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CONTENTS

COMPARISON OF MESOPHILIC AND HYPER-MESOPHILIC REGIME FOR SYNGAS BIOMETHANATION IN TRICKLE BED-REACTOR

Dominik Andreides[1*]

Dana Pokorná[1]

Jana Zábranská[1]

[1] Department of Water Technology and Environmental Engineering, University of Chemistry and Technology Prague, Technicka 1905, 166 28 Prague, Czech Republic, *e-mail: dominik.andreides@vscht.cz

[2] Department of Water Technology and Environmental Engineering, University of Chemistry and Technology Prague, Technicka 1905, 166 28 Prague, Czech Republic

[3] Department of Water Technology and Environmental Engineering, University of Chemistry and Technology Prague, Technicka 1905, 166 28 Prague, Czech Republic

ABSTRACT

Syngas contains H_2, CO, and CO_2 at a different ratio. These gaseous components can be biologically converted to CH_4 via an anaerobic consortium. In this paper, a trickle-bed reactor with a biofilm culture was operated to compare the syngas biomethanation under mesophilic (35°C) and hyper-mesophilic (45°C) regimes. The artificial syngas (45% H_2, 25% CO_2, 30% CO) was continuously injected into the reactor. Findings revealed that achieved syngas conversion efficiency was 80% and 95% under the mesophilic and hyper-mesophilic regime, respectively. Furthermore, higher CH_4 production of 7% was observed under the hyper-mesophilic regime.

Keywords: anaerobic digestion; biofilm; syngas; trickle-bed reactor

INTRODUCTION

Synthetic gas, or syngas, contains mainly hydrogen (H_2), carbon monoxide (CO) and carbon dioxide (CO_2) at a different abundance, and it is produced by thermochemical processes such as pyrolysis or gasification of lignocellulosic waste biomass [1]. Syngas can be converted to methane (CH_4) by catalytic methanation (i.e. the Sabatier process). However, this method requires extreme operating conditions and the presence of catalysts prone to poisoning. Therefore, using the biological conversion of syngas to CH_4 by carboxydotrophic methanogens, which are commonly present in mixed anaerobic culture, is proposed in this work. Compared to catalytic methanation, syngas biomethanization offers sufficient robustness, lower investment costs and the absence of sensitive catalysts [2].

The main limiting parameters for sufficient syngas biomethanation are temperature and gas-liquid mass transfer [3, 4]. Syngas in the anaerobic digestion process can be utilized directly or indirectly by a syntrophic relationship between several microbial groups, which are commonly present in the mixed-anaerobic culture. The direct biological conversion of syngas to CH_4 is mediated by carboxydotrophic methanogens (Eq. 1) and hydrogenotrophic methanogens (Eq. 2) [5].

$$4\,CO + 2\,H_2O \rightarrow CH_4 + 3\,CO_2 \tag{1}$$

$$4\,H_2 + CO_2 \rightarrow CH_4 + 2\,H_2O \tag{2}$$

The indirect metabolic pathway consists of intermediate products such as acetic acid (Eq. 3) and H_2 (Eq. 4). These intermediate products are subsequently utilized in the final step of methanogenesis [6]. The preference of intermediate products production is dependent mainly on the temperature regime of the reactor. Specifically, acetic acid and H_2 are the primary methanogenesis precursors at mesophilic (35 °C) and thermophilic conditions (55 °C), respectively (Guiot et al., 2011; Sipma et al., 2003).

$$4\,CO + 2\,H_2O \rightarrow CH_3COOH + 2\,CO_2 \tag{3}$$

$$CO + \,H_2O \rightarrow CO_2 + H_2 \tag{4}$$

Compared to mesophilic conditions, the superiority of the thermophilic regime for higher CH_4 production was confirmed in numerous studies [3, 5, 7]. However, the knowledge gap for syngas biomethanation under the hyper-mesophilic regime (45 °C) is still present.

High-tech distribution devices (e.g. membrane modules, Venturi-type injection systems) were tested in numerous studies to improve the gas-liquid mass transfer of syngas (or CO) [8, 9]. Nonetheless, the implementation of these diffusers for further scale-up will be reflected in the technology's higher investment and operational costs.

In the context of the above, the aim of this study is to compare the efficiency of syngas biomethanation under mesophilic and hyper-mesophilic conditions in a trickle-bed reactor (TBR). Furthermore, the novelty of this work is the absence of a gas distribution device in the reactor to eliminate biofouling problems that could occur in the further scale-up.

MATERIALS AND METHODS

INOCULUM AND ANALYTICAL METHODS

The inoculum was sourced from a mesophilic biogas plant processing waste biomass as maize, grass and manure. The inoculum had TS 18 ± 0.8 g/L, VSS 10 ± 0.6 g/L and N-NH_4^+ 0.4 ± 0.1 g/L. As a growth medium to supplement the macro- and micro-nutrients for biomass growth, the digestate was supplied in TBR at a hydraulic retention time of 5 days.

pH value was measured continuously in TBR using the pH probe (Hamilton, Switzerland). The VFA concentrations (acetate, propionate, butyrate, valerate and caproic acid) in the collected samples were analyzed by a gas chromatograph equipped with a flame ionization detector. A biogas composition (H_2, CO, CO_2, CH_4, and air content) was determined by a gas chromatograph equipped with a thermal conductivity detector. A detailed description of VFA and biogas samples preparation, sampling and gas chromatographs configurations can be found in our previous study, respectively [10].

EXPERIMENTAL SET-UP

TBR with a total volume of 4.5 L was inoculated for 30 days using 2.5 L of inoculum. During the inoculation phase, the external addition of syngas (of 45% H_2, 25% CO_2 and 30% CO) at the syngas loading rate of 0.2 L/L/day was continuously applied in TBR. This phase has not been evaluated. TBR was maintained in mesophilic conditions (35 ± 1 °C), and in the later phase of the experiment, the mesophilic regime was switched to hyper-mesophilic conditions (45 ± 1 °C).

TBR was packed with carriers (AL-FK30L, AQUALOOP) with a specific surface area of 320 $m^2/m^{3,}$ and the packed bed was not submerged in a liquid reservoir. On the bottom of the reactor, a liquid reservoir of 0.8 L was present. The liquid medium was continuously recirculated using a centrifugal mag-drive pump and distributed over the top of the bed by a spray nozzle. The syngas mixture of 45% H_2, 25% CO_2 and 30% CO was continuously injected into TBR. The syngas loading rate was 3 L/L/day. The syngas was dosed through a mass flow controller (Bronkhorst, Netherlands). The syngas entered the TBR at the lower part (no distribution device used), and it passed in up-flow mode through the packed bed, where the syngas was thoroughly mixed with a counter-current falling liquid medium (Fig. 1). The produced gas, containing CH_4, was continuously measured using a gas counter (Ritter, Germany).

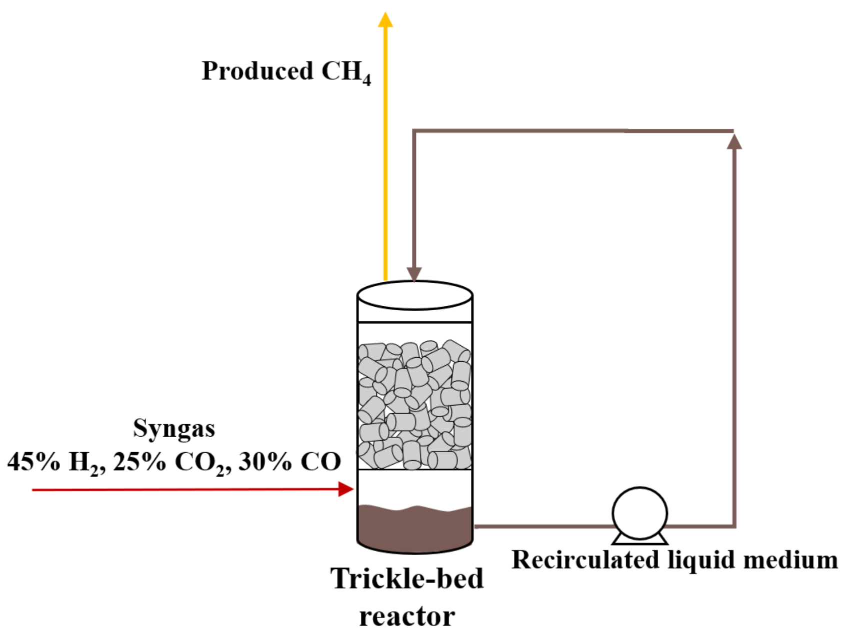

Figure I: The simplified scheme of the trickled-bed reactor for syngas biomethanation.

RESULTS AND DISCUSSION

The performance of different temperature regimes in TBR was evaluated according to the headspace composition, syngas conversion efficiency and the volumetric CH_4 production. At the start of the experiment, no lag-phase was observed, and the anaerobic mixed culture was adapted very rapidly on the gaseous substrate. After 5 days of the experiment, the H_2 and CO conversion efficiency exceeded 80% and 75%, respectively (Fig 2). On average, the conversion efficiency of H_2 and CO during the mesophilic conditions was 90% and 77%, respectively.

After the temperature switch from mesophilic conditions to the hyper-mesophilic regime, lower conversion efficiencies occurred. However, rapid biomass stabilization was observed since TBR reached maximum conversion efficiencies within 5 days. Generally, the hyper-mesophilic regime provided higher conversion efficiencies than the mesophilic conditions since the average conversion efficiency of H_2 and CO exceeded 95%. Moreover, the volumetric CH_4 production increment by 7% was observed compared to the mesophilic conditions.

Since the CO_2 was provided in a stoichiometric excess (Eq. 1 – 4), the consumption of H_2 and CO resulted in the production of CO_2, which exceeded the CH_4 concentration in the produced gas [3]. However, the produced gas can be upgraded to pure CH_4 through an external supplement of reducing equivalents (H_2) [10].

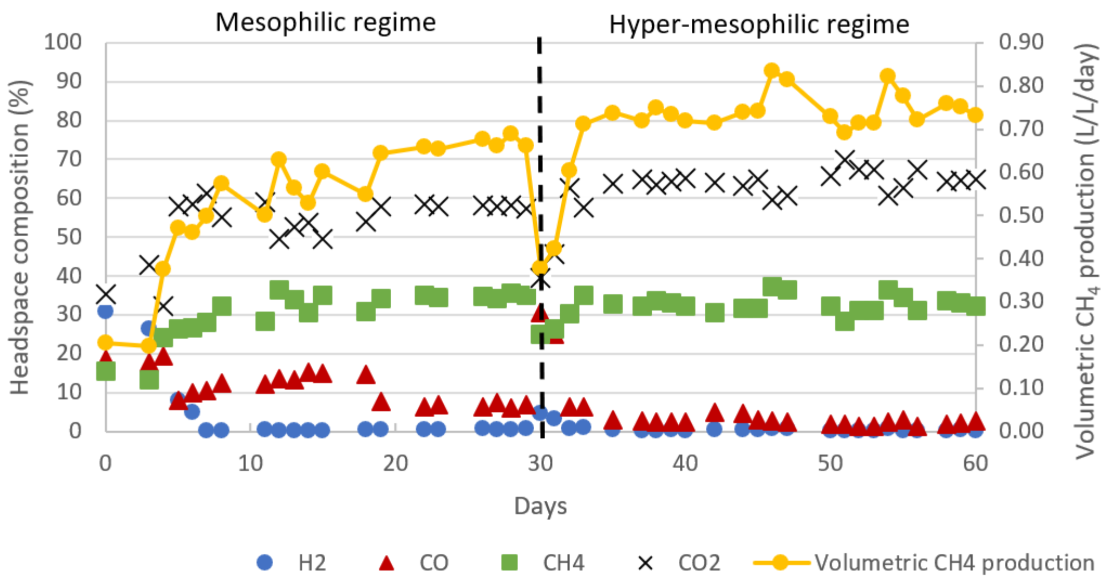

Figure II: The headspace composition and volumetric CH_4 production according to the temperature regime.

CONCLUSION

The hyper-mesophilic conditions can enhance the syngas biomethanation in TBR. The biofilm culture provided robustness since the switch between the mesophilic and hyper-mesophilic was successful without significant lag-phase. Moreover, hyper-mesophilic conditions achieved higher volumetric CH_4 production over 7 % compared to the mesophilic regime. Generally, under hyper-mesophilic conditions, higher conversion efficiencies of CO and H_2 were observed. In further research, there is a need to be addressed the comparison between hyper-mesophilic and thermophilic conditions.

ACKNOWLEDGEMENTS

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MEMBRANE PROCESSES IN WATER TREATMENT

Raghad Awad[1]

Danka Barloková[2]

Ján Ilavský[3]

[1] Department of Sanitary and Environmental Engineering, Faculty of Civil Engineering, Slovak University of Technology in Bratislava, Radlinského 11, 810 05 Bratislava, Slovakia, e-mail: xawad@stuba.sk

[2] Department of Sanitary and Environmental Engineering, Faculty of Civil Engineering, Slovak University of Technology in Bratislava, Radlinského 11, 810 05 Bratislava, Slovakia, e-mail: danka.barkolokva@stuba.sk

[3] Department of Sanitary and Environmental Engineering, Faculty of Civil Engineering, Slovak University of Technology in Bratislava, Radlinského 11, 810 05 Bratislava, Slovakia, e-mail: jan.ilavsky@stuba.sk

ABSTRACT

This scientific paper deals with advanced water treatment rather than conventional water treatment processes. The use of conventional water treatment processes becomes increasingly challenged with the identification of more contaminants, rapid growth of population and industrial activities, and diminishing availability of water resources. The emerging treatment technology featuring membrane processes provide alternatives for better protection of public health and environment. The emphasis was placed on the basic principles, main applications, and new developments. It can be concluded that, along with the growing knowledge and the advances in manufacturing industry, the application of this technology will be increased at an unprecedent scale.

Keywords: conventional water treatment processes, membrane technology, water treatment

INTRODUCTION

Many countries around the world, especially in developing countries, lack access to clean filtrated potable water. The problem of water shortage and water treatment filtration in several areas is not only a problem of proper techniques, but also a social and education problem depending on national and international efforts as well as on technical solutions. The facts are glaring, around 2.1 billion people living without safe drinking water at home and nearly four billion people experience sever water scarcity during at least one month of the year. [1] In this vein several efforts have been to continuously improve the water treatment strategy being used. Advanced water treatment strategy which features membrane process are more efficient in use to provide treatment to a higher level than conventional treatment. This paper deals with membrane processes used in obtaining quality potable drinking water and their basic characteristics and their efficiency in comparison to conventional treatment methods. There is a continuous modification of membrane modules, and membrane elements to enhance the reduction in membrane fouling, which is a major challenge for membrane processes. The paper also discusses the prospects of membrane technology.

MEMBRANE FILTRATION

Membrane processes are modern physicochemical separation techniques that use differences in permeability (of water constituents) as a separation mechanism. During membrane treatment, water is pumped against the surface of a membrane, resulting in the production of product and waste streams, as shown on Figure I. The membrane, typically a synthetic material less than 1 mm thick, is semipermeable, meaning that it is highly permeable to some components in the feed stream and less permeable (or impermeable) to others. During operation, permeable components pass through the membrane and impermeable components are retained on the feed side. As a result, the product stream is relatively free of impermeable constituents and the waste stream is concentrated in impermeable constituents. [2]

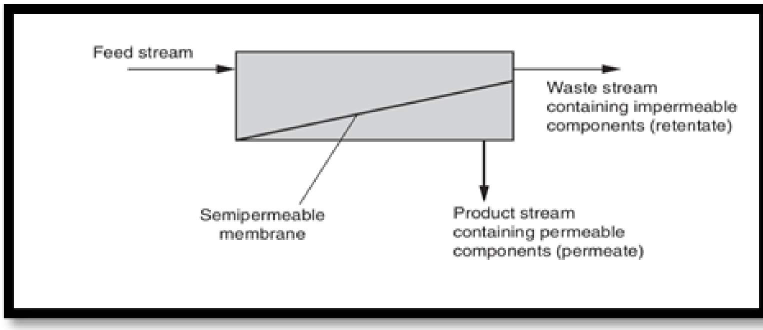

Figure I: schematic of separation process through semi permeable membrane.

There are four types of membrane processes, which are commonly used in water treatment: -Microfiltration (MF) -Ultrafiltration (UF) -Nanofiltration (NF) -Reverse osmosis (RO)

All four technologies rely on membrane transport, the passage of solutes or solvents through thin, porous, polymeric membranes. They are currently used in municipal water treatment. A membrane is defined as an intervening phase separating two phases forming an Active or passive barrier to the transport of matter. Membrane processes can be operated in various process configuration: 1) Dead-end Filtration; and 2) Cross -flow filtration as presented in Figure II below. Dead-end filtration refers to filtration at one end. A problem with these systems is frequent membrane clogging. Cross flow filtration overcomes the problem of membrane clogging and is widely used in water treatment. Both flow configurations offer some advantages and disadvantages. The dead-end membranes are relatively less costly to manufacture and the process is easy to implement. The main disadvantage of a dead-end filtration is the extensive membrane fouling and concentration polarization, which requires periodic interruption of the process to clean or substitute the filter. [3] The tangential flow devices are less susceptible to fouling due to the sweeping effects and high shear rates of the passing flow.

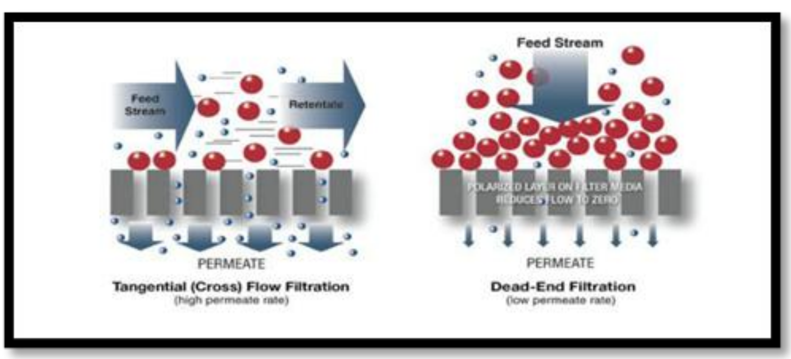

Figure II: Membrane flow configurations Left: Cross flow filtrations; Right: Dead-end filtration

Water that passes through the membrane is called permeate and the fraction that does not pass through the membrane is called the “retentate” or the “concentrate as illustrated in the Figure III below. Membranes occupy through a selective separation wall. Certain substances can pass through the membrane, while other substances are caught. Membrane filtration can be used as an alternative for ¸flocculation, sedimentation techniques, filtration and adsorption (instead of sand filters and active carbon filters, ion Exchangers). When membrane filtration is used for the removal of larger particles, microfiltration and ultrafiltration are applied. Because of the open character of the membranes the productivity is high, while the pressure differences are low. When salts need to be removed from water, nanofiltration and reverse osmosis are applied. The pressure that is required for nanofiltration and reverse osmosis is much higher than the pressure required for micro and ultrafiltration, while productivity is much lower.

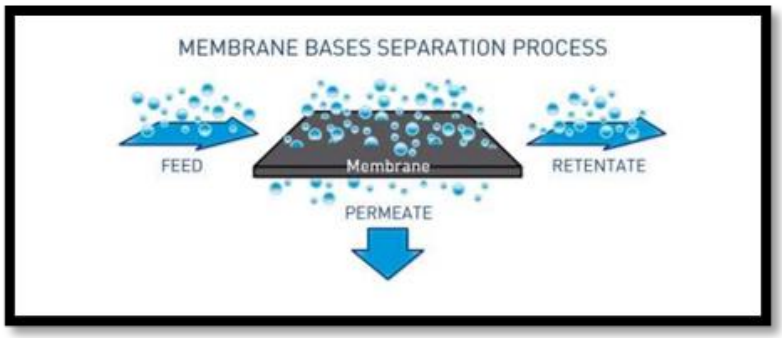

Figure III: Membrane bases separation process

MEMBRANE PROCESSES:

MICROFILTRATION (MF):

Microfiltration is a pure straining process; removing particles in the size range 0.1– 100 mm without affecting the soluble materials in the water being treated. Microfiltration has a larger pore size than ultrafiltration. Microfiltration (MF) lies on the upper end of the spectrum of pressure-driven membrane techniques, with membranes containing the largest pore size of the aforementioned processes. It is often used as a precursor step to downstream filtration applications in order to achieve the desired degree of separation within a given feed stream. Due to the larger pore size of MF membranes, many of these processes are capable of being run at lower pressures than those with membranes containing smaller pores. Common MF applications involve the separation of large macromolecules in clarification steps, such as in the removal of bacteria from cellular broths and in fat removal processes in the dairy industry. More porous membrane is used than in the other membrane separation technologies, thus yielding a relatively higher flux. [4]

ULTRAFILTRATION (UF):

Ultrafiltration is a filtration process using very fine pores such that as well as all suspended matter, large organic molecules are removed, with the cut-off point dependent on the characteristics of the membrane. [5] The process also removes all micro-organisms which will only be removed by membranes with a small pore size. This method uses a lower pressure differential than reverse osmosis and doesn't rely on overcoming osmotic effects. It is often a cross-flow filtration process. Ultrafiltration is not any different from reverse osmosis, microfiltration or nanofiltration except in terms of the size of molecules and they operate at far lower pressures than RO membranes typically between 2 and 5 bar. It is useful for dilute solutions of large, polymerized macromolecules where the separation is roughly proportional to the pore size in the membrane selected. Ultrafiltration membranes are commercially manufactured in hollow, capillary, and tubular forms. This technology is useful for the recovery and recycle of suspended solids and macromolecules. The largest industrial use of ultrafiltration is the recovery of paint from water-soluble coat bases (primers) applied by the wet electrodeposition process (electrocoating) in auto and appliance factories. Many installations of this type are operating around the world. The recovery of proteins in cheese whey (a waste from cheese processing) for dairy applications is the second largest application, where a market for protein can be found (for example, feeding cattle and farm animals). Water and some dissolved low molecular weight materials pass through the membrane under an applied hydrostatic pressure. Emulsified oil droplets and suspended particles are retained, concentrated, and removed continuously as a fluid concentrate.

NANOFILTRATION (NF):

In contrast to MF and UF, in which solutes are separated according to size, both size and charge play a role in nanofiltration (NF) separation processes. With a pore size between 0.1-10 nm, NF membranes are capable of retaining low molecular weight, uncharged solutes, such as sugars and other organic molecules. It has developed as improvements in membrane materials have allowed membranes to be optimized for removal of larger molecules and ions. It operates at lower pressures, partly because the membranes let through most monovalent ions, leading to lower osmotic pressure, and mainly because the membranes themselves are more permeable, with a much lower head loss. Nanofiltration is not used for the production of drinking water from brackish water or seawater but is used to soften water and for nitrate removal. It can also be used to treat waters to remove organic matter that would react with chlorine to form trihalomethanes (THMs) and for colour removal. [6] Applications for NF membranes range from the removal of natural organic matter in wastewater treatment, hardness reduction in water purification, and demineralization in dairy processing. Nanofiltration is better suited than Reverse osmosis and ultrafiltration for treating wastewater streams, e.g., removing heavy metals, and separating dyes and colour compounds in the textile industry.

REVERSE OSMOSIS (RO):

Reverse osmosis (RO) membranes contain the smallest pores of the pressure-driven membrane processes and are capable of retaining all dissolved particles within a feed stream, including monovalent ions. This degree of separation results in a permeate consisting of a pure solvent, which, in many cases, is water. The necessity of overcoming the osmotic pressure, in addition to the extremely narrow pore size found in RO membranes, results in RO processes requiring higher pressures than those previously mentioned. The most common applications for RO are in the preparation of drinking water and beverage concentration. The effective driving force responsible for the flow is osmotic pressure. Reverse osmosis is a means for separating dissolved solids from water molecules in aqueous solutions as a result of the membranes being composed of special polymers which allow water molecules to pass through while holding back most other types of molecules; In an actual reverse osmosis system, operating in a continuous-flow process, feed water to be treated or desalinated is circulated through an input passage of the cell, separated from the output product water passageway by the membrane. RO uses a semi-permeable membrane. As such, the membrane is permeable to only very light molecules like water. Under atmospheric conditions the fresh water flows into the solution which is called osmotic flow. But for purification purposes, this is no use, and hence we employ the reverse of osmotic flow. [7] For this to happen, we need to apply external pressure in excess of osmotic pressure. The osmotic pressure is given by:

$$\Delta p = nRT \quad (1)$$

One if familiar with this equation (the Ideal Gas Law), where 'n' is the molar concentration of solute, R is the universal gas law constant, and T is absolute temperature in K. The permeate flow can be calculated from:

$$J_W = A_m(\Delta P - \Delta p) \quad (2)$$

A_m is the membrane permeability coefficient

Table I shows the comparison of membrane processes by showing the size of materials retained, driving force, and type of membrane for various membrane separation processes.

Table I: Comparison of membrane processes

Process	Minimum particle size removed	Applied pressure	Type of membrane
Microfiltration	0.025 - 10 µm microparticles	(0.1 - 5 bar)	Porous
Ultrafiltration	5 - 100 nm macromolecules	(0.5 - 9 bar)	Porous
Nanofiltration	0.5 - 5 nm molecules	(4 - 20 bar)	Porous
Reverse Osmosis	< 1 nm salts	(20 - 80 bar)	Nonporous

MEMBRANE MATERIALS

Membranes can be made from a large number of materials. The material is selected based on processing requirements, thermal and chemical stability and fouling tendency, cost, ease of fabrication and resistance to environmental factors such as pH, temperature and pressure. Membrane performance is affected strongly by the physical and chemical properties of the material. The ideal membrane material is one that can produce a high flux without clogging or fouling and is physically durable, chemically stable, nonbiodegradable, chemically resistant, and inexpensive. The most common material is polymeric with an asymmetric (anisotropic) or symmetric (microporous) structure. Asymmetric membranes are used in RO, NF and UF, whereas MF membranes are either anisotropic or symmetric membrane consists of a very dense skin supported by a porous sublayer of thickness 50- 150 mm. Inorganic membranes, introduced in the 1980s, are confined to UF and MF. Each method produces a different membrane morphology in terms of porosity, pore size distribution and ultrastructure. [8]

MEMBRANE MODULES

Membrane module is the way the membrane is arranged into devices and hardware to separate the feed stream into permeate and retentate streams. The requirements on the module separate the feed stream into permeate and retentate streams. The requirements on the module are large surface of the membrane on the unit volume of the Module, cheap production, simple access during the treatment and easy to exchange of the membrane. Membrane module design is usually correlated to the efficiency of membrane fouling prevention. In general, membrane fouling occurs by the deposition and accumulation of undesirable materials (i.e., organic compound, inorganic compound, or a combination of both) on membrane surfaces. Current membrane modules consist of up to 20,000 hollow fiber held together with either an epoxy or urethane resin. Membrane modules designs are available in five basic designs, hollow fiber, spiral wound, tubular, plate and frame and capillary as presented in Figure IV. Due to the particular operating requirements of individual membrane separations and the applications to which they are put, the choice of module design is limited. This situation has arisen because of a variety of design requirements such as the need for easy cleaning, high packing densities, cost effective operation and membrane replacement. Also, in design, liquid based separations factors such as frictional losses, hydrodynamic properties and material properties impose different design requirements compared to gas or vapor-based separations. [9]

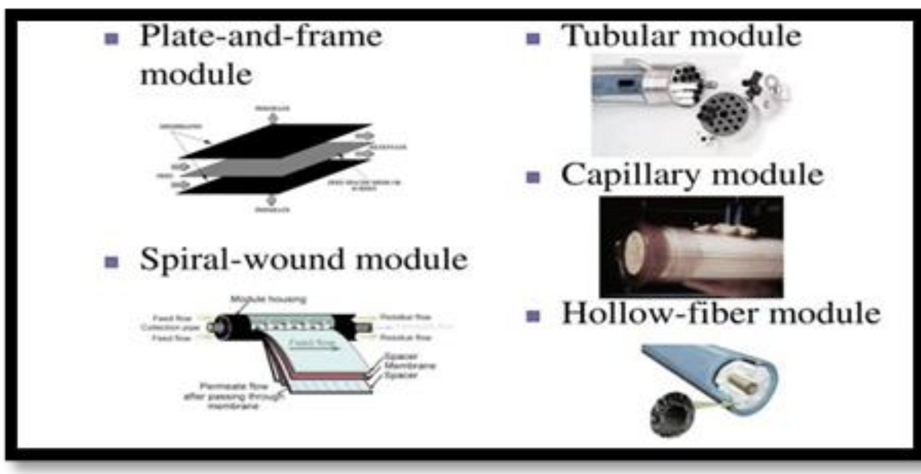

Figure IV: Basic designs of Membrane Modules

MEMBRANE FOULING

Membrane fouling is a phenomenon where suspended or dissolved substances from the liquid phase deposit onto a membrane surface and/or into membrane pores in a way that degrades the membrane's performance. Membrane fouling is influenced by three major factors: the membrane material properties (e.g., hydrophilicity, roughness, and electrical charge), the feed solution characteristics (e.g., the nature and concentration of the foulant) and the operating conditions. The interactions between the membrane and the foulants determine the degree of fouling. Fouling can be divided into reversible and irreversible fouling based on the attachment strength of particles to the membrane surface. Reversible fouling can be removed by a strong shear force of backwashing or by lowering driving pressure on the surface. Formation of a strong matrix of fouling layer with the solute during a continuous filtration process will result in reversible fouling being transformed into an irreversible fouling layer which cannot be removed by physical cleaning. Even though membrane fouling is an inevitable phenomenon during membrane filtration, it can be minimized by strategies such as appropriate membrane selection, choice of operating conditions and cleaning.

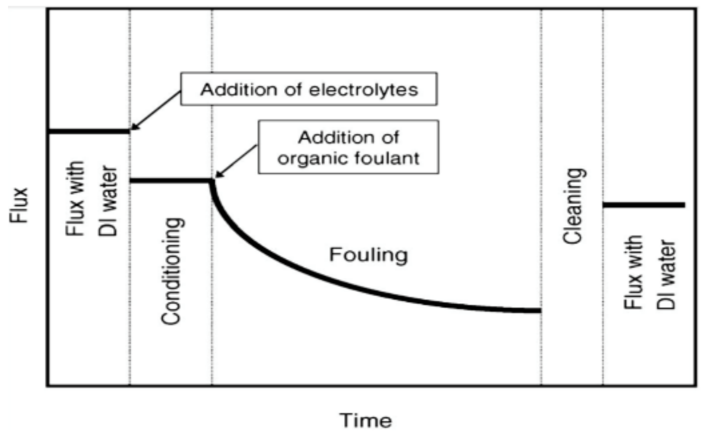

Figure V: Fouling and cleaning of RO membrane

MEMBRANE CLEANING

All membranes will eventually foul either from organic or inorganic foulants. How often depends on many factors, including the application, the water source, how well the pre-treatment protects the membranes and the operational parameters that the system is operated under. However, cleaning is one of the areas where you can slow down the fouling process and thereby prolong the lifetime and efficiency of your membranes. Depending on the above factors, membranes need cleaning anywhere between every week and once or twice a year. Membrane cleaning is required to remove scalants/foulants and restore flux and rejection. Chemical cleaning is applied almost universally since it is applicable to cleaning all module designs. Cleaning is mostly done with acid, caustic, or enzyme solutions. Chemical cleaning is based on chemical reactions hydrolysis, saponification, solubilisation, dispersion, chelation and/or peptization to break down bonds and cohesion forces between the membrane surface and the foulants. Acids are used first to remove precipitated salts or mineral scale. Alkalis are used for removing organics and proteins; they act by solubilising them. Polyphosphates are added to help solubilise carbonates and emulsify fats. Typically, MF membranes need to be cleaned most frequently and RO membranes least frequently because the former is susceptible to pore plugging while the latter uses pretreated water. [10]

BACKWASHING

Backwashing of a membrane refers to the reversal of flow through a membrane system in comparison to the normal flow direction required for permeate production. The purpose of backwashing is to assist with removing or loosening foulants from the membrane surface and within the membrane pores to control membrane fouling. It is a fundamental membrane operational step to control the rate of transmembrane pressure increase over time. Backwashing is utilized with low pressure membrane systems, i.e., microfiltration and ultrafiltration, while high pressure membrane systems, i.e., nanofiltration and reverse osmosis, do not employ backwashing to control fouling. Backwashing is most commonly initiated on a timed cycle; usually it occurs automatically at timed intervals ranging from 30 to 90 min. The increase in transmembrane pressure during the filtration cycle is typically 0.01 to 0.07 bar. The engineer must consider the time requirements to complete one backwash cycle and ensure that there is sufficient time for all units to be washed within the allowable time between backwashes, including a factor of safety. If sufficient time is not available, more than one backwash system may be necessary. [11]

GBELY WATER TREATMENT PLANT

Membrane process used in the Gbely water treatment plant featuring Ultrafiltration has been in operation since 2013. Water is at first treated in WTP Kúty (conventional filtration) then is transported to Senica Group Water Supply system. In the Gbely water treatment plant iron is removed, which enters the water during transport through a senica group water supply system from the pipeline. The capacity of WTP is about 8 l/s. The membranes material is made of polyethylene sulphate. The membranes at the WTP were primarily designed to last for about 6-7 years but due to efficiency of the material it lasted more than the indicated duration which is about 10 years. The backwashing happens there 20 times. Backwashing occurs automatically at timed intervals ranging from 30 to 90 min. The backwash cycle lasts 1 to 3 min, and the sequence is run entirely by the control system. All modules in a rack are backwashed simultaneously. Chemical cleaning takes place once a year. After backwashing the unclean water is later then neutralized with PH from 6-8 and clean water is added there to help in neutralization then it is thrown into the sewage system to not cause any harm. Water is disinfected with sodium hypochlorite.

Figure VI: Membrane modules taking place after the mechanical filtration

CONCLUSION

It can be concluded that, along with the growing knowledge and the advances in manufacturing industry, the application of this membrane technology without any doubt will be increased at an unprecedent scale. Some of the advantages we meet such as the simple operation, high and efficient performance and the usage of less space than conventional treatment systems. Some of the slight disadvantages that we meet are Membrane fouling, production of Polluted water from backwashing, and the constant replacement of membranes on a regular basis. However; with the abundant advantages and the efficient usage of membrane process in water treatment plants and the usage of this technology in several applications makes it highly compatible and commercially attractive. The selection of an appropriate method strongly relies on the compatibility of membrane materials with the durability of the membrane materials for modifications that might involve harsh conditions, cost-effectiveness, the purpose of separation, and the types of operation as well as the practicability for large-scale operations. It is anticipated that with advances in the field of membrane development and system optimization, high-performance membrane technology will continue to flourish in various separation processes, particularly on a large commercial scale. [14]

ACKNOWLEDGMENT

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RESEARCH OF THE BLUE-GREEN INFRASTRUCTURE IN EUROPEAN CITIES AND ITS IMPLEMENTATION IN SLOVAK REPUBLIC

Marek Csóka[1]

Gergely Rózsa[2]

Ivana Marko[3]

Štefan Stanko[4]

[1] Department of Sanitary and Environmental Engineering, Faculty of Civil Engineering, Slovak University of Technology in Bratislava, Radlinského 11, 810 05 Bratislava, Slovakia, e-mail: marek.csoka@stuba.sk

[2] Department of Sanitary and Environmental Engineering, Faculty of Civil Engineering, Slovak University of Technology in Bratislava, Radlinského 11, 810 05 Bratislava, Slovakia, e-mail: gergely.rozsa@stuba.sk

[3] Department of Sanitary and Environmental Engineering, Faculty of Civil Engineering, Slovak University of Technology in Bratislava, Radlinského 11, 810 05 Bratislava, Slovakia, e-mail: ivana.marko@stuba.sk

[4] Department of Sanitary and Environmental Engineering, Faculty of Civil Engineering, Slovak University of Technology in Bratislava, Radlinského 11, 810 05 Bratislava, Slovakia, e-mail: stefan.stanko@stuba.sk

ABSTRACT

The drainage of urbanized areas with blue-green infrastructure helps to decrease and slow down immediate stormwater surface runoff in cities. This helps to reduce occurrence of combined sewer or stormwater sewer overflow. The goal of this study is to investigate stormwater management in European cities with usage of a blue-green infrastructure. Obtained data will be assessed for best implementation of blue-green infrastructure for cities in Slovak republic. The selected cities in Europe are based on similarity with Slovak cities in climate, demographical, geographical, or urban parameters.

Keywords: Blue-green infrastructure, Rain, Stormwater management

INTRODUCTION

Urban areas in cities and towns are commonly based on grey infrastructure solutions such as impermeable surfaces (asphalt, concrete), underground retention objects, or pipeline systems. General disadvantage of grey infrastructure is that usually it carries out only one function and it has low resilience level. Climate change, extreme rainfall events or continual grow of urban areas are main reasons why grey infrastructure starts to fall behind and its not able to properly handle increasing stormwater demand. Blue-green infrastructure (BGI) at the same time is able to handle multiple functions and bring more benefits in the same places as a grey infrastructure. The grey infrastructure will always be needed but it can be enhanced with nature-based solutions. Research shown that this type of infrastructure can be cheaper than convectional infrastructure in long-term time period due its maintenance and protection of local environment [1].

The principle of BGI as a stormwater management tool is that it is relying on natural processes. It utilizes functions such as infiltration, detention, storage and biological uptake of pollutants thus managing stormwater quality and quantity. Another benefit are flood hazard mitigation, thermal reduction, biodiversity amplification, and social factors like aesthetic, recreation, and education [2].

BGI SYSTEMS

In Table I bellow are listed commonly used systems of blue-green infrastructure. It includes variety of nature-based urban systems, which are ingeniously designed to mimic natural hydrology. Systems can be implemented individually or in combination to help achieve better management of quantity and quality of stormwater runoff in the area. Trees, bushes, or grass surfaces are helpful, but they will not be listed, because their usage in Slovakia is adequate. Systems such as permeable paving, underground storage tanks, or rainwater harvesting cisterns will not be listed either, because they are not ecosystem based as elements of BGI are.

Table II: Properties of BGI

BGI System	Benefits	Limitations	Functions
Green roof	Enhancing urban microclimate, Dust reduction, Building energy reduction, Prolongation of roof isolation lifespan	Maintenance cost, Increased initial investments, Increased load of the roof, Require perfect hydro isolation	Infiltration, Evapotranspiration, Retention, SWT[1], SWR[2]
Green façade	Enhancing local microclimate, Decreasing building overheating, Shadow protection, Dust reduction, Noise reduction, Air treatment	Increased initial investments, Increased maintenance cost, Slow growth of vegetation types	SWR[2]
Bioswale	Increasing soil humidity, Low maintenance, Reliable function	Not able to treat heavy pollution	Retention, Evapotranspiration, Infiltration, SWT[1], SWR[2]
Detention basin	Increasing soil humidity, Low maintenance, Low space requirements with increased depth	Space requirements, Not able to treat heavy pollution	Retention, Evapotranspiration, Infiltration, SWT[1]
Retention basin	Increasing soil humidity, Increasing air humidity	Space requirements, Not able to treat heavy pollution	Retention, Evaporation, Infiltration, Accumulation, SWT[1]
Constructed wetland	Increasing soil humidity, Enhancing local climate, Temperature stability, Increasing air humidity	Space requirements, Difficult to implement into urban area	BSWT[3], Evaporation, Retention, Adjusting of water quality

1 SWT - Stormwater treatment, 2 SWR – Stormwater reduction, 3 BSWT – Biological stormwater treatment

Table I contains benefits, limitations, and functions of common types of BGI systems. Benefits like improving biodiversity, enhancing aesthetic look of area, or increasing value of building, or locality are similar for all systems, thus are not listed in the table. Listed properties with examples, design principles, and materials are listed in BGI building standards for city of Olomouc [3]. Every state, city, or building company has its own standards with similar fundamentals as are in Table I.

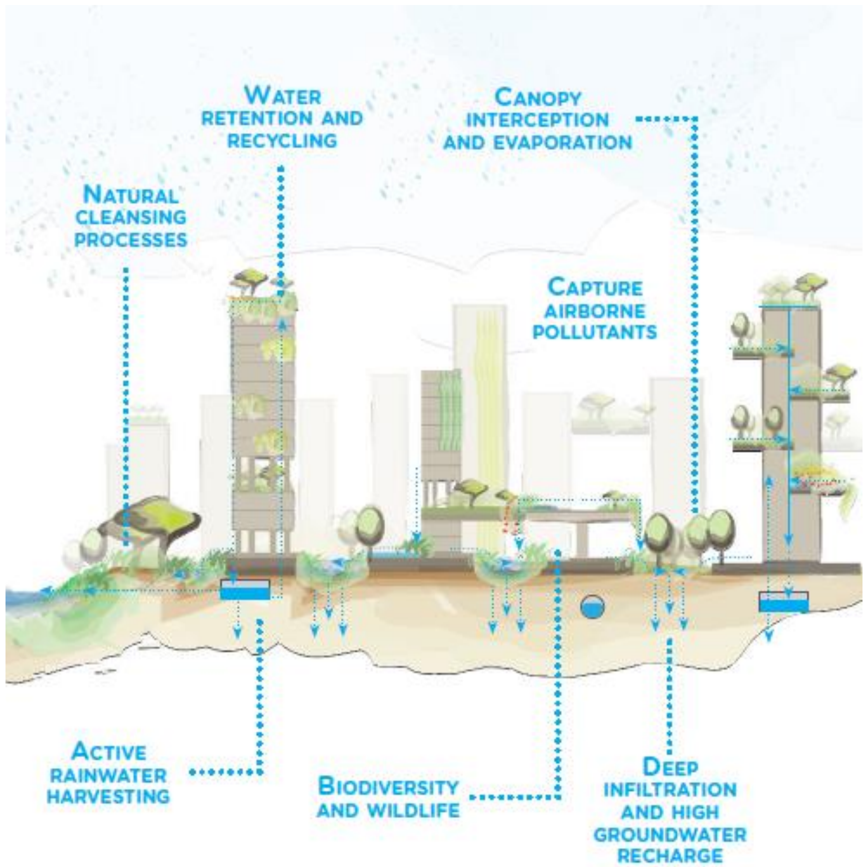

Figure I : Functions of BGI systems [4]

CASE STUDIES

Research of this article is comparing implementation of blue-green infrastructure in European cities and its positive or negative effects on the urbanized area. Case studies should represent opportunities for future projects of integrating blue-green infrastructure in Slovakia. There are several beneficial projects like residential district Hannover-Kronsberg in Germany, or different projects in Copenhagen, but for this work main focus will be on BGI project in Olomouc. Case study in Olomouc is chosen because its availability and detailed analysis of the BGI elements, strategy, opportunities and threats connected with them. Another advantage is that parts of Olomouc city can be compared with parts of cities and towns in Slovak republic without big differences. The results and lessons learned for Slovak republic strategy will be assessed in next chapter.

COPENHAGEN – DENMARK

The case study projects in Copenhagen focus more on flood control than stormwater utilization. Areas in project are Lindavang Park (redevelopment of an existing urban park), Taasinge Square (socio-cultural enhance in a residential area), and Sct. Anne Square (redevelopment of a historical square). In case study projects BGI was designed for stormwater management and to provide additional benefits such as aesthetics, recreation, or education. Taasinge Square has increased biodiversity and livability. Reuse of collected stormwater from roofs and roads to supply fountain in the square was canceled due strict water quality for recreation. Lomdevang Park is providing detention for small rains and potential detention for a 100-year rain event. Sct. Annae Square helps mainly with flood control, with minor water balance improvement, on the other hand historical architectural features limit design of visible water ponds to enhance social aspect of the area. Improving the local water balance was minor focus for the case studies. Design mostly focusses on a integration to combine stormwater management with civic amenities, tilted more to social benefits than managing stormwater [5].

POSTDAMER PLATZ – BERLIN - GERMANY

Postdamer Platz is located in the centre of Berlin. It is important traffic junction with Berlin metro station and train station. In the early 90s the Postdamer Platz was redesigned with BGI elements. The goal of the project was to reduce stormwater runoff to zero. The project is using varied systems. Green roofs evaporate more than half of the precipitation with 12 000 m^2 area and rest is discharged into cisterns. Artificial water areas with vegetated biotope serve as a storage reservoir with additional functions to increase water quality. Approximately 15% of annual precipitation is reused for flushing toilets in office buildings, or to irrigate green surfaces. Remaining 85% is retained in the water surfaces or on the roofs where it evaporates, or it is discharged in small amount into the nearby Landwehr Canal during extreme rainfalls. The stormwater management in Postdamer Platz is progressive and successful. Possibilities to improve is in the green part of the BGI systems, because vegetation plays a minor part in the project [6].

Figure II : Potsdamer Platz [7]

HANNOVER-KRONSBERG – GERMANY

Hannover-Kronsberg is a residential area with 3000 houses built 1992 to 2000. This area was exhibit for the World Exposition 2000 titled as Human – Nature – Technology. The goal of this innovation project was to combine sustain infrastructure with urban life. Focus was on energy efficiency, soil management, rainwater management, waste management, and environmental communication. As for rainwater management to balance traditional stormwater drainage with BGI systems, increasing permeability, retention, and stabilizing groundwater levels for nearby woodland area. The BGI system provides decentralized retention, where rainwater from impermeable surfaces is channeled into a trench system to soak into soil or to be discharged in optimal amount into the public drainage system. Hannover-Kronsberg is a pilot project for environmental based construction for new urban areas [4].

Figure III : Hannover-Kronsberg neighbourhood [4]

BOSCO VERTICALE – MILAN – ITALY

Bosco Verticale is two towers project completed in 2015. The aim of the project is to be example for sustainable housing. Towers also contributes to reforestation and naturalization of the urban area, because they are covered with dense vegetation of 20 000 plants, with 700 trees. The plants contribute to the energy balance of the building, shading, and microclimatic effect. Water management needs to be improved. It bears no integrated rainwater management, and the grey water from the apartments is discharged without any other usage into the public sewage system. The backflow of irrigation increases the volume in the city sewer system. This means that the building is creating a large amount of a wastewater rather than reducing it. The Bosco Verticale symbolize a classic, green-motivated way at a building urban level, but the water management concept needs to be improved to be beneficial as a blue-green infrastructure system [6].

OLOMOUC – CZECH REPUBLIC

The case study in the city of Olomouc compared with previous studies is not constructed. Project is about implementation of blue-green systems was prepared as a guideline how to design elements of BGI, with all its parameters. Study also unfolds topics like dotation for BGI, how to increase awareness, or affection to develop BGI systems.

