Retention and treatment of overflows from combined sewer systems and of storm water from separate sewer systems

In a nutshell

SUMMARY
In the case of combined sewers, it is best practice to treat the overflow of the retention tanks, by means of fine screens (4-6 mm) and sediment tanks, and, depending on the water quality of the received water, by soil retention filters or other techniques with a similar suspended solids, COD, heavy metals and organic pollutants removal efficiency. In the case of separate sewers, it is best practice to treat the storm water depending on its level of pollution, and directly discharge only storm water with no or low pollution.
Target group
Public administrations responsible for waste water management and urban drainage.
Applicability
This best practice is applicable to all local authorities responsible for waste water management and urban drainage.
Environmental performance indicators
• For combined sewer systems, ratio of pollutants (total suspended solids, COD and heavy metals) discharged to water bodies from waste water treatment out of the total emissions (from treated waste water plus storm water overflows) (%) • For separate sewer systems, percentage of contaminated impervious areas from which storm water is adequately treated (%)
Benchmarks of excellence
N/A

Description

Regarding the disposal of storm water and wastewater, there are basically two different types of sewer systems; the separate and the combined sewer system. In the separate system, storm water and waste water are collected and disposed of via separate sewer networks whereas in the combined system, waste water and, in case of storm or rain events, storm water is collected in one sewer network. In both cases, the most important hydraulic design element is flood protection, i.e. the sewers should be designed to avoid floods in built areas. However, the sewer systems cannot be designed for to accommodate for any magnitude of heavy rain event. On the European level, for new building areas and planned rehabilitation of built areas, it is recommended to design the sewer system in a way that at most one flood event in 10 years for rural areas is acceptable whereas the recommended frequency for city centres and industrial areas is only once in 30 years (CEN 752, 2008). The two lower figures in Figure 1 indicate that the two different systems can be optimised as described in the technique on environmentally friendly and more sustainable water drainage. Then, the two systems are called ‘modified separate’ and ‘modified combined’ sewer system. Consequently, this technique and the one on environmentally friendly and more sustainable water drainage have to be always considered together.

