# Decentralised treatment of stormwater

## Research project for implementation of the NRW Separation Directive

Test installation for decentralised stormwater treatment systems at the IKT

**Emissions-relevant requirements for treatment of stormwater using the separation system are governed in North Rhine-Westphalia by the circular directive dated 26 May 2004 by the Ministry for Climate Protection, Environment, Agriculture, Nature Conservation and Consumer Protection (the „Separation Directive" for short). The „Decentralised treatment of stormwater in separation systems - Implementation of the Separation Directive" research project successfully tested systems for decentralised treatment of stormwater from Category II (low-level pollution) surfaces.**

The precondition for the use of decentralised installations is comparability with the centralised treatment processes listed in the directive in terms of pollutant retention and continuous operation. The tests demonstrated that decentralised treatment systems for precipitation run-off are, in principle, comparable with centralised systems, with primary attention to rainwater sedimentation tanks (RSTs).

The research project examined a number of different decentralised systems in the laboratory and in operation, determined their mass and hydraulic efficiency, and calculated the comparability of decentralised and centralised systems. In the laboratory, the IKT measured the performance of the systems on a test apparatus under repeatable conditions. Examination of continuous operation of the systems across a period of one year by means of practical testing in two separation zones was monitored by Grontmij GmbH. The TU Kaiserslautern studied the comparability of decentralised and centralised installations.

In addition to the institutions mentioned above, the Cologne municipal drainage utility, the Ministry for Climate Protection, Environment, Agriculture, Nature Conservation and Consumer Protection of the Federal State of North Rhine-Westphalia (MKULNV), the Cologne regional government, Hydro-Ingenieure GmbH and Dr. Eckhart Treunert also participated in this research project.

### Assignment and objective

It is necessary, in the field of treatment of precipitation run-off, to differentiate between centralised and decentralised systems. In the case of centralised treatment, the entire volume of waste-water - equivalent to the maximum burden of the catchment areas - must be treated, even if this applies only to a portion of the surfaces. In residential areas, however, even one Category II polluted street can, for example, result in greater cleaning requirements. Separate, decentralised treatment of the polluted stormwater from this street makes it possible to meet the requirements for these surfaces and significantly reduce the quantity of stormwater requiring treatment.

Many diverse applications for decentralised systems for drainage of transport surfaces can, therefore, be expected in practice. The tests performed within the scope of this research project focused on use for public transport surfaces. No statements concerning other polluted surfaces, such as commercially used sites, are made, and may also not be derived.

The project assignment was the study of six different systems and verification of the required comparability with centralised systems in physical and operational terms. The following working stages were necessary for this:

- Determination of possible inward pollution migration and possible capacity limits of the decentralised systems for treatment of stormwater.
- In its laboratory tests, the IKT examined six decentralised systems under defined and repeatable boundary conditions and determined their hydraulic performance and mass retention characteristics.
- The systems were tested under practical conditions in order to demonstrate that they will function trouble-free for prolonged periods under local conditions, and that the servicing/maintenance needs can be estimated.
- A methodological concept which permitted comparative study of the mass burdens imported into the system and exported into environmental water under various conditions for the system types tested was developed.

Another aim of the project was that of drafting methodological principles which would permit a statement concerning the fundamental comparability of centralised and decentralised systems. This decisively facilitates the future evaluation of other system types.

## Selection of systems for testing

Systems which
- can be used in existing road gullies,
- can replace existing road gullies,
- can treat stormwater from multiple gullies

were selected for this research project.
The type of road gully (variants as per DIN 4052) and the resultant space requirements in the gullies are an important factor in the use of the first system type mentioned. When systems which replace the road gully are used, the existing road gully is removed and replaced by the system's own shaft element. When the last-mentioned systems are used, a number of road gullies can be connected to the treatment system. These (semi-centralised) system types are flexible, but their space requirements are greater, due to their design. A filter shaft system was also selected for these tests.

