Constructed Wetlands for Combined Sewer Overflow Treatment

CSO-CWs are generally agreed to be efficient in overflow treatment, but national approaches differ widely in their design and operation.

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Abstract

Combined sewer systems are designed to transport stormwater surface runoff in addition to the dry weather flows up to defined limits. In most European countries, hydraulic loads greater than the design flow of wastewater treatment plants are discharged directly into the receiving water bodies with minimal treatment (screening, sedimentation) or with no treatment at all. One feasible solution to reduce negative impacts on receiving waters is the application of vertical flow constructed wetlands. In Germany, first attempts to use this ecological technology were made in early 1990's. Since then, the further development let to a high level of treatment performance. During recent years, the national 'state-of-the-art' (defined in 2005) was adapted in other European countries including France and Italy. Against the background of differing national requirements in combined sewer system design, substantial development steps were taken. The use of coarser filter media in combination with alternating loadings of separated filter beds allows direct feedings with untreated combined runoff. Permanent water storage in deep layers of the wetland improves the system's robustness against extended dry periods, but contains operational risks. The constructions show similar functions despite different designs and layouts, but the correct dimensioning of all approaches (as well as inside sewer system simulation tools) suffer from uncertainties (e.g. impermeable surfaces, parasitic runoff and dry weather flow) in long-term runoff predictions. Current research studies aim to improve predictions of the system performance under varying conditions – both for classical wastewater parameters and emerging pollutants.

Introduction

Annual combined sewer overflow (CSO) pollutant loads can exceed those of WWTP effluent due to the enormous discharge volumes. This kind of pollution can lead to a high impact on the receiving water body over differing periods of time (e.g. short-term: acute oxygen demand, release of fish toxic NH_3-N, re-suspension of solids / long-term: sludge accumulation, eutrophication). To reach the requirements of the EC Water Framework Directive, CSOs need not only to be managed, but also require the effluent to be treated in many locations. One of the most (economically and ecologically) feasible solutions seem to be vertical flow constructed wetlands (VFCWs), specified as constructed wetlands for CSO treatment (CSO-CWs) in general and "retention soil filters" (RSFs) in Germany.

Compared to dry weather flows, flows from CSOs are usually diluted in terms of classical parameters like COD or NH_4-N. This correlation results in lower inlet concentrations for treatment facilities compared to WWTPs, but the hydraulic loads of single overflow discharges can exceed the typical loading of a VFCW due to enormous volumes of water.

Background

RSFs, as described in Uhl and Dittmer (2005), are able to retain numerous pollutants (Frechen et al., 2006; Dittmer & Schmitt, 2011; Tondera et al., 2013a,b). In German combined sewer systems, RSFs are generally located in series with stormwater tanks (Fig. 1-A). In the Federal State of North Rhine-Westphalia, about 1,870 stormwater tanks for CSO are operated – approximately 120 of them are combined with RSFs.

Main outcome of the session:

The main outcome of the session was the opportunity to demonstrate and to explain the differences between CSO-CWs and other types of vertical flow constructed wetlands both in general and in detail for (a) operation, (b) design requirements, and (c) research studies.