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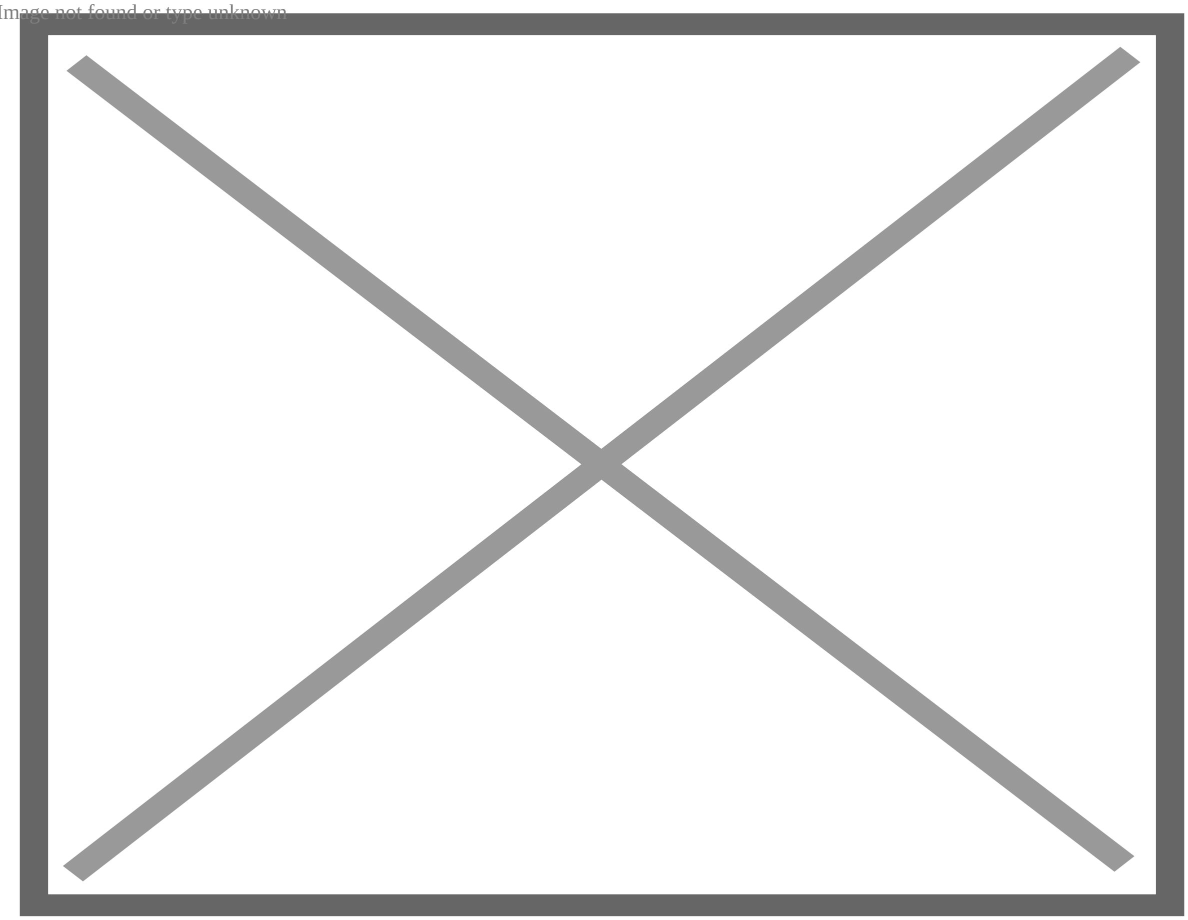
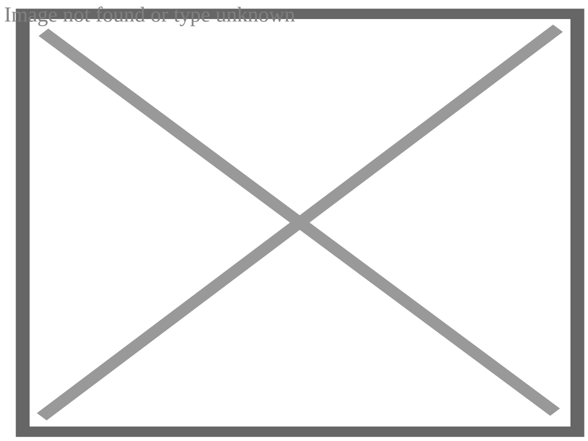


Figure 1: The combined and separate sewer systems as the two basic approaches to collect waste water and storm water (the two upper figures) and ways to modify (optimise) them by means of techniques on environmentally friendly and more sustainable water drainage, based on (Brombach/Weiß/Fuchs, 2004)

The two systems are compared in an idealised form in Figure 1. Thereby, it is assumed that the overflow from the combined system is treated, but not the storm water from the separate system (however, the latter is eventually also required depending on the degree of pollution). Also runoff which is by-passing the sewer system and is directly reaching the receiving waters is neglected. The groundwater infiltrating into the sewer is taken into account as it is a relevant part when balancing the flows. The other way round, the exfiltration of waste water/storm water is not considered. The numbers in Figure 1 reflect the average flow rates per hectare of impervious area in Germany but are only illustrative as the purpose of Figure 1 is to show the basic differences of the two sewer systems.