The decentralised systems also differ in terms of treatment process and/or efficiency. Physical treatment methods include, for example, filtration, sedimentation, removal of light fractions and removal of "floats" (i.e., buoyant) fractions. Dissolved substances are captured by means of chemical processes, such as sorption and ion exchange, for instance. Both process forms occur, using a substrate, in physico-chemical treatment systems.

Six decentralised rainwater treatment systems were selected on the basis of the above-mentioned criteria for the laboratory tests performed at the IKT:
- The geotextile filter bag (Paul Schreck GmbH)
- SSA separating road gully (ACO Tiefbau Vertrieb GmbH)
- Centrifoel (Roval Umwelt Technologien Vertriebsges. mbH)
- Innolet (Funke Kunststoffe GmbH)
- 3P Hydrosystem (3P Technik Filtersysteme GmbH)
- MLK-R plate separator (Mall GmbH)

All these systems, with the exception of the Mall MLK-R plate separator, were also tested in practice.

## Test parameters

After extensive literary research, the filterable substances were selected as the most important parameters, since solids may have a range of negative effects on environmental water and its organisms. The ingress of solids into environmental water may, for example, contribute to blockage of the porosity system of the waterway or lake bed and to retarded absorption of oxygen. In addition, a large proportion of other pollutants are adsorbed onto such solids.

Among the heavy metals, copper and zinc are of particular importance, since they have a toxic action and since large amounts are contained in precipitation run-off from tyre and brake-lining abrasion. Pollution of stormwater with petroleum hydrocarbons (PHs) is frequently close to the quantitation limit of the analytical methods used. They are nonetheless taken into account and validated in the laboratory tests, in order to eliminate any possible hazard for environmental water.

The following list of parameters to be quantified thus results:
- Filterable substances (FSs)
- PHs
- Heavy metals (copper and zinc)

## Laboratory tests

The aim of the laboratory tests performed at the IKT - Institute for Underground Infrastructure was that of assessing the hydraulic performance and mass retention of decentralised precipitation-water treatment systems under comparable conditions. The main focus of the tests was on retention of filterable substances.

Input of the test apparatus for measurement of hydraulic performance and mass retention

## Test apparatus and performance

Two different test systems were used.
Test System 1 was designed in such a way that both the hydraulic performance and retention of filterable substances (FSs) and of petroleum hydrocarbons (PHs) could be determined. The six decentralised precipitation-water treatment systems were tested for retention of a total of four different particle types (the "four-parameter model"), taking account of the maximum servable surface area stated by the particular manufacturer. The following substance particles were used for the four-parameter model (see Figure 1):

- Fine-particled mineral FS (Millisil W4)
- Coarse-particled mineral FS (a mixture of gravel and sand with a particle-size distribution of between 0.1 mm and 4.0 mm)
- Coarse-particled suspended matter (buoyant) in the form of polyethylene (PE) granulate
- Coarse-particled suspended matter (non-buoyant) in the form of polystyrene (PS) granulate

