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title: **Effect of vegetation cover on infiltration rates in artificial basins**

author(s): **Erik Milde**
University of Applied Sciences Dresden, Germany, milde@htw-dresden.de

Wolfgang Macheleidt
University of Applied Sciences Dresden, Germany, mach@htw-dresden.de

Ankea Siegl
University of Applied Sciences Dresden, Germany, siegl@htw-dresden.de

Thomas Grischek
University of Applied Sciences Dresden, Germany, grischek@htw-dresden.de

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INTRODUCTION

The area of impervious cover in urban environments, including roads, paved surfaces and railways, is continuously increasing. To limit the resulting impact on the water balance and groundwater levels, surface water runoff is often collected and transported to artificial infiltration basins or natural infiltration areas. The infiltration capacity of infiltration basins, ponds and constructed wetlands often decreases after several months or years. Small sediment particles and organic material is retained in the pore space which results in clogging and reduced infiltration rates. Removal of the clogging layer in order to achieve the initial infiltration capacity is costly.

There is a dispute over the advantages or disadvantages of vegetation cover in infiltration basins among practitioners and researchers. Some researchers found that the infiltration rates are higher with vegetation cover compared to bare soils (Gajic et al., 2008; Orradottir et al., 2008; Hatt et al., 2009; Martinez-Zavala, Jordán-Lopéz, 2008). Vegetation cover may change as a result of climate change, e.g. long dry periods during summer. This affects the rate of infiltration during storm events. Lange and Scheufele (1987) illustrated that grassland has a positive effect on infiltration rates. Infiltration increases due to higher soil humidity (shadowing effect) and roots of vegetation in the upper soil layer. However, the infiltration capacity can decrease if a biofilm is created. This may occur when a reservoir is filled over a long time and the vegetation is not suitable for the site conditions.

The objectives of this study were to: (1) analyse the infiltration rate at storm water infiltration basins beside motorways and (2) to investigate the impact of typical wetland plants and their effect on infiltrations rates in artificial basins.

MATERIALS AND METHODS

Site description

The study includes investigations at four sites in Saxony, Germany between 2009 and 2010: (1) a storm water infiltration basin beside a motorway near Dresden, (2) a newly constructed wetland for wastewater treatment in Reichenbach, (3) a fallow field near Meissen and (4) a rain water infiltration trench in Dresden-Pillnitz. The main focus of this article is on the motorway storm water infiltration basin. Results from investigations at the other three sites will be discussed in other papers.

The study site at the motorway in Dresden includes three storm water infiltration basins with areas of (B1) 845 m^2, (B2) 1213 m^2 and (B3) 2520 m^2. The basins were constructed in 2000 and partially reconstructed in 2005. Each basin consists of three main parts: (1) a settling basin, to remove small particles like dirt and dust to prevent clogging of the infiltration basin and to capture floating solids like heavy metals (e.g. lead, cadmium, nickel, copper, zinc) (2) a downflow baffle and (3) an infiltration basin. The infiltration basin at B2 is 4.5 times larger than the settling basin (Figs. 1 & 2). The upper soil in the infiltration basin was sampled by digging a hole to a depth of 50 cm. The soil can be characterized as sand and consists of 1.7 % silt, 86.4 % sand and 11.9 % gravel.

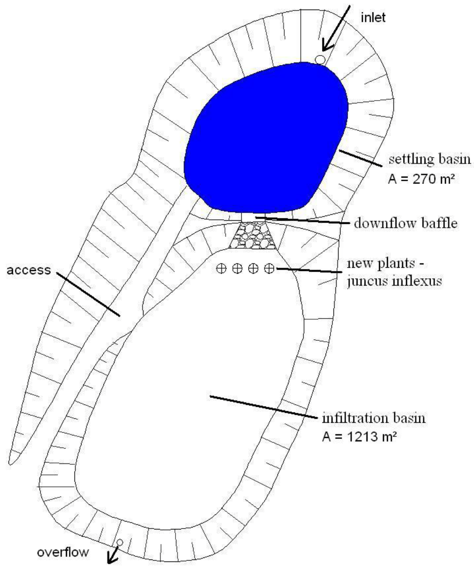

Figure 1. Layout of the storm water infiltration basin B2.

Figure 2. Cross section of the storm water infiltration basin B2.

Dresden has a cold-moderate to continental climate with hotter summers and colder winters than the German average. The average value of selected climate parameters of the Dresden-Klotzsche climate station is shown in Tab. 1 for the period from 1961 to 1990. The average temperature in January is 0.8°C and in July 17.9°C. The driest months are February and March, with precipitation of 39 mm and 42 mm per month. The wettest months are June and August, with 75 mm and 76 mm per month.