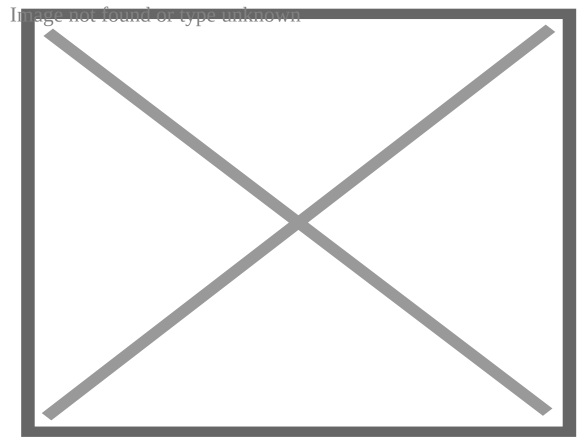
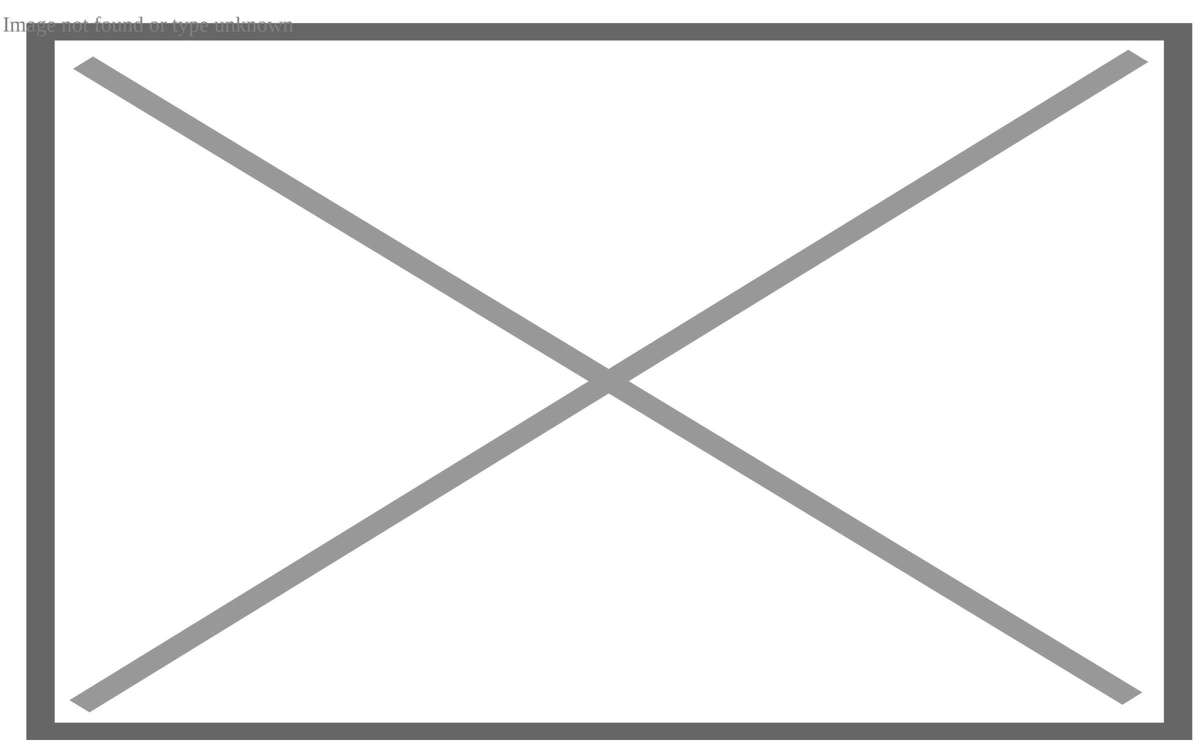


Figure 2: Idealised combined (left) and separate (right) sewer system with average (German) flow rates in m3/haimpervious yr, (Brombach/Weiß/Fuchs, 2004)

For the assumptions made for the calculated low rates in Figure 2, see: Brombach/Weiß/Fuchs, 2004

Concerning pollution load and discharge to receiving waters, based on a large database (Fuchs/Brombach/Weiß, 2004), a comparison has been made for different parameters. For better illustration, the ratios of loads are plotted rather than the absolute values. As a reference, the total load of a separate sewer system serves as 100 % for the different parameters. The white columns in Figure 3 indicate the load of the municipal waste water treatment plants. From the values, it can be concluded that none of the two systems is better than the other. For some parameters, lower values are achieved with the combined sewer system, and with the separate system for others. However, in many countries, preference is given to the separate sewer system in the sense that storm water with no or very low pollution should not be disposed of in combined sewers but should be locally infiltrated or directly discharged to natural waters (e.g. Denmark, Netherlands, UK, Germany, Sweden). This also means that storm water with significant pollution requires adequate treatment prior to its discharge.