One part of the study is proposing solutions how to implement blue-green infrastructure systems into already build urban area. Project suggest that during small repairs, or complete reconstructions of urban parts they should apply suitable elements of stormwater management. This will gradually increase positive influence on whole urban area. Every measure needs to be appropriately designed with best intent to use its full value and with as much functions as is possible. Listed bellow are proposed ideas how to implement BGI into built-up areas:

- Replace parts of conventional roofs with green roofs with system to collect and storage rainwater with later usage.
- Variety of bioswales can be added into the streets. Swales will provide reduction and retention of surface runoff and can treat it from pollutions.
- Some streets, sidewalks, or spaces between buildings can have their slope changed to provide surface runoff retention and to support combined sewer system during extreme rainfall events as watercourse and transport surface runoff.
- Areas like parking lots, or city parks can be designed to temporarily detain stormwater – Detention basins. This will also bring other benefits of BGI.
- Local measurements can be installed on buildings to increase flood resistance.
- Sidewalks, or park paths, which are jointed to grass areas can be build higher so rainwater can flow directly into green surfaces.

Interventions into the already build development should lead to reduction of overload in sewer system during extreme climatic conditions [3].

Examples how to apply BGI into different parts of a city

Another section handles different restrictions and building standards combined with space limitations and suggest options based on type of an urban area. For every type of residential area there are selected streets with designed elements of BGI.

Historical city centre is oldest part of a city with narrow streets and houses protected as architectural landmarks. Majority of impermeable surfaces in the area combined with narrow streets makes it difficult to implement BGI. BGI systems can be applied during reconstruction, but only in a small amount as retention and infiltration objects, or as a major improvement but at cost of moving engineering systems (water supply pipeline, sewerage pipes etc.) [3].

Compact part of the city. Usually block type of development with wider streets. The green strips with planted trees divide the road and sidewalks next to façade of buildings. Wider street area with already build in green stripes create more opportunities to implement BGI systems. Variety of bioswales can be applied or green strips with planted trees can be enhanced for example with underground retention furrow. Focus needs to be also on stormwater pollution treatment [3].

Modern part of the city, or neighbourhood unit area characterized by block of flats situated into the open area creating system of districts. Large areas with plenty of space provide realization of BGI mostly without limitation [3].

Suburbs usually development of lower scale formed mostly by family houses with gardens divided onto parcels. Street is bordered by fences or walls. Restriction in this part of city is usually width of the street between opposite houses, but in majority of cases bioswales or infiltration grooves can be easily applied. Public sidewalks, or parking spaces can be designed as semi-permeable surfaces with sufficient pollution treatment [3].

RECOMMENDATIONS

There can be several lessons learned from previously mentioned case studies. As was in case of Copenhagen not every part of a project plan can be applied due architectural, space, quality, or other type of limitations, but either small implementation of BGI element into the urban area can increase its properties. The Bosco Verticale in Italy showed that application and design of blue-green infrastructure can be beneficial, but some things and solutions can affect other parts of an urban features. Major question in both problems was how it can affect functionality of BGI and its surroundings and if can be solved with another usage of BGI systems.

Employing own pilot project can serve as an example to extend interest in implementation of mentioned systems and elements. Pilot projects offer chance to experiment with small scale designs that can increase understanding of opportunities connected with BGI. They can serve as a long-lasting example for future projects. The observation of financial, social, ecological, and stormwater management effects can demonstrate benefits that this system can bring. Later based on pilot project technological standards or guidelines can be generated [8]. Hannover-Kronsberg in Germany can be shown as an example.

CONCLUSION

Blue-green infrastructure provides sustainable rainwater harvesting and management, local flood protection, increase urban ecosystem and improve social aspect of city or town. Elements of this infrastructure follows principles based on hydrological, ecological, urban, that combine blue and green surfaces, create multifunctional and interactive systems [3]. Based on acquired knowledge from case studies, BGI accompanied with sophisticated planning and design can improve urban areas mainly in local flood protection, stormwater retention, and reduction. Pilot projects in Slovakia are needed to be created and announced to spread benefits of BGI systems. For Slovak region the Olomouc case study project can serve as an example with its extensive approach with design standards.

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ON RIVER-AQUIFER INTERACTIONS DURING FLOOD EVENTS

Gadadhara Ferraz[1]

Tamás Krámer[2]

[1] Department of Hydraulic and Water Resources, Faculty of Civil Engineering, Budapest University of Technology and Economics, Műegyetem rkp. 3, 1111, Budapest, Hungary, e-mail: gadadhara.ferraz@emk.bme.hu

[2] Department of Hydraulic and Water Resources, Faculty of Civil Engineering, Budapest University of Technology and Economics, Műegyetem rkp. 3, 1111, Budapest, Hungary, e-mail: kramer.tamas@emk.bme.hu

ABSTRACT

River floods and groundwater interactions are important not just as drivers of water-table rise, but also as contributors to the mitigation of floods. During a flood, part of the surface water is temporarily stored in the riverbanks and released back to the river slowly after the peaking of the flood wave. The cumulative effect in long river valleys is a considerable damping of flood peaks in the downstream reaches. The purpose of this article is to review the main aspects related to river-aquifer exchanges with a focus on flood events, in addition to citing studies of analytical and numerical modeling.

Keywords: Flood attenuation; river-aquifer interactions; bank storage; modelling; field measurements

INTRODUCTION

The interaction between surface water and groundwater keeps being the focus of numerous studies and review papers. Characterization of these interactions is made based on geophysical and hydrological factors. In river-aquifer systems, seasonal changes in the level of the river will induce the groundwater flow either from or towards the river. However, major floods events, due to meteorological factors, will provoke a rapidly rise in river level, and on some occasions the river level may flood the floodplain overbank. In that case, surface water will infiltrate vertically and horizontally into the groundwater [4]. The infiltrated water will be temporarily stored (i.e., bank storage), and return to the river after the flood wave passes downstream [5]. Parameters such as shape of the flood hydrograph and hydraulic properties of the aquifer will play a role in the amount of bank storage volume and groundwater flow [10].

Quantification of the exchange between groundwater and surface water in rivers is typically accomplished by measuring water levels in wells, for example, installed within the floodplain, on the banks of the river. As an alternative, the exchange can be determined by measuring the river levels and comparing those two sources. However, other techniques might be used to quantify these interactions, such as tracing techniques, net-flow analysis, and even modelling [3].

Analytical models have been used to quantify the exchanges between groundwater and surface water, as well as the bank storage volume (e.g., [5]). For complex scenarios, that is, in the general case, numerical flow models can be used (e.g., [7]; [26]). In floods events, not only the transverse dimension should be considered, but also the initiated groundwater movement parallel to the river (e.g., [11]).

The purpose of this article is to present the current level of understanding of these interactions, thereby assisting in the management of river floods and surface water dynamics. To this end, a review of exchange processes between river waters and groundwater is offered, focusing on the effects of these interactions on river floods, in addition to bringing cases of analytical and numerical modeling.

SURFACE WATER AND GROUNDWATER INTERACTIONS IN FLOODPLAINS

Groundwater interacts with surface water in almost all landscapes, from small streams, lakes, and swamps in the headwaters to the main river valleys and seacoasts. To understand the interactions of surface and groundwater it is necessary to know the effects of the hydrogeological environment, such as topography, geology, and climate.

The best-known characterization of groundwater movement was given by Tóth (1963) based on the physiography of a small basin [2]. Its characterization divides the groundwater flow system in three types: local, intermediate, and regional. In a local flow, groundwater flows from a topographic high (recharge area) to a topographic low (discharge area) adjacent to each other. In an intermediate system, more than one topographic high and low may exist between the recharge and discharge area. Lastly, a regional flow system may occur when the recharge area is in the divider line of the basin, and the discharge area is the bottom of the basin. However, not only the topographical aspects influence the interaction between surface and groundwater, but also the hydrological processes, such as the high the gradients between surface and subsurface waters (caused by precipitation, snow melt, reservoir discharge, for example) and evapotranspiration of the groundwater through riparian vegetation [1].

From the direction of the net flow between the river and the aquifer, it is possible to characterize whether it is from the water table to the river (gaining river reach), or from the river to the water table (losing river reach) [3]. In a gaining river reach, the water table level is higher than the river level (Figure IVA). On the other hand, a losing reach occurs when the level of the river is higher than the level of the water table (Figure IVB).

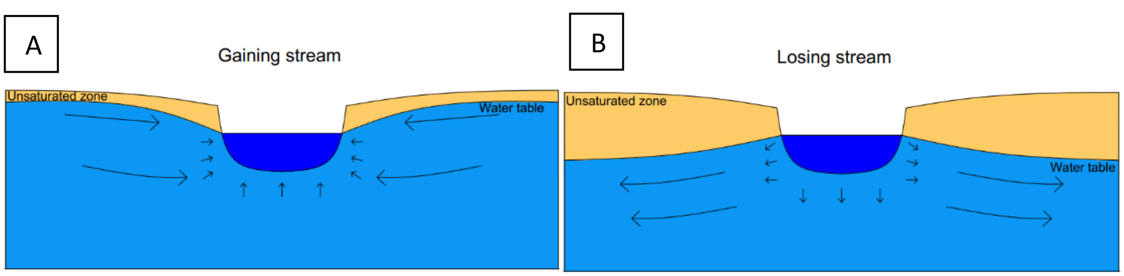

Figure IV: Flow direction: (A) gaining and (B) losing river reach (Source: author).

When the level of the river increases, the river behaves as losing river; when river levels decrease, the river is gaining river [1]. Considering that, when floods occur, water can infiltrate across the floodplain surface, during floodplain flow and, subsequently, under ponded waters. When the flood wave passes, the river water level drops, and there is a reversal in the hydraulic gradient and the groundwater movement is oriented from the alluvium back to the river (e.g., [4]). The volume of water stored in the alluvium and released after the flood in this process is referred to as bank storage.

Bank storage is a significant hydrologic process for flood management because it can attenuate the flood wave in a river that has permeable bank materials [7].

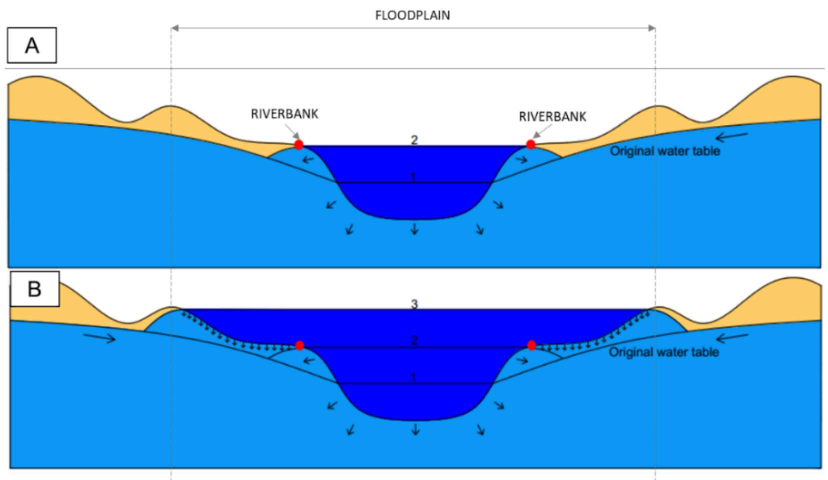

Figure V: Seepage from the river to the aquifer due to rise of river water level (1 – initial river level; 2 – river level in-bank; 3 – river level overbank) (Source: author).

The banks storage volume depends on the duration, height and shape of the flood hydrograph, the transmissivity and storage capacity of the aquifer [8], and the topography/morphology of the river valley [9]. In a flood hydrograph with a lower concentration time rate (tc) per flood duration ($Td = 24h$), there will be a sharper rise in the flood wave and, consequently, a higher infiltration rate. However, the banks storage volume will be less due to the short rise time [10].

For high values of aquifer diffusivity (i.e., the transmissivity ratio for storage), the occurrence of the peak of the groundwater level occurs in earlier time, due to the faster wave propagation into the aquifer. On the contrary, the discharge and bank storage decreases with the increase in the aquifer diffusivity [11]. For higher values of transmissivity, with constant diffusivity, the discharge and bank storage increases, but groundwater levels remain constant over time [10]. Because of this, in rivers with coarse alluvium, the discharge and bank storage increase [6]. Transmissivity must reflect the properties of the soil and therefore will be influenced by the hydraulic conductivity of the riverbed and the aquifer [13].

Meteorological factors, such as evapotranspiration, can affect the relationship between surface and groundwater. The presence of riverine vegetation can decrease the level of the water-table [14]. For a higher potential evapotranspiration rate, slightly more river water infiltrates into the aquifer, but also more bank storage is lost to evapotranspiration [15]. However, in the case of a flood event, the duration of a flood is usually short enough to neglect the evaporation processes [16].

To determine the typical flood hydrographs and the properties of the aquifer, field monitoring must be carried out, which includes hydrological measurements, such as surface water level and groundwater, soil samples, among others. This will be elaborated in the next section.

FIELD MONITORING OF THE FLOODPLAIN WATER TABLE

The choice of the best method will depend on the physical and hydrological conditions present in the case to be studied, as well as the scale of the interaction. For a small spatial scale, that is, rivers with an extent of tens to hundreds of meters, methods of infiltration flow measurements as seepage meters, “minipiezometers” or hydraulic potentiomanometers, may be most appropriate [17]. However, tracking techniques have been widely used to characterize flow paths and estimate groundwater flow rates [18]. On a larger spatial scale, in the order of meters to kilometers in length, the methods of analysis include surface flow modeling, groundwater flow modeling and flow-net analysis [19], longitudinal flow river sampling [20], and longitudinal chemical river sampling [21].

Bank storage volume can be inferred based on the hydraulic head in observation wells near the river and the application of Darcy's law [12], and also by measuring changes in solute concentrations, for example, in wells near the river and modelling [22]. Well observations at locations away from the river show a damped and delayed effect of variations in the river stage. Studies documented hydrological interactions between river stage and groundwater level in floodplain environments, observing the process of propagating pressure waves. In addition, field instrumentation generally covers only a limited part of the floodplain with piezometer transects [14].

A dense network of wells provides a quantitative estimate of the volume stored in riverbanks. To illustrate this, we present the groundwater table map by Kullman et al (2013) produced based on instantaneous groundwater positions data recorded during the flood of the Danube in 2013 (Figure VI). The flood peak reached the new historic maximum flow rate in Bratislava, equivalent to 10.540 m^3/s. It is clear from the map that the rise of the groundwater table was strongest in the Rye Island (Žitný ostrov) branch system which presents a high ratio of bank length to floodplain surface area. As a rough estimate, an average rise of 1,5 m in this area of 150 km^2 is equivalent to a water volume of about 100 million m^3 temporarily stored in groundwater, assuming a porosity of 0.5 [35]. This represents a considerable volume that would be accumulated by three hours of peak Danube discharge. This is a clear motivation to research the contribution of bank storage to the attenuation of river floods.

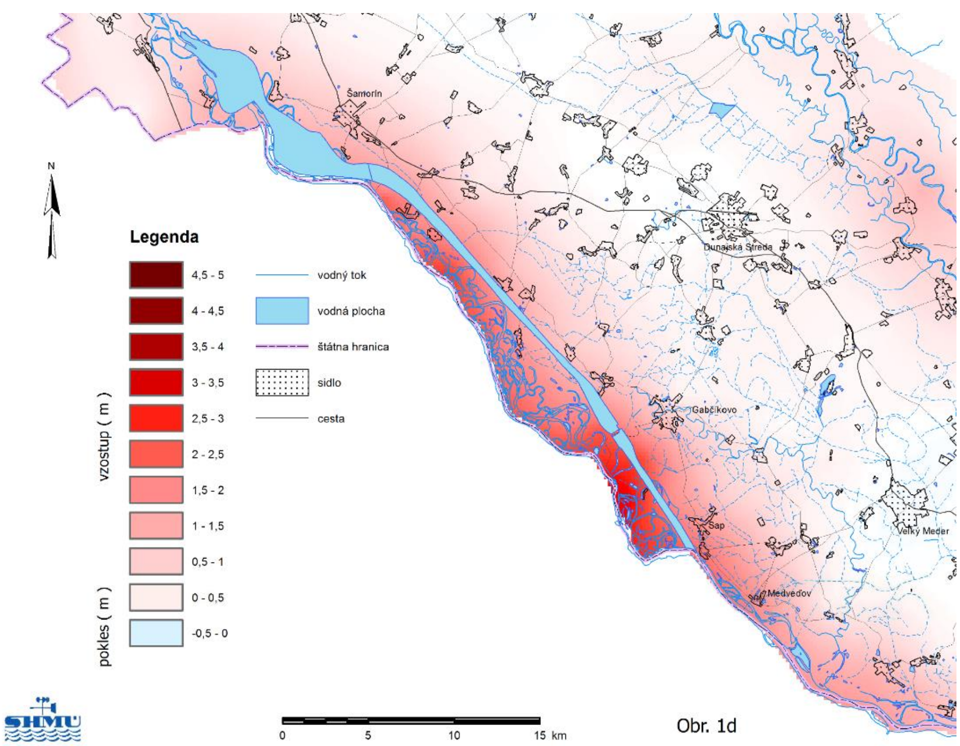

Figure VI: Rise of the groundwater table in the Rye Island region (Slovakia) on 12 June 2013 compared to 25 May 2013. (Source: Kullman et al. 2013) [35].

By the nature of extreme events, only a few studies documented large overbank flood events (e.g., [4]) based on observed data from piezometer and river stages. A technique using heat as tracer tracer to quantify streambed fluxes for extreme hydrologic events was used by Barlow and Coupe (2009), demonstrating the ability to restrict estimates of water flow from the streambed and the critical flow reversal stage, with little data available from the groundwater levels, by using temperature as a tracer during extreme stage events [23].

MODELLING STUDIES

The movement of water between surface and groundwater can be described analytically or using numerical flow models. Analytical solutions that describe and quantify the movement of the bank storage water between surface and groundwater have been put forward by many researchers (e.g., [5]; [24]). On the other hand, numerical flow models have also been used for many decades to simulate the highly complex movement of the water for banks storage in the alluvial aquifer (e.g., [7]; [26]).

Analytical solutions are useful for understanding the physical processes in a groundwater flow system, for predicting short-term water-table fluctuations in response to a transient flood wave, the flow of water between the aquifer and the river, the accumulated bank storage, and for determining the hydraulic properties of the aquifer [27]. Solutions to surface and groundwater interactions are derived from Darcy's law and the law of conservation of mass (continuity equation), which states that the net rate of fluid mass flow into any elemental volume of aquifer is equal to the time rate of change of fluid mass storage within the element. The solutions are determined by defining a specific set of boundary and initial conditions [28].

Some of the assumptions before modelling surface and groundwater interactions problems assumed by several researchers are: the alluvial aquifer is homogeneous, isotropic and of finite extent (e.g., [27]; [29]); the aquifer's bottom is horizontal and impermeable (e.g., [27]; [11]); assumptions of Dupuit-Forchheimer conditions (e.g., [31]; [7]); the flow is saturated (e.g., [7]); the river fully penetrate the aquifer (e.g., [27]; [11]); an unconfined (e.g., [11]; [32]; [25]), confined (eg., [27]; [12]), and leaky aquifer (e.g., [27]; [25]; [12]). However, according to Sharp (1977), some of these assumptions do not fit with observed hydrogeologic conditions [33]. Aquifer homogeneity, for example, it is not fulfilled once the hydraulic conductivity increases exponentially with depth in main alluvial aquifers (e.g., [34]). The Dupuit-Forchheimer conditions are not satisfied because groundwater flow is not uniform over the depth of flow and is not necessarily horizontal, in the vicinity of the riverbed, for example, flow is predominantly vertical, and the vertical flow component often predominates near the water-table (see Figure V) (e.g., [29]; [6]). A fully penetrating river is violated because most of alluvial aquifers are in fact partially penetrating river (e.g., [30]). Also, this condition leads to invalidity of the Dupuit-Forchheimer conditions, which makes most of one-dimensional models prone to inaccuracy [33].

Solutions for one-dimensional lateral flow into the aquifer due to a highly fluctuating river boundary condition were proposed based on the linearized Boussinesq equation with the Dupuit-Forchheimer assumptions [31]. The results were accurate in terms of the general shape of the curve that predicts inflow to the bank storage as a function of time, but not in terms of maximum flow rate. Although the use of analytical solutions in one-dimensional lateral flow is widely used among researchers, on a small time scale, as is the case of a flood event, the use of a two-dimensional solution would be more appropriate [33]. Dever and Cleary (1978), for example, demonstrated that infiltration can occur under the streambed when considering a permeable streambank [25]. Neglecting the permeability of the riverbank in mathematical models can lead to an underestimation of the amount of flood attenuation by bank storage and, because of this, such an assumption should not be made when analyzing aquifer-river systems, unless supported by field evidence.

During floods events, a diffusive flood wave along the river commonly occurs. And because of that, river-aquifer interactions should consider groundwater flow perpendicular and parallel to the river, so analytical solutions have to couple groundwater and open channel flows equations [32]. The solutions proceed iteratively in such a way that the first step is to find the solution of the flood wave disregarding the infiltration of the bank [24], then, this solution will be used to obtain an approximate solution of the groundwater equations, which in turn will be used to obtain a second order approximation for the flood wave solution [7]. The results of this approach confirm the theory known so far: during the flood, the river recharges the aquifer faster, and as the flood wave passes downstream in the river, the level of the river begins to decrease, and thus most of the water infiltrated into the aquifer will return to the river in shortly after the peak. With that in mind, a flood event has a significant effect on the groundwater recession in the beginning, but the impacts of the flood event will gradually disappear over time. Note that, in this type of approach, in cross-section, the hydraulic load is not only affected by the river flood wave, but also influenced by the groundwater flow parallel to the river [11].

Due to the limitations of using analytical solutions, such as the presence of complicated boundary conditions of the aquifer, heterogeneous aquifer or complicated flow and stage relationships, it may be necessary to use numerical modeling methods that combine open channel flow equations and flow equations groundwater to simultaneously resolve the river-aquifer interactions. In addition, numerical modeling is the only general method of predictive analysis, which can be extended to arbitrary morphologies of rivers and soils.

One of the first studies to couple open channel flow and groundwater flow, and to demonstrate flood hydrograph modification due to bank storage through numerical modelling, was developed by Pinder and Sauer (1971). The model aims at solving the differential equations that describe the flow in open channel and the flow of groundwater through the wetted perimeter, by Darcy's law. The result indicates the importance of bank storage in shaping the river hydrograph, by delaying the flood wave arrival, and by lowering the flood peak [7]. Since then, many authors have been developing and applying numerical solutions to real cases. For example, Squillace (1996) constructed a two-dimensional (in the cross-section of the river, vertical plane) groundwater flow model through MODFLOW in the Palisades study site, located on a part of the floodplain of the Cedar River (Iowa). Simulations have shown that a 2 m rise in the river level caused bank storage volume to move 30 m horizontally and 4 m vertically below the river bottom. Thus, the bottom portion of the bank storage volume can be significant in wide and shallow rivers, because the width of the river is much bigger than the depth. So, even in narrow rivers such as the Cedar river, the bottom storage may be significant [26].

Some limitations is a general assumption of a rectangular channel with vertical banks. Doble et al (2012) explore the implications of assuming a vertical riverbank and saturated flow for calculating bank storage and return flows. Numerical simulations of bank storage and return flow in river-aquifer cross sections with vertical and inclined margins were performed using a fully coupled surface-subsurface flow model (HydroGeoSphere). The model simultaneously solves the approximation of the diffusion wave of the two-dimensional shallow water equations for the surface water flow and the Richards' equation that governs the three-dimensional transient subsurface flow in a variably saturated porous medium with a physical coupling between the two domains. Results show that sloping riverbanks have been found to increase infiltration rates by 98% and storage volume by 40% compared to vertical riverbanks and the saturated flow, delaying the return flow of the bank more than four times [29].

As mentioned earlier, some researchers contest the use of Dupuit assumptions. Whiting and Pomeranets (1997) [6], for example, developed a model (WaTAb2D) that describes the unsteady flow of saturated unconfined groundwater, interfacing the river with a free movement boundary condition. Similar to WaTAb2D, Bates et al. (2000) developed a numerical model (ESTEL) to determine the effects of water fluxes to and from hillslopes on the response of the floodplain and, for the first time, has examined hydrological processes occurring during large out-of-bank flood events [4]. the model provides an advance on generic models such as MODFLOW.

As can be seen from the review of numerical and analytical models, there are several premises to be considered when analyzing a problem with surface and groundwater interactions, as well as a variety of methodologies, whether analytical or numerical, to solve this problem. The determining factor for choosing the most appropriate method is to compare of field information from the specific case study with previous works, considering the limitations of each method.

CONCLUSION

Many researchers have focused on exchanges between rivers and the aquifer due to changes in the level of surface water. When the river level rises, the surface water infiltrate along the riverbank into the aquifer. The amount of water infiltrated and stored during this process is called bank storage. When the river level drops, groundwater flows towards the river. Such a process can take a long time. However, during floods, the level of the river will increase in a short period of time and, on some occasions, it may exceed the floodplain. Bank storage will play an important role in attenuating river floods.

The quantification of these parameters depends on factors such as the shape of the flood hydrograph, topography and morphology of the river valleys and parameters of the aquifer. In a sharper hydrograph, for example, less volume will be stored on the riverbank, due to the short duration of peak time, and the groundwater wave does not have time to penetrate deep into the aquifer. In the case of valleys with a coarse soil, the hydraulic conductivity will be greater, and therefore, more volume will be stored in the riverbank. Evapotranspiration can be important when considering a long river reach or a long period of time, which is seldom the case with flood events.

Field monitoring is necessary to analyze these interactions and is usually done through monitoring wells, however, other techniques can be used for monitoring, such as tracing techniques. The technique to be chosen will depend on the specific scenario to be analyzed, especially on the temporal and spatial scale of the problem. Note that in floodplains, field instrumentation covers only a limited part of the physical process. Extreme flood events can rarely be captured using dedicated field surveys due to the low probability of occurrence and the demand for time to prepare for a flood triggered deployment, in this case, modeling is the universal method of analysis for the bank storage during extreme events.

Analytical and numerical solutions seek to represent real cases, defining specific assumptions and boundary conditions. Several studies have been done over the years to improve the modeling for a more realistic scenario. In the case of flooding events, simulations should be carried out using models of groundwater and surface water, where not only a lateral flow to the river, but also a longitudinal flow.

This paper cited many theoretical results and practical studies related to the general observations, to help an engineer select the right methods of analysis.

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TESTING OF SIPHONIC ROOF DRAINS

David Fucik[1]

Jan Rucka[2]

[1] Institute of Municipal Water Management, Faculty of Civil Engineering, Brno University of Technology, Zizkova 17, 602 00 Brno, Czech Republic, e-mail: fucik.d@fce.vutbr.cz

[2] Institute of Municipal Water Management, Faculty of Civil Engineering, Brno University of Technology, Zizkova 17, 602 00 Brno, Czech Republic, e-mail: jan.rucka@vut.cz

ABSTRACT

The article deals with testing of siphonic roof drains, which are used for drainage of flat roofs. The author's team deals with the development, shape solution and hydraulic optimization of roof drains. As part of the development to date, shape variants have been proposed for siphonic drains, which have been tested on a laboratory measuring circuit. When measuring the hydraulic capacity of the drains, the height of the water level above the drain and the related value of the water flow in the outflow pipe at a steady flow were recorded. Flow curves were plotted from the measured data.

Keywords: water flow, roof drain, siphonic system, water level

INTRODUCTION

The paper deals with the issue of drainage of flat roofs, for which a gravitational or siphonic drainage system is used. The paper itself focuses on the topic of siphonic drainage system and describes siphonic roof drains, thanks to which it is possible to drain the roof area. These are relatively sophisticated industrial products, on which great emphasis is placed during construction.

Roof drains are installed in vertical penetrations, which are prepared in flat roof structures. They are therefore installed in such a way that they drain rainwater from the roof surface. Each roof drain is connected to a drain pipe, which drains rainwater outwards from the building into the rain sewer, retention tanks, etc. In the case of a siphonic drainage system, it is desirable to create a siphonic flow regime, i.e. suction, in the pipe line when a certain flow rate is reached, which increases the hydraulic capacity of the entire system. For larger roof areas, such as production halls or warehouses, department store buildings, etc., it is desirable for the drains to have the largest possible hydraulic capacity in order to disturb the roof structure with as few building openings as possible.

The author's team deals with the development, shape solution and hydraulic optimization of roof drains together with the air partition, for which it uses the tools of mathematical and physical modeling. As part of previous development work, one variant of a siphonic roof drain was designed, which was tested on a laboratory hydraulic measuring circuit.

During the laboratory measurement of the hydraulic capacity of the drains, the height of the water level on the board simulating the roof cladding and the related value of water flow in the drain pipe at steady flow, which can convert the roof drain at this height of swelling, were always recorded. From the measured data, flow curves were plotted, which show the course of water flow depending on the height of the water level on the simulated roof.

During the testing, photographs were recorded showing the hydraulic conditions in the pipeline. The recording was made for the proposed variant of the siphonic drain, as well as for its modifications. Furthermore, the course of hydraulic conditions in a transparent drain pipe was monitored. The hydraulic conditions in the waste pipe were monitored in order to determine the height of the water level above the roof drain, at which full flow occurs in the siphonic system.

SIPHONIC ROOF DRAIN

The base of the body of the siphonic roof drain is based on the shape of the gravitational drain. The main difference is the air baffle, which is part of every siphonic roof drain. The air baffle is a kind of plate, which is located above the drain part. This partition may also serve as a protective basket or may be installed in addition to the protective basket [1]. In the case of gravitational drainage, at a certain height of the water level, a water vortex begins to form above the gravitational drain, which draws a large amount of air into the system. The air barrier prevents this phenomenon. As a result, a siphonic system operating below atmospheric pressure can operate efficiently [2], [3].

EMERGENCE OF A SIPHONIC EFFECT

The emergence of a siphonic regime of water flow in the system accompanies the four basic phases of water flow in the drain pipe of the entire system. The first phase is called gravitational flow. At this stage, the degree of water filling in the system pipeline reaches a maximum of 15 % of the design value of precipitation intensity. The second phase is called piston flow. In this phase, the water flow regime in the system fluctuates, ie between the gravitational mode and the siphonic mode. The degree of water filling in the system piping is given in the range from 15 % to 60 % of the design value of precipitation intensity. The third phase is called bubble flow, ie when the degree of water filling in the system piping exceeds 60 % of the design precipitation intensity. During this phase, the system piping is completely flooded with rainwater, but a large amount of air is still present in the system, which occurs in the piping in the form of air bubbles. The fourth and also the last phase is the full flow, which occurs when the degree of water filling in the system piping exceeds 95 % of the design value of the precipitation intensity. At this stage, maximum water flow rates in the pipeline are reached and the system can operate efficiently [4].

When air particles enter the system, strong vibrations occur at the point of inflow, which is accompanied by loud noise. The maximum arises in the case of bubble flow, when the water flow is already affected by the siphonic effect, which achieves a higher speed of water flow in the system and in the drain part. Due to the fact that the swelling of the water is not so great at this stage, the amount of air entering the system, which represents 5 % - 40 % [4].

DESCRIPTION OF THE PROPOSED VARIANTS

One proposed variant of the siphonic drain and its other two alternatives were tested on a laboratory measuring device. The body of the designed drain is based on the body of the gravitational drain. This gravity drain was supplemented by an air barrier with a diameter of 189 mm. The air baffle was fitted to the level of a horizontal lamella, which is part of the protective basket, which is part of the entire element of the siphonic drain. The drain height, ie between the integrated drain sleeve, which connects to the waterproofing layer of the roof sheathing, and between said lamella (lower edge of the air partition) is 14 mm.

For the other two alternatives of the siphonic drain, which from the drain described above, the levels of the location of the air baffle were adjusted. The air baffle was moved 5 mm upwards in one variant and 5 mm lower in the other variant. In the event of a change in the level of the air baffle, the drain area will change, which will result in a change in the hydraulic conditions. The drain velocity changes at the drain, which results in a change in the flow. This adjustment further changes the value of the loss factor at the point of the drain edge. The level of the air baffle was changed precisely in order to determine the behavior of the water outflow at the drain of the siphonic drain and the dependence of the drain surface on the flow. The section of the proposed variant of the siphonic drain is evident from Figure I.

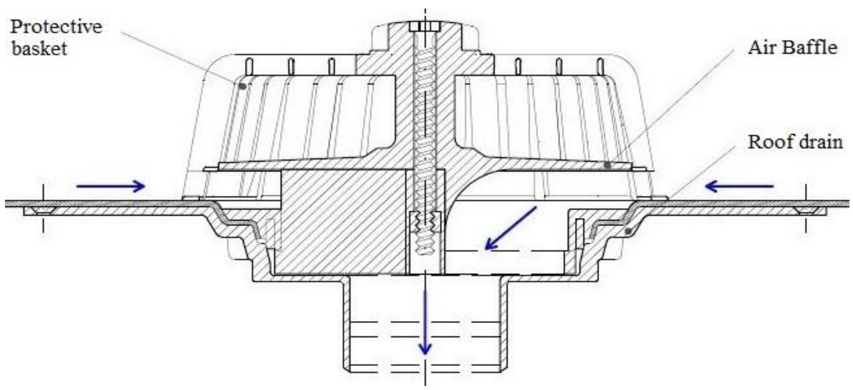

Figure I: Roof drain section

The method of attaching the air baffle, the protective basket and the drain body was the same for all the above-described variants of the siphonic drains. Three vertical lamellas are guided in the middle of the proposed variants of siphonic drains, which direct the flow of outflowing water. Said lamellae are connected as a whole by means of a ring which is guided along the edge of the lamellae. This insert is pressed between the drain body and the drain flange and thus forms an inseparable part of the drain body. The insert is evident from Figure II.

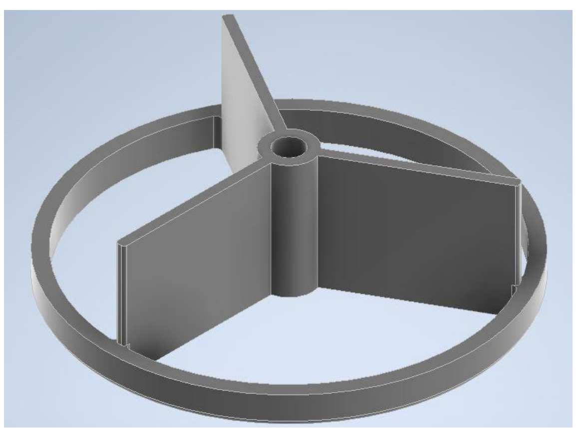

Figure II: Roof drain insert

MEASURING EQUIPMENT AND LABORATORY MEASUREMENTS

The measuring device, for measuring flows, local losses and pressures, will be assembled according to CSN EN 1253 - 2: Gullies for buildings - Part 2: Roof drains and floor gullies without trap.

The arrangement of the test equipment for measuring flows through siphonic roof drains has several conditions that should be met. Failure to observe some condition can lead to a state in which we would obtain only irrelevant values from the measurement. In justified cases, it is possible to change or violate any of the conditions, but we cannot always do so. For example, the construction height of a measuring device cannot be chosen lower than specified in the standard. The reason is that the given height is the minimum height at which the siphonic effect of water flow in the system is created. With a lower height of the measuring device structure, this siphonic effect would work incorrectly, or it might not be created at all [5].

MEASURING EQUIPMENT

The measuring device consists of subcomponents, including a circular or square storage tank with a diameter or side length of at least 1.75 m. The tank can be placed, for example, on a supporting lattice structure and must be at least 4.2 m above the control valve. The control valve is located at the bottom of the downpipe, ie at the point where the flow passes from the siphonic mode to the gravity mode. The siphonic roof drain must be installed in a vertical position, it must also be placed in the middle of the storage tank, so that the flowing water is not affected by the side wall and also so that the water flows symmetrically towards the drain. The inflow of water into the tank must prevent the formation of a water vortex which could adversely affect the measured values. A measuring point for measuring the height of the water swell, 500 ± 5 mm from the center of the roof drain, must be located above the tank at two opposite points. A level measurement with a tolerance of ± 2 mm must be provided in the storage tank [5]. The value of the level height, resp. The height of the water swell on the simulated roof is marked with the letter h. The zero point for measuring the height of the swell must be the upper edge of the water overflow, from which the water overflows into the drain and drains through the drain pipe. For the purpose of observing the flowing liquid, a glass part of the pipe must be installed on the drain pipe [5].

In order to be able to perform measurements, we need a water source (we can use a second collection tank, which we place at floor level) and a pump to transport water to the upper tank.

LABORATORY MEASUREMENTS

The measuring device consists of an upper tank measuring 1800 mm × 1800 mm × 500 mm. The tank was placed on a supporting structure at a height of 5250 mm above floor level. The inflow to the tank is directed to the corners of the tank and is provided by four inflow pipes in DN100. The level fluctuation that occurs when water enters the tank was prevented by submerged walls. The main, ie vertical, part of the DN150 discharge series is equipped with a flow meter and control valve. The drain pipe DN75 is situated in the middle of the upper tank and is led to the lower tank, the bottom of which lies at floor level. The diameter and height of the lower tank are identical, their value is 1500 mm. Pumping into the upper tank is ensured by a hydrodynamic centrifugal pump, which is located at floor level. The measurement of the height of the water level above the overflow edge is ensured by means of a caliper, which is mounted on a beam lying on the upper tank.

The course of laboratory measurement takes place under the conditions described below and its successful completion is considered when we measure the flow values for all water level heights above the measured drain. The recording of the flow values can start at least 5 minutes after the water level in the tank has stabilized. When measuring, we are interested in the water level height of 55 mm (standardized water level height for the siphonic drainage system). Minimum flow values are also specified in the standard. For the drain solved by us, we will consider the dimension 75 mm (DN75), for which the flow is at least 12 $l \cdot s^{-1}$ [5].

When measuring the siphonic drain and its variant modifications, the flow value was recorded for predetermined values of the water level on the simulated roof, ie 5 mm, 15 mm, 25 mm, 35 mm, 45 mm, 55 mm and 100 mm. In the immediate vicinity of the drain, the level is reduced, which is caused by the outflow of water towards the siphonic drain. For this reason, the height of the water swell was measured at a distance of 450 mm from the drain axis. This is the distance at which the level reduction should no longer occur.

When measuring each water level, a total of 11 flow values were recorded with a reading of one minute. The values were recorded only after the water level on the simulated roof was properly stabilized. From the measured values, the arithmetic mean was then calculated, which enters, together with the height of the water level on the simulated roof, into the graph. This graph represents the outflow curve of the tested siphonic drain

Stabilization of the water level in the upper tank was performed using a control valve, which was mounted on the discharge branch. After the level has stabilized, the amount of water at the drain to the tank is equal to the amount of water at the tank outlet.

MEASURED VALUES

The tables I – III below show the measured flow values for the given water swelling heights when measuring siphonic drains. From each row of the table, the flow values over time are shown for each water level above the simulated roof. It can be stated that the highest hydraulic capacity, with a value of 18.38 $l \cdot s^{-1}$ at a water swell height of 55 mm, is reached by the first variant of the siphonic drain. The value for the second variant is 18.32 $l \cdot s^{-1}$. In comparison, a difference of only 0.06 $l \cdot s^{-1}$ is obtained, which corresponds to a 0.33% decrease in hydraulic capacity. Unfortunately, the value of the hydraulic capacity for a water level of 55 mm in the third variant was not measured. The measurement for the given variant was completed at a height of 35 mm. The reason was the exhaustion of the drain capacity, which did not increase depending on the increasing height of the water level on the simulated roof, at the same time the outflow was accompanied by loud noise. The measured data enter the graph, which is evident from Figure III.

Table I: Measured values of hydraulic capacity for designed siphonic drains

water level [mm]	0. min	1. min	2. min	3. min	4. min	5. min	6. min	7. min	8. min	9. min	10. min
0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5	0.30	0.50	0.38	0.39	0.55	0.42	0.30	0.30	0.56	0.38	0.44
15	2.92	2.93	2.89	2.82	2.95	2.93	2.84	2.95	2.65	2.74	2.80
25	9.06	8.96	9.19	8.94	9.05	8.87	9.05	8.73	9.04	9.15	9.03
35	10.30	13.93	14.11	13.82	14.12	14.21	14.08	14.05	14.15	14.13	14.06
45	18.11	18.23	17.96	18.06	18.10	18.23	18.07	17.97	18.21	18.01	17.84
55	18.47	18.30	18.12	18.46	18.42	18.37	18.64	18.49	18.49	18.28	18.13
100	18.27	18.46	18.64	18.64	18.50	18.32	18.67	18.52	18.88	18.52	18.53

Table II: Measured values of hydraulic capacity for designed siphonic drains: the air baffle is located above

water level [mm]	0. min	1. min	2. min	3. min	4. min	5. min	6. min	7. min	8. min	9. min	10. min
0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5	0.78	0.51	0.60	0.56	0.60	0.84	0.72	0.60	0.61	0.80	0.55
15	4.09	4.32	3.88	4.08	4.01	3.71	3.82	3.96	3.96	3.85	3.95
25	8.10	8.53	8.37	8.47	8.22	8.56	8.52	8.31	8.25	8.30	8.89
35	13.50	13.11	13.53	13.48	13.26	13.30	13.42	13.30	13.63	13.38	13.41
45	17.99	18.21	18.25	18.07	17.90	18.32	18.05	17.91	18.09	17.95	18.27
55	18.17	18.25	18.45	18.60	18.23	18.03	18.15	18.65	18.21	18.46	18.35
100	18.35	18.73	18.67	18.34	18.92	19.11	18.09	19.36	19.25	18.68	18.57

Table III: Measured values of hydraulic capacity for designed siphonic drains: the air baffle is located below

water level [mm]	0. min	1. min	2. min	3. min	4. min	5. min	6. min	7. min	8. min	9. min	10. min
0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5	0.97	1.20	1.05	0.97	1.07	0.86	0.77	1.09	0.97	0.94	0.99
15	3.92	3.85	3.91	3.70	3.89	3.73	3.92	3.89	3.75	3.92	3.94
25	8.97	8.70	9.07	8.92	8.85	8.66	8.91	8.68	8.73	8.95	9.03
35	14.60	14.66	14.43	14.81	14.75	14.60	14.65	14.84	14.79	14.73	14.66

The graph shown in Figure III represents the outflow curves of the siphonic drains, i.e. the dependence of the flow rate and the height of the water swell on the simulated roof. The horizontal axis represents the values of hydraulic capacity in $l \cdot s^{-1}$ and the vertical axis the height of water swell in mm. The orange line at the level of 55 mm shows the value at which the minimum value of hydraulic capacity is to be met, see above [5].

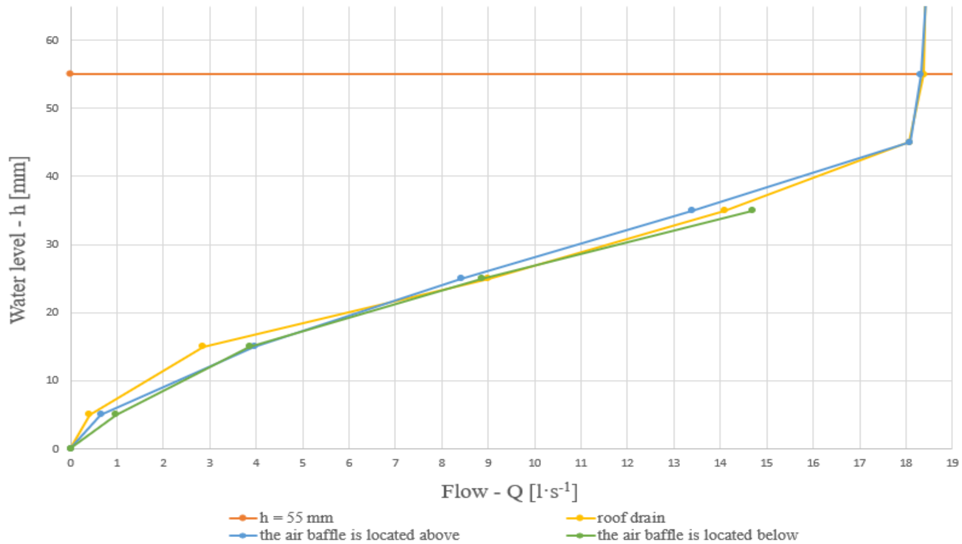

Figure III: Outflow curves of proposed variants of siphonic drains

Figure IV shows photographs of a transparent drainage pipe, from which the flow of water flowing out during the testing of siphonic drains is visible. The water flow in the drain pipe is valid for a water level of 55 mm. The photographs show the full flow for both tested variants of siphonic drains. For the first two alternatives of the siphonic drain, a siphonic effect occurs, ie full flow, already at water level heights of 45 mm, which is indicated by the measured flow values. At lower water level some of the air entered the system, resulting in the system not working efficiently. Vibration and considerable noise are generated when air enters the system [4].

The hydraulic conditions in the drain pipe for the first two variants are very good and reach almost identical values. In the third variant, the measurement was performed only up to a water level of 35 mm, which is the height at which full flow was not reached and the system did not operate under siphonic. The water stream at this stage contained a considerable amount of air particles

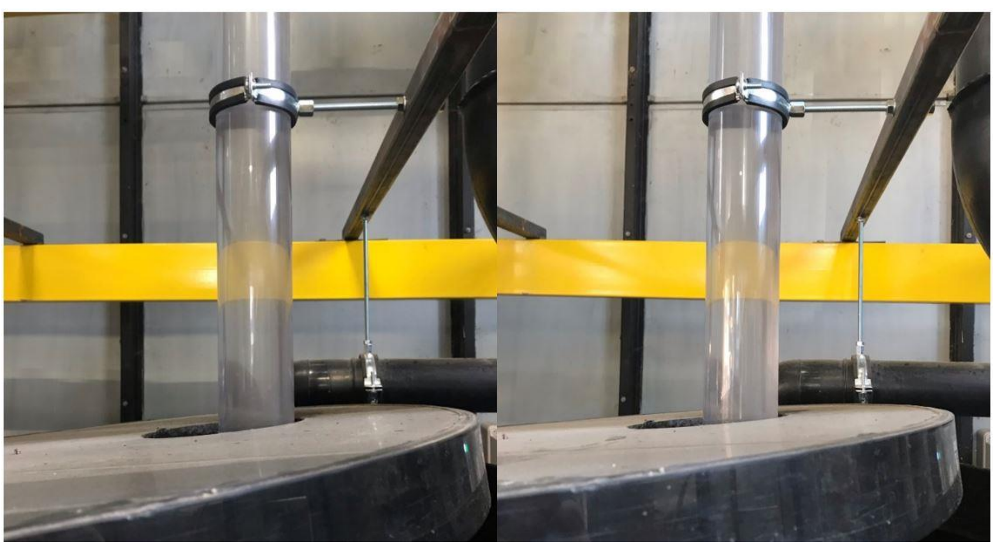

Figure IV: Flow in the drain pipe valid for a water level of 55 mm

CONCLUSION

Following the performed testing and evaluation of the hydraulic capacity and hydraulic conditions of the proposed variants of siphonic drains, it can be stated that the best results were achieved with the first variant of the drain. The siphonic drain meets the condition of minimum hydraulic capacity, which is given according to CSN EN 1253-2. The value of the limit hydraulic capacity is $12.00\ l\cdot s^{-1}$ at a swelling height of 55 mm. The hydraulic capacity of the siphonic drain for a swelling height of 55 mm is $18.38\ l\cdot s^{-1}$, ie 53.16% increase compared to the limit value. At this swelling height, the condition of full flow is also met, when the system works optimally.

