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IKT - Institute for Underground Infrastructure

2012-2014

RESEARCH & TESTING

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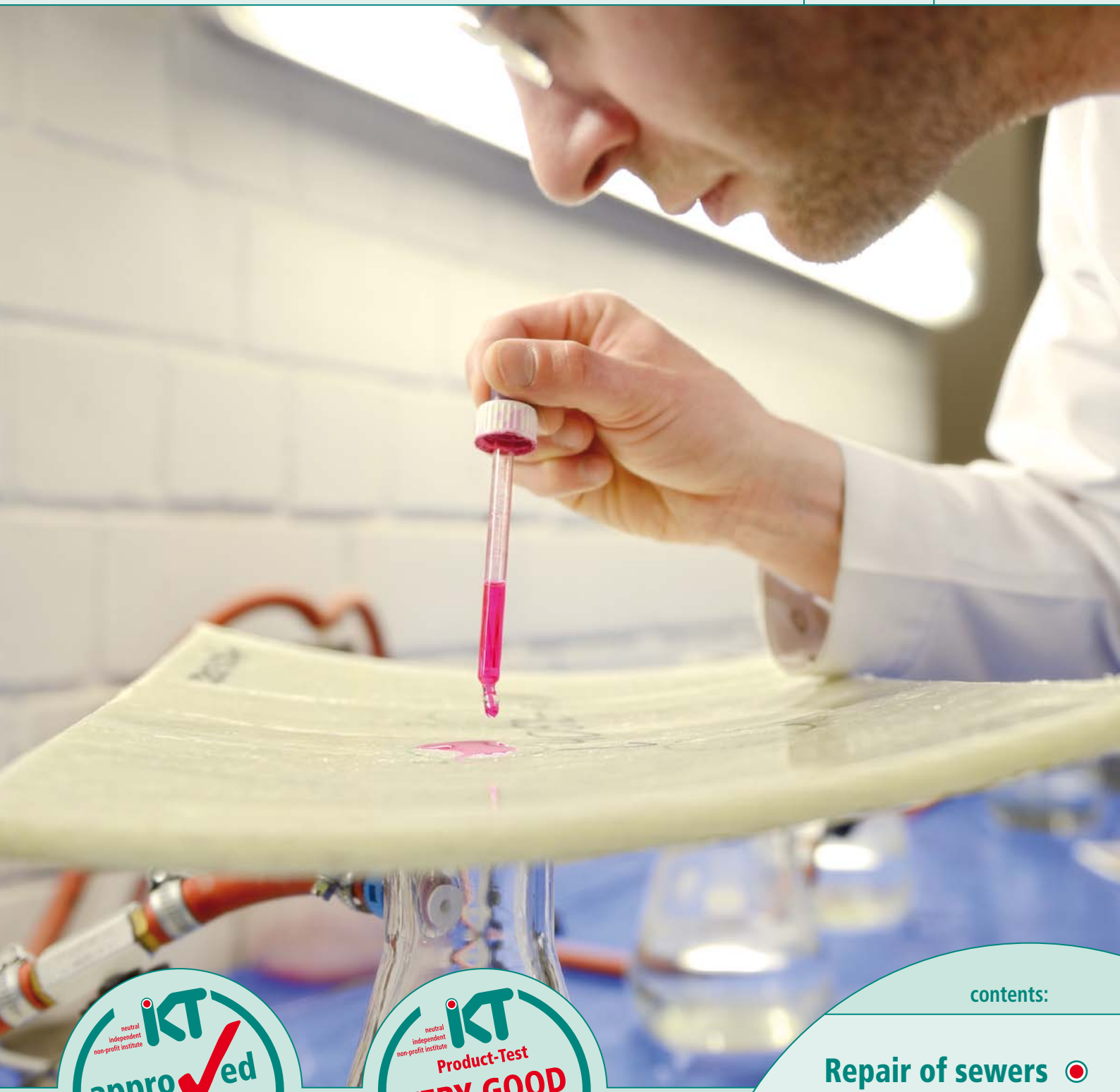


contents:

Ten years of the IKT LinerReport

» The IKT test centre has been publishing annual reports on the results of its tube liner tests since 2004. An excellent occasion, therefore, to chance a look back at the statistics, and assess the developments in the quality of the most important refurbishing method.

The focus, from the very start, was the extent to which a number of pivotal quality criteria promised by tube liner suppliers to customers, and specified for their products in the approvals, are actually met in on-site practice.

The IKT's aim with its LinerReport has always been, and remains, to achieve transparency and publicity, in order thus to prompt tube-liner quality improvements. The overall picture shows a significant improvement in the test results: 10 percent quality improvement in 10 years!

The quality of CIPP liners available on the market has improved measurably. Transparency now prevails where clients were previously obliged to rely solely on suppliers' promises. This has driven both product and procedure improvements, and also technical innovations which would not otherwise have occurred. There is now not only price, but also unequivocal quality competition on this market.

The beneficiaries are primarily the clients. They, however, will be well advised to continue consistently requiring quality tests on tube liners for every installation site - there would otherwise be a danger of a creeping retreat from the peak success of 2013. «

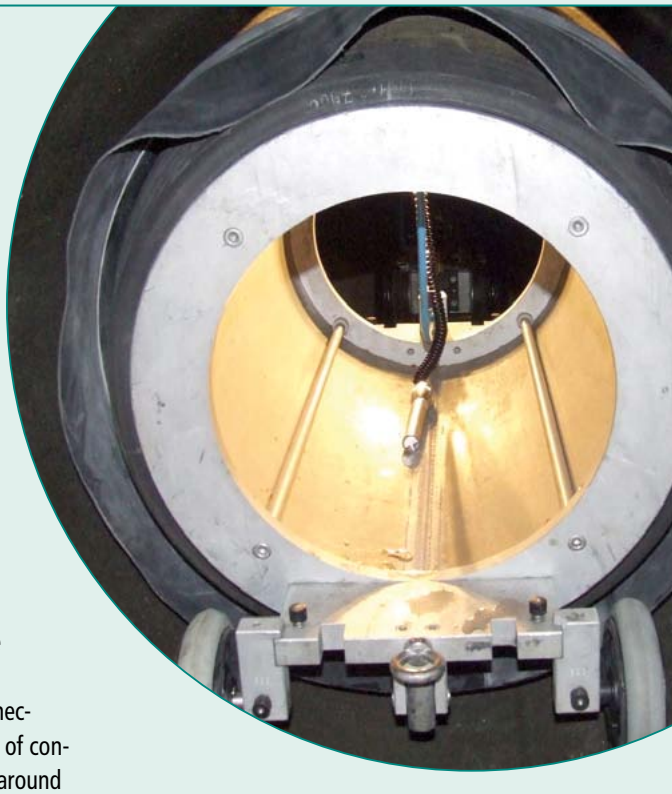
Roland W. Waniek

Managing Director
IKT - Institute for Underground Infrastructure

Content

Repair of main drains and sewers

Experience from research and testing



Operators of waste-water systems at all times aim to achieve their refurbishing targets effectively and at the lowest possible cost. The advantage is with those who judiciously combine the various renovation and repair methods. New measuring systems now permit „before/after" comparisons, allowing the rational selection and combination of such methods. The necessary preparatory work is frequently neglected during on-site implementation, however. Repair procedures tested by IKT proved to be differingly immune to such application errors.

Background

There has, in the past, been significant uncertainty on the part of system operators concerning what the various repair methods can actually achieve, what quality can be attained, and what criteria need to be taken into account in tendering procedures, award of contract and on-site supervision. These techniques are used for the rapid, flexible and rational-cost repair of distributed damage, using a large bandwidth of procedures. The same also applies when renovation methods are implemented, since repair procedures are routinely used here for pre-sealing, reprofiling, connection of manholes and the integration of connecting lines. Throughout Germany, around 25 percent of drain/sewer damage is eliminated using specifically „repair" methods [2].

Figure 1: Repair methods in IKT projects: short-liners

The independent and impartial IKT - Institute for Underground Infrastructure has already tested repair methods, with the following focuses, in a large range of projects:

- Drain/sewer pipes: „Repair methods for DN 200 - DN 600 main drains" [15], Investigations into the adhesion properties of short-liners [16], Stability analysis of large-calibre drain/sewer sections [13], Investigations of behaviour under exposure to external water pressure/"infiltration tightness" [16, 11] (Figure 1)
- Waste-water manholes: Investigations of the repair of manhole covers [8, 9, 10] and into the repair of manhole structures using injection methods [12] (Figure 2)
- Laterals: Comparative product assessments in the IKT „Repair methods for sewer laterals" product test [14] (Figure 3)

The project results are examined below in more detail, with the focus on the repair of drain/sewer pipes in main drains and sewers. Questions concerning both walk-in and non-walk-in cross-sections, and concerning flexibility and service-lives are also discussed.

Figure 2: Repair methods in IKT projects: manhole sealing – injected polyurethane on the manhole exterior

Figure 3: Repair methods in IKT projects: Injection/pressure refurbishing on sewer laterals

Repair methods for DN 200 - DN 600 main drains and sewers in the IKT product test

Aims and methods examined

The aim of every IKT product test is that of achieving a comparative assessment of the quality of products and methods available on the market, of outlining potentials for improvement, and of simultaneously exerting corresponding market pressure, in order that the suppliers will actually make use of these potentials. The drain/sewer system operator, as the customer, specifies the quality requirements made on the products. A total of twenty-four system operators participated in the IKT "Repair methods for DN 200 - DN 600 main drains and sewers" comparative product test and provided intensive support in terms of subject matter and expertise.

Twelve different methods from the three method groups of "Injection/grouting/pressure methods", "Short-liners" and "Internal sleeves" were used and comparatively tested in the test lengths under defined and repeatable boundary conditions (Figures 4 to 6). All the results were published in [15] and [16], and are available for free-of-charge download at www.ikt.de (German version only).

Test programme

The test programme had three central emphases: the method suppliers' Quality Assurance (QA) provisions, system testing of the methods in the test lengths, and on-site assessments.

The "Quality Assurance" item quantified the extent to which the particular supplier supported high-quality refurbishing in the use of his repair method by means of systematic QA provisions, such as a method manual, training provisions for users, potentials for outside supervision, and supplementary test certificates.

The system tests submitted the repair methods to a comprehensive programme of testing in the test lengths, the prime focus being on the tightness, correct functioning and operational safety and reliability of the drain/sewer lengths refurbished. Both clay and concrete test lengths were used, and load-exposure situations approximating closely to practical conditions simulated.

In the case of the tests on short-liners and internal sleeves, in which the soil does not play a part in the refurbishing result, the test lengths were supported on the floor of the IKT testing facility (Figure 7). A wrapping consisting of EPDM rubber mats and steel strapping, and calculated using FEM models, was applied here at and around the points of damage in the case of the "Intact pipe bedding" situation. The test lengths for the injection/grouting/pressure methods were installed in steel containers with sand overcover (Figure 8), since these procedures in some cases involve the systematic injection into the surrounding soil of resin, which then solidifies ("cures"), with the inclusion of portions of the soil.

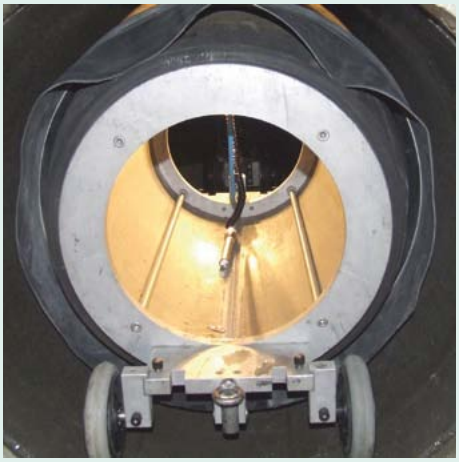


Figure 5: Internal sleeve under test: sleeve on the packer in the conduit

Figure 7: IKT Product Test „Repair methods for DN 200 - DN 600 main drains and sewers": Test apparatus for short-liners and internal sleeves

Figure 4: Pressure/grouting method under test: results of the grouting method

Figure 6: Pressure/grouting method under test: results of the grouting method

Figure 8: IKT Product Test „Repair methods for DN 200 - DN 600 main drains and sewers": Test apparatus for injection and grouting/pressure methods

High-pressure cleaning was selected as the critical operating load; all points of repair were exposed after completion to fifteen cleaning cycles.

The on-site tests served the purpose both of verifying the plausibility of the use of the repair methods in the test lengths and that of determining the practicability of these methods under on-site conditions (e.g. weather, time pressure).

Large spread of results

The overall picture of the repair results after completion of the refurbishing work was a positive one. Only very minor anomalies, which would have no significant influence on the correct functioning of the drain/sewer, were found. These included minimal losses of conduit cross-section resulting from the short-liner, sleeve and, in some cases, the injection processes themselves, and slight burring on the edges of the sleeves, with no flaring.

Traces of the cleaning action, ranging from only slight to significant, were apparent on many repaired points after high-pressure cleaning, however. In the case of the short-liners, the surface was generally slightly abraded (roughened), at least in the baseline area. In the case of individual short-liners, glass fibres were exposed on the surface, or spalling and/or cracking, primarily in the baseline area, had occurred. For the injection and grouting/pressure methods, spalling is generally of no consequence for the sealing action of the repair, but remnants of resin detached and/or projecting into the cross-section may also cause obstruction to fluid flow. The sleeves tested exhibited greatly differing results under exposure to HP flushing. In some cases, no deficiencies were observed, while in others the toothed racks of the locking wheels exhibited deficiencies with declining tensioning.

All the repaired points were tightness tested both immediately after completion and after simulation of operational loads with exposure to internal water pressure. The tightness tests relevant for the evaluation were conducted by means of visual inspection for the escape of water on the outer pipe side of the repaired point of damage after high-pressure flushing.

These methods manifested a large spread of results, depending on the product used. The effects of HP cleaning on the tightness of the repairs could, in all cases, be considered slight, however.

Suitability for practical use confirmed

The on-site tests in all cases confirmed the practicability of the methods tested. It was, however, also apparent that the work performed on site deviated in some cases from the method manuals. This can occur for time and cost reasons, due to differing quality standards set by the refurbishing contractors, or also as a result of work not specified - and therefore not paid for - by the client. This applies, in particular, to preparatory and support provisions, such as high-pressure flushing and mechanical deglazing, the non-performance of which is not immediately apparent when the result of repair is acceptance inspected.

