ESTIMATION OF THE POTENTIAL RUNOFF QUALITY IMPROVEMENT AS A RESULT OF APPLIED GREEN INFRASTRUCTURE MEASURES IN A HUNGARIAN TOWN

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Abstract

Green infrastructure measures provide several services – improves the microclimate of a town, improves air quality, decreases noise and improves the quality of surface and subsurface waters as well along with increasing the water balance on the town level. These facts are proved by several studies which will be quoted in the study. The aim of the study is to estimate the potential runoff quality improvement as a result of applying green infrastructure elements along traffic roads in the town. This improvement is of high priority in the aquifer protection area from where runoff water may infiltrate into the aquifer carrying with it pollutants from the surface. Estimations is going to be applied on more levels, first we determine the surface of traffic roads, then estimate the quantity of different kinds of pollutants accumulated on the surface and thirdly we estimate the expected performance of the applied green infrastructure elements based on findings in the literature in this topic. We determine the impervious urban surface area associated with transport-related functions within the protected drinking water recharge area using GIS technic using available orthophotos. We introduce data regarding the roads with the densest traffic in 2016. within the investigated area. We estimate the expected reduction of runoff pollution if sustainable storm water management practices are applied in the area. The overall goal is to make the significance of diffuse pollution more obvious and enhance drinking water protection through taking diffuse pollution into consideration.

Keywords: *traffic related urban surfaces, reduction of pollution load from roads, protected drinking water recharge area, stormwater management practices, water sensitive urban design, developing a GIS for urban water runoff management*

1. INTRODUCTION

1.1. General

Urbanization increases both the absolute amount of pollutants on surfaces and in surface runoff (Saara Lehtinen, 2014.). Road infrastructure is an integral part of urban development. Impervious urban surface area associated with transport-related functions such as roads, driveway, car-parks etc., is a prominent source of suspended solids and associated trace metals, polycyclic aromatic hydrocarbons and nutrients (Tony Wong et.al.,2000.).

The relative contribution road infrastructure makes to changes in pollutant export is directly related to its contribution to total catchment imperviousness; transport related surfaces can account for up to 70%. In most urbanized catchments, the local road network (eg. major and minor roads, residential streets, parking areas, and driveways) represents the major proportion of transport related imperviousness and therefore significantly alters the catchment hydrology. The quality of runoff from the local road network depends on traffic density. Stormwater management options for the local road network needs to be integrated into the overall catchment planning and management (land use planning, residential design, drainage design, etc.) as part of water sensitive urban design (Tony Wong et.al.,2000.).

A significant amount of gross pollutants as well as particulate and soluble contaminants accumulate on transport related surfaces and are conveyed into stormwater drainage networks during runoff events or run off onto nearby sites available for infiltration. Between runoff events, pollutants, primarily particulates and attached pollutants, enter drainage networks as a result of ineffective street sweeping, wind action and vehicle movement. The level of road pollution varies and is influenced by the local environment and applied management practices. Thus, it is necessary to understand the quantity and quality of road pollution to develop effective control practices for road nonpoint pollution (Yunn-Jinn et. al.,2013.). For this reason here we introduce a selection of facts published in this topic.

1.2. Facts about the protected drinking water recharge area

Protection of public water supplies in Debrecen involves the preventive method of designated protection zones which protects the confined aquifers from pollutions percolating downwards from the surface. Protection zones are of special significance because if contamination occurred, using an alternative source would be prohibitively expensive (A.A. Konopliantsev, 1988). Institutional as well as technological preventive measures are needed to avoid groundwater pollution must be applied at sources or potential sources of the pollutants. Many groundwater pollution cases are only of local extent, but collectively they are of regional concern and need watershed- level planning including protective actions. The protection is ensured by regulations which controls and limits polluting activities within the protection zones either by prohibiting new polluting activities or requiring a preliminary environmental impact assessment to be carried out. Currently operating activities may be subject of environmental impact assessment as a review to decide upon permitting or prohibiting of further operation.

Although transportation activities are not restricted Government Decree No. 123/1997. (VII. 18.), it cannot be banned or relocated to other sites either though it could contaminate drinking water supplies. The relevant National River Basin Management Plan (2015.) which was developed according to the Water Directive (2000/60/EK The Water Framework Directive) specifies urban runoff to be one of the two main nonpoint source pollutions.

