Measures to Prevent Surface Leaks in a Periurban Area Using Responsible Environmental Approaches

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Abstract. Climate change and environmental degradation are an existential threat for Romania and for the whole world. Restoring nature will be a central element of the EU’s recovery plan from the coronavirus pandemic, providing immediate investment opportunities to revive the European economy. Both urban and industrial developments are changing landscapes from vegetated permeable surfaces to a series of interconnected impermeable surfaces, resulting in large amounts of rainwater runoff, which requires management. Rainwater runoff is treated by the authorities as a liability and a nuisance that endangers human health and property. Starting from this aspect, over time, systems for collecting and transporting rainwater directly to watercourses have been designed, but without considering the conservation of ecosystems. Rainwater runoff is a source of pollutants washed off hard or compacted surfaces during rain events. These pollutants can be pesticides, herbicides, hydrocarbons, traces of metals but also organic compounds. Water Sensitive Urban Design (WSUD), Low Impact Development (LID), Sustainable Drainage System (SuDS) are spatial planning and technical design approaches that integrate the urban water cycle, including stormwater management, groundwater and wastewater and water supply, in urban design to minimize environmental degradation and improve aesthetic and recreational attraction. The article presents possible solutions applicable to a locality in the west of Romania that is facing the drainage of meteoric waters. This locality was one of the most affected by the recent floods, with over 6,700 ha of almost destroyed crops, 300 flooded houses, 70% of compromised gardens, the most affected being the new residential neighbourhoods. Timiş County is one of the Romania counties with the largest network of hydrotechnical arrangements (about 480,000 ha on which hydro-amelioration works are executed and over 11,500 km of drainage, irrigation, and soil erosion control channels), it risks becoming a swamp again due to the indifference or ignorance of some of the decision - makers, the lack of appropriate legislation, the non - application of the existing one and the low underfunding after 1990.

1. Introduction
In the natural circuit of water, soil and plants are essential for the quality of water that reaches in the ground from rainfall. In the urbanized areas, the surface of the land is often sealed, and rainwater is directed into the sewer system, causing pollution, erosion, or flooding of watercourses. According to specialized studies, the surface runoff is only 10% for a natural area and 55% for developed / urbanized areas [1-4].

In these urbanized areas, the natural depressions in which rainwater would collect are usually covered by impermeable surfaces, such as asphalt, pavement, or concrete, and are arranged for car use.
Global climate change is increasingly generating extreme weather events, manifested by prolonged periods of drought followed by heavy rain showers. These extreme phenomena, combined with the rapid increase in urbanization, dramatically require hydraulic sewerage systems in most urban developments. Thus, there is a need to design, and think based on sustainability principles how rainwater is managed in industrial and commercial construction projects. The application of these principles, summarized in the concept of rainwater management - collection, treatment, mitigation, discharge - reduces the risk of floods and pollution. In this way, the elements that can affect the safety and health of people and the integrity of their property are kept under control. The problems generated by the waterproofing of the soil and the contamination of the waters due to the surface leaks can be combated by bioretention units [5, 6].

1.1 Bioretention units
Bioretention units/rain garden can be independent landscaping or components integrated in parks area or in ecological corridors on the watercourse’s banks. These bioretention units are specially designed to be flooded during rainy periods, having major benefits on water quality and the environment but also reducing the costs of rainwater collection and treatment infrastructure. They allow water to filter through the soil and plant roots, infiltrate it into the soil and finally replenish underground and above ground water sources with high quality water. Areas where bioretention cell can be applied includes areas newly developed residential areas, industrial / commercial areas, road projects, areas institutional, urban stormwater management projects, street projects development, landscaping projects applied to residential areas, parks, and pedestrian paths. Bioretention can be applied regardless of the soil and topography of the area if rainwater percolate through a design soil bed. One of the reasons for not opting for bioretention would be the lack of space in an already aranged area. However, the location of bioretention areas can be achieved in places that are generally "not used", such as traffic islands; parking lots; along the edges of public playgrounds, schoolyards, or markets; in the yard; and instead of traditional landscape planting areas [7-10].

2. Reasons why bioretention systems are not implemented in Romania
Although sustainable urban drainage systems are technologies known for a long time, in Romania there are certain motives that prevent their use.

As shown in their papers, Brown and Farrelly [2] are 12 different types of socio-institutional motives that hinder the transition to sustainable urban rainwater management: an uncoordinated institutional framework; Limited Community advisory structures, both as a skill and as a participation; regulatory framework limited to the provisions of the legislation; insufficient resources, capital and human resources; unclear responsibilities; lack of information, knowledge and understanding in the application of integrated and adaptive forms of management; poor communication; no long-term vision, strategy; dependencies on the technocratic path; and missing of political and public will [10].