In the second variant of the measured siphonic drain, almost similar results were achieved as in the first variant. It follows that an increase in the level of the air barrier, with a consequence of an increase in the drain area, does not have a large effect on the resulting flow values. Furthermore, it has been found that lowering the level of the air barrier is not very appropriate. When the level of the air barrier is reduced, we reduce the maximum possible flow capacity of the siphonic drain. When the drain area is reduced, the speed of the water flowing into the drain also increases, which leads to considerable turbulence and further to the formation of strong noise. Furthermore, in this variant, the full flow of water in the drain pipe was not achieved, the reason being that the drain cannot transfer the flow that can transfer the drain pipe in the dimension of 75 mm.

ACKNOWLEDGEMENTS

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USE OF CULTURAL LANDSCAPE RETENTION CAPACITY IN THE AREA OF THE EASTERN SLOVAK LOWLAND

Richard Hanzlík[1]

Ľuboš Jurík [2]

Jozefína Pokrývková[3]

Peter Lukáč[4]

[1] Department of Water Resources and Environmental Engineering, Faculty of Horticulture and Landscape Engineering, Slovak University of Agriculture in Nitra, Hospodárska 7, 949 01 Nitra, Slovakia, e-mail: hanzlik.richard94@gmail.com

[2] Department of Water Resources and Environmental Engineering, Faculty of Horticulture and Landscape Engineering, Slovak University of Agriculture in Nitra, Hospodárska 7, 949 01 Nitra, Slovakia

[3] Department of Water Resources and Environmental Engineering, Faculty of Horticulture and Landscape Engineering, Slovak University of Agriculture in Nitra, Hospodárska 7, 949 01 Nitra, Slovakia

[4] Department of Water Resources and Environmental Engineering, Faculty of Horticulture and Landscape Engineering, Slovak University of Agriculture in Nitra, Hospodárska 7, 949 01 Nitra, Slovakia

ABSTRACT

Retention function means the holding of surface or infiltrated water runoff in the landscape and its use in a given locality. The aim of the work is to find out the possibilities of using the retention capacity of the current landscape and built water management works in the Easter Slovak Lowland for the needs of flood and drought protection. The solved area is defined by the district of Trebišov. It is a large flat area whose altitude does not exceed 200 meters above sea level, is influenced by a number of natural factors that interfere with the solution of flood protection. After a comprehensive mapping of local conditions in relation to water management facilities, we solve the need of the maximum accumulation potential of watercourse beds and drainage channels for retention in the country use.

Keywords: Eastern Slovak Lowland, landscape retention capacity, potential, channel

INTRODUCTION

The running water is the most active factor transforming the landscape on the earth's surface. Waterways erode, transport and deposit rocks and sediments to create relief, such as canyons, valleys, deltas, alluvial meadows and floodplains. Streams (any flow of water in a natural channel, regardless of size) are the most important channel flows that affect the landscape. The upper streams of the watercourse are the place where the stream originates, usually at higher elevations of the mountain terrain. The stream flows down the hill and through lower altitudes to its end, where it enters another stream, lake or ocean. This end is called the mouth of the stream [2].

As with all aspects of the water cycle, the interaction between precipitation and surface runoff varies with time and geography. Surface runoff is influenced by meteorological factors, as well as geology, pedology and topography of the landscape. Only about a third of the rainfall that rains to the mainland flows into streams and rivers and returns to the oceans. The other two thirds are evaporated or soaked (infiltrated) into groundwater. Surface runoff can also be diverted by humans for their own use [3].

Hoogestraat also notices in her article [3]:

- Meteorological factors influencing runoff: type of precipitation (rain, snow, rain with snow, etc.); precipitation intensity, amount of precipitation; duration of precipitation; distribution of precipitation in the collector area; direction of storm movement; precipitation that occurred earlier and saturated the soil and other meteorological and climatic conditions that affect evapotranspiration (temperature, wind, relative humidity, season).
- Physical properties affecting runoff: land use; vegetation; soil type; drainage area; the shape of the basin; height above sea level; topography (especially slope); channel drainage networks; ponds, lakes, water reservoirs in the basin (delaying or preventing runoff from continuing downstream).

The following factors have an impact on slowing down the water runoff from an agricultural use basin area [4]:

- terrain configuration,
- method of land use.

Surface runoff from the area causes erosion and deposition of eroded particles, including humus, in the lower parts of the area. This phenomenon is extremely dangerous and results in soil degradation and damage and redistributes material on the slope [1].

Subsurface runoff is the outflow of water through a permeable rock environment. Even when water flows below the Earth's surface, water is enriched with various substances. Groundwater reserves are formed in areas with impermeable subsoil [4].

Two basic approaches to flood protection are often at odds. The first is based on the assumption of a significant effect of the landscape retention capacity, which can in fact prevent the formation of surface runoff and the formation of floods and can significantly transform the flood wave. The second approach argues that the country's retention capacity is almost negligible and that the only reliable flood protection can be provided by extending the technical structures of flood protection measures mainly and directly on watercourses [5].

MATERIALS AND METHODS

The solved area is defined by the district of Trebišov. It is a large flat area whose altitude does not exceed 200 meters above sea level and is influenced by a number of natural factors that interfere with the solution of flood protection. From a pedological point of view, most heavy clay soils occur in most areas, with a very low intensity of water infiltration, which causes excessive surface runoff from the area. From a hydrological point of view, the Eastern Slovak lowland is interwoven with a number of rivers, such as the Ondava, Topľa, Laborec and Latorica (Figure 1). From a climatic point of view, it is a warm area with an average temperature of around 18 °C in the summer months and around -3 °C in the winter months [6].

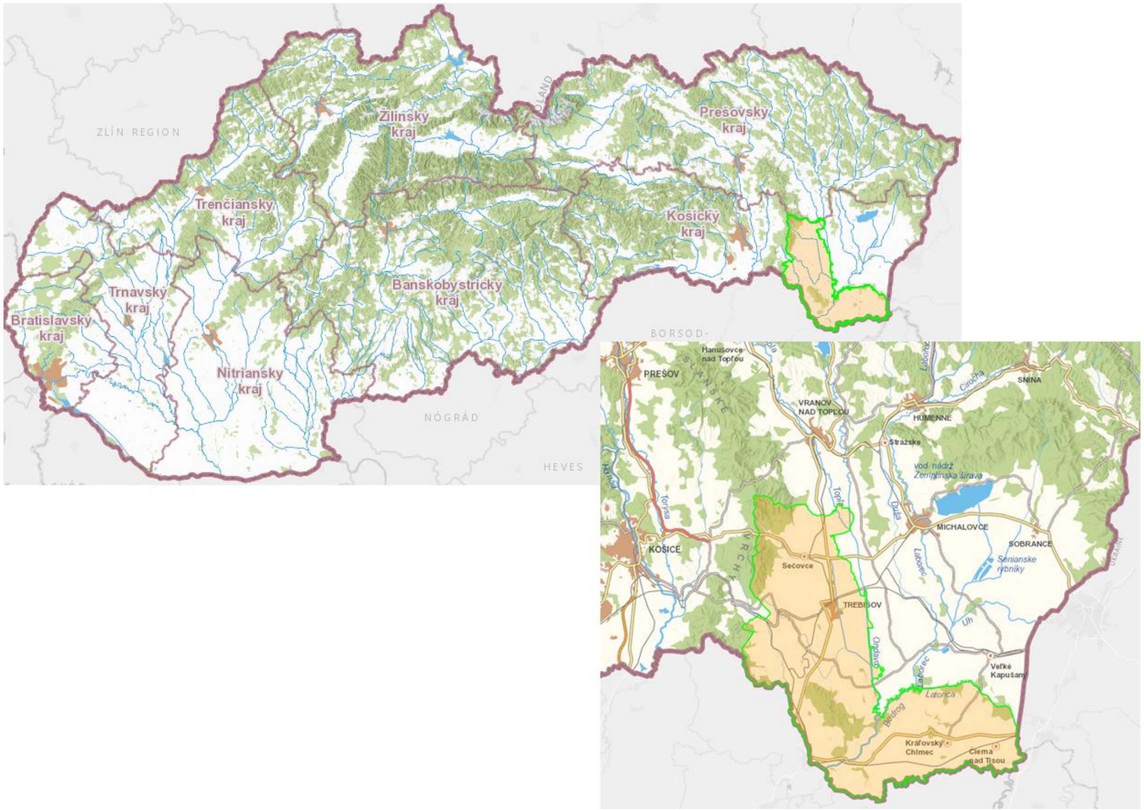

Figure I: Situation of the district of Trebišov in the Eastern Slovak lowland (ZBGIS, 2021).

Hydromelioration channels in the solved area

According to Hydromeliorations, s. e. from 2015 we record the following hydromelioration channels [7], [8], [9]:

- The Hospodársky channel (ev. no. 5 412 057 001) is located in the cadastral area of Trebišov. The channel begins west of the town of Trebišov, leads south to southeast and empties into the Čerjaky channel, which then empties into Trnávka (Figure 2).

- The Sirník channel (ev. no. 5 412 075 001) is located in the cadastral areas of Hraň and Sirník. The route of the channel begins east of the village of Hraň, leads south and flows into the Ondava above the village of Sirník (Figure 3).

- The channel 02 (ev. no. 5 412 200 003) is located in the cadastral area of Bačkov. The channel begins in the field, at a distance of about 0.5 km from the southwestern edge of the built-up area of the village Bačkov (Figure 4). The route of the channel leads approximately in a southeast-east direction and from the road Kravany - Sečovce it continues through the channel K3 (ev. no. 5 412 206 001).

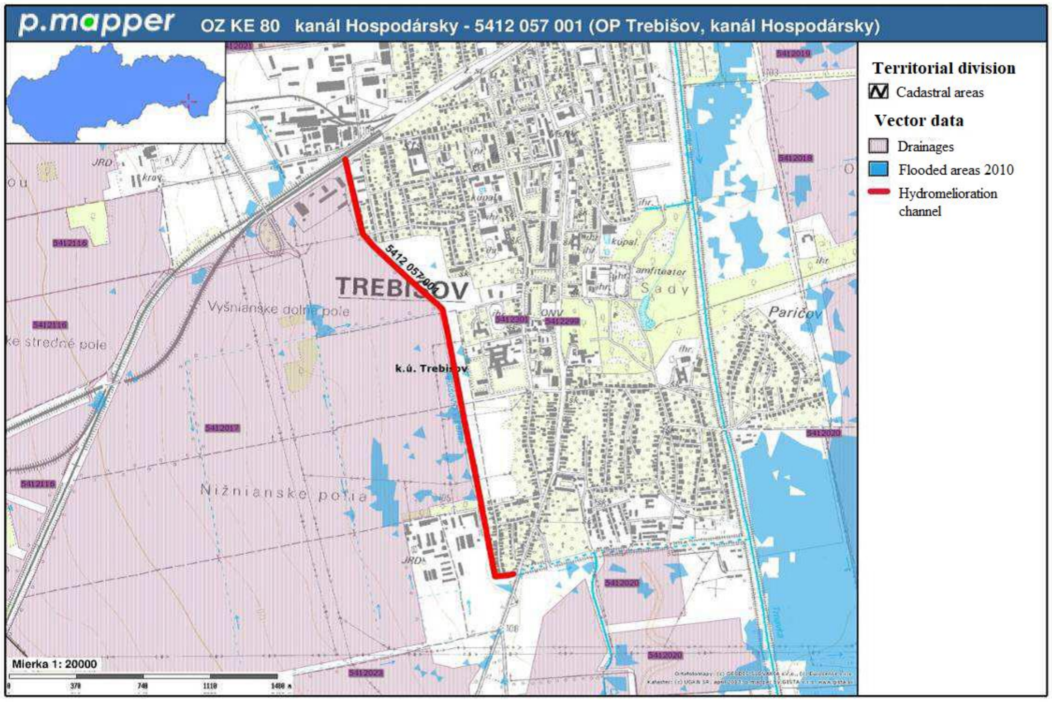

Figure II: Situation of channel Hospodársky - ev. no. 5 412 057 001 [7].

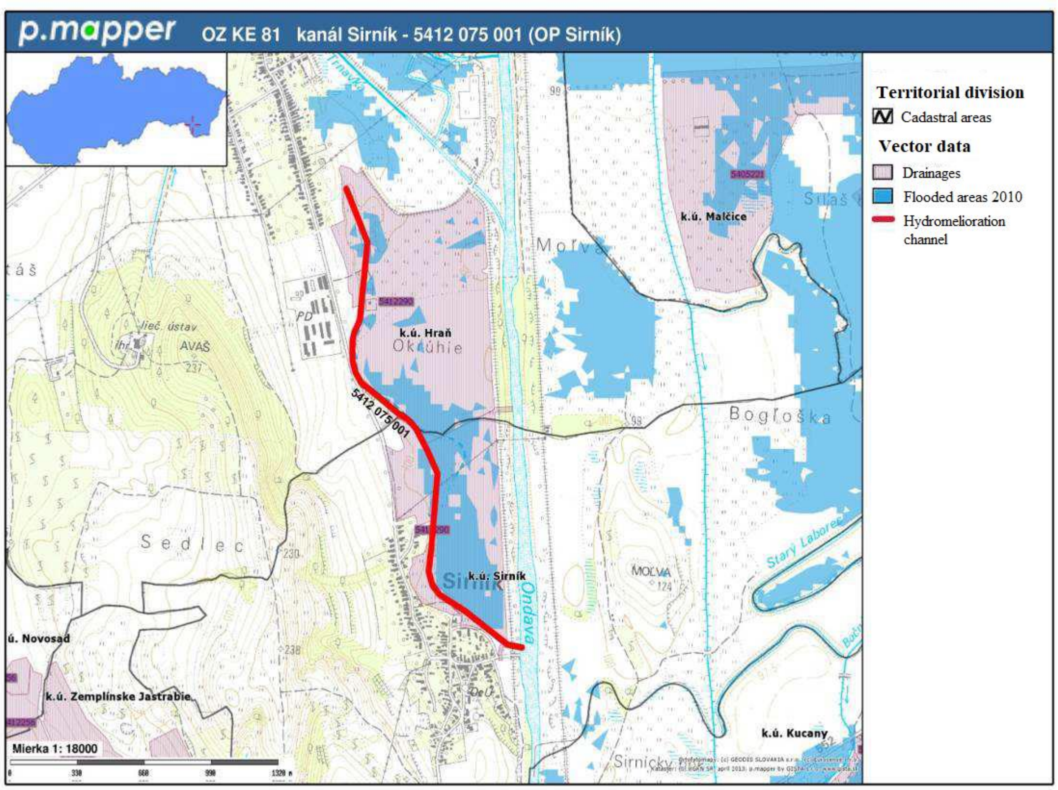

Figure III: Situation of channel Sirník - ev. no. 5 412 075 001 [8].

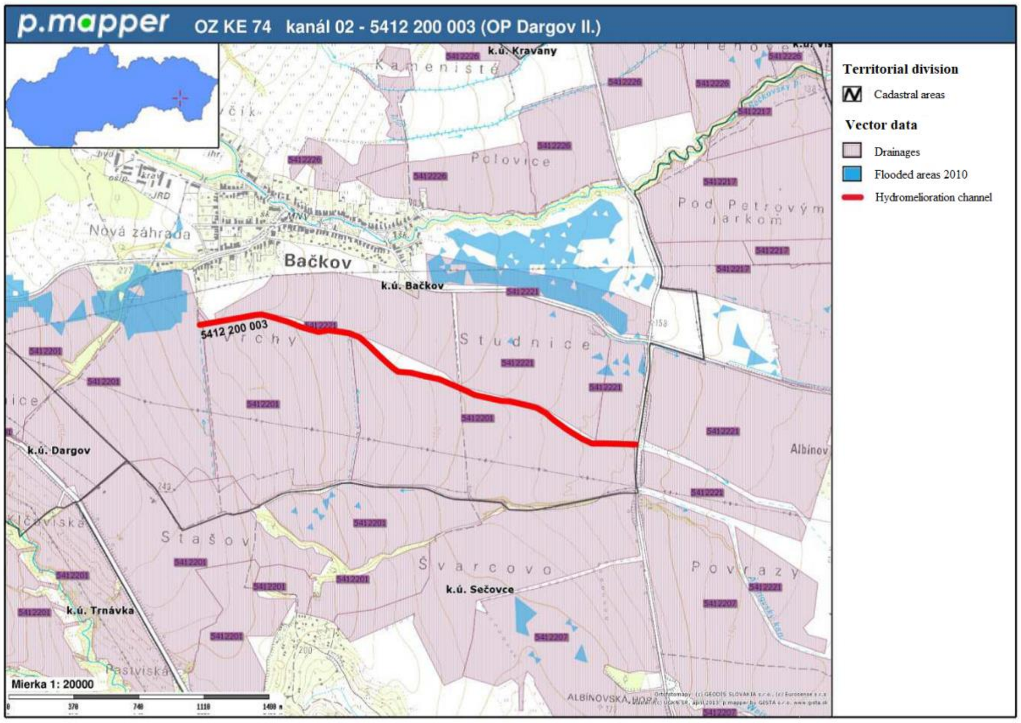

Figure IV: Situation of channel 02 - ev. no. 5 412 200 003 [9].

Flood risk assessment

The location is included in a humid subhumid area, which is risky in terms of floods. In the critical year of 2010, when almost all susceptible localities were flooded in Slovakia, floods occurred in the given area. Floods are likely to occur in the area affected by the hydromelioration channels, which are particularly vulnerable to floods caused by prolonged or intense rainfall, melting snow or the simultaneous occurrence of these phenomena, and the possibility of flooding the groundwater above the surface due to prolonged precipitation cannot be ruled out. Therefore, in addition to the main function in the drainage of excess soil water during wet periods, the potential for the use of hydromelioration channels is also in the drainage of internal water during floods. In times of drought, the channels are used to hold water in the affected area. There are on average 50 to 100 days of drought in the area, with a trend of a slight increase in the number of dry days [6].

RESULTS AND DISCUSSION

Hospodársky channel

The hydromelioration channel Hospodársky is located in the town of Trebišov and is 2,760 km long. The proposed and built transverse profile of the channel was trapezoidal, the depth of the riverbed changed and was 1.0; 1.5 and 2.0 m, but the bottom width was constant and was 1.0 m. The fortification of the bottom and slopes of the channel was solved by grassing. At present, the flow profile of the channel is reduced by mud deposits, overgrown with weeds and shrubs. The fortifications of the bottom and slopes are damaged, as well as bridges and culverts, which significantly limit the functionality of the channel. The area affected by the Hospodársky hydromelioration channel has an area of 200 ha. The drainage opens into the channel to 75% of its length and covers an area of 200 ha. The technical solution for the reconstruction of the hydromelioration channel is trivial (Figure 5), because simple, technically undemanding procedures will restore the original function of the existing water structure proposed mainly for the drainage of excess water from the agricultural landscape. Reconstruction of the channel consists mainly in the removal of sediments, weeds and overgrowth trees. It is assumed that the contractor will use standard construction machines for the execution of earthworks (excavators) from the banks of the channel for the reconstruction [7]. It will be necessary to make a fundamental distinction between excavation work in channels with water and in canals without water. The decision on the location of sediments will be important. The sediments meet the conditions for application to arable land in all analysed parameters.

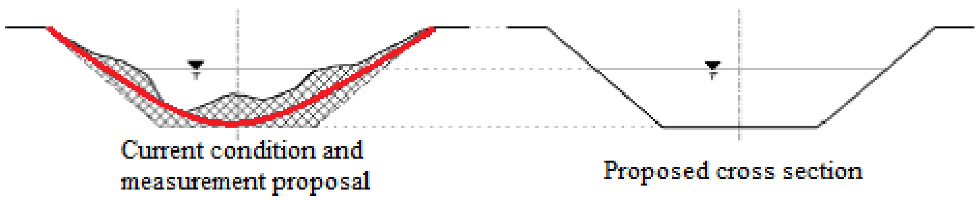

Figure V: Cross section (profile) of the Hospodársky channel [7].

Sirník channel

The hydromelioration channel Sirník is located in the municipalities of Hraň and Sirník and is 2,666 km long. The proposed and built profile of the channel was trapezoidal, the depth of the riverbed was 1.5 - 2.5 m and the width of the bottom 0.5 - 1.0 m. The fortification of the bottom and slopes of the channel was solved by grassing. At present, the flow profile of the channel is reduced by mud deposits, overgrown with weeds and shrubs. The fortifications of the bottom and slopes in the channel are damaged and the bridges and culverts are also damaged, which limits the functionality of the channel. Sluice and flap are not fully functional. The area affected by the Sirník hydromelioration channel has an area of 250 ha. The drainage into the channel opens to 95% of its length and covers an area of 117 ha. The technical solution for the reconstruction of the hydromelioration channel is trivial, because simple, technically undemanding procedures will restore the original function of the existing water structure proposed mainly for the drainage of excess water from the agricultural landscape. Reconstruction of the channel consists mainly in the removal of sediments, weeds and overgrowth trees (Figure 6). It is assumed that the contractor will use standard construction machines for the execution of earthworks (excavators) from the banks of the channel for the reconstruction [8].

Figure VI: Conditions of the Sirník channel before revitalization [8].

02 channel

The hydromelioration channel 02 is located in the village Bačkov and is 2,698 km long. The designed and built transverse profile of the channel was trapezoidal, the depth of the riverbed was 1.5 to 2.0 m and the width of the bottom 0.5 to 1.0 m. The theoretical volume of water in the channels is V = L x S. The usable flow area is about 2 m^2 and the potential volume of water is then V = 2698 m x 2 m^2 = about 5400 m^3. However, this state is dynamic and the volume of water can be retained several times during the year. Similarly, it is possible to determine the potential volume of water in other channels. The surface treatment of the bottom and slopes of the channel was solved by grassing. At present, the flow profile of the channel is reduced by mud deposits, overgrown with vegetation and shrubs. The fortifications of the bottom and slopes of the channel are damaged, which limits the functionality of the channel mainly due to the large roughness. Drainage opens into the channel to 100% of its length and spreads over an area of 244 ha. The proposed functional element, which is a change of the original solution, will be the extension of the channel equipment with small tumblers, thus creating conditions for water accumulation in the period flowing from the collection area (Figure 7), preventing rapid water runoff and offering time retention during dry periods [9]. The volume of the channel space was not stated in the channel documentation, which is actually the potential volume of retained water today. It is necessary to distinguish the state if water flows and the static state of water when the channel is dammed with a tumbler.

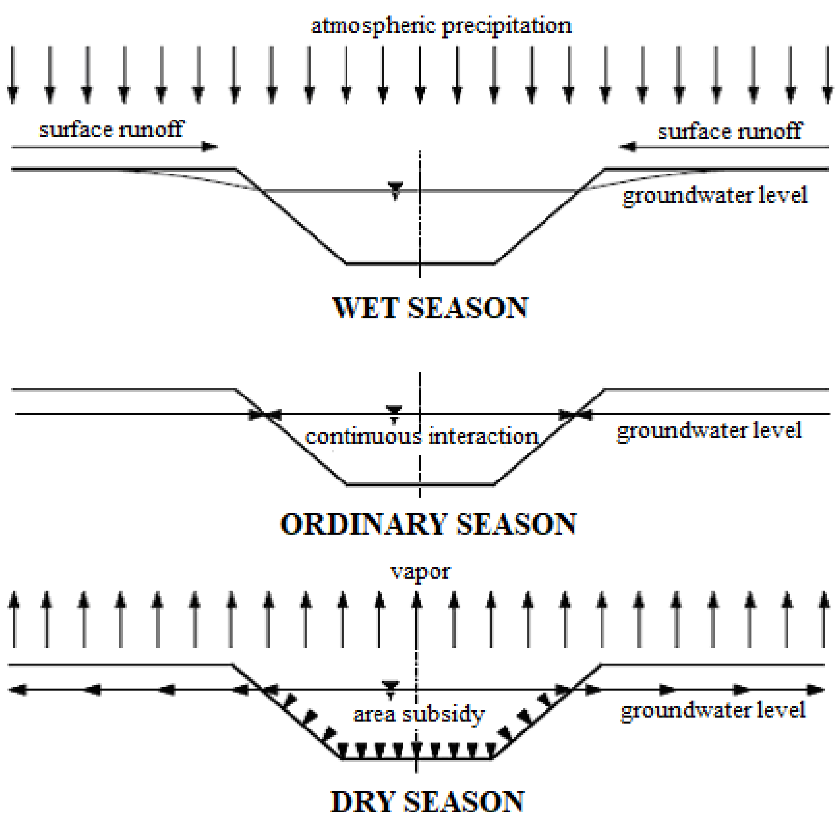

Figure VII: Hydrological water balance and retention capacity of the channel 02 [9].

CONCLUSION

After a comprehensive mapping of local conditions in relation to water management facilities, we solve the need to use the maximum accumulation potential of watercourse beds and drainage channels for retention in the country. We record a total of 14 hydromelioration channels with a total length of approximately 50 km and a surface drainage area of 4250 ha in the given district of Trebišov. Several decades have passed since the construction of the drainage network of channels in the Eastern Slovak lowland, which caused considerable damage to most of the water management structures. Due to their insufficient maintenance and irregular revision, the drainage function of the hydromelioration channels is degraded. After the revitalization and reconstruction of a significant number of hydromelioration channels in 2015, the hydrological water balance in the district of Trebišov and the use of the retention potential of hydromelioration channels improved, thus increasing the retention capacity of the country in the Easter Slovak lowland. The volume of potentially retained water in the transverse profile of the channels to create indigenous water reserves in their localities is also significant.

ACKNOWLEDGEMENTS

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WASTEWATER DISPOSAL – HISTORICAL RESEARCH REVIEW

Jaroslav Hrudka[1]

Marek Šutúš[2]

Marek Csóka[3]

Andrea Raczková[4]

Ivona Škultétyová[5]

[1] Department of Sanitary and Environmental Engineering, Faculty of Civil Engineering, Slovak University of Technology in Bratislava, Radlinského 11, 810 05 Bratislava, Slovakia, e-mail: jaroslav.hrudka@stuba.sk

[2] Department of Sanitary and Environmental Engineering, Faculty of Civil Engineering, Slovak University of Technology in Bratislava, Radlinského 11, 810 05 Bratislava, Slovakia, e-mail: marek.sutus@stuba.sk

[3] Department of Sanitary and Environmental Engineering, Faculty of Civil Engineering, Slovak University of Technology in Bratislava, Radlinského 11, 810 05 Bratislava, Slovakia, e-mail: marek.csoka@stuba.sk

[4] Department of Sanitary and Environmental Engineering, Faculty of Civil Engineering, Slovak University of Technology in Bratislava, Radlinského 11, 810 05 Bratislava, Slovakia, e-mail: andrea.raczkova@stuba.sk

[5] Department of Sanitary and Environmental Engineering, Faculty of Civil Engineering, Slovak University of Technology in Bratislava, Radlinského 11, 810 05 Bratislava, Slovakia, e-mail: ivona.skultetyova@stuba.sk

ABSTRACT

Public sewerage systems were built thousands of years ago. Sewers were primarily used to drain rainwater mixed with sewage. In the development of sanitation on the territory of the Slovak Republic, the first modern methods of management date back to the beginning of the 20th century. The sewerage network has been built on the territory of Bratislava since 1903 and its construction is ongoing until now. The first pantographs were initiated without cleaning directly into the Danube. Only in the second half of the 20th century, the construction of the first Rača WWTP began.

Keywords: history, sewer network, wastewater

INTRODUCTION

The first preserved attempts at public sewerage are dated to the period 4000 BC in the Mesopotamia empire. The pipes, which were made of burnt stone, were preserved and used to drain sewage from homes. In the BC period, there were a number of civilizations that created a sophisticated wastewater management system. For example, the Indus civilization, Minoans, Greece states, and China empires used public sewers to transport wastewater outside the site. But the most sophisticated approach was in the ancient past of the Romans. Their spa and aqueduct system, transporting drinking water as well as the outflow of wastewater, has been redesigned to a high level, as evidenced by the fact that some sewers are still operational after more than 2000 years. After the demise of the Roman Empire, the dark ages came for hygiene and wastewater management. Therefore, in this period up to the beginning of the 19th century. Humanity has also been plagued by many epidemics of bacterial origin, which have been spread on the basis of drinking water that has been contaminated with infectious wastewater. In the next section, we will focus on the history of sewerage at the part of the present Slovak Republic.

HISTORY OF DRAINAGE IN SLOVAKIA

Historically, the oldest objects used in the territory of the Slovak Republic were the walls near the castles. In this simple way, sewage was only transported outside the dwelling to close proximity to the castle, thus not addressing the infectivity of wastewater and thus supporting the spread of diseases. On the territory of the Slovak Republic, the first construction of public sewerage systems dates back to the construction of modern water supply systems. The most developed area of water management was in the field of mining, central Slovakia. This was also due to the construction of the first water mains, needed either for drinking purposes or for the purpose of obtaining technological water for the extraction of ores. The first sewers were built for the purpose of only transporting wastewater outside the built-up area, without the use of any cleaning [1].

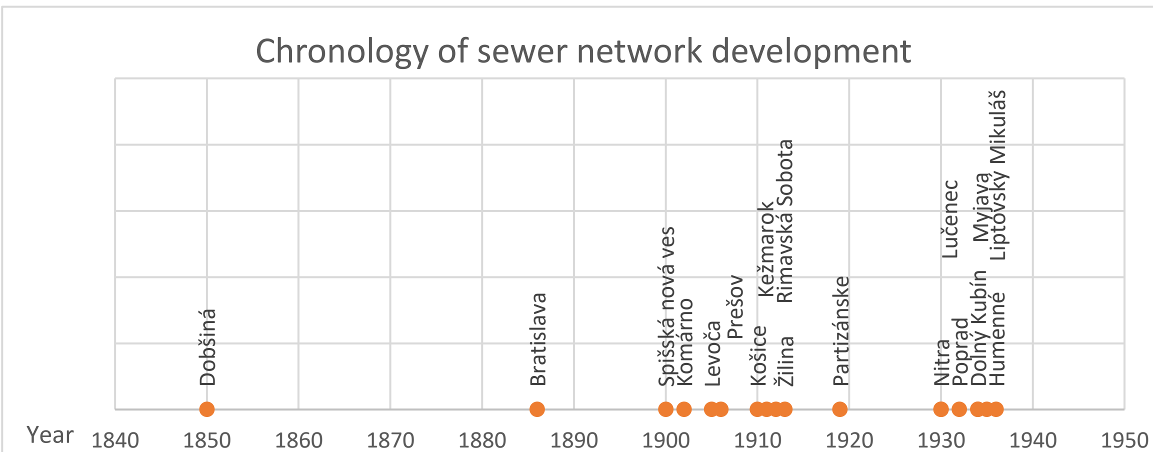

Figure I: Sewer system chronology in area of Slovakia [2]

Water and sewerage systems were built on the basis of a decision of municipalities and towns with subsidies from the state or county. The first sewerage systems were built primarily with a view to saving money without any plan for the development of municipalities. Between 1945 and 1650, only 12.5% of the total population of 3,463,000 million were connected to the public sewer system.

Table I: Sanitation in Slovakia 1950 [3]

The population	3 463 000
% of population supplied from water supply	19,9 %
% of the population connected to the sewer	12,5 %
Total length of the water supply network	1428 km
Total length of sewerage network	580 km
Number of wastewater treatment plants	16

Table I: Development of sanitation in Slovakia [3]

Parameter	**Unit / year**	**1950**	**1960**	**1965**	**1970**	**1975**	**1980**	**1985**	**1990**	**1995**	**2000**
Total population	thousand	3463	3994	4374	4529	4739	4984	5160	5304	5364	5396
Population supplied by water supply	thousand	689	1104	1423	1966	2481	3125	3591	3990	4257	4455
Ratio	%	19,9	27,6	32,5	43,4	52,4	62,7	69,6	75,2	79,4	82,6
Length of water supply network	km	1428	3325	5340	8184	11250	13808	16392	19058	21236	23254
Number of inhabitants connected to the public sewer	thousand	429	785	985	1277	1608	2025	2382	2689	2815	2928
Ratio	%	12,4	19,6	22,2	28,2	33,9	40,4	46,2	50,7	52,5	54,5
Length of sewerage network	km	590	1237	1854	2527	3308	3951	4684	5122	5640	6208

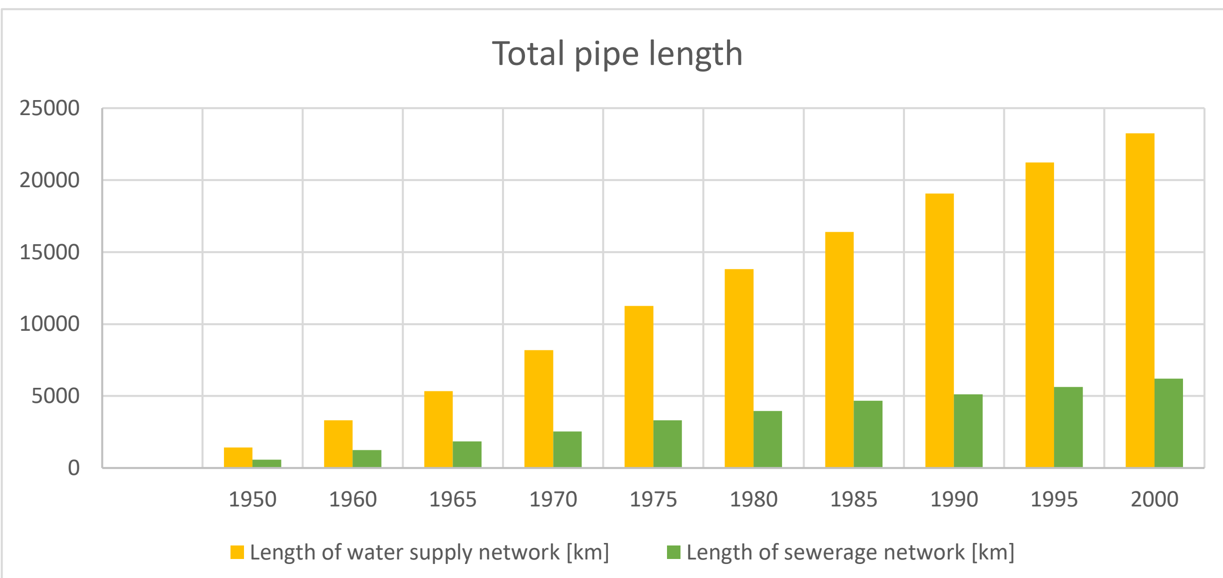

Figure II: Length of sanitation in Slovakia 1950-2000 [3]

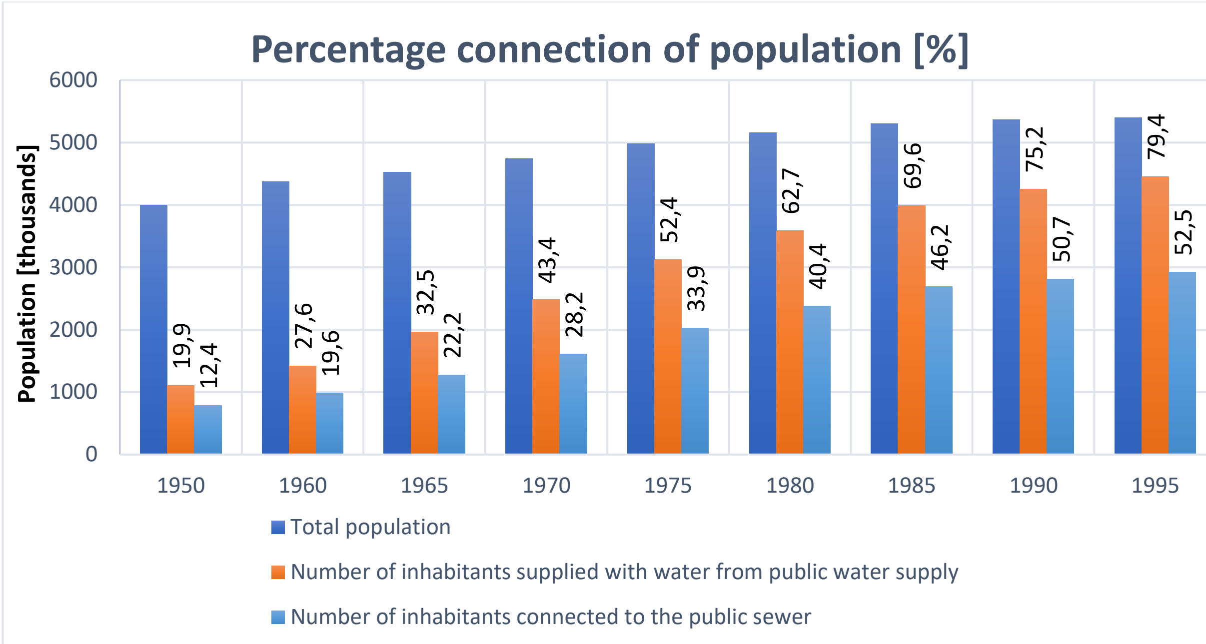

Figure III: Connection to sanitation 1950 – 2000 [3]

BRATISLAVA WASTEWATER SEWER SYSTEM

The history of Bratislava goes back to the prehistorig past. Already during the settlement of the first people in Central Europe, the settlement was established here at a very strategic point: the clash of the Little Carpathians and the Danube. The emergence of the settlement is documented during the early Stone Age. The first documents on the creation of an urbanized water-management area date back to the 10th century when a more sophisticated fortification was created. However, it was only during the reign of Belo IV (1235-1270) that a well was built together with the Wässerturm water tower in Vidriec. This building can be described as the first public water source on the territory of Bratislava. In the following centuries, the city was developed, and thus more water was needed. Gradually, wells were built in the city in several places. Wastewater from dwellings was solved only by surface drainage of waste into rivers. As in the rest of Europe, rigols were built to drain mostly rainwater, in which sewage was mixed from roads that people poured there.

The modern sewerage system has been built since the beginning of the 20th century. In the most urbanized center, the original brick or stone stems were replaced primarily designed for drainage of surface water. The project of a single double-line sewerage network in 1897-1900 was designed by the Water Department of the Ministry of Interior in Budapest. The proposal considered with 80 000 inhabitants the consumption of water 100 l/pers/day and the drainage of atmospheric precipitation125 l/pers/day. Drainage of the upper zone of the city is solved by the main collector A XIV starting at Račianske Mýto. He then continued through the (Slovak National Uprising) SNP Square at the same time, around the Stone Square, and the ase was near Comenius University. At this point, the main A sewer was also powered, which sewerled the lower zone of the city – at the same time the waterfront of Army General Ľ. Svoboda. As part of this project, a wastewater pumping station was also designed at the site of the current winter port. The project also considered the location of a lightening chamber at the site of the old bridge. The aulet collectors were built from original stone or brick stacks, which were powered by new main pantographs.

In 1903, a total of 4.1 km of new sewerage network was seen and in 1905 a gas station in which modern electric motors powered centrifugal pumps with a power of 3 x 1800 l/s were installed. This pumping station was used to pump wastewater over the high water level in the Danube River during floods.

Figure III. Sewer water pump [1]

In 1918, 53 km of public sewerage systems were already built, mostly egg cross-section made of brick material or concrete. The main pantographs were profile 800/1200, 1000/1500, 1200/1800 mm. The aulition sewers were of DN 300 and 300/450 mm respectively. The development of the sewerage system was targeted with the development of the city – towards the current Prague Street and the Tehelné pole. The sewerage project did not consider an enormous increase in the population, which resulted in insufficient capacity of the cane. In 1933, the provincial authority gave the city the task of developing a new sewerage project for the whole city. In 1964 he was invited to solve this project as a leading consultant, acclaimed expert and author of a national methodology for calculating the amount and time of the outflow of atmospheric precipitation Ing. Bartoška. Subsequently, until completion, the project was revolutionary in the proposal to divert the main collector A from the main danube flow, which until then was considered as the main recipient. The newly proposed pantograph was redirected to Vrakune and resulted in the Little Danube. The correctness of this proposal is confirmed by the current very effective functionality of this sewer. In 1938, the sewerage network was revised, which had a total length of 120 km and from this length 27% was significantly underestimated. And they had to be restored[4].

During The Second World War, sewerage practically ceased to be built, except for a few streets in the city center. During this period of war, there was also no maintenance of the existing statues. There was only occasional flushing of sewer collectors. In the post-war period from 1947 onwards, there was a mass expansion of the statues mainly east of the city center. In the first decades, sewers were built directly into the Danube. With the constant increase in wastewater production, it was necessary to start addressing also the quality of the discharged water. As the first treatment plant in Bratislava, a wastewater treatment plant in Rača was built. The year 1958 in the action "Z" was the largest development of public sewerage. During this event, the primary emphasis was placed on the sewerage of new housing estates around the city center. Subsequently, in 1967, the total length of the sewerage system in Bratislava reached 341 km [1].

CONCLUSION

Real functional public sewerage system in the territory of the Slovak Republic was solved only at the beginning of the 20th century. In the previous period, sanitation was handled at least locally, using cesspools and septic tanks. However, with the development of cities, primarily with an enormous increase in the population in cities, the development of sewer networks in the whole territory of the Slovak Republic was also gradually developed. The largest and one of the oldest networks, which is still functional in part even today, is the sewerage network in Bratislava. Some sewers are over 110 years old.

ACKNOWLEDGEMENTS

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INNOVATIVE WAYS OF PROTECTION THE WASTEWATER PUMPS FOR WET ACCUMULATION CHAMBERS

Ľuboš Hurban[1]

Roman Rusnák[2]

Jarmila Božíková[3]

[1] Department of Sanitary and Environmental Engineering, Faculty of Civil Engineering, Slovak University of Technology in Bratislava, Radlinského 11, 810 05 Bratislava, Slovakia, e-mail: lubos.hurban@stuba.sk

[2] Aqua4um s.r.o., Clementisova 1, 949 01 Nitra, Slovakia, e-mail: rusnak@aqua4um.sk

[3] Department of Sanitary and Environmental Engineering, Faculty of Civil Engineering, Slovak University of Technology in Bratislava, Radlinského 11, 810 05 Bratislava, Slovakia, e-mail: jarmila.bozikova@stuba.sk

ABSTRACT

At present bar screen, mechanically scraped bar screens or sieves are used for capturing solids in wastewater pumping stations. Accordingly, current technologies require frequent human intervention into the process. Necessary handling of caught solid particles (rakings) that have been removed from the pumping station and transported to waste dump or wastewater treatment plant is a disadvantage of baskets, bar screens and sieves. In these cases, operation services of pumping stations are financially demanding due to frequent dispatch of maintenance workers to pumping stations. New solution will be lead to a reduction in the service costs of the pumping station itself.

Keywords: PUMP PROTECTOR™, self-cleaning, filtration, separator

THE CURRENT STATE OF KNOWLEDGE

At present bar screen baskets and manually or mechanically scraped bar screens or sieves are used for capturing solid particles in wastewater pumping stations. Accordingly, current technologies require frequent human intervention into the process. However, long-term and comprehensive experiences in operating such pumping stations show that said devices suffer from significant drawbacks. Necessary handling of caught solid particles (rakings) that have to be removed from the pumping station and transported to a waste dump or to a wastewater treatment plant is a disadvantage of baskets, bar screens and sieves.

There are also cases when no devices for separating those particles are installed into pumping stations. In those cases, pumps having greater throughput rate and comprising crushing devices are chosen.

When choosing a pump enjoying a greater throughput rate, pumping over greater solid particles anticipated in wastewater is provided, however, it is a common practice that greater solid particles in wastewater tend to clump. If a pump sucks such a cluster having dimensions greater than a maximum possible throughput of an impeller of the respective pump the pump blocks. Such situations occur in practice quite often.

On the other hand, pumps comprising a crushing device often suffer from rapid abrasion of crushing devices resulting in their non-functioning. Consequently, the pumps are blocked and damaged, which require physical cleaning of pumps or their maintenance.

In these cases, operation services of pumping stations are financially demanding due to frequent dispatch of maintenance workers to pumping stations. Handling the rakings and pump cleaning often result in contamination of surroundings of a pumping station by wastewater.

POLLUTION IN WASTEWATER

Wastewater is chemically polluted with organic and inorganic one's substances. Pollution in wastewater is assessed according to a) physical, b) chemical, c) biological indicators.

From a physical point of view, depending on the size of the dispersed particles, these may be present in the flow wastewater as:

- crude substances
- sand
- insoluble (suspended) as settable, non - settable and buoyant
- dissolved in true solutions as ionically dissolved (electrolytes) or as non-ionically dissolved (non-electrolytes)

Physical indicators of wastewater pollution also include:

- concentration hydrogen ions pH,
- temperature,
- color,
- alkalinity,
- conductivity and
- odor.

The chemical indicators include:

- organic substances in particulate form or as dissolved, by indirect parameters organic substances are BOD and COD, a direct indicator is TOC,
- biodegradable substances, their indicator being biochemical oxygen demand usually and 5 days (BOD)
- not readily biodegradable or non-biodegradable substances the organically bound carbon (Corg) indicator reported in abroad as TOC (Total Organic Carbon) or DOC (Dissolved Organic Carbon).

