atmosphere. In addition, as rainwater passes through the grassy humus layer, suspended solids are filtered, ion exchange and adsorption of heavy metals and hydrocarbons, and biodegradation of degradable contaminants [2].

Trenches - The infiltration trench is a linear device that serves for underground infiltration of rainwater. It is an underground space filled with incoherent gravel material (washed river gravel) covered with geotextile that separates gravel from the surrounding environment. The water supply to the building can be realized as surface or sub-surface.

In the case of a subsurface inflow, a drainage pipe is part of the trench, which ensures better water distribution in the body. It must also be vented so that the air in the pores of the gravel filling does not prevent the water from spreading [2]. It is better to preclude coarse and fine suspended solids before inflow into the groove to prevent clogging of suspended solids [2]. Surface inflow is preferable from the nature-close drainage point of view. It is recommended to drain the rainwater into the trench through the grassy area. The precipitation effluent is attenuated, partially pre-cleaned of solid particles and is further filtered through a gravel layer. The layer on the trench surface should also be separated from the underground by geotextile to prevent ballast particles from entering and the gravel to collapse. The top layer must be cleaned or replaced regularly to avoid losing its filtering ability. The infiltration grooves perform their function best if they are sequenced together with other measures.

Retention rainwater reservoir (water square) - Retention rainwater reservoirs are terrain depressions used to capture rainfall runoff from drainage area (see Figure 2). They reduce the culmination flow and are supplemented with a throttle device to control their emptying. For most of the year, the reservoir is dry (in the case of polders), water only appears temporarily during and immediately after the rainfall.

Retention rainwater reservoirs are usually designed as grassy objects, and the rain can naturally seep through a layer of grassy topsoil. In less heavy rains, the grassy area naturally slows downfall and the water partially absorbs into the soil or evaporates back into the atmosphere. The advantage is again the cleaning ability of the object. Nevertheless, in the TNV 75 9011 standard, it is recommended to create a smaller, separate settling space at the point of rainwater inflow into the reservoir, from which water purified from suspended solids and sediments falls into the main retention space [2].

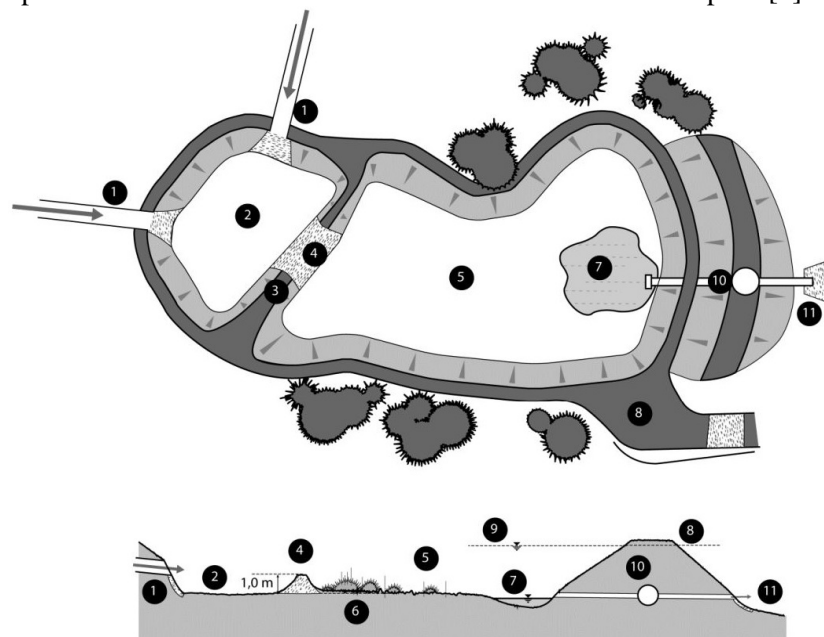


Figure 2. Diagram of dry retention rain tank (1 - Inlet object; 2 - Part of the sediment collection tank; 3 - Dyke; 4 - Permeable material / aggregates; 5 - Main retention space; 6 - Greening; 7 - Space with water level; 8 - Safety overflow; 9 - Max. retention level; 10 - Drain regulator; 11 - Outflow object) [2].

5. Secondary measures - objects and equipment

Green measures - Vegetation and other roofs. Vegetation and gravel roofs primarily reduce the volume of surface runoff, but also fulfill many accompanying functions. They have good insulating properties, especially on hot summer days they effectively prevent overheating of the under-roof areas

[5]. The vegetation layer promotes evapotranspiration but also captures dust particles contained in the urban environment. These properties increase with the intensity of the greening of the roof. The construction of the vegetation roof consists of several layers (see Figure 3) and it depends on what option we choose. The general composition is shown in Figure 3 [4].