1.3. Runoff quality -general findings and documented pollutant concentrations in road runoff

1.3.1. General findings

Sources of contaminants in urban storm water runoff are streets, driveways, roads, roadsides, industrial landscaped areas, commercial landscaped areas, parking lots, bridges, vehicle maintenance areas, automobile exhaust causing atmospheric deposition (Urban Storm Water Preliminary Data Summary, EPA). Since stormwater contaminants are discharged from a large number of individual points over a wide range within the catchment, their characteristics and contaminant loadings are not easily understandable (Bharat Maharjan et.al., 2016.). Runoff in stormwater is intermittent, as it depends on the magnitude of rainfall, land use and anthropological activities in the catchment area. It is difficult to assess annual average and event mean concentration which causes troubles in decision-making for sustainable planning, design and policy formulation. The paper provides the options for choosing an appropriate sampling program that could balance the degree of certainty and resource availability. Overall, it ensures proper guidance and recommendations for all planners and designers to design the monitoring program. Priority pollutants in urban stormwater runoff include nutrients (i.e. nitrogen and phosphorus), heavy metals (i.e. Pb, Zn, Cu, Cd), organics (e.g. petroleum hydrocarbons), pathogens, suspended solids, and salts (Peter T. et.al.,2008.).

Literature review of Shuai Liu et.al. summarizes the qualitative impacts of urban areas stating that pollutants total nitrogen, total phosphorus, total potassium, heavy metals, polycyclic aromatic hydrocarbons (PAH-s), polychlorinated biphenyls (PCB-s), pesticides, pharmaceuticals, debris, temperature and microbial contaminants have an increasing impact on the natural water cycle compared to undeveloped catchments (Shuai Liu et.al., 2017.).

Stormwater runoff rates and volumes increase in urban areas due to increased impervious surface areas (Liesl L. et.al.). Urbanization also increases the number of sources, the types of constituents, and the amount of pollutants in surface runoff. Although stormwater discharges are currently perceived as one of the largest inputs of pollutants, and toxic effects are regularly measured in receiving waters, large variability and uncertainty remain associated with runoff mass emission estimates. Variability and uncertainty are the results of runoff loadings, which largely depend upon runoff amounts and precipitation. variability and uncertainty in runoff mass emission estimates are amplified by three factors: infrequent but intense rainfall patterns, differing watershed characteristics, and infrequent monitoring. The first factor, infrequent but intense rainfall patterns, is characterized by long dry periods without rain (six months) followed by rain flow rates that can change by orders of magnitude in less than one hour. The second factor, differing watershed features, affects runoff quantity/quality and variability in pollutant concentrations. According to the study of Tony Wong et.al., (2000.) the quality of runoff from the local road network depends on traffic density.

1.3.2. Documented pollutant concentrations in road runoff

The impervious surfaces of waterways leading to the ocean, 3 such as the channelized Ballona Creek, pose the most damage to water quality when urban runoff and trash flow to the ocean. Watersheds with impervious surfaces lead to high volumes of discharged water and runoff due to a bypass of natural filtration (Uma Bhandaram et.a.,2011.).

From a database with more than 300 monitoring sites, this review includes all studies that presented traffic area runoff loads for the metals Cd, Cr, Cu, Ni, Pb, Sb, antimony and Zn. The values were always reported as total (recoverable) metals. The sample preparation and analysis conducted by the selected studies had a low influence on the results because all studies used automatic composite samplers to obtain a large number of samples for each rain event - active sampling - or a mixed sample of a part of the complete runoff - passive sampling (Maximilian Huber et.al., 2016.)

Pollutant concentration in synthetic stormwater applied in the simulation carried out in Sydney. The concentration of each pollutant in the synthetic stormwater was based on the median value that was reported for laboratory simulations elsewhere, averaged with the median value for six grab samples for first flush events at Sydney sites where field units were to be constructed. It is important to note, that on this basis, synthetic stormwater formulation would vary for each City catchment and that some standardization is ultimately needed (Macnamara et.al.,2017.)

In the study of Liesl L. et.al. 25 nearly 2000 samples were collected at 15-min intervals during the 1997/98 wet season from the Santa Ana River, an urbanized watershed in Orange County, California, to assess the magnitude of "first flush" versus seasonal flushing, and to assess pollutant variability within and among storm events. All samples were analyzed for total suspended solids (TSS); and a selected subset was analyzed for total organic carbon (TOC), total nitrogen (TN), and trace metals - cadmium, chromium, copper, lead, nickel, and zinc.

Concentrations of typical pollutants in road runoff, compiled from Göbel et.al., 2007., Urban Storm Water Preliminary Data Summary, EPA and Krafft,, 2006 can be found in **Table 1**. The Nationwide Urban Runoff Program (NURP) is a research project conducted by the United States Environmental Protection Agency (EPA) between 1979 and 1983. It was the first comprehensive study of urban stormwater pollution across the United States. Sampling was conducted for 28 NURP projects which included 81 specific sites and more than 2300 separate storm events.