Biodegradable substances in sewage represent three main groups: a) carbohydrates such as carbohydrates, starch and cellulose, b) proteins represented by amino acids and urea, c) lipids. Microbial contamination is detected by the number of bacteria (KTJ / ml or KTJ / 100 ml) of coliforms, whose presence in water is a good indicator of faecal contamination as well as the number of bacteria mesophilic and psychrophilic. [1]

THE ESSENCE OF THE TECHNICAL SOLUTION

Wastewater containing solid particles flowing through an inlet pipe into a wet accumulation chamber is directed to the separation chamber through a supply pipe. It further flows from the separation chamber through the solid particle's separator via the bidirectional pipe and through a pump into the wet accumulation chamber. The solid particles separator captures solid particles and thereby they accumulate in the separation chamber. Particles having higher dimensional weight (sand, gravel) than a pumped medium accumulate at the bottom of the separation chamber due to sedimentation and they do not pass further onto a pump impeller. After starting the pump pressurized water is pumped back from the wet accumulation chamber through the bidirectional pipe, solid particles separator and through the separation chamber into the discharge pipe and further to a sewerage network. Simultaneously, the separator is washed by reverse pumping of wastewater. A reversing valve precludes reverse flow of wastewater into the supply pipe.

A solid particle is understood to be a solid particle having dimensions exceeding a throughput rate of a pump impeller installed in a pumping station or a particle capable of causing abrasion of blades of the pump impeller. Sand, gravel as well as fabrics, hygienic tissues, foils of various types, clusters of various materials and the likes can form the solid particle.

Preferably, the separation chamber is shaped as a cylinder that may be arranged either vertically or horizontally. The separation chamber comprises an upper part, bottom and side wall/walls. The separation chamber further comprises openings for respective pipes.

A bidirectional pipe and a discharge pipe are attached in a lower part of the separation chamber so that their orifices are situated opposite each other across the separation chamber. The lower part of the separation chamber is meant to be a space immediately above the bottom of the separation chamber. Such arrangement results in that solid particles pumped together with wastewater accumulated at the bottom of the separation chamber are discharged from the separation chamber into the discharge pipe and transported further to the sewerage network or to the wastewater treatment plant. That results in self-cleaning of the separation chamber from separated solid particles.

Preferably, the supply pipe is situated so that it opens into the separation chamber on its top. The reversing valve may consist of for example a seat and a float ball. During pumping water pressure presses the float ball into the seat preventing backflow of wastewater.

Preferably, the discharge pipe directs from a side wall of the chamber first obliquely upward at an angle of 30° to 70° with respect to the bottom of the separation chamber, more preferably at an angle of 50° and then it is curved so that it is directed perpendicularly upward. It is an advantage of said embodiment that the pipe does not include a right angle and solid particles are discharged through the discharge pipe without any problems by water pressure.

According to another preferred embodiment the bidirectional pipe is branched. One branch opens through a side wall into the lower part of the separation chamber, like in the previous case, and the other branch opens through the side wall into the upper part of the separation chamber. The upper part of the separation chamber is understood as a space of the separation chamber below the reversing valve. Both branches are attached to the separation chamber through an individual solid particles separator. Branching of the bidirectional pipe into two height levels results in enhancement of hydraulic characteristics in the separation chamber. After the pump is switched on, pressurized flow is partially directed through one branch of the bidirectional pipe to the upper part of the separation chamber and a part of the pressurized flow is directed through another branch of the bidirectional pipe to the lower part of the separation chamber. Said results in mixing of the contents of the separation chamber in the immediate moment prior to the discharge of the captured solid particles into the discharge pipe itself. The self-cleaning effect as such is even increased by the present solution and a risk that the separation chamber is not completely cleared of the separated solid particles is minimal.

Greater filtration capacity of the device that also deals with eventual occurrence of an impact plurality of deposited solid particles is another advantage of the branched bidirectional pipe. Said situation is not exceptional in the practice of sewerage network operations. Accumulation of solid particles at the bottom of the separation chamber may result in partial or total blockage of the flow capacity (clogging) of the first solid particles separator positioned in the lower part of the separation chamber. In the branched bidirectional pipe wastewater filtration will continue through the second solid particles separator positioned in the upper part of the separation chamber and through the upper branch of the bidirectional pipe. After the pump is switched on, wastewater is pumped reversely causing washing the separators and cleaning the separation chamber.

According to another embodiment the supply pipe is in the form of an inlet channel. From a certain height walls of the inlet channel are provided with filtration perforations. The function of the channel is on one hand directing water into the separation chamber, but simultaneously also separation and filtration of storm sewage through perforations in the side walls of the channel. Size of perforations in the side walls of the channel is dimensioned according to the throughput rate of the pump impeller installed in the pumping station. Arrangement of perforations on the walls, their amount and design are determined by the value of the maximal critical inlet into the pumping station. Accordingly, an average daily flow is securely let into the separation chamber through the inlet channel and eventual critical flow is passed through the filtration perforation directly into the wet accumulation chamber in order to avoid flooding of the separation chamber. Filtration perforations prevent passing the solid particles of sizes greater than the throughput rate of the pump impeller into the accumulation chamber and said solid particles are passed through into the separation chamber by the channel.

The accumulation chamber may comprise a plurality of pumps, in that case each pump is provided with a separate device according to the present solution. Said devices may, however, share one supply pipe or inlet channel.

A sieve having opening sizes dimensioned according to the throughput rate of a pump impeller may be a solid particles separator. A disadvantage of the sieve is that it is quickly clogged, in particularly, when there are fabrics or disposable hygienic tissues and the like in wastewater. In addition, when wastewater is pumped reversely the separator is only partially washed as the said fabrics tend to enmesh into the sieve.

According to a preferred embodiment a device according to the present technical solution may comprise a rod solid particles separator. The rod separator consists of a frame provided about the inner circumference with rods having at minimum two or three or more lengths. The frame may preferably be of an annular shape. Alternatively, the outer circumference of the grame may be of a square, rectangular or other geometric shape. Rods are arranged alternately (long, short, long, short) on the frame. Rods protrude radially from the body plane onto one side at an angle in such a manner that a surface that longitudally intersects all rods forms a truncated cone or truncated pyramid (frustum). Rods are arranged so that a space between two neighboring rods and at the same time space between free ends of any two long rods does not exceed the size the throughput rate of the pump impeller is dimensioned for. In practice a distance between the rods is in the range of 15 to 100 mm. Rod length may be for example 20 and 50 mm, 20 and 60mm, 15 and 60mm, 20 and 80mm and the like. Length of the rods primarily depends on the throughput rate of the pump impeller. Said rod solid particles separator is positioned between a flange of the bidirectional pipe and a flange of the separation chamber in a way the rods are directed into the space of the separation chamber. The rod separator may be preferably provided with means for fastening in the flange e.g., in the form of openings. The rod separator may be preferably provided with at least one groove for mounting a sealing.

Increasing of filtration surface of the solid particles separator resulting in lowering a risk of clotting the separator is an advantage of the rod design of the separator. In addition, during reverse pumping of wastewater the separator is washed more thoroughly as fabrics tend to slip from the rods.

The pump is commonly positioned at the bottom of the wet accumulation chamber and according to the present technical solution it may be attached to bidirectional pipe of the device by means of a dismountable coupling through a pipe of the pump. The discharge pump of the device may be connected by a dismountable coupling to the discharge pump of the pumping station. Lengths of individual pipes depend on a depth of the pumping station and a distance of the inlet pipe of wastewater from the bottom of the pumping station.

For better handling during installation of the device according to the present technical solution into a pumping station the bidirectional pipes and the pipe of the pump as well as the discharge pipe and the discharge pipe of the pumping station are connected with dismountable couplings at the separation chamber proximity.

The device provides for the pump not to come into contact with solid particles that cause its excessive wearing-off, clogging and breakdowns.

The device can be installed into wet chambers of new as well as majority of existing pumping stations without a requirement of building modifications of the pumping stations. Accordingly, in majority cases the device requires no other than already existing space in the pumping station, nor further construction works. After installation, frequency of dispatching of operator's maintenance workers to the pumping stations for pump cleaning, maintenance and repair purposes decreases, pump life increases, the need for handling the rakings is eliminated resulting in reduction of ecological burden of environment in the surrounding of the pumping station.

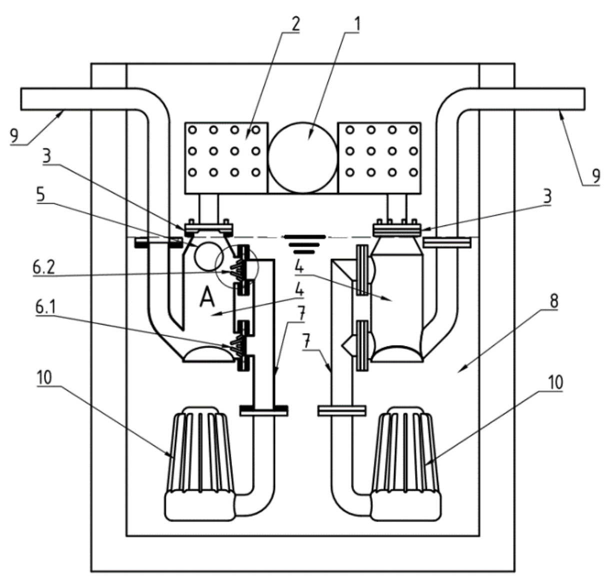

Figure I: Functional diagram of Pump Protector (1 – Inlet pipe, 2 – inlet perforated gutter, 3 – Reversing valve seat, 4 – Separation chamber, 5 – Float ball, 6.1 – First solid particles separator, 6.2 – Second solid particles separator, 7 – Bidirectional pipe, 8 – Pumping station wet accumulation chamber, 9 – Pump station discharge pipe, 10 – Pump

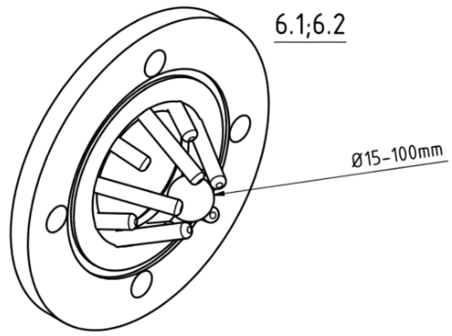

Figure II: Solid particles separator of Pump Protector (6.1 – First solid particles separator, 6.2 – Second solid particles separator)

Figure III: Pump Protector TM (Source: https://www.aqua4um.sk/en/#1562744118886-d1416465-3c31)

CONCLUSION

Trial testing of the device is ongoing. Prototypes have already been installed for real operation in real pumping stations. We collect new data and evaluate it. There is a significant reduction in failure rates at pilot pumping stations.

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THE USE OF WADDING TO CLEAN THE INTERNAL SURFACES OF PIPELINES

Yulia Kazhaeva[1]

Yulia Pakhomova[2]

Natalia Gatapova[3]

[1] Department of Technological Processes, Apparatus and Technosphere Safety, Faculty of Technology, Tambov State Technical University, Sovetskaya 106, 392000 Tambov, Russia, e-mail: ikazhaeva98@mail.ru

[2] Department of Technological Processes, Apparatus and Technosphere Safety, Faculty of Technology, Tambov State Technical University, Sovetskaya 106, 392000 Tambov, Russia, e-mail: puvdom@yandex.ru

[3] Department of Technological Processes, Apparatus and Technosphere Safety, Faculty of Technology, Tambov State Technical University, Sovetskaya 106, 392000 Tambov, Russia, e-mail: gatapova.nc@mail.tstu.ru

ABSTRACT

The aim of the study is to determine the effectiveness of various methods for cleaning pipelines. During the operation of pipelines in the paint and varnish industry, there is a decrease in throughput due to various reasons. To prevent the accumulation of water and internal deposits in the pipes, the inner cavity of the wire must be cleaned by passing cleaning devices. Basic cleaning methods: hydrodynamic, chemical, mechanical.

The wadding method was chosen as a production tool. Determining the effectiveness of using the wadding method, we conducted comparative tests at the enterprise and the results obtained were compared with the results of the laboratory of the manufacturer of the wadding system. As a result of the implementation of this project, the labor intensity of cleaning technological pipelines has been reduced, the number of particles has decreased in comparison with the traditional method, which means that energy costs have been reduced.

Keywords: pipelines, cleaning methods, hydrodynamic, chemical, mechanical

INTRODUCTION

During the operation of pipelines in paint and varnish production, a gradual decrease in throughput occurs due to: with the accumulation of deposits of chemical elements, with an increase in the roughness of the pipe walls as a result of their internal corrosion and the accumulation of corrosion products and mechanical impurities, as well as the accumulation of water in low places of pipelines, as well as at the upper points of the pipelines of air locks.

A decrease in throughput leads to a sharp decrease in the efficiency of pipelines, a significant increase in the cost of pumping paint and varnish fluid. The accumulation of deposits in the product pipelines, in addition, leads to a deterioration in the quality of the pumped products due to their contamination with mechanical impurities. In order to maintain the throughput and prevent the accumulation of water and internal deposits, as well as to prepare the pipeline section for in-line inspection and re-testing, the internal cavity of the wire should be cleaned by passing cleaning devices.

Process pipelines are pipelines designed for the transportation of initial, intermediate and final products at an absolute pressure of 0.001 MPa (0.01 kgf / cm2) to 100 MPa incl. (1000 kgf / cm2), as well as pipelines for supplying coolants, lubricants and other substances necessary for the operation of the equipment.

Process pipelines operate in a variety of conditions, are exposed to significant pressures and high temperatures, corrode and undergo periodic cooling and heating. Their design is becoming more and more complex due to an increase in the operating parameters of the transported product and an increase in the diameters of pipelines and the tightening of requirements for the reliability of operating systems.

The costs of construction and installation of pipelines can reach 30% of the cost of the entire facility. In this regard, a matter of paramount importance for specialized design, construction and operating organizations is the technical improvement and re-equipment of technological schemes based on the introduction of the latest scientific achievements and the use of advanced technology. Saving material resources and reducing losses of the pumped product depend on the correct choice of structures, high-quality manufacturing of elements and organization of construction.

The constant impact on the pipeline from the side of pumping products through them, affects them negatively, the throughput decreases. Therefore, they need to be cleaned. Piping should be flushed or purged according to project guidelines. Flushing can be carried out with water, chemicals and other permissible substances.

Blowing can be done with compressed air, steam or inert gas.

Flushing should be carried out at a speed of 1 - 1.5 m / s.

After flushing, the pipeline must be completely emptied and purged with air or inert gas.

Blowing of pipelines should be carried out under a pressure equal to the working pressure, but not more than 4 MPa (40 kgf / cm2). Blowing of pipelines operating under an excess pressure of up to 0.1 MPa (1 kgf / cm2) or vacuum should be carried out under a pressure of no more than 0.1 MPa (1 kgf / cm2).

The duration of the purge, if there are no special instructions in the project, should be at least 10 minutes.

During flushing (purging), diaphragms, devices, control and safety valves are removed and coils and plugs are installed.

During flushing or purging of the pipeline, the fittings installed on the drain lines and dead-end sections must be completely open, and after the completion of flushing or purging, carefully inspected and cleaned.

Mounting washers installed in place of the measuring orifice plates can only be replaced with working orifice plates after flushing or purging the pipeline.

OVERVIEW OF CLEANING METHODS

In the practice of operating pipeline networks, various methods of cleaning them from contamination are known:

1. Hydrodynamic: This method is widely used to clean pipelines using the kinetic energy stored in the gravity flow of water at the lowest point in the line. This ensures that dirt is removed from the pipelines after hydrotesting. For quick drainage of the system, air purging can be performed simultaneously to push the water out.

2. Chemical: This method uses chemical reactions to remove rust, mill scale, oil, grease, etc., from the surfaces of pipelines and equipment, as appropriate.

3. Mechanical: this method involves stripping, tapping or rubbing the surfaces of pipelines with special tools [1].

HYDRODYNAMIC METHOD

Pipeline cleaning using the hydrodynamic method has been used not so long ago. This modern method is distinguished by its efficiency and effectiveness, it is often used for the purpose of cleaning internal and external pipe networks [2].

In the process of hydrodynamic cleaning, specialized compact equipment with a special nozzle is introduced into the pipe. It is through it that a high pressure water jet is supplied. In this case, the use of any chemical agents is not envisaged, therefore we can say that this cleaning method is safe not only for the pipeline, but also for human health. All work technology fully complies with environmental standards.

By using this cleaning method, the risk of pipe damage is minimized, since no particular stress is applied to the pipeline system. As a rule, the water from the nozzle is supplied at a certain angle, which makes it possible to achieve the best result during flushing work.

Since the nozzles can be of different diameters, it becomes possible to clean any pipe. Many are afraid that when flushing the system, breakdowns may appear in the pipe, but this is just a myth.

The principle of operation of this method is based on the action of a jet of water supplied under high pressure. Rather, it is not just one jet that is supplied, but several at once. They effectively and quickly break up and remove deposits that settle on the inner surfaces of the sewer pipes [3].

Sewerage cleaning is carried out using special flushing equipment equipped with special nozzles.

So, we can say with confidence that using the hydrodynamic method of cleaning pipes, you can quickly remove internal deposits of any origin without compromising the integrity of the pipeline.

The pipe with the nozzle moves along the pipe due to the jet thrust, which is specially created by means of the pressure of water discharged from the holes in the nozzle. The device easily directs the water in the required direction.

Advantages of using the hydrodynamic cleaning method.

Flushing the pipeline with jets of water has a number of advantages, which include: high-quality pipe cleaning, which destroys all existing deposits and plugs; a small amount of time for a very effective procedure; gentle cleaning of pipes without harmful effects on them, using only water without chemical impurities; this method is applicable for different cases of pipeline configurations of any complexity; this method is considered environmentally friendly not only for the inner surfaces of pipes, but also for human health.

However, do not forget that in the paint and varnish industry this method is popular only for those pipelines into which water-based paint is supplied.

CHEMICAL METHOD

For a long time, the main method for cleaning equipment from deposits was the chemical method using aqueous solutions of various types of reagents, which allows flushing the entire inner surface of the pipeline. The number of different methods and means for flushing pipelines of all types is constantly increasing. The list is constantly replenished with innovative modern technologies and chemicals, reliable equipment is used that works very efficiently [3].

Chemical components capable of removing even petrified deposits from pipeline walls, sludge, rust, and other contaminants formed during the operation of the system in a matter of hours are quite simple to select. Despite the large number of methods used to control pollution, chemical flushing remains the most widely used, and it does an excellent job of cleaning pipelines. Practice shows that it works effectively even in the case when the hydrodynamic method cannot be applied. This is especially true if the pipelines are hidden or difficult to access.

New cleaning and washing solutions, highly effective reagents are constantly appearing on the market. This means that for each type of metal from which pipelines, heat exchangers and radiators are made, there is a powerful chemical cleaning agent. The task of such flushing is simple - to soften the deposited contaminants, dissolve them, and then flush them from the system.

The main trouble with pipeline systems is the deposition of chemical elements on the walls of pipelines, radiators, heat exchangers. To reduce its formation, it is recommended to install softening filters, since in most cases it is she who is used as a heat carrier. But even if such filters are installed, it is advisable to do chemical flushing at least once a year - this way you can remove all existing contaminants from the system. However, this method has significant drawbacks: significant consumption of expensive reagents; requirements for neutralization and disposal of waste water after treatment.

MECHANICAL METHOD

Mechanical cleaning is the cleaning of pipelines using specialized devices. The wadding method was chosen as a tool for our production.

Blowing pipes (puffing) - cleaning the pipeline by running a piston along it. Buzzing helps to clean the system from the remnants of chips after welding, as well as other foreign contamination. Piping is purged to detect defects, namely, an arbitrary decrease in pressure in the system. Without testing by pumping air and running the system, there is a huge risk of at least digging out and carrying out additional. Work, and in the worst-case scenario - to cause multimillion-dollar damage to yourself, and invaluable damage to the environment. Therefore, great attention is paid to this procedure.

The pneumatic cleaning tool is designed for cleaning the inner working surface of pipelines for supplying liquids. The wad, made of polyurethane foam, is launched into the pipeline using compressed inert gas supplied with a hand-operated trigger gun. During the movement of the wad through the pipeline, its lateral surface with force interacts with the walls of the pipe. The supplied gas drives the cleaning wad forward through the pipeline.

The advantages of pipe maintenance using the presented cleaning system are: reducing the risk of component failure due to contamination; reduced wear of parts; reducing the flushing time; increased service life of filter elements; reduced costs; reduced costs.

The pipeline cleaning system consists of 3 main components: specially designed air gun for maximum pressure; nozzles for various sizes and types of pipes, pipes, pipelines and joints; wads performing a cleaning function.

The main elements of the pistol: housing to hold all moving parts together; front plate, on which the adapter ring and nozzle are mounted; a latch that is put on the top of the gun and secures the working position of the front plate; quick detachable connection for supplying compressed air to the gun under pressure (8 mm inlet to the compressed air pipe); adapter ring for mounting on the front plate, where the nozzle is inserted; o-ring between gun body and faceplate; trigger mechanism to ensure the movement of the wad in a pipe or pipe under pressure.

There are 4 different types of nozzles:

- Nozzle (H) for Pipea. The nozzle is inserted into the pipe, so the diameter of the nozzle must be smaller than the inner diameter of the pipe. Example: Pipe nozzle (H06). Pipe (6 mm) DN 6 - 1/4 ".

- Nozzle (BSP) with internal cone for connection to pipes. The nozzle (B06) connected to the end of the pipe. Pipe thread with 60 ° taper. Example: BSP-Nozzle (B06). Pipe (6 mm) 1/4 ".

- Nozzle (JIC) with external cone for connection to pipes. The nozzle (JO6) is connected to the end of the pipe. Pipe thread with 74 ° taper. Example: JIC-Nozzle (J06). Pipe (6 mm) 1/4 ".

- Tube nozzle. The inside diameter of the tube inserted into the nozzle must be less than the nozzle diameter. Example: Nozzle (T06) Inner tube diameter (6 mm).

Wads clean the inner surface of pipes, tubes, pipelines under pressure.

There are 3 different types of wads: Standard (S) Standard wads are made of dense polyurethane foam. For the cleaning process, the wad is selected to be approximately 20% larger than the inner diameter of the pipe or pipe; connecting (C) Medium density polyurethane foam connecting wads; have a high compression ratio; abrasive (A) Wads made of high density polyurethane foam with abrasive pad. The wad is selected approximately 20% larger than the inner diameter of the pipe or pipe.

Application area

Research in the hydraulic industry has proven that 70% of hydraulic system failures are caused by contamination. Tests carried out at the university have proven that a pipe or pipe cut with a circular saw has 800-1200 micron particles with a weight of 30-50 milligrams per 1 meter of pipe length. Compri's technical department has studied the various cleaning grades in the hydraulic industry before recommending the best approach.

Tests carried out at the University clearly demonstrate how standard wads remove contaminants by absorbing liquid, while compound wads remove even fine particles.

The wad selection tables set out their recommended sizes (standard, connecting, abrasive) for pipes, tubes and fittings. Individual features require a choice of larger or smaller sizes. Cleaning will not be effective if the nozzle wad is too small or too large.

When cleaning is done, it is normal to reduce the size of the spent wad.

If the wad is stuck in the pipe, pipe, the gun should be reinstalled on the other end of the pipe or tube and cleaned. It is very important to ensure a tight seal. If you see a sealing problem, try a smaller nozzle [5].

3. Experimental part

In order to determine the effectiveness of using the pipeline wadding method, we carried out comparative tests at the enterprise, the results of which were compared with the results of the laboratory of the manufacturer of the wadding system.

Wadding system manufacturers conducted a series of tests to analyze the effectiveness of their equipment.

Pipeline cleanliness tests were carried out on four AISI 316 stainless steel pipes one meter long and 18 mm ID.

The results are shown in Table 1 below

Table 1 - Pipe cleanliness according to manufacturer's test results

Size range, µm	Uncleaned pipe	Air blown pipe	Cleaned by Compri system 2 wads	Cleaned by Compri system 4 wads
5-15	6017	2746	397	260
15-25	8219	522	40	29
25-50	13087	124	12	11
50-100	2446	3	0	0
100-400	41	0	0	0

The data from this study showed that pipe cut by a circular saw may contain excessive amounts of contaminating solids. To validate the above test data, I conducted my own evaluation of the efficiency of liquid line cleaning equipment.

For the experiment, three meter fragments of a pipeline section were selected for feeding pigments into the reactor, with an inner diameter of 50 mm. Each piece of pipe was cut to size, fittings were installed, and then the ends of the pipe were closed to avoid intrusion or accidental removal of contaminants prior to proof testing. The first test tube was left in its uncleaned state, the second was purged with air, and the third was cleaned using the equipment under test.

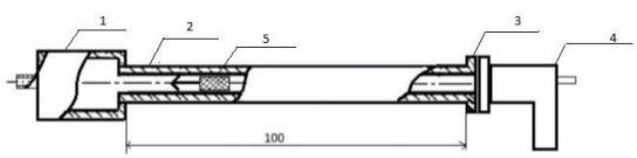

Figure I: Scheme of the experimental setup

1-wad receiving chamber; 2-pipe; 3-wad launch chamber; 4-pneumatic pistol; 5-wad.

The supply of compressed air to the starting gun is provided through a hose fitting from an external source. An air pressure of 600 kPa (6 bar) was used. The compressed air source is a standard compressor with a capacity of 200 to 400 liters per minute or an air cylinder (without oxygen).

Course of action:

1. Install the nozzle of the pipeline cleaning system. To do this, open the front panel of the CE gun by pressing the lever handle. Select the appropriate nozzle. An adapter ring is used for nozzles smaller than 38 mm.

2. Then we load the recommended wad into the starting pistol.

3. Close the front panel. We check the tightness of the seal, making sure that the lever snaps into place.

4. Before commissioning, make sure that the inlets of all elements are tightly connected and safe from injury.

5. For cleaning, place the nozzle of the CE gun into the pipe and pull the trigger. Next, make sure that the wad appears at the other end.

After the wad has passed the entire working path, it is important to diagnose the degree of cleaning of the pipeline or hose.

A filtered (up to 0.8 micron) solvent was preliminarily prepared to wash and clean each pipe. Each pipe was flushed in two stages, the first stage was used to separate and collect large particulate contaminants from the pipe, and the second stage was used to remove smaller particles. During each flushing step, the pipe ends were closed. Solvent from both wash cycles was collected in clean sterile containers for accurate test evaluation.

Finally, to assess the level of contamination of each pipe, the corresponding used flushing solvent was passed through a 0.8 μm membrane filter. The deposited particles were examined with a 100x microscope. An image of the results of examining samples from three tests of purity assessment is shown in Fig. 3, 4 and 5.

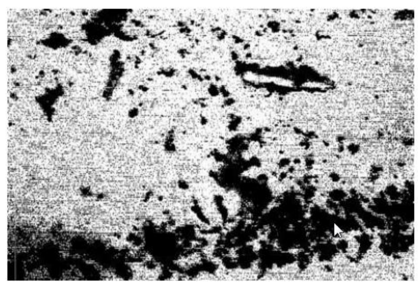

Figure II: Test # 1 (uncleaned pipe)

The first solvent filtration sample showed heavy particle contamination and was gray in color. The contaminants contain large quantities of rubber, silicone, filaments and metal particles ranging in size from 10 to 400 microns. It is obvious that rubber particles (75 microns in size) and filaments (400 microns in length), which appeared during the pipe cutting process, have settled on the filter. There are also particles of dust and dirt (up to 100 microns) that have come from the environment. Metal particles up to 30 microns got into the pipe during the fitting of the fittings.

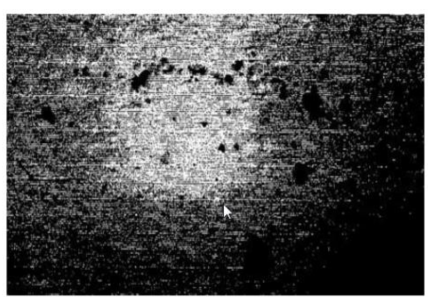

Figure III: Test #2 (pipe washed with water)

The second solvent filtration sample was white, but visible particle contamination was observed. Most of the large pieces of rubber and fibers were removed by blowing with air. However, heavy silicone and metal particles still remain in the pipe.

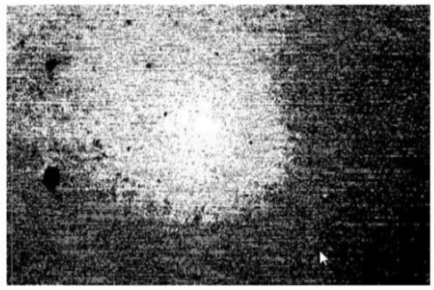

Figure IV: Test #3 (pipe cleaned by the wadding system)

The last solvent filtration sample was also white and microscopic observation showed a small amount of contamination particles. At 100x magnification, only particles ranging in size from 5 to 10 microns were detected on the filter.

The final step in the test was to examine the surface of the polyurethane foam wad under a microscope. The effectiveness of the wad is based on the foam's ability to absorb particulate contaminants inward as it travels through the pipeline. The structure of the material of the wad is specially designed to provide density, strength and flexibility to prevent it from collapsing from motive forces during pipeline cleaning. Figure 5 shows the surface of a cleaning wad at 100x magnification, demonstrating the foam's effectiveness at absorbing dirt particles. The larger particles shown in the photograph are about 100 microns in size.

Figure V: Surface of polyurethane wad at 100x magnification

The manufacturer's test data on the effectiveness of the equipment used and confirmed by the results of our laboratory tests led to the following conclusions. The use of a pneumatic trigger gun and polyurethane foam wad to clean pipes and liquid lines during their production will reduce the risk of failure of machine components. During the installation of hydraulic systems, if the cleanliness requirements are not followed, solid particles of contamination can enter the system lines. Therefore, reducing the amount of solids that enter the hydraulic system during the installation of the pipeline is an important method of protecting against system breakdowns even at the stage of its start-up [5].

CONCLUSION

Research results of the implementation of this project, the following conclusions can be drawn. Reduce the labor intensity of cleaning process pipelines. The number of particles has decreased in comparison with the traditional method. Accordingly, the use of the new method will lead to a decrease in hydraulic resistance, that is, to a decrease in energy consumption.

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WASTEWATER TREATMENT BY ULTRAVIOLET RADIATION

Yulia Koliukh[1]

Yulia Pakhomova[2]

Natalia Gatapova[3]

Štefan Stanko[4]

[1] Department of Technological Processes, Apparatus and Technosphere Safety, Faculty of Technology, Tambov State Technical University, Sovetskaya 106, 392000 Tambov, Russia, e-mail: koliyukka@gmail.com

[2] Department of Technological Processes, Apparatus and Technosphere Safety, Faculty of Technology, Tambov State Technical University, Sovetskaya 106, 392000 Tambov, Russia, e-mail: puvdom@yandex.ru

[3] Department of Technological Processes, Apparatus and Technosphere Safety, Faculty of Technology, Tambov State Technical University, Sovetskaya 106, 392000 Tambov, Russia, e-mail: gnzpri@mail.tstu.ru

[4.] Department of Sanitary and Environmental Engineering, Faculty of Civil Engineering, Slovak University of Technology in Bratislava, Radlinského 11, 810 05 Bratislava, Slovakia, e-mail:, stefan.stanko@stuba.sk

ABSTRACT

The article is devoted to the treatment and disinfection of wastewater using ultraviolet radiation. The material is the advantages of this cleaning method. A comparison is made with alternative methods in terms of the mechanism of action and the main indicators of disinfection.

Keywords: treatment and disinfection of wastewater, ultraviolet radiation, mechanism of action, indicators of disinfection.

INTRODUCTION

Wastewater is water contaminated with household waste and industrial waste and removed from the territories of populated areas and industrial enterprises by sewerage systems. They also include waters formed as a result of atmospheric precipitation within the territory of settlements and industrial facilities. Organic substances contained in wastewater, getting into water bodies in significant quantities or accumulating in the soil, can quickly rot and worsen the sanitary condition of water bodies and the atmosphere, contributing to the spread of various diseases. In the vast majority of surface waters (for groundwater, this problem is less acute, but it is not eliminated at all), various microorganisms live - bacteria, viruses, protozoa, as well as microscopic algae and fungi. Among them there are both harmless to human health and those capable of causing diseases (sometimes deadly). The latter are usually called pathogenic. Pathogenic microorganisms in wastewater can cause various infectious diseases, these include causative agents of diseases such as cholera, dysentery, typhoid fever, etc. In order to prevent these bacteria from there, it is necessary to regularly purify water from pathogenic microorganisms[1].

The number and variety of microorganisms in water bodies that are located near settlements is especially high, since they are constantly contaminated with sewage and industrial wastewater. In general, human activity has a great impact on the microbial composition of water bodies.

Water constantly undergoes self-purification - microorganisms die due to the action of sunlight and chemicals. Also, the course of microbiological processes in water bodies is influenced by the composition of aquatic inhabitants, their number and sedimentation of the bottom.

Therefore, the issues of purification, neutralization and disposal of wastewater are an integral part of the problem of nature protection, improvement of the human environment and provision of sanitary improvement of cities and other settlements.

Wastewater treatment - treatment of wastewater with the aim of destroying or removing harmful substances from it. Removing wastewater from pollution is a complex process. Wastewater is usually treated at mechanical and biological treatment facilities located in series, while the treatment method and composition of treatment facilities are selected depending on the required degree of treatment, the composition of the waste liquid, the capacity of the station, ground conditions, and the capacity of the reservoir. At the final stage of wastewater treatment, as a rule, they are disinfected.

Among the many branches of modern technology aimed at improving the living standards of people, the improvement of populated areas and the development of industry, water supply takes a large and honorable place. After all, water is an indispensable part of all living organisms, the vital activity of which is impossible without water. For the normal course of physiological processes in the human body and for the creation of favorable living conditions for people, the hygienic value of water is very important. Currently, providing the population with high quality water has become a real problem [2].

The problem of drinking water supply affects many aspects of the life of human society throughout the history of its existence. Currently, it is a social, political, medical, geographic, as well as engineering and economic problem. About 5-6% of the total water consumption is spent on drinking and household needs of the population, communal facilities, medical institutions, as well as on the technological needs of food industry enterprises. Technically, it is not difficult to ensure the supply of such an amount of water, but the needs must be satisfied with water of a certain quality, the so-called drinking water.

Drinking water is water that meets the quality in its natural state or after treatment (purification, disinfection) to the established regulatory requirements and is intended for drinking and domestic needs of a person. The main requirements for the quality of drinking water: be safe in terms of epidemic and radiation, be harmless in chemical composition, have favorable organoleptic properties [3]. To meet these requirements, a whole range of measures for the preparation of drinking water is currently used.

Of course, in rivers and other bodies of water, a natural process of self-purification of water takes place. However, it is very slow. Rivers have been unable to cope with wastewater discharges and other sources of pollution for a long time. But the level of bactericidal effect in wastewater often exceeds the norm by thousands and millions of times. Wastewater flows into rivers and lakes, and most city water utilities take water from them. Thus, the essential processes in the preparation of drinking water are high-quality purification and disinfection of wastewater.

Disinfection of water is the process of destroying microorganisms located there. In the process of primary water purification, up to 98% of bacteria are retained. But among the remaining bacteria, as well as among viruses, there may be pathogenic (disease-causing) microbes, for the destruction of which special water treatment is needed - its disinfection.

With the complete purification of surface water, disinfection is always necessary, and when using groundwater - only when the microbiological properties of the source water require it. But in practice, the use of both underground and surface waters for drinking is almost always impossible without disinfection.

The water used for the production of paints and varnishes must be regularly cleaned and its chemical composition controlled. Mechanical impurities in the water negatively affect the quality of the products, various organic and inorganic compounds lead to rapid wear of the equipment on which the production takes place.

Currently, there are various methods of water disinfection: thermal disinfection method - boiling; oligodynamic method of disinfection - treatment with ions of noble metals; chemical method of disinfection - exposure of water to strong oxidants such as chlorine, bromine, iodine, potassium permanganate, hydrogen peroxide, ozone and their compounds; physical method of disinfection - exposure to ultraviolet radiation, ultrasound, etc [4].

Thermal and oligodynamic methods of water disinfection are very expensive and are not used on an industrial scale. Whereas chemical and physical methods are quite common. The method of ultraviolet disinfection, as one of the most effective methods of cleaning and disinfecting water, allows you to reduce all these listed risks to a minimum.

ULTRAVIOLET DISINFECTION

Water purification from pathogenic microflora in ultraviolet disinfection installations is carried out when the liquid passes through a metal tube in which a bactericidal lamp is placed. Electromagnetic radiation affects the cellular material of microorganisms, destroying it and thereby purifying the water. Ultraviolet radiation is formed in the wavelength range from 100 to 400 nm, while most pathogenic microbes die in the electromagnetic field generated by waves from 240 to 280 nm.

A standard decontamination plant is equipped with discharge lamps filled with mercury gas. Lamps of this type generate radiation of 254 nm, that is, they have the maximum bactericidal effect, destroying most of the viruses and bacteria contained in the water. Water purification occurs immediately when it enters the installation, does not require re-treatment and is fully usable.

Different types of bacteria have different degrees of resistance to the action of bactericidal rays, which is taken into account by the coefficient of resistance of bacteria, determined as a result of research.

The process of disinfection of water with bactericidal rays is carried out on special installations in which water flows around the sources of bactericidal radiation in a relatively thin layer - mercury-quartz or argon-mercury lamps. Water exposed to irradiation should have the highest permeability to bactericidal rays, that is, it should be as transparent as possible.

The method of water disinfection with bactericidal rays has a number of advantages over the chlorination method: relative ease of operation, no need to introduce any reagents into the disinfected water, no deterioration of the taste of water [5].

The cost of water disinfection with bactericidal rays does not exceed the cost of chlorination.

A bactericidal lamp is a low-pressure electric mercury gas-discharge lamp with a bulb made of uviol glass or other material that provides a given spectrum of ultraviolet radiation transmission. Ultraviolet radiation has disinfecting properties, which gave the lamp its name.

In germicidal lamps, the spectrum of ultraviolet radiation is selected so as to minimize the formation of ozone and harmful effects on the skin and eyes by cutting out hard ultraviolet radiation from the lamp's radiation spectrum. They try to leave only the spectral line of soft ultraviolet radiation with a wavelength of 253.7 nm. Such lamps are also called "ozone-free" due to the minimization of ozone formation. This is how germicidal lamps differ from a quartz lamp, in which a quartz bulb does not trap hard ultraviolet light. After quartzization with a germicidal lamp, it is not necessary to ventilate the room, unlike a quartz lamp.

Germicidal lamps are used to disinfect indoor air and surfaces, disinfect drinking water, sterilize items and medical instruments. They neutralize the bulk of microorganisms such as viruses, bacteria, mold, fungi, yeast, spores, etc.

Germicidal lamps are used in various devices such as germicidal irradiators, germicidal recirculators, devices for water disinfection, etc. When working with germicidal lamps, remember about the dangers of ultraviolet radiation for eyes and skin [6].

The disadvantages of the method include the lack of simple and reliable ways to control the effect of disinfection and the impossibility using the method for disinfection of waters characterized by increased color turbidity.

FEATURES OF ULTRAVIOLET WATER DISINFECTION

The ultraviolet water disinfection method is physical. The water passes through the disinfection chamber of the installation, in which it is exposed to bactericidal ultraviolet (UV) radiation. The death of microorganisms occurs as a result of damage to the DNA structure responsible for hereditary mechanisms.

- All types of microorganisms, including viruses, are destroyed by ultraviolet radiation. High doses of UV irradiation of water are used harmlessly for the consumer to destroy the most resistant forms of microorganisms.
- Has instant action - does not require contact reservoirs. Water disinfected by UV radiation is ready for use immediately.
- By placing the UV disinfection unit just before water consumption, the problem of contaminated water supply is eliminated.
- The effectiveness of UV disinfection does not depend on the pH and temperature of the water.
- UV technology for water disinfection is environmentally friendly, since UV treatment of water, unlike chlorination and ozonation, does not change its chemical composition.
- Installations of UV water disinfection are harmless for the service personnel and do not require the constant presence of people. This is an economical method that does not require reagents and maintenance of an appropriate farm. UV disinfection of water is an effective, environmentally friendly, economical method. The only drawback of UV water disinfection is the absence of aftereffect. Therefore, an important condition for the adequate use of UV technology is the placement of installations immediately before water consumption.

In cases where the UV installation cannot be placed immediately before the consumption of water, the combined effect of UV irradiation and chlorination is used. In this case, small doses of chlorine are used (several times less than when using only chlorination), which avoids the problems associated with the appearance of organochlorine in the water due to the practical absence of excess chlorine in the water [7].

COMPARISON OF DISINFECTION METHODS.

Table I: Comparison of disinfection methods in terms of the mechanism of action, its effect and results

Wastewater disinfection method	Mechanism of action	"Side" effect of exposure	Result
Chlorination	Damage to the cell membrane, destruction of nucleic acid	Organochlorine compounds are formed that are toxic, mutagenic, carcinogenic	Long lasting action
Ozonation	Destruction of protoplasm, walls and membranes of bacteria, protein membranes	Few harmful substances are formed	Short-term action
Ultraviolet disinfection	Damage to the structure of DNA and RNA, violation of membrane permeability	No toxic products are formed	Short-term action

*A short-term effect is an effect on the microflora of water at the initial moment of time, but it does not have a long-term effect. As can be seen from the table, only chlorination provides a long-term disinfection effect, however, the same method is the least safe, while UV irradiation is the safest.

Table II: The main indicators of the three methods of disinfection

Method	**Ultraviolet disinfection**	**Ozonation**	**Chlorination**
Capital expenditures	average	high	average
Operating costs	low	high	average
Service	simple	very difficult	difficult
Service frequency	rarely	often	average
Disinfection efficiency	excellent	good	good
Contact time	1-5 sec	5-10 minutes	30-60 minutes
Toxic reagents	no	there is	there is
Change in chemical composition	no	there is	there is
Aftereffect	no	weak	there is

These tables make it possible to determine that ozonation is the most expensive and difficult to maintain method. The chlorination method occupies an intermediate position in terms of efficiency and ease of implementation. Disinfection of waste water by UV irradiation "wins" in terms of its efficiency, environmental friendliness and economy, but does not have a long-term aftereffect.

CONCLUSION

Based on the above material, conclusions can be drawn regarding the comparison of wastewater disinfection methods - chlorination, ozonation and UV irradiation. Each of the technologies presented above, if applied in accordance with the norms, can provide the necessary degree of inactivation of bacteria, in particular, for the indicator bacteria of the E. coli group and the total microbial count. Ozone and ultraviolet light have a sufficiently high virucidal effect at doses that are real for practice. Chlorination is less effective against viruses.

The technological simplicity of the chlorination process and the lack of chlorine deficiency determine the widespread use of this particular method of disinfection. The ozonation method is the most technically complex and expensive in comparison with chlorination and ultraviolet disinfection. Ultraviolet radiation does not change the chemical composition of water even at doses that are much higher than practically necessary. Chlorination can lead to the formation of undesirable organochlorine compounds with high toxicity and carcinogenicity. Ozonation can also result in the formation of by-products classified by the regulations as toxic (aldehydes, ketones and other aliphatic aromatic compounds). Ultraviolet radiation kills microorganisms, but the "formed fragments" (cell walls of bacteria, fungi, protein fragments of viruses) remain in the water. Therefore, subsequent fine filtration is recommended. Thus, giving preference to one or another method of wastewater disinfection, a number of factors should be taken into account - the degree of purification that they want to achieve, the duration of the effect, the economic and environmental aspects of the method's functioning.

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BALANCE OPTIONS POSSIBILITIES AND MONITORING OF PHOSPHORUS AT A WASTEWATER TREATMENT

Peter Lukáč[1]

Ľuboš Jurík[2]

Jozefína Pokrývková[3]

Richard Hanzlík[4]

[1] Departmentof Water Resources and Environmental Engineering (WREE) Slovak University of Agriculture in Nitra, Hospodárska 7, 94976 Nitra, Slovakia, e-mail: rndr.peter.lukac@gmail.com

[2] Departmentof Water Resources and Environmental Engineering (WREE) Slovak University of Agriculture in Nitra, Hospodárska 7, 94976 Nitra, Slovakia

[3] Departmentof Water Resources and Environmental Engineering (WREE) Slovak University of Agriculture in Nitra, Hospodárska 7, 94976 Nitra, Slovakia

[4] Departmentof Water Resources and Environmental Engineering (WREE) Slovak University of Agriculture in Nitra, Hospodárska 7, 94976 Nitra, Slovakia

ABSTRACT

Wastewater is becoming a subject of interest for cities and water companies due to changes in the criteria for the quality of discharged water as well as charges for remaining pollution. For cities and water companies, not only the quality of treated water is important, but also the cost of the processes themselves. A significant problem is the removal of phosphorus. The work addresses the process of necessary analyses in the processes of wastewater treatment plants to evaluate the balance of phosphorus and organic matter at a large wastewater treatment plant. The result of the analysis is also the solution of the possibility of phosphorus handling.

Keywords: wastewater treatment plant, phosphorus, nutrients, removal

INTRODUCTION

To know the quality and quantity of wastewater supplied to the wastewater treatment plant (WWTP) is one of the basic prerequisites for the correct dimensioning and operation of the WWTP. Wastewater can be characterized as a raw material coming to the treatment plant to the WWTP and therefore its composition (quality) and quantity (quantity) must be known as best as possible. The aim of our work was to compare the hydraulic and material load of the WWTP in the operation of Western Slovakia Water Company, s. e. (WSWC). The amount of inflowing wastewater and the material load of the WWTP show significant differences every year. These differences are probably caused by the inflow of industrial waters from major producers; to a small extent, the share of ballast resp. rainwater. They reduce the operating capacity of the WWTP and increase the economic costs of operating the public WWTP [1].

The amount of wastewater from households (also called sewage) is closely related to the living standards of the population. Water consumption in households depends on the equipment of dwellings. It does not depend only on the size of the dwelling and the municipality, although there is observed trend of higher water consumption in larger municipalities and cities [2]. The approximate average specific water demand per person ranges from 100 $l.d^{-1}$ to 145 $l.d^{-1}$, depending on the type of heating and the type of bath. Real statistical data on the actual production of water in households in the Slovak Republic in recent years indicate a markedly declining trend in water consumption, in small municipality only 60 - 80 $l.inh^{-1}.d^{-1}$ (Table 1).

