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Article

Impact of Various Paved Areas to Storm Water Quality

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Abstract: One of the main problems is handling rainwater management in urban areas is water quality from urban runoff. Currently, the emphasis is on using rainwater in cities as much as possible. The concentration of pollutants is the most problematic in rainwater. After precipitation falls on surfaces, surface water is immediately contaminated. This pollution must be cleaned or contained and transported to a wastewater treatment plant through the sewer network. Among the primary pollutants that we can identify in surface water are, for example, heavy metals. In our research, we focus on the analysis of real surface waters taken from 13 locations on the territory of the Slovak Republic. The result of the research is an analysis of the suitability of reusing these waters. From the results of the analyses, it is clear that not a single sample is suitable for irrigation, as the limits of at least one monitored parameter were exceeded in all samples. The monitored lead concentration parameter was exceeded in all monitored samples. The quality of underground water in the monitored locations is in a bad state. For comparison, zinc concentrations range from 26 to 8 µg/l over a 5-year period, and zinc concentrations in surface drain water are at the level of 111 µg/l.

Keywords: urban runoff; irrigation; stormwater; urban hydrology

1. Introduction

Due to the intensified formation of urbanised areas in cities, a new diffuse source of pollution, known as surface runoff, has been identified [1]. Surface runoff or rainwater runoff can be defined as the product of the interaction between climate change and the way in which a given area is used. Extreme climate change affects the distribution and temporal variability of atmospheric precipitation, while how the land is used leads to drainage processes. In determining the basic characteristics of the runoff, these are decisive factors that largely affect and change rain's physical and chemical properties. Surface runoff is a complex resource whose characteristics depend on hydraulic processes describing the movement of precipitation water from the impact on the surface to entanglement in the sewer sieve and hydrological processes such as evaporation, infiltration, surface retention and waterlogging, and permanent runoff losses [2]. In foreign literature, surface runoff is designated by the term "surface runoff" or "urban runoff." The formation of the precipitation-runoff process occurs after exceeding the capacity of the subsoil – filling in hydrological losses, especially during short torrential rains or so-called flash floods. It causes an increase in the volume of runoff, an increase in the peak of the flood wave, and an increase in the contamination of urban rainwater [3]. It is characterized by the fact that it is formed predominantly in areas with a complex division of territory or in urban areas where there is a lack of vegetation areas and inlet and retention objects to capture and temporarily retain rain surface runoff. A fundamental problem of the formation of

surface runoff in urban basins is the load on the existing sewer network and the possible deterioration of the quality of water bodies.

Water Pollution from Roads

The chemical composition and concentration of pollutants in surface runoff diverted from different types of roads, e.g., roads, car parks and pedestrian pavements, depends on the type of material used [1], traffic intensity, road inclination [4], the number of emissions from the vehicles themselves, winter maintenance, abrasion and corrosion as a result of vehicle movement and accidents, etc. Due to these sources of pollution, various oils and fats, lubricants, sprinkling salt substances, dust particles, heavy metals (lead, vats, zinc, copper, iron), polyaromatic hydrocarbons (PAHs) and other organic and inorganic substances enter the surface runoff in this way. In foreign literature, these substances are named as "road-deposited sediments" (RDS) or road sediments, which accumulate on the surface of communications during droughts and are diverted to a sewer network in the event of a precipitation event. Information on pollutants found in rain runoff from roads and their sources of formation are given in Table 1.

Table 1. Sources of pollution of rain surface runoff from communications [5].

	Source of pollution	Pollutants
From the vehicle	Brakes	Ba, Cu, Fe, Mo, Na, Ni, Pb, Sb
	Tires	Al, Zn, Ca, Cd, Co, Cu, Mn, Pb, hydrocarbons, PAH (pyrene, benzo(a)pyrene, fluoranthene)
	Catalyst	Pt, Pd, Rh
	Vehicle body	Cr, Fe, Zn
	Exhaust gases	Ag, Ba, Cd, Cr, Co, Mo, Ni, V, Sb, Zn, PAH (on Naphthalene), MTBE, BETX
	Engine oil leakage	PAH, Pb, Ni, Zn, organic substances, oils, fats, hydrocarbons, Cu, Cr
The rest	Road surface (asphalt, bitumen)	Al, Ca, Fe, K, Mg, Na, Pb, Si, Sr, Ti, PAU
	Dusty substances	Ca, Mg, Na, Cl, ferro-cyanide
	Road equipment (e.g. traffic sign)	Ca (galvanized steel)
	Detergents used for washing tunnels	surfactants
	Vegetation spray	herbicides

The concentration of road sediments has been the subject of research for many years, given the potential impact on the environment and human health. Among all these substances, considerable attention is paid to the occurrence of heavy metals due to their high toxicity and non-degradability in the environment [6], the characteristics of pollutants [7], the complexity of identifying the source of pollution [8] and the risk assessment [9]. By comparing many studies, the most commonly occurring metals in surface runoff from communications are lead and zinc, due to their high usability in the automotive industry (flashlights, tires, oils, lubricants and others) [10].