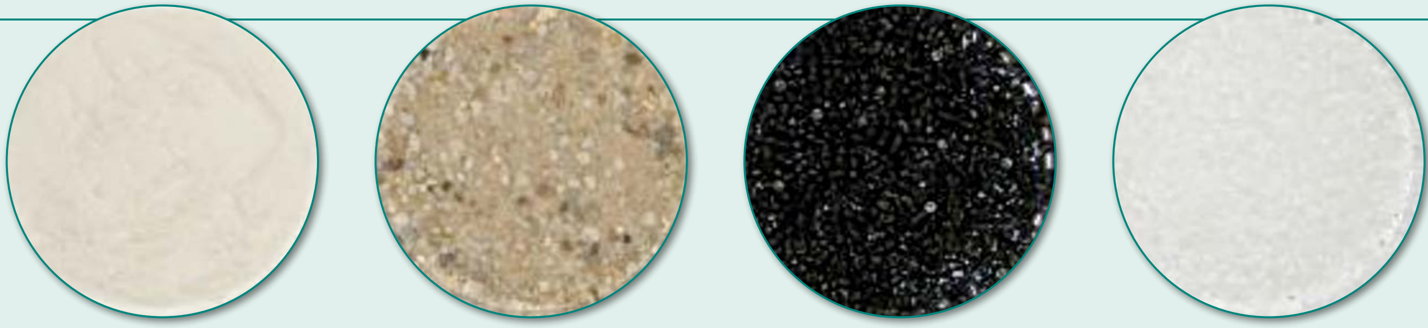

Figure 1: The FSs used (left to right): Millisil W4, gravel/sand mixture, PE granulate (black) and PS granulate (white).

The fine-particled mineral FSs were added across defined test periods in three sub-tests with reference to the DIBt (German Institute for Building Technology) approval principles. The application of an annual fine-particle burden of 50 g/(m² × a) surface area served and the use of a Millisil W4 ground quartz (manufacturer: Quarzwerke GmbH) should be noted as the essential data. Millisil W4 ground quartz covers the particle-size range up to 400 µm. The substance was in each case added at the precipitation intensities to be simulated of 2.5 l/(s × ha), 6 l/(s × ha) and 25 l/(s × ha), at a ratio of 3:2:1, referred to total mass. The extent to which captured FSs are flushed out under simulated heavy rain at a rainfall intensity of 100 l/(s × ha) was investigated in a fourth sub-test (see Table 1).

**Table 1: Rainfall intensities and periods of testing for retention of FSs.**

| Sub-test | Rainfall intensity value | Test duration | |
|---|---|---|---|
| - | [l/(s × ha)] | [h] | [min] |
| 1 | 2,5 | 8 | 480 |
| 2 | 6 | 3.33 | 200 |
| 3 | 25 | 0.8 | 48 |
| 4 | 100 | 0.25 | 15 |

The result subsets were evaluated using the procedure described in the DIBt approval conditions. The coarse mineral FSs of the particle-size range between 0.1 and 4.0 mm were in each case flushed in at simulated rainfall intensities of 25 l/s × ha, referred to the respective servable surface area. This particle-size fraction was fed intermittently into the volumetric flow. Retention of coarse mineral FSs was determined by comparing the total mass added to the total mass screened out. Retention of polystyrene suspended matter and polyethylene floating (buoyant) matter was determined in the same manner. Retention of dissolved heavy metals was determined using a second test apparatus (Test System 2). These tests were performed on columnar substrate-filled sections of filter which reflected the structure of the substrate filters of the "INNOLET" and the "3P Hydrosystem".

Petroleum hydrocarbons are metered in the influx.

Five of the six decentralised precipitation-water treatment systems were tested for retention of petroleum hydrocarbon (PH), taking account of the maximum servable surface area stated in each case by the manufacturer. The tests were performed using Test System 1 and EL fuel oil (see Table 2). The EL fuel oil was added uniformly within the first five minutes of each of three sub-tests. Medical hypodermic syringes were used for addition. One third of the assumed annual burden of 0.68 g petroleum hydrocarbon per m² of served surface area was in each case metered in during the three sub-tests.

The quantities of PH resulting for a served surface area of 500 m² are shown by way of example in Table 2, taking account of subdivision into three sub-tests (see "FS Test"). Sub-test 4 is also regarded here as a flush-out test.

An overview of the tests performed is shown for each test system in Table 3.