Table 1. Concentrations of typical pollutants in road runoff; compiled from Göbel et.al., 2007., Urban Storm Water Preliminary Data Summary, EPA and Krafft, 2006

Parameter Concentration	Concentration			Source of data
	Unit	Min.	Max.	
TSS, suspended solids	mg/l	74,00	937,00	Göbel. et.al.,2007.
TN	mg/l	0,50	18,30	Göbel. et.al.,2007.
TP	mg/l	0,23	0,34	Göbel. et.al.,2007.
Cl	mg/l	3,90	669,00	Göbel. et.al.,2007.
TPH	mg/l	0,70	6,60	Urban StormWater Preliminary Data Summary
COD	mg/l	63,00	146,00	Göbel. et.al.,2007.
PAH-s	μg/l	0,24	17,10	Göbel. et.al.,2007.
Oil and grease	mg/l	0,20	3,00	Krafft, 2006.
Microbial contaminants	MPN/100 ml	1,80	430,00	Urban StormWater Preliminary Data Summary

Studies have shown that contaminant concentrations in urban runoff can vary widely by season, location, traffic volumes, and rainfall volumes and intensity (Peter T. et.al.2008.) therefore it is better to calculate with load data when available. In their study Maximilian et.al. (2016.) calculated median annual runoff loads of more than 300 monitoring sites which allows us to calculate heavy metal runoff loads from total traffic areas for the study area. The number of measurements for Ni and Pb was low. Results can be found in **Table 2**.

Table 2. Calculated median annual runoff loads of 300 sites (Maximilian et.al., 2016.)

mean value [g/ha/yr]	6,8	75	355	66	14	2018
parameter	Cd	Cr	Cu	Ni	Pb	Zn

1.4. Stormwater management measures

Within the past decade, a number of novel, nature-based stormwater control measures have been developed and are being implemented to help address the growing urban stormwater problem. Specific technologies include bioretention, vegetated swales and filter strips, green roofs, and permeable pavements. Nature-based stormwater control measures commonly include some type of soil-based media to promote water storage and infiltration. Water quality improvements, due to pollutant removal mechanisms such as sedimentation, filtration, and biological transformation, are expected as well and have been documented in several studies (Lensa J.et.al., 2017., National Management Measures to Control Nonpoint Source Pollution from Urban Areas; Peter T. Weiss et.al., 2008.)

One of the fundamental axioms of modern stormwater management is source control: preventing problems by control as close to the source as possible (Marsalek, J. 2013.). In most scenarios involving urban stormwater runoff, decentralized, incentive-based strategies using small-scale capture devices is more cost-effective than centralized strategies (Cutter, W.B. et.al., 2008.)

Stormwater management measures besides the traditional measures are Best Management Practices (BMPs), Low Impact Development (LID), Water Sensitive Urban Design (WSUD), Sustainable Urban Drainage Systems (SUDS) and Green Infrastructure (GI). The objective of Water Sensitive Urban Design is to combine the demands of sustainable stormwater management with the demands of urban planning, and thus bringing the urban water cycle closer to a natural one (Hoyer, J. et.al., 2011.). Water Sensitive Urban Design (short: WSUD) is the interdisciplinary cooperation of water management, urban design, and landscape planning. It considers all parts of the urban water cycle and combines the functionality of water management with principles of urban design (Hoyer, J. et.al.,2011.). Fine media filtration systems, particularly those that are vegetated (commonly known as biofiltration systems, bioretention systems, and rain gardens), are an increasingly popular technology for mitigating the deleterious effects of urbanization on the ecological health of receiving waters. These systems are engineered to reduce runoff peaks and volumes and to improve water quality via mechanisms such as sedimentation, filtration, and sorption, as well as biological uptake if the filter is vegetated (Maximilian et.al.,2016.).There are only slight differences in principles as well as solutions and elements. They provide not only conveyance as traditional drainage systems but rainwater use, treatment, detention and infiltration. A huge amount of literature is available which help us learn about the assets, their application and documented water quality improvement performance (Hoyer et.al.,2011.).

1.5. Potential negative impacts of infiltration systems on groundwater quality

It needs to be mentioned without detailed account that there are concerns about the potential negative impacts of infiltration systems on groundwater quality. It needs further investigations before designing at a specific site. The purpose of the literature review (Peter T. Weiss et.al., 2008.) is to examine the current state of research regarding possible soil and groundwater pollution caused from stormwater infiltration practices. Research has shown that many of the priority pollutants in urban stormwater runoff have some potential to compromise groundwater supplies. Furthermore, concentrations of the pollutants in the receiving soil may become elevated above acceptable levels. Study (Macnamara et.al., 2017.) does not point at a considerable risk for groundwater contamination due to stormwater infiltration but highlights that well absorbable contaminants readily available in urban stormwater runoff eventually build up in surface soils and subsurface sediments to environmentally critical levels. Thus, on the one hand stormwater infiltration systems may act as effective pollution traps and on the other hand they may pose a potential solid waste disposal problem that future stormwater management based on local infiltration will have to face (Macnamara et.al., 2017.).