The concentration and chemical composition of RDS can also influence the development of the automotive industry – so-called hybrid vehicles. Although from one point of view, they are environmentally friendly vehicles, these vehicles contain batteries that increase their weight and, the heavier the car, it produces more emissions [10,11]. In addition to heavy metals in recent years, some scientists have begun to address the presence of polyaromatic hydrocarbons (benzene, naphthalene, pyrene) in surface runoff due to their high concentrations in the soil (in some cases higher than in the air). The presence of these pollutants in rain runoff conditions car emissions resulting from incomplete combustion of biomass and fossil fuels are considered one of the main sources of PAHs. [12].

Water Pollution from Roofs

The quality of surface drainage from the roofs of buildings and communications depends on several factors. It is conditioned by the type of roofing material (wooden shingle, concrete tiles, clay tiles and others) [13], the geometry of the roof (slope, length, width) [14], and the environmental conditions of the area (climatic conditions, air pollution, etc.) [15]. Surface runoff pollutants may originate:

- from roofing – material used for roofing, edging, etc.,
- from dry settling on the roof surface – flying substances, insects, foliage, and bird liquors
- from atmospheric contaminants washed out by rainwater [16].

Various studies have shown the presence of inert roof sediments (e.g. dust and fecal sediments of animals), heavy metals (nickel, chromium, zinc, iron, copper, aluminum), nitrogenous pollution, insoluble substances and bacteria (*Escherichia Colli*, *Enterococci*) in the roof drain. The concentration of these substances also depends on the characteristic of the rainy event: the length of the rainless period, the intensity of precipitation, the duration of precipitation, the direction of wind flow, etc. The presence of high concentrations of pollutants in roof runoff can be problematic, especially in areas with increased emissions in the air, i.e., urban agglomerations due to intensive traffic and local sources of pollution.

The influence of the type of roofing material on the quality of surface runoff from roofs was also confirmed by Lee in his study. Lee et al. (2010) [15] In this study are compared four types of coverings, finding that of all the types of coverings considered, wood shingle had the greatest effect on increasing pH, electrical conductivity and zinc, with galvanised steel covering being shown to be the most appropriate material. Zand et al (2014) compared the quality of surface runoff from conventional roofing and green roofing, finding that a green roof, despite all the positive environmental impacts, is not the most appropriate solution for collecting rainwater with a paved area, but ceramic tiles [13].

The Impact of Surface Runoff on the Environment

Rainwater before it drops on the earth's surface, contains harmless concentrations of foreign substances, such as various gases, dust particles, aerosols, etc. After contact with the paved area, the number and variety of these substances increase significantly, and their concentrations can exceed the limit values several times and thus cause serious environmental damage. Due to the increasing trend of building paved areas, rainwater from surface runoff results in a range of environmental problems that can leave acute or cumulative effects caused by pollution. According to STN 75 0170, acute sources of pollution can be considered to be their one-off effects that occur within 48 hours, while cumulative ones have long-term effects that manifest themselves after months or years.

A number of factors determine the chemical composition of surface runoff from paved areas, and its environmental impact depends on how they are managed in the urbanised area [1,4]. Many studies consider rainwater runoff from communications to be a direct source of pollution due to the increased content of dust particles and mixtures of toxic substances such as heavy metals (Ba, Cr, Cu, Fe, Mn, Ni, Pb and Zn) [12,17]. The toxicity of these substances may pose potential ecological risks that vary according to the type, quantity, toxicity and mobility of pollutants. Given the current trend of deriving surface runoff from urbanised areas into the sewer network, the likelihood of sediment formation in sewers increases, which causes losses in the flow profile and, if lightened, can compromise surface water quality. Diversion of surface runoff to the nearest recipient (river, lake, canal) provides significant benefits in terms of water quality (nutrient enrichment and eutrophication), although at high concentrations, there is a risk of disturbance to the aquatic environment. Sediments and heavy metals are considered to be key factors in urban aquatic environments that cause serious problems in the aquatic ecosystem. They can cause a decrease in purity and light penetration - habitat change, immediate oxygen consumption, dust particles can cause clogging of the gills, acute and toxic effects on aquatic species, increase in maximum flow and others [18]. In addition to their environmental impact, hazardous substances found in surface runoffs

may pose a risk to human resources due to the possibility of reuse (e.g. in case of an accumulation from roofs and domestic use). Many studies report heavy metals and polyaromatic hydrocarbons (PAHs) as the most dangerous contaminants due to their high toxicity and carcinogenic effects. The above studies indicate that the presence of a single type of heavy metal does not pose a significant risk if the presence of several types of heavy metals can cause health problems [12,17,19,20]. The authors of the astonished studies also consider mercury, cadmium, copper and zinc to be the most dangerous metals, while their risk to human health is significantly influenced by the volume of traffic and industrial activity of the territory, given that the risk associated with rainwater from industrial areas is higher than from residential areas. Inadequate management of secondary runoff has become a significant problem both at regional and global levels, which requires a better understanding given the diversity of surface runoff pollutants and their impact on water bodies. Direct diversion of the urban surface runoff to the nearest recipient, without any modifications, is considered a potential source of environmental pollution. Given the ever-increasing demand for water in the future, this could pose a serious environmental problem.

2. Materials and Methods

Based on the initial measurement campaign, sampling points were selected throughout the Slovak Republic. The choice of areas of interest for the purpose of sampling resulted from several factors, and it was important to select and compare different locations in the urbanized areas in the cadastral area of Bratislava, Trnava, Trenčín, Žilina, Poprad, Kežmarok, etc. The location of the sampling points is shown in Figure 1.