**Table 2: Testing for retention of petroleum hydrocarbons, correlation between drainage areas and PH concentrations.**

| Sub-test | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| Rainfall intensity value [l/(s × ha)] | 2,5 | 6 | 25 | 100 |
| Drainage area [m²] | 500 | 500 | 500 | 500 |
| Volumetric flow [l/s] | 0.125 | 0.3 | 1.25 | 5 |
| Volume [l] | 3600 | 3600 | 3600 | 4500 |
| Total PH: 340 g | 113.3 g | 113.3 g | 113.3 g | |

**Table 3: Overview of systems tested and tests performed in each case, showing assignment to the test systems used.**

| Systems | Tests | | | |
|---|---|---|---|---|
| | Test System 1 | | | Test System 2 |
| | Hydraulic performance | Filterable substances[1] | Petroleum hydrocarbons | Dissolved heavy metals[2] |
| Geotextile filter bag | • | • | • | - |
| Centrifoel | • | • | • | - |
| Separating road gully (SSA) | • | • | - | - |
| Mall plate separator (MLK-R 20/09) | • | • | • | - |
| Innolet | • | • | • | • |
| 3P Hydrosystem 1000 heavy traffic | • | • | • | • |

• Test performed; - Test not performed
1 Four-parameter model: Millisil W4, gravel/sand mixture, polyethylene and polystyrene granulate
2 Heavy metals (copper and zinc)

**Table 4: Results of tests of hydraulic performance in as-new condition**

| Systems | Servable surface area | Hydraulic performance limit: manufacturer's information | | Hydraulic performance limit: As-new condition, measured | |
|---|---|---|---|---|---|
| | [m²] | [l/s] | [l/s × ha] | [l/s] | [l/s × ha] |
| Geotextile filter bag | 300* | 238** | 7933** | 20 | >> 666.6 |
| SSA | 400 | 10 | 250 | 20 | >> 500.0 |
| MLK-R 20/09 | 500*** | 8,6 | 172 | 8,7 | 174 |
| Centrifoel | 400 | 2.5 | 62.5 | 1.13 | 28.3 |
| Innolet | 250 | 0.625 | 25 | 1,5 | 60,0 |
| 3P Hydrosystem 1000 heavy traffic | 500 | k. A. | k.A. | 13,5 | 270.0 |

* filter element made up specifically for the application examined
** calculated from the manufacturer's system data
*** the servable surface areas are determined by Mall for each application. The 500 m² selected here was a figure proposed by the manufacturer as a typical application.

**Table 5: Results for mass retention in as-new condition[1]**

| Systems | FS | | | PH | Heavy metals | |
|---|---|---|---|---|---|---|
| | Mineral | | Suspended matter | | | |
| | Coarse | Fine | PE and PS | PH | Kupfer | Zink |
| | | Copper | Zinc | [%] | [%] | [%] |
| Geotextil-Filtersack | [%] | [%] | [%] | [%] | [%] | [%] |
| SSA | 97.9 | 76.6 | 10 | - | - | - |
| MLK-R 20/09 | 100 | 93.9 | 100 | 95.0 | - | - |
| Centrifoel | 92.3 | 60.2 | 0 | - | - | - |
| Innolet | 93.5 | 45.4 | 80 | - | 78.1 | 45.3 |
| 3P Hydrosystem | 100 | 95.6 | 100 | 90.2 | 97.2 | 96.9 |

[1] It should be noted in the case of systems of comparatively low volume that the actual mass retention can in practice greatly depend on local operating boundary conditions and on reliable and regular servicing and maintenance.

### Results: Hydraulic performance and mass retention

The laboratory tests performed in all cases indicated good mass retention rates for the decentralised precipitation-water treatments systems selected. As expected, pollutant retention in as-new condition proved to be dependent on the type and the functional mechanisms included in the individual systems. The removal of solids occurs primarily via sedimentation, whereas dissolved heavy-metal contents can be eliminated only in systems featuring suitable filter substrates (by means of ion exchange, for example). Those systems which permit removal of light fractions exhibited significant retention effects in the removal of PH. Evaluable results were determined for the MLK-R and the 3P Hydrosystem. All in all, the derived "efficiencies" for these systems confirmed both the data found in the technical literature and the information provided by the manufacturers.