If infiltrated into the soil, some contaminants have the potential to degrade soil and groundwater quality and, therefore, are of concern. This potential is higher in case of aquifers lacking sufficient natural protection. According to Peter T. Weiss et.al.(2008.), these are the following materials:

- According to Peter T. et. al. (2008.), nickel and zinc would have high groundwater contamination potential in infiltration systems and chromium and lead have moderate potential. If sedimentation pretreatment were used, all metals would probably have low groundwater contamination potential.
- Because salts are soluble, easily transported in surface and sub-surface flow, non-filterable, and do not readily sorb to solids, they have high potential for groundwater contamination. Rather than being reduced, salt concentrations typically increase as water moves through soil due to leaching of salts into the water. Groundwater contamination potential of pathogens depends on the soil chemical properties, adsorption capability, the ability of the soil to physically strain the pathogens, and pathogen survival. Bacteria survive longer in low pH soils and in soils with high organic content. Bacteria and viruses can move through soil media and may be transported to aquifers by infiltrating stormwater. The transport distance of bacteria seems to be a function of bacteria density and water velocity through the soil.
- Some organic compounds - 1,3-dicholobenzene, pyrene and fluorene - may have high groundwater contamination potential in subsurface infiltration/injection systems without pretreatment but would probably have lower contamination potential in surface infiltration systems. A series of other organics may have moderate groundwater contamination potential when no pretreatment system is used.
- According to Peter T. Weiss et.al.(2008.), nitrate, due to its typical low concentrations, has low to moderate groundwater contamination potential for surface percolation and subsurface infiltration/injection systems. If nitrate concentrations are high, however, the groundwater contamination potential would also be high. The movement of nitrate towards the groundwater is

dependent on the rate and volume of infiltration, horizontal and vertical groundwater flow, depth to the water table, and preferential flow paths (Peter T. Weiss et.al., 2008.).

According to the Water Management Technical Guidelines infiltration systems are not permitted in areas where contamination of ground water is possible or where the site is known or suspected of being contaminated. Also, areas with land slip or geotechnical problems associated with reactive soils, with existing seepage problems, exposed bedrock at surface, shallow soil over rock or shale, steep (>10%) terrain or high water table are not appropriate for placing infiltration systems. The Water Management Technical Guidelines serves to provide technical water management guidelines to community, developers and decisionmakers. It contains planning controls relating to the management of all aspects of the water cycle in an integrated and consistent manner. Complying with these guidelines ensure long-term sustainable social, ecological and economic outcomes.

1.6. Basic mechanisms and documented water quality improvement performance of nature-based stormwater control measures

Fine media filtration systems, particularly those that are vegetated - commonly known as biofiltration systems, bioretention systems, and rain gardens-, are an increasingly popular technology for mitigating the negative effects of urbanization on the ecological health of receiving waters. These systems are engineered not only to reduce runoff peaks and volumes but to improve water quality via mechanisms such as sedimentation, filtration, and sorption, as well as biological uptake if the filter is vegetated. The lifetime of the media will depend on the strength of the adsorption and the concentration of the incoming pollutants. The media may be expected to have a long lifetime for metals and hydrocarbons - many years -, but less for phosphorus - few years or less. Studies of Lensa Jotte et.al. (2017.) and many others describe the primary mechanisms that take place in nature-based storm water management units. These are:

<u>Sedimentation</u> is the primary mechanisms for removal of particulate matter from water. Higher density particles are effectively removed via sedimentation.

<u>Filtration/infiltration</u> technologies will filter fine particles. Excellent removal of suspended solids in field bioretention systems has been noted. Field studies support the concept of filtration and ultimate die off of pathogen indicator species as well.

<u>Adsorption</u> The soil-based media common in filtration/infiltration facilities provides numerous opportunities for the adsorption of a variety of pollutants. Hydrophobic organic compounds such as PAH and other fuel-based hydrocarbons will partition into soil organic matter. Metal adsorption is generally a strong function of pH, with increasing metal adsorption at higher pH. Because of the low metal concentrations typical of urban runoff, effective adsorption of metals tends to occur within the pH range of the soil media. Orthophosphate will also adsorb to soils.

<u>Microbiological Processes</u> are generally slow as compared to physicochemical processes. Since the timeframe of a runoff event is not enough for these processes pollutants adsorbed or otherwise trapped are expected to be biotransformed during the inter-event duration. Transformations will be most rapid with the proper mix of water and oxygen (water tends to limit oxygen availability), substrate availability, and temperature. The rates will likely decrease during times of water saturation, periods of very dry conditions, and low. Field studies have demonstrated the benefit of increased hydraulic retention time for bioretention and permeable pavement. Hydrocarbons can be biodegraded aerobically under optimized environmental conditions.

<u>Denitrification</u> can be expected in areas of water saturation where common aerobic processes have readily consumed the available oxygen. Pockets of high organic matter content, low flow media, and high microbial levels may lead to areas in which denitrification can occur. Nitrate performance can vary greatly among stormwater control measures. Efforts have been made to engineer bioretention facilities to improve nitrate removal via denitrification; some results show some improvement when a carbon source was added, while others had no statistically significant improvement. In the experiments carried out and documented by Amir Aloni et.al.(2017.), it was found that crude cotton could serve as an effective carbon source for denitrification.