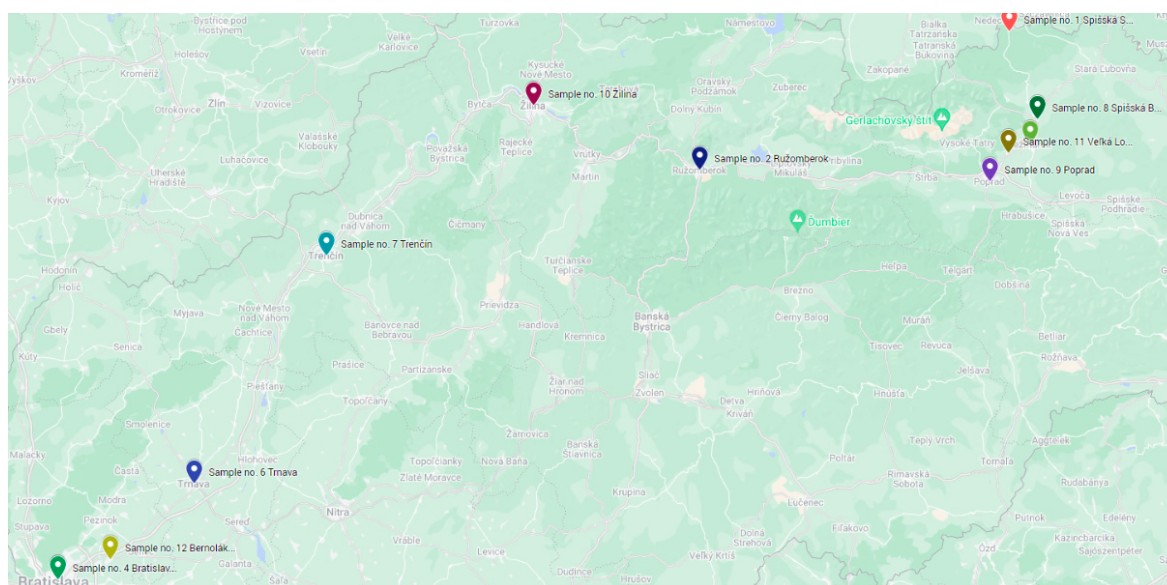


Figure 1. Locations of 13 sampled areas in the Slovak republic.

When using water from surface runoff, the composition of the soil into which the water will be used for irrigation is also extremely important. The pH value influences the solubility and transfer of heavy metals from the inlet zone to groundwater. At the same time, they also affect the course of decomposition of salts that are present in water. Despite the same characteristics, soils with lower pH values have smaller concentrations of heavy metals. The oxidation-reduction potential of water, especially for iron and manganese compounds, is important for the solubility of the mentioned heavy metals. With a negative oxidation-reduction potential, they mostly form metals and poorly soluble sulfides. Increasing the transfer of some heavy metals can temporarily increase the concentration of chlorides, which can occur especially in the winter period through the use of NaCl and CaCl₂ in the form of sprinkling defrosting salts.

Government Regulation No. 269/2010 legislatively regulates water discharge from surface runoff into groundwater and surface water. While they lay down the requirements for achieving

good status of these waters in §9 in points 1-3, the Government Regulation does not directly specify individual limit values for pollution indicators when discharging water from surface runoff. For the assessment of the quality of precipitation water, we compared the values that were measured in interest locations in Slovakia with the limits of the Regulation of the Government of the Slovak Republic No. 269/2010, which also mandates limits on the concentration of water pollution, which can be used for irrigation.

The main goal of the work was to compare the quality of rainwater in individual areas of interest in Slovakia. Chemical analysis of water (obtained on rainy days) was carried out in the laboratory of the Faculty of Chemical and Food Technology of the Slovak University of Technology in Bratislava in the range of COD, Al³⁺, Ni, Pb, Cu, Zn, Cr, Cd, Fe, using standard methods (Hach Lange cuvette tests), spectrophotometric determinations were carried out on the UV-VIS spectrophotometer of Hach Lange (DR 6000).

3. Results

The aim was to analyze the first flush of the quality parameters of the infiltrated water for the sites of interest and to compare the concentration values of heavy metals in the areas concerned. The aim is to compare them with the legislative requirements for water which can be used for irrigation in the territory of the Slovak Republic. When evaluating the analyses, we focused on pollutants: Al³⁺, Ni, Pb, Cu, Zn, Cr, Cd and Fe.

The infiltration of rainwater from the surface runoff into the soil horizon has a positive effect on the hydrological regime of the territory. First of all, it ensures the replenishment of groundwater reserves and the partial capture of flood waves and has a beneficial effect on the city's microclimate. Significantly high concentrations of nutrients, heavy metals and organic compounds that infiltrate the soil horizon can be a problem. The presence of contaminants in surface runoff varies greatly and depends on the time of year, location, traffic density and the volume and intensity of precipitation [11]. The infiltration of contaminated water into the soil horizon causes local changes in groundwater hydrology, affects the increase in groundwater level (flood level), causes groundwater pollution, and may even cause pollution of surface water as a result of sediment transport [21].

In recent decades, the infiltration of rainwater from singing grounds has been dealt with by many authors (Datry et al. (2004) [13], Tedoldi et al. (2016) [23] and many others) who pointed out that the upper soil layer and the unsaturated zone act as a filter layer and most of the harmful substances do not penetrate deep into groundwater, but remain within shallow groundwater levels. An example of the most frequently occurring pollutants in groundwater due to infiltration (infiltration) is given in Table 2.