Legend

TSS: total suspended solids, SS: settleable solids; BOD_5: biochemical oxygen demand in 5 days; COD: chemical oxygen demand; TOC: total organic carbon; P_{tot}: total phosphorus; NH_4-N: ammonia as N; NO_3-N: nitrate as N; N_{tot}: total nitrogen, Cd: cadmium; Cr: chromium; Ni: nickel; Pb: lead; Cu: copper; Zn: zinc; WWTP: waste water treatment plant

Figure 3: Comparison of pollution of the combined and separate sewer system for different parameters; all loads are standardised setting the total load from a separate system (discharges from storm water and waste water treatment plants) as 100 % (Brombach/Weiß/Fuchs, 2004)

For organic compounds (pollutants), the comparison of the two systems can be further detailed as in Table 1, which shows estimations for some relevant organic compounds.

Table 1: Estimated percentages of the annual load which is discharged to receiving waters via combined sewer overflows - in [% compared to the quantity discharged via WWTPs], based on (Welker, 2005)

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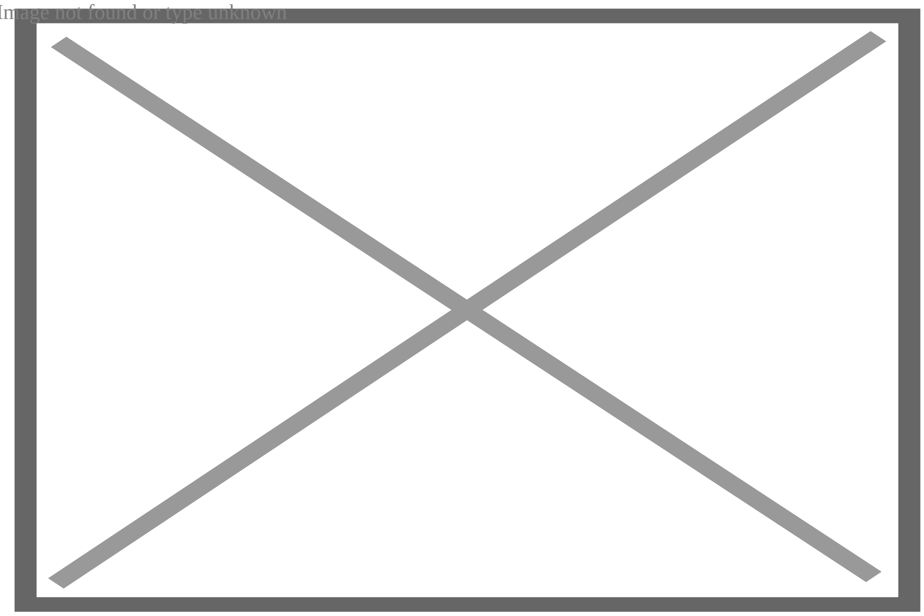

In the future, more and more organic pollutants will be detected and considered in storm water and waste water disposal and treatment (e.g. Ellis et al., 2013; Gasperi et al., 2014).

For both, the combined and separate sewer system, it appears to be best environmental management practice

- to implement environmentally friendly and more sustainable water drainage (see the best practice on sustainable urban drainage systems) in order to reduce the flow in combined and separate sewers, and to locally infiltrate storm water; this also means to disconnect already developed impervious areas from the sewer (e.g. Sieker et al., 2006; Geiger/Dreiseitl, 2009);
- to minimise combined sewer overflows by means of the aforementioned local infiltration, including the disconnection of already developed areas (impervious pavements), the retention of combined waste water (mixture of waste water and storm water) in dedicated tanks, and increased capacity of waste water treatment plants for combined sewer flow (considering the waste water treatment plant and storm water management, especially combined sewer overflows, as a whole, i.e. in an integrated way) in order to limit overflows to situations of unusually heavy rainfall (Merscough/Digman, 2008; ECJ, 2012),

- in case of combined sewers, to treat the overflow of the retention tanks by means of fine screens (4 - 6 mm) and sediment tanks, and, depending on the water quality of the receiving water concerned, by soil retention filters or other techniques with similar removal efficiency of suspended solids, COD, heavy metals and organic pollutants,
- in case of separate sewers, to treat the storm water depending on its level of pollution, and, as indicated above, to directly discharge storm water with no or low pollution; for this purpose, the areas of a municipality have to be systematically categorised according to their pollution.