Phytobiology in stormwater control measure performance has not been firmly established or quantified. Several recent studies have demonstrated the importance of vegetation in nutrient uptake. Removal of plant-accumulated pollutants makes cutting or harvesting inevitable may promote subsurface microbiological and/or physicochemical processes within and around the rhizosphere.

Based on four sources (Xiao, Q.F et.al., 2011.; National Management Measures to Control Nonpoint Source Pollution from Urban Areas; Lensa Jotte et.al., 2017.; Macnamara J. et.al., 2017.) pollutant removal efficiency of stormwater biofilters expressed in % of the inflow concentrations are summarized in **Table 3.** An estimated total pollution decrease as a result of a potential stormwater management implemented in Debrecen is calculated with efficiency 73,8 %.

Table 3. Pollutant removal efficiency of stormwater biofilters expressed in % of the inflow concentrations; compiled from four sources of literature

Parameter	Source of data				Average
	Xiao, Q.F. et.al., 2011.	National Management Measures to Control Nonpoint Source Pollution from Urban Areas	Lensa Jotte et.al., 2017.	Macnamara J. et.al., 2017.	
TSS, suspended solids		86,00	82,50		84,25
Nitrogen	97,00		40 ÷ 70		50,67
TN		58 ÷ 94	29,50	89,00	67,63
TP		58 ÷ 94	61,10	68,50	70,40
Metals	87,00	68 ÷ 93	85 ÷ 90		84,60
Pb		81,40	76,10	91,80	83,10
Zn		79,90	71,30	85,10	78,77
Ni				88,60	88,60
Oil and grease		81,00	82,00		81.50
Microbial contaminants			90,00		90,00
BOI_5	95,00				95,00
PAH-s			85,30		85,30
total	**95,40**				**73,83**

2. MATERIALS AND METHODS

2.1. Study area

The study area is the Northern urbanized part of the town of Debrecen in Eastern Hungary. This part is the overlapping of the urbanized zone and the protected drinking water recharge area.

2.2. Data and tool description

- Digitalized form of the designated water resource protection areas provided by the local Water Authority for research purposes
- We ordered the orthophoto of the town Debrecen, taken in summer, 2005, resolution is 0,4m/px
- We downloaded the traffic density online dataset <http://internet.kozut.hu/lapok/forgalomszamlalas.aspx>
- We downloaded the precipitation data <http://www.ksh.hu/docs/hun/xstadat/xstadat_eves/i_met002c.html>
- We used the open access Open Jump software to produce the GIS

2.3. Data process method

2.3.1. Producing a GIS

Impervious surfaces have been widely recognized as an indicator for urbanization and environment monitoring. Plenty of methods have been proposed to extract impervious surfaces using remote sensing images. However accurate estimation of impervious surfaces remains challenging due to the diversity of urban land covers (Shuai Liu et.al., 2017.).

An orthophoto is an aerial photograph or image geometrically corrected such that the scale is uniform: the photo has the same lack of distortion as a map. Unlike an uncorrected aerial photograph, an orthophotograph can be used to measure true distances, because it is an accurate representation of the Earth's surface, and it is also geo-referenced (Varga Zsolt et.al., 2015.).

Orthophotographs are commonly used in Geographic Information Systems (GIS) as a "map accurate" background image. Some software can process the orthophoto and produce the linework automatically.

In order to create our own thematic Geospatial Information System (GIS), we use an open source software “Open Jump”. Image analysis processes was used for creating thematic maps with the purpose of providing primary data for the calculations carried out and also for further research and spatial analysis. Here we introduce the main steps of the process:

STEP_1_We open a new Open Jump project

STEP_2_We import the orthophoto as a new raster layer into our project

STEP_3_We create new layers for the roads of different width which can be measured directly on the orthophoto. We created 12 layers for this purpose. In each of these layers we locate vector line strings representing the roads.

STEP_4_We create a new layer for the vector polygons representing the parking lots.

STEP_5_We create a new layer for the streets with the densest traffic.

STEP_6_We carry out queries requesting surface data

Beyond data extraction the graphical presentation provided by GIS is very useful.

2.3.2. Calculating total annual pollution loads

Stormwater runoff rates and volumes increase in urban areas due to increased impervious surface areas. Urbanization also increases the number of sources, the types of constituents, and the amount of pollutants in surface runoff. Although stormwater discharges are currently perceived as one of the largest inputs of pollutants, and toxic effects are regularly measured in receiving waters, large variability and uncertainty remain associated with runoff mass emission estimates (Liesl L. et.al.). The amount of heavy metal pollution load from total traffic area is calculated by multiplying the specific loads given by Maximilian, H. et al. with the size of the area, if the runoff coefficient is 0,9:

$$\text{pollution load [kg/year]} = \text{specific load [kg/yr/m}^2\text{] / * area [m}^2\text{] * 0,9}$$

For most of the parameters we found no specific loads in the literature. In these cases we calculated runoff loads from total traffic area by multiplying the concentration data with the height of annual precipitation and with the size of the area, if the runoff coefficient is 0,9:

total pollution load [kg/year] = concentration [mg/l] / 1000* [mm] / 1000 * area [m^2] * 0,9

To assess actual concentrations and mass loads needs time and source demanding measurement program which also needs to be designed carefully. Study of Bharat 26 Maharjan (2016.) provides an opportunity to select the suitable monitoring program from the effective options such that it can be utilized to obtain coherent stormwater data.