Table 2. An example of the most frequently occurring substances in groundwater due to the infiltration of surface runoff, the source of occurrence and the possibility of reducing the risk [23].

Pollutant	Risk of deterioration	Source of occurrence
Nitrate	low to medium	fertilizers, atmospheric deposition, animal waste, etc. road salt
Chloride	low to medium	
Phosphorus	low	plant and leaf litter, soil particles, animal waste, fertilizers, road salt and atmospheric deposition particles
Toxic metals	low	substances caused by transport and surface treatment of paved surfaces
Pathogens	low to medium	areas where there are ducks, geese, pets and other animals
Organic compounds	low to medium	transport, industry, pest control, production and others

As part of the definition of risk due to the indirect effects of climate change, which can cause a crisis due to water scarcity, drought and possible threats to the quality of water resources, restrictions have been set to cover the water management area. Among the most significant are the

Environmental Protection Agency (EPA) recommendations, which support an integrated rainwater management solution system. Within Europe, it is possible to define the Water Framework Directive (2000/60/EC), which requires the protection and improvement of watercourses, as well as other Directives of the European Parliament relating to the field of water policy. In order to ensure the protection and availability of water, new conceptual approaches based on hydrological invariance have been proposed, introducing more natural methods for retaining, utilizing or treating water from surface runoff. Based on this, various recommendations and guidelines for the construction and operation of objects on HDVs, recommendations on soil structure, pH value and soil infiltration capacity, as well as requirements for water quality with regard to the purpose of its use (drinking, utility) have been developed in some countries. These recommendations vary from country to country, usually following the parameters that control the processes at the site (hydraulic efficiency, running of runoff, plant growth, etc.) and adapted to the country's conditions.

The Water Framework Directive sets out quality thresholds for surface and underground waters, as well as requirements for discharges of surface runoff water into sub-ground and surface waters. This must be respected by all EU Member States but can be adjusted in light of the state's political status. In line with EU legislation, Danish legislation has been developed that considers rainwater runoff to be wastewater that can be incorporated into sewers and rivers or infiltrated into the soil after obtaining permission from the relevant national authorities. There are no specific criteria that surface runoff must meet, and approval will only be obtained if certain standard measures are used. The authority may require specific quality only if it considers rainwater runoff to be a risk to a particular body of water as defined in the European Water Framework Directive. In this case, in order to obtain permission from the competent authorities, the outflow of rainwater with paved areas before discharge or infiltration into the soil must comply with certain limit values, which are local and individual. The criteria for surface water [24] and groundwater [25] developed by the Danish Public Authority do not specifically concern the discharge of rainwater surface runoff. Still, they serve as a guide in the event of a risk of endangering water bodies.

4. Discussion

Water quality in the territory of the Slovak Republic has a trend of worsening. Currently, the majority of underground water is used for drinking purposes, but a large part of water resources is threatened by potential sources of pollution in the form of surface water. The Slovak Hydrometeorological Institute has built a network of monitoring sampling points on the territory of the Slovak Republic. We present the evaluation of the trend of deterioration of groundwater quality for comparison with a 5-year period. Sampling is carried out on a six-monthly basis. This means 2 relevant samples during one year. The trend of groundwater quality deterioration is evident in almost all evaluated locations. Contamination of groundwater is most pronounced in the Bratislava District. Evaluation of groundwater quality is focused on trace elements of selected indicators. The quality assessment was carried out on the basis of legislatively defined limits of quantification (LOQ), which is the lowest concentration of a substance that can be reliably measured using standard tests.

Table 3. Limitné hodnoty pri vyhodnocovaní koncentrácie látok ktoré je možní s istotou merať s použitím štandardných testov.

Trace element	LOQ	Unit
Arsenic As	0.5	µg/l
Aluminum Al	0.01	mg/l
Cadmium Cd	0.1	µg/l
Copper Cu	2	µg/l
Nickel Ni	2	µg/l
Zinc Zn	2	µg/l

Data on the quality of underground water in the Bratislava Gaštanový Hájik location were obtained on the basis of publicly available information provided by the Slovak Hydrometeorological

Office at its website www.shmu.sk. From the monitoring results of the Slovak Hydrometeorological Institute from 2017 to 2022, only one location was evaluated. The trend of deterioration of groundwater quality in urbanized areas is confirmed in the case of Aluminum and Zinc. The other observed trace elements did not show increasing concentrations from the measuring object.