Good standard of repair quality, depending on method

A high-quality repair result can, in principle, be achieved with either an injection or grouting/pressure method, or with a short-liner or an internal sleeve. The test also demonstrated that quality can fluctuate significantly between the individual methods of a particular group, however. Methods which were awarded the grades "Good" to "Sufficient" can be found in all the groups. The three methods which received only "Sufficient" were, however, also scarcely recommendable for practical use in the development status in which they were tested. The manufacturers in question themselves reacted immediately to the test results, with the consequence that these methods are no longer available in the form tested at IKT and/or that, according to information from the manufacturer, corresponding further development has been initiated.

Of particular technical informational value was the fact that refurbishing frequently generates extremely complex systems, consisting of the original pipe, the repair/refurbishing element, and the soil, with potential interactions between them. In addition, there is also a possibility of an alteration or even a spread of the damage under the influence of internal packer and/or sleeve pressures. Repairs must always be anchored in undamaged areas of the pipe. It appears recommendable to extend the repair beyond the adjoining bell sockets, particularly in the case of cracking in clay pipes and the danger of further crack propagation under exposure to internal pressure. The use of a short-liner of an appropriate length may therefore be a good option, particularly in the case of extensive ramified cracking. Where more extensive spalling has occurred, a sleeve or an injection/pressure method, or possibly also a combination of injection/pressure and short-liner, may be more suitable for the avoidance of bulging or leaks in the laminate as a result of inadequate counterpressure during curing.

Varying method robustness (surface preparation)

On-site implementation, and thus also relative immunity to execution errors, is the definitive factor in the quality of all these methods. There is in all repair methods the danger in principle that important operations may be shortened or even completely omitted on site, particularly preparatory and supporting work, such as HP flushing and mechanical deglazing, and allowance of the necessary, or maximum, curing times.

In all the methods based on repair resin products, the sealing function depends essentially on bonding between the resin and the pipe wall and its resistance to abrasion. The extent to which mechanical deglazing exerts a significant influence on the adhesion, tightness, operational reliability and durability of short-liners, and can thus be regarded as preparatory work necessary and therefore to be included in tendering documentation (see [5]) has been examined in detail in more extensive investigations [16], with the following conclusions being drawn:

- Removal of glaze from clay piping: The necessary tensile adhesions were generally not achieved on glazed clay surfaces, whereas extremely high adhesion data were attained on mechanically deglazed clay surfaces.
- Necessity of thorough cleaning and removal of corroded concrete: Residual grease has been proven to have a potentially significant influence on tensile adhesion in short-liner procedures, and must therefore be removed by means of thorough cleaning. Adequate tensile adhesion can be attained in corroded pipes only provided the defective concrete is removed until only undamaged concrete is left.
- Differences in the immunity ("robustness") of the methods/products: The tensile adhesion of the individual products, and their immunity to fluctuations in surface preparation, in particular, exhibited significant variations. Adequate tensile adhesions may be anticipated from all these products provided cleaning and surface preparation are sufficiently thorough, however.

These tests also confirmed the immunity of the methods to execution errors (in surface preparation, in this case) as a particular quality criterion. Similar circumstances are also known from manhole refurbishing, see [12].

Large-calibre conduits necessitate structure-analytical evaluation

Repair methods and structural analysis

Specific standardised calculation methods such as are known for renovation procedures, for example, are lacking in the case of repair methods (see [4]); deductions based on analogy, on the other hand, require special expertise (see [7]). As a consequence, a structure-analytical calculation is generally omitted in practice, or is not even expected (in the case of pipe joints, for example). Structure-analytical evaluation can, however, become a central concern and play a critical role in the refurbishing task and the selection of suitable methods, precisely in the case of large-diameter drains and sewers.

The situation becomes even more critical where the fact of "no proof" is interpreted as "no contribution" to stability at the competition stage: this fails to take account of the performance of injection methods, for example. In combination with renovation procedures, in particular, such repair methods can make a special contribution, since stability is determined not by the conduit alone, but instead, in every case, by the entire conduit/soil system. Typical interactions in the pipe trench, such as silo effects, vertical load division, support stresses and horizontal (bedding) reaction pressure, impressively reflect this.

The soil must then be regarded as part of the system fabric, and injection methods, in particular, can thus make a significant contribution to subsequent renovation work (such as sealing using a liner, for example), actually meeting the definition of "renovation" [6] – i.e., "Provisions for the improvement of the current functioning of waste-water conduits and drains involving the complete or partial inclusion of their original fabric".

Particular importance therefore attaches to the inclusion of the soil in overall planning and in any combination of repair and renovation methods. Both the original and the refurbished condition of the conduit/soil system should be recorded and evaluated, in order to permit a "before-and-after" assessment. New developments in structure-analytical evaluation are now available for this purpose.

New concepts for structure-analytical evaluation

Further development work is currently going on at IKT on a non-destructive test procedure, known as "MAC" and introduced by Eau de Paris, in order to close the gap in structure-analytical proofs prevailing up to now by means of systematic before-and-after tests. This procedure provides, by means of direct force/deformation measurements, substantiated information on the stiffness of the conduit/soil system, and thus the basis for a reliable assessment of stability and for checking of success, in the case, for example, of the use of injection methods (Figure 9). The technical concept and the applications for this procedure are described in detail in [1].

The main application for this procedure is for the identification of zones featuring defects or weakening of the supporting system consisting of the conduit and the surrounding soil. A special calculation algorithm, which has been tested on numerous practical examples, makes it possible to determine the extent to which the conduit, on the one hand, or the soil, on the other hand, contributes to overall stiffness or, conversely, exhibits weaknesses - thus a decisive contribution to the selection and combination of repair and renovation methods.

Figure 9: The MAC method: measurements of the system stiffness of the main drain/soil system

Flexibility vs. long-term solutions

The term "intergenerational equity" can, for our case, also be interpreted as: We should construct, operate and maintain our facilities and systems in such a way that the coming generation will have no problems with the consequences; our descendants should not find these consequences a burden, either in a technical or a financial sense. Repair methods can manifest special advantages in this context: clarity in the means used, systematic restorative action on the local damage scenario, and a residual flexibility to accommodate future developments. Judicious combination of renovation and repair methods then makes it possible to attain, cost-efficiently and with certainty, the technical targets, i.e., long-lasting stability, tightness and operational safety and reliability. In addition, repair methods, in particular, provide opportunities, even in case of the endangerment of these targets, to initiate appropriate immediate action during the planned period of service, while at the same time retaining the scheduled (re-)investment cycles at overall network and section level.

Conclusions

On an overall view, we are obviously confronted less with a problem of choosing between repair and renovation, or even with a contradiction between the two approaches, and more with the task of achieving the refurbishing aim effectively and at rational cost using a judicious combination of the various methods. Here, repair procedures make a decisive contribution, some with possible additional benefits for stability. In this context, we should note by way of summary:

Quality is decisive in practice: Installation necessitates high-quality preparatory work, such as mechanical deglazing and cleaning. In this respect, the methods and materials exhibit significant differences in their immunity to execution errors, with respect, for example, to the tensile adhesions achieved.

Recognition and registration of the structure-analytical contribution: Stability is a function of the behaviour of the entire conduit/soil system. Injection methods are capable of making a significant contribution to the structure-analytical improvement of this overall system. New measuring systems, such as "MAC", offer perspectives for before-and-after comparative assessments, and therefore for the economically rational selection and combination of refurbishing methods, particularly in the case of large-diameter conduits.

The criterion of flexibility: Cost appraisals have up to now generally only taken account of cash flows. The value of flexible selection of the time and place of refurbishing is generally not formally considered. This is where strategic planning for future generations is needed, and repair procedures are capable of making an interesting contribution.

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Ten years of the IKT LinerReport

Quality and transparency oblige

Three-point bending test on a tube liner

The IKT test centre has been publishing annual reports on the results of its tube liner tests since 2004. Are tube liners better today? What trends are apparent? And what is the current picture?

There is cause for a small celebration: the IKT now presents its LinerReport, an annual overview of tube liner quality, for the tenth time in succession. An excellent occasion, therefore, to chance a look back at the statistics, and assess the developments in the quality of the most important refurbishing method.

The aim: market transparency via publicity

Not everyone will be reaching straight for the champagne, however - this year's IKT LinerReport, as always, touches on one or two sore points, setting off agitated discussions among the expert public that has not always remained unclouded by emotion. The focus, from the very start, was the extent to which a number of pivotal quality criteria promised by tube liner suppliers to customers, and specified for their products in the DIBt (German Institute for Building Technology) approvals, are actually met in on-site practice. The IKT's aim with its LinerReport has always been, and remains, to achieve transparency and publicity, in order thus to prompt tube-liner quality improvements.

The tightness debate

Even after the very first IKT LinerReport in 2004, a heated debate flared up concerning whether tube liners really need to be 100 percent tight. A number of liner producers and users pointed out that the test standards permitted water losses during tightness testing, even in the case of new pipes, drawing from this the conclusion that a tube liner should not be assessed more strictly than a newly installed concrete pipe.

Municipal system operators, above all, drew attention, conversely, to the legal requirement that waste-water conduits must be tight, in order to protect the environment, arguing that the test specifications for concrete pipes could not automatically be applied to tube liners produced from ultra-modern plastics, due to the totally different material properties, and that only additions of water, and under no circumstances water losses, are actually tolerated. The debate ended with a victory for the clients' view that tube liners must be tight.

One particular marginal note was the controversy concerning cutting of the inner film prior to the water-tightness test (see „Overview of test and inspection criteria"). Some producers argued in their own defence that such cutting would damage the liner laminate and thus actually be the cause of leakage. They were unable to produce any evidence for this, however.

Diagram 1: Number of liner samples
IKT-LinerReport 2003 - 2013

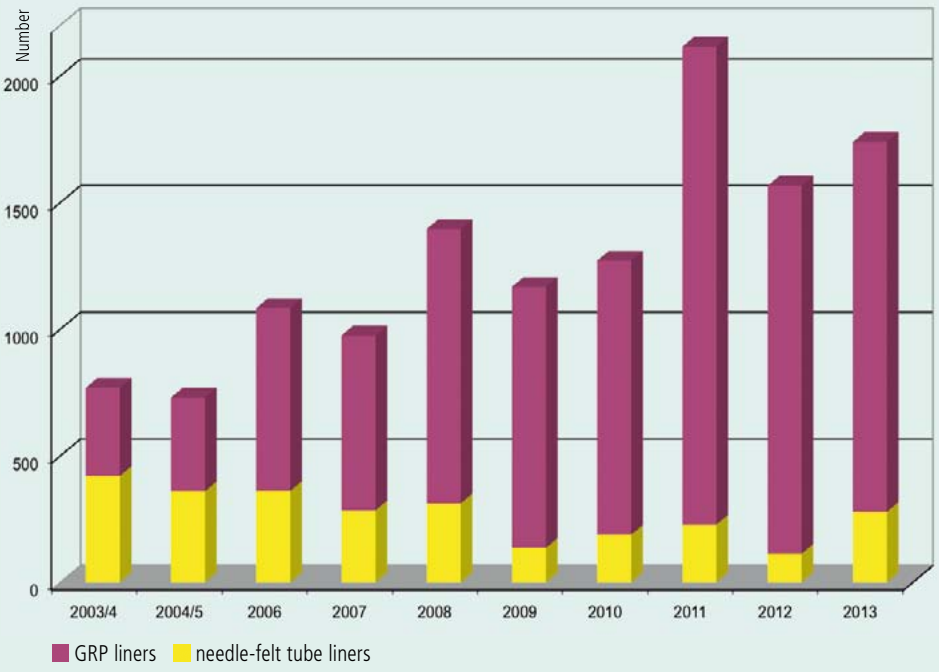


Diagram 2: Test results of all samples
Average „Target value achieved"

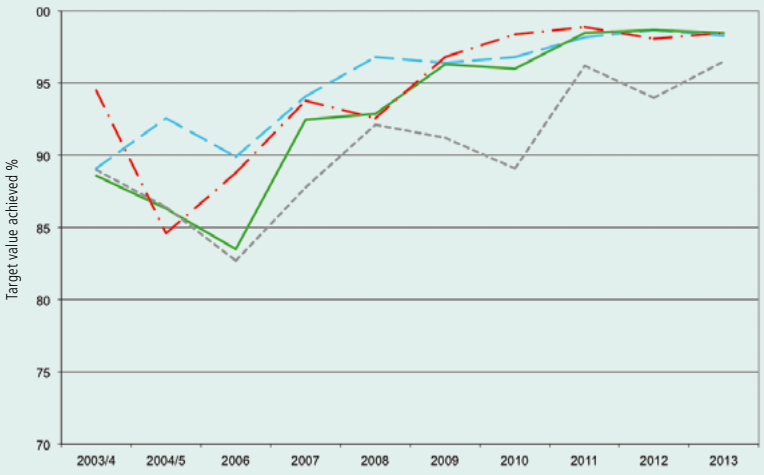


Diagram 3: Test results GRP liners
Average „Target value achieved"

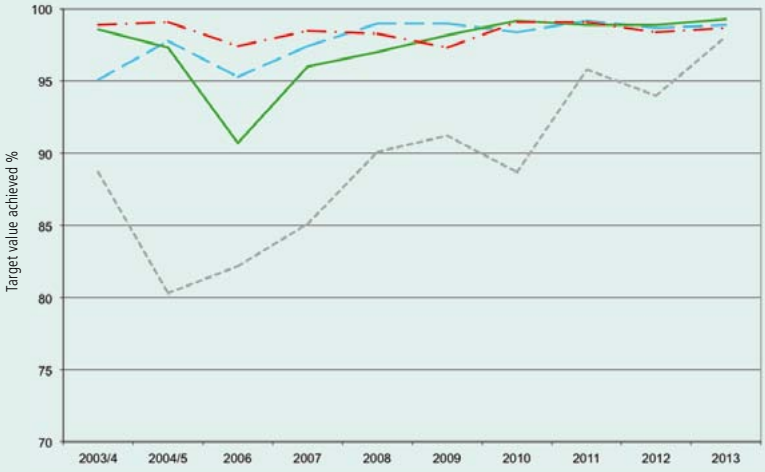


Diagram 4: Test results needle-felt tube liners
Average „Target value achieved"

- Modulus of elasticity
- Flexural strength
- Wall thickness
- Water-tightness

This controversy, which was scarcely comprehensible even for expert insiders, ultimately concluded with a number of producers of needle-felt tube liners applying for amendment of their DIBt approvals. The inner film has since this time been defined as an integral part of the liner and is no longer cut prior to the test. It was, however, necessary to demonstrate in advance the suitability of these films by means of a DIBt test programme. The results of the water-tightness test then improved significantly (from 2009 onward, see Diagram 4).