Table 1. Average values of climate parameters — Location Dresden-Klotzsche (222 m above sea level), 1961–1990.

	Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Year**
Air Temperature in °C	0.8	0.3	3.7	7.9	13.0	16.3	17.9	17.6	14.1	9.7	4.4	0.9	8.8
Precipitation (P) in mm	45	39	42	53	63	75	69	76	51	46	51	58	668
Days with P ≥ 0.1 mm	17.6	15.3	15.5	15.4	15.2	15.4	14.1	13.7	13.2	13.0	16.3	18.7	183.4
Days with P ≥ 10 mm	0.5	0.5	0.7	1.3	1.7	2.3	2.1	2.2	1.4	1.2	0.9	1.1	15.9

Planting of a test area

Artificial basins are ecosystems with seasonally flooded or waterlogged conditions. The selected plants have to grow under these changing conditions with strong root growth. Lesser pond-sedge *carex acutiformis* and European meadow rush *juncus inflexus* are plants typical of wet areas. Grass is a typical plant in dry areas and the reed *phragmites austral* is a typical plant in flooded areas. These kinds of marsh plants can be found in nature all over the world and are suitable for a range of applications.

The species *Juncus inflexus* was planted over an area of more than 10 m^2 in November 2009 at each storm water infiltration basin, to determine the effect of roots on infiltration rates. The remaining area of the infiltration basins is overgrown by grass.

Methods for measuring hydraulic conductivity

The first measurements were made in summer 2006. The infiltration rates were measured using two different methods: double ring infiltrometer tests and laboratory column experiments. The measurements were repeated in summer 2009 using the same methods at the same places in the basin as in the year 2006.

The inner and outer rings of the double ring infiltrometer have a diameter of 30 cm and 60 cm, respectively. The rings were driven 20 cm into the ground and a constant water level in the inner ring was maintained by using a Mariotte's bottle (Fig. 3). Darcy's equation was applied for the calculation of hydraulic conductivity (K).

The soil column experiment is another method to determine hydraulic conductivity. Metal columns with 10 cm diameter and a length of 55–100 cm were driven into the ground using a hammer (Cobra, Atlas Copco). The columns were extracted using a hydraulic system, closed with special fittings, placed in a special box and transported to the geohydraulic laboratory of the University of Applied Sciences Dresden. Figure 4 shows the experimental setup to measure the flow passing through the soil column. The soil columns are fixed at the ground (1) and the water flows through the columns under an adjustable head difference (3). The volumetric flow rate can be measured per time using overflow buckets (2). The soil columns must be saturated before starting the experiment.

Figure 3. Double ring infiltrometer.

Figure 4. Soil column experiments.

The temperature of the infiltrated water is measured to normalize the hydraulic conductivity for 10 °C using a formula of Poiseuille:

$$K_{10°C} = \frac{1.359}{1 + 0.0337 \cdot T + 0.00022 \cdot T^2} \cdot K = \alpha \cdot K \quad [m/s]$$

where:

T — water temperature [°C],

K — hydraulic conductivity without temperature standardization [m/s].

Table 2. Factor α including the viscosity of water.

Temperature in °C	**5**	**10**	**15**	**20**	**25**
α	1.158	1.000	0.874	0.771	0.686

Before measuring the infiltration using double ring infiltrometers each point was flooded over several minutes to achieve saturation. The measurements were repeated at least once for each measuring location and the mean value was recorded.

RESULTS

The comparison of the measurements from the years 2006 and 2009 revealed some significant changes in the infiltration rate. Figure 5 shows the measured infiltration rates in basin B1 and basin B2 using a double ring infiltrometer. In basin B1 the infiltration rate decreased at 5 of 8 locations by 80 % and remained constant at the other 3 locations.

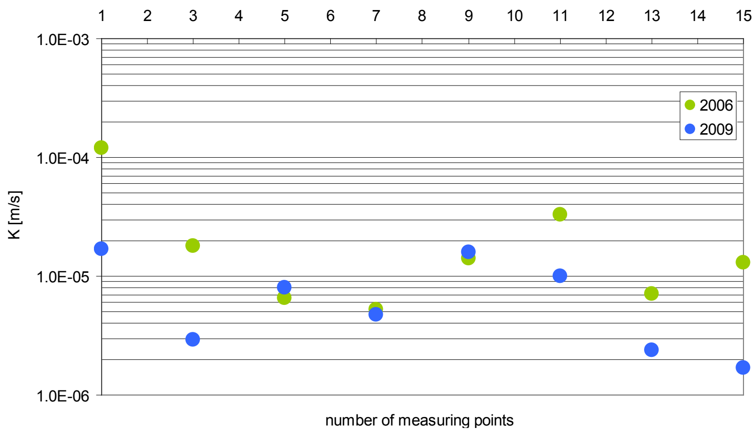

Figure 5. Hydraulic conductivities determined using a double ring infiltrometer in basin B1 (measuring locations 1–7) and basin B2 (measuring locations 9–15).