The results for hydraulic performance in as-new condition produced a heterogeneous picture. The hydraulic performance claimed by the manufacturer was, for example, confirmed in the case of the MLK-R 20/9 plate separator, whereas that of the Centrifoel fell below the manufacturer's claim and that of the INNOLET bettered it by far. Table 4 and Table 5 show the numerical data derived from the tests for hydraulic performance and mass retention of the decentralised precipitation-water treatment systems tested.

### Operational experience

An important element in this research project consisted of investigations of technological feasibility and the suitability for practical use of the decentralised treatment systems; these factors depend both on the design features of the systems themselves and on the circumstances of the catchment area, or rather, the served surface areas of origin of the precipitation run-off. These investigations were performed by Grontmij GmbH at two locations, in Cologne and Königswinter.

The existing road gullies were firstly selected for installation of the treatment systems at the test locations, and the connected transport surfaces determined. In view of the obligation not to endanger road traffic, only every second road gully was selected in this project for equipping with a decentralised system.

## Results of operational monitoring

Intensive operational monitoring of the decentralised treatment systems installed was an integral component of the in-situ tests. During the more than twelve-month monitoring period, inspection took place initially every two weeks and then (after around six months) every four weeks. The following items were assessed:

- Condition of feeds
- Leaf trap filling level
- Sludge level
- Reaction of overflows (where installed)
- Any need for cleaning/maintenance

The systems installed exhibited, on the whole, a high level of reliability during operation. No system-induced problems occurred with respect to the ingress of leaves in the autumn, ingress of road grit during the long winter and frost period, pollen dispersal in the spring, or heavy precipitation events during the summer months. It was, however, apparent that careful installation of all system components by the operating staff is necessary to assure correct functioning. This also applies to inspections, cleaning and maintenance.

On-site testing of hydraulic performance after prolonged periods of operation and exposure to various loads was also performed, in addition to the routine periodic inspections of the decentralised systems during their operation. This was intended to permit a statement, with respect to the "approvability" of these systems, concerning their performance in used condition. These inspections were performed repeatedly during the period of the project. It was possible, in combination with the inspections during operational monitoring, to derive information concerning the possible service-lives of these systems, and to define inspection, maintenance and cleaning intervals, including filter-changing, where necessary.

**Table 6: Overview of and technical data for the selected locations**

| | Porz-Lind (Cologne) | Königswinter |
|---|---|---|
| Vehicle frequency [24h] | approx. 5,000 | approx. 6,500 |
| Road category as per Separation Directive | IIb | IIb |
| Mean precipitation [mm/a] | 710 | 700 |
| $A_{e,k}$ [ha] | 6.8 | 0.0615 |
| $A_u$ [ha] | 4.3 | 0.0615 |
| $A_{u,Straße}$ [ha] | 1.1 | 0.0615 |

**Table 7: Installation of the systems in the separation zones**

| Porz-Lind (Cologne) | Königswinter |
|---|---|
| Geotextile filter bag | 3P Hydrosystem |
| SSA separating road gully | |
| Centrifoel | |
| Innolet | |

**Table 8: Results of operational monitoring; recommendations for cleaning and maintenance intervals**

| Decentralised system | Inspection [1/a] | Cleaning [1/a] | Maintenance/ replacement[1/a] |
|---|---|---|---|
| Geotextile filter bag | 0 | 3-6 | 0.5 |
| SSA | 1 | 1 | 0.2 |
| MLK | System was not submitted to practical test | | |
| Centrifoel | 2 | 2 | 0.5 |
| Innolet | 3 | 2 | 0.5 |
| 3P Hydrosystem | 0 | 1 | 0.33 |

The following recommendations for monitoring of the various decentralised systems were determined, by way of summary, for the locations investigated (see Table 8):

The inspection frequencies stated here relate solely to the locations studied and cannot be applied to other areas. The above restriction is the result of the experience, gained during the project, that the necessary frequency of inspection and cleaning of these systems depends on local conditions (such as vehicle frequency, for example), plant growth, amounts of fine sediments from exposed surfaces and site gradients.