According to specialized studies, bioretention systems have many advantages, but a poor design and construction of these systems can cause many maintenance problems. In Romania there are no design guides for bioretention systems. There are several norms and standards that regulate the sizing of sewerage systems in a separate system for meteoric waters but do not make any reference to bioretention systems. Hence the reluctance of designers to propose such infrastructures. For a transition to sustainable stormwater management, the involvement of government, academia, industry, and civil society is needed to define an optimal strategy [11].

If the construction of the bioretention system is not done according to some design guidelines, then the operation will be deficient. Most of the designers and builders are not familiar with construction of the bioretention system. Wrong choice of drainage layer can affect infiltration capacity, and the system cannot perform in good conditions, which leads to huge losses of investment cost and can increase distrust that bioretention systems can operate in good conditions.
The implementation of bioretention systems would be easy to apply when developing new areas (residential, commercial, industrial neighbourhoods). Here should intervene local authorities to impose on real estate developers such integrated rainwater management techniques and thus avoid the problems caused by rainwater Figure 1. The bioretention system requires an adequate maintenance and management plan, but local authorities do not have sufficient knowledge in this regard. Therefore, they cannot maintain the bioretention system and it loses its function after some periods of time. For some local authorities and traditional stormwater collection systems can be a challenge to heavy rains even if these systems are easy to maintain and monitor and do not require management practices.

Figure 1. Old area/New area after heavy rain

3. Dynamic simulation model of the rain-runoff process
Several calculation models can be used to estimate hydrological performance of bioretention units. The Stormwater Management Model (SWMM) produced by the Environmental Protection Agency was selected to model the hydrology of study area.

SWMM is a distributive model, which means that a study area can be subdivided into many irregular sub-areas, to better capture the effect of spatial topographic variability, drainage paths, coverage of land and soil characteristics on the generation of surface runoff. An ideal sub-area is designed as a rectangular surface that has a uniform slope and a length of L that drains into a single outlet channel. Each sub-area can be further divided into three surfaces: a waterproof surface with water retention in depression (retention), a waterproof area that does not have depressions, and a permeable area with water storage capacity in depressed areas and by interception). Only the last surface allows water loss through infiltration into the soil [12].

4. Study case
The study area is a peri-urban zone located in the metropolitan area of Timisoara and has a surface of 0.5 ha. Is a new residential area near an industrial development which are changing landscapes from permeable vegetable surfaces to a series of interconnected impermeable surfaces, resulting in large amounts of rainwater runoff, which requires management. The area is characterized by a moderate continental climate with Mediterranean influences. The annuals average temperatures in January are -1 degree Celsius and in July 22-25 degrees. The amount of multiannual precipitation is 60 mm. March-September period shows low atmospheric humidity, the values varying between 62% (July) - 66.6% (April). Sunny days represent about 75% of the total days, Figure 2.
In the study area, the sewerage system is separate for meteoric waters. One of the problems facing the local authorities is the collection and evacuation of rainwater. In the old area of the locality, the rainwater is collected through the system of street trenches and discharged in drainage channels. But because about 70% of the ditches in the locality are clogged and drainage channels are unmaintained with a lot of vegetation (which decreases the flow of water from 4-5 km / h to 200 m / h) often rainwater runoff on the streets. If the rainwater is directed to watercourses (is often warmer than water that normally supplies a watercourse) can have negative effects on aquatic ecosystems, mainly by reducing dissolved oxygen (DO). The SWMM includes a series of hydrological processes that lead to the production of surface runoff in rural and urban areas such as: Rainfall time series; Evaporation of water from the soil surface; Accumulation of snow in layers and its melting; Interception of rain by depressed areas; Water infiltration in unsaturated soil; Percolation of infiltrated water from the upper layer into groundwater; Sewage system infiltrations /exfiltration; Water retention and infiltration through LID (Low impact developments) practices / Green Infrastructure units.

Five types of LID units can be modelled with SWMM: 1. bioretention units (green roofs, rain gardens or street plantations); 2. infiltration trenches; 3. permeable pavement; 4. retention basins; 5. Vegetative swale [12]. When integrating bioretention into an area, the designer must take in consider the following elements: site conditions and constraints, uses proposed types of land, types of plants, types of soil, types of pollutants contained in rainwater, soil moisture conditions, water recharge underground, discharge and the most important is proper drainage. For the arrangement of bioretention systems it is necessary to choose some plant species that withstands large fluctuations in soil moisture. Therefore, a close collaboration between specialists is necessary [6-9].