Wall thickness a weak point

The IKT LinerReport also disclosed a number of weak points in the mechanical properties of the tube liners. It became apparent, for example, that the specified load-bearing capacities and the wall thicknesses necessary on a structural-analysis basis were not achieved on every site. This, again, set off a heated debate on test and measuring procedures, with confrontation between those advocating a less stringent interpretation of clients' specifications and those in favour of higher quality standards. The latter pointed out that a minimum service-life of fifty years is promised to them, as customers, for their tube liners. The specified materials characteristics data, they asserted, must therefore be assured at least at the time of installation.

Binding quality criteria for all

As objections from the ranks of the municipalities became ever more vociferous, and a number of them actually discontinued the use of tube liners, the tube-liner manufacturers and municipal representatives ultimately formed a workgroup which defined binding quality criteria for tube liners, up to and including sanction mechanisms to be applied in case of non-compliance. This workgroup was assisted by engineering consultancies and test institutions.

The test procedures for tube liners were also defined by mutual agreement within a similar framework. The original dispute concerning liner tightness was decided unequivocally in favour of the tight liner. In a final step, these papers were incorporated into DWA (German Association for Water, Wastewater and Waste) codes A 143, Part 3 and M 144, Part 3 in 2012.

Retrospective 2003 – 2013

The ten previous IKT LinerReports incorporated the test results of a total of just on 13,000 site samples. Of these, 10,000 were taken from GRP liners, and slightly less than 3,000 from needle-felt (NF) liners. The numerical balance between GRP and NF liners had been virtually equal in the first two LinerReports, but the picture changed clearly, in favour of GRP liners, from 2006 onward at the latest (see Diagram 1), reflecting the now greater market importance of this composite material. New suppliers have entered the market in recent years, NF suppliers have added GRP to their ranges, and traditional GRP suppliers have improved their products and launched new versions.

10 percent plus in 10 years

The overall picture for the past ten years shows a significant improvement in the test results for modulus of elasticity, flexural tensile strength, wall thickness and water tightness. As late as 2008, the data still fluctuated between an average of 85 percent and 95 percent of tests passed which, conversely, means that there were, on average, problems with tube liners immediately after installation in an average of 15 percent of all cases. The results consistently exceeded the 95 percent boundary on average only from 2009 onward, and are currently tending toward the 98 percent mark. Only in the case of the „wall thickness" criterion are the targets achieved less frequently.

All in all, tube-liner quality manifests a clear upward trend. The results for all four criteria have improved by an average of 10 percentage points in the last ten years.

Assessment of GRP vs. needle-felt liners

It is readily apparent, when one examines the test results for GRP and NF liners (see Diagrams 3 and 4) that GRP liners achieve scores of above 95 percent on average almost continuously for the criteria of modulus of elasticity, flexural tensile strength and water tightness (exception: 2006). The results for wall thickness lag significantly behind, however, catching up with the good results for the other three criteria only in 2013. Whether this will be a permanent improvement remains to be seen.

Except in the case of wall thickness, the average test results for the NF liners are generally significantly below those for the GRP liners, on the other hand (see Diagram 4). They also fluctuate significantly from year to year. They consistently cross the 95 percent mark only from 2011 on, catching up with the GRP liners although, with the exception of water tightness, they drop back again slightly in 2013.

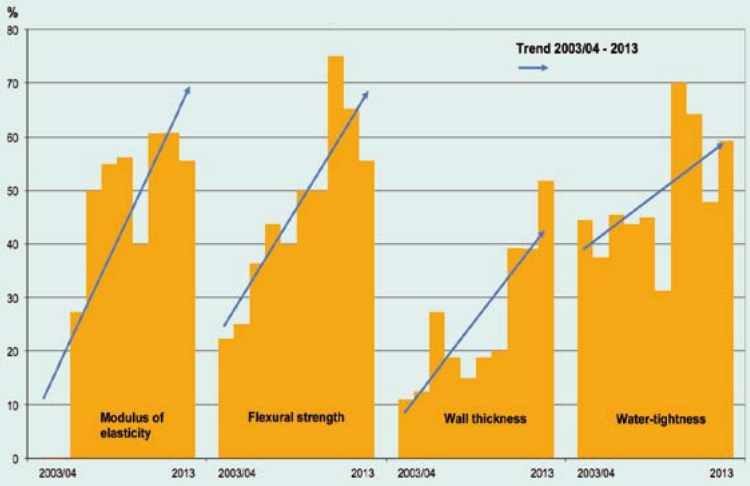
The data-base for 2013

The IKT LinerReport 2013 includes the results for those refurbishing contractors for whom the IKT tested not less than twenty-five liner samples of one liner type from five different sites. This condition is fulfilled by twenty contractors. Of these, five are represented by more than one liner type. Three contractors worked only in the Netherlands, while two worked in Switzerland. For the first time, the list also includes a company from Austria. These companies are indicated by (NL), (CH) and (A) in the tables.

In 73 percent of cases, the project clients (or their engineering consultancies) commissioned the IKT directly for laboratory testing of liner samples. 27 percent of orders originated from the refurbishing contractors themselves (see Table 1).

Diagram 5: Refurbishing contractors with 100% success rates

Number of contractors in percent per test criterion



Overview of test and inspection criteria

Modulus of elasticity (short-term flexural modulus)

- Tube liners must be capable of withstanding loads such as those arising from groundwater, road traffic and soil pressure
- The modulus of elasticity is an indicator of load-bearing capability
- Stability may be endangered if modulus of elasticity is too low
- Test method: Three-point bending test as per DIN EN ISO 178 and DIN EN ISO 11296, Part 4/DIN EN 13 566, Part 4*

Results: see Table 2

Wall thickness (mean combined thickness)

- Minimum value is specified in the stress-analysis calculation
- Wall thickness and modulus of elasticity jointly determine the stiffness of the liners
- Excessively low wall thickness can endanger stability
- Test method: Mean combined thickness is measured in accordance with DIN EN ISO 11296, Part 4**, using a precision slide gauge

Results: see Table 4

Flexural strength (bending stress at rupture = short term-σ_{fb})

- This indicates the point at which the liner fails due to excessively high stress
- If flexural strength is too low, the liner may rupture before the permissible deformation is reached
- Test method: Increase of load up to failure in the three-point bending test; in accordance with DIN EN ISO 178 and DIN EN ISO 11296, Part 4/DIN EN 13 566, Part 4* (short-term flexural strength)

Results: see Table 3

Water tightness

- A cut is made into the inner film if the latter is not an integral component of the liners; the outer film (if any) is removed
- Water containing a red dye is applied internally
- A 0.5 bar partial vacuum is applied externally
- The liner is „Not tight" if water penetrates through
- Test period: 30 min.

Results: see Table 5

* DIN EN ISO 11296, Part 4 superseded DIN EN 13566, Part 4 with effect from July 2011. The test results are nonetheless evaluated on the basis of DIN EN 13566, Part 4 for a number of liner systems, since the Target data for the mechanical properties (national technical approvals) were determined in accordance with this standard.

** Determination of combined thickness remains unchanged in DIN EN ISO 11296, Part 4 vis-à-vis DIN EN 13566, Part 4.

Table 1: Refurbishing contractors and liner systems 2013

Refurbishing contractors	Liner systems	Liner type	Number of samples	IKT test commissioned by	
				Refurbishing contractor %	Project client %
Aarsleff Rohrsanierung GmbH	Impreg liner	GRP	60	12	88
Aarsleff Rohrsanierung GmbH	PAA GF liner**	GRP	66	3	97
Aarsleff Rohrsanierung GmbH	PAA SF liner**	NF	158	2	98
Arkil Inpipe GmbH	Berolina liner	GRP	82	28	72
Arpe AG (CH)	Alphaliner	GRP	31	45	55
Diringer & Scheidel Rohrsanierung GmbH & Co. KG	Alphaliner	GRP	29	0	100
Diringer & Scheidel Rohrsanierung GmbH & Co. KG	RS CityLiner	NF	39	0	100
Diringer & Scheidel Rohrsanierung GmbH & Co. KG	Saertex liner	GRP	34	53	47
Erles Umweltservice GmbH	Impreg liner	GRP	140	74	26
Geiger Kanaltechnik GmbH & Co. KG	Alphaliner	GRP	47	43	57
Geiger Kanaltechnik GmbH & Co. KG	Berolina liner	GRP	70	3	97
Hamers Leidingtechniek B.V. (NL)	Alphaliner	GRP	59	70	30
Huneke Kanalsanierung GmbH	Saertex liner	GRP	78	0	100
Insituform Rioolrenovatietechnieken bv (NL)	Insituform tube liner (NL)*** Netherlands	NF	82	0	100
ISS Kanal Services AG (CH)	Alphaliner	GRP	27	56	44
Jeschke Umwelttechnik GmbH	Alphaliner	GRP	66	46	54
Jeschke Umwelttechnik GmbH	Brandenburg liner BB+75/120	GRP	37	0	100
Kanaltechnik Agricola GmbH	Impreg liner	GRP	26	42	58
KATEC Kanaltechnik Müller & Wahl GmbH	Alphaliner	GRP	42*	0	100
Max Bögl Bauunternehmung GmbH & Co. KG	Brandenburg liner BB 2.0/2.5	GRP	47*	43	57
Rainer Kiel Kanalsanierung GmbH	Saertex liner	GRP	38	37	63
Strabag AG (A)	Brandenburg liner BB 2.0/2.5	GRP	27	93	7
Swietelsky-Faber GmbH Kanalsanierung	Alphaliner	GRP	49	2	98
Swietelsky-Faber GmbH Kanalsanierung	Berolina liner	GRP	29*	0	100
TKT Jens und Lutz Meißner GbR	Alphaliner	GRP	140	21	79
Umwelttechnik und Wasserbau GmbH	Alphaliner	GRP	195	37	63
Van der Velden Rioleringsbeheer B.V. (NL)	Impreg liner	GRP	42	38	62
Total			**1.740**	**27**	**73**

GRP: Glass-fibre backing material | NF: Needle-felt backing material

* from four sites

** The Danish building contractor Per Aarsleff A/S increased its shareholding in Insituform Rohrsanierungstechniken GmbH to 100 percent in mid-2013 and renamed the company Aarsleff Rohrsanierung GmbH. The products previously known under the Insituform GF-Liner and Insituform tube liner designations were renamed PAA GF liner and PAA SF liner. Test results prior to 8 August 2013 were obtained on site samples for Insituform Rohrsanierungstechnik GmbH, but are listed here under the new Aarsleff Rohrsanierung GmbH designation.

*** no DIBt approval

Target/Actual analysis

The properties of modulus of elasticity, flexural strength, wall thickness and water tightness of the tube-liner samples from the sites were tested. The Actual values are compared against the Target values from the DIBt approvals and/or with any divergent Target specifications by the client. Tube liners with no DIBt approval are indicated in Table 1. The Target values for wall thickness are specified on the basis of structural-analysis calculations, or are specified by the client.

There are two procedures for testing of the water tightness of needle-felt liners: with and without cutting of the inner film. The latter procedure is selected where the DIBt approval for the particular liner confirms that the inner film is an integral element and plays a role in tightness. The inner film is cut on all other needle-felt liners.

GRP liners are tested without cutting unless they have an inner film which remains in the conduit.

Table 2: Test results 2013 for modulus of elasticity (short-term flexural modulus)

Refurbishing contractors	2013		2012	Trend
	Number of samples	Target value* achieved in % of tests	Target value* achieved in % of tests	
Aarsleff Rohrsanierung GmbH with Impreg liner	60	100.0	100.0**	◂▸
Arkil Inpipe GmbH with Berolina liner	82		97.4	▲
Diringer & Scheidel Rohrsanierung GmbH with Alphaliner	29		97.1	▲
Diringer & Scheidel Rohrsanierung GmbH with Saertex liner	34		100.0	◂▸
Erles Umweltservice GmbH	140		100.0	◂▸
Geiger Kanaltechnik GmbH & Co. KG with Berolina liner	70		100.0	◂▸
Hamers Leidingtechniek B.V. (NL)	59		98.1	▲
ISS Kanal Services AG (CH)	27		100.0	◂▸
Jeschke Umwelttechnik GmbH with Alphaliner	66		100.0	◂▸
Jeschke Umwelttechnik GmbH with Brandenburg liner BB+75/120	37		–	–
Kanaltechnik Agricola GmbH	26		100.0	◂▸
Max Bögl Bauunternehmung GmbH & Co. KG	47		–	–
Strabag AG (A)	27		–	–
Swietelsky-Faber GmbH Kanalsanierung with Berolina liner	29		100.0	◂▸
Van der Velden Rioleringsbeheer B.V. (NL)	42		98.4	▲
Umwelttechnik und Wasserbau GmbH	195	99.5	98.4	▲
TKT Jens und Lutz Meißner GbR	140	98.6	100.0	▼
Aarsleff Rohrsanierung GmbH with PAA GF liner	66	98.5	100.0**	▼
Average		**98.3**	**98.7**	▼
Swietelsky-Faber GmbH Kanalsanierung with Alphaliner	49	98.0	–	–
Aarsleff Rohrsanierung GmbH with PAA SF liner	158	97.5	100.0**	▼
Huneke Kanalsanierung GmbH	77	97.4	–	–
Rainer Kiel Kanalsanierung GmbH	38	97.4	98.3	▼
Arpe AG (CH)	31	96.8	–	–
KATEC Kanaltechnik Müller & Wahl GmbH	42	95.2	90.1	▲
Diringer & Scheidel Rohrsanierung GmbH with RS CityLiner	39	94.9	–	–
Insituform Rioolrenovatietechnieken bv (NL)	82	91.5	96.9	▼
Geiger Kanaltechnik GmbH & Co. KG with Alphaliner	45	88.9	–	–

* Target values as per client's data (structural analysis/traveller card) | ** Insituform Rohrsanierungstechniken GmbH in 2012 | – not evaluated, too few liner samples

Table 3: Test results for flexural strength (Short-term-σ_{fb})