Inspection of a road gully equipped with a geotextile filter bag

The operational inspections performed were used to extrapolate operating costs resulting from inspection, maintenance and cleaning work and, where appropriate, from changing of filter substrates or filter columns. It became apparent in this context that the operating costs to be anticipated are lower in the case of systems necessarily involving civil-engineering work for their installation (in our case: SSA and Centrifoel, which replace the road gully) than in the case of the smaller and more easily retrofittable systems (filter bag and Innolet).

A comparative assessment of the operating costs determined for decentralised systems against the known cost rates for centralised systems indicates that centralised systems may be the more rational-cost solution compared to rainwater sedimentation tanks when operating costs are included. It is important to take account of all boundary conditions in planning for this purpose, however.

### Comparability in accordance with the Separation Directive

The question of the comparability of decentralised and centralised treatment systems from a mass viewpoint was examined by the TU Kaiserslautern by means, on the one hand, of a methodical assessment of mass retention efficiency and, on the other hand, by means of operational monitoring and evaluation of durability. These studies demonstrated that there is comparability in principle between decentralised treatment systems for precipitation run-off and centralised systems, focussing primarily, here, on rainwater sedimentation tanks.

### Comparability of mass retention

A balance of the extracted mass burdens of the selected substance parameters of FS, chemical oxygen demand (COD), PH and zinc was drawn in order to investigate the comparability of the mass retention of centralised and decentralised treatment systems. The investigation was conducted on the basis of annual data for substance volume and the mean efficiencies of the treatment systems examined. Graduated concentration data were used for the three burden categories as the mean pollution level of the annual precipitation run-off specified as a constant.

This balance was drafted for four catchment areas of differing surface-type composition, consisting essentially of Burden Categories I and II, in order to analyse the influences of differing surface-type ratios. In addition, the influences of a graduated detachment of surface area elements and of various specifications for precipitation run-off pollution and the effectiveness of mass retention in the treatment systems were also studied in a sensitivity analysis.

### Efficiencies of decentralised and centralised systems

Table 9 shows the data ("working data") on mass retention for the decentralised and centralised treatment systems studied, which formed the basis for the methodical comparison. Where appropriate, these include a reduction in case of limitation of influxes, for hydraulic design for a critical rainfall intensity value, as is customary in the case of rainwater sedimentation tanks.

### Results of comparison of mass retention

The comparative mathematical balances clearly illustrate the superiority of the retention soil filter over rainwater sedimentation tanks and the decentralised filter cartridge and filter bag system types where mass retention is concerned. Under the methodology selected, comparative assessment of "Rainwater sedimentation tank vs. decentralised systems" is, for its part, significantly influenced by the proportions of Burden Categories I and II surface-area types.

Due to the deliberately significantly differingly assumed efficiencies of filter bag and filter cartridge, the overall efficiencies of the RST are between those of these two decentralised system types in various configurations. The "Decentralised treatment using filter bag-type system" correspondingly performs better than centralised treatment using rainwater sedimentation tanks. The results for the effectiveness of decentralised systems in the IKT tests are indicative of lower - and, in some cases, contrary - differences in the efficiencies of the filter bag and filter cartridge system types.

The influence of surface-area detachment confirms and amplifies the effects of increasing Category II area contents which, as a result of the method used, cause an improvement in the effectiveness of decentralised systems. It should be emphasised, however, that catchment areas with a low proportion of polluted run-off and surface-areas of Burden Category II (and, where appropriate, III) are particularly suitable for the use of decentralised systems, since they can be systematically configured for the more heavily polluted run-off. Treatment can be implemented here both more efficiently and also significantly more cost-effectively than in a central treatment facility connected to all sub-areas and dimensioned for the entire influx.