An important design factor to take into consideration when proposing bioretention is the scale at which it will apply as follows [10-14]:

- Bioretention unit/ Rain Gardens. These are small, distributed practices designed to treat leakage from small areas, such as individual roofs, detached residential facilities. The entrance is a sheet flow or may be concentrated flow.
- Bioretention Basins. These are green infrastructures that treat parking lots, commercial roofs, usually in commercial or institutional areas. The entrance can be either sheet flow or concentrated flow. Bioretention basins can also be distributed throughout the residential subdivision, but ideally it should be in common areas.
- Urban bioretention. These are structures like extended tree pits, edging and foundation extensions planters located in developed ultra-urban areas such as the urban landscapes of the streets.

For study area we used the follow LID: bioretention units-rain garden, infiltration trenches, permeable pavement. The design consideration for bioretention unit is show in the table 1.
The Curve Number model was chosen to calculate the infiltrations. Curve Number derives from the well-known SCS Curve Number method, used to simplify surface runoff patterns. The advantage of this model is that the infiltration rate is calculated according to the land use.

Both the time step for calculating rainwater runoff and reporting were chosen to be done in 5 minutes.

Table 1. Design consideration for bioretention unit [5-11, 13]

| Required Space |
|----------------|
| The bioretention surface will be 3% to 6% of the contributing drainage surface (CDA), depending on the imperviousness of the CDA and the desired bioretention ponding depth. |

| Minimum filter media depth should be: |
|--------------------------------------|
| • 0,60 m for grass cells and 0,90 m for shrub cells, and 0,45 m and 0,60 m for rain gardens or micro-bioretention |

| Specification of Filter Media |
|-----------------------------|
| Filter media to contain: |
| • 85%-88% sand |
| • 8%-12% soil fines |
| • 1%-5% organic matter |
| For trees |
| 50% sand, |
| 30% topsoil |
| 20% acceptable leaf compost |

| P-Index |
|-----------------------------|
| The recommended range for bioretention soil P-index is between 10 and 30 corresponds to a phosphorus content range within the soil media of 7 mg/kg to 23 mg/kg. |

| Ponding depth: 0.15-0.30 m |
|-----------------------------|

| Length of shortest flow path/length: 0.3 |
|------------------------------------------|

| Depth: 0.6 m to water table / bedrock |
|---------------------------------------|
| This distance is measured from the bottom of excavated bioretention area and up to the seasonal high groundwater table. |

| Slopes: |
|---------|
| Greater than 1% and less than 5%. |

| Media permeability: |
|---------------------|
| ≤ 0.01 m/h or needs underdrain |

| Available Hydraulic Head |
|--------------------------|
| Bioretention is established according to the invert elevation of the existing transport system at which the practice is unloaded. A height of 1.2 m to 1.5 m above this inverter is required to accommodate the necessary storage and filtration. |
| All bioretention basins should include observation wells. |

The resulting surface runoff was analysed. For each sub-area, the runoff coefficient was checked and compared with the runoff coefficient values specific to the different types of soil cover in Romanian standard SR 1842-2: 2007. It was observed that for each type of soil cover the resulting runoff coefficient falls within the limits of Table 2 - SR 1842-2: 2007. For example, for the park, a drainage coefficient of 0.05 was obtained, the limits from Table 2 - SR 1842-2: 2007, being between 0.05-0.15 differing depending on the slope of the land; in the case of street, a drainage coefficient of 0.9 was obtained and in Table 2 - SR 1842-2: 2007, the values varying between 0.85-0.90 depending on the slope of the land; in the case of roof, a drainage coefficient of 0.9 was obtained, the limits from Table 2 - SR 1842-2:
2007, is 0.90. Figure 3 shows the studied area. The meteoric water from the roof is sent to the bioretention unit and meteoric water from the parking lot is first sent to a grit/oil separator then sent to the wet pond. Water from the wet pond is used to irrigate the nearby park.

Figure 3. Hydrologic model in study area’s using the Stormwater Management Model [15]

In the figure 4 is observed the sub catchment runoff. Following the analysis of the results obtained after performing several simulations, it was concluded that the surface of the rain gardens must be 6% of the impermeable surface it takes over. The same percentage is recommended in the Tennessee Permanent Stormwater Management and Design Guidance Manual [5].

Figure 4. Subcatchment Runoff
5. Conclusion

Bioretention can be designed to mimic pre-existing hydrological conditions by treatment of volumes associated with leaks. The use of bioretention not only provides control over water quality and quantity but adds value and diversity to the landscape. Also offers several additional environmental benefits (habitat for wildlife and indigenous plant varieties, improving air quality, reducing energy consumption, improving the urban climate. The effectiveness of bioretention is related to design processes, construction techniques and how to use it. Lack of a national framework and national standards, prevents the development of a coordinated strategy at national level. The challenge of overcoming this situation must be determined by the system of governance by raising awareness, community involvement and coordination of the various actors involved in the transition process.

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