METHODICS AND MATERIALS

Wastewater quality is usually defined in mass concentrations (exceptionally in substance concentrations). BOD_5, COD, suspended solids (SS), concentrations of nitrogen forms (NH_4-N, NO_2-N, NO_3-N, N_{org}), concentrations of phosphorus forms (PO_4-P, P_{total}, pH, dissolved substances (DS), etc. In certain specific cases, the concentrations of other components are also determined, such as heavy metals, surfactants, fatty acids, sulphates, etc. Fluctuations in the quality of domestic wastewat*er are caused by many factors. T*ype and quality of sewerage network, etc. Differences in concentrations of some components can exceed the average values up to several times. Indicative values of specific production of pollution per capita are given in Table 1.

Table I: The amount of specific pollution and the volume of wastewater produced by one inhabitant (by STN 75 6401)

Substance	**Anorganic** $g.d^{-1}$	**Organic** $g.d^{-1}$	COD_{Cr} $g.d^{-1}$	BOD_5 $g.d^{-1}$	$N_{tot.}$ $g.d^{-1}$	$P_{tot.}$ $g.d^{-1}$	**Volume** $l.inh^{-1}.d^{-1}$
suspended	15	40	60	30	1	0.2	-
settleable	10	30	40	20	1	0.2	-
unsettleable	5	10	20	10	0	0	-
dissolved	75	50	60	30	10	2.3	-
overall	90	90	120	60	11	2.5	-
wastewater	-	-	-	-	-	-	100 - 200

In Nitra wastewater treatment plant (170 000 PE, 28 000 $m^3.d^{-1}$) wastewater is treated by activated sludge process with an integrated biological nitrogen and phosphorous removal. Sludge is dewatered and stabilized by windrow composting. In the treatment plant, phosphorus balance in various treatment steps was studied and potential technologies for extracting phosphorus were reviewed.

TREATMENT PROCESSES AT WWTP NITRA

The sewage treatment plant has been operating since 1968, the construction of which began in 1963. From the beginning it consisted of a mechanical part, as well as a biological part, with sludge cleaning and gas management. It was designed for PE = 83 200 and the sewage treatment plant capacity is 14 215 $m^3.d^{-1}$. In 2006 it was modernized. A phosphorus and nitrogen purification section (3rd stage of biological treatment) was added. It is predicted that in 2022 the PE will amount to 175 000 and in 2030 it will increase to 215 000. The current capacity of the treatment plant is 36 300 $m^3 \cdot d^{-1}$. The treatment plant was modernized due to poor biological treatment capabilities. This part of the treatment plant had a capacity of 19 008 $m^3.d^{-1}$, the rest of the sewage was discharged directly after mechanical treatment to the river Nitra (Figure 1).

The wastewater goes to the treatment plant via the sewage system, and from the non-sewage areas it is transported with sewage fleet without limit to the catchment point located within the treatment plant. It is recommended to empty the septic tank within 1 - 2 months and to pass the sewage through the sewage treatment plant during larger daily flows. For this purpose, the facility has a small retention reservoir for the accumulation of sewage brought in for a few hours. It is justified by the fact that the supplied sewage has a high concentration of BOD_5. Therefore the sewage must be mixed with the sewage flowing in through the collector.

Figure I: View of the sewage treatment plant in Nitra (Source: photo from the WWTP)

Based on the Ordinance of the Government of the Slovak Republic on May 25, 2010, which sets out the requirements for achieving good water status, the treatment plant in Nitra obtained a permit to discharge treated municipal wastewater to the Nitra River:

In the amounts today:

Qmaxh = 786 $l.s^{-1}$ = 67 910 $m^3.h^{-1}$

Qdav = 420 $l.s^{-1}$= 36 288 $m^3.d^{-1}$

Qrmax,d = 0,516 $l.s^{-1}$

With the following parameters:

BOD5 = 15 $mgO_2.l^{-1}$

COD = 90 $mgO_2.l^{-1}$

Suspended solids = 20 $mg.l^{-1}$

Total nitrogen = 15 $mg.l^{-1}$

Total phosphorus = 2 $mg.l^{-1}$

pH = 6.0 – 9.0

The city of Nitra has no heavy metal limits. It is justified by the fact that each plant in Slovakia should have its own guidelines and treat sewage within its scope. Moreover, there is no industry in Nitra with processes that need to be refined with heavy metals.

The technological system used to treat wastewater at the WWTP Nitra consists of: Screens with clearance of 40 mm for sparse grates and 6 mm for dense grates and fine screens. There are 2 types of Archimedean pumps in the treatment plant. They differ in flow. There are two small ones with an inlet width of 1 400 mm with a flow of 420 $l.s^{-1}$ and two large ones with a width of 1 600 mm and a flow of 800 $l.s^{-1}$. Depending on the amount of rainfall, large pumps will operate with higher rainfall. 2 types are operating 1 400 with flow 420 $l.s^{-1}$ and 1 600 with flow 800 $l.s^{-1}$. Horizontal sandbox aerated by two chambers; 2 radial pre-settlers 42 m in diameter. There are 3 stages of sewage treatment in the primary sedimentation tank; Settling tanks providing mechanical cleaning; Open anaerobic zone serving for biological phosphorus removal; Sludge regeneration increasing the activity of sludge microorganisms (nitrification, denitrification); Activated sludge chambers. The facility consists of 4 circulating activation reservoirs, 61 m long, 13 m wide, with a wall thickness of 500 mm and a bottom depth of 500 mm. Each of the reservoirs is divided into 2 channels with a width of 6.40 m with separate zones that are anoxic (in the pre-denitrification chamber), anaerobic (the dephosphatation chamber), anoxic (the denitrification chamber) and aerobic (the nitrification chamber) and 2 secondary radial settling tanks.

The biological removal of phosphorus from wastewater is further augmented using chemical agents (aluminum or iron salts). Overall, the system applied in the treatment of wastewater ensures integrated removal of organic carbon, nitrogen and phosphorus compounds from wastewater (Municipal Services Department, 2018).

The facility provides dosing of chemicals - iron sulphate for the possibility of chemical reduction and complete phosphorus removal at the effluent from the sewage treatment plant. Dosing is applied before the activation (aeration) tank (Figure 2). The iron sulphate is stored in a double wall reservoir. A precipitation tube in front of the activation tank is used for dosing. This is only used for the chemical precipitation of phosphorus.

Figure II: The chamber for the separation of sewage into two parts of the biological stage of the reactor with dosing of chemicals for the removal of phosphorus

PHOSPHORUS IN WASTEWATERS

The need for phosphorus recycling in waste water and sewage sludge has received an immense attention the last decade as phosphate rock prices have raised and the direct application of sewage sludge to agriculture has been difficult due to high pollution levels (heavy metals and organic pollutants). Also an increased focus on a sustainable society has put more pressure on looking for alternatives to the use of phosphate rock for fertilizer production. Centralized municipal WWTPs represent a great phosphorus source, and even though it cannot cover the increase in phosphorus demand, it plays a key role for sustainable use of phosphorus.

Many organic waste materials contain significant amounts of phosphorus in various forms: organic, poorly absorbed by plants, and inorganic, better assimilated by plant organisms. Sewage sludge contains the second greatest amounts of this element [3]. The only organic waste containing more phosphorus is bone meal, but on a global scale it is produced in much smaller quantities than sludge. Therefore, sludge is considered a very promising source of phosphorus [4]. The most widely used technology of biological treatment is conducting alternating aerobic and anaerobic processes, called enhanced biological phosphorus removal (EBPR). The first step is to carry out the anaerobic process, during which the organisms in the activated sludge hydrolyse polyphosphates and release phosphorus from cells. Next, the activated sludge goes into an oxygenated chamber, where the bacteria which have the ability to store larger amounts of phosphorus that is necessary for their physiological needs begin to retain phosphorus, in the form of polyphosphate, in their cells [5].

The recovery of phosphorus is dependent on the method of phosphorus removal, and chemical and biological phosphorus removal have been briefly been reviewed [6]. Chemical phosphorus removal tend to decrease the bioavailability of the phosphorus in the sludge and the phosphorus needs to either be redissolved with wet chemical technologies [3].

RESULTS AND DISCUSSION

Over the analysed period, the plant received very variable loads, with between 23 900 and 25 100 $m^3.d^{-1}$ inflowing wastewater. Concentrations of phosphorus in this raw wastewater also varied, e.g. from 6 to 8,5 $g.m^{-3}$ (Table 2).

Nitra WWPT is the largest within the joint stock company. The company operates 43 WWTP. They are with a very different capacity. WWTP Nitra is constructed and operated for 180 000 EI and the smallest is in the village Kamenica with a capacity of 275 EI.

We selected the largest of them and analysed the inflow P in the raw wastewater. Inflowed wastewater is a mixture of municipal wastewater and water from local industry. Therefore, the concentrations do not vary much (Table 2). There are significant differences in the total phosphorus content of the effluent in the inflow per year (Table 3).

The amount of phosphorus in the inflow informs about the potential use of phosphorus removal technology. Tables 2 and 3 show that investment in new phosphorus management technology is currently economically inefficient in almost all WWTPs. In the city of Nitra, the sap of changing the tariffs for wastewater discharge or changing the legislation on phosphorus management could consider the necessary solution. A closer analysis of phosphorus concentrations in WWTP processes has been addressed, but the results are not very clear.

The phosphorus balance in the extended analytical sites did not give a clear result for the most basic balance Inflow = Outflow. The reason is the water cycle itself within WWTP and also the time of phosphorus retention in processes related to sludge treatment where we enter the balance of phosphorus from previous periods and the constant return of water from sludge treatment to the inflow to the biological stage and also the retention of sludge in the object of its regeneration.

Table II: The amount of specific pollution and the volume of wastewater produced by one inhabitant (by STN 75 6401)

		2010	2011	2012	2013	2014	2015	2016	2017	2019
WWTP	EI	P_{tot}	P_{tot}	P_{tot}	P_{tot}	P_{tot}	P_{tot}	P_{tot}	P_{tot}	P_{tot}
		$mg.l^{-1}$	$mg.l^{-1}$	$mg.l^{-1}$	$mg.l^{-1}$	$mg.l^{-1}$	$mg.l^{-1}$	$mg.l^{-1}$	$mg.l^{-1}$	$mg.l^{-1}$
Nitra	152 645.74	6.09	6.09	8.3	6.00	7.30	7.70	6.30	6.70	6.7
Vráble	12 450.23	7.61	7.61	11.6	7.80	9.80	9.20	8.60	8.50	9.6
Zlaté Moravce	21 983.83	4.58	4.58	6.6	3.80	5.50	9.10	5.00	6.20	9.9
Dunajská Streda	15 302.47	3.70	3.70	3.5	1.80	1.50	6.40	9.80	5.30	3.9
Galanta	15 201.40	5.00	5.00	6.5	5.30	7.90	4.60	3.60	4.50	10.1
Sereď	42 082.87	4.21	4.21	5.32	4.10	4.50	5.40	9.60	9.70	3.9
Nové Zámky	45 030.76	5.79	5.79	6.86	4.80	4.90	4.10	9.90	4.20	4.80

Table III: The amount of specific pollution and the volume of wastewater produced by one inhabitant (by STN 75 6401)

		2010	2011	2012	2013	2014	2015	2016	2017	2019
WWTP	EI	P_{tot}	P_{tot}	P_{tot}	P_{tot}	P_{tot}	P_{tot}	P_{tot}	P_{tot}	P_{tot}
		$t.y^{-1}$	$t.y^{-1}$	$t.y^{-1}$	$t.y^{-1}$	$t.y^{-1}$	$t.y^{-1}$	$t.y^{-1}$	$t.y^{-1}$	$t.y^{-1}$
Nitra	152645	57.0	57.0	66.0	65.1	69.5	70.1	59.8	57.6	58.5
Vráble	12450	4.9	4.9	5.0	5.6	4.9	4.7	5.8	4.9	5.1
Zlaté Moravce	21983	7.4	7.4	8.4	7.7	9.3	14.8	9.0	10.6	13.3
Dunajská Streda	15302	24.5	24.5	23.0	11.9	9.7	0.9	1.6	0.9	22.9
Galanta	15201	7.2	7.2	7.5	8.3	10.0	7.6	8.7	11.5	13.4
Sereď	42082	11.2	11.2	9.1	9.6	9.4	4.2	12.5	12.3	11.4
Nové Zámky	45030	23.0	23.0	20.8	17.4	16.0	14.7	14.9	13.3	14.7
WSWC. s. e.	518969	258.9	258.9	255.1	229.1	233.4	255.0	236.1	240.8	271.7

CONCLUSION

In the treatment plant, phosphorus balance in various treatment steps was studied and potential technologies for extracting phosphorus were reviewed. Recovery of phosphorus for recycling, rather than its transfer into dewatered sewage sludge, may offer economic and environmental rewards for the water industry. In WWTP Nitra, Slovakia, 55 - 65 tons of phosphorus enters into the WWTP, and 71 – 100 tons is removed as part of the dewatered sludge. Large proportion of it could be removed from liquid phase in most phosphorous abundant sources, e.g. sludge liquor. For the phosphate industry, extraction of nutrients holds out the promise of a significant source of sustainable raw material – phosphorus, which is comparatively free from heavy metals. These benefits must be compared with the investment and running costs of phosphorus recovery installations.

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EFFECT OF AIR POLLUTION ON RAINWATER QUALITY

Ivana Marko[1]

Réka Wittmanová[2]

Jaroslav Hrudka[3]

Štefan Stanko[4]

[1] Department of Sanitary and Environmental Engineering, Faculty of Civil Engineering, Slovak University of Technology in Bratislava, Radlinského 11, 810 05 Bratislava, Slovakia, e-mail: ivana.marko@stuba.sk

[2] Department of Sanitary and Environmental Engineering, Faculty of Civil Engineering, Slovak University of Technology in Bratislava, Radlinského 11, 810 05 Bratislava, Slovakia, e-mail: reka.wittmanova@stuba.sk

[3] Department of Sanitary and Environmental Engineering, Faculty of Civil Engineering, Slovak University of Technology in Bratislava, Radlinského 11, 810 05 Bratislava, Slovakia, e-mail: jaroslav.hrudka@stuba.sk

[4] Department of Sanitary and Environmental Engineering, Faculty of Civil Engineering, Slovak University of Technology in Bratislava, Radlinského 11, 810 05 Bratislava, Slovakia, e-mail: stefan.stanko@stuba.sk

ABSTRACT

In the last few years, the rapid development of urban areas, transport, and technical infrastructure will significantly influence the environment's quality. These phenomena are the excessive production of gases, particularly carbon dioxide, methane, sulfur dioxide, and nitrous oxide, which are considered the most hazardous greenhouse gases, influencing climate change. Due to the current trend of capturing and using rainwater runoff from paved areas, air pollution significantly changes rainwater runoff quality. In the research study, we evaluate the published studies, which dealt with the characteristics of air pollution, its impact on rainwater quality, and the possible reduction of adverse effects.

Keywords: air pollution, climate changes, rainwater runoff, urban area, quality of rainwater

INTRODUCTION

The beginning of the 21st century was considered a historically significant period when the number of inhabitants living in urban areas exceeded the number in rural settlements [1]. It is characterized by the mass migration of inhabitants and the rapid development of urban areas. This brings specific problems associated with changing the city's spatial structure. By changing land use and intensifying the building of paved surfaces, large built-up areas have been created, disrupting the area's natural state and inefficiency. Due to the suppression of vegetation for impervious surfaces and the inappropriate way of managing rainwater from urbanized areas, significant changes in the area's climatic and hydrological characteristics have occurred [2, 3]. This phenomenon's negative consequence is an increase in surface runoff formation, climate changes, and especially the excessive production of emissions that directly impact air quality.

Air pollution is one of the essential by-products caused by intensive human activity, large-scale urbanization, and industrial and transport infrastructure, impacting climate change and the Urban Heat Island (UHI) effect's creation. Although the cities covering a small percent of the earth's surface, there are consumes a large amount of energy for proper functioning, about 75 % of the world's consumption of resources (oil, coal, biomass, waste, etc.) [4]. Part of this energy dissipates in the form of heat, causing the UHI effect to form [5]. Fossil fuels represent the largest amount of energy consumed. According to International Energy Agency (IEA), industrializing countries such as China, North America, and Western Europe consume about 2/3 of total world energy [6]. At present, those countries produce the highest amount of emissions of carbon dioxide, methane, sulfur dioxide, and nitrous oxide. These gases considered to be the most dangerous greenhouse gases, which are the drivers of climate change, cause several environmental problems: extreme temperature changes, changes in humidity, changes in clouds, long rainy periods, changes in airflow, influence the formation of acid rain, fog, and photochemical smog [5], [7].

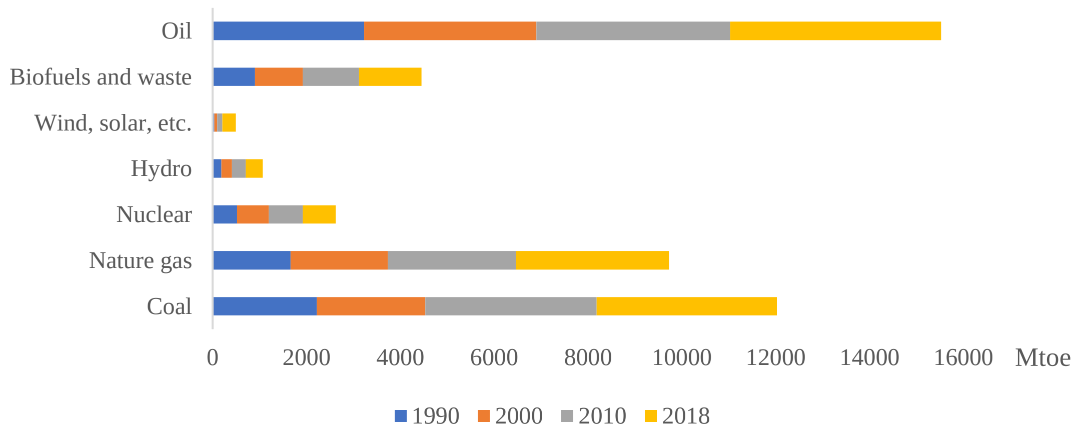

Figure I: Total energy supply by source, World 1990 – 2018 [5]

Considering the current environmental problem associated with the water crisis and climate change, capturing and using rainwater runoff from paved areas is an alternative solution. It would help cities resolve many problems. Ensures the required water quality and quantity supports biodiversity and creates a comfortable environment for the residents [8]. The main problem of rainwater management is air pollution, which significantly changes the atmospheric water's qualitative parameters. In the research study, we evaluate the published studies, which dealt with the characteristics of air pollution, its impact on rainwater quality, and the possible reduction of adverse effects. This study could be the basis for designing and proposing rainwater harvesting measures.

WHAT IS AIR POLLUTION?

According to the World Health Organization (WHO), air pollution has become one of the world's most important problems after climate change [9,10]. It poses a significant threat to the environment and adversely affects human health. In the last few years, more than 92 % of the population has been exposed to increased air pollution concentrations, as confirmed by WHO data [9]. Nine out of ten people all over the world breathe air every day that exceeds the air quality limit values set by the EU Ambient Air Quality Directives (European Council Directive 2008/50/EC) [11] and the WHO Air Quality Guidelines [12]. Many studies point to the negative consequences of air pollution and increase in emission and concentration worldwide [4,5,7,10]. Whether outdoor or indoor, bad air quality causes various diseases: various lung and cardiovascular diseases, strokes, etc.

Air quality is closely linked to global climate change and the ecosystem [9]. Many factors that affect the chemical composition of air are also the cause of climate change, the creation of the UHI effect, and greenhouse gases [4,5,7]. Changing the air's qualitative parameters changes both the air's properties in the outdoor and indoor environment. Air quality can be impaired in many ways: by changing the outside (burning fossil fuels, exhaust gases from vehicles) and the indoor air (domestic heating), aeroallergens, etc. The diversity of substances in the air mainly depends on the discharge of the emissions into the environment. With high amounts of pollutants in the climate, the area change's climatic properties: increase in temperature, humidity, frequency and intensity of precipitation, wind flow direction, and another factor affecting the environment. [9, 14]

SOURCE OF AIR POLLUTION

Air quality is not the same everywhere and varies over time. Different pollution varies from place to place, from region to region, as can be seen on the Real-Time Air Quality Index map [15]. Air pollutants can be of chemical, biological and physical origin. According to their method of origin, they are classified as substances of natural and anthropogenic origin. Air emissions concentration depends mainly on the area's use, whether it is an urban environment or rural areas. The chemical composition of air in rural and mountainous regions consists of substances from natural sources, including dust particles from the earth's surface, sea salt, and biological material in the form of pollen, plant residue, volcanic activity, and the like. In urban areas, the presence of air pollutants greatly affects the lifestyle of the population. Depending on the place of origin, air pollutants can be classified into primary and secondary substances. Primary substances enter the air from natural sources - they are released directly into the atmosphere; wheels secondary pollutants are formed directly in the air by atmospheric reactions.

The hazardous substances that affect air pollution are divided into two forms: gaseous pollutants and particulate matter. These include sulfur, carbon, and nitrogen compounds, halogen compounds, radioactive substances, and solid particles [18,19]. These atmosphere emissions play an important role in complex chemical processes that cause several environmental pollution problems in the environment. According to these, the Environmental Protection Agency (EPA) and WHO have identified six pollutants as the most dangerous emissions. These six pollutants are carbon monoxide (CO), nitrogen oxides (NO_x), ground-level ozone (O_3), ammonia (NH_3), particle pollution ($PM_{2,5}$, PM_{10}) and sulfur oxides (SO_x) [13,19]. Particle matters ($PM_{2.5}$) and ground-level ozone (O_3) are considered to be the primary urban air pollutants [20]. PM2.5 and O3 largely depend on the inhabitants' standard of living and the city's habitat structure (paved or vegetated areas). These substances damage the ecosystem, with O_3 being considered the most harmful air pollutant in terms of vegetation and biodiversity effects [21].

Anthropogenic sources

In the last decade, rural-urban migration has caused significant economic development in some countries, leading to the discharge of large amounts of pollutants into the urban environment. This trend has primarily affected countries in Europe, North America, and Asia, which have seen economic, demographic, and functional urban sprawl [4]. As a result of rapid urbanization, infrastructure, and industrial and agricultural activities in the atmosphere's chemical composition, anthropogenic origin substances have been emitted from motor vehicle exhaust emissions, fossil fuel emissions, ore dust, production, and agricultural dust construction, etc. [5,7]. The main sources of air pollution are considered to be agriculture, households, and public buildings, industry and, in urbanized areas, transport (Fig.II).

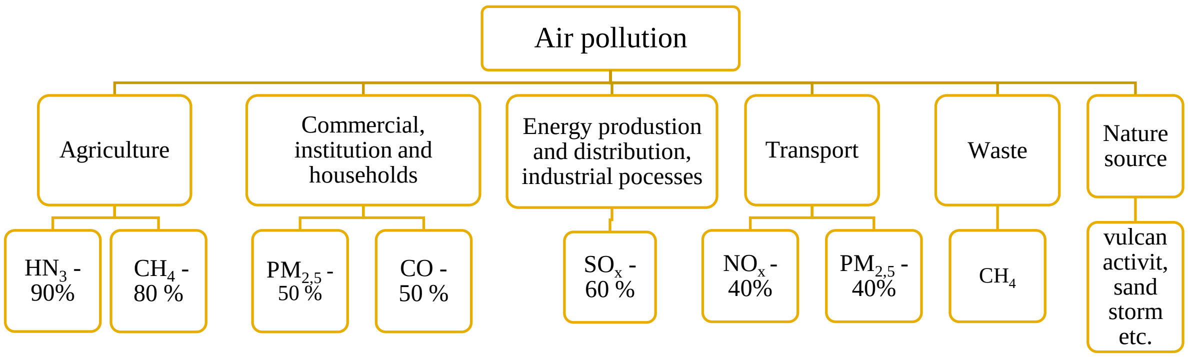

Figure II: Scheme of main sources of air pollution

Due to economic development in the urban environment, gases such as NO_2, SO_2, O_3, and particle matter have increased significantly. They are produced by burning fossil fuels such as coal, oil and gas, car exhaust fumes, biomass combustion, and electricity generation. The concentration of some emissions into the air gradually diminishes due to legislative measures, although it has recorded harmful levels in many areas. In recent years, the concentration of these substances has been gradually decreasing, as evidenced by many studies. [7,23]. Despite the introduction of many measures, atmospheric emissions are gradually declining but continue to be an important global problem, as confirmed by WHO mortality data [12]. In its study, Sicard compared air quality (6 main emissions according to WHO and EPA) in the 28 EU Member States from 2000 to 2017. During this period, it found significant reductions in some emissions of up to 80%, while limit values were still exceeded. Of the monitored pollutants, the highest concentrations were recorded for SO_x, NO_x, and non-methane volatile organic compounds (NMVOCs) [10].

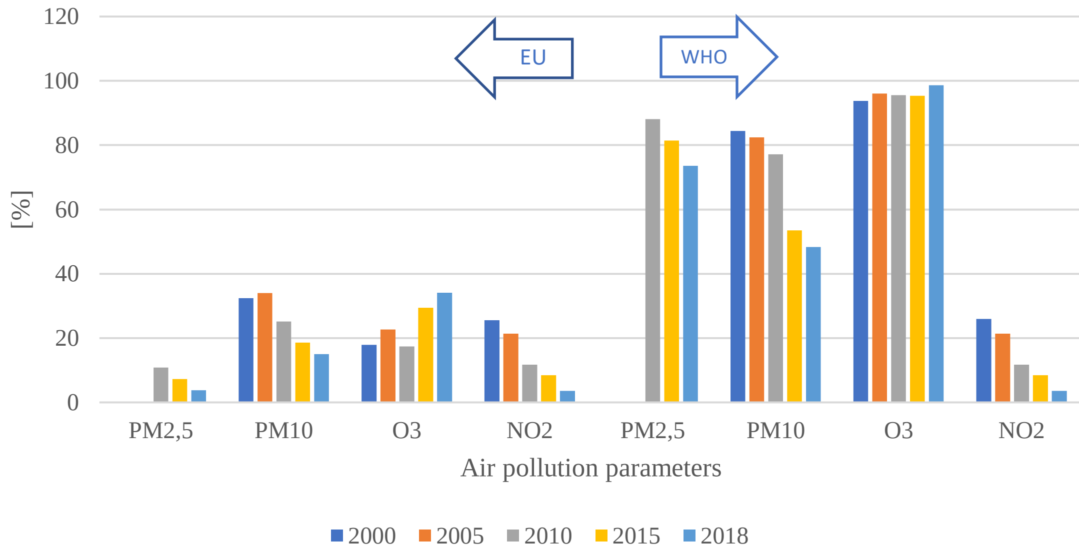

Figure III: Urban population exposed to air pollutant concentrations above selected EU and WHO air quality standards [22]

Figure III shows the percentage concentrations of pollutants above the WHO [12] and EU [11] standards. The WHO criteria for air quality are much stricter than the EU, and therefore the percentage of excess emissions is much higher. Given the results shown in the figure, it can be stated that over the period from 2000 to 2018, the percentage of exceedances' limits value is gradually decreasing. However, in some years, there has been an increase in some substances. In 2018, up to 48 inhabitants were exposed to increased PM_{10}, $PM_{2.5}$, NO_2, and SO_2 concentrations. At present, the biggest problem of pollution is O_3, which has not changed significantly over the period, while approximately 94 % of inhabitants are exposed to its adverse effects [22]. SO_2 concentrations have reached a significant reduction (about 20 %) in the period from 2000 to the present.

According to EU criteria the population should not be exposed to higher concentrations for $PM_{2,5}$ = 25,0 µg.m^3, PM_{10} = 50,0 µg.m^3 (more than 35 days a years), O_3 = 120,0 µg.m^3 (max daily 8-hours), NO_2 = 40,0 µg.m^3 [11]. Based on WHO air quality guidelines the population should not be exposed to higher concentrations for $PM_{2,5}$ = 10,0 µg.m^3, PM_{10} = 20,0 µg.m^3 (more than 35 days a years), O_3 = 100,0 µg.m^3 (max daily 8-hours), NO_2 = 40,0 µg.m^3 [12].

The concentration of air emissions varies significantly regionally, especially in industrial areas [10,7,23]. This phenomenon was recorded in many countries last year (2020) due to the spread of the dangerous coronavirus SARS-CoV-2. Many countries have enforced measures during which socio-economic closures have taken place. This led to a significant reduction in air emissions, mainly from transport and industry. Many studies that have addressed this issue have pointed out a drastic decrease in emission production: NO_2, CO, SO_2, and $PM_{2.5}$, PM_{10} [16, 24, 25]. In some parts of Europe, the reduction in NO_2 was reported to be up to 70 %. Also, during this period, the concentration of PM was reduced by up to 40 % [16]. During this period, there has been a significant improvement in air quality in several countries worldwide.

EFFECT OF AIR POLLUTION

As mentioned in previous chapters, air pollution is considered one of the most dangerous impacts on the environment. It causes negative consequences for humans, adversely affects the ecosystem, is directly related to the earth's climate. It directly affects the natural environment and biodiversity. The presence of nitrogen oxides and sulfur dioxide disrupts terrestrial and aquatic ecosystems, causing soil and surface water oxygen. Air pollution also causes significant changes in the climate; the climatic conditions of the area are changing. The presence of pollutants (CH_4, SO_2, NO_x, $PM_{2,5}$, PM_{10}) in the air causes global warming. Methane causes the formation of natural ozone, which in turn has a negative impact on biodiversity and the ecosystem. [9,10,16,25-27]

Many studies point out the danger of air pollution to human health. According to the WHO, air pollution is a significant cause of premature death and many human diseases. About seven million people worldwide will die from exposure to airborne emissions. Heart disease, stroke, or lung diseases such as cancer are the most common air pollution consequences. Short-term or long-term exposure to polluted air can result in respiratory infections, asthma, infertility, can affect diabetes two, etc. Based on these negative influences, the International Agency for Researcher on Cancer considers air pollution the main component of carcinogen cancer. [9,16]

IMPACT ON RAINWATER QUALITY

At present, atmospheric precipitation is one of the most controversial topics due to air pollution and its direct or indirect impact on the environment. The nature of pollutants in rainwater runoff is divided into primary sources of pollution - the rain itself's composition (air emissions) [2,3]. The source of secondary pollution occurs after contact of rain with the paved surface [2,3]. In terms of further rainwater management in urban areas, both pollution sources are significant factors that can significantly reduce rainwater runoff quality.

Several factors condition the chemical composition of atmospheric precipitation. First, rainwater quality depends on the air's composition and emissions, accounting for about 60 % to 70 % of rainfall [18]. These include gaseous and dust emissions, which are the primary source of air pollution (CO, NO_x, O_3, NH_3, PM, SO_x). Second, the chemical composition of rainwater can be affected by climatic parameters such as the speed and amount of rain and the trajectory of mass and airflow, air temperature, humidity, etc. [18, 24].

Under normal conditions (unpolluted areas), rainwater contains chlorides, sulfur, nitrates, potassium, calcium, and magnesium in concentrations up to 10 $mg.l^{-1}$ [24]. In contrast, in areas with polluted air, e.g., In industrial areas, urban areas, the concentration of these substances is several times higher and significantly exceeds the limit values set by government regulations, the Environmental Protection Agency (EPA) and the World Health Organization (WHO) [11,12]. Undesirable substances occurring in the rain runoff can be various organic and inorganic substances such as dust, sand, heavy metals (Zn, Cu, Pb), sulphates, chlorides, nitrogen compounds, phosphorus, petroleum substances, chlorination of hydrocarbons, PAH, PCB, pesticides, dioxides, various microbial substances, etc. In rainfall events, pollutants in the atmosphere reach the earth's surface and represent a primary transport medium for contaminants that can cause serious damage to the environment in the aquatic ecosystem or endanger human health [2,3].

The presence of harmful substances in the air significantly affects the pH fluctuations of atmospheric waters. From the water management point of view, the pH value represents the parameter's meanings that determine the rainwater acidity. The acidity of precipitation is affected by trace gases NO_2 and SO_2, which are involved in acid rain formation [7,23]. In areas with no air pollution, in mountain areas, the pH value of rainfall ranges from 5,5 to 6,0, while in industrial areas, the pH value may be less than 3,5 [24].

The composition of rain varies over time and depending on the content of pollutants in the atmosphere. Many authors have dealt with the evaluated qualitative parameters of precipitation [25,26,27]. Keresztesi A. et al. (2019), in their study, evaluated the chemical composition of rainfall, pH change, acidification, and neutralization processes of rain from 27 European countries from 2000 to 2017 (only countries that were members of the EU at the time) [25]. The daily study concludes that the chemical composition of rain in European countries is relatively homogeneous, and deviations of the measured concentrations are relatively small, varying depending on the country's economic development and environmental protection implementation.

CONCLUSION

In recent years, the concentration of undesirable substances in the atmosphere has increased worldwide, mainly due to the influence of transport and industry, which has confirmed the trends of measured values. Emissions such as SO_x, NO_x, CO, $PM_{2.5}$, PM_{10} play a significant role in our atmospheric environment and are gaining more and more attention. The presence of these substances in the air is significantly affected by the excessive combustion of fossil fuels, biofuels, power plant production, etc. [7]. At higher concentrations of emissions in the air, adverse effects on the environment have been reported. Air pollution has become a major global problem, causing serious health problems for people, even death.

Due to the current rainwater capture and use trend, the air's chemical composition causes a significant reduction in the rainwater quality. Many countries are currently working to reduce air emissions, which led to the conclusion of the United Nations International Framework Convention on Climate Change and the Paris Agreement (12.12.2015). The aim to contribute to sustainable development at the global level and ensure collective action, which would limit the impact of climate change.

Despite the progress made in reducing air emissions by introducing air quality limit values, reducing air emissions remains a challenge. Without introducing radical changes in mobility, energy and food systems, and industry, air quality objectives are unlikely to be met in the future.

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DIMETHACHLOR IN DRINKING WATER. OCCURRENCE, DETECTION AND REMOVAL BY GRANULAR ACTIVATED CARBON

Michal Marton[1]

Ján Ilavský[2]

Danka Barloková[3]

[1] Department of Sanitary and Environmental Engineering, Faculty of Civil Engineering, Slovak University of Technology in Bratislava, Radlinského 11, 810 05 Bratislava, Slovakia, e-mail: michal_marton@stuba.sk

[2] Department of Sanitary and Environmental Engineering, Faculty of Civil Engineering, Slovak University of Technology in Bratislava, Radlinského 11, 810 05 Bratislava, Slovakia, e-mail: jan.ilavsky@stuba.sk

[3] Department of Sanitary and Environmental Engineering, Faculty of Civil Engineering, Slovak University of Technology in Bratislava, Radlinského 11, 810 05 Bratislava, Slovakia, e-mail: danka.barlokova@stuba.sk

ABSTRACT

Dimethachlor is a pesticide used in agriculture. It is used for grass and broadleaf weed control in corn, soybean, peanuts and cotton. It is also used in combination with other herbicides. As it is still allowed in some European countries, including Slovakia, it can be found in the environment. Dimethachlor is a synthetic organic compound with complex structure. Therefore, it is difficult to remove it from environment by standard procedures and more complex processes are needed. As the paper shows, two types of granular activated carbon were used to treat water. Filtrasorb 400 and WG12 were both proved to be very efficient adsorbents. Reaction kinetics was also studied for both granular activated carbons and Filtrasorb 400 has faster reaction kinetics than WG12. As for adsorption efficiency, both activated carbons exceeded efficiency of 90%.

Keywords: activated carbon, adsorption, micropollutants, pesticide, water treatment

INTRODUCTION

Agricultural use of pesticides results in increase of crops, but their effects are less desirable when they get into the environment. These pesticides used in agriculture contribute to pollution in rivers and streams, which are often drinking water sources. [1,2] In some countries, the elimination of pesticides used in agriculture are possible, but some studies pointed out the decrease of about 45 to 50% of the crop yield. [3,4] Pesticides may enter water environment via diffuse or surface runoff. Surface runoff is a process by which pesticides are transported in dissolved or particulate forms into the water environment. [5,6]

Pesticides currently used are intended to be more environmentally friendly than organochlorine pesticides, due to their higher effectiveness towards pests, lower persistence and lower non-target toxicity. Nevertheless, numerous pesticides currently used in the world are very persistent and toxic. [7,8,9] For instance, more than 150 compounds registered in EU and approved pose great aquatic toxicity. Some have toxic effect on reproduction, have endocrine disrupting properties or have carcinogenic effects. [10] Dimethachlor belonsg to the group of pesticides which are still allowed for agricultural use. In many countries including Slovak Republic, Czech Republic, Austria, Germany, Poland and others, this substance is allowed for agricultural use. This herbicide causes some serious health issues when in contact with humans. It is known to induce respiratory problems, skin irritation and even problems with reproduction. [11]

Dimethachlor can be successfully removed from water using various types of adsorbents like biochar, silicagel and activated carbon. Activated carbon is one of the most used adsorbents in the world. It has a wide spectrum of applications. It is due to its adsorption capacity and selectivity. Other parameters describing activated carbon are, e.g. particle size, density, abrasion, uniformity coefficient and specific surface area 400-1500 m2 / g (or specific adsorption surface). [12,13,14] Adsorption capacity for activated carbon depends on the physicochemical properties and the origin of the adsorbate. [15]

There are several studies concerning with the removal of chloroacetanilide herbicides. By removing these group of herbicides from water using various types of adsorbents. For example, Gustafson et al. conducted experiments using powdered activated carbon for removal of herbicides from water. Their study proved that approximately 90% of the parent herbicide was removed using PAC with the dose of 20 mg/l. With the contact time of 60 min they achieved adsorption efficiency in the range from 60 to 80% and in some cases even 95%. [16]

Vymazal et al. conducted experiments using plants to remove dimethachlor from water. Their experiments shows that after 21 days the concentration of the herbicide is very low, comparing to the system where no plants were used. In those systems the concentration was barely changed. System with plants show reduction of herbicide after 21 days about 99%. Which can be considered as very successful. These experiments show that using plants for removal of herbicides can be very effective. [17]

MATERIAL AND METHODS

Dimethachlor standard was obtained from ALS Czech Republic. Activated carbon Filtrasorb 400 was obtained from Chemviron and activated carbon WG12 was obtained from Envi-pur s.r.o.

Table I: Properties of activated carbons WG12 a F400

	WG12	**F 400**
Iodine number [-]	1001	1000
Particle size > 0,17 [w%]	0.02%	5%
Particle size < 0,425 [w%]	3%	4%
Surface area B.E.T. [m^2/g]	1000	1050
Density [kg/m^3]	450	450
Effective Particle Size D_{10} [mm]	1.0 – 1.5	0.6 - 0.7
Uniformity Coefficient [-]	1.3	1.7

Pesticide standard was prepared as 0,5µg/L solution in 5L of volume. This stock solution was then used in experiments where 400 ml of this solution was taken and put in the Erlenmeyer flasks. Then 400 mg of activated carbon was added. These flasks were stirred at 400 rpm by orbital shaker (Orbital

Shaker OHAUS, bought from Thermo Fisher Scientific). All experiments were conducted in the laboratory setting with temperature of 22°C and pH value of 7.6. Samples were taken at 30, 60, 120 and 240 minutes and put in the vials filled with conservation substance. ALS Czech Republic then conducted analytical experiments to determine the concentration of pesticide in the water by HPLC method.

RESULTS AND DISCUSSION

Adsorption efficiency and speed constant for both types of activated carbon were calculated from measured data. These data are presented in tables II and III. Graphical presentation of these data is shown in graphs below (Graph….) Chemical kinetics for the reaction was also calculated for both types of granular activated carbon.

Table II: Concentration [c], Adsorption efficiency [η] and speed constants[k_0, k_1] at sampling time for activated carbon WG12

WG12						
t	0	30	60	120	240	[min]
c	0,340	0,289	0,218	0,171	0,021	[μg/l]
η	0	15,00	35,88	49,71	93,82	[%]
k_0	/	0,0017	0,0020	0,0014	0,0013	[μ/l.min]
k_1	/	0,0054	0,0074	0,0057	0,0116	[min^{-1}]

Table III: Concentration [c], Adsorption efficiency [η] and speed constants[k_0, k_1] at sampling time for activated carbon F400

F400						
t	0	30	60	120	240	[min]
c	0,340	0,217	0,134	0,047	0,010	[μg/l]
η	0	36,18	60,59	86,18	97,06	[%]
k_0	/	0,0041	0,0034	0,0024	0,0014	[μ/l.min]
k_1	/	0,0150	0,0155	0,0165	0,0147	[min^{-1}]

From Tables II and III it is clear that adsorption efficiency for removal of Dimethachlor from water with granular activated carbon WG12 was in range from 19,86 to 94,06%. Adsorption efficiency for activated carbon Filtrasorb 400 was in the range from 23,01 to 96,16%. These conclusions can be determined from picture I, where both activated carbons have different reaction course. In this picture it can be observed that both granular activated carbons have almost same adsorption efficiency after reaction time of 4 hours. The difference between these two activated carbons was really small.

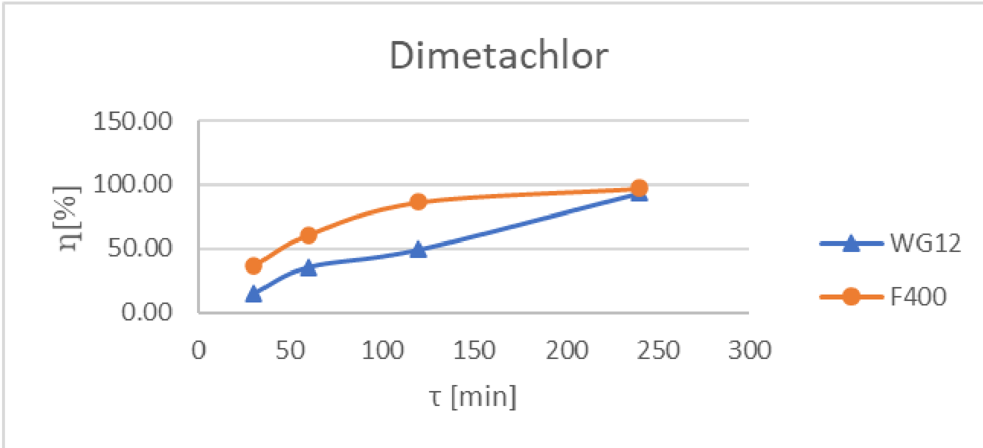

Figure I: Adsorption efficiency for both activated carbons WG12 and F400

Reaction kinetics was determined for whole order of reaction (0th, 1st and 2nd). By integration it was determined which order of reaction suits best for the adsorption reaction. For activated carbon WG12 we determined that 0th order of reaction was the most accurate and for Filtrasorb 400 it was 1st order of reaction. These data are also presented in figure II and III.

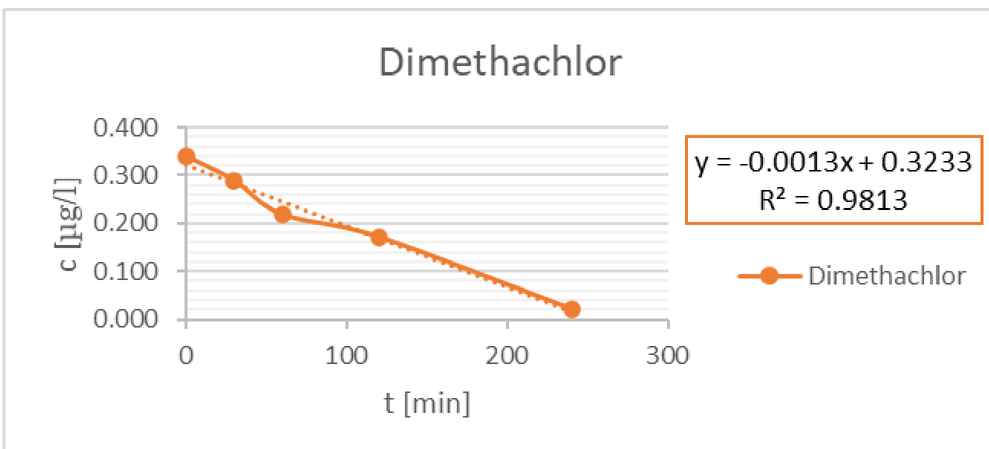

Figure II: 0th order of reaction kinetics for activated carbon WG12

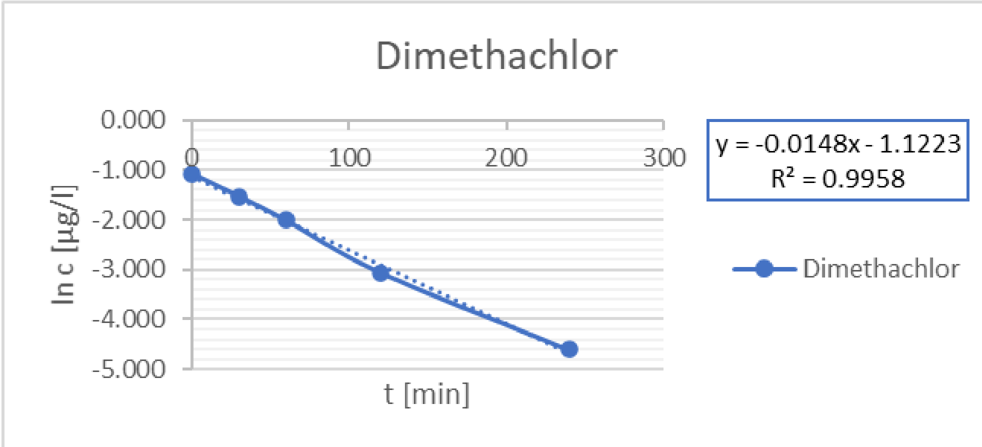

Figure III: 1st order of reaction kinetics for activated carbon F400

For the determination of the best adsorption isotherm for the adsorption process, several calculations were made. Two types of adsorption isotherms were compared, Frundlich and Langmuir. The results are presented in the table IV and graphical representation of these data can be observed in the picture IV. By comparing these data, it can be determined that Freundlich isotherm is far more accurate than Langmuir isotherm.

