Surface runoff as a potential source of pollution

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Abstract. Due to the accelerated development of urbanized areas, the increase of paved and impermeable surfaces, permanent changes in the environment of the city occur. The spatial structure of the city is changing. There are creating significant artificial landscape elements that are not able to absorb rainwater. As a consequence of this unnatural phenomenon in the city was identified a new area pollution source - surface runoff. The formation of surface runoff is affected by several factors. For us, it is important the character of the pollutants in the surface runoff. The paper aims to point out the impact of surface runoff from urbanized areas on the environment. Compare quality parameters of rainwater runoff from different types of paved areas (different types of roof, roadway, car parking). To get acquainted with the legislation covering the area permitted criteria for the content of undesirable substances and the method of their removal.

1. Introduction

Significant climate change has been increasingly reported in recent years, long periods without rain, extremely high temperatures, especially in summer and frequent heavy rainfall. All of these are natural phenomena that cause many of the problems we have been facing lately. Accelerated land use, elimination of vegetation, and alteration of the landscape's spatial structure by urbanization lead to adverse effects [1], [2]. There is a change in the hydrological system, including infiltration, higher maximum flow and volume, and increased pollutants [1]. One of the reasons for this global problem is the mass migration of the population, resulting from an uncontrolled increase in hard surfaces. Infrastructure development and urbanization have a significant impact on the structure of the city. Instead of conservation vegetation areas and natural conditions of rainwater infiltration across the soil horizon, rainwater from urbanized areas is a diversion into the sewerage network [3], [4]. This currently unacceptable method of draining surface runoff can cause congestion in the sewerage network while increasing the pollution burden by rainwater and the occurrence of urban floods [5].

A significant effort currently is made to develop more resilient and sustainable technologies to address this problem to prevent the spread of impermeable surfaces. Municipal authorities are trying to use nature-friendly measures that support a system of efficient rainwater management [6]. It is a complex of measures and devices with Low - impact development (LID). It is an attractive alternative to the vegetation surface instead of the traditional impermeable surface [3], [7]. These measures can reduce surface runoff in the city, capture maximum rainwater flow and infiltrate rainwater, thereby preventing pollution of highly urbanized areas [7], [8].

There are many possibilities for measures to boost urban green land by applying LID. When properly designing LID, it is essential to know the outflow characteristics resulting from different types of precipitation rainfall events [7], [9]. The result of using LID mainly depends on the quality and quantity of rainwater. At present, great attention is paid to the qualitative and quantitative parameters of rainwater from hard surfaces due to the possible occurrence of hazardous substances. The composition of stormwater can adversely affect water quality and quantity, habitats and biological resources, population health, and the aesthetic appearance of urban waterways [7], [10].
The paper aims to point out the impact of surface runoff from urbanized areas on the environment. Compare quality parameters of rainwater runoff from different types of paved areas (different types of roof, roadway, car parking). To get acquainted with the legislation covering the area permitted criteria for the content of undesirable substances and the method of their removal.

2. Legislative regulation

The European Union has been dealing with the problem of "surface water protection" for decades. The result of which are several standards and recommendations. Among the most important, it is possible to define the Recommendation of the United States Environmental Protection Agency (EPA), the Water Framework Directive (2000/60/EC), which requires the protection and improvement of watercourses [11], as well as other relevant European Parliament Directives on water management.

The management of urban stormwater in the Slovak Republic is not dealt with in detail by regulations and technical standards. Partially, this topic is dealt with in the Water Plan of Slovakia by following Article 4.7 (d), the Water Framework Directive (2000/60/EC) [11], and Government Regulation of the Slovak Republic No. 269/2010 [12]. A shortcoming of the Slovak regulations is the setting of limit values of indicators of rainwater pollution from surface runoff, which infiltrate into the soil horizon. In GR, SR No. 269/2010 in § 9 in points 1–3, only briefly set requirements for discharges of surface runoff water into surface and groundwater [12].

As in Slovakia and Serbia, all standards and recommendations related to this topic are based on EU regulations. Among them, it can define the Water Framework Directive (2000/60/EC), the Water Law of the Republic of Serbia ("Sl. Glasnik" No. 30/10) [13], and the Government Regulation of the Republic Serbia ("Sl. Glasnik" No.24/2014) [14].

Table 1. Comparison of limit values of pollutants in surface waters in Serbia and Slovakia [12], [14].

|                  | MAC for surface water quality ((in parentheses are AA)) - GR SR No.269/2010 | MAC for surface water quality ((in parentheses are AA)) – “Sl. Glasnik” RS No.24/2014 |
|------------------|-----------------------------------------------------------------------------|-----------------------------------------------------------------------------------|
| Cadmium (Cd)³    | 0.45 – 1.5 (0.08 – 0.25)                                                   | 0.45 – 1.5 (0.08 – 0.25)                                                          |
| Cr (VI)          | 9.0                                                                          | -                                                                                 |
| Copper (Cu)      | (1.1 – 8.8)                                                                  | -                                                                                 |
| Nickel (Ni)      | (20.0)                                                                      | 34.0                                                                              |
| Lead (Pb)        | (7.2)                                                                       | (14.0)                                                                            |
| Zinc (Zn)        | (7.8 – 52.0)                                                                 | -                                                                                 |
| Benzo(a)pyrene   | 0.1 (0.05)                                                                   | 0.27                                                                              |
| Fluoranthene     | 1.0 (0.1)                                                                    | 0.12                                                                              |
| Naphthalene      | (2.4)                                                                        | 130.0 (2.0)                                                                       |
| Phenanthrene     | 2.0 (0.28)                                                                   | -                                                                                 |
| Sum of polyaromatic hydrocarbons (PAU) | -                          | -                                                                                 |
| Single pesticide | -                                                                            | -                                                                                 |
| Sum of pesticides | -                                                     | -                                                                                 |

Notes: AA – annual average  
MAC – maximum allowable concentration.
3. Surface runoff

As a result of the urbanization of the city was the areal pollution source. It is a complex element influenced by several factors, such as the duration and intensity of the rainfall event, the length of the previous non-rainfall season, the surface characteristics of land use, and other factors [15]. The size of the surface runoff mainly depends on the percentage of paved surfaces and the total rainfall. During heavy rains, pollutants from impermeable areas (mostly car parks and roads) get in motion and create surface runoff. This type of urban runoff can cause substantial damage in an urbanized area and environmental damage [15].