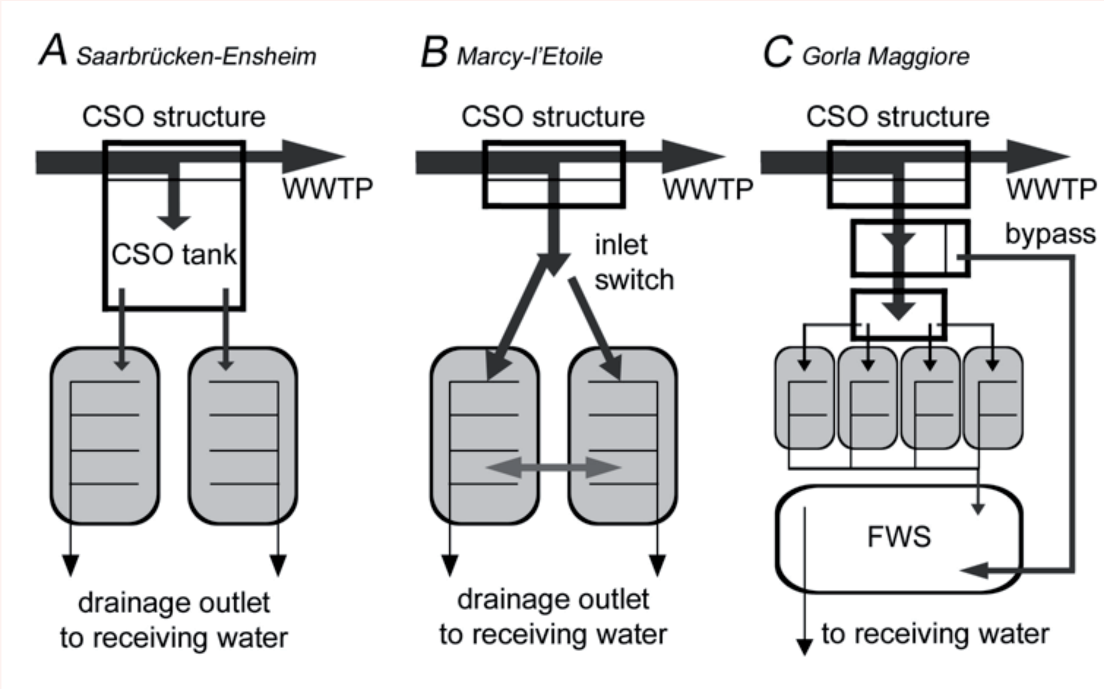

Figure 1: Simplified system sketch for (A) RSFs in Germany, and CSO-CWs in (B) France and (C) Italy (Meyer et al., 2013)

The French solution avoids the need for concrete basins (Fig. 1-B) if a treatment demand was noticed by sewer simulations showing overflows on a regular basis. This direct discharge results in heavier loads of particulates. In order to reduce clogging risks for small and concentrated as well as regular events, an alternating loading of two filter beds is necessary. In "French design" VFCWs (treating domestic wastewater), one bed is operated for about 3 - 4 days, while two other beds can regenerate sludge load abilities via mineralization (Molle et al. 2005). This kind of process control cannot be transferred to CSO-CWs directly, because system feedings are only corresponding to rain fall events. Experiences from the currently running research projects "SEGTEUP" and "ADEPTE" (full-scale Marcy-l'Etoile) will indicate adapted operation strategies for switching the feedings between the two beds.

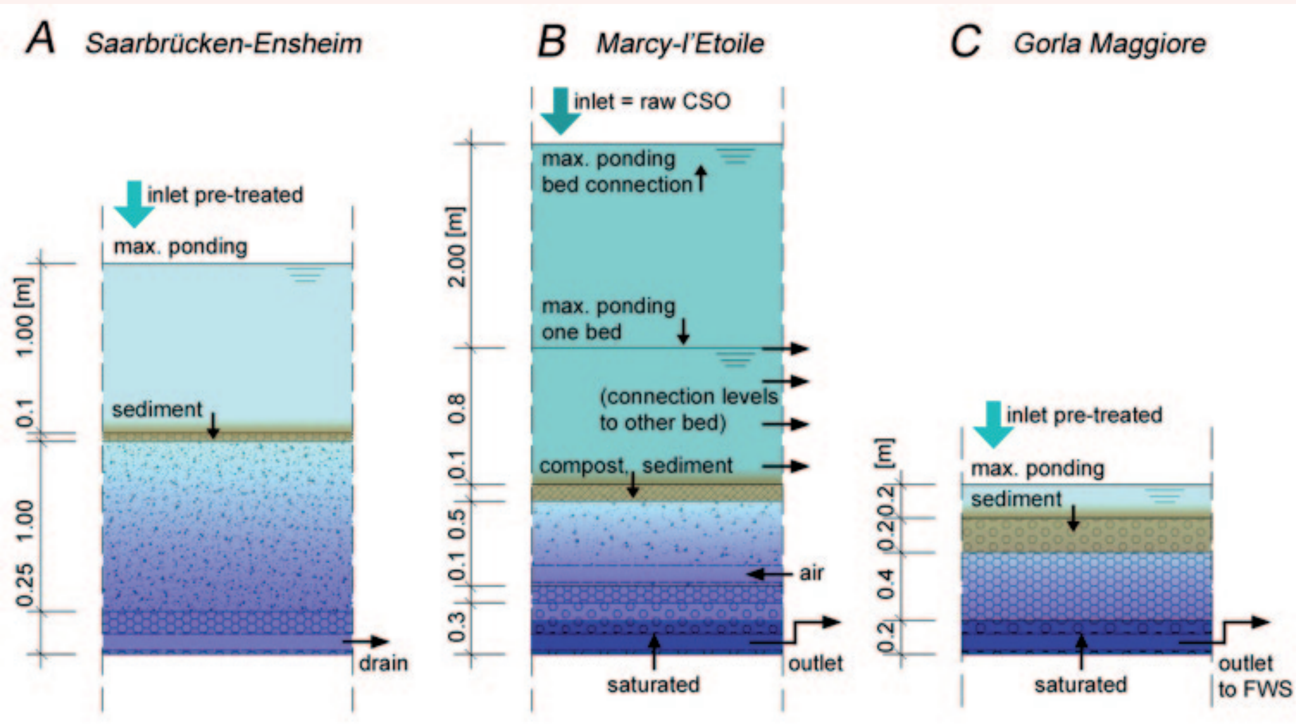

Figure 2: Simplified cross-sections of CSO-CWs in (A) Germany, (B) France and (C) Italy (Meyer et al., 2013)

Table 1: Comparison of characteristic design criteria (Meyer et al., 2013)