Table IV: R factors for Freundlich and Langmuir isotherm for granular activate carbons WG12 and F400

	Freundlich	**Langmuir**
WG12	0,7274	0,3534
Filtrasorb 400	0,7789	0,4006

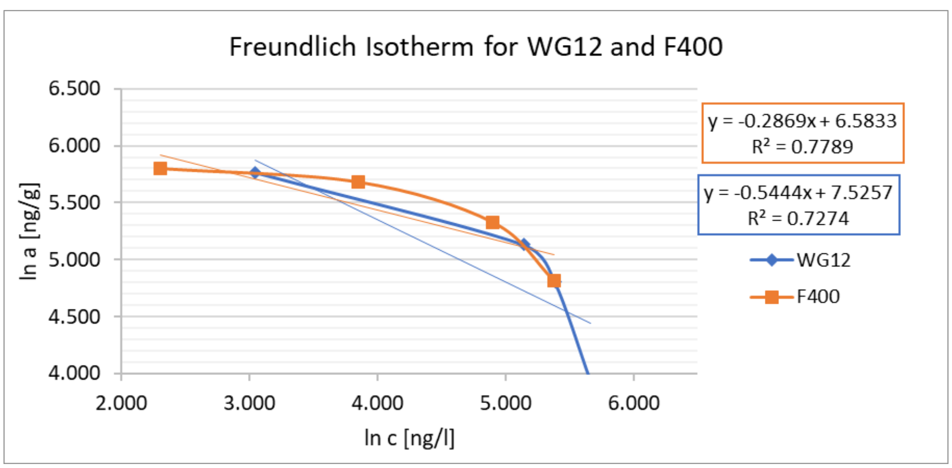

Figure IV: Freundlich adsorption isotherm for activated carbons WG12 and F400

CONCLUSION

This article is focused on comparing the adsorption efficiency of two types of granular activated carbons (WG12 and F400). This adsorption efficiency was applied in removal of dimethachlor from water solution. As it was presented in the tables and pictures above, both granular activated carbons were efficient in removal of this pesticide from water. Filtrasorb 400 as well as WG12, had the adsorption efficiency above 90% after 4 hours of reaction time. From the reaction kinetics we can determine that Filtrasorb 400 had faster adsorption kinetics than activated carbon WG12. This adsorption process can also be applied to flow reactors, where we can compare which activated carbon better handles the adsorption of dimethachlor. In the flow reactors, several different values can be observed. For example, the filtration rate, water residence time in the column, adsorption capacity, amount of water for washing filters, filtration cycle and others. After these experiments we can better determine which activated carbon would better adsorb the pesticide from water at a water treatment plant. But there is also different point of view which is the economy. For the best choice, the price of the material and its renewability must be included.

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OPTIMIZATION OF A SHORT DENITRIFICATION INHIBITION TEST FOR PESTICIDE TESTING

Kristína Pániková[1]

[1] Institute of Chemistry, Faculty of Civil Engineering, Brno University of Technology, Žižkova 17, 602 00 Brno, Czech Republic, e-mail: kristina.panikova@vutbr.cz

ABSTRACT

Pesticides and nitrates often enter groundwater through seepage. The denitrifying conditions that are typical for groundwater allow nitrate reduction. Little is known about the fate of pesticides under these conditions.

A batch laboratory test was proposed to investigate the influence of pesticides on the denitrification process. The proposed methodology allows the reliable testing of pesticides over a period of seven days. Individual test parameters were optimized.

Using this methodology, seven-day tests were performed with atrazine and tebuconazole. Neither of the investigated compounds was found to inhibit or stimulate denitrification significantly. A biotic loss (3.9 %) was found only for atrazine.

Keywords: pesticides, denitrification process, poplar wood shavings

INTRODUCTION

Agriculture is vital for human survival since this activity produces food, and population growth is placing an ever-increasing demand on food production supported by this activity [1]. Among the many intense processes related to agriculture, the use of chemicals to control pests and weeds, and to enhance food production, is significant [2]. However, the widespread use of pesticides in modern agriculture contributes to agricultural nonpoint source pollution in rivers and streams across the world, threatening drinking water resources and aquatic ecosystems [3]. Once pesticides reach water bodies, they can impact the whole ecological food chain [2].

The primary source of pesticide substances is agricultural areas. Pesticides are applied to land together with nitrogen-based fertilizers, which are the main source of nitrate in the soil. Nitrate, as a very migratory form of nitrogen, easily accumulates in natural waters, thereby leading to water quality degradation [4]. The consequence is eutrophication, toxic algal blooms, loss of biodiversity and drinking water contamination [5]. Pesticides and nitrates enter groundwater through seepage. Denitrification is generally recognized as the most significant process of nitrate removal from groundwater [6]. For this process, an organic substrate which serves as a source of energy is a necessity. These organic compounds oxidize during denitrification [7]. Nitrate can reduce to nitrogen gas; however, we do not know the fate of pesticides under these conditions.

In many European countries, a significant proportion of monitored groundwater is contaminated by triazines, primarily atrazine, terbuthylazine and their desethyl-degradation metabolites [8]. In the Czech Republic, more than 70 % of the water supply is contaminated by pesticides, which is more than was previously assumed. In 5 % of the cases, limit values have been exceeded for these compounds. In fact, pesticides have been on the first place as the cause of “exceptions” in the quality of drinking water since 2017 [9].

Denitrification can support the biodegradation of pesticides; it was improved in cases with atrazine [10] and chloroacetanilide pesticides [11]. Currently, no method exists for studying the behavior of pesticide compounds under denitrification conditions. The denitrification process is significantly influenced by the carbon source type, pH, and dissolved oxygen. The main object of this study is the development and optimization of a short denitrification test for the testing of two pesticides, namely atrazine and tebuconazole.

MATHERIALS AND METHODS

OPTIMIZATION OF THE TEST

The development of the test is described in Pániková [12]. A laboratory denitrification batch test was simulated in 2-litre bottles, which contained poplar wood shavings of a chosen mass and fraction as well as 2000 ml of deionized water with dissolved $NaHCO_3$ and KNO_3. The contents of each bottle were aerated with argon until the concentration of dissolved oxygen (DO) dropped below 0.5 mg/l. The bottles were closed and incubated at $T = 20 \pm 0.5$ °C in darkness.

At the end of each test, values were measured for each of the parameters to be optimized: pH, DO, COD and NO_X-N. From these measured values and from the temporal development of the denitrification, the best variant was evaluated for use in subsequent tests. Optimization of the following parameters was performed: the mass and fraction of poplar wood shavings, the initial nitrate concentration, and pH.

Mass and fraction of organic material

For the optimization of the ratio between the mass of the poplar wood shavings and the aqueous phase, the testing of two variants was conducted: variant 1 – mass of wood shavings 50 g; variant 2 – mass 25 g. Each variant was tested in 5 replications.

The optimization of the fraction was performed via a test in which 4 bottles contained a 1.0–1.5 cm fraction, while the other 4 bottles had a fraction of 0.5–1.0 cm.

Initial concentration of nitrate and pH

Initial nitrate concentrations of 20, 25, 30 and 40 mg/l were tested, each in two replications. The test was terminated after sixteen days. The bottles were opened regularly in order to measure the concentration of NO_X-N. After the measurements, the bottles were closed and incubated.

For the optimization of pH, two variants were tested over 7 days with different doses of $NaHCO_3$: 2 g/l and 3 g/l. Each variant had 3 replications.

SHORT DENITRIFICATION TEST WITH ATRAZINE AND TEBUCONAZOLE

For the short denitrification test, atrazine (ATR) and tebuconazole (TEB) were chosen. The tests were performed with the following optimized parameters: an $NaHCO_3$ dose of 3 g/l, an initial nitrate concentration of 30 mg/l, a 1.0–1.5 cm fraction of poplar wood shavings, and a 25 g mass of shavings per 2 liters. The bottles were divided into three groups, each with two replications. The principle behind the test is described in Table 1.

The effect of pesticides on the denitrification process was evaluated from their inhibitory effect on the denitrification rate, which was calculated from the initial and final concentration of NO_X-N. The effect of the tested substance was evaluated from the difference between the denitrification rates of groups 1 and 2.

The abiotic loss of the tested substance was assessed from the decrease in its concentration in group 3. The decrease in the tested substance due to biodegradation was assessed by comparing the decrease in concentrations of the tested substance in group 2 (biotic loss + abiotic loss) and 3 (abiotic loss).

Table I: Types of samples

Group	Composition of liquid medium	Description
1	KNO_3 (30 mg/l NO_3-N), $NaHCO_3$ (3 g/l for ATR, 0.5 g/l for TEB), methanol (0.1 ml/l)	Denitrification in progress.
2	KNO_3 (30 mg/l NO_3-N), $NaHCO_3$ (3 g/l for ATR, 0.5 g/l for TEB), the tested pesticide (100 µg/l; solution in 0.1 ml/l of methanol)	Denitrification and biodegradation in progress, adsorption on wood shavings.
3	KNO_3 (30 mg/l NO_3-N), $NaHCO_3$ (3 g/l for ATR, 0.5 g/l for TEB), the tested pesticide (100 µg/l; solution in 0.1 ml/l of methanol), $HgCl_2$ (6.5 mg/l, inhibitor)	Biological processes stopped, adsorption on wood shavings.

ANALYTICAL METHODS

The laboratory analyses were performed as follows: DO and pH with a Hach HQ40D multi meter, COD via the semi-micro method with potassium dichromate and photometric evaluation, and NO_X-N (NO_3-N + NO_2-N) via the UV absorption method with a Hach optical Nitratax plus sc Sensor. NH_4-N and NO_2-N values were measured using a spectrophotometer, NH_4-N via the Nessler method and NO_2-N via α-naphthol.

Pesticides were extracted from the water samples using solid phase extraction (SPE) cartridges. High-performance liquid chromatography (HPLC) analysis was performed using an Agilent 1200 chromatographic system (Agilent, Santa Clara, CA, USA) equipped with an Agilent Triple Quad 6410 mass spectrometer (Agilent, Santa Clara, CA, USA).

RESULTS AND DISCUSSION

OPTIMIZATION OF THE TEST

Mass and fraction of organic material

The use of a suitable mass and fraction of the selected organic material ensures there is sufficient COD to support denitrification and obtain consistent results. The minimum COD is approximately 100 mg/l for denitrification [13]. The shavings were tested in two mass variants, 25 g and 50 g per 2 liters. Figure I presents the denitrification process with a mass of 50 g. At this mass, a high variability of results was seen, with a coefficient of variation of more than 16 %. COD was measured as being at 660 mg/l at the end of the test. The lower mass of poplar wood shavings, 25 g per 2 liters, produced adequate variability of results (coefficient of variation 3 %); additionally, it ensured there was sufficient COD, which averaged 350 mg/l at the end of the test.

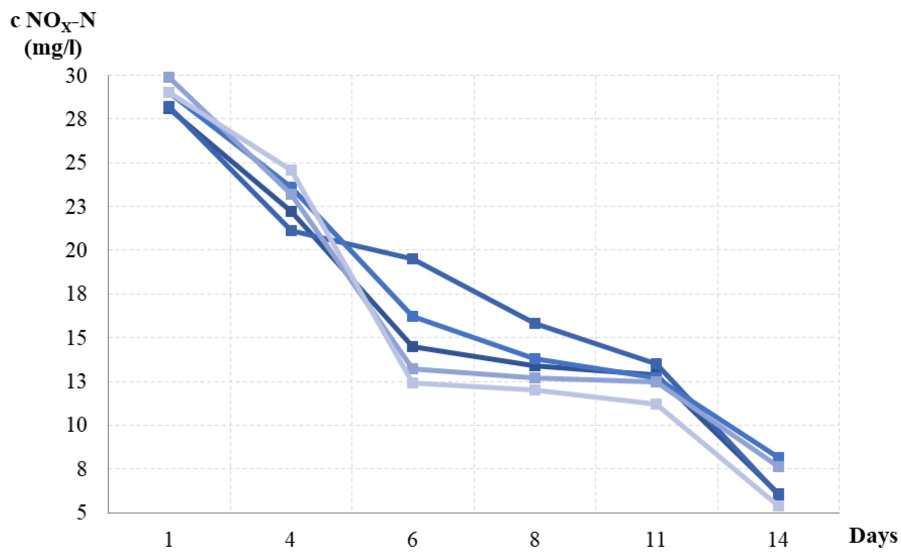

Figure I: Denitrification process with 50 g per 2 l

In the case of the 25 g mass of poplar wood shavings, two fractions were tested: 0.5–1.0 cm and 1.0–1.5 cm. Figure II displays the temporal development of denitrification for the two fractions. The higher coefficient of variation (12 %) was found in the test with the 0.5–1.0 cm fraction, with a mean COD value of 450 mg/l. The second fraction (1.0–1.5 cm) had a 5% coefficient of variation, while the COD was comparable with that of the first fraction. The reproducibility of the results was better with the 1.0–1.5 cm fraction. The 1.0–1.5 cm fraction was evaluated as being the best.

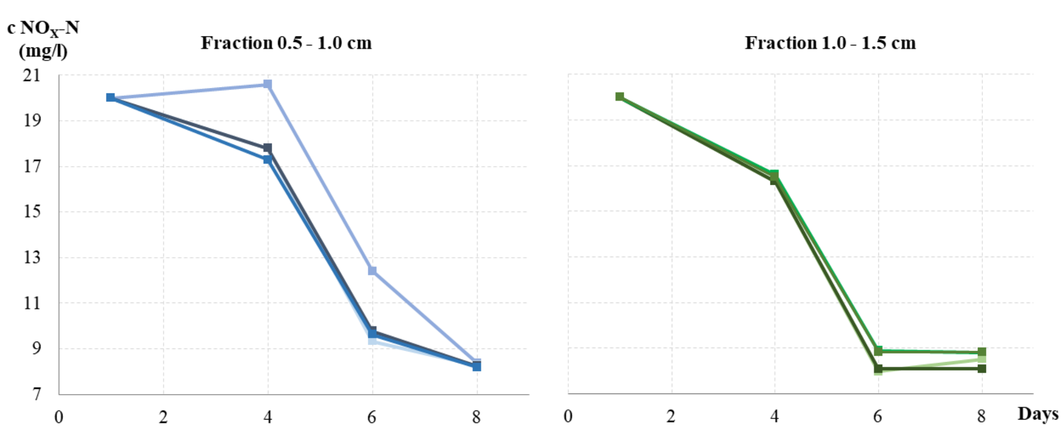

Figure II: Denitrification processes with two different fractions

Initial concentration of nitrate and pH

High nitrate values are not common under natural conditions; on the other hand, low initial nitrate concentrations may not be sufficient during denitrification tests. From the results of the denitrification process (Figure III), it was found that higher concentrations are not associated with a higher increase in nitrate on the first day. In the case of the initial concentrations of NO_X-N, there was an increase during one day of 7.15 mg/l and 7.25 mg/l for the respective initial concentrations of 20 and 25 mg/l.

The average denitrification rate increased with higher concentration. The lower initial concentration of nitrate, 20 mg/l, had an average denitrification rate of 1.38 mg/l/d. The higher initial concentration, 40 mg/l, reached the value of 2.10 mg/l/d. The initial NO_X-N concentration of 30 mg/l was evaluated as being optimal, since this dose should be sufficient for 7-day denitrification tests.

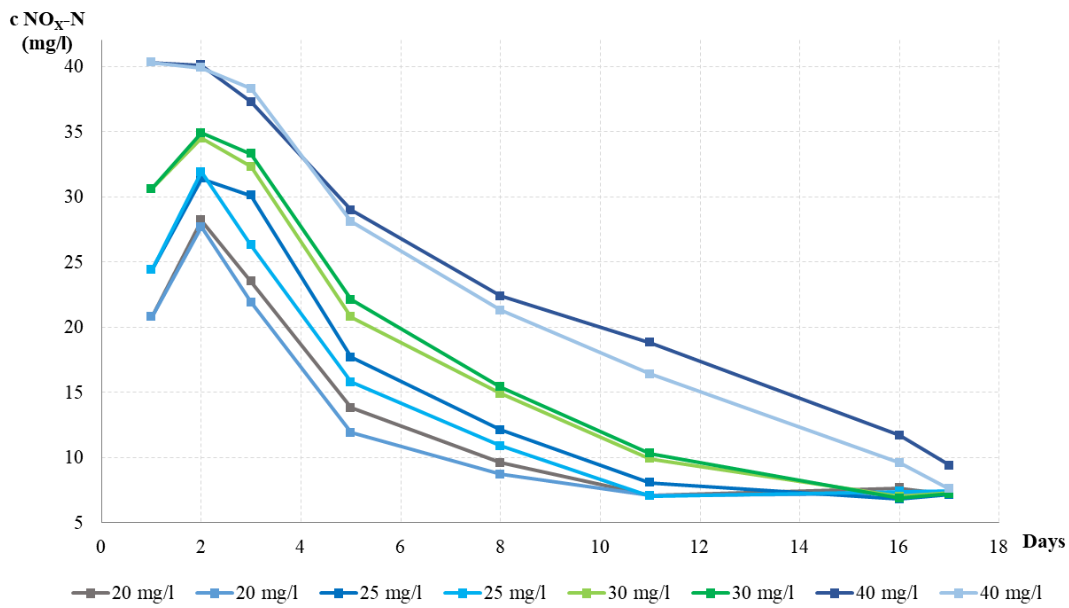

Figure III: Denitrification processes with different initial nitrate concentrations

Organic acidic compounds are released from poplar wood shavings during denitrification, which has a negative effect on the pH value. The most suitable $NaHCO_3$ dose in deionized water keeps the pH value in the range of 7.0 to 8.5 after 7 days. The dose of 2 g/l had a pH value in the range of 7.07–7.15. The pH values measured in the case of the 3 g/l dose ranged from 7.73 to 7.86 after 7 days. The optimal pH value for denitrification was found for both variants [7, 14]. The best $NaHCO_3$ dose was evaluated as being 3 g/l, which has sufficient buffering capacity for the preservation of optimal pH for the denitrification process.

SHORT DENITRIFICATION TEST WITH ATRAZINE AND TEBUCONAZOLE

Two pesticide substances were studied using the batch test: atrazine (ATR) and tebuconazole (TEB). During the tests, organic substances of acid character were released from the wood shavings. The dose of 3 g/l of $NaHCO_3$ had a sufficient buffering capacity to preserve the pH at a value that is beneficial for the denitrification process. During the test with ATR, the pH increased to 8.97 ± 0.07. These values are on the verge of being optimum. In the case of TEB, the dose of $NaHCO_3$ was reduced to 0.5 g/l, and the measured pH values were 7.52 ± 0.11. These values are better for denitrification [14] than those measured during the ATR test.

An amount of COD sufficient to support denitrification was released from the 25 g of poplar wood shavings of the 1.0–1.5 cm fraction [13]. The COD values ranged from 200 to 210 mg/l for the test with ATR, whereas values of 220 mg/l were found for the test with TEB.

It was appropriate to use argon aeration to accelerate the onset of denitrification. In the analysed samples without added inhibitor (group 1 and 2), DO values lower than 0.5 mg/l were measured after seven days.

The NO_2-N values in the case with ATR were higher than expected, ranging from 3.63 to 21.34. The highest values were found in the sample with added ATR (group 2). During the test with TEB, NO_2-N concentrations ranging from 0.106 to 9.03 mg/l were observed. Similarly high nitrite accumulations or N_2O emissions were also observed by Pan et al. [15] and Li et al. [16], who state that this could be associated with conditions where pH < 6.0. However, our results were observed for the pH values of 7.52 ± 0.11 (TEB) and 8.97 ± 0.07 (ATR), respectively.

The initial NO_3-N concentration of 30 mg/l was found to be suitable to provide denitrification conditions for the seven days of testing. In the case with atrazine, an average final NO_3-N concentration of 15.26 mg/l was measured, whereas with TEB it was 20.79 mg/l (group 1 and 2). These concentrations are sufficient for another seven days. Thus, a 30 mg/l initial concentration of NO_3-N can be sufficient for 14-day test periods. .

Woodchips generally release high NH_4-N during the initial period [5]. The average NH_4-N value (group 1 and 2) was found to be 0.88 mg/l (ATR), while in the case with TEB a higher value was measured, 4.03 mg/l.

During the test with ATR, the average denitrification rate was 2.44 mg/l/d (group 1). With the addition of extra ATR (group 2), the rate was slightly reduced to 2.33 mg/l/d. In the case of TEB, the results were different from ATR, i.e. rates of 1.30 mg/l/d (group 1) and 1.54 mg/l/d (group 2). The tested pesticides had a negligible effect on the denitrification rates in a seven-day test at a concentration of 0.1 mg/l.

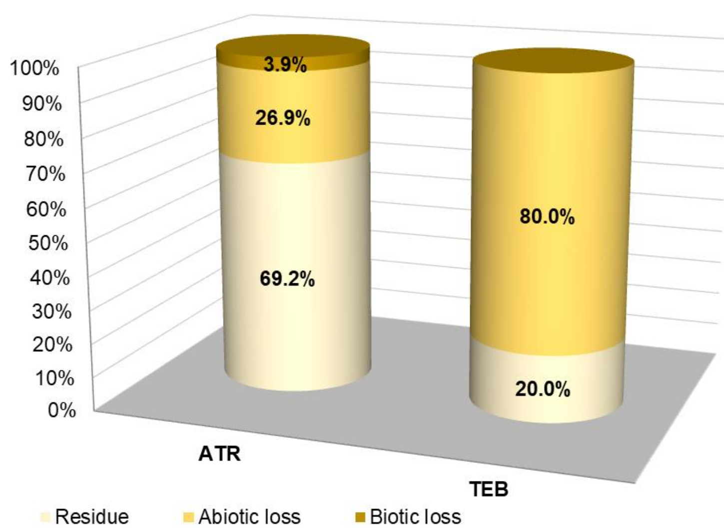

Figure IV: Individual processes occurring during batch tests

Figure IV presents individual processes occurring during the batch tests. Abiotic loss was evaluated as the dominant process in all tests. Mean abiotic loss was 26.9 % (ATR) and 80.0 % (TEB). The prevailing mechanism of abiotic loss was the sorption of pesticides on the wood shavings [17]. It can be assumed that the differences in abiotic loss are determined by the chemical structure and properties of the tested compounds [18]. According to Herrero-Hernández et al. [19], the degradation of TEB is influenced by the organic carbon content; low organic carbon contributes to decreased adsorption, and therefore encourages the microbial degradation of the fungicide. In the case of ATR, a biotic loss of 3.9 % was measured, but no biotic loss for TEB was found. A lower residue value was measured for TEB, namely 20.0 %.

More details about the ATR and TEB tests and their results are presented in Pániková et al. [20].

CONCLUSION

Optimal denitrification conditions were achieved with an $NaHCO_3$ dose of 3 g/l, an initial nitrate concentration of 30 mg/l, a 1.0–1.5 cm fraction of poplar wood shavings, and a 25 g mass of shavings per 2 liters.

During seven-day laboratory batch tests with pesticide concentrations of 0.1 mg/l, the tested substances (atrazine and tebuconazole) had negligible effects on the denitrification process. Losses due to biochemical processes were low; tebuconazole did not display biotic loss, whereas atrazine had a biotic loss of 3.9 %. The dominant process was abiotic loss, the highest value of which was measured in the case of tebuconazole (80%).

The presented optimized methodology was verified with two chosen pesticides and will be used to test other pesticides in the future. Moreover, the methodology will be further developed to allow longer test durations.

ACKNOWLEDGEMENTS

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MODERN PROBLEMS OF WATER PURIFICATION IN THE REGIONS OF THE RUSSIAN FEDERATION ON THE EXAMPLE OF THE TAMBOV REGION

Maksim Portnov[1]

Ekaterina Tarabrina[2]

Ivana Marko[3]

Štefan Stanko[4]

[1] Department of Technological Processes, Apparatus and Technosphere Safety, Faculty of Technology, Tambov State Technical University, Sovetskaya 106, 392000 Tambov, Russia, e-mail: maksportnov1997@mail.ru

[2] Department of Technological Processes, Apparatus and Technosphere Safety, Faculty of Technology, Tambov State Technical University, Sovetskaya 106, 392000 Tambov, Russia, e-mail: cool.z1z1z3@yandex.ru

[3] Department of Sanitary and Environmental Engineering, Faculty of Civil Engineering, Slovak University of Technology in Bratislava, Radlinského 11, 810 05 Bratislava, Slovakia, e-mail: ivana.marko@stuba.sk

[4] Department of Sanitary and Environmental Engineering, Faculty of Civil Engineering, Slovak University of Technology in Bratislava, Radlinského 11, 810 05 Bratislava, Slovakia, e-mail: stefan.stanko@stuba.sk

ABSTRACT

Today, in the central-western part of Russia, we can observe the situation with poor-quality drinking water, as well as serious problems with wastewater. There are various reasons, one of which is the old water supply system in cities, that needs modernization. We will try to analyze this problem using the example of the Tambov region.

Keywords: Plumbing, reservoir, the method of pulling, water purification, water supply system

INTRODUCTION

The plumbing and water supply systems are an important engineering system of any city or company. People, the economy, and the production process need water. For the extraction and transportation of water, there are entire systems of water intake facilities, water treatment plants, and pipelines that operate using various technologies. In the western European part of the Russian Federation, we can observe a problem with the water quality from the water supply in houses and apartments and problems with wastewater treatment plants. For example, in Moscow, it is possible to drink water from the water supply system, but it is impossible to do this in practice. The water undergoes a fairly high-quality treatment, but other factors affect water quality from the mains. It is also typical for other territories. Let's try to analyze this problem in detail using the example of the Tambov region, located 350 km from Moscow.

Water supply in the city is a monopoly. This is carried out by one centralized enterprise responsible for the extraction of water and its purification and supply. Based on a set of economic and technical indicators, it also determines the water sources and the schemes for its delivery to people.

HISTORY REFERENCE

Let us use a little historical information to better delve into the essence of today's problem. The water supply system has existed in Tambov for 130 years. In the 19th century, the city was small, and the supply of drinking water for the population was from the nearby rivers - Tsna, Studenets. For drinking and cooking was used water from wells. There were many springs on the territory of Tambov; today, they are almost not preserved. The quality of river water in those years in the city was low. For the technical needs that appeared in Tambov at that time, the river water was suitable, but it needed to be treated for domestic needs.

Later, the water supply construction began; everything was done by hand since there were no technologies that we can use today. Two years later, the system was fully operational. The reconstruction of the water supply system was at the beginning of the 20th century. In 1936, the city began operating the sewerage system. In the 1960s, the sewerage system lagged behind the city's growth in its development; this was a huge problem for the town at that time [1]. There was no wastewater treatment plant, and therefore all wastewater was directed to the Tsnu River, causing irreparable damage to it. It is very dangerous for the environment. And then, they decided to build a treatment facility to purify wastewater.

In the late 1960s - early 1970s of the XX century, a water supply and sewerage system were being completed in Tambov, which has remained practically unchanged to this day. It is worth noting that since then, there has been a very small amount of reconstruction work that defines one of the problems of the region today.

In the 1980s - 1990s, the water supply system developed, but very slowly. But the development required the expansion of the city within the radius. Therefore, the city's water supply system entered the new century with some problems. Thus, the historical background makes us understand today's reasons for the plumbing system's poor water quality. The fact is that the system itself developed very slowly and did not keep pace with time. And most of the water supply networks have not been modernized since the last century.

WATER RESOURCES OF THE REGION

The Tambov region's river network is represented by 1398 rivers with a total length of 9110 km (the river network's density is 0.26 km/km^2), most of which belong to small rivers and streams. The region's rivers are flat in nature, with small slopes, low flow rates, river floodplains are often swampy. The Tambov region rivers are characterized by mixed feeding with a predominance of snow (60–70%). The region's rivers belong to the Eastern European type of water regime; they are characterized by high spring floods, summer-autumn low-water periods, interrupted by rain floods, and low winter low-water periods. Freeze in late November - early December, open in mid- ate March [3].

There are more than 2,900 lakes and artificial reservoirs on the territory of the Tambov region, with a total area of about 190 km^2 (lake content 0.54%), including about 120 lakes with an area more than 0.01 km^2 and several smaller lakes. At the moment, Tambov uses several reservoirs, located in the Tambov region.

In the lower reaches of the Lesnoy Tambov River, near the city of Kotovsk, there is the largest reservoir and the youngest reservoir of the Tambov region - the Kotovskoe reservoir. It was created in 1995. The normal retaining level is 128.0 m. The total volume of the reservoir is 92.0 million m^3; the useful volume is 88.9 million m^3, the area of the water surface at the normal retaining level is 20.8 km^2, the length of the reservoir is 12.5 km, the width is 2, 6 km, average depth - 4.6 m. The length of the coastline is 35.0 km.

The reservoir carries out long-term flow regulation. The largest reservoir in the Tambov region in terms of total and useful volume of water. The banks of the reservoir contain vegetation such as coniferous-deciduous forest. There is a small residential village on the reservoir's left bank, not far from the dam. Several comfortable sandy beaches stretch along the right bank.

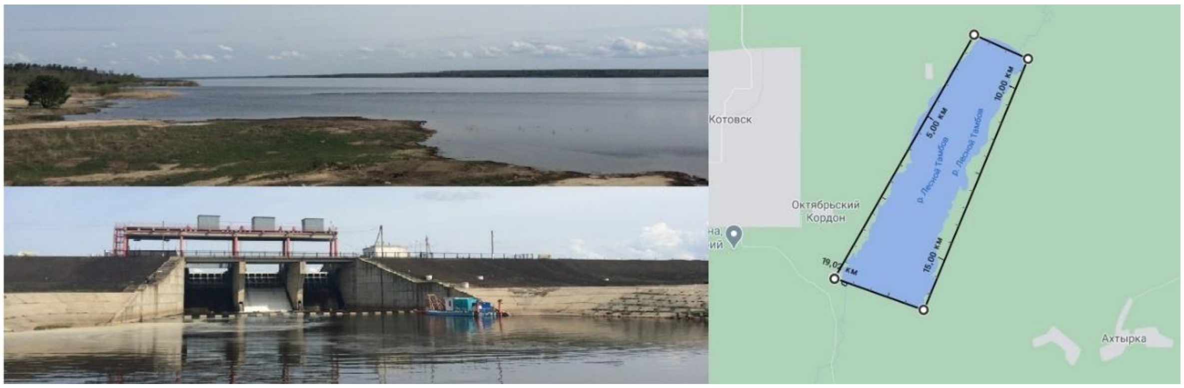

Figure I: Kotovskoe reservoir

The Lesnoy Tambov River, thanks to the constructed reservoir; is of great importance for regulating the flow of the Tsna River. The area around the reservoir on the Lesnaya Tambov River has great recreational potential.

The water of the Tambov reservoir is usually characterized as «slightly polluted» or «polluted» In terms of quality.

The oxygen regime of the reservoir during the open water period is usually satisfactory. The dissolved oxygen content is 7.82–8.52 mg / dm^3. The nitrate-nitrogen content is noted at a level close to the maximum permissible concentration (MPC). The concentration of oil products does not exceed 1.5 MPC.

The water resources of the reservoir are used for sanitary and special seasonal releases of water into the downstream of the hydroelectric complex; in the interests of various sectors of the economy and environmental protection (environmental releases); improving the conditions for water intake in the cities of Kotovsk, Tambov; fisheries.

SUPPLYING THE CITY WITH WATER

Water for consumption in the city is taken from wells, wells, and reservoirs. Before the water can be used for drinking purposes, it must first go through a filtration process. Water filtration is the process of removing suspended impurities, chemical compounds, biogenic components, dissolved gases from natural aqueous solutions [4].

Thorough water purification is necessary in case of obtaining water from a well or dug well, as well as filtering drinking water from a public water supply system – after all, they go a long way through pipes to your apartment. The water, filtered through complex post-treatment systems, is transparent in appearance and has a pleasant taste. It is saturated with compounds beneficial for the body in a normalized amount.

The following methods of water filtration are used in Tambov. First, coarse cleaning takes place using mesh or disc filters; this step is mandatory regardless of the water quality in the well or well.

Further, iron, manganese, and hydrogen sulfide are removed from the water using aeration systems and reagent filters. The latter is relevant when septic tanks or industrial effluents are located close.

After that, the water is softened using ion-exchange filters, they are very well suited for this purpose. Filters are used in conjunction with carbon cartridge installations. Then water is finely purified using reverse osmosis membranes. And the last stage is water disinfection. Unlike tap water, fences from wells are not treated with chlorine, if the efficiency of fine filters is insufficient or in order to save their resources, ultraviolet lamps or ozonizers are introduced into the circuit [5].

This technology is used in many enterprises in the Russian Federation. Let us explain in detail the technological scheme of the water purification process in Tambov.

Untreated water flows from an external water reservoir No. 1 through pipes into a metal basin made of stainless steel with a stirrer No. 2, where a coagulant is added at a concentration of 0.86 g / l of a 10% solution (86 g dry powder / m³) and mixed, followed by the composition is fed by gravity into the flocculation tank No. 3, where the flocculant is added at a concentration of 0.4 g / l of 0.2% solution (0.8 g of dry powder / m³) without stirring, the resulting solution is fed through pipes to the settling tank No. 4, which poured out of concrete and lined with tiles, where for a long time the coagulant and flocculant interact, and the process of precipitation of flakes occurs, which, in turn, precipitate and settle to the bottom of this sump.

Next, purified water from the upper point of the settler is fed through pipes to the filtration unit No. 5, here the main process of water purification takes place through the technological chain of ultrafiltration, first the water passes through a mechanical coarse and fine filter from solid inclusions, then comes into contact with a membrane consisting of multichannel fibers, which are made from modified polyester sulfone.

Untreated water flows from an external water reservoir No. 1 through pipes into a metal basin made of stainless steel with a stirrer No. 2. Here will be added a coagulant whit a concentration of 0.86 g / l of a 10% solution (86 g dry powder / m³) and mixed. Subsequently, the wastewater is discharged by gravity into flocculation tank No. 3, where the flocculant is added at a concentration of 0.4 g / l of 0.2% solution (0.8 g of dry powder / m³) without stirring. The resulting wastewater is fed through pipes to the settling tank No. 4., which is poured out of concrete and lined with tiles. In this tank and the process of precipitation of flakes occurs, which, in turn, precipitates and settles to the bottom of this sump.

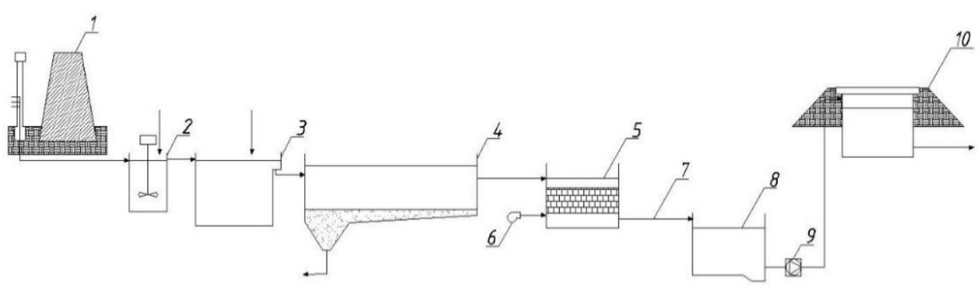

Figure II: Technological scheme of the water purification process in Tambov.

How much water goes to the consumer, the same amount of water goes back to the sewer. Therefore, before discharging water into open sources, it must be cleaned.

The main amount of wastewater that comes to the treatment plant is from the domestic and the residential sector. And only about 10% of wastewater comes from industrial enterprises.

The first point where dirty water gets in Tambov at the sewage treatment plant is the grates. The grates are about one centimeter apart, and solid household waste gets stuck in them, such as rags, bags, large pieces of vegetables and fruits, etc. After the grates, the drains go to the sand traps. This is where finer impurities are removed: sand and mineral impurities [6]. They settle, and the water is directed further. It is very important to remove sand from the water so that the equipment of the treatment plant does not corrode. After the sand traps, wastewater is directed to the primary sedimentation tanks.

Within an hour and a half, suspended substances, the so-called sludge, are precipitated from the wastewater, which is removed to the dehydration workshop. At the same time, fat inclusions are collected from the sump's surface by its rotating part; it is equipped with a grease trap.

This completes the mechanical stage of purification and begins the biological purification. Clarified water enters aeration tanks, where it mixes with activated sludge microorganisms. Due to the vital activity of microorganisms, water is purified from organic contaminants. In other words, microorganisms simply "eat" all the dirt - mainly nitrogen compounds [7].

Figure III: Biological treatment (Aeration tank)

In turn, to maintain the activated sludge microorganisms themselves, a whole system of their life support has been created. Special turbines supply air, which is also necessary for mixing water and for removing metabolic products. At the bottom of the aeration tanks are installed porous pipes. The whole system can be compared to the operation of the aeration system of an aquarium: oxygen is thrown into the water in small bubbles.

When the pores become clogged, the throughput becomes less. In aeration tanks, wastewater is purified within 6-8 hours, after which it is sent to secondary sedimentation tanks.

In secondary sedimentation tanks, activated sludge is removed from the water within an hour, and biologically treated water goes further into contact tanks for disinfection.

Part of the settled sludge is pumped to aeration tanks. And the excess sludge is sent to the mechanical dewatering workshop. After dewatering the sludge and sludge from the primary sedimentation tanks, the resulting substance is mixed with sawdust and composted for six months, after which a valuable fertilizer for agricultural production is obtained.

In the contact tank, already clear water is disinfected with sodium hypochlorite. And after only half an hour, it is discharged into water sources. Thoroughly purified water meets all accepted environmental standards.

At each stage, the water supplied to the treatment plant is subject to laboratory control. Without laboratory tests, it is sometimes difficult to say how many reagents and how much time is needed for each purification stage [8].

Today, Tambov's wastewater treatment plants are coping with the load imposed on them. After all stages of purification, the water meets the accepted and, by the way, rather strict standards. But the object is already outdated, and it needs serious reconstruction.

WATER QUALITY ISSUES

We can see that the water in the city goes through a very serious filtration and decontamination procedure, but it cannot be used for drinking from the mains. Therefore, water goes a long way to the consumer through pipes that are worn out, have internal pollution and corrosion.

According to a discrepancy of tap water with hygienic standards, the main sanitary and chemical indicators are iron content, total hardness, low fluorine content, and organoleptic indicators (color, turbidity). The percentage of water samples with an iron content of more than 0.3 mg / l was 29.6% of the total number of studies. There are only 11 drinking water treatment in the region with iron removal processes, which is extremely insufficient.

The main part of the pipeline consists of steel pipes, which are subject to corrosion and deterioration over time. The Tambov water supply system has not been reconstructed for a very long time. Only in new areas of the city are pipes laid from modern materials that do not corrode, but such cases are isolated and individual. Inside 85% of living quarters, pipes are also made of steel.

Pipeline accidents are very common in the city. In the warm season, diagnostics, scheduled and unscheduled pipeline repairs are carried out. Water is supplied to the pipes at a higher pressure and, as a result, breakdowns occur in certain areas, which are subsequently repaired.

In this regard, people have to spend a long time in houses without hot water. According to plans, such work is carried out in 10-14 days, but often repairs can be delayed for many months because new local damage occurs. Pipes are found underground at a depth of 2-3 meters. Due to the appropriate weather conditions, the pipeline is covered with an insulating material that prevents water from freezing in the cold season.

Failures in pipelines can be divided into local (point) and longitudinal deformations. Local defects include violations in the joints and insignificant longitudinal and transverse slots in the pipe body. Longitudinal deformations include destruction that occurs along the entire or almost the entire length of the pipe.

At the moment, some means make it possible to carry out spot repairs of pipelines in the shortest possible time without stopping their functioning. In practice, things are a little different. And when repairing pipes in cities, the method of replacing the pipeline can be used, which allows you to eliminate longitudinal deformations and is carried out with a stop of its functioning. This is a method of pulling a new pipe into an old one.

Pulling can be carried out both with the destruction of the dilapidated pipeline and without destruction. The method of pulling in a new pipe with the destruction of the old one is the most versatile method of trenchless replacement of pipelines. Using this method, dilapidated drainage pipelines are restored in sections up to 50 m long from ceramics, asbestos cement, cast iron, concrete, and steel by replacing them with polyethylene ones [9]. Also, this method requires certain financial costs.

Figure IV: The method of pulling a new pipe into an old one

CONCLUSION

The wear of networks in the city reaches 82%. In some parts, the pipes are much more worn out, almost completely destroyed. In 2018 in the city were performed more than 16 thousand repairs and maintenance. Therefore, today almost 3 billion rubles (~ 35 million euros) are required to modernize the water supply system. Another 6 billion (~ 70 million euros) will be allocated for the reconstruction of the drainage and sewerage system. This is a large-scale work on the renovation of urban water supply systems in the city, which requires a huge investment of time and effort.

Such large-scale work cannot be done quickly. It is possible to cast in the long run. Large-scale reconstruction will be implemented in stages using modern materials and techniques. Such work may take tens of years. Analysts make rough predictions that by 2038 it will be possible to replace the pipeline system in Tambov by 90%. These numbers are incredible. And by then it will be possible to use the water from the pipeline system for drinking. And now we have to use additional filtration units.

ACKNOWLEDGMENTS

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IMPLEMENTATION OF RAINWATER COLLECTION SYSTEMS WITH A PERSPECTIVE TO THE FUTURE DEVELOPMENT OF CITIES AND MUNICIPALITIES

Andrea Raczková[1]

Ivona Škultétyová[2]

Maksim Portnov[3]

Jaroslav Hrudka[4]

[1] Department of Sanitary and Environmental Engineering, Faculty of Civil Engineering, Slovak University of Technology in Bratislava, Radlinského 11, 810 05 Bratislava, Slovakia, e-mail: andrea.raczkova@stuba.sk

[2] Department of Sanitary and Environmental Engineering, Faculty of Civil Engineering, Slovak University of Technology in Bratislava, Radlinského 11, 810 05 Bratislava, Slovakia, e-mail: ivona.skultetyova@stuba.sk

[3] Department of Technological Processes, Apparatus and Technosphere Safety, Faculty of Technology, Tambov State Technical University, Sovetskaya 106, 392000 Tambov, Russia, e-mail: maksportnov1997@mail.ru

[4] Department of Sanitary and Environmental Engineering, Faculty of Civil Engineering, Slovak University of Technology in Bratislava, Radlinského 11, 810 05 Bratislava, Slovakia, e-mail: hrudka.jaroslav@stuba.sk

ABSTRACT

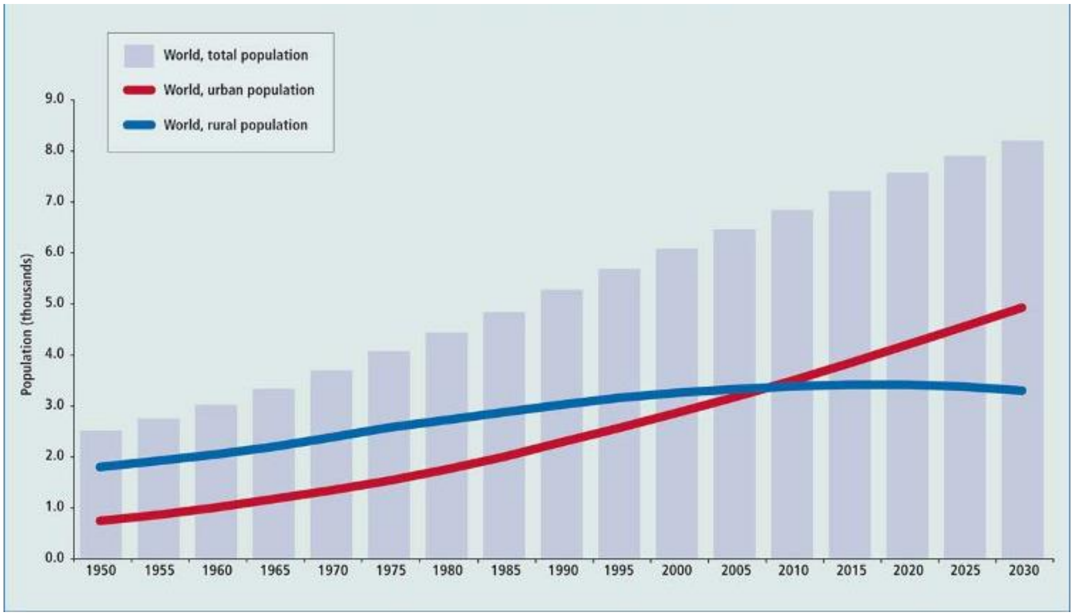
The cities in present have to face enormous challenges. Not only in terms of ever-expanding urbanization, but also the impacts of climate change on the natural water cycle. One of the necessities, in order to protect water resources that are not inexhaustible, is the implementation of a new principle for the sustainable management of rainwater, with the possibility of using various systems that support natural infiltration at the point of their impact. Effective use of rainwater to replenish of groundwater resources is one of the most important tasks of the principle.

Keywords: adaptation, drainage systems, protection of water resources

INTRODUCTION

In the context of climate change, considered one of the biggest challenges today, and also due to urbanization and a growing population (Figure I), many countries around the world, including Europe, face enormous challenges. Extreme weather fluctuations are becoming more frequent. Some regions of the world are struggling with floods, while others are struggling with extreme drought due to rising temperatures and a lack of precipitation. Although the manifestations of climate change vary around the world and in different regions of Europe (Figure II), its adverse consequences are becoming increasingly significant and require an active solution.

a)



b)

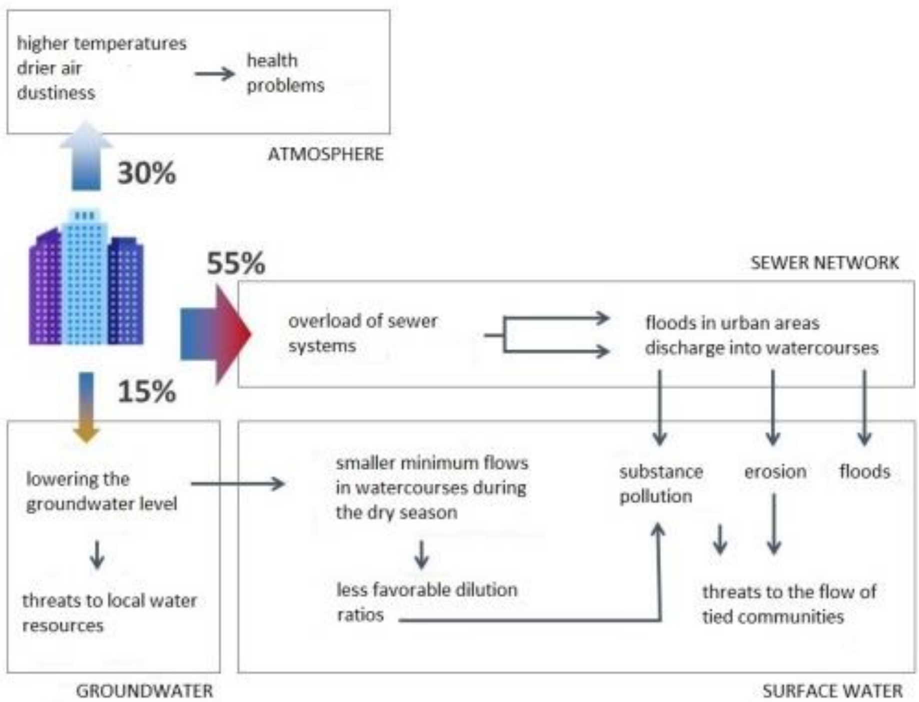


Figure I: a) Population development in the world 1950-2030 [10]
b) The impact of urbanization on the water regime [7]

In the context of ongoing climate change, observed increasingly intensively, perhaps the biggest problem is water scarcity in the soil environment, due to adverse changes in precipitation - runoff regime. A solution that could prevent or at least minimize the risks mentioned (Figure II) and the negative consequences, represents a nature-friendly approach to rainwater management.