Refurbishing contractors	2013		2012	Trend
	Number of samples	Target value* achieved in % of tests	Target value* achieved in % of tests	
Arkil Inpipe GmbH with Berolina liner	82	100.0	100.0	◂▸
Arpe AG (CH)	31		–	–
Diringer & Scheidel Rohrsanierung GmbH with Alphaliner	29		100.0	◂▸
Diringer & Scheidel Rohrsanierung GmbH with RS CityLiner	39		–	–
Diringer & Scheidel Rohrsanierung GmbH with Saertex Liner	34		100.0	◂▸
Geiger Kanaltechnik GmbH & Co. KG with Berolina liner	70		100.0	◂▸
Hamers Leidingtechniek B.V. (NL)	59		100.0	◂▸
ISS Kanal Services AG (CH)	27		100.0	◂▸
Jeschke Umwelttechnik GmbH with Alphaliner	66		100.0	◂▸
Jeschke Umwelttechnik GmbH with Brandenburg liner BB+75/120	37		–	–
Kanaltechnik Agricola GmbH	26		100.0	◂▸
Rainer Kiel Kanalsanierung GmbH	38		100.0	◂▸
Swietelsky-Faber GmbH Kanalsanierung with Alphaliner	49		–	–
TKT Jens und Lutz Meißner GbR	140		99.4	▲
Van der Velden Rioleringsbeheer B.V. (NL)	42		98.4	▲
Umwelttechnik und Wasserbau GmbH	195	99.5	98.4	▲
Erles Umweltservice GmbH	140	99.3	100.0	▼
Huneke Kanalsanierung GmbH	77	98.7	–	–
Aarsleff Rohrsanierung GmbH with PAA GF liner	66	98.5	100.0**	▼
Average		**98.5**	**98.7**	▼
Aarsleff Rohrsanierung GmbH with Impreg liner	60	98.3	100.0**	▼
Max Bögl Bauunternehmung GmbH & Co. KG	47	97.9	–	–
Geiger Kanaltechnik GmbH & Co. KG with Alphaliner	45	97.8	–	–
KATEC Kanaltechnik Müller & Wahl GmbH	42	97.6	96.4	▲
Aarsleff Rohrsanierung GmbH with PAA SF liner	158	97.5	98.8**	▼
Swietelsky-Faber GmbH Kanalsanierung with Berolina liner	29	96.6	100.0	▼
Strabag AG (A)	27	96.3	–	–
Insituform Rioolrenovatietechnieken bv (NL)	82	85.4	87.5	▼

* Target values as per client's data (structural analysis/traveller card) | ** Insituform Rohrsanierungstechniken GmbH in 2012 | – not evaluated, too few liner samples

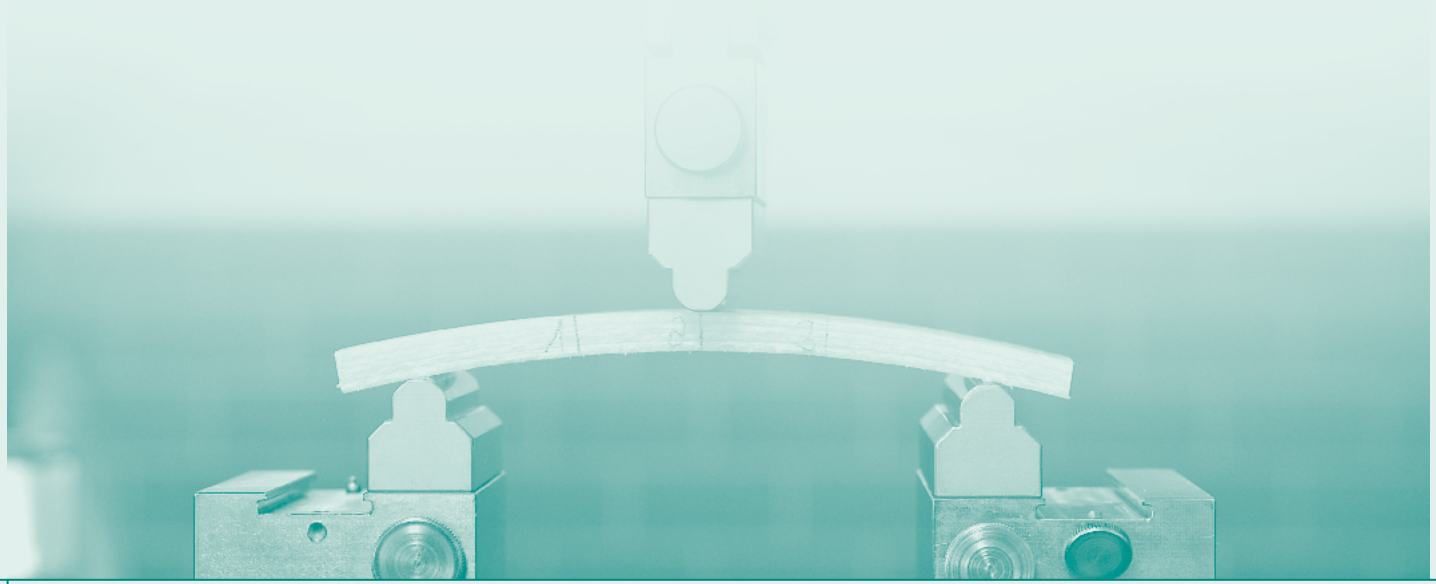
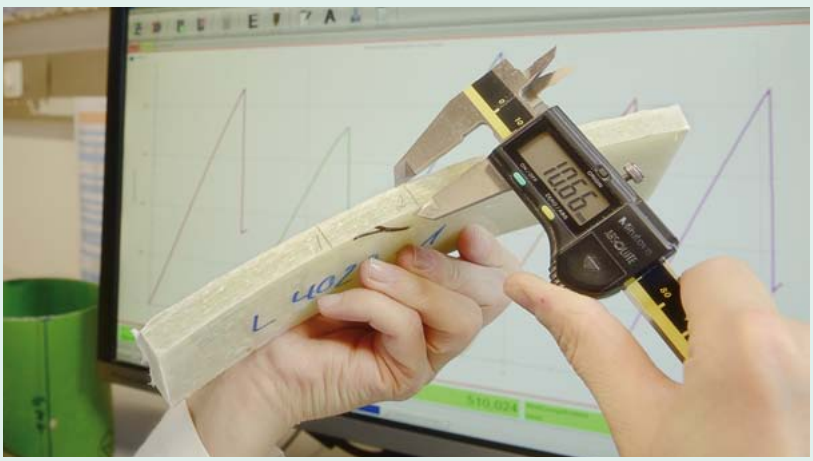


Table 4: Test results for wall thickness (average combined thickness in accordance with DIN EN ISO 11296, Part 4)

Refurbishing contractors	2013		2012	Trend
	Number of samples	Target value* achieved in % of tests	Target value* achieved in % of tests	
Aarsleff Rohrsanierung GmbH with PAA GF liner	45	100.0	88.7**	↑
Arpe AG (CH)	11		–	–
Diringer & Scheidel Rohrsanierung GmbH with RS CityLiner	25		–	–
Geiger Kanaltechnik GmbH & Co. KG with Alphaliner	35		–	–
Hamers Leidingtechniek B.V. (NL)	59		100.0	↔
ISS Kanal Services AG (CH)	26		95.2	↑
Jeschke Umwelttechnik GmbH with Alphaliner	57		100.0	↔
Jeschke Umwelttechnik GmbH with Brandenburg liner BB+75/120	37		–	–
Kanaltechnik Agricola GmbH	26		100.0	↔
Max Bögl Bauunternehmung GmbH & Co. KG	47		–	–
Rainer Kiel Kanalsanierung GmbH	14		100.0	↔
Strabag AG (A)	22		–	–
Swietelsky-Faber GmbH Kanalsanierung with Alphaliner	25		–	–
Umwelttechnik und Wasserbau GmbH	144		95.0	↑
Huneke Kanalsanierung GmbH	66	98.5	–	–
KATEC Kanaltechnik Müller & Wahl GmbH	37	97.3	88.2	↑
Van der Velden Rioleringsbeheer B.V. (NL)	34	97.1	80.7	↑
Erles Umweltservice GmbH	132	97.0	97.5	↓
Average		**96.5**	**94.0**	↑
Aarsleff Rohrsanierung GmbH with Impreg liner	25	96.0	100.0**	↓
TKT Jens und Lutz Meißner GbR	73	95.9	100.0	↓
Aarsleff Rohrsanierung GmbH with PAA SF liner	95	95.8	100.0**	↓
Diringer & Scheidel Rohrsanierung GmbH with Saertex Liner	22	95.5	100.0	↓
Geiger Kanaltechnik GmbH & Co. KG with Berolina liner	21	95.2	85.7	↑
Arkil Inpipe GmbH with Berolina Liner	58	91.4	***	–
Diringer & Scheidel Rohrsanierung GmbH with Alphaliner	22	90.9	95.7	↓
Insituform Rioolrenovatietechnieken bv (NL)	82	76.8	87.5	↓
Swietelsky-Faber GmbH Kanalsanierung with Berolina liner	2	***	96.0	–

* Target values as per client's data (structural analysis/traveller card) | ** Insituform Rohrsanierungstechniken GmbH in 2012 | – not evaluated, too few liner samples
*** too few samples with details of Target value for combined thickness



Combined thickness and pure-resin layer are measured using precision slide gauges

Tightness testing of tube liners

Table 5: Test results 2013 for water tightness

Refurbishing contractors	2013		2012	Trend
	Number of samples	Watertight in % of tests	Watertight in % of tests	
Aarsleff Rohrsanierung GmbH mit PAA SF-Liner*	158	100.0	100.0**	◂▸
Arkil Inpipe GmbH mit Berolina Liner	82		92.3	▲
Arpe AG (CH)	29		–	–
Diringer & Scheidel Rohrsanierung GmbH mit Alphaliner	29		97.1	▲
Diringer & Scheidel Rohrsanierung GmbH mit Saertex Liner	34		100	◂▸
Geiger Kanaltechnik GmbH & Co. KG mit Alphaliner	47		–	–
Hamers Leidingtechniek B.V. (NL)	59		100.0	◂▸
Huneke Kanalsanierung GmbH	78		–	–
ISS Kanal Services AG (CH)	27		100.0	◂▸
Jeschke Umwelttechnik GmbH mit Alphaliner	66		100.0	◂▸
Jeschke Umwelttechnik GmbH mit Brandenburger Liner BB+75/120	37		–	–
Kanaltechnik Agricola GmbH	26		100.0	◂▸
Max Bögl Bauunternehmung GmbH & Co. KG	47		–	–
Rainer Kiel Kanalsanierung GmbH	38		90.0	▲
Strabag AG (A)	27		–	–
Swietelsky-Faber GmbH Kanalsanierung mit Berolina Liner	9		96.5	▲
Umwelttechnik und Wasserbau GmbH	195	99.0	98.4	▲
Erles Umweltservice GmbH	139	98.6	99.1	▼
Geiger Kanaltechnik GmbH & Co. KG mit Berolina Liner	70	98.6	98.7	▼
Aarsleff Rohrsanierung GmbH mit PAA GF-Liner	66	98.5	96.2**	▲
Average		**98.5**	**98.1**	▲
Aarsleff Rohrsanierung GmbH mit Impreg Liner	54	98.1	96.8**	▲
Swietelsky-Faber GmbH Kanalsanierung mit Alphaliner	49	98.0	–	–
Diringer & Scheidel Rohrsanierung GmbH mit RS CityLiner	37	97.3	–	–
TKT Jens und Lutz Meißner GbR	140	97.1	100.0	▼
KATEC Kanaltechnik Müller & Wahl GmbH	42	92.9	97.1	▼
Van der Velden Rioleringsbeheer B.V. (NL)	42	92.9	98.4	▼
Insituform Rioolrenovatietechnieken bv (NL)	82	91.5	81.3	▲

* without cutting of the integrated inner film | ** Insituform Rohrsanierungstechniken GmbH in 2012 | – not evaluated, too few liner samples

Table 6: Test results by liner type

Liner system	Water-tightness		Modulus of elasticity		Flexural strength		Wall thickness	
	Number of samples	Watertight in % of tests	Number of samples	Target value* achieved in % of tests	Number of samples	Target value* achieved in % of tests	Number of samples	Target value* achieved in % of tests
Brandenburg liner BB+75/120	37	100.0	37	100.0	37	100.0	37	100.0
PAA GF liner	66	98.5	66	98.5	66	98.5	45	100.0
Alphaliner	683	98.5	683	98.2	683	99.6	489	98.8
Berolina liner	161	99.4	181	100.0	181	99.4	79	92.4
Brandenburg liner BB 2.0/2.5	74	100.0	74	100.0	74	97.3	69	100.0
Impreg liner	261	97.7	268	100.0	268	99.3	217	97.2
Saertex liner	150	100.0	149	98.0	149	99.3	102	98.0
PAA SF liner	158	100.0	158	97.5	158	97.5	95	95.8
RS CityLiner	37	97.3	39	94.9	39	100.0	25	100.0
Insituform tube liner Netherlands	82	91.5	82	91.5	82	85.4	82	76.8
Average		**98.5**		**98.3**		**98.5**		**96.5**

above or equal to average
below average

* Target values as per client's data (structural analysis/traveller card)

Table 7: Test results compared to previous year

Liner type	Watertight in % of tests			Modulus of elasticity Target* achieved in % of tests			Flexural strength Target* achieved in % of tests			Wall thickness Target* achieved in % of tests		
	2013	2012	+/–	2013	2012	+/–	2013	2012	+/–	2013	2012	+/–
Average												
of all samples	98.5	98.1	+0.4 ▲	98.3	98.7	-0.4 ▼	98.5	98.7	-0.2 ▼	96.5	94.0	+2.5 ▲
GRP	98.7	98.4	+0.3 ▲	98.9	98.7	+0.2 ▲	99.3	98.9	+0.4 ▲	98.1	94.0	+4.1 ▲
NF	97.1	94.3	+2.8 ▲	95.3	99.1	-3.8 ▼	94.3	95.6	-1.3 ▼	88.6	93.9	-5.3 ▼

GRP: Glass-fibre backing material
NF: Needle-felt backing material
* Target values as per client's data (structural analysis/traveller card)

Test results 2013

The overall average of the test results is, for the third time in succession, at an extremely high level. The mean non-pass rate for modulus of elasticity, flexural strength and water tightness is below 2 percent, that for wall thickness below 4 percent. All in all, the test results for 2013 are predominantly „Good" to „Very good". The poorer NF test results compared to the previous year can be attributed primarily to a supplier from the Netherlands.

Four 100 percent top groups

A top group of refurbishing contractors has now formed for each of the four test criteria. The liner samples from these contractors achieve the Target values for at least one test criterion in 100 percent of cases (see Tables 2 to 5). Assessment of performance across time discloses a clear trend: the four 100 percent top groups have become significantly larger since the publication of the first IKT Liner-Report ten years ago. The number of refurbishing contractors included in the four 100 percent top groups was between 0 percent and 22 percent (mechanical criteria) and 44 percent (water tightness) in 2003/2004, whereas more than half of the contractors were included in these groups in 2013 (see Diagram 5). 70 percent of all contractors were already in the top groups for the criteria of flexural tensile strength and water tightness in 2010 and 2011, however.