When considering storm water management objectives, the preservation of groundwater and base flow characteristics, the prevention of undesirable and costly geomorphic changes in watercourses, prevention of flood risk potential, protection of water quality, and maintenance of appropriate abundance and diversity of aquatic life and opportunities for human beneficial uses should also be taken into account (Marsalek, 2013). In addition, the impact of climate change on the sewer systems, especially the possible occurrence of more heavy rain events, has become an intrinsic element of storm water drainage and treatment, specifically the disconnection of impervious areas from combined sewers (Villarreal et al., 2004; Emschergenossenschaft, 2005; Myerscough/Digman, 2008; Semadeni-Davies et al. 2008a; Semadeni-Davies et al. 2008b; Schmitt, 2011, Emschergenossenschaft, 2012; City of Hamburg, 2012; Emschergenossenschaft, 2013; City of Hamburg, 2014; Togersen et al., 2014).

Concerning the disposal of storm water as runoff from impervious areas, it is required to systematically assess all areas with respect to their pollution potential. It has been demonstrated to be an adequate approach to have three categories (as laid out in table 2 below).

Table 2: Requirement for the treatment of storm water depending on the level of pollution of impervious areas (Schmitt, 2012; Sieker, 2012)

Assessment of the contamination	**Description of impervious area (examples)**	**Requirement of treatment**
Category I Low contamination	Green roofs, roofs and yards in residential areas, cycling and walking paths, roads with an average daily traffic volume of less than 2000 cars	No specific treatment required
Category II Moderate contamination	Roads with an average daily traffic volume of more than 2000 cars, yards and parking areas in commercial and industrial areas	Treatment required in principle
Category III High contamination	Roads in industrial areas with significant air pollution, special areas, aircraft parking areas	Discharge to a WWTP or treatment with comparable efficiency

Available treatment techniques for the treatment of storm water are compiled in Figure 4. They are grouped into central end-of-pipe techniques and decentralised techniques at source. Practical details about most of the mentioned techniques are compiled in (Sommer et al., 2014). Some of the decentralised techniques are described in the best practice on environmentally friendly and more sustainable water drainage.