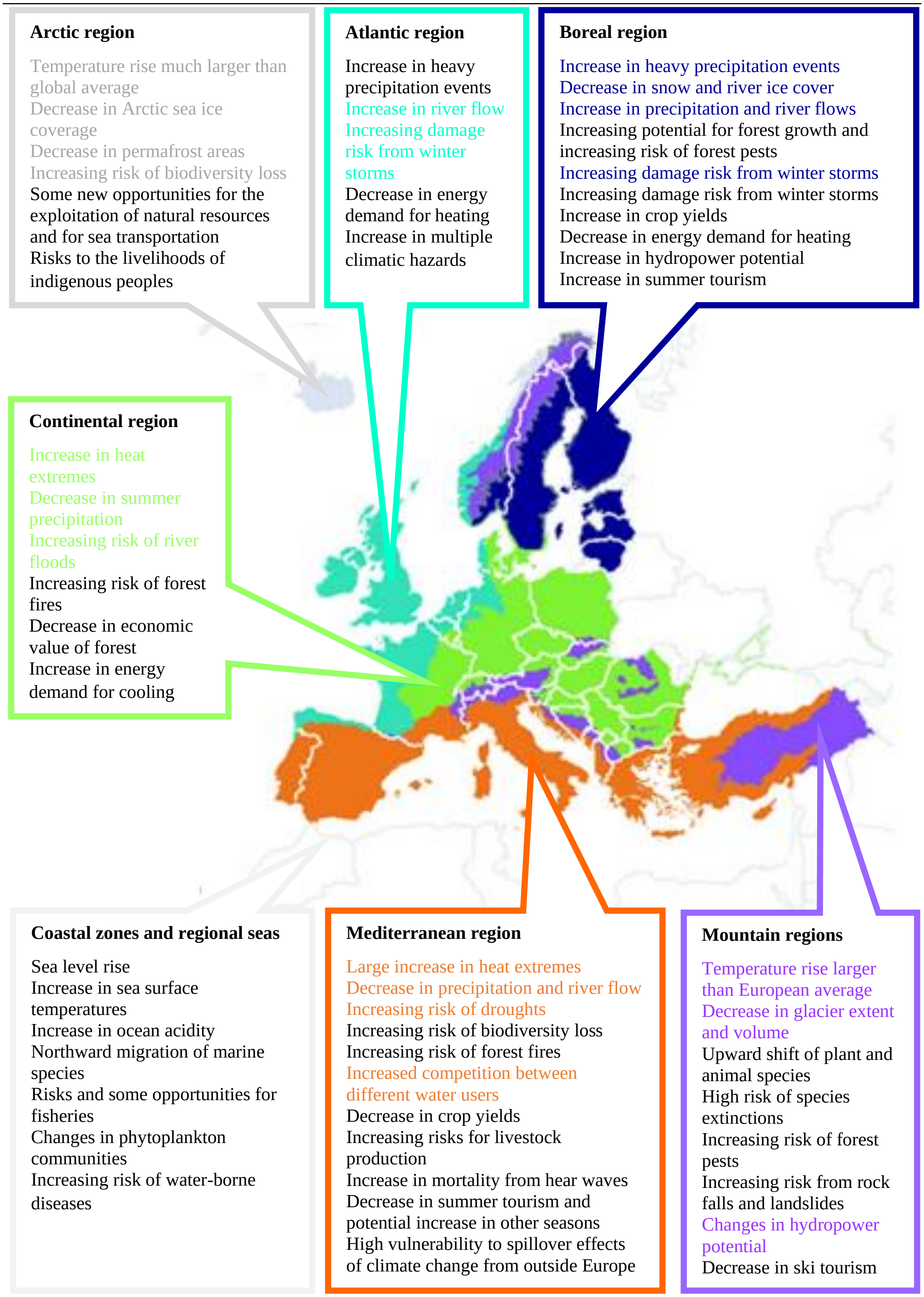


Figure II: Climate change and impacts for the main regions in Europe [1]

PRESENT APPROACH TO RAINWATER MANAGEMENT

The general effort of the current method of drainage of urban areas is to mimic the natural runoff characteristics of the site as much as possible, compared to the conditions in the urbanized area. The basis of rainwater management is a decentralized method of drainage, supporting natural infiltration at the point of impact of precipitation. By means of adaptation measures (Figure III), facilities and equipment that can be combined and interconnected in terms of usability.

Rainwater retention in an urbanized area can be achieved by infiltration, retention with regulated runoff or accumulation in surface or underground retention systems with the aim of its reuse. Which of the methods is the most suitable to use in the solved locality is decided by local, especially hydrogeological conditions (soil permeability, groundwater level, flow direction). And also the size of the drainage area or the runoff coefficient and the intensity of the rain.

Figure III: Adaptation measures and their benefits to the sustainable development of cities and municipalities

The flexibility of potentially applicable techniques is one of the indisputable advantages of rainwater management. From a long-term point of view, their implementation in practice can gradually not only reduce the costs of operation of sewer networks and WWTPs, but also reduce the material or hydraulic load of watercourses.

RAINWATER MANAGEMENT IN PRACTICE

In more developed countries, such as in Germany and Switzerland, they have been addressing the issue of rainwater management for many years. One of the priorities in the design of individual solutions is the sustainability of cities and municipalities. The emphasis in this solution is on the already mentioned decentralized method of drainage of urban areas.

Wales

A prime example of how to effectively implement the new principle of rainwater management in a built-up housing estatecan be mentioned by the example carried out in the town of Llanelli in the areas of the Stebonheath School, for reasons related to flooding. The proposed system consisted of disconnecting rainwater from a single sewer and from several interconnected objects, supporting the deceleration of rainwater runoff (Figure IV).

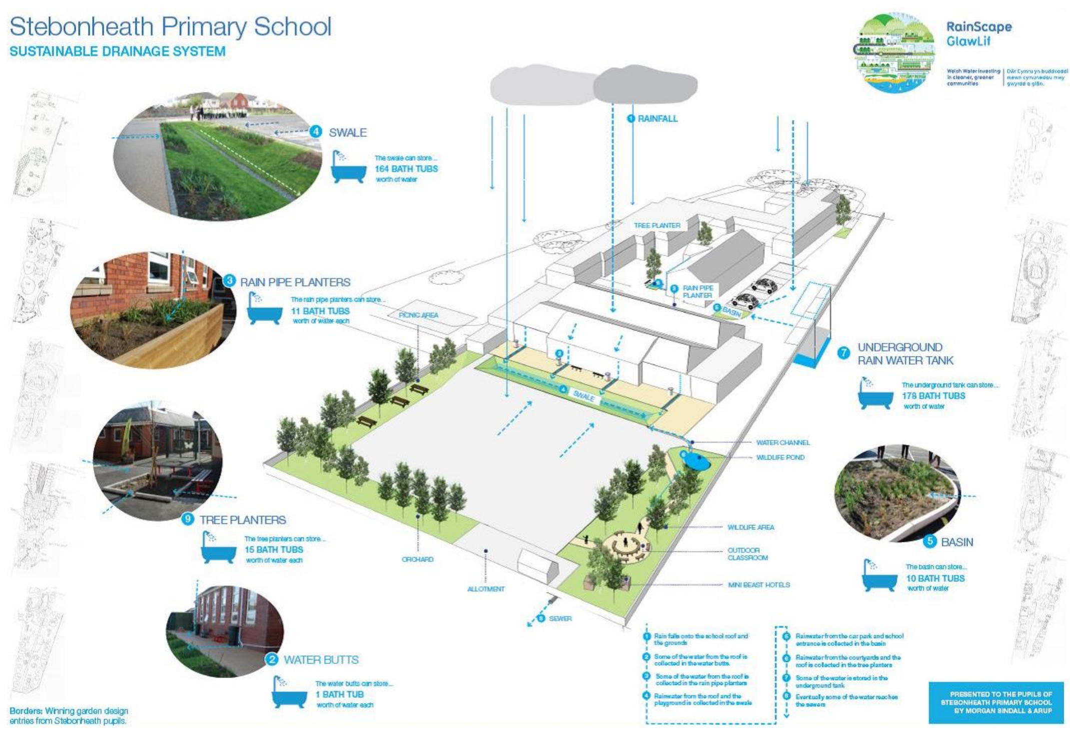


Figure IV: Plan of rainwater management in Stebonheath School [6]

Sweden

An illustrative example of how the drainage of existing buildings can be rebuilt in view of the problems with local floods, based on the principle of taking into account the management of rainwater with a focus on nature-friendly solutions, is the residential district of Augustenborg in Malmö. The plan consisted in disconnecting rainwater from the single sewer network and subsequently building a system of surface drainage of the urbanized area in the form of nature-friendly flood control measures. The proposed system consisted of 10 retention ponds and wetlands, 6 km long water canals and green roofs, with an area of more than 10 000 m² (Figure V).

a) b)

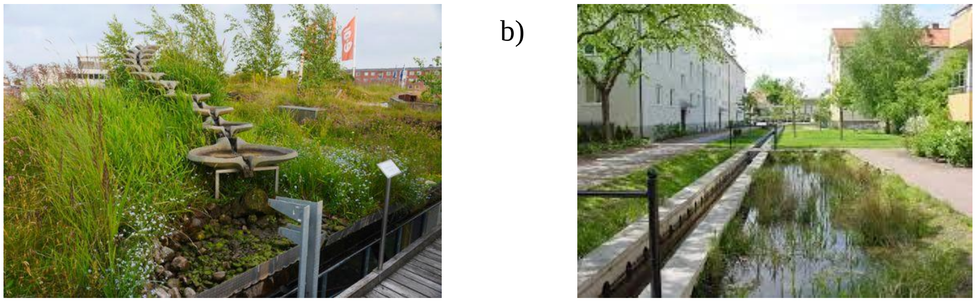


Figure V: Examples of rainwater management in Malmö
a) Green roof in Botanical Garden [3], b) Open rainwater runoff system [5]

However simple the essence of the new approach in rainwater management may seem, its application in practice, based on previous experience especially abroad, points to a relatively complicated matter. Mainly due to the lack of generally binding rules in many countries, which would clearly and in a coordinated formulate a society-wide interest. Without their understanding, there is a risk that individual measures will be implemented unconceptually. What may ultimately lead to the loss of their original meaning.

IMPACTS OF URBANIZATION AND CLIMATE CHANGE IN SLOVAKIA

Urbanization and its influence on the hydrological cycle

Although the rate of urbanization in Slovakia lags behind the European average (Figure VI), anthropogenic activity has been growing at a dizzying rate in recent decades. Due to the increasing extent of impermeable areas and the loss of natural vegetation cover, the first negative effects on people's lives in our country can be observed today. Due to unnaturally high surface runoff, there are fundamental changes in hydrological conditions, due to the disturbed balance between surface and groundwater. In view of rising air temperatures as well as below-average precipitation totals, especially in summer and spring, drought occurs adversely affecting groundwater resources. As groundwater is the primary source of drinking water in Slovakia, its protection is all the more necessary today.

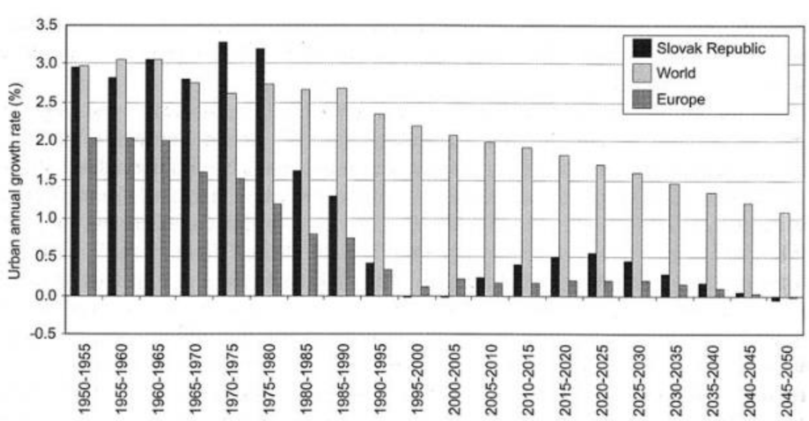


Figure VI: Urbanization dynamics in Slovakia, Europe and in the world in 1950-2050 [4]

Consequences of climate change

The negative balance of atmospheric precipitation, as a result of which it is possible to observe temporarily drying up riverbeds of some smaller streams, a decrease in groundwater levels, as well as a decrease in the abundance of most springs, has prevailed in Slovakia since 2011. The reason is global warming, characterized by an increase in the average annual temperature over the last 100 years by 1,1 °C.

The year 2018 was one of the warmest in the history of measurements in several places in Slovakia. In particular, the summer of this year was extremely above normal. what is also indicated by the evaluation of meteorological observations from selected meteorological stations in our territory (Figure VII).

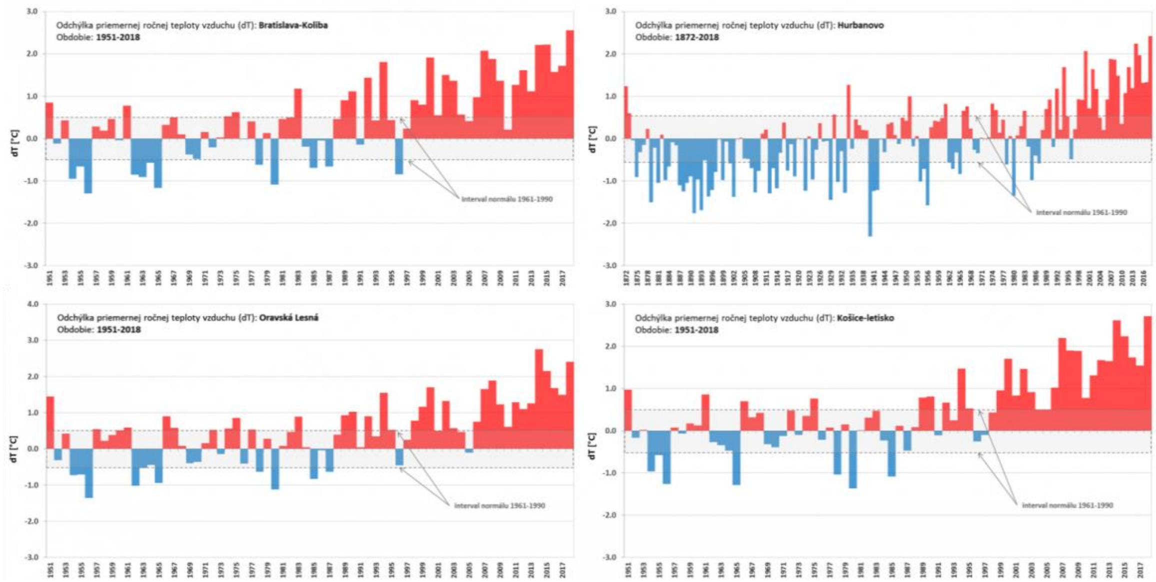


Figure VII: Deviation of the average annual temperature in 2018 from the normal 1961-1990 at selected meteorological stations in Slovakia [11]

Long-term observations of the Slovak Hydrometeorological Institute also show that the total atmospheric precipitation in a given year was much lower than the long-term 30-year average. The most significant difference from the selected precipitation measuring stations was recorded in Nové Mesto nad Váhom (Figure VIII).

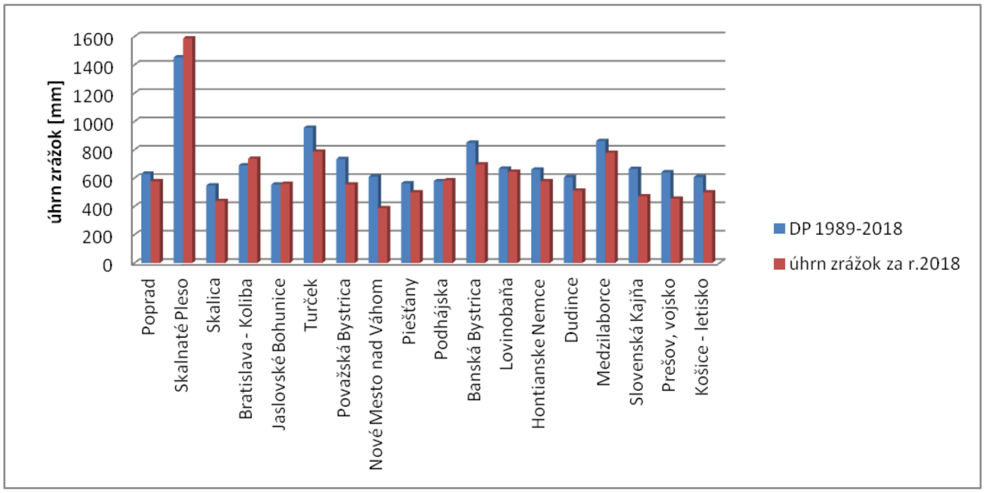


Figure VIII: Total atmospheric precipitation in selected precipitation measuring stations in Slovakia in 2018 and their comparison with the long-term average 1989-2018 [8]

SUMMARY

The main causes of negative effects on surface water resources, and in particular groundwater, are often closely interlinked together. From a global perspective, we can talk about climate change, urbanism or demographic change. Special attention must be paid to anthropogenic activity, which negatively affects the natural hydrological cycle in the country. From the point of view of the protection of our water resources, adaptation measures in the field of water management are necessary. In a comprehensive solution to the problems, with the aim of sustainable development of cities and municipalities with regard to the future of us and our future generations, it is necessary to perceive the country and also the change in the way it is used.

Whether we will be able to adapt to changing climate conditions and the expected extreme weather will depend very much on how quickly and effectively we can use increasingly accurate information on climate change in the decision-making and planning process.

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CALCULATION OF THE LEVEL OF MUNICIPAL WASTE SEPARATION BASED ON THE REGULATIONS OF SLOVAK LEGISLATION

Gergely Rózsa[1]

Réka Wittmanová[2]

Jaroslav Hrudka[3]

Ivona Škultétyová[4]

[1] Department of Sanitary and Environmental Engineering, Faculty of Civil Engineering, Slovak University of Technology in Bratislava, Radlinského 11, 810 05 Bratislava, Slovakia, e-mail: gergely.rozsa@stuba.sk

[2] Department of Sanitary and Environmental Engineering, Faculty of Civil Engineering, Slovak University of Technology in Bratislava, Radlinského 11, 810 05 Bratislava, Slovakia, e-mail: reka.csicsaiova@stuba.sk

[3] Department of Sanitary and Environmental Engineering, Faculty of Civil Engineering, Slovak University of Technology in Bratislava, Radlinského 11, 810 05 Bratislava, Slovakia, e-mail: jaroslav.hrudka@stuba.sk

[4] Department of Sanitary and Environmental Engineering, Faculty of Civil Engineering, Slovak University of Technology in Bratislava, Radlinského 11, 810 05 Bratislava, Slovakia, e-mail: ivona.sklutetyova@stuba.sk

ABSTRACT

Waste separation is part of the waste management hierarchy as well as landfilling. By separation, we can reduce the amount of waste that would then end up in a landfill. The optimization of waste management introduced a new waste collection system, and new technologies also help reduce the waste. Unseparated municipal waste must be landfilled, or energy recovered. However, this process is not free. The new law on the amount of the fee should regulate the fee according to the level of sorting. Under the new procedures, the level of sorting will be calculated according to a predefined formula. Based on this number, each city and municipality will have to pay their fees for depositing municipal waste in a landfill. The paper aims to understand the laws and regulations regarding the amount and determination of the cost for depositing municipal waste in a landfill.

Keywords: landfill fee, landfilling, law, waste, waste management

INTRODUCTION

The easiest way to protect nature is to separate waste. Today, the separation of plastics and paper from municipal waste has been introduced in almost every municipality and city. Since 2010, all municipalities in Slovakia have been obliged to introduce a separate collection of at least four components of municipal waste (CO) - paper, plastics, metals, and glass [1]. In 2013, to these components was added biodegradable waste. For many municipalities, this means a significant increase in waste management costs, investment (in the purchase or rental of waste containers), and operating costs. As the number of separated commodities increases, so does the number of waste shipments from the municipality. Separation is only the first step in reducing the amount of municipal waste that should end up in landfills [2]. By optimizing the frequencies of collection of individual separated components of municipal waste, it is possible to achieve cost savings that will favorably affect the rate of increase in fees for municipal waste collection in municipalities.

The most frequently sorted waste includes paper, plastic, metals, and glass, as well as biodegradable waste [3]. However, certain types of waste are dangerous for humans and the environment. These are, for example, accumulators, batteries, medicines after the expiration date, which requires special conditions for separation and storage. Therefore, it is necessary to have a civic amenity site with stored spaces to store common sorted waste in each location.

The efficiency of the civic amenity site lies in the quality of the sorted waste. The conditions must be met so that the waste is stored in the right place in the civic amenity site respectively thrown into the correct container. To comply with all regulations and instructions, it is recommended that there be a person in the collection yard who controls all this. By adhering to these conditions, we save nature and reduce the amount of waste that would otherwise end up in landfills.

Sorted types of waste can be processed and used in the waste management cycle [2]. The unsorted municipal waste ends up in landfills or is energy recovered [4]. Another motivation for municipalities to ensure the collection of sorted waste is the landfill fee. The more waste the citizens of a given locality sort, the less we will have to pay for landfilling waste.

METHODOLOGY

Waste management is an activity aimed at preventing and limiting the generation of waste and reducing its danger to the environment by Act no. 79/2015 Coll. on waste as amended [5]. Waste management is the collection, transport, recovery, including sorting and disposal of waste, including the supervision of these activities and the subsequent care of disposal sites. It includes the actions of a trader or broker [2,5].

Various systems are used for waste collection. The choice of collection system depends on the amount and type of waste, the mode of transport, and local conditions. According to the method, waste collection systems can be divided into the system with the container and the system without the container [6].

The amount, composition, and type of waste determine the required capacity of the system and its elements, especially in the case of separate collection. The structure of settlements, population density, and construction method are affected by determining the collection sites, the number, and the size of collection containers. The topography of the area is decisive, e.g., for the collection system, transport options, the size of the collection vehicle used, but may also affect the size and type of collection container. The choice of system should be based not only on financial requirements but also on the environmental impact of the proposed solution [3].

SEPARATE WASTE COLLECTION

Separate collection is focused mainly on the types of waste that can be recovered by processing. Municipal waste is sorted by households and then collected according to a predetermined method. Depending on the location of the collection containers, two basic methods are known. In the first method, the sorted waste is collected in collection containers on their land, from where they collect the sorted waste using collection vehicles. And in the second method is necessary to bring the separated waste to the collection point, distinguishing between collection points and civic amenity sites[3,7].

MUNICIPAL SOLID WASTE

The definition of municipal waste is complicated in Slovak legislation. However, a uniform definition framework is lacking both within the EU and globally. In Slovakia, but also in the Czech Republic, in terms of standard practice, municipal waste is perceived only as group 20 of the Waste Catalog, in the narrower sense, the so-called mixed municipal waste (20 03 01) [8]. In the countries of the old E15, however, municipal solid waste is understood in a slightly broader sense, including the so-called trade waste and other waste from the local community, as long as they are collected together [9].

The unsorted municipal waste ends up in landfills after collection from municipalities or is recovered for energy. The amount of the fee for depositing municipal waste in a landfill is determined by government regulation. The last holder of the waste shall pay the landfill fee. The fee payer for municipal waste is self-government [10].

FEES FOR LANDFILLING THE MUNICIPAL SOLID WASTE

The landfill operator calculates the fee for depositing municipal waste at a landfill according to the amount of waste and the fee for the given type of waste. When disposing of mixed municipal waste and bulky waste at a landfill, the applicable rate is determined based on the level of sorting of municipal waste. The level of sorting of municipal waste is calculated according to formula (1).

The municipality bases the calculation of municipal waste sorting in the relevant calendar year on the data from the records on the types and quantities of waste for the previous calendar year. The municipality is responsible for the correct calculation of the level of municipal waste sorting.

The municipality is obliged to publish information on the level of municipal waste sorting for the previous calendar year by 28 February of the relevant calendar year on its website address and the official notice board of the municipality. Furthermore, it is obliged to provide, at the request of the landfill operator, the Slovak Environmental Inspectorate, the district office, and the Environmental Fund, information on the level and method of calculating the level of municipal waste sorting for the relevant calendar year within ten days of their request. Most landfill operators request quantities of individual types of waste for inspection and calculate the percentage of sorting level for inspection [11].

Suppose the municipality does not provide the landfill operator with a rate indication. In that case, the landfill operator shall use the highest rate for calculating the fee for the disposal of mixed municipal waste and bulky waste for the relevant calendar year, prescribed by the government regulations.

CALCULATION OF THE FEE FOR LANDFILLING THE MUNICIPAL SOLID WASTE AT A LANDFILL

The amount of fees is determined by a government regulation, which sets municipal solid waste disposal fees. From 1 January 2019, thanks to the new system, the amount that municipalities will pay for landfilling of mixed waste will depend on the level of its sorting [11].

The following formula is used to calculate the level of municipal waste sorting for the relevant calendar year:

$$LS_{MSW} = \frac{m_{component\ 1} + m_{component\ 2} + m_{component\ n}}{m_{MSW}} \tag{1}$$

Where the: LS_{MSW} is the value of municipal waste sorting for the previous calendar year expressed as a percentage. The result should be rounded to 2 decimal places.

In the numerator of the formula, the values of m are a component. It is the weight of the sorted component of municipal waste collected in the municipality in the previous calendar year. The weight of municipal waste components is expressed in kilograms. The list of sorted components included in the amount of sorted municipal waste is set out in government regulation (see Table II).

The denominator of the formula contains the values of m_{MSW}, which is the weight of municipal waste generated in the municipality for the previous calendar year. The weight of municipal waste generated is also expressed in kilograms [11].

Table I: Amount of municipal waste landfilling fee according to the level of sorting for the given year [12]

	Municipal waste sorting level x [%]	**Fee for the year in euro, t^{-1}**		
		2019	**2020**	**2021 a following years**
1	$x \leq 10$	17	26	33
2	$10 < x \leq 20$	12	24	30
3	$20 < x \leq 30$	10	22	27
4	$30 < x \leq 40$	8	13	22
5	$40 < x \leq 50$	7	12	18
6	$50 < x \leq 60$	7	11	15
	$x > 60$	7	8	11

The amount of the fee for depositing municipal waste at a landfill depends on the level of sorting. The government approved a three-year transition period, during which each year the amount of the deposit fee increased by individual percentages. In the worst category, where the level of sorting is less than 10% according to formula (1), the landfill fee has almost doubled in three years. According to the level of classification, specific fees for individual years are set by Government Regulation No. 330/2018. since 2019, municipalities have been paying for municipal waste disposal at a landfill according to the level of sorting [11]. At that time, a transitional period began since the individual municipalities already care about how they classify. In 2021, those fees have stabilized, at least for the next few years. The amount of the fee for the disposal of municipal waste according to the level of sorting can be seen in table No. I. Now, it is up to the municipalities, cities, and municipalities to ensure the best possible system for collecting sorted municipal waste.

Table II: List of separable components of municipal waste that are used to calculate the level of sorting of municipal solid waste [11]

Waste code	Name of the waste
20 01 01	paper and cardboard
20 01 02	glass
20 01 03	multilayer composite materials based on cardboard (cardboard-based composites)
20 01 04	metal packaging
20 01 08	biodegradable kitchen and restaurant waste
20 01 10	clothing
20 01 11	textiles
20 01 21	fluorescent lamps and other wastes containing mercury
20 01 23	discarded equipment containing chlorofluorocarbons
20 01 25	edible oils and fats
20 01 26	oils and fats other than those mentioned in 20 01 25
20 01 33	batteries and accumulators specified in 16 06 01, 16 06 02, or 16 06 03 and unsorted batteries and accumulators containing these batteries
20 01 34	batteries and accumulators other than those mentioned in 20 01 33
20 01 35	discarded electrical and electronic equipment other than those mentioned in 20 01 21 and 20 01 23, containing dangerous parts
20 01 36	discarded electrical and electronic equipment other than those mentioned in 20 01 21, 20 01 23, and 20 01 35
20 01 38	wood other than that mentioned in 20 01 37
20 01 39	plastics
20 01 40	metals
20 01 40 01	copper, bronze, brass
20 01 40 02	aluminum
20 01 40 03	lead
20 01 40 04	zinc
20 01 40 05	iron and steel
20 01 40 06	tin
20 01 40 07	mixed metals
20 02 01	biodegradable waste

CONCLUSION

The new law proposal aimed not to demand as much money as possible from municipalities for fees for depositing municipal waste in landfills. The aim was to motivate municipalities to sort more, ensure a better municipal waste collection system, and provide residents with better services and opportunities to collect sorted municipal waste [13].

According to Eurostat data from 2016, Slovakia was one of the Member States of the European Union with the lowest share of recycled or composted municipal waste. We separated only about 23 percent of the total amount of waste. Most municipal waste is landfilled or incinerated. Slovakia is one of the powers in landfilling; we have only two significant classifications for energy recovery. The new law and charging system should help increase the level of sorting. Some towns and villages have already introduced new measures, methods of waste collection and have been able to ensure a better level of separation during those years.

Ultimately, the change in the charging system has helped to improve the state of waste management. The authorities instead felt the changes in the amount of the fee; they did not immediately try to put it on the population but instead began to build a new collection of sorted municipal waste to achieve a better level of sorting.

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FLOOD RISK ASSESSMENT – THE REVIEW OF THE CASE STUDIES

Mária Šugareková[1]

Martina Zeleňáková[1]

[1] Ústav environmentálneho inžinierstva, Stavebná fakulta, Technická univerzita v Košiciach, Vysokoškolská 4, 040 01 Košice, Slovensko; email: maria.sugarekova@tuke.sk

[2] Ústav environmentálneho inžinierstva, Stavebná fakulta, Technická univerzita v Košiciach, Vysokoškolská 4, 040 01 Košice, Slovensko; email: martina.zelenakova@tuke.sk

ABSTRACT

This article presents a brief overview of three selected flood risk assessment studies. The assessment on the Luvuvhu River focused on risk assessment based on threat and vulnerability parameters. To these parameters was added another, the exposure parameter in the assessment in the study of Sri Lanka. A threat, vulnerability and exposure assessment were also performed on the Yangtze River in China, where the authors presented a proposal for a multi-index flood risk assessment concept. The output of these studies are flood risk maps for each indicator, as well as individual risk assessments in the given area.

Keywords: flood risk assessment, vulnerability, exposure, hazard

INTRODUCTION

One of the most widespread natural disasters is floods, which also bring with them a certain level of risk. One of the most discussed topics is the protection of people and property against floods, as well as mitigating the negative impacts of floods on environmental components. An effective defense mechanism can be to prevent floods by building flood protection measures, or to be aware of the need for information on the causes and consequences of floods. In 2007, Directive 2007/60 / EC of the European Parliament and of the Council on the assessment of flood risks entered into force, requiring the Member States of the European Union to draw up flood hazard maps and flood risk maps. This paper focuses on a brief overview and comparison of selected studies that assess flood risk. However, selected studies were not performed in the Member States of the European Union, but their output is flood risk maps based on selected indicators.

MATERIALS AND METHODS

FLOOD RISK ASSESSMENT

According to the generally accepted definition, risk can be expressed as a combination of the probability of damage occurring and its consequence. The risk is most often expressed by multiplying the value of the probability of the occurrence of a negative phenomenon P and the value of the severity of its consequence D [1]. A similar equation is used to express flood risk, but is supplemented by other relevant values.

Luvuvhu river catchment

A study carried out in South Africa [2] focused on the analysis of flood frequencies and the assessment of flood risk in the Luvuvhu river basin, which covers an area of 4 826 km^2. The Luvuvhu River (Figure I) springs in the south-eastern slopes of the Soutpansberg mountain range and flows through the Kruger National Park. On the border between Mozambique and Zimbabwe, it flows into the Limpopo River. The northern border of the river Luvuvhu is formed by a dominant topographical element - the Soutpansberg mountain range. The highest and steepest slopes of this mountain range are located at the top of the basin. The variable topography has a significant impact on the overall hydrological conditions in the river basin.

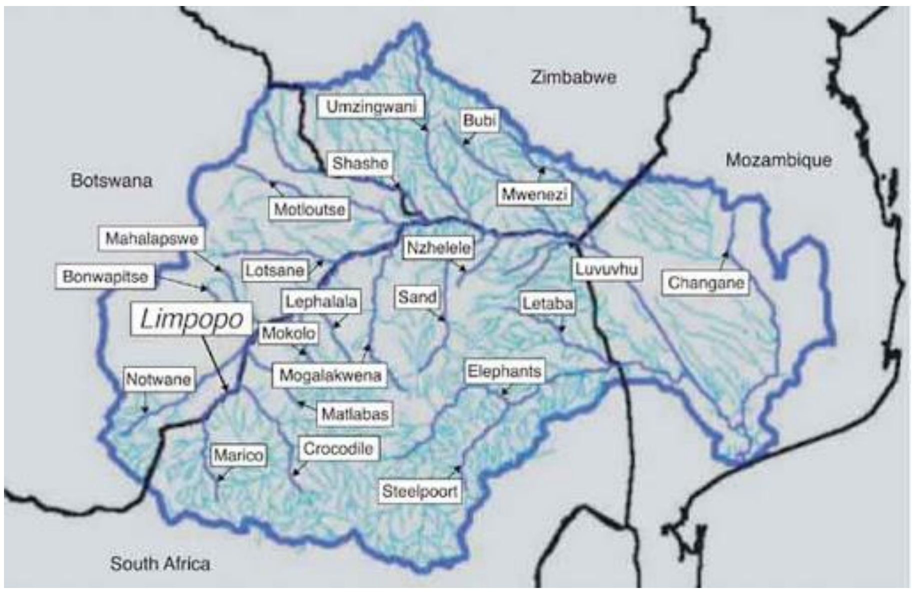

Figure I: Luvuvhu river catchment

Based on the availability and distribution of data, 4 stations were selected in the river basin, where a vulnerability and threat analysis were carried out. The main goal of the vulnerability analysis was to identify risk elements in the studied area. However, in terms of the scope of work, the study included only an analysis of spatial vulnerability. The vulnerability aspect was analyzed by determining the use of the area to be exposed to the flood and the total area flooded at the time of the flood. The vulnerability aspect has been identified for specific land uses. To assess the flood risk, the authors of the study used the method of Gilard and Givone, which consists in combining the results of the hazard analysis and the vulnerability analysis. The combination is based on the existing relationship between flood hazard classes and vulnerability classes of land use in the area addressed. Flood risk, the first aspect of flood risk, analyzes the determination of hydraulic parameters such as the extent of the flooded area or the depth of the flooding. This aspect suggests that a particular flooded area will be affected by a flood with the same hydraulic parameters, regardless of what the area (land) is used for. The vulnerability of land use as a second aspect points to the sensitivity of individual land use classes. This means that floods present a different level of risk depending on land use. For the purposes of this study, the threat was determined using an analysis of the frequency of floods, flooded areas and a map showing the hydraulic parameters of floods. Vulnerability was determined by analyzing the use of land exposed to floods.

The results of the study show that although a flood with the same hydraulic parameters will occur in the entire floodplain, the level of risk will not be the same in the entire study area, due to land use. For this reason, flood classes with a risk value were determined based on the flood depth analysis.

West province of Sri Lanka

In the study by Weerasinghe and colleagues [3], the exposure parameter was also assigned to the threat and vulnerability parameter. The study presents the results of a qualitative assessment of flood risk based on the expression of the mentioned parameters.

Data on topography, precipitation intensity, land cover and geology were used to analyze the flood risk. Thematic maps, on the creation of which selected input parameters were used (flow accumulation, precipitation intensity, land use, slope, altitude, length of the drainage system) were generated using the GIS platform. Each selected parameter was assigned a weight rating according to the extent to which it contributes to the flood. The total value of the threat is expressed as the sum of the products of individual parameters with their weight rating. The exposure analysis consisted of identifying the elements at risk of flooding. The elements were categorized into two groups - real estate and population. The elements were further quantified on the basis of the ratio between the total number (real estate and population) in the addressed area and the number of endangered elements in the area. The authors of this study took into account 3 types in the analysis of vulnerability: social vulnerability, economic vulnerability and housing vulnerability. The social vulnerability index was calculated on the basis of the claim that society's ability to cope with natural risks depends on the wealth factor. Although vulnerability (not only the territory) is influenced by many other factors, the authors of this study relied mainly on the financial possibilities of the population in the area. The indicator of social vulnerability was the age of the population, in this case gender was not taken into account. Each age group was assigned a weight score based on Flanagan [4] and Jonkman [5] qualifications, as well as subjective perception. The total social vulnerability index was calculated in a standard way - the sum of the products of each age category with a weighted rating. The analysis of economic vulnerability consisted in dividing the population according to economic status into employed, unemployed and economically inactive (children and pensioners). The basic assumption for the evaluation was that unemployed and economically inactive people depend on employed people, and thus the expression of economic vulnerability is the ratio of the sum of unemployed and economically inactive population to the sum of employed population. The last vulnerability assessed was the vulnerability of housing. The indicator was the number of housing units with low resistance to hazards, on the basis of which housing units were divided into permanently inhabited, temporarily inhabited and uninhabited. According to the claim that temporarily inhabited and uninhabited units are often damaged by floods, housing vulnerability was quantified by the ratio of the sum of temporarily inhabited and uninhabited housing units to the sum of inhabited units.

The overall flood risk was finally determined by the product of threat, exposure and vulnerability. In this case, the partial results were summed and fitted to the final equation.

Yangtze river catchment

A risk assessment procedure based on hazard, vulnerability and exposure parameters was also used in a case study on the Yangtze River in China [6]. This river is one of the largest rivers in the world, with a catchment area of approximately 1.8 million km^2. The river springs in the north of the Tanggula Mountains and flows through 11 regional provinces. Its range is more than 6,300 km, and eventually flows into the East China Sea on the island of Chongming in Shanghai. As its other tributaries extend to other areas, the river eventually flows through 19 regional provinces and occupies approximately 18.75% of China's total area.

A study carried out on this river looked at the development of a multi-index concept (MIC) based on GIS modeling. The MIC consists of three layers - the object layer, which includes the Yangtze River; an index layer that includes hazard, vulnerability and exposure parameters, and the last is an indicator layer that contains 13 flood risk indicators. These 13 indicators are divided between the index layer as follows: the threat parameter contains an indicator of the cumulative average of precipitation in a maximum of 3 days. The vulnerability parameter includes data on absolute elevation between a point and the Yellow Sea level, relative elevation (difference between absolute heights of two points), runoff density (depending on the density of the river network in the area), surface runoff factor and surface coverage, financial returns, financial savings, health service levels and the monitoring and warning system. The last exposure parameter contains data on population density, GDP, degree of soil erosion and risk of soil contamination.

To assess the relative importance of flood risk indicators, the method of the AHP analytical hierarchy was subsequently used, which assigned a weight rating to each indicator. After normalization, the data were transferred to the GIS environment, from which flood risk maps for each indicator were subsequently generated.

RESULTS

FLOOD RISK ASSESSMENT

Selected studies presented in this article assessed flood risk at various levels. The study carried out on the Luvuvhu River, unlike the others, contained only two parameters according to which the flood risk was assessed. However, the differences in the studies are not only in the number of evaluation parameters, but also in the method of flooding. In contrast to the flood risk on the Luvuvhu River and the Yangtze River, where river floods were taken into account, in the western province of Sri Lanka, an assessment of the flood risk caused by torrential rain floods was considered.

As the assessments were based on different input data and different indicators, these results cannot be unambiguously generalized. Therefore, the results of the studies are presented as separate subchapters.

Results of the flood risk analysis in the Luvuvhu river basin

The flood risk in this study was analyzed on the basis of threat and vulnerability parameters. However, in terms of the scope of work, only spatial vulnerability was addressed. The authors of the study were based on data on land use, and on the consequences of flooding given types of land use. The result of the study is that even if the flood floods the whole area, the flood risk will not be the same in all places. Therefore, based on the flood depth analysis, the following classification was established is presented in Figure II.

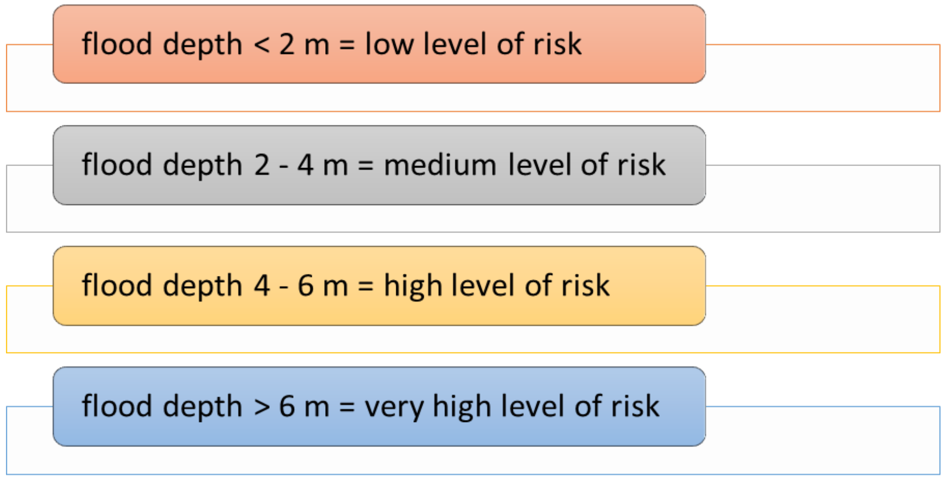

Figure II: Established classification of the level of risk

In this case, the damage depends on the depth of the flood, regardless of the purpose of land use. The results of the study testify to the truth of this statement.

Results of the flood risk analysis in the western province of Sri Lanka

The authors of the study took into account the parameters of risk, vulnerability and exposure when analyzing the flood risk. The parameters of vulnerability were based on the state of the population in terms of social, economic, and in terms of housing. The exposure parameter was divided into asset and population exposure. The result of this study is flood risk maps that apply to each type of assessment parameter. These 3 maps are individually analyzed, the results relate to the area addressed. The flood risk value is determined on a rating scale from 1 to 5, where a value of 1 indicates a very low risk and a value of 5 indicates a very high risk. In the results of the analysis for the population, economic vulnerability appears to be a better indicator compared to social vulnerability. The results of this study serve to prepare for the planning of measures aimed at early warning of natural disasters, have an informative character for the population and also provide a basis for the allocation of funds to mitigate the consequences of natural disasters.

Results of the flood risk analysis in the Yangtze river catchment

In this study, too, the parameters of risk, vulnerability and exposure were included in the flood risk analysis. In this case, however, the authors proposed a multi-index concept, which consists of 3 layers, namely the object, index and indicator layer. The results of this study can be summarized as follows: the flood risk posed by the Yangtze River depends smoothly on precipitation. GDP indicators, the surface runoff and land cover factor, as well as the degree of soil erosion also play an important role. Separate risk values were also determined for each parameter. The risk of exposure has changed significantly over time, while the risk of vulnerability and exposure has changed relatively less over time. The main advantages of the proposed procedure include its comprehensive proposal for the selection of indicators for flood risk assessment, and the output of maps from the GIS environment.

CONCLUSION

Flood risk assessments can be carried out at different levels and on the basis of different available data. This article presents a brief overview of flood risk assessment procedures based on hazard, vulnerability and exposure parameters. As no common approach to unambiguous flood risk assessment is recognized worldwide, the authors of the individual studies relied on available data for the country. Differences in the assessment and assessment of flood risk can be visible already in the selection of assessment parameters, but despite the same assessment parameters, the results will always be different. Threats, vulnerabilities and exposure are abstract concepts to which each assessor can assign their own indicators on the basis of which their assessment will be made.

However, the differences may not only be in the input indicators, but also in the scope of the evaluation. The flood risk can therefore be determined for the river basin, which covers an area of several thousand km2, but also in an area smaller than the cadastral area of a small village. However, the definition of risk remains the same, the difference may be in its interpretation.

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ANALYSIS OF COMBINED SEWER OVERFLOWS IN THE CITY OF TRNAVA

Marek Šutúš[1]

Gergély Rózsa[2]

Marek Csóka[3]

Štefan Stanko[4]

[1] Department of Sanitary and Environmental Engineering, Faculty of Civil Engineering, Slovak University of Technology in Bratislava, Radlinského 11, 810 05 Bratislava, Slovakia, e-mail: marek.sutus@stuba.sk

[2] Department of Sanitary and Environmental Engineering, Faculty of Civil Engineering, Slovak University of Technology in Bratislava, Radlinského 11, 810 05 Bratislava, Slovakia, e-mail: gergely.rozsa@stuba.sk

[3] Department of Sanitary and Environmental Engineering, Faculty of Civil Engineering, Slovak University of Technology in Bratislava, Radlinského 11, 810 05 Bratislava, Slovakia, e-mail: marek.csoka@stuba.sk

[4] Department of Sanitary and Environmental Engineering, Faculty of Civil Engineering, Slovak University of Technology in Bratislava, Radlinského 11, 810 05 Bratislava, Slovakia, e-mail: stefan.stanko@stuba.sk

ABSTRACT

Combined sewer overflows (CSO) are used to regulate the flow of rain and are therefore a typical object of these combined sewer systems. Their purpose is to reduce the amount of stormwater supplied to the treatment plant and to overflowed part of the rainwater to the recipient. However, these waters contain various contaminants, including coarse solids, fine suspended solids, and solutes. In the city of Trnava, exceeding overflow limits and also reduced water quality in reciprocity were recorded. The effectiveness of the CSOs depends on proper design and regular maintenance. To ensure compliance with strict current environmental regulations, it is necessary to determine the current state of the chambers and, if necessary, to design a suitable remediation.