The nature of the pollutants occurring on the surface of the runoff primarily depends on the pollution of the rain itself and local conditions (industrial zone, countryside, city). When passing through the atmosphere, rain may contain substances such as chlorides, sulphates, nitrates, potassium, calcium, and magnesium in concentrations below 10.0 mg.l\(^{-1}\) [17]. As concerns rain from industrial areas, this is an increased share of fossil fuel combustion products. The chemical composition of the surface runoff from urbanized areas mainly affects the material used for the impermeable surface and the utilization of the given area (parking lot, roof, road). Under normal conditions, rainfall from urbanized areas contains substances predominantly from motor vehicles such as heavy metals, oil, fats, organic materials, and others [17]. These usually occur in harmless concentrations. During a long without rainy season, the concentration of these substances can be several times higher.

3.1. Comparison of the quality parameters of rainwater

Currently, many studies deal with the quality of stormwater runoff from different types of impermeable areas. Primarily are monitored the qualitative and quantitative parameters of rainwater from roadways, parking lots, walkways, and roofs. Many authors in their studies focus on the analysis of the quality of urban rainwater runoff from different types of materials from which paved surfaces are made [3], [15], [18], [19]. Angrill (2016), in her research, focused on monitoring rainwater runoff from three types of paved areas (roads, parking, and walkways) and two types of materials (concrete and asphalt) [18]. Another researcher Lee (2012), analysed the rainwater from different types of roof covers (wooden shingles, concrete tiles, clay tile) [19]. Martins and all. (2019) was harvesting rainwater from an urban area in Brazil [20]. In the analysis of captured rainwater samples from paved areas, were monitored chemical, physical, and microbiological parameters. After the analysis, in the samples from the catchment surface, among other specific parameters (ions - Mg\(^{2+}\), NH\(_4^+\), Na\(^+\), etc.) were detect heavy metals like zinc, aluminium, copper, lead, nutrients, toxic compounds, suspended solids [18], [19], [20]. Also, in some samples were found batteries as Escherichia coli and Enterococci [19]. The pH value, conductivity, and chemical oxygen demand were monitored in each study, as these parameters can significantly affect rainwater quality.

Table 2. Comparison of the qualitative parameters of rainwater from different types of impermeable surface [18], [19].

| Roof materials         | pH [-] | Al [μg.l\(^{-1}\)] | Cu [μg.l\(^{-1}\)] | Fe [μg.l\(^{-1}\)] | Pb [μg.l\(^{-1}\)] | Zn [μg.l\(^{-1}\)] |
|------------------------|--------|---------------------|--------------------|---------------------|---------------------|---------------------|
| Wooden Shingle         | 6.7    | 227                 | 58                 | 154                 | 10                  | 135                 |
| Concrete Tile          | 7.1    | 535                 | 37                 | 160                 | 14                  | 196                 |
| Clay Tile              | 7.1    | 243                 | 59                 | 155                 | 11                  | 131                 |
| **Urban surface**      |        |                     |                    |                     |                     |                     |
| Asphalt road           | 7.8    | -                   | -                  | 110                 | -                   | 15                  |
| Concrete road          | 7.5    | -                   | -                  | 35                  | -                   | 70                  |
| Asphalt parking        | 7.75   | -                   | -                  | 20                  | -                   | 5                   |
| Concrete pedestrian area| 8.0   | -                   | -                  | 280                 | -                   | 20                  |

Table 2 shows the average concentration of some of the quality parameters found in the chemical analysis of rainwater from different surface types. It can be stated that runoff water quality depends on the catchment surface material and types of active development activity. The concentration of the listed parameters in the table 2 above all varied on the duration of rain and the length of the no-rain season.
Increased attention currently is to research into the quality of the first runoff, given that most of the pollutants accumulate at the beginning of the rainfall.

4. Conclusion

Against the current trend in the development of urbanized areas, it is necessary to provide an effective solution to drain and capture rainwater runoff from the impermeable surface. Lack of vegetation causes the formation of surface runoff, and thus increases the maximum flood flow. All this affects the contamination of the pollutants and the degradation of the environment.

As was a state in the previous part of this article, surface runoff can contain substances like heavy metals nutrients, toxic compounds, suspended solids, and bacteria. The occurrence of these substances primarily depends on the type of urban area, material, and the rainy season. Based on the mentioned articles, the most polluted surface runoff is from the roadway and parking; that way is necessary to do something with that.

The new management of rainwater supports the construction of nature-friendly measures. These are measures and equipment with Low – impact development LID. These are mainly infiltration systems such as infiltration ditch, rain gardens, and ponds, and other objects that contribute to the creation of the city's environmental development. Their primary function is to capture, filter, and drain rainwater. The application of these systems would reduce the load on the sewerage network and prevent ground and surface water pollution.

5. References

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