An estimated total pollution decrease as a result of a potential stormwater management implemented in Debrecen is calculated with efficiency 73,8 %. The total expected pollution load is multiplied with the expected efficiency taken from the literature

total pollution decrease [kg/year] = total pollution load [kg/year] * 73,8 % /100

An estimated decreased total pollution as a result of a potential stormwater management implemented in Debrecen is calculated with efficiency 73,8 %.

decreased total pollution [kg/year] = total pollution load [kg/year] *(100-73,8)% /100

3. RESULTS

The size of the protected drinking water recharge area (PA) is 194,12 km^2 (**Fig. 1.**)

The size of the urbanized area of Debrecen (UA) is 49,64 km^2 (**Fig. 1.**)

The size of the intersection of the protected drinking water recharge area and the urbanized area of Debrecen (UA ∩ PA) is 34,64 km^2 (**Fig. 1.**)

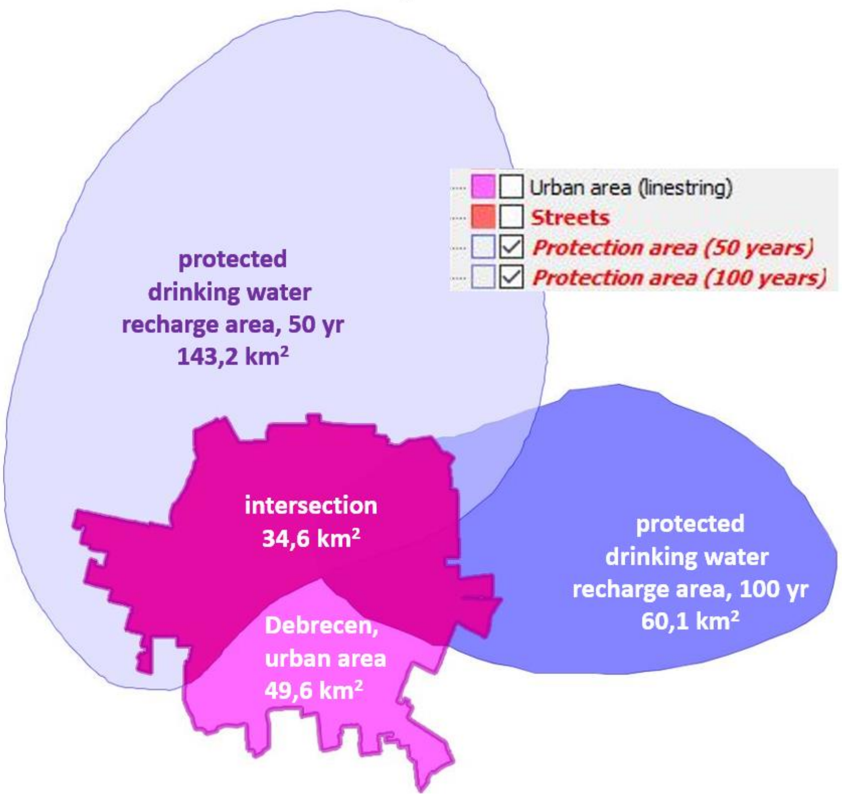

Figure 1. An image from the GIS representing the size of the protected drinking water recharge area, the urbanized area of Debrecen and the size of the overlapping which is the study area; Source: authors

The size of the impervious urban traffic area within the intersection of the protected drinking water recharge area and the urbanized area of Debrecen is 2,36 km^2 = 235,85 ha. This area involves areas like parking lots of significant size which are supposed to be used for traffic purposes. Nonpoint pollution from vehicle traffic runs off from this area, represented by (**Fig. 2.**). The whole area is tipified into 14 groups 12 of which are roads of different width, one is for traffic areas of significant area and one for unpaved roads. It is assumed that in the near future these will be paved, too. We suppose this does not decrease the accuracy of the size of the whole study area since driveways, for instance, are not taken involved.