Keywords: combined sewer overflow, sewerage, water pollution,

INTRODUCTION

"Urban drainage systems handle two types of flow: wastewater and stormwater. An important stage in the history of urban drainage was the connection of wastewater to ditches and natural streams whose original function had been to carry stormwater." [1]

There are two types of sewerage system: a combined and separate system. In combined system, wastewater, and stormwater flow in the same pipe, and in separate system we have separate pipes for these waters.

TRNAVA SEWER SYSTEM

The city of Trnava has, within the scope of the existing urban area, built a public sewerage system with a mechanical-biological wastewater treatment plant, located south of the city in near village Zeleneč. The sewerage system has the character of a combined network for the drainage of sewage, industrial and rainwater.

There is a combined sewer network in the city of Trnava with a total length of 111,236 km in 2015. A total of 36 municipalities are connected to the city's sewerage network. The sewer network in the city centre and in older buildings is already obsolete and overloaded, resp. undersized, resulting in operational difficulties. There are 22 combined sewer overflows on the sewer network to ensure the spill flow of stormwater. Stormwater from the PSA and Technopol industrial zone is drained through the stormwater [2].

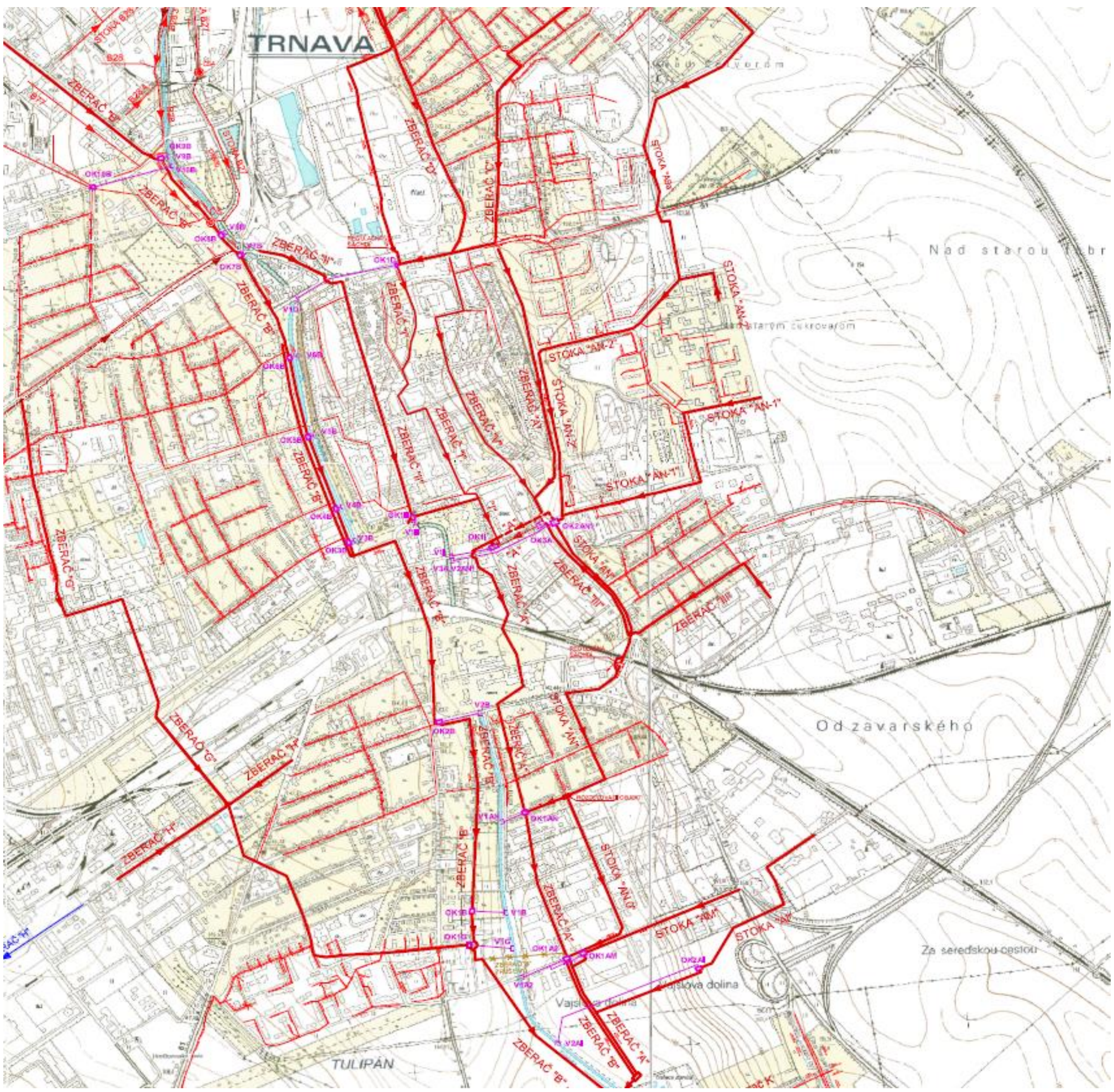

Figure I: Sewerage system with highlighted CSOs [4]

ASSESSMENT PROCEDURE

In the terms of [3], expert assessment of precipitation and runoff conditions and determination of the number of cases of overflow is needed. In addition, each CSO must meet a basic criterion, i.e., mixing ratio.

In the §6, section 3 of [3], the mixing ratio is defined by as the ratio of the average daily flow of municipal wastewater in the non-rainy period to the flow of water from the surface runoff that is discharged to the WWTP during the rain. In section 4, minimum ratio is set to 1:4. In the event of the need for increased protection of the recipient, the state water administration body may prescribe a value of the mixing ratio of up to 1:8.

According to §6, section 5 of [3], the basis for proving the number of cases of overflow during the year in the case of large sewerage networks with the number of CSOs greater than 10 is an expert assessment of precipitation conditions and runoff conditions. With a flow time through the sewer network to the CSOs equal to or longer than 15 minutes, the number of overflow cases may not exceed 15 per year on a long-term average. With a flow time through the sewer network to the CSO of less than 15 minutes, the number of overflow cases may not exceed 20 per year on a long-term average.

As mentioned above, there are 22 CSOs in Trnava. It follows that the sewerage network must be assessed in terms of the number of overflows.

FLOW MEASUREMENT

During the measurements, the conditions for hydraulic flow measurements were unfavorable. In most cases, sedimentation at the bottom, but also clogged and contaminated CSOs, were an obstacle to measuring. All measurements were performed out at the time of the morning peak of flows, or in the morning, when there is usually an average or above-average flow on the sewer networks.

Table IA: Measured values

	OK1	OK2	OK3	OK4	OK5	OK6	OK7	OK8	OK9	OK10	OK11
Depth [mm]	30,00	200	50	200	150	400	150	100	30	50	200
Velocity [$m.s^{-1}$]	0,4	0,3	1,35	0,2	0,2	0,05	0,5	0,1	0,4	0,7	1

Table IB: Measured values

	OK12	OK13	OK14	OK15	OK16	OK17	OK18	OK19	OK20	OK21	OK22
Depth [mm]	500	50	300	300	100	400	550	100	20	50	
Velocity [$m.s^{-1}$]	0,3	0,5	0,4	0,3	0,5	0,35	0,2	0,2	0,1	0,2	

HYDRAULIC CALCULATIONS

During the inspection, the inflow of wastewater into the CSO was measured, which is the basis for determining the hydraulic assessment criterion - mixing ratio. Determination of the inflow to the CSO was performed by determining the velocity and depth of the water in the inflow sewer. Based on the depth of the water in the inflow sewer, we derived the flow area and by multiplying the flow area by the speed, we obtain the flow.

$$v_{zv} = \sqrt{\frac{2g * (p + h_p + i_0 * l - m * D)}{\alpha + \xi_{vt} + \lambda * \frac{l}{D}}} \quad (1)$$

According to equation (1), the pressure flow velocity in the throttle drain was calculated. In equation (1) denotes: g (m/s^2) - gravitational acceleration, p (m) - water pressure height above the throttle drain, h_p (m) - overflow height, i_0 (-) - inclination of the throttle drain, l (m) - length of the throttle drain, m (-) - coefficient for determining the pressure line, D (m) - diameter of the throttle drain, α (-) - Coriolis number, ξ_{vt} (-) - coefficient of local losses at the inlet to the throttle drain, λ (-) - coefficient of friction.

The flow is then calculated using equation (2).

$$Q = v_{zv} \frac{\pi * D^2}{4} \quad (2)$$

As not all drains had a circular diameter, for some drains the flow area had to be estimated.

MIXING RATIO

To assess the mixing ratio, we will consider an operating state in which the level in the drain is at the level of the overflow edge, i.e. at the level when the water begins to overflow through the overflow edge into the relief drain. Mixing ratio is calculated according to equation (3).

$$n = \frac{Q_{odt}}{Q_{24}} - 1 \quad (3)$$

In equation (1) denotes: Q_{odt} ($m^3.s^{-1}$) – outflow, Q_{24} ($m^3.s^{-1}$) – average daily flow.

NUMBER OF OVERFLOWS

The equation (4) was used to calculate the number of overflows per year. The yield of block rain was determined based on the estimated flow time (length, inclination of the basin) and orographic characteristics for the ombrographic station Trnava – Vrútky. The calculations assumed an outflow time of 15 minutes for each CSO.

$$m_0 = \left[(1 - \tau) * \left(Q_m * \frac{n_0}{Q_d}\right)^{0,83} * \left(1 + c_1 * \frac{log}{p}\right) + \tau\right]^{-3} \quad (4)$$

In equation (1) denotes: τ (-) – climatic coefficient, c_1 (-) – local coefficient, Q_m ($l.s^{-1}$) – average urban waste water flow, Q_d ($l.s^{-1}$) - design flow of rainwater flowing from the river basin above the CSO, n_0 (-) - is the mixing ratio in a particular CSO, p ($year^{-1}$) – periodicity.

RESULTS

The Table II shows the results of the calculations for the mixing ratio and the number of overflows.

Table II: Condition of CSO

	Mixing ration [-]	Number of overflows [-]	Condition
OK1	4,10	4,1	Satisfactory
OK2	2,7	35,6	Unsatisfactory
OK3	14,3	2,1	Satisfactory
OK4	10,3	10,3	Satisfactory
OK5	16,9	3,6	Satisfactory
OK6	14,8	8,5	Satisfactory
OK7	6,9	18,3	Unsatisfactory
OK8	20	2,4	Satisfactory
OK9	8,3	12,8	Satisfactory
OK10	10,1	14,1	Satisfactory
OK11	1,2	51	Unsatisfactory
OK12	2,8	63,6	Unsatisfactory
OK13	11,8	39,3	Unsatisfactory
OK14	4,1	39,9	Unsatisfactory
OK16	33,2	1,3	Satisfactory
OK17	4,2	20,5	Unsatisfactory
OK18	6,6	5,4	Satisfactory
OK19	31,4	14,3	Satisfactory
OK20	11,5	35	Unsatisfactory
OK21	18,6	20,8	Unsatisfactory
OK22	6,1	0,8	Satisfactory

CONCLUSION

According to the results summarized in the Table II, we can evaluate that some CSOs do not meet the limit on the mixing ratio, the number of overflows or both conditions at once. In case of unsatisfactory CSOs, a building modification is proposed. However, as we can see in (Fig. II, III) the conditions of all CSOs are in a very poor construction condition, entrances into CSOs does not comply with safety regulations. According to [1] § 6, section. 2, the CSO must include a device for capturing floating substances, but as can be seen in (Fig. II), it is also not present.

Figure II: Overflow edge of CSO [4]

Figure III: Unknown hole in the CSO wall [4]

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WAYS TO SOLVE WASTE RECYCLING PROBLEMS IN RUSSIAN FEDERATION AND WESTERN EXPERIENCE

Ekaterina Tarabrina[1]

Maksim Portnov[2]

Gergely Rózsa[3]

Ivona Škultétyová[4]

[1] Department of Technological Processes, Apparatus and Technosphere Safety, Faculty of Technology, Tambov State Technical University, Sovetskaya 106, 392000 Tambov, Russia, e-mail: cool.z1z1z3@yandex.ru

[2] Department of Technological Processes, Apparatus and Technosphere Safety, Faculty of Technology, Tambov State Technical University, Sovetskaya 106, 392000 Tambov, Russia, e-mail: maksportnov1997@mail.ru

[3] Department of Sanitary and Environmental Engineering, Faculty of Civil Engineering, Slovak University of Technology in Bratislava, Radlinského 11, 810 05 Bratislava, Slovakia, e-mail: gergely.rozsa@stuba.sk

[4] Department of Sanitary and Environmental Engineering, Faculty of Civil Engineering, Slovak University of Technology in Bratislava, Radlinského 11, 810 05 Bratislava, Slovakia, e-mail: ivona.skultetyova@stuba.sk

ABSTRACT

Waste recycling in the nowadays Russian Federation is really on the first place There is not fully satisfied separate waste collection in the country. Waste is usually stored in one place for a couple years with no-environmental positive effect. The article suggests the ways how to solve this problem and the ways to modernize the waste recycling system.

Keywords: Environmental safety, sorting and recycling of waste, waste incineration plants, waste reform.

INTRODUCTION

There are too many environmental problems in the modern world that adversely affect both the environment and human life in general. The most important problems include air pollution from road transport exhaust fumes, waste from chemical plants, improper handling of solid waste, and the creation of landfills for waste disposal.

Humanity throws out about 5 million tons of waste every day. In the Russian Federation, each person throws out more than 400 kg of waste every year. Nevertheless, not among the countries with the highest waste production for the resident. For example, in Italy, every person throws more than 550 kg of waste per year, and in the USA, this figure reaches 800 kg per year per person. However, at the same time, in the United States of America, 24% of wastes are recycled, 10% goes to compost, 14% is incinerated, and the rest is stored in landfills. Unfortunately, in Russia, only 4 to 5% of wastes are recycled, 1% is incinerated or goes to compost, and 95% is dumped. Landfills occupy more than 1,000,000 hectares of the Russian Federation. This paper will try to understand this problem and find ways to solve the country ecological waste crisis.

RESEARCH AND FIGHT AGAINST PLASTIC IN THE WORLD

According to research, the predominant percentage of the discarded waste is food waste and paper products. They represent about 70-75% of all waste. Plastic and glass account for approximately 13-19% of all waste produced and depend on the state. Russia accounts for about 14% of such waste.

Plastic products began to be mass-produced in the early 50s of the XXth century. More than 8 billion tons of plastic have been produced, and currently, 75% of plastics are dumped. However, there are many areas where we need plastic products. It would not be easy to replace these plastic products with products made of another material.

In the modern world, products made of plastic can be replaced to some extent. As practice shows, at the moment, about 40 countries around the world have abandoned plastic bags in exchange for fabric or paper bags, as well as mesh bags. For example, in France, in addition to the ban on the sale of plastic bags, it is planned to abandon disposable plastic products almost completely from 2020; this includes plastic dishes, cotton swabs, etc. In Denmark, in the early 90s of the twentieth century, was introduced a tax on plastic bags. The price of such products also increased in supermarkets; they have become unprofitable. People, therefore, started using reusable bags that can be carried with them. Also, it should be mentioned experience with the reduction of plastic waste in Germany. To give up plastic altogether is a challenging task. The advantage of plastics is that they can be reused and recycled to some extent. Many plastic and glass bottles could be found on supermarket shelves in Germany, which can be reused. The price of such bottles can be around 25 €, which sometimes can reach the point of absurdity because the contents of a small plastic bottle can cost less than the container itself. However, this encourages people to return to the supermarket with empty bottles and get their money back for recycled glass or plastic. In Germany, glass bottles tend to dominate supermarket shelves due to recyclability.

On the territory of the Russian Federation, there is a lot of challenges to solve the native problem of recycling. Plastic bottles are thrown away, only 3-4% of them go to recycling. Glass waste also does not often reach recycling; of course, there are many collection points for glass containers, but not every glass product can be recycled [1].

Of course, in recent years in the Russian Federation, much time, effort, and money has been devoted to waste recycling. In many large cities, special containers are installed for the separate collection of waste. We can also see special containers for collecting plastic bottles in small settlements, but this waste often ends with municipal waste in landfills.

WASTE REFORM IN THE RUSSIAN FEDERATION

On January 1, 2019, a waste reform began in Russia to significantly change the processing and disposing of municipal waste. Many of the planned preparatory and organizational activities have already taken place or are in high readiness.

Simultaneously, there is a certain lag in terms of the stated target indicators, primarily creating the necessary infrastructure. Of particular importance in such a situation is foreign, primarily European, experience in solving this problem.

The necessity for reform leads to solve the environmental problems. There are more than 60 billion tons of waste on Russia's territory, and the area of landfills continues to grow. There are more than 14 thousand large landfills in the country (not counting unauthorized spontaneous ones). Their area is more than 4 million hectares; It's like the four islands of Cyprus. According to Greenpeace Russia, every Russian sends 400-500 kg of waste to the landfill per year. Simultaneously, 94% of the waste is not subject to recycling; that is, waste accumulates and occupies more and more territory.

According to ecologists, within ten years, the area of landfills will double if there will be no changes in waste management [2].

An example of a waste problem in Russia can be mentioned the Rostov region, where was created an unauthorized landfill near the village Vesely, which is also a bowery. Any waste brought here without sorting. The height of the waste mountains is approximately 4-5 story buildings.

Figure I: Bowery Vesely, Rostov region.

The reform aims is to reduce the elimination of unauthorized landfills, reducing the number of landfills, constructing complexes for the treatment and disposal of waste, and increasing the share of processing solid municipal waste. The reform will be achieved by transferring the entire waste management chain - from collection to disposal - under the control of regional operators, whose status is determined by the competitive selection, strict control over the delivery of waste by companies, separate waste collection, construction of waste sorting stations and factories, waste disposal, elimination of old landfills.

The reform is also designed to rid the country of the unmanaged and unauthorized landfills in forests and ravines. It is planned that landfills will turn into modern high-tech complexes. Spontaneous landfills near residential areas will be eliminated, the land will be rehabilitated, and urban infrastructure will be created in place of former landfills.

Accordingly, as a new reform is introduced, taxes on waste collection and disposal, which citizens will pay, will change. Everyone pays for their waste produced, whether they go and a natural or legal person. The payment of waste services will depend not on the man, where is living but on the numbers of apartment entities.

This reform began to eliminate competition in the waste disposal management in favor of special operators. It was decided to liquidate the old landfills primary and follow to buildup waste processing plants. But suggested situation is still not clear. Makes a question, what will happen concerning time management if the landfill closing will be earlier than the waste management processing in waste factories. From one side, this is good solution, but on the other hand, landfills could be starting to grow.

In the most regions, there is no infrastructure for the implementation of waste reform. We are not even talking about modern waste processing plants' construction but about installing containers for separate waste collection. The population is not used to sorting waste. This requires additional effort because to separate waste; a person must have five instead of one waste bin: glass, plastic, metal, paper, and biodegradable. Also, the contents of these waste bins must be emptied into appropriate street containers that are not always easy to find near home or even in an entire neighborhood or city.

According to the new law, regional operators are responsible for waste management; as there were contractors and subcontractors, they remain. Only now are they being hired by operators, not management companies [3]. Simultaneously, the operators are likely to be companies affiliated with local administrations, which could be a problem with improving the fair-play waste management execution. Thus, we can say that the unjust waste management did not disappear but changed the management role.

The task of forming a tariff for payment for communal services transferred to regional authorities. The tariff can be calculated based on the number of square meters and the number of inhabitants living in the area. Therefore, tariffs may differ: in one region may be higher, in the neighboring - lower. It causes some tension between citizens.

It would be logical during the implementation of the reform to build waste processing plants, equip houses and streets with special containers, inform the population about the separate collection of waste and why high prices are set for the waste management service, but such measures are not taken.

The tariffs for payment for waste management in the country, on average, increased by ten times. The main problem with the reform is that citizens will have to pay more. At the same time, positive results after two years are not yet visible. After analyzing, we can say with certainty that the waste reform wasn't fulfill. There is no equilibrium between spent money for the waste and the construction of waste recycling plants, which has not begun; some landfills are closed. Lot of are overflowing and cannot contain more waste; there is no infrastructure for separate waste collection in cities, except Moscow and St. Petersburg. Russia needs to make a lot of effort and time to implement this global problem. Let us try to analyze and consider the optimistic scenarios for developing the waste reform events, relying on our Western colleague's experience.

CONCEPT OF CONSTRUCTION OF WASTE INCINERATION PLANTS

In the wake of the waste reform, they are increasingly talking about the possibility of obtaining energy from waste. For example, they will build an incinerator near Kazan, against which the inhabitants are actively protesting. They also want to build 15 waste incineration complexes in the Krasnoyarsk region. There is also an incineration plant near Moscow. At first glance, everything looks great: instead of a vast number of landfills, which have already ceased to cope with the waste that appears in the country, we can build incinerators. Moreover, we will get rid of waste, and we will receive energy. At the same time, officials constantly refer to the successful European experience. However, not everything is as simple as it seems at first glance.

Therefore, it is worth understanding the waste incineration process and understanding this topic in more detail. Yes, incineration makes it possible to obtain electrical and thermal energy, and the raw material will be waste that no one needs. However, a problem will arise - there will be a load on the environment. During their operation, incinerators emit dioxins, mercury, cadmium, and other harmful substances into the air. Emissions are dependent on filters as well as timely maintenance. And then, the question arises in the control of this area of activity. Will the factories be adequately maintained, and the filters changed on time? We cannot be 100% sure of this, as practice shows the opposite.

Europe has much experience in waste incineration. In Sweden, about 50% of the waste goes to the incinerator. However, does this mean that the Swedish experience is unambiguously joyous and easily applied in Russia? Not really. There is a fundamental difference [4]. In European incinerators, waste is loaded after sorting, that is, an order of magnitude less harmful substances sent into the atmosphere than when trying to incinerate everything. The principles of waste separation in Europe Union and Russia are different. Moreover, Russia cannot boast of the quality of waste separation. It is essential to understand that the same incineration plant in Russia can emit another and different substances into the atmosphere than in Sweden, Finland, or any other country where separate waste collection is organized. To begin with, it is necessary to introduce separate waste collection and sorting.

However, even in Europe, it is recognized that modern incinerators pose a threat to the environment and health. Let us remind ourselves again that during their operation, incinerators emit dioxins into the air. Moreover, the World Health Organization says dioxins are highly toxic and can cause reproductive health and development problems, damage to the immune system, hormonal disorders, and cancer. Their half-life in the body is estimated at 7-11 years. In the environment, dioxins tend to accumulate in the food chain. In 2017, the Council of Europe called on to completely abandon the construction of incinerators where they do not yet exist. Moreover, to decommission those already built, switch to more advanced waste disposal methods [5].

Lot of people in Russia still suppose that waste incineration can solve the waste problem. It is important to note that many new incineration complexes would have to be built to incinerate even a tiny part of Russian waste.

The construction of incinerators can cause the several problems:

1. The spread of incineration at a particular stage will come into conflict with the development of the waste recycling industry; there will be competition for raw materials;

2. Processing enterprises will need raw materials, their development will be in a state of stagnation. Small and medium-sized enterprises in the collection and processing of secondary raw materials risk to be forced to close; jobs will be unsustainable;

3. State support for incineration through the "green" tariff could indirectly fall on consumers: could indirectly attack the consumer prices.

So, the incinerators buildup will generate the necessity for their load for their life cycle. It will be challenging to organize waste processing in Russia's regions, without the further incentive. There is minimal incentive to reduce the amount of waste, as the waste is needed for the factories. New technologies for waste processing, in contrast to incineration, allow not to destroy waste but turn it into something useful [6]. Recycling waste will allow us to reuse resources. Here we need to understand that today, far from everything can be recycled. A large percentage of waste cannot be recycled. Moreover, the question remains, what to do with it today. Someone says that burning is indispensable. Some, on the contrary, suggest not to rush, but to store waste, which cannot be recycled today, since technologies are rapidly developing and tomorrow the situation may change. However, the development and construction of waste incineration complexes could destroy the waste reform, which is not doing well nowadays. It seems, that there is necessary to evaluate more waste management scenarios and find the best one for the development of waste management in Russia.

WASTE SORTING AND PROCESSING DEVELOPMENT STRATEGY

Today, the waste reform does not serve the development of the recycling industry. Although the reform is formally designed to reduce the environmental burden by abandoning waste disposal and the transition to secondary use of raw materials, neither the goals of the development of processing nor the further involvement of recyclable materials in industrial circulation are enshrined in it. The speed of emergence and the quality of this industry primarily depend on households and business activity. Therefore, even though existing processing plants face a burden due to the lack of high-quality recyclable materials.

Some steps at the state level towards the development of waste processing were also taken before the reform, but these are only isolated initiatives so far. In June 2017, the government amended the legislation, according to which citizens sharing waste will be offered a reduced tariff for the waste management service. In September 2016, the government approved a list of wastes that are prohibited from dumping: scrap and waste with ferrous metal, cast iron, steel, copper, lead, zinc, and tin, as well as items made of bronze, copper, brass. The list also included car tires, aluminum beverage cans, glass containers, polyethylene products, aluminum foil, books, newspapers, and other paper products. Lamps, household, and electrical appliances are also subject to recycling. That is all; there are no other regulatory legal acts.

The processing enterprises in Russia that make valuable products from secondary raw materials include only a few items. Today, about 20-30 companies across the country deal with waste recycling, and about 50 specialize in sorting waste. These are such small numbers that are not even noticeable throughout the territory of Russia. Let us remind ourselves that only 4-5% of waste is recycled.

The transition to separate waste collection allows us to contribute to the improvement of the ecological situation. Through this procedure, the recyclable raw materials are separated from the materials that are not reused. Residual raw materials have harmful properties. One of them is a long decomposition period. Once in the soil, solid residues such as polyethylene and plastic are stored for decades.

For the environment, the process of separating waste has highly positive consequences. However, the main problem with the segregated waste collection comes from implementation difficulties. The organization of a processing plant and reception points requires investments, the return on which is slow. The high cost of processing equipment should also be noted. Moreover, one of the main problems is the unwillingness to deal with the sorting of citizens. Most people think it makes no sense to sort the waste, as all the waste will go to one landfill [7]. There is some truth in this, but not always.

There are very few recycling complexes today, but at the same time, they are sometimes empty because, in principle, there is very little sorted waste that can reach such complexes. Accordingly, facilities that sort waste cannot cope with the load, so it is essential to start sorting waste in homes. It is the most critical first step that was implemented in Russia. Moreover, this is a huge problem today. When sorting waste to landfills, 80% less waste is sent from one person.

Now there are collection points for recyclable materials, which are located only in large cities. The problem is that people have to carry their sorted waste there themselves. Of course, the majority does not want and will not want to do this since citizens pay for waste removal on average ten times higher, this creates indignation, and now we need to carry waste ourselves. According to statistics, only one person per 1000 is engaged in this, and even then, not to the fullest. Most do not have such opportunities absent due to poor health, lack of personal transport, remoteness or lack of places for receiving recyclable materials, or simply unwillingness to do this.

CONCLUSION

The state needs competent waste sorting and creating a sound infrastructure that will allow people to do this. People can get some benefit from this and purity around them. Citizens can be encouraged to sort their waste thanks to reduced tax rates on waste collection. With the help of infrastructure, more and more people will be willing to sort and benefit society. Furthermore, we can increase tax rates and create all conditions for sorting waste for citizens for those unwilling. Otherwise, it can turn out as a waste reform, which takes money, but we must turn the view for efficiency.

We can conclude that incineration plants' concept does not suit Russia and other worldwide countries today since it is first necessary to establish a waste sorting system. However, while this system works, it could take some time. Such plants' construction could be no longer be relevant because developed countries are already beginning to abandon this concept. The best option for the development of events is to direct all efforts to create a system for the separate collection of waste, educate citizens in this direction and build waste recycling enterprises.

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IMPACT OF URBANIZATION ON THE SEWER NETWORK CATCHMENTS: PLUVIAL FLOODS

Réka Wittmanová[1]

Ivana Marko[2]

Marek Šutúš[3]

Štefan Stanko[4]

[1] Department of Sanitary and Environmental Engineering, Faculty of Civil Engineering, Slovak University of Technology in Bratislava, Radlinského 11, 810 05 Bratislava, Slovakia, e-mail: reka.wittmanova@stuba.sk

[2] Department of Sanitary and Environmental Engineering, Faculty of Civil Engineering, Slovak University of Technology in Bratislava, Radlinského 11, 810 05 Bratislava, Slovakia, e-mail: ivana.marko@stuba.sk

[3] Department of Sanitary and Environmental Engineering, Faculty of Civil Engineering, Slovak University of Technology in Bratislava, Radlinského 11, 810 05 Bratislava, Slovakia, e-mail: marek.sutus@stuba.sk

[4] Department of Sanitary and Environmental Engineering, Faculty of Civil Engineering, Slovak University of Technology in Bratislava, Radlinského 11, 810 05 Bratislava, Slovakia, e-mail: stefan.stanko@stuba.sk

ABSTRACT

The impacts of climate change affect the operation of sewer networks and the possibility of urban floods. As a result of climate change, long periods of drought are increasingly occurring, alternating with extreme rain events, often heavy torrential rains. We consider rapid urbanization, the expansion of impervious areas, the age and capacity of existing sewer networks, and, last but not least, extreme precipitation events to be the leading causes of these floods. During pluvial floods, sewers' backflow can occur - flooding of cellars, traffic collapse, and urban infrastructure. The present paper summarizes the causes of urban floods and testifies to the most significant urban floods that have occurred in Central and Northern Europe in the last decade.

Keywords: extreme precipitation, pluvial floods, sewer network, urbanization

INTRODUCTION

Due to the population increasing in urban settlements, the use of the territory and the surface variability of urban settlements are changing rapidly. The conversion of agricultural land to building plots, deforestation, and other settlements structure contributes to global climate change and has a significant impact on the local microclimate [1]. The replacement of natural areas in urban catchments has a negative effect on the natural water cycle, which is reflected in lower water infiltration, reduced groundwater subsidies, more inferior groundwater quality, and faster surface runoff [2].

The increase of impervious areas in urban river basins causes changes in the region's hydrological characteristics [3]. The development of areas covered with impervious materials contributes to accelerating the runoff process, intensifying surface runoff concentration, the concentration of surface runoff pollution, and changing the regional microclimate [4]. Surface runoff from urban river basins can be characterized as the primary source of the receiving water's pollution during torrential rains [5].

All the above-mentioned adverse effects of urbanization can, under certain conditions, result in urban flooding. The topic of urban floods has come to the forefront of scientific research only in the last decade, probably due to their smaller scale or due to minor damage. Pluvial floods are defined as floods caused by the concentration of surface runoff in an urban catchment area with insufficient sewer network capacity during torrential rains [6]. They occur when the sewer network's capacity reaches a maximum and the surrounding soil environment is saturated. It is the most commonly associated with short-term, high-intensity precipitation events [7]. The occurrence of these floods is conditioned by the characteristics of the rainfall event and the features of the urban river basin, and the length of previous rainless periods.

The aim of the paper is to characterize the impact of urbanization on surface runoff and the impact of global climate change on the urban environment. The article further focuses on the emergence of urban floods and the most significant and most devastating urban floods in the last decade in Europe.

EFFECT OF GLOBAL CHANGE ON URBAN CATCHMENT

UHI EFFECT

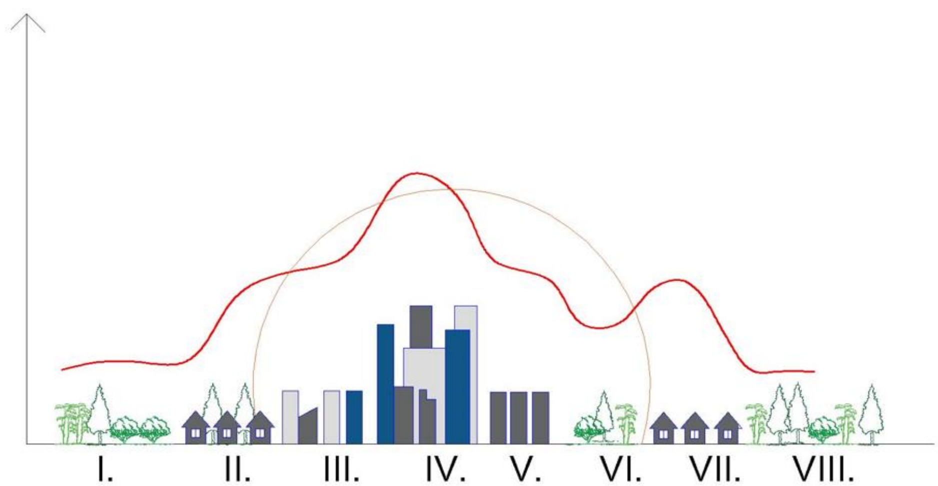
Urbanization harms the environment through the production of pollutants, the modification of the chemical and physical properties of the atmosphere and the hydrosphere, and changes in the surface treatment of the soil. The cumulation of all these effects is considered the UHI ("Urban Heat Island") effect, which is defined as the increase in temperature in an artificially created urban environment compared to the surrounding natural environment, the countryside [8]. This topic began to receive attention in the 1980s. However, mentions of studies dealing with higher air temperatures in cities can be found as early as the 19th century. The list of publications on UHI is summarized by Mohajerani et al. [9]. Early studies have shown that the UHI effect can cause a temperature increase in 2 to 8 ° C [10]. Over time and intensive urbanization, this range has shifted, and today there is talk of a temperature increase of 5 to 15 ° C [11]. The development of heat islands is contributed to by the change in urban areas' character, the reduction of evapotranspiration by replacing vegetation with dark impermeable areas with low albedo [12].

Debbage and Shepherd (2015) investigated the effect of cities' spatial distribution on the intensity of the UHI effect on the assumption that high population density increases intensity. During the research, they focused on the 50 largest cities in the United States. The study results point to a connection between the spatial structure of cities and the intensity of the UHI effect [13]. Figure I shows the temperature distribution due to the UHI effect.

UHI causes local climate change, manifested by a decrease in humidity, a long period of drought, and extreme rain events with increased intensity and frequency of rains. The lack of permeable surfaces causes an increase in surface runoff into the sewer network. Acceleration of the runoff process leads to an increased concentration rate, the achievement of maximum sewer flows, and the possibility of local floods [4]. Other adverse consequences have been summarized in many studies and include increased energy consumption for cooling, smog generation and air quality degradation, intense impact on urban ecosystems, thermal stress in the population, and increased risk morbidity due to high temperatures [9].

CLIMATE CHANGE

Climate change in the Slovak Republic conditions was manifested mainly by an increase in the average annual air temperature, a decrease in the total precipitation in the southern areas, and an increase in the total in the north of the country. However, the most significant and unfavorable impact of climate change is the change in precipitation events' time variability. Rainy and dry periods have alternated intensively in recent decades [14]. Climate models predict a 10% reduction in total precipitation and a change in their temporal and spatial distribution. The frequency of heavy rainfall events can increase by up to 50% (Ministerstvo životného prostredia Slovenskej republiky, 2018).



I. Countryside, II. Suburban residential zone, III. Industrial zone, IV. Highly urbanized zone (city center), V. Urban residential zone, VI. Park, VII. Suburban residential zone, rural agricultural zone.

Figure I: Temperature distribution due to UHI effect (author)

The impacts of climate change also affect the operation of sewer networks and the possibility of urban floods. As a result of climate change, long periods of drought are increasingly occurring, alternating with extreme rain events, often heavy torrential rains. These can cause an increase in the relief of mixed wastewater into the recipient or overloading of sewer networks, resulting in urban floods. According to the IPCC (2014), an increase in extreme meteorological phenomena such as, e.g., long periods of drought and sudden torrential rains. Due to climate change, precipitation intensities and frequencies of torrential rains are expected to increase in northern and central Europe [16].

PLUVIAL FLOODS

In the natural water cycle, the impact either evaporates or soaks into the soil after effect on its surface. However, the natural progression of the water cycle in an urbanized area is disturbed by many impervious regions, contributing to surface runoff formation [17]. Figure II shows the influence of urbanization on the course of surface runoff. In rural areas and the natural environment, the surface runoff wave is flattened, caused by infiltration, evaporation, and evapotranspiration. In the semi-urban area, the wave increases due to the larger ratio of impervious areas. With a high proportion of the impervious regions in an urbanized area, the surface runoff wave is deformed, i.e., the concentration-time is shorter, but the total runoff volume is more significant. Surface runoff is discharged from the urbanized area either by a single sewer network to the wastewater treatment plant or by a divided sewer network to the recipient. However, in torrential rains, the capacity of sewer networks may not be sufficient [18].

After exceeding a certain level of wastewater in the unified sewerage network, the recipient's mixed flow is relieved. With the divided sewer, the sewer's storage capacity begins to be filled until the flood is wholly flooded and subsequently overflowed and local floods occur. The flow of rainwater can reach the level of capacity flow during torrential rains, fill the pipeline's cross-section, and create a pressure flow, or backflow, and subsequently pluvial flooding.

According to Li et al. (2018), pluvial floods occur when the volume of surface runoff generated exceeds the city's drainage capacity or urban drainage system and the rate of infiltration [19].

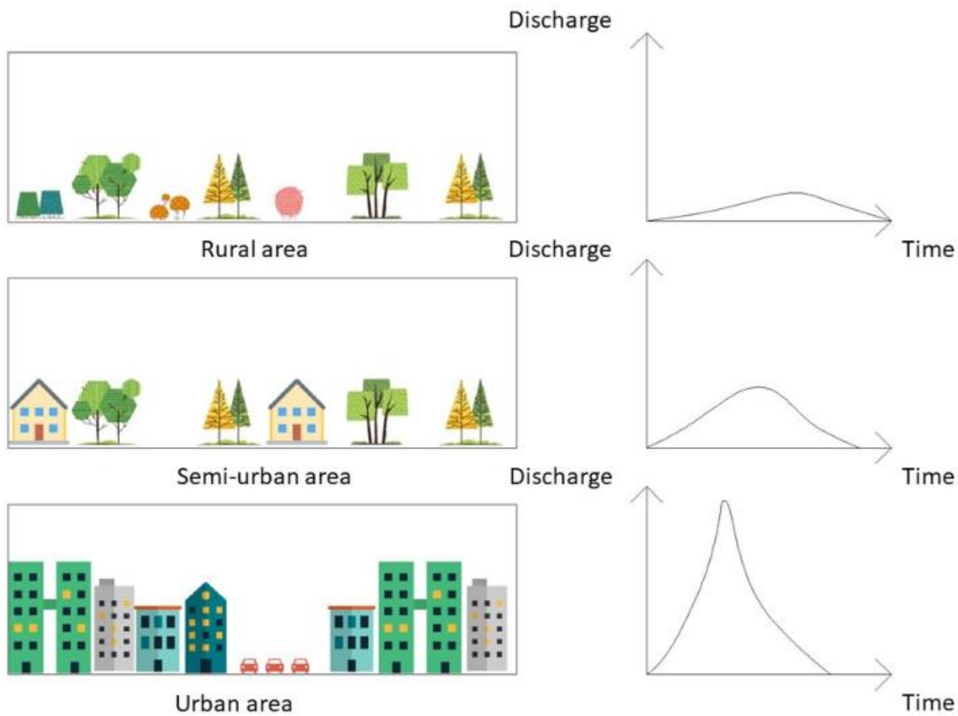


Figure II: Influence of urbanization on the course of surface runoff (according to [20]).

Urban "pluvial" floods occur due to the frequent occurrence of torrential rains and changes like the environment. The increased proportion of impermeable areas causes a reduction in evapotranspiration and water retention in the country and an increase in the volume of surface runoff, the rate of concentration, and the maximum volume of floods [2]. The intensification of negative phenomena is caused by climate change and a high rate of urbanization.

Butler and Davis (2008) emphasize that the sewer system does not consist only of a pipeline network. They distinguish between minority and majority components of the system. They define it as a minor system the components of a traditional drainage system, e.g., rain gutters, shafts, and storage drains. The majority system consists of surface floodplains, including roads and temporary retention areas (parking lots, playgrounds). The flood (exceeded) flow is considered the exceeded capacity flow of the minority system, which will appear on the majority system's surface [20]. Various factors are behind the increase in flood risk in urban areas. The effects of climate change complement population growth, development, and the number of impervious areas. These are mainly short-term rain events with high intensity and a significant total precipitation [21].

The risk of urban floods is increased by the following factors, which were summarized in the study by Prokić et al. (2019): old sewer networks are not adapted to today's degree of urbanization, combined sewer networks in older buildings are more sensitive to overload than divided sewer networks, poor maintenance of street drains and sewer networks, the occurrence of clogged sections by deposits, improper management of surface runoff in the urban environment [16].

Figure III: Floods during torrential rains (Bratislava, 06.06.2018) Source: Imhd [22]

Figure IV: Flood caused by torrential rain in Malmö (31.08.2014) Source: Johanna Sørensen [23].

Such intense precipitation events occurred on June 6, 2018, in southwestern Slovakia, 53.8 mm of precipitation was measured at Bratislava Koliba, 60.5 mm in Žihárec, and 65.5 mm in Jakubov [24]. Pluvial floods are not only a problem in Slovakia. In the last decade, a series of storms have hit northern Europe, causing urban floods in Copenhagen (2011) and Malmö (2014). On July 2, 2011, Copenhagen was hit by a 1,000-year rainfall event, a 2-hour storm. The total precipitation reached a value of up to 150 mm, and a large part of the city found itself underwater [25].

Figure V: Pluvial flood in Copenhagen. Source: [25].

The precipitation event on 31 August 2014 in Malmö, which lasted more than 6 hours and the total precipitation exceeded 120 mm, was also significant. This precipitation event is also addressed in the study by Mobini et al. It compared combined and separated sewers in terms of flood risk [26].

There have been many devastating storms and urban floods in the UK in recent years. During the summer of 2007, the most affected areas were North East, Yorkshire, the East Midlands, and the West Country. Another devastating pluvial flood was caused by torrential rain on June 28, 2013, in Newcastle. During this storm, the total precipitation per hour reached 32 mm. Similar situations occurred on 18 - 19 December 2013 in Northern Ireland and the west of Scotland, June 23, 2016, in London. Cumbria (in December 2016) was hit by a storm typical of the cyclonic area, during which up to 405 mm of rain fell in 48 hours [27]. When designing new sewer networks, flood risks are taken into account, and the impact of climate change on the course of precipitation is often taken into account. An essential step in securing existing sewer networks is to reduce rain inflow into the network and flatten the maximum rain flow rate [20]. To this end, several practices have been developed based on the principles of water retention, infiltration, accumulation, and reuse of water [28]. These procedures include integrated rainwater management solutions in cities such as Integrated Urban Water Management, Water Sensitive Urban Design, Low Impact Development, Active Beautiful Clean, Sponge Cities, Sustainable Urban Drainage System [29]. They combine nature-friendly measures (wetlands, green roofs, green belts) with technical measures (surface and subsurface infiltration) into one integrated system [30]. Not all of the above procedures have been primarily designed to reduce urban catchment floods, but their application helps to minimize rainfall into the network [28].

CONCLUSION

The occurrence of pluvial or urban floods has recently become an increasingly common phenomenon. The reasons are outdated sewer networks, rapid urbanization, an increase in impervious areas, and changes in the characteristics of rainfall events caused by climate change. Many studies suggest that the damage caused by pluvial flooding may outweigh the damage caused by fluvial flooding in the future Therefore, it is necessary to focus on developing and implementing adaptation measures in a highly urbanized area. As mentioned above, the adaptation is welcome for life in urban areas, not only because of their protective function, but they complement the technical environment with green-blue elements that contribute to a healthier environment, reducing the UHI effect, dust, and humidity. Many world capitals are already well on their way to a sustainable urban environment, thanks to introducing these adaptation and mitigation measures.

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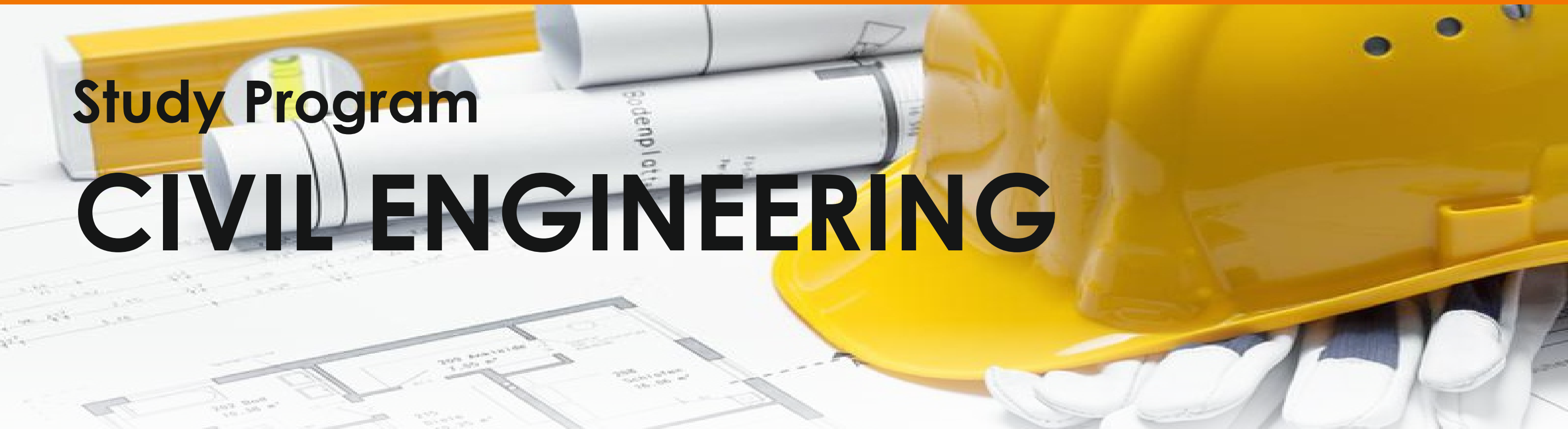

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