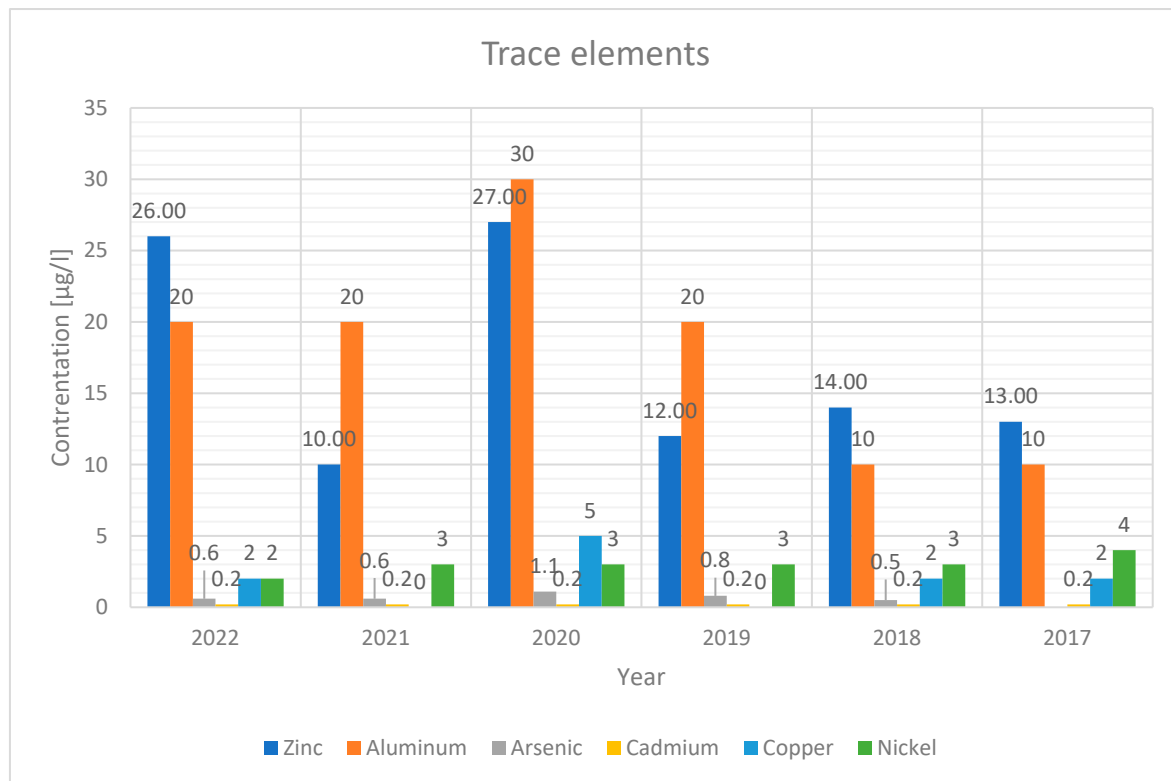


Figure 2. Concentration of trace elements in underground water in Bratislava region.

Similar research on deteriorating water quality in urbanized areas has also been noted by scientists in studies of urban hydrology. When researching urban hydrology, it is also important to determine the concentrations of total insoluble substances, which is one of the most basic indicators of pollution concentration. The total concentration of insoluble substances is variable during the duration of the rain, which also confirms the research of *N A Zuraini* and the team (2018) [26]. However, information on insoluble substances does not define what substances are in the water. With a focus on ana pollutants from transport, *Zhang et al.* (2015) [27] published a study aimed at evaluating the concentration of metals in water from surface runoff - The concentrations of metals in this case study correspond to the results obtained during the evaluation of the presented study focused on the location of the Slovak Republic. For optimal water management in urbanized areas, it is also necessary to obtain accurate information about the amount of precipitation and its direct impact on water quality from surface runoff. *Haibin Yan et al.* (2023) [28] directly followed such research, where they defined the relationship between the quality and quantity of a rain event using correlation analysis. In their research, they focused on TSS and total nitrogen concentrations. *Christián et al.* (2020)[29] in their research confirm the trend of the need to evaluate the state of water from surface runoff in cities. They focused on trace elements as well as microbiological evaluation of samples, the most important parameter of which is *E. coli* and faecal coliform bacteria. *Qi et al.* (2020) [30] offer an improvement of the current state of deterioration of water quality in urbanized areas compared to current analyzes and evaluation of the current state.

Removal of micropollutants such as heavy metals from water from surface runoff in cities is possible with a combination of filters and an accumulation tank in which rainwater is accumulated and subsequently purified. Water purification can, for example, be ensured by filtration using biochar, as stated by the authors *Muhammad B., S., and the collective* (2020) [31], who in their research examined the possibilities of using different types of biochar.

5. Conclusions

In the research work, we focused on the analysis of rainwater surface water concerning its possible use for irrigation in urbanized areas. This is due to different emissions and pollution in the localities and various materials affecting the quality of rain runoff (road surface, roof surface, traffic congestion, industrial pollution). We focused on individual areas of interest in Slovakia, where samples were taken from the surface of roads and parking lots on rainy days.

The aim was to assess the precipitation runoff and the concentration of primarily heavy metals in individual interest locations in Slovakia.

The secondary objective was to assess the values of the first flush of rainwater and their heavy metal concentrations and to compare them with the concentration limits set out in Government Regulation No 269/2010, which is dealt with by the quality of the water used for irrigation.

Table 2. Overall assessment of exceeded limit values of heavy metal concentrations.