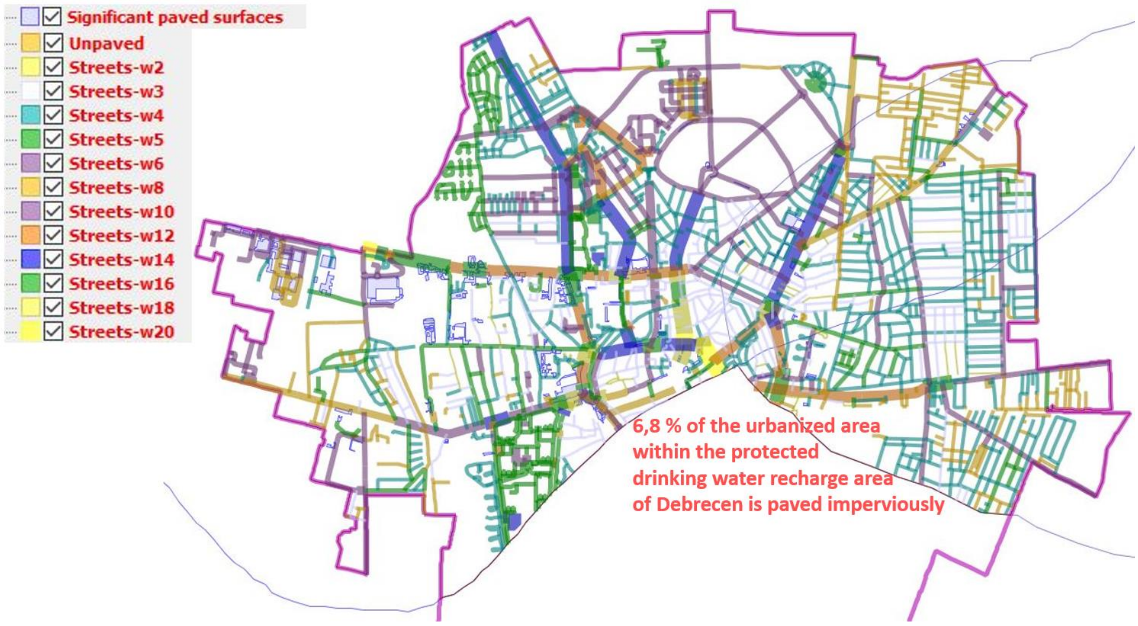

Figure 2. 6,8 % (2,36 km^2) of the urbanized area within the protected drinking water recharge area of Debrecen is traffic related area paved imperviously

Utilizing the average pollution load introduced in the introduction we calculate the annual pollution load that may contaminate the recipient environmental elements. The amount of heavy metal pollution load from the investigated 235,85 ha of traffic area is 598 kg annually **Table 4**, multiplying the specific loads given by Maximilian, H. et al. with the size of the area, if the runoff coefficient is 0,9:

$$\text{pollution load [kg/year]} = \text{specific load [kg/yr/m}^2\text{]} / * \text{area [m}^2\text{]} * 0{,}9$$

Table 4. Expected total annual mass of heavy metal pollutants on the investigated traffic area of Debrecen in kg, calculated from specific loads given in the introduced literature (Maximilian, H. et al., 2016.)

Cd	Cr	Cu	Ni	Pb	Zn	Total
1,6	17,7	83,7	15,6	3,3	475,9	597,8

The quality of runoff from the local road network depends on traffic density. Stormwater management options for the local road network needs to be integrated into the overall catchment planning and management (land use planning, residential design, drainage design, etc.) as part of water sensitive urban design (Tony Wong et.al.,2000.). Although we have not found results regarding correlation between road traffic density and runoff pollution, we have collected data for traffic density and represented the most heavily loaded roads on one of the layers in the GIS (**Fig. 3.**).

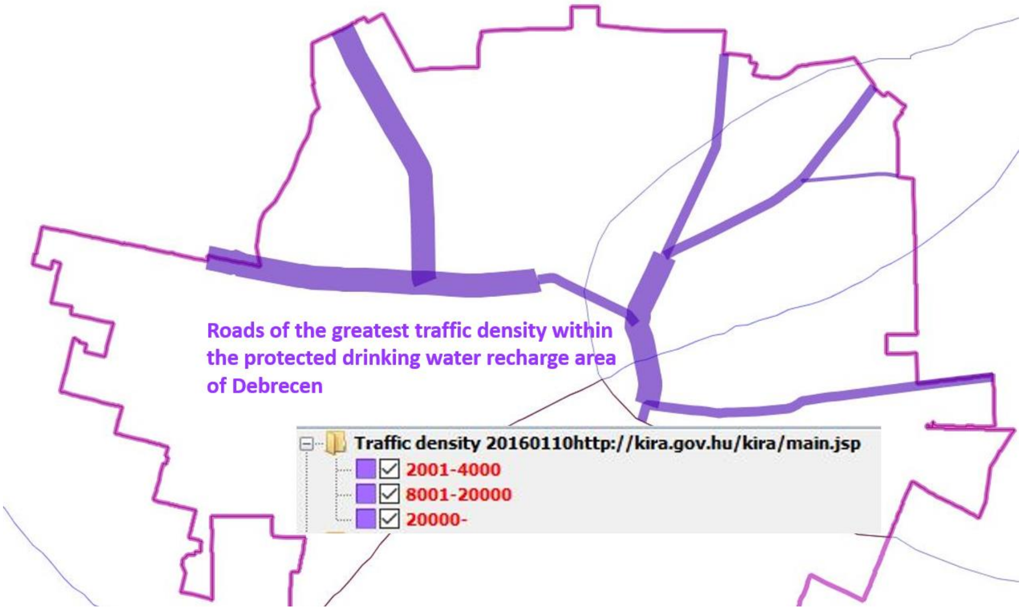

Figure 3. Roads of the greatest traffic density within the protected drinking water recharge area of Debrecen; Source: authors