The 100 percent top groups include not only German, but also a number of foreign contractors, from the Netherlands, Austria and Switzerland, all of whom use German liner systems, however. German liner manufacturers are therefore gradually succeeding not only in exporting liners „Made in Germany", but also in training the foreign installation crews to a high level.

Conclusion

The annual IKT LinerReport published since 2003/2004 can claim to have tripped off an important debate concerning tube-liner qualities on the German refurbishing market. It continues to be a reliable mirror of current tube-liner quality. The in some cases extremely good success rates in the IKT LinerReport demonstrate independently and impartially that tube-liner technology is rightly the most frequently used refurbishing method.

A look back over the past ten years shows that the installation quality of the tube liners available on the market has improved measurably. Transparency now prevails where clients were previously obliged to rely solely on suppliers' promises. This has driven both product and procedure improvements, and also technical innovations which would not otherwise have occurred. There is now not only price, but also unequivocal quality competition on this market.

The beneficiaries are primarily the clients. They, however, will be well advised to continue consistently requiring quality tests on tube liners for every installation site - there would otherwise be a danger of a creeping retreat from the peak success of 2013.

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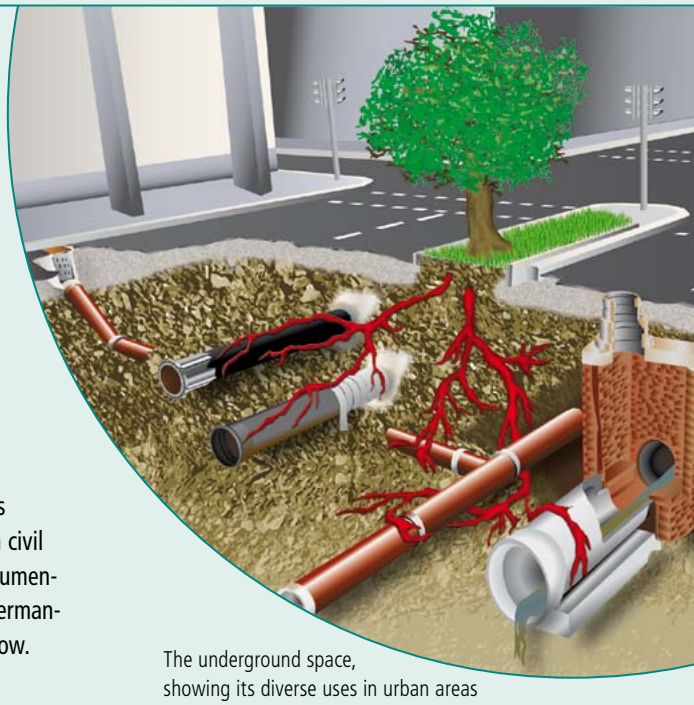
Crowded Ungerground

Soil and in-fill material requirements



The underground space, showing its diverse uses in urban areas
Source: Tracto Technik, moderated

Things are getting tight under our towns and cities! Germany has more than 2.7 million kilometres [1] of supply and disposal cables and conduits installed underground. There are drains, sewers, gas, water and district-heating pipes, plus electricity and telecommunications cables under our streets and pavements (see [2] and [3]). All users make many diverse demands on soils and in-filling materials.

The use of underground space

We must also add higher requirements for seepage drainage of rainwater (see [4]), while street-side trees and other vegetation also demand space underground for healthy root and plant growth (see [5], [6], [7] and [8]).

Every utilisation requires corresponding ambient conditions. This is true both of the civil-engineering and horticultural properties of the soils and in-fill materials used, and of the natural functions of the soil. In practice, this can result in overtaxing of the underground, with significant conflicts and development bottlenecks as the consequence. Appropriate solutions are needed both in planning and in civil engineering. Important lines of argumentation and developments for the German-speaking regions are examined below.

Uses and codes of practice

The soil, with its natural functions, is a finite asset. This fact is reflected in current legislation and in the codes of practice for the protection of the soil. A harmonised European provision has not yet been enacted, but already exists in draft form [9]. Until its enactment and ratification, protection of the soil will continue to be governed at national level. In Germany, soil protection was given a uniform basis in 1998, in the form of the German Federal Soil Protection Act and the Federal Soil Protection and Contamination Ordinance. This foundation has subsequently been expanded by means of higher-level legislation, such as the German Closed Substance Cycle and Waste Management Act, the Water Management Act and the Federal Nature Conservation Act. In Switzerland, protection of the soil is governed, for example, by the Environmental Protection Act, augmented by the Soil Pollution Ordinance. Under the German Federal Soil Protection Act [10], the natural functions which make the soil a finite asset include the following properties:

- Natural functions as
  - The foundation and space for the life of humans, animals, plants and soil organisms
  - Status as a constituent of the natural environment, including its water and nutrient cycles, in particular and
  - Degradation, balancing and strengthening medium for physical effects, due to its filter, buffer and metabolic properties, also including the protection of the groundwater, in particular
- Functions as an archive of natural and cultural history
- Utility functions as
  - A source of mineral resources
  - Space for living and recreation
  - The location for agricultural and forestry-management utilisation and
  - The location for other economic and public utilisations, transport, supply and disposal.

Agglomeration pipe trench: gas, drinking water, telecommunications and roots
Source: Dr. Markus Streckenbach
www.streckenbach.org

Function: agricultural utilisation
© Berggeist007 / pixelio.de

Function: archive of natural and cultural history
© Peter Fenge / pixelio.de

Not only the natural functions, but also the technological properties of soils and in-fill materials, play an important role for the underground infrastructure. These are cited, for example, in numerous reference works and codes, inter alia, with particular focus on the following applications and utilisations:

- Foundations, and stable substrates, in particular, see (for example) DIN 1054-1 [11], DIN 1536 [12] and DIN EN 1997-1 [13]
- Highway construction, particularly the underground space and the subgrade surface, see (for example) RASt 06 [14], DIN 4301 [15] and DIN EN 13286 [16]
- Drain/sewer and conduit engineering, plus bedding effects and loads exerted by the predominant in-fill materials, in particular, see (for example) ATV-DVWK-A 127 [17], DIN 4124 [18] and DIN EN 1610 [19]
- Rainwater management and, in particular, seepage-drainage capability and water storage, see (for example) DWA A138 [4], DIN 1989-1 [20], BWK Technical Information 1/2013 [21] and Code for Seepage-Drainage Capable Transport Surfaces [22]
- Heat recovery from waste-water, see (for example) DWA M114 [23]
- Heat storage, see (for example) ITW research report [24]
- Rerouting of high-tension power lines, increasingly in the form of underground cables, see (for example) dena [25], 26th BImSchV [26] and BGV B11 [27]

Function: in-fill material for drain/sewer and conduit engineering

- Pipelines (for gas, water, oil), and the associated bedding and corrosion properties, in particular (protection, aggressiveness); see (for example) DIN 30675-1[28], DIN 50929-3:1985-09 [29], DVGW GW 9 [30] and ÖWAV Working Aid 39 [31]
- Local/district heating pipes, and their friction behaviour, in particular, see (for example) FW 401 Part 1-18 [32] and FW 420 Part 5 [33]
- Planted areas and, in particular, their substrate properties, see (for example) DIN 19731 [34], FLL Recommendations for Planting of Trees [7] and RAS-LP4 [35]

Potential conflicts and trends

In densely populated urban areas, the above-mentioned uses are frequently superimposed on one another, with the consequence that one and the same body of soil is required to perform several of the above functions simultaneously. Typical examples of this include:

- Seepage drainage and storage of rainwater in the underground root space of trees
- Bedding and trench in-filling in pipeline engineering as the substrate for roads and, simultaneously, as a protecting envelope against interactions with vegetation
- The creation of hold-back space to lessen the impact of peak run-off in case of severe precipitation events, to protect roads against blockage.

Even greater use of underground space must be anticipated, in view of current developments, for instance:

- Underground installation of power cables, and the expansion and modification of gas-supply systems as a result of power-to-gas developments and for temporary storage and transmission of gas from regenerative sources, in the course of the energy turnaround (see [36], [37])
- Provisions for the management of flooding events and greater diversion of stormwater into and via the underground space, as a consequence of climate change (see [21])
- Provisions for the improvement of the urban climate by means of the provision of green spaces and shade, with greater concomitant requirements made on root space and substrate quality, for enhancement of the quality of life in towns and cities (see [38])
- Expansion of the broadband infrastructure and installation using (semi-)open-trench and trenchless methods (see [39], [40])
- System for regulation of the groundwater in former mining areas, and higher groundwater tables (see [41], [42])

The above-mentioned developments make conflicts likely. Exploiting these conflicts as an opportunity for future-orientated use of the soil will be a focal task in the coming years.

Potentials and challenges

There are special perspectives for long-term regional planning and co-ordination. These apply, on the "product side", to the use of innovative soils and in-fill materials in the underground space of our towns and cities [43] and, at the planning stage, to design and project management. Requirements made on space needs and the use of soils have up to now been derived from surface utilisations (see [8], [6]) or are defined on an industry-specific basis, making no allowance whatsoever for other utilisations. Typical examples can be found in DIN 1998 [2], with general relevance to conduit and cable systems, DIN EN 1610 [19], in the case of open-trench installation

of drains, sewers, and cables, FGSV RAL [44] with respect to surfaced roadways, DVGW GW 9 [30] concerning the bedding of gas and water supply pipes, AGFW FW 401 [32], the code of practice for district-heating systems, DWA-A 138 [4], in rainwater management, and the FLL recommendations [7], specifying plant substrates. In some cases, minimum distances from other users' routings are also defined (see [45], [5]), thus confronting planners with boundary conditions and conflicts of aims which can nowadays scarcely be resolved in densely populated conurbations.

In the past, diverse utilisations have also been implemented in cases in which the above-mentioned normative boundary conditions could not at all be met. The challenge is in assessing the particular situation realistically, accepting it and organising responsibility in such a way that it can in fact be accepted by all participants. Acceptance can be enhanced, in particular, if drain/sewer engineering, for example, is used as the driving force for co-ordinated action (see Göttingen [46]). A particular important role is then played by open-trench installation and the selection of the soils used, since conflicts of aims arising, for instance, from generalised minimum spacings, can be solved only by means of the clear spatial assignment of soil functions for foundations, conduit/cable routes, plant root space and other utilisations.

Further potentials arise if life-cycle analyses are harmonised with one another on a supra-infrastructural basis. This applies as much to the pipes and components installed as to the soil and the in-fill materials, since these must also be regarded as elements in the overall structure [47]. Pore space and water permeability play a special role in this context in cases, for instance, in which local barriers (for root protection, for example, see [48]) are intended to assure permanence while, conversely, water permeability is a hydrogeological requirement in the overall geographical area, in order to attain long-term water-management targets. Structure-analytical interactions between the pipe/soil system and adjacent projects, as a result of transference of loads, for example, must also be taken into account. The analysis of existing soil systems, the development of new soils and in-fill materials, engineering methods, and the use of innovative planning instruments [49] can all help in increasing the stability of the system throughout its life-cycle. The use of temporarily flowable in-fill materials may be mentioned by way of example, with a view to shallower trench depths, permanently stable bedding conditions and defined penetrability in case of subsequent excavation work (see [50], [43]).

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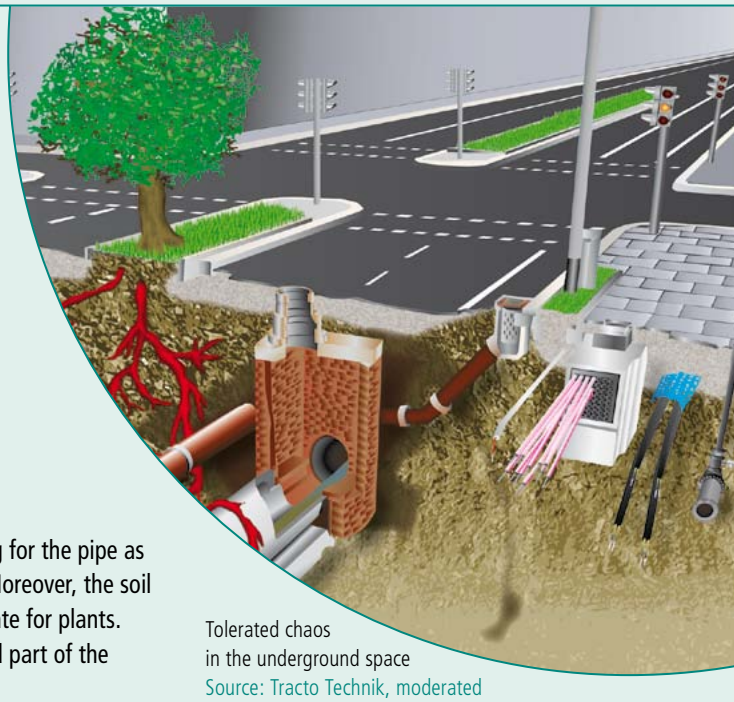
Managing the Crowded Underground



Tolerated chaos
in the underground space
Source: Tracto Technik, moderated

Who is responsible for our streets and roads? Who is entitled to lay pipelines, sewers and cables throughout our cities? Where in general do we find these pipes in the first place? After all, who is responsible for planning, construction and operation of our infrastructure?

Claims for underground space

There are many players claiming space in the underground, all with viable needs figure 1). In German cities, for example, the supply lines and cables are usually placed under the sidewalks, be it for gas, drinking water, electricity or data transmission. In the middle of the road, in greater depth, we find sanitary and storm water sewers or combined systems. Sometimes the larger supply mains and district heating lines are placed there also. As a consequence pipe trenches serve as foundations for roads and sidewalks. Hence, the soil has to meet many requirements; it's the bedding for the pipe as well as a base for the road. Moreover, the soil may also be used as a substrate for plants. Every tree has roots that need part of the underground space.

And finally, the underground can be regarded as a complex hydrological body. Soil absorbs, contains, purifies and stores water. Sometimes the groundwater level can even be above our pipeline system.

Against this background we must ask:
Who manages our underground space?
Who feels responsible for our infrastructure?
Basically, we can distinguish three groups of players (figure 1):

- First the asset owner - the one who keeps all the assets such as roads, pipelines, manholes and pumps on account.
- Secondly, the asset manager - the entity who is handling and operating the network and is responsible for construction, operation and maintenance with a fee for these services. It is often the so called "municipal utilities" who are doing this job, many utilities being a public asset themselves.
- Finally - the service providers who render their assistance to utilities and industry, from sewer cleaning to construction and accounting.