The concentration data used for substance influx and substance transportation by precipitation run-off include significant uncertainties with respect to absolute values. The variant calculations performed for this purpose demonstrate that the ratio of the assumed concentrations between Burden Categories (I : II : III) has a significant influence on the result of the mass comparison. On a relative view, higher concentrations in the run-off requiring treatment compared to Category I boost the effectiveness of the decentralised systems.

**Table 9: Selected efficiencies $\eta_{dez}$ and $\eta_z$ of the treatment systems examined for the methodical comparative assessment**

| Make / manufacturer | Applications | FS | COD | PH | Zinc |
|---|---|---|---|---|---|
| Decentralised treatment systems with efficiency $\eta_{dez}$ | | | | | |
| 3P Hydrosystem, 3P Technik Filtersysteme GmbH | Roof surfaces | 0.90 | 0.70 | 0.90 | 0.85 |
| Geotextile filter bag (Schreck) | Transport surfaces and vehicle standing surfaces | 0.80 | 0.65 | 0.80 | 0.65 |
| INNOLET filter cartridge (Funke Gruppe GmbH) | Transport surfaces and vehicle standing surfaces | 0.50 | 0.40 | 0.50 | 0.40 |
| Centralised treatment system with efficiency $\eta_z$ | | | | | |
| Intermittent rainwater sedimentation tank (RKBoD) | All surfaces | 0.40 | 0.35 | 0.50 | 0.30 |
| Retention soil filter (RSF) | All surfaces | 0.75 | 0.70 | 0.75 | 0.70 |

All in all, it is possible to confirm the comparability of decentralised and centralised systems in terms of achievable mass retention. The investigations and calculations, despite residual uncertainties, nonetheless provide a substantiated basis for the mass comparison. Also to be noted is the fact that a broad spectrum of differing circumstances provided the basis, in the form of the three catchment areas observed and the four different substance parameters.

### Comparability in continuous operation

The experience gained from the operational monitoring conducted over a period of one year has been compiled for each of the decentralised systems included in an evaluation matrix based on the three principal criteria of

- Hydraulics
- Retention capacity
- Maintenance

and in each case evaluated for comparability of treatment in a comparison with the evaluation of the rainwater sedimentation tank. Sub-categories which permit estimation of the respective decentralised system were established for this evaluation in addition to the above-mentioned principal criteria. The project participants agreed on the following arrangement for the evaluation criteria:

#### Results of comparison of continuous operation

As the compiled evaluations demonstrate, the overall observation confirmed for each system the comparability of treatment on operational criteria. A constant and standard ("homogenous") evaluation could scarcely be expected in view of the bandwidth of relevant influencing factors, the various evaluation criteria for the comparative assessment and the system-inherent differences between centralised and decentralised systems. This was true both of the decentralised system as a group, but divergent estimations by the project participants also occurred for the individual criteria of the single decentralised system observed. These should be regarded more as aids to selection for the specific requirements of each individual application, however.

**Table 10: Evaluation matrix for comparison of RST/decentralised treatment**

| „Decentralised rainwater treatment systems in separation systems" research project<br>Evaluation matrix for comparison of centralised / decentralised systems | | |
|---|---|---|
| System types | System type | Decentralised |
| | Functional mechanism | Mechanico-physical systems |
| | Manufacturer | Name |
| | Designation/type | Name |
| Hydraulics | Capacity | |
| | Backlog performance (>$Q_{krit}$) | |
| | Specific storage behaviour | |
| Retention capacity | Coarse materials, general | |
| | AFS | |
| | Behaviour in emergency | |
| | Low-density liquids | |
| Maintenance | Cleaning intervals | |
| | Input | |
| | Accessibility from traffic space | |
| | Spares | |
| Evaluation | Hydraulics | |
| | Retention capacity | |
| | Maintenance | |

Evaluation was effected using the following system:
Conditions fulfilled: „o"; Not fulfilled „-"; more than comparable system „+"

It should, on the whole, be emphasised that the evaluations of durability were drawn on a purely qualitative basis. A numerical, quantitative comparative assessment would have necessitated, in the case of the "hydraulics" and "mass retention" criteria, parallel investigation of both systems and complete registration of the local influx and run-off situation across a prolonged period, in order to obtain a hydrologically representative overall data-base for the burden spectrum.