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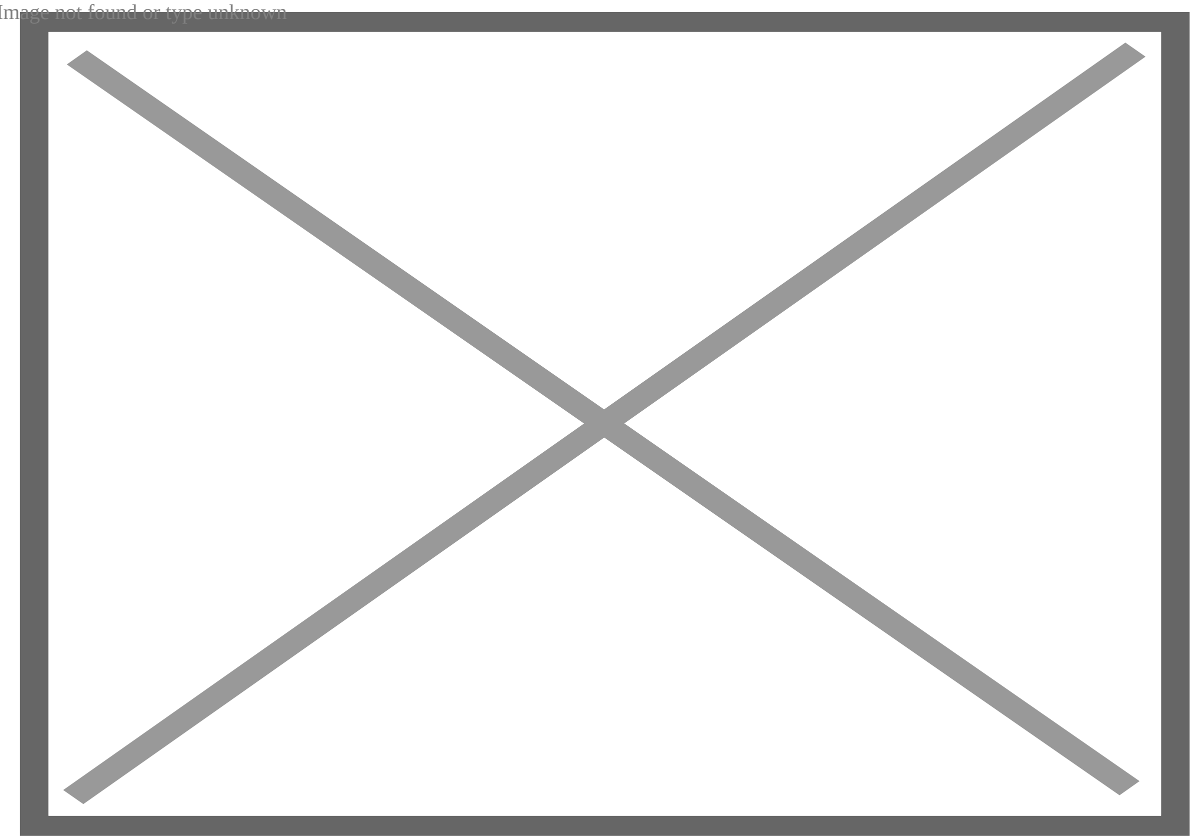

Figure 4: Overview of different techniques for the treatment of storm water, according to (Sieker, 2012)

No individual technique fits for all applications. The individual circumstances determine the selection of the suitable technique (Sieker et al., 2008; Sommer et al., 2014).

Environmental benefits

The main environmental benefits are the reduction of water pollution (reduction of oxygen consuming compounds, heavy metals and organic pollutants) and the improvement of the water quality as well as the local water balance in case of decentralised systems.

Figure 5 shows the overflow duration for about 100 tanks for the treatment of combined sewer overflows in Central Europe (Germany) over a time period of some years. With the techniques described, the overflow duration is short or very short which is associated with an improvement of the quality of receiving waters.