But what are the topics those players are mainly interested in? Once again we can set three flags:

- The owner by nature is interested in securing his asset values. Owning the assets and making these assets available results in profits.
- The owner and the manager are both interested in the capacity and output of the network. For water and gas e.g., that's the very basis for charging the customer.
- Moreover, quality is crucial. Drinking water has to be hygienic and palatable. Data networks must serve around the clock and gas pipes need safety constraints.

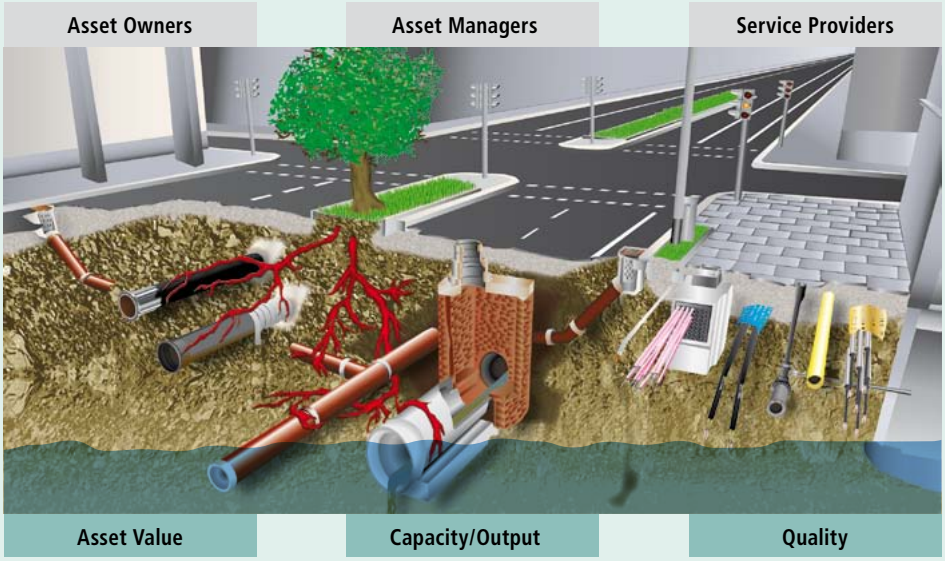


Figure 1: Many players claiming space in the underground
Source: Tracto Technik, moderated

Figure 2: pipelines criss-crossing the underground
Source: Heidelberger Versorgungs- und Verkehrsbetriebe GmbH

As we can see, all parties have multiple tasks. To achieve these they need the means and the room to act. We all know they will take what they need. Pipelines are everywhere in our cities, criss-crossing the underground (figure 2). Those who want to repair or rehabilitate their pipes can only hope that they are on top of the knot or that they can use trenchless techniques. On CCTV those conflicts become even more obvious. Roots grow into pipes (figure 3) and some piercing techniques were not only used to pierce the ground, but also to pierce other pipelines as well (figure 4).

Figure 3: Excavated pipe penetrated by roots

In the Netherlands e.g. the foundation RIONED has just recently collected and evaluated the available data from such conflicts [1]. The data collected for this region of about 17 Million inhabitants gave an impressive number of 4000 piercings of sewers and pipelines, all caused by other boring activities. Per year 250 new cases are expected. Even the Dutch Parliament discussed the problem in detail [2]. Now everybody is wondering how they can improve the situation. Some initial ideas are a new monitoring and reporting system as well as restrictions for pipe laying activities.

Figure 4: Piercing techniques piercing other pipelines

Motivation and Strategies

This leads us to a fundamental question: what are the general strategies to improve the situation? To address this issue we start from a well-known psychological approach for describing the motivation of individuals, and expand it to our world of the underground , including asset owners and managers (figure 5, cp. [3]).

The first base line is connecting two poles: individuality and society. The second base line is defined between continuity and change. In this scheme we can define four strategies as a part of infrastructure management. We start with the options in the two quadrants on the left of figure 5.

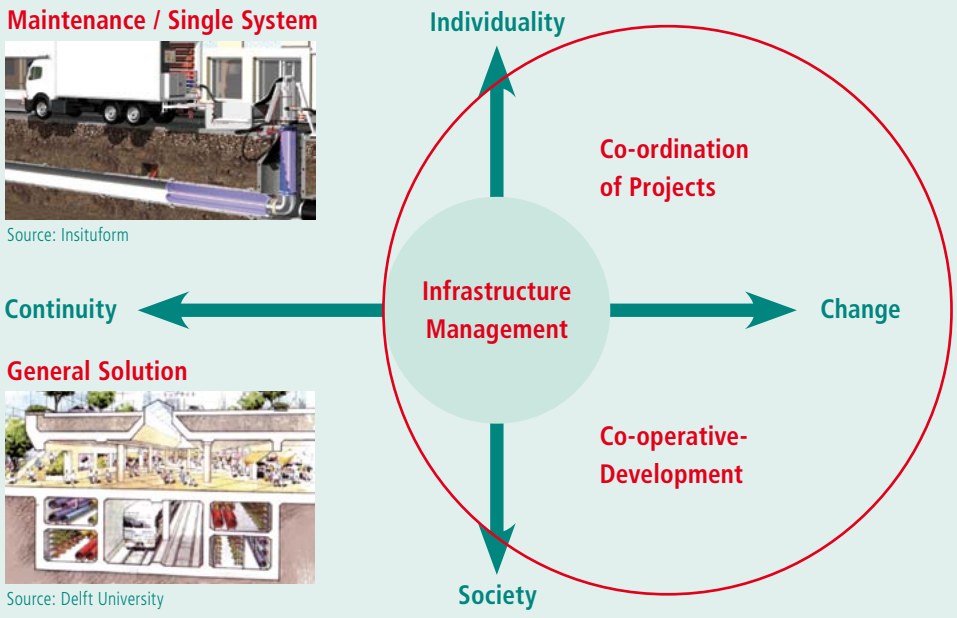


Figure 5: Motivation and Strategies

First quadrant

The first quadrant, down and left, is a combination of continuity and society. We can call it a "general solution". It means that "once for all" and "all together" we decide how to proceed, and all infrastructures and utilities are included. Nobody is left behind. In a technical sense we talk about large collectors for all kinds of pipelines and infrastructure. In this example even the traffic ways, trees and shopping areas are integrated in the system, each possessing its defined zone in the ground.

Second quadrant

In the next quadrant, we stay with the idea of continuity. However, now we want to preserve the freedom of each player to find his own way, to preserve the individuality of his network. We call this maintenance or rehabilitation of a single system. Trenchless Technology is the keyword; these techniques allow us to work without disturbing other carriers in the crowded underground.

One good example is CIPP lining. In this case it is possible to use the space that has already been occupied by the network itself. A new pipe is installed within the old pipe without any disturbance of the soil or other structures close by. However, the capacity remains unchanged, although it was often planned for requirements of the last century.

Apparently, those two solutions on the left side of figure 5 relate lot to technical optimization. The management question occurs if we look at the right side. There, it is about co-ordination of projects and co-operative development. We are ready for change, be it within each network or for the infrastructure as a whole.

Third quadrant

Quadrant three shows what municipalities and utilities, at least in Germany, pretend to already do: co-ordination. However, each utility still cares only for its own network and assets, so the investments, too, are still planned separately and independently. At regular intervals, two or four times a year, all current activities are reported to a co-ordination group which is set up by the utilities and the city. This group then discusses how to minimize conflicts during construction and maybe even how to combine some measures to reduce costs. Thus, it is not a long-term strategy, but it is rather about harmonizing the on-going activities.

A famous German Standard, the DIN 1998 [4], underscores this idea of trustful co-operation. Figure 6 shows a graphic from one of the first issues of this standard. It is a standardized cross section of underground space beneath a road. The road and every line are placed where they should be, that is in a defined and permitted zone. However, in daily practice, things might be different (cp. figure 2 and 3).

Fourth quadrant

Finally, against this background, quadrant four seems even more interesting. We are open for change, but we want to do this as a member of society, feeling responsible for the public good. We can call this "co-operative development". Municipalities and utilities are going to act in a flexible way open for change, but they have a clear strategic vision of a greater good, of society and of long-term developments and responsibilities.

However, what might sound great and easy is not that simple. Usually, in a Democracy, it is the political leadership which is responsible for such things. The municipal council and the mayor decide on long-term strategic developments of a city, with impact on society. As a consequence, it is the political system that counts and the people in this system. And, there are many complex rules and regulations like laws, contracts, easements and covenants to follow and these seem indeed to be a hindrance for a true strategic management of our infrastructure. The political task to align all these regulations is enormous. Moreover, most municipalities have lost their freedom of choice already as many concessions, agreements and contracts have already been stipulated in the past and are still valid for the next decades.

Thus, at first look, the major questions remain unsolved: What can we do in general to improve the situation? How can we attain the higher goal of integrated infrastructure management?

To find an answer let us return to our base lines. We have realized that there are many ideas on how to act in this complex environment. Also, we have seen that any solution which focuses on one quadrant only seems out of place or full of limits. Like in psychology, where a sound and healthy person may be attracted by the poles but always has a clear focus on the center, municipalities as well as asset owners and managers have to look for a balanced overall strategy. This way, the advantages of all four of the above opportunities can be used without approaching a single extreme.

Conclusions and Outlook

In our cities, there are a lot of claims for underground space with regard to e.g. road foundations, the bedding of pipelines, plants needing space for roots and growth, and rainwater interflow, retention and infiltration. Against this background utilities and municipalities face a broad range of requirements. Technological and quality issues have to be resolved and innovative solutions have to be developed. All this happens in a stressful environment full of conflicts between individuality and society and between continuity and change. Apparently, the focus of Integrated Asset Management Strategy is about balancing the available opportunities and solutions in a feasible and economical way.

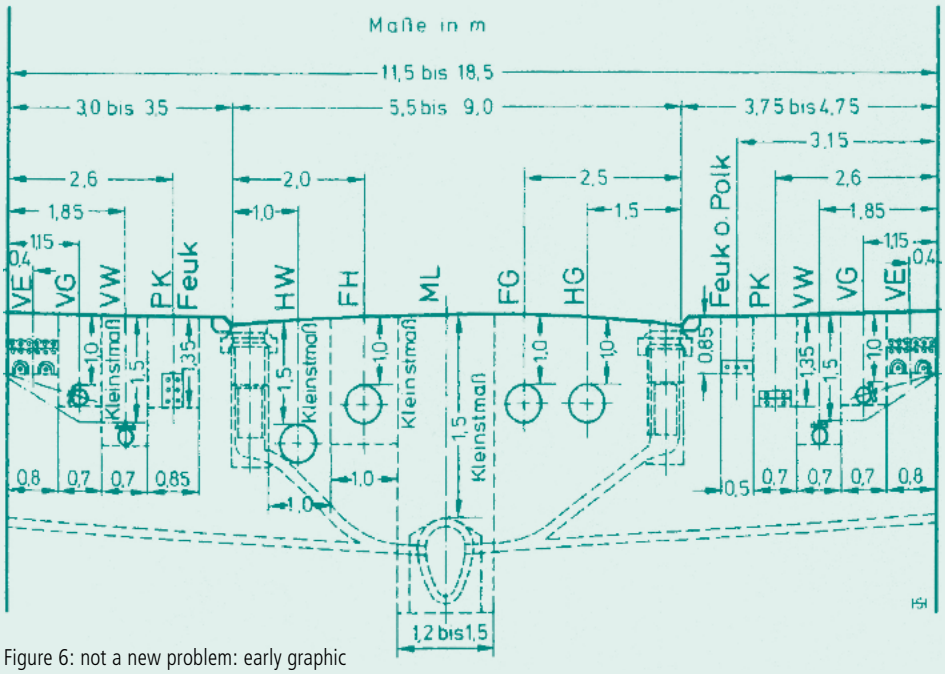


Figure 6: not a new problem: early graphic in a German Standard, DIN 1998

How this can be accomplished, and how we can cull the benefits of an integrated approach in practice has been the focus of IKT's Asset Management activities since 2013. We will continue, together with our members and partners to seek solutions. Recent and upcoming highlights are:

IKT-Webinars on Asset Management of Underground Infrastructure

Strategies and methods to obtain cost-effective and reliable solutions are currently discussed worldwide. During IKT's series of webinars an overview of cutting edge research and practical experience is given by international experts from Europe and North America, all session being supported by our partner from the US, the International Right of Way Association (IRWA, cp. [5], also see page 51). The focus of the first series 2013/2014 was on waste water infrastructure issues; however, many ideas can be adapted for other underground networks, too.

The focus of the second series of webinars in 2014/2015 will be on energy networks for gas and oil as well as power lines and district heating. Members of the IKT Network, guests and partners can still apply for a ticket.

IKT-Conference including Asset Management Workshops 16th to 18th September 2014

As part of its 20th anniversary, the IKT will conduct an international program with many new practical and future-oriented topics related to the theme of Asset Management. There will be presentations about the latest developments and experiences in Asset Management as well as workshops on "Trends and Challenges" and "Vegetation and Infrastructure". This conference offers a unique opportunity to exchange knowledge and ideas about state-of-the-art topics in Asset Management and to identify future innovations. Meet and network with attendees coming from all industry sectors: clients, contractors, designers, consultants, suppliers and manufacturers. During this InfraTech Knowledge 2014 Conference you will be attending the IKT 20 Years Celebration and the Forum where methods, techniques and lectures will be presented. For updates and more information, see www.ikt.de/AM

The major sessions are available via Youtube: (Keywords IKT Asset Management)

Session 1/8: www.youtube.com/watch?v=YC49yOW2JMs
Session 3/8: www.youtube.com/watch?v=IdNWTaY3Ht4
Session 5/8: www.youtube.com/watch?v=iInd7uI62vM
Session 6/8: www.youtube.com/watch?v=NKonyNQzrm8
Session 7/8: www.youtube.com/watch?v=ltovnZPDVjo

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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

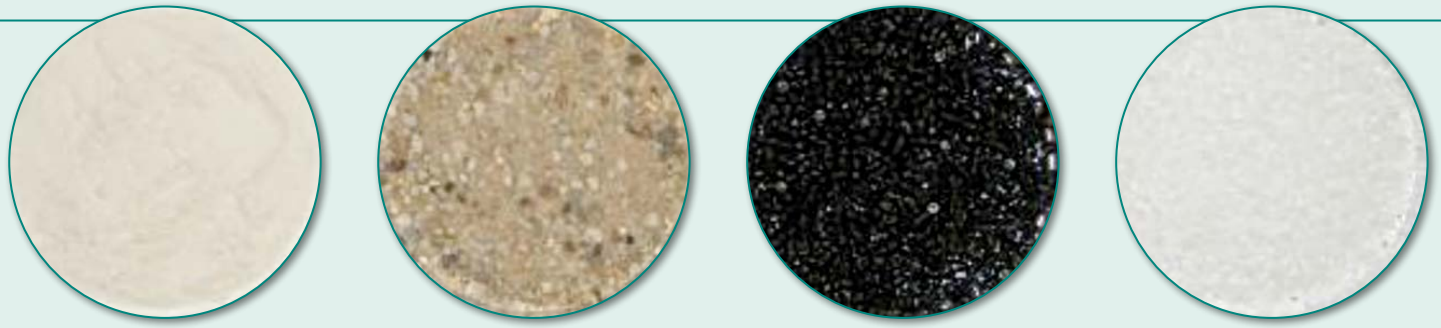

Figure 1: The FSs used (left to right): Millisil W4, gravel/sand mixture, PE granulate (black) and PS granulate (white).