### Conclusion on the comparability of mass retention and continuous operation

The tests performed document, all in all, the equivalence of the decentralised systems examined with the centralised treatment system (RST type) in terms of mass retention and continuous operation.

#### Mass retention

The methodical comparison of the mass-retention performance documents the effectiveness of decentralised systems for a targeted mass retention. These systems can be configured specifically for each application, depending on the utilisation of the run-off surfaces and anticipated pollution and/or depending on the requirements of the environmental water into which discharge is to take place for protection. The evaluations of mass-retention performance from the methodological comparison relate less to the named system type and should, rather, be understood as a characterisation of decentralised systems.

The systematic - and then also particularly cost-efficient - installation of decentralised systems for only small surface-area elements with elevated pollution levels is a further advantage over the centralised arrangement, despite the fact that a mathematical comparison initially produces a different picture. It should also be noted that both types of system can also be installed with only little civil-engineering input into existing road gullies, whereas, on the other hand, relatively high capital expenditure is necessary in the case of a rainwater sedimentation tank of only small capacity.

### Continuous operation

The difference in type of the decentralised systems and the significantly larger number of operating locations which require inspection and servicing at regular intervals also result in other requirements for operation, in order to assure long-term operability. The usually significantly lower costs of construction/installation must be set against greater operational expense for the assurance and maintenance of correct functioning and performance across the entire operating life-cycle. This fact in no way contradicts the overall evaluation result of fundamental comparability of treatment.

### Note on hydraulic capacity

The centralised rainwater sedimentation tank (RST) system selected as a reference is generally designed for a critical precipitation run-off. Any influxes exceeding this are routed past the installation via an overflow weir. Operational problems can be easily visually detected and then rectified during the regular inspections. The difficulty in the case of decentralised systems is that of detecting any decline in hydraulic capacity or other operational problems. Continuous operation therefore also involves the requirement that it is assured, with a hydraulically limited treatment-unit design, that influxes up to this limit can actually be passed through the treatment unit and that the hydraulic capacity above this threshold value remains, or that any drop below the threshold value is quickly detected. Mere visual inspection at even short regular intervals would probably not permit the detection of such problems.

## Conclusion

The laboratory tests performed as part of this research project demonstrated that the decentralised treatment systems examined exhibit in as-new condition high effectiveness both in mass and in hydraulic terms. No significant deficiencies were observed during the deployment of these systems at the practical locations in Cologne and Königswinter for a period of one year.

It is apparent that there is comparability in principle between decentralised and centralised treatment systems for polluted precipitation run-off from road surfaces. Decentralised treatment systems involve significantly lower civil-engineering complexity and lower investment costs for installation of the equipment. This must, however, be set against greater operational expense for maintenance and cleaning across the entire operational life-cycle, in view of the large number of operating locations.

The experience gained indicates certain potential difficulties in the detection of declining hydraulic capacity in decentralised systems. This is true, most particularly, of systems featuring an overflow. This could result in premature but impermissible activation of the overflow in case, for example, of colmation ("clogging") in the filter body. In case of the present systems, detection of this phenomenon by means of visual inspection, even at shorter intervals, would appear difficult. The manufacturers should, in this context, consider the possibility of creating monitoring facilities.

Despite the fundamental comparability of decentralised and centralised treatment systems for stormwater run-off, the special boundary conditions and the water-management significance of the specific catchment area require due care in case of use for specific individual projects and in drainage planning. This demands holistic observation of the task from project participants and clearly illustrates the high quality demands made on planning.

Whether decentralised treatment systems can be approved on the basis of a Germany-wide building-supervision approval in the long term is not currently foreseeable. Procedural-law provisions can, for the transitional period, be implemented by means of directives at federal-state level.

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