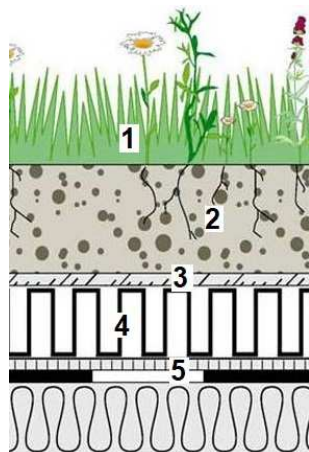


Figure 3. Schematic section of the structure of the vegetation roof (1 - Planting; 2 - Substrate; 3 - Geotextiles; 4 - Drainage layer; 5 - Waterproofing) [4].

Green measures - permeable unpaved surfaces (flat surface, however). The standard does not directly define the object of permeable unpaved surfaces, but recommends to keep them as much as possible and minimize the amount of impermeable paved surfaces. Surface infiltration through the grassy humus layer could also be included in this category. Its disadvantage is the high space demand, as it requires at least 20% of the total area of the drainage area. Therefore, in practice, its use is very limited and is feasible rather in the built-up areas of linear buildings or parking lots. Another reason is the fact that this object is usually designed as a precedent to another object and is mainly used for pre-treatment of precipitation runoff [4].

Green measures - trees. Trees have several very beneficial functions in cities. They contribute to the efficient management of rainwater, beautify and enhance the urban environment and increase the value of residential and commercial zones, reduce the annual energy consumption of buildings by mitigating the local climate (providing shade in the summer and cooling their surroundings) air, trees create oxygen, act as a noise barrier, provide habitats to living organisms and increase biodiversity [6].

Grey measures - permeable paved areas - These are paved areas, e.g. roads, sidewalks, cycle paths, car parks, etc., which are adapted or selected so that the rainwater falling on their surface is absorbed as far as possible into the structural layers surface and further into the subsoil. The permeable paved areas serve mainly to slow down the precipitation runoff and reduce its volume. In cases where the structural layers of the surface are adapted to this, cleaning processes can also take place here, similar to, for example, grooves. When introducing RM at a particular site, there should always be an effort to replace all impermeable hard surfaces with a permeable variant, which makes it possible to effectively reduce the surface runoff of rainwater [2].

6. Conclusion

The paper is focused on the formulation of principles and procedures of designing RM objects and their integration into the urbanized space structure. The result of the research is an overview of measures, which are based on the knowledge of the contemporary view of the issue of near-natural drainage of built-up areas in the world, with regard to the adaptation of settlements to climate change and their sustainable development. A major benefit is the division of RM measures into two categories (primary and secondary measures). Such a division offers a greater range of options for the application of RM objects in design. Primary objects are those listed by TNV 75 9011 as objects and equipment for rainwater accumulation and use, in addition to their other variants and examples. Secondary objects are composed of objects listed in the above-mentioned standard as objects and equipment for reducing or preventing the occurrence of precipitation at source, and at the same time they are

supplemented with other measures not mentioned in the standard. In contrast to the conventional design of RM, where in practice only primary objects are used for the system, the work emphasizes the use of a combination of primary and secondary measures, which makes it easier to achieve a more compact solution [7].

Acknowledgments

The work was supported by funds for Conceptual Development of Science, Research and Innovation for 2019 allocated to VŠB - Technical University of Ostrava by the Ministry of Education, Youth and Sports of the Czech Republic.

References

- [1] Teichmann M, Szeligova N and Kuda F 2018 Influence of Flash Floods on the Drainage Systems of the Urbanized Area (Leiden: CRC Press/Balkema) pp 623-628
- [2] TNV 75 9011 2013 Rainwater Management, Center for Technical Standardization (Prague: Sweco Hydroprojekt a.s.) p 36
- [3] Echlos S and Pennypacker E 2015 Artful rainwater design: creative ways to manage stormwater (Washington: Island Press)
- [4] Information on <http://www.hrwallingford.com/news/new-suds-manual-delivers-practical-guidance-for-sustainable-drainage-systems>
- [5] Ballard B W et al. 2007 The SUDS manual (London: CIRIA) p 387
- [6] Butler D 2019 Rainwater Harvesting to Rainwater Management Systems, Green Energy and Technology (Cham: Springer) pp 3-9
- [7] Castonguay A C et al. 2018 *Environ. Model. Softw.* **105** 270-285