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 η_{dez} and η_z of the treatment systems examined for the methodical comparative assessment

Make / manufacturer	Applications	FS	COD	PH	Zinc
Decentralised treatment systems with efficiency η_{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 η_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 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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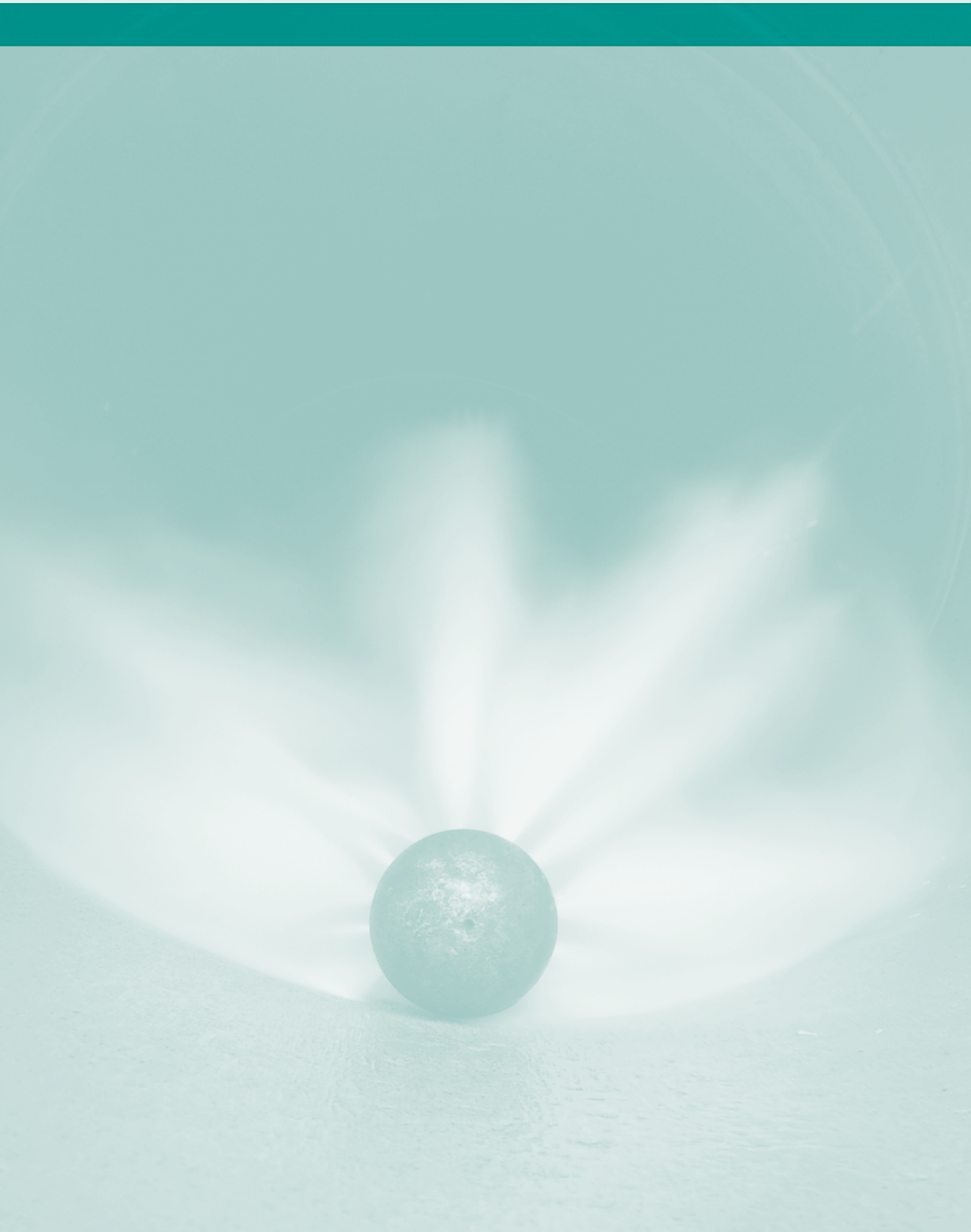


Needs-orientated conduit cleaning

There is still a need for discussion.

We drive our cars through the car wash only when they're dirty - and that's totally logical. But many operators of waste-water systems continue to clean their drains and sewers to a fixed schedule. The IKT has conducted a research project into the optimisation potentials of needs-oriented cleaning strategies.

Cleaning of conduits makes an important contribution to assuring the functioning of our drain and sewer systems, and accounts for a significant portion of the responsible municipalities' budgets. It is often the case, however, that system operators' resources are not used efficiently and/or that, due to inadequate knowledge of the current condition of the conduit systems, lengths are cleaned without this really being necessary. Many sectors are not, or only insignificantly, fouled when they are cleaned, for example, whereas other lengths exhibit heavy fouling. It is therefore possible to exploit potentials for optimisation and save costs by introducing a needs-orientated cleaning strategy, without risking impaired operational safety and reliability by universally increasing cleaning intervals.

Investigation of needs-orientated drain/sewer cleaning

The IKT focused on this topic, in co-operation with the Ruhr University of Bochum, in the context of a research project funded by the environmental ministry of the state of North Rhine-Westphalia (NRW). Measurements of pollutant burden and hydrogen sulphide content, and also fouling analyses, were performed in real-life drains and sewers under the project title of „Investigation of needs-orientated drain/sewer cleaning exploiting operational synergies". Particular attention was devoted, inter alia, to the analysis of typical weak points in the drain/sewer system. A statistical problem survey was conducted and the statistics evaluated.

Problems in drain and sewer systems

Very largely trouble-free disposal of waste-water is, with very little doubt, the aim of every waste-water system operator. The real situation is generally rather different, however. In practice, a range of problems can occur and impair correct functioning of the drain/sewer network in a number of ways, extending from minor obstructions up to and including total blockage of the conduit. Such problems attract particular attention when they directly result in complaints by customers, as a result, for example, of overflows or odour nuisances.

Practical experience up to now demonstrates that no statistics complete with details of location, frequency, effects and causes, are generally kept on such problems. There has, correspondingly, also been no available information up to now on the problem situations that are of particular practical relevance. A „Problems in drain/sewer operation" operators' hotline was set up as part of this research project, in order to obtain an initial overview. The aim here was that of identifying the relevant problem situations and elaborating suitable conceptual solutions. Problems could be reported by telephone, e-mail or using a special problem-report form. More than seven hundred problems were ultimately notified by seven waste-water authorities using this hotline.

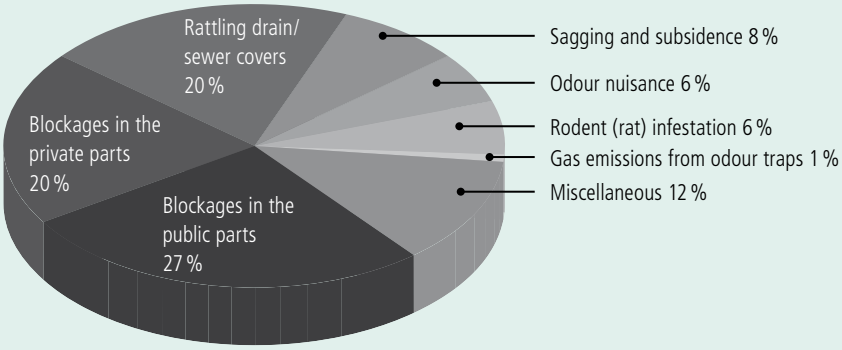
The following problem groups were noted:

- Blockage in the public part of the system
- Blockage in the private part of the system
- Rattling drain/sewer covers
- Odour nuisances
- Rodent (rat) infestation
- Sagging and subsidence
- Gas emissions from odour traps
- Miscellaneous

Cleaning crews retrieve foreign objects like these from drains and sewers again and again.

Analysis of the problem data survey showed that the largest proportion (27 percent) of the problems reported involved blockages in the public part of the system. The second and third highest rankings of the cases reported were held by blockages in the private part of the system and rattling drain/sewer covers, each at 20 percent. These three problem situations in practice account for nearly 70 percent of all problems.

Conduit Cleaning



Together, blockages in the public and the private parts of the system, plus rattling drain/sewer covers, are responsible for two thirds of problems.

Building rubble causing obstruction to flow: after-completion inspections may be appropriate in the zone around completed civil-engineering work.

Other problems in the drain/sewer network occurring regularly in practice include sagging and subsidence, odour nuisances, rodent infestation and gas emissions from odour traps. In everyday practice, however, these phenomena occur rather more rarely. Finally, all other "isolated incident" reports, such as oil spills, etc., were all grouped together in the "Miscellaneous" category. Such problems also occur only extremely rarely.

Talks on cause analysis with system operators showed that the occurrence of a problem is generally preceded by a particular event or a particular deviation from planned figures. These apply, for example, to the structure and geometry of the waste-water conduit, such as narrowing cross-sections and adverse gradients, unscheduled discharges of water and/or the fly tipping or other ingress of foreign bodies, such as building rubble or tree/plant roots.

Recurring problems: Knowing where depositions regularly occur permits systematic cleaning.

Results, remarks and recommendations for cleaning practice

In most cases, no recording and documentation of such problems has generally taken place in practice up to now. Those system operators that do document problem reports only rarely also record the possible causes. Even when they do, only generalised categories, such as "Blockage in the public part of the system" are usually noted. It is therefore not, or at best only scantily, possible to identify weak points in the drain/sewer system, with the result that this factor, too, is also initially left out of account in cleaning planning. It is better practice to record reports of problems and to follow through until the cause has been found. This makes it possible to detect weaknesses in the drain/sewer system and take them into account in cleaning planning. The setting-up of a problem register is an option for documentation of such problems. The sites, frequency and effects of problems arising during system operation should be continuously logged and documented for this purpose.

Differentiation between isolated and recurring problems is recommended analytical practice. An isolated (i.e., "once-only") problem, such as a collapsed dirt trap, for example, is of no further importance for deployment planning once it has been rectified. In the case of recurring problems, such as blockages at adverse gradients, or the penetration of roots, on the other hand, the affected areas should be kept under long-term observation and cleaning intervals shortened if appropriate. Even better, such weak points should wherever possible be eliminated by means, for example, of corresponding refurbishing. After-completion inspection of the nearby drain/sewer sectors should also be practised after civil-engineering work and, in particular, roadworks, etc., in order to detect any resultant problems.

The data survey for this research project also indicated a greater number of reports concerning rattling drain/sewer manhole covers. The solution usually selected is the installation of an underlay ring. Repair of the top of the manhole shaft is generally necessary if the problem recurs, however. Here, too, there are also possible synergy effects in terms of labour deployment. In other words, greater deployment of the freed human resources to other tasks, such as the repair of manhole shafts and similar activities, is recommendable if it has been possible to reduce the labour needed for cleaning.

Conclusions drawn from this project

A comprehensive concept for the exploitation of further potentials within needs-orientated drain/sewer cleaning was drafted, with the involvement of NRW municipalities, in the context of this now completed research project. Internal synergies within the limits of drain/sewer operation itself, on the one hand, and also potentials for optimisation by means, for example, of inter-municipal co-operation, were outlined. Technological tests performed on a test length of conduit were used, on the other hand, for the determination of actual cleaning needs as a function of the fouling situation.

The practical tests performed during this research project clearly showed that the decision concerning cleaning of a conduit should not be made solely on the basis of an "instantaneous picture" of the level of fouling, since the latter is subject to great fluctuations as a result of precipitation events and other factors. Instead, regular inspections should be performed, since these assist in determining the characteristic state of a length of conduit and its fouling across longer periods, permitting the definition of correspondingly adjusted cleaning intervals. Such cleaning intervals must never be of infinite duration, however, since the solidity of the fouling depositions, and thus the necessary cleaning effort, increases with time. On the basis of knowledge gained up to now, the generation of hydrogen sulphide plays only a subordinate role in the scheduling of cleaning intervals, since the beneficial effects of a cleaning cycle on hydrogen sulphide evolution last only a few days.

In parallel to the practical tests conducted, the project also created numerous contacts in the context of workshops and inter-operator discussions, and these enabled system operators to exchange experience regarding the particular cleaning strategies. This generated wide-ranging insights into the boundary conditions and requirements set at the various system operators. It became apparent that there will never be a single "optimum" strategy universally applicable to all system operators and that, instead, every operator will need to find the solution that best fits his requirements and circumstances.

Download research report "Investigation of needs-orientated drain/sewer cleaning exploiting operational synergies – phase 1": www.ikt.de (German Version)

Presently, this subject is being analyzed further in the second project phase.

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Handling of drainage-system water from private sites

The discharge of site and drainage-system water into the public sewer network is expressly prohibited in the majority of waste-water regulations in North Rhine-Westphalia. In many municipalities there are, nonetheless, numerous such drainage connections. How, then, should this issue be handled at local level? A guideline drafted by the IKT and the NRW Municipal Agency (KommunalAgenturNRW) provides orientation.

There can be a range of reasons for connected water-drainage systems. It may be, for example, that a drainage system was actually intended only for the construction phase, but then remained connected "just to be on the safe side". Or the drainage system might have been installed despite the ban on permanent drainage. Leaking building sewer laterals and site sewer laterals can also act as drainage systems. Why do the municipalities prohibit the discharge of ground and drainage-system water, and why is drainage-system water discharged, despite the ban?