(mg/l)	1	2	3	4	5	6	7	8	9	10	11	12	13	Limit
Alumi (Al).	0,043	0,011	0,048	0,014	0,009	0,027	0,021	0,03	0,063	0,063	0,037	0,011	0,04	1
Nickel (Ni)	0,091	0,031	0,297	0,068	0,028	0,215	0,207	0,24	0,026	0,026	0,219	0,142	0,282	0,1
Lead (Pb)	0,101	0,084	0,13	0,101	0,099	0,089	0,165	0,25	0,118	0,118	0,293	0,142	0,389	0,05
Copper (Cu)	0,163	0,049	0,29	0,089	0,088	0,204	0,222	0,184	0,061	0,061	0,196	0,129	0,322	0,5
Zinc (Zn)	0,266	0,088	0,185	0,111	0,053	0,15	0,228	0,221	0,021	0,021	0,23	0,094	0,196	1
Chrom. (Cr)	0,032	0,018	0,022	0,026	0,024	0,028	0,023	0,04	0,017	0,017	0,032	0,037	0,042	0,2
Cadmi. (Cd)	0	0	0	0	0	0	0	0	0,014	0,014	0	0	0	0,05
Iron (Fe)	0,16	0,15	0,57	0,09	0,08	1,28	1,36	2,2	0,08	0,08	1,32	0,26	2,21	10

Since the heavy metal concentration values contained in the samples taken from the sites of interest are too high, it is necessary to design a heavy metal and petroleum separator before filtering rainwater into the subsoil in order to ensure sufficient quality of the inlet water and thus avoid subsequent contamination of the water. The graphically expressed results of the analyses can be seen in Figure 3.

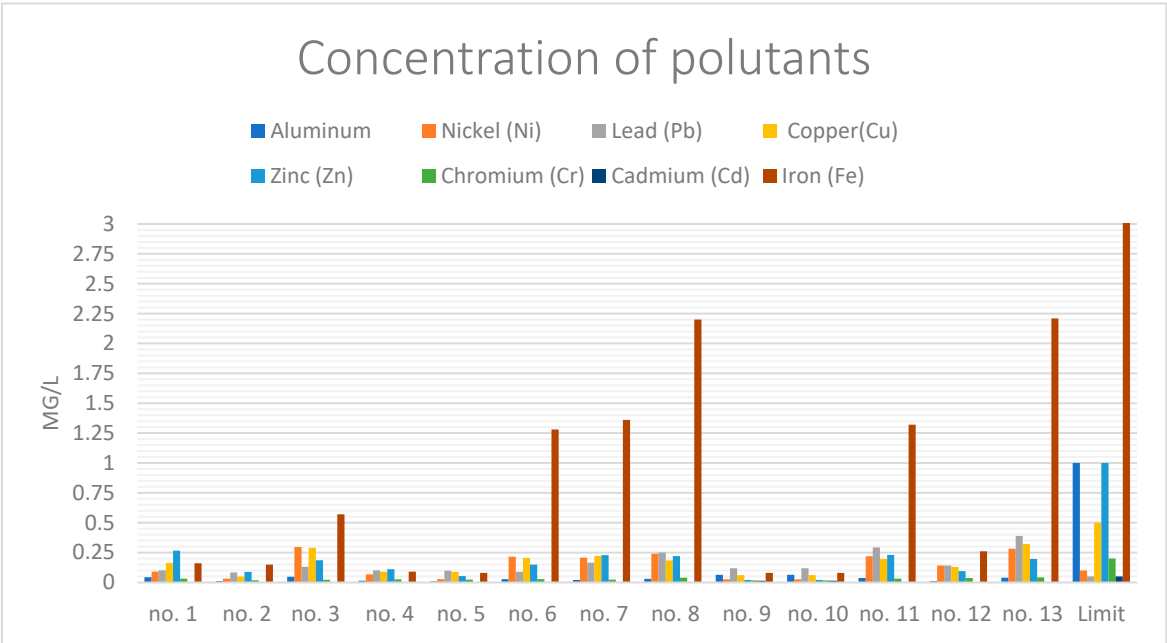


Figure 3. Graphic display of pollution concentration in samples.

The results of the analyses confirmed the unsatisfactory quality of the samples taken and the impossibility of using these waters for irrigation in urbanised areas. From Table 2, it is clear that the limits in the three Monitored parameters have been exceeded. The lead concentration parameter is exceeded in all samples. Another parameter that does not meet the limits are cadmium in two cases and nickel in 6 cases.

The quality of underground water in the monitored locations is in a bad state. For comparison, zinc concentrations range from 26 to 8 µg/l over a 5-year period, and zinc concentrations in surface drain water are at the level of 111 µg/l. Nickel was measured in groundwater in concentrations from 2 to 5 µg/l compared to water from the surface runoff where the concentration was measured up to 68 µg/l. Groundwater in Bratislava shows a high degree of pollution, which can be evaluated on the basis of contamination from surface water.

The issue of surface runoff water is highly topical and there is a need for long-term research with regard to pollution concentrations. At present, emphasis is placed on water retention directly at the place where it falls, however, the quality of such water as confirmed in our research is unsuitable for the possibility of using it for irrigation or for the possibility of seeping into the subsoil.