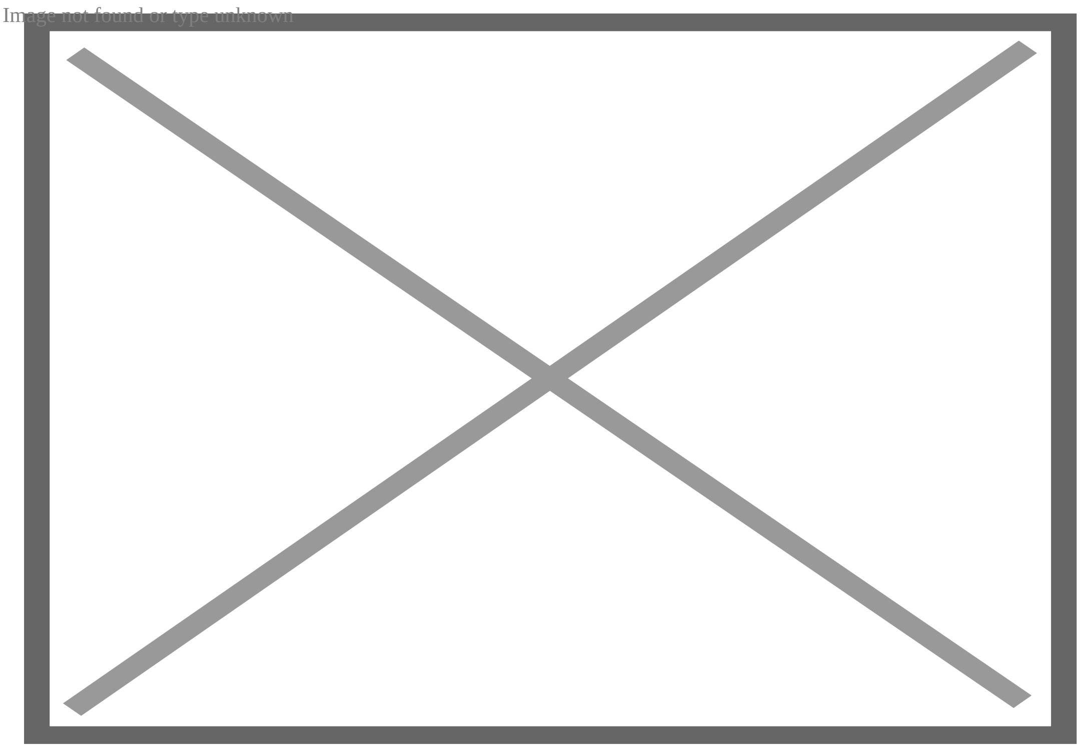

Figure 5: Annual overflow duration of about 100 tanks for the treatment of water of combined sewers, (Nichler et al., 2012) – example for Central Europe (Germany), the data were collected over a time period of some years

Side effects

For decentralised techniques, filter media may result as a waste. However, this does not appear to be an important cross-media effect.

Applicability

There is no technique that fits all applications (Sommer et al., 2014). In principle, it is required to distinguish between developed and new areas. Whereas in new areas, the spectrum of applicable techniques is broad, in developed areas the local conditions have an impact on the technique to be selected, such as

- position in the urban area
- existing subsurface infrastructure
- condition of the existing infrastructure (road gullies, shafts, sewer etc.)
- pollution of the area considered
- topography
- requirements on the discharged water
- initial level of pollution of the receiving water considered.

In case of decentralised techniques with disconnection of impervious areas, the information and involvement of individual owners is important. The same is true for the space availability for trenches, swales, etc.

Retention soil filters are recommended for both combined sewer overflow and storm water as runoff from impervious areas. Figure 6 shows an example.

Figure 6: Retention basin (sedimentation) and retention soil filter for the disposal/treatment of storm water

The space requirement for retention basins is relatively high. Thus, retention soil filters require a base area of about 100 m^2/ha (Sieker, 2012). When adding the enclosure, intake structure and operating building, the space requirement of a central retention soil filter is between one and two per cent of the connected area. For existing impervious areas, this space is often not available. Another limitation is the fact that soil retention filters need a height difference of about 1 – 2 metres which is not always available (Sieker, 2012). Consequently, the applicability of retention soil filters can be limited.

Economics

The costs for retention soil filters are comparatively high; the costs are about 1000 EUR/m2 filter area or about 7.50 EUR per square metre connected impervious area (Sieker, 2012).

Depending on the type of decentralised technique, the investment costs are between 0.1 and 8 EUR/m^2 connected impervious area (Sommer et al., 2014).

Decentralised techniques are not more expensive than central systems but the total costs depend on the required intensity of maintenance (Koch, 2010; Knippenberg/Werker, 2014).

Driving forces for implementation

The improvement of the quality of receiving waters is a major driving force, but also legal requirements are also in force in the different Member States, as well as the judgment of the European Court of Justice (ECJ, 2012) concerning the limitations of spills from storm water overflows of combined sewers.

Reference organisations

Many cities and municipalities in the UK (e.g. London), Germany (e.g. Freiburg and Karlsruhe) and other EU Member States apply the aforementioned techniques. In the German federal state North Rhine Westphalia, many cities and municipalities are frontrunners, especially with respect to separate sewers. In this state, the Emschergenossenschaft (Water Management Association of the Emscher Basin) is a frontrunner, both for combined and separate sewers. Hamburg is also implementing many of the described techniques. The city of Karlsruhe is prioritising the treatment of combined sewer overflows according to the results of their impact on the quality of receiving waters.

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