Figure 6 shows the infiltration rates in basins B1 and B2 determined using the soil column experiments. The infiltration rate decreased at 4 of 8 measuring locations, was constant at 2 locations and increased at 2 locations. The changes in the infiltration rate indicate increased clogging of the basin. Of course, the local infiltration rate depends on the soil structure and the pore system of the soil. Results can be substantially skewed by preferential flowpaths, wormholes or even large pebbles in the subsoil. Compaction and different saturation of the soil could be other reasons for differences, thus demanding a high number of measuring points to achieve reliable results.

The K-values determined in the column experiments were higher than those from the double ring infiltrometer. By hammering the columns into the ground, the upper millimetres of a potential clogging layer might be disturbed. Furthermore, the side effects at the column wall may have greater impact because the area is smaller than in the double ring infiltrometer. The differences between the results from the infiltrometer measurements and the column experiments warrant further research, as well as into the influence of compaction and saturation.

The results of the measured K-values or infiltration rates at the newly planted section in storm water infiltration basin B1 are shown in Figure 7.

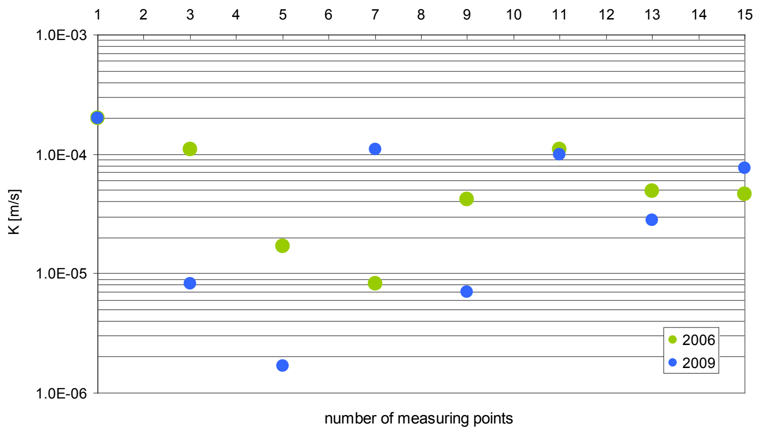

Figure 6. Hydraulic conductivities determined using soil column experiments for basin B1 (measuring locations 1–7) and basin B2 (measuring locations 9–15).

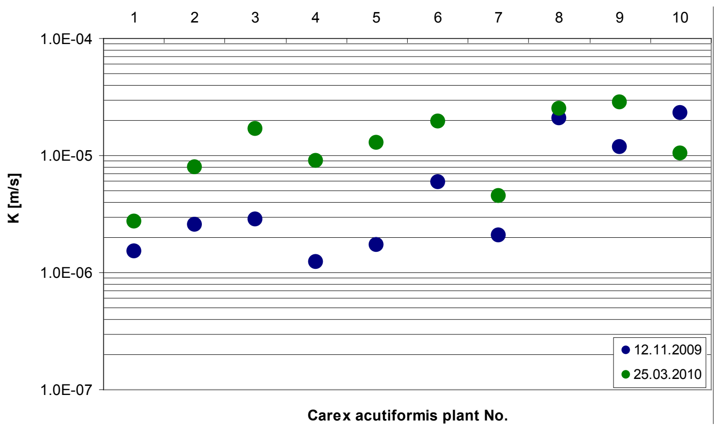

Figure 7. Changes in the infiltration rate of the storm water infiltration basin B1.

The infiltration rate increased an average of 63% at 9 of 10 locations over 4.5 months from November 2009 to March 2010, which might be a result of the long winter in 2009/2010 with severe frost and the loosening of the ground during planting. The (promising) changes in the infiltration rate do not yet allow a clear statement about the effect of vegetation cover. A complete growing season is essential to properly analyse the effect of vegetation and to obtain significant results, which will be shown after September 2010.

CONCLUSION

It is assumed that the infiltration rate in artificial basins can be maintained or even improved by the introduction of suitable plants. Based on the present results and literature studies, an increase of hydraulic conductivity by an order of magnitude is expected. It should be possible to make more precise suggestions regarding the design and planting of artificial basins after analysing the results from the 2010 growing season.

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