For most of the parameters we found no specific loads were found in the literature, we calculated runoff loads from total traffic areas for the study area by multiplying the concentrations with the height of precipitation and the size of the area, if the runoff coefficient is 0,9:

pollution load[kg/year] = concentration[mg/l] / 1000* 540 [mm] / 1000 * 2 358 503 [m^2] * 0,9

Concentration values taken from sources Lensa, J. et.al, 2017., Göbel. Et.al. and Urban Storm Water Preliminary Data Summary, EPA are summarized in **Table 5.**

Table 5. Expected total annual mass of pollutants on the investigated area calculated from concentrations taken from sources Lensa, J. et.al, 2017., Göbel. Et.al. and Urban Storm Water Preliminary Data Summary, EPA

Parameter Concentration	Concentration average	Load [kg/yr]
TSS, suspended solids	505,50	579 420,51
TN	9,40	10 774,59
TP	0,29	326,68
Cl	336,45	385 649,91
TPH	3,65	4 183,75
COD	104,50	119 781,29
PAH-s	8,67	9937,84
oil and grease	1,60	1833,97
microbial contaminants	215,90	-
Total Mass of Annual Pollutant Load		1 111 908,5

The total annual mass of all the relevant pollutants:

1 111 908,5 + 597,8=1 112 506,3 kg = 1112,5 ton

Total annual pollution decrease = 1 112 506,3 kg * 73,8 % /100 = 821 030 kg = 821 ton

The decreased total annual pollution = 1 112 506,3 kg *(100-73,8)% /100 = 291 476 kg = 291 ton

The portion of urbanized area within the protected drinking water recharge area and the protected drinking water recharge area in per cent is

34,64/194,12 = 0,18 = 18 %.

It means that 18 % of the protected drinking water recharge area is urbanized.

The portion of urbanized area within the protected drinking water recharge area and the whole urbanized area of Debrecen in per cent is

34,64/49,64 = 0,7 = 70 %.

It means that 70% of the urbanized area is protected recharge area at the same time.

The portion of impervious urban traffic area within drinking water protected recharge area in per cent is 2,36/194,12 = 0,012 = 1,2 %.

It means that 1,2 % of the investigated area is affected by traffic.

The portion of impervious urban traffic area and the intersection of protected drinking water recharge area and urbanized area (UA ∩PA) in per cent is

2,36/34,64 = 0,07 = 6,8 %.

It means that 6,8 % of the urbanized area within the protected drinking water recharge area is paved impermeably for vehicle traffic purposes.

4. DISCUSSION AND CONCLUSIONS

Due to the impervious feature, these surfaces heavily affect the urban hydrological and energy balances. Accurately extracting the extent and spatial distribution of impervious surfaces is crucial not only for urban water management but heat island effect analysis and other environmental investigations. The whole impervious surface involves the area of the buildings. Since this area is not significant from the aspect of pollution we have not determined this area this time. However, it will be considered in further research as a source of rechargeable water resource.

The accuracy of determining the size of the impervious surfaces with the method used in our study is not known but it can be determined in a further study. However, we suggest that for the purpose of this study the accuracy is sufficient.

Selected concentration data show great variability due to the many factors influencing pollution concentration during a specific rain event. When estimating the annual pollution load of an area we get a more reliable value if we use mean load values developed from many measurements compared to event specific concentration data. However, neither of these estimations is efficient for concrete designing purposes. Several studies prove that preliminary research taking several specific features into account is needed for every town for designing purposes.

The accuracy of this study could be improved by taking the type and efficiency of drainage sewer in the streets into consideration because only the runoff water which is not conveyed by sewers towards the wastewater treatment plant or into the receiver watercourse, is a potential pollution source of the drinking water resources.

Also, we would like to emphasize that although street sweeping is not a water quality control measure we need to consider this as a seemingly effective prevention of runoff pollution. The study area is a sensitive area, therefore, for precautionary reasons we suggest that all the road pavement surface water runoff should be collected via sealed drainage systems and conveyed to a receiving surface water body after treatment by an engineered bioretention system to provide treatment for the runoff.

In urban areas beyond the study area the road pavement surface water runoff should be treated and reused on-site by engineered bioretention and infiltration system since in most scenarios involving urban stormwater runoff, applying decentralized, small-scale capture devices is more cost-effective than centralized strategies.

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