In the territory of the Slovak Republic, rainwater management in the urbanized area is not yet dealt with in detail by legislation and technical standards. This topic is partly dealt with in the Water Plan of Slovakia in accordance with Article 4.7(d), the Water Framework Directive (2000/60/EC), which unreservedly supports measures for the construction of water retention facilities in urbanized areas and by Regulation of the Government of the Slovak Republic No. 269/2010 Collection of Laws (Coll.) laying down requirements for achieving good water status. Part of the content of the NV SR No. 269/2010 in § 9 in points 1–3 is the requirements for the discharge of water from surface runoff into surface water and groundwater. This regulation defines that in the event of a presumption of the content of non-hazardous substances in the surface runoff before indirect discharge, the necessary measures must be taken [32]. According to Slovak regulations under surface drainage with paved areas means runoff from weaned and installation areas, from areas of industrial sites and other areas where there is a risk of accumulation of pollutants. The requirements for the discharge of surface runoff into surface waters are also described by the Water Act No. 364/2004 Coll., which in § 2 will (i) define rainwater as "water from the surface runoff", which has not soaked into the ground and which is drained from the terrain or external parts of buildings to surface water and groundwater. That law, in Paragraph 36(17), describes how rainwater from surface runoff is managed, under what conditions it is possible to discharge precipitation runoff into surface waters and in which measures need to be proposed [33]. Lack of Slovak regulations covering the field of water management the limit indicators of pollution for the discharge/removal of rainwater from surface runoff (communications, car parks, roofs of buildings) is precise to groundwater and surface water.

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References

1. ANGRILL, S., PETIT-BOXI, A., MORALES-PIZÓN, T., JOSA, A., RIERADEVALL, J., GABARRELL, X. Urban rainwater runoff quantity and quality – A potential endogenous resource in cities? *Journal of Environmental Management*, **2017**. Volume 189. Pages 14-21. ISSN 0301-4797.
2. RAGAB, R., BROMLEY, J., ROSIER, P., COOPER, J.D., GASH J.H.C. Experimental study of water fluxes in a residential area: 1. Rainfall, roof runoff and evaporation: the effect of slope and aspect. *Hydrological Processes*, **2003**. Volume 17. Issue 12. Pages 2409-2422. ISSN 0885-6087.

3. MAMOON, A.A., JAHAN, S., HE, X., JOERGENSEN, E. N., RAHMAN, A. First flush analysis using a rainfall simulator on a micro catchment in an arid climate. *Science of The Total Environment*, **2019**. Volume 693. ISSN 0048-9697.
4. WANG, Q., ZHANG, Q., WANG, X.C., HUANG, J., GE, Y. Impact of key factors on heavy metal accumulation in urban road-deposited sediments (rds): Implications for RDS management. *Chemosphere*, **2020**. Volume 261. Article No. 127786. ISSN 0045-6535.
5. MELAND, S. Management of contaminated runoff water: current practice and future research needs. Brussels, Belgium. **2016**. 84 p. ISBN 979-10-93321-18-9.
6. FERNÁNDEZ-OLMO, I., PUENTE, M.L., IRABIEN, A., Source contribution to the bulk atmospheric deposition of minor and trace elements in a Northern Spanish coastal urban area. *Atmospheric Research*, **2014**. Volumes 145–146. Pages 80-91. ISSN 0169-8095.
7. YU, J., YU, H., XU, L., XTAO, N.B., ZHANG, Y., HUA, Y., NKOLOLA, N.B., Characteristic comparison of heavy metal contamination between road-deposited and roof-deposited sediments in suburban area. *Environmental Photocatalysis and Photochemistry for a Sustainable World: A Big Challenge*, **2017**, Volume 24. Issue 14. Pages 12871–12881.
8. JAYARATHNE, A., EGODAWATTA, P., AYOKO, G.A., GOONETILLEKE, A. Intrinsic and extrinsic factors which influence metal adsorption to road dust. *Science of The Total Environment*, **2018**. Volume 618. Pages 236-242. ISSN 0048-9697.
9. LIU, E., YAN, T., BIRCH, G., ZHU, Y. Pollution and health risk of potentially toxic metals in urban road dust in Nanjing, a mega-city of China, *Science of The Total Environment*, **2014**. Volumes 476–477. Pages 522-531. ISSN 0048-9697.
10. HAYNES, M.H., TAYLOR, G.K., ROTHWELL, J., BYRNE, P. Characterisation of road-dust sediment in urban systems: a review of a global challenge. *Journal of Soils and Sediments*, **2020**. Volume 20. Issue 12. Pages 4194–4217.
11. TIMMERS, R.J.H.V., ACHTEN, A.J.P. Non-exhaust PM emissions from electric vehicles. *Atmospheric Environment*, **2016**. Volume 134. Pages 10-17. ISSN 1352-2310.
12. SUMAN, S., SINHA, A., TARAFDAR, A. Polycyclic aromatic hydrocarbons (PAHs) concentration levels, pattern, source identification and soil toxicity assessment in urban traffic soil of Dhanbad, India. *Science of The Total Environment*, **2016**. Volumes 545–546. Pages 353-360. ISSN 0048-9697.
13. ZHAND, Q., WANG, X., HOU, P., WAN, W., LI, R., REN, Y., OUYANG, Z. Quality and seasonal variation of rainwater harvested from concrete, asphalt, ceramic tile and green roofs in Chongqing, China. *Journal of Environmental Management*, **2014**. Volume 132. Pages 178-187. ISSN 0301-4797.
14. GIKAS, G.D., TSIHRINTZIS, A.V. Assessment of water quality of first-flush roof runoff and harvested rainwater. *Journal of Hydrology*, **2012**. Volumes 466–467. Pages 115-126. ISSN 0022-1694.
15. LEE, J.Y., BAK, G., HAN, M. Quality of roof-harvested rainwater - Comparison of different roofing materials. *Environmental Pollution*, **2012**. Volume 162. Pages 422-429. ISSN 0269-7491.
16. JEDRZEJCZAK, M. Preliminary study of the toxicity of rainwater runoff from the roofs with varying coverage. *Folia Pomeranae Universitatis Technologiae Stetinensis. Agricultura, Alimentaria, Piscaria et Zootechnica*, **2016**. 330(40)4. Pages 101-112.
17. LIU, A., LIU, L., GUAN, Y. Characterizing heavy metal build-up on urban road surfaces: Implication for stormwater reuse. *Science of The Total Environment*, **2015**. Volumes 515–516. Pages 20-29. ISSN 0048-9697.
18. CHARTERS, F.J., COCHRANE, T.A., O'SULLIVAN, D.A. The influence of urban surface type and characteristics on runoff water quality. *Science of The Total Environment*, **2021**. Volume 755. Part 1. ISSN 0048-9697.
19. SAKSON, G., BRZEZINSKA, A., ZAWILSKI, M. Emission of heavy metals from an urban catchment into receiving water and possibility of its limitation on the example of Lodz city. *Environmental Monitoring and Assessment*, **2018**. Volume 190. Issue 5. Article No. 281.
20. MA, Y., EGODAWATTA, P., MCGREE, J., GOONETILLEKE, A. Human health risk assessment of heavy metals in urban stormwater. *Science of The Total Environment*, **2016**. Volumes 557–558. Pages 764-772. ISSN 0048-9697.
21. TROJAN M.D., GULLIVER S.J., FAIRBAIRN J.D. Groundwater Impacts from Stormwater Infiltration Practices. *Encyclopedia of Water: Science, Technology, and Society*, **2019**. DOI: <https://doi.org/10.1002/9781119300762.wsts0103>.