Criterion	RSF Germany (DWA-M 178, 2005)	CSO-CW France (full-scale Marcy-l'Etoile)	CSO-CW Italy (full-scale Gorla Maggiore)
Inlet water	CSO tank overflow	raw CSO	raw CSO (pre-treated before infiltrated)
Filter beds	1 or more in parallel	2 alternated loaded, in parallel for extreme events	4 alternated loaded, in parallel for extreme events
Retention layer depth	not defined (usually ~ 1.0 m)	flexible (0.1, 0.35, 0.6 or 0.8 m each bed), 2.0 m for connected beds	minimum 0.2 m
Filtration layer	0.75 m minimum (sand 0/2 mm, carbonate content > 10%)	minimum 0.5 m (one bed sand + zeolite, one bed pozzolana)	0.2 m (gravel 10 mm) + 0.4 m (gravel 2/6 mm)
Saturated layer	none (drainage layer 0.25 m gravel 2/8 mm)	flexible, minmum 0.2 m (0.3m gravel 10/20 mm, 0.1m gravel 3/8 mm)	0.2 m (gravel 40/80 mm)
Outflow limitation	0.02 L/(m²/s)	0.02 L/(m²/s)	0.004 L/(m²/s)
Max. hydraulic loads	40 m³/m² in annual average (maximum 60 m³/m² per year)	~ 40-80 m³/m² per year	35-40 m³/m² in annual average (maximum 50 m³/m² per year)
Design tool	long-term hydraulic sewer simulation	long-term hydraulic sewer simulation	long-term hydraulic sewer simulation

In Italy, in a first flush concept the needs of treatment are separated from those of hydraulic retention. The prototype located in Gorla Maggiore consists of two inlet splitters, four filter beds in parallel as well as an extended retention basin for the second flush flow (Figure 1-C). A maximum first flush of up to 640 L/s, generated by a rainfall event of 10 mm/h, can be retained. Exceeding volumes are bypassed into to the additional free water surface wetland (FWS).The filter inlet has to pass through an automatic screen and a grit separation tank (volume 110 m3) as a rough mechanical pre-treatment. Flow from the filter bed outlets are also fed into the FWS for secondary treatment. The FWS water level can be raised inside its artificial basin in order to release a maximum flow of 700 L/s to the River Olona due to flood protection. The water flow values given are representing a system in which almost all CSO will be treated by passing through the filter beds. Only peaks of maximum events with a return period of 10 years will pass by.

The cross-sections of the differing national approaches also show variations due to the specific needs (Fig. 2, Tab. 1): The French and the Italian CSO-CWs both provide permanent water layers. This is not particularly correlated to treatment processes – the design provides water for the reeds during extended dry periods, especially during hot and dry summers. In order to improve re-aeration after feedings an additional set of pipes was implemented (in RSFs the two functions of drainage and aeration are given by the same pipe system). Earlier German experiences with permanent saturation showed negative effects: Treatment efficiencies were decreased, low pH-values led to a release of carbonates, and anaerobic conditions caused odors. In comparison, the Italian CSO-CW will show shorter ponding periods due to the smaller retention space.

Until now, the filter design in all given countries is based on similar annual hydraulic loads (Tab. 1). The permanently increasing database – in combination with simulation tools – may lead to increased maximum annual and single event loads in future. This could be achieved by strategies to take higher benefits from divided filter beds. Pollution load criteria as design parameters could increase the adaptability to specific treatment needs.

Current research topics

In opposite to the French and Italian approaches, RSFs in Germany are under operation for more than 20 years. The national design guideline is currently under revision in order to implement the technical progress since 2005, e. g. for decreased CSO tank volumes. As an example, experiences from a completed research project on large-scale plants after several years of operation in Germany (Tondera, 2013a) can be summarised as follows:

- Micropollutants were investigated in a one year sampling phase. The reduction rates for substances like diclofenac, metoprolol and bisphenol a - up to a median of almost 75% - is at a level which makes further investigation worthwhile.
- Substances like carbamazepine, 1-h-benzotriazole and sulfamethoxazole were retained with a median between 26 and 39%. However, it was not possible to set up an inlet/outlet mass balance. To determine long-term retention or degradation, further investigations should be conducted in bench-scale.

In France and Italy, the basic function of the systems needs to be proven first. First monitoring results from 2013 show retention performances for C, N and P comparable to the well-known German approach. A special focus is given on a simplified modeling tool called RSF_Sim (Meyer, 2011), which allows to estimate the treatment performances in a long-term view. The following topics are currently investigated in detail:

- Retention limits, e.g. NH_4-N adsorption limits.
- Effects of the permanently saturated water layer.

- Risks of shortcut flows due to the coarser filter media.
- Maximum ponding time spans.

Summary of the discussion

The discussion was focussed on detailed questions about the main design ideas in France and Italy. The attended responsible persons (F. Masi, D. Esser, P. Molle & S. Troesch) could explain how they adapted their approaches starting from the German design guideline due to national requirements. In addition, the aims of current research projects could be explained in detail by the presenting authors (D. Meyer, K. Tondera, F. Masi).

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