22. DATRY, T., MALARD, F. A GIBERT, J. Dynamics of solutes and dissolved oxygen in shallow urban groundwater below a stormwater infiltration basin. *Science of Total Environment*, **2004**. Volume 329. Issues 1–3. Pages 215–229. ISSN 0048-9697.
23. TEDOLDI, D., CHEBBO, G., PIERLOT, D., KOVACS, Z., GROMAIRE, M-C. Impact of runoff infiltration on contaminant accumulation and transport in the soil/filter media of Sustainable Urban Drainage Systems: A literature review. *Science of The Total Environment*, **2016**. Volumes 569–570. Pages 904–926. ISSN 0048-9697.
24. MINISTRY OF ENVIRONMENT AND FOOD OF DENMARK. *Departmental Order Concerning Establishment of Environmental Goals for Streams, Lakes, Transition Waters, Coastal Waters and Groundwater*. Bek. Nr. 1070 af 09/09/2015. Ministry of Environment and Food of Denmark. Copenhagen, Denmark. **2015**.
25. DANISH ENVIRONMENTAL PROTECTION AGENCY. *List of Quality Criteria in Relation to Polluted Soil and Quality Criteria for Drinking Water*. Denmark, Copenhagen, **2015**.
26. N A Zuraini et al *Journal of Physics: Conference Series*, **2018**. Volume 1049, DOI 10.1088/1742-6596/1049/1/012039
27. Hua Zhang, Zhaofeng Wang, Yili Zhang, Mingjun Ding, Lanhui Li, Identification of traffic-related metals and the effects of different environments on their enrichment in roadside soils along the Qinghai–Tibet highway, *Science of The Total Environment*, Volumes 521–522, **2015**, Pages 160–172, ISSN 0048-9697, <https://doi.org/10.1016/j.scitotenv.2015.03.054>.
28. Haibin Yan, David Z. Zhu, Mark R. Loewen, Wenming Zhang, Shuntian Liang, Sherif Ahmed, Bert van Duin, Khizar Mahmood, Stacey Zhao, Impact of rainfall characteristics on urban stormwater quality using data mining framework, *Science of The Total Environment*, Volume 862, **2023**, 160689, ISSN 0048-9697, <https://doi.org/10.1016/j.scitotenv.2022.160689>.
29. Christian, L.; Epps, T.; Diab, G.; Hathaway, J. Pollutant Concentration Patterns of In-Stream Urban Stormwater Runoff. *Water* **2020**, 12, 2534. <https://doi.org/10.3390/w12092534>
30. Qi, Y.; Chan, F.K.S.; Thorne, C.; O'Donnell, E.; Quagliolo, C.; Comino, E.; Pezzoli, A.; Li, L.; Griffiths, J.; Sang, Y.; et al. Addressing Challenges of Urban Water Management in Chinese Sponge Cities via Nature-Based Solutions. *Water* **2020**, 12, 2788. <https://doi.org/10.3390/w12102788>
31. Shakoor M. B., Ali S., Rizwan M., Abbas F., Bibi I., Riaz M., Khalil U., Niazi N. K., Rinklebe J., (2020) A review of biochar-based sorbents for separation of heavy metals from water, *International Journal of Phytoremediation*, 22:2, 111–126, DOI: 10.1080/15226514.2019.1647405
32. NATIONAL COUNCIL OF THE SLOVAK REPUBLIC. REGULATION OF THE GOVERNMENT of the Slovak Republic No. 269/2010 Coll. of May 25, **2010** establishing requirements for achieving good water status.
33. NATIONAL COUNCIL OF THE SLOVAK REPUBLIC. LAW No. 364/2004 Coll. of May 13, **2004** on water and amending the Act of the Slovak National Council no. 372/1990 Coll. on offenses as amended.

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