Illegal drainage system connection to a public sewer
source: Municipality Möhnesee

Entirely divergent interests are obviously at work here. The "Handling of drainage-system water from private sites - Pragmatic conceptual solutions and aids to argumentation" guideline provides an aid to orientation concerning how a system operator can make his strategic decision for the handling of drainage water and justify it to citizens, politicians and supervisory authorities in a substantiated manner. This aid has been drafted by the IKT - Institute for Underground Infrastructure and the NRW Municipal Agency at the initiative of and in co-operation with the Detmold regional government.

Possible problems caused by drainage water Interflow water, confined water or seepage water and, where groundwater tables are high, also groundwater, can ingress, as "drainage-system water", from private sites into a sewer network. Discharge of drainage water into the public sewage or combined drain/sewer system has in many cases been tolerated in the past, despite the fact that it is generally not permitted under municipal waste-water regulations. Groundwater and drainage water becomes "extraneous water" as soon as it enters a sewer system. It is not possible to state a global limit, as from which extraneous water run-off becomes a problem for a specific area. The reason is that this depends on a range of different factors, such as the hydraulic capacities of the network and the treatment plant, and the capabilities of the sewage treatment facilities affected.

Particularly in areas with high water tables, the extraneous water content in the public sewer system can rise as a result of the discharge of drainage-system water, and cause problems such as the following:

- There may be more frequent overloads for sewer conduits and pumping stations.
- The discharge of drainage-system water dilutes and cools the sewage. This can impair the cleaning performance of the sewage treatment plants and endanger environmental water by overloading such plants and rainwater ponds. Elevated carry-over of pollutants into environmental water may be the result if no countermeasures are implemented.
- There may also be a significant increase in the operating costs for sewage collection and treatment (e.g. cleaning). In many cases, the sewage charge may be increased, or exemption from a sewage charge sacrificed.

In the future, the increase in heavy rainfall events as a consequence of climate-change, causing further burdens on systems, will also exacerbate this situation.

Drainage for the protection of man-made structures must, on the other hand, be set against this (DIN 4095). Drainage systems are intended for temporary collection and removal of any slope interflow, confined water or seepage

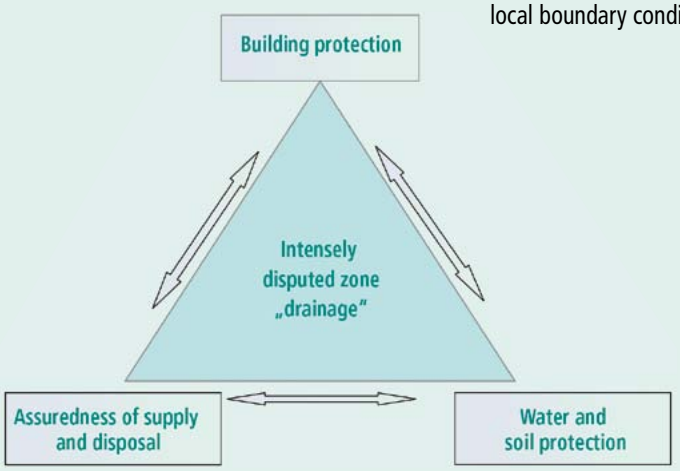
water below the site datum surface, in order, in combination with the building's sealing system, to prevent damp damage to buildings. The question of where the water can be routed should be examined on building-law and water-law criteria during the planning and dimensioning work on the drainage system.

In each individual case, there are frequently conflicts of interest between the following factors when examining drainage systems:

- Protection of buildings (drainage systems against damp in basements);
- Assuredness of supply (protection of drinking water, as a necessary resource, from groundwater and river water);
- Assuredness of disposal (correct and assured functioning of the overall drainage/sewer system);
- Protection of environmental water (avoidance of high frequencies of discharge into environmental water at storm-water overflow structures, adherence to permissible burden levels in the case of discharge flows from treatment plants and overflow structures);
- Avoidance of soil pollution (prevention of overflows into the drainage systems from combined and/or sewage systems)

Guideline as an aid to orientation

The question of how a municipality should handle drainage systems in a specific area is coming increasingly into the foreground. The problems examined above provide the reasons for this.



The intensely disputed zone of water-drainage systems

Drainage systems are intended to protect against damp in basements

The reduction of extraneous water in sewage systems and thus, ultimately, indirectly the handling of drainage systems, is also anchored in the range of provisions for implementation of the Water Framework Directive. The focus in this context is, in particular, on plant and system safety, and on the reduction of pollution of environmental water due to the discharge of sewage. In addition, this topic is also under discussion in connection with the tightness testing of private sewage installations. It has, in the past, been perfectly normal practice to connect drainage systems to the public sewer system, despite the fact that discharge of drainage-system water was generally prohibited by waste-water regulations. It must, for this reason, be assumed that successive investigations of public site sewer laterals and private sewage lines will reveal a large number of water-drainage system connections.

There will never be universally applicable procedures for the handling of drainage systems, since pragmatic conceptual solutions are required to take account of the commensurateness of the provisions, against the background of local boundary conditions. The IKT - Institute for Underground Infrastructure and the NRW Municipal Agency therefore drafted the "Handling of drainage-system water from private sites - Pragmatic conceptual solutions and aids to argumentation" guideline on the initiative and in co-operation with the Detmold regional government, in order to provide municipalities and system operators with an aid to orientation.

This guideline is intended as an instrument to support municipal system operators in their practical work. The involvement of a group of municipal system operators ensures the practical relevance of the guideline. An expert workshop assured the incorporation of further arguments and conceptual solutions. In addition, all the regional governments of NRW were included in the relevant discussion. The project was funded by the environment ministry of the state of North Rhine-Westphalia (MKULNV). This guideline is available for download on the state environment agency's homepage (www.lanuv.nrw.de/wasser/abwasser/forschung/kanal.htm, German version only)

Contents of the guideline

The guideline provides notes, suggestions and examples for the assessment of the drainage-system water situation. It outlines ideas for solutions, and also methods of assessing and selecting suitable pragmatic provisions, and supplies aids to argumentation to support the implementation of a strategic decision once taken. The guideline also includes notes on the manner and handling of communications with the various target groups, and is thus intended to achieve greater acceptance for the planned provisions at both the citizen's and at local political level, and facilitate in advance the dialogue to be conducted with the supervisory authorities.

The emphasis in this guideline is on its practical benefits for the user. It therefore includes "tools", such as check-lists for assessment of the drainage-system water situation, detailed specimen scenarios, and a "question/answer" list to improve argumentation. These tools assist the system operator in orientation concerning the handling of drainage-system water, but leave him the necessary discretion to take into account the individual situation in the particular area (e.g. hydrology, demography, regulations, overall drainage system).

The guideline is orientated around the following processing phases:

- Assessment of the drainage-system water situation and of the need for action
- Definition of aims and taking of a strategic decision
- Identification and evaluation of ideas for solutions
- Drafting of an argumentation list specific to the particular municipality
- Establishment of a communication strategy for the process as a whole

The user can start at the corresponding processing stage in the guideline, depending on the particular application and the progress already made in processing. The most important "Guiding principles for handling of drainage systems", which have been derived from discussion and interchange between the municipalities, experts and NRW regional governments involved in the project, are also included.

"Tools" included in the guideline

The guideline for action and the tools make it possible to take individual account of the specific situations and aims of the municipalities. The guideline is intended to make tackling of the subject of "Handling of drainage-system water from private sites" easier for system operators. It provides them with a system for the holistic examination and evaluation of existing problems and for the delineation of a pragmatic solution embedded in the necessary independent (municipal) strategic decision.

The guideline contains the following working aids:

- Drainage-system water situation

A list of questions - with suggestions for possible answers - can be used to estimate the extent to which there is a need for action regarding the reduction of drainage-system water within the municipal territory or a part thereof, and those solution options which can be excluded as a result of specific boundary conditions. The concluding assessment can be made only by the municipality itself, against the background of the current situation and anticipated developments.

- Definition of aims

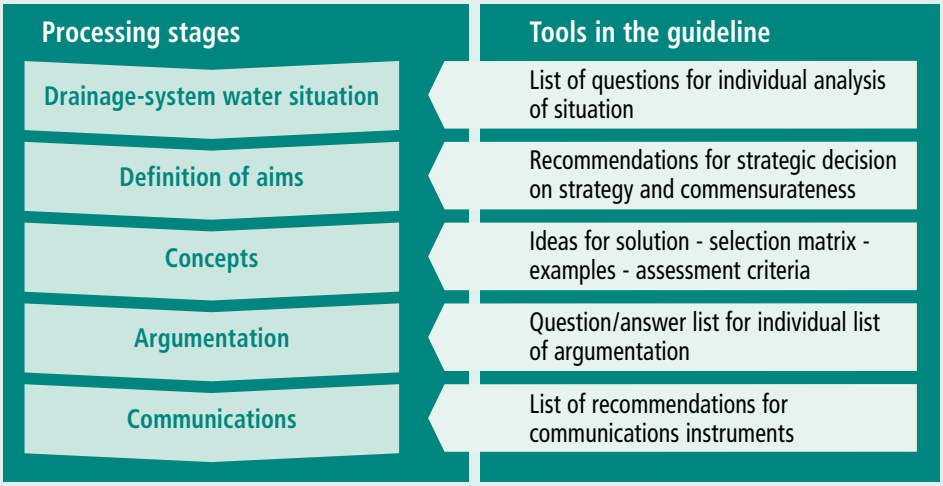
Once the municipality has provided itself with an overview of the drainage water situation and any resulting need for action, it can then define overall targets and strategies for its entire municipal territory and/or individual districts of it. The main emphases (water-management targets, environmental aspects, official requirements) can be extremely diverse. Costs, the various interests, and the acceptance of decisions concerning the handling of drainage systems and integration of the procedure into an overall water-management concept must all be taken into account in any examination of commensurateness. Corresponding recommendations are compiled in the guideline. The target-definition phase concludes with the strategic decision for handling of drainage systems.

- Concepts

On a holistic view, the influence of drainage-system water on the overall sewer and drainage system is of importance - from the place of occurrence up to and including discharge into environmental water.

Due to the interactions between the individual elements, conceptual solutions for drainage-system water can start at various points in the overall system: at a building, in the sewage/drainage-system water facilities sector, and at special installations, such as pumping stations, rainwater ponds and treatment plants. The provisions adopted for a particular planning zone may be extremely diverse, depending on local boundary conditions and objectives, and may range from (1.) tolerance and retention of the current situation, via (2.) provisions for stopping of existing discharges of drainage water into the sewage system (e.g. disconnection of drainage systems and retrospective sealing-off of the existing buildings), (3.) prevention of new discharges of drainage water (e.g. via construction only of impermeable-concrete structures in new development zones), (4.) provision of an alternative receiver for the drainage water (by means of construction of a new main water drain, for example), up to and including (5.) expansion and/or uprating of the above-mentioned special facilities as a supporting measure or - in an absolutely exceptional case - as an end-of-pipe solution.

The guideline provides, depending on the connected drainage-system situation in the existing buildings, a selection matrix which outlines the range of options and evaluates them on the basis of various criteria, such as ecology, cost-efficiency, technical feasibility, public acceptance, legal aspects and prospects of success. Selected solutions already implemented in practice are described in detail and awarded grades in specimen scenarios.



The content of and tools included in the guideline

Argumentation:
The implementation and acceptance of the concept selected are furthered by means of knowledgeable and broadly based argumentation. The guideline therefore includes a list of question and answers, plus notes, which provide orientation for the municipality in communicating its need for action, its concept and its strategic decision to local politicians and citizens, in particular. This "fund" of material can be used by the municipalities to compile an individual list of arguments, covering the aspects of ecology/environmental protection, operation, building-safety/health, cost-efficiency/financing, feasibility/acceptance and legal/supervisory-authority requirements.

Communications:
One important precondition for project success is that politicians, supervisory authorities and citizens all support the municipality's strategic decision. The involvement of all parties is necessary at an early stage to achieve this. In addition, an uninterrupted flow of information must be assured throughout the process. The communications strategies listed in the guideline provide assistance in selecting the correct mode and scope of communication for each particular target group.

Guiding principles for handling of drainage systems

The following guiding principles for handling of drainage systems stated here in abbreviated form are a result of the project and are derived from the project discussions. They provide municipalities in NRW with orientation concerning the implementation of applicable legal requirements via pragmatic conceptual solutions.

Ecology/environmental protection

1. Alterations to the aquifer should be avoided wherever possible. Exceptions may be permissible if conflicts of utilisation would otherwise result.
2. In order to avoid the above-mentioned problems, drainage-system water from private sites should, as a matter of principle, never be discharged into public or private sewage systems.
3. End-of-pipe and/or plant-technology solutions (modifications to rainwater-treatment facilities, pumping stations or treatment plants) should always be the absolute exception, since it will remain necessary to collect the entire extraneous water and, where necessary, pump and treat it.

Operation

4. The handling of drainage systems should be viewed differently in the context of new and of existing buildings (connection to rainwater, combined sewer and purely sewerage systems). Exceptions involving the continued use of existing drainage-system connections (in case of potential damp damage to buildings) may be appropriate in the existing range of buildings in individual cases.
5. Provided the sewage system is otherwise operated in accordance with the generally recognised rules of technology and there is no other need for action (elevated amounts of extraneous water, for example), the municipality can decide on its own responsibility how it wishes to deal with drainage-system water discharges.
6. Where there are problems with extraneous water and/or where the sewage system does not conform to the generally recognised rules of technology, there is need for action from the viewpoint of the supervisory authorities.
7. In areas of heavy extraneous water concentrations, drainage systems should be diverted and alternatives created if there is otherwise a danger of damp damage to buildings or the problem could simply shift to other system elements.
8. In areas other than extraneous water territories, the municipality should take the decision concerning handling of existing drainage systems within the framework of its strategic decision for the specific area. Corresponding provisions should be incorporated into the municipal waste-water regulations (Article 7, Para. 2, No. 11 of the specimen regulations).
9. The handling of drainage systems in many cases necessitates differing strategic decisions for individual municipal districts, depending on local boundary conditions such as hydrology, demography, regulations, drainage/sewage system as a whole, for example.

Building protection/health

10. Holistic concepts, including approaches which take account of anticipated future developments, are recommendable, in order to make allowance for the effects of planned provisions on (for example) the groundwater table and existing buildings.
11. Wherever possible, the status quo concerning the groundwater table should be retained, with consideration of building protection/health.

Cost-efficiency/financing

12. Drainage-system water as an element in extraneous water causes costs. Every municipality should consider, and decide within the political sphere, how such costs are to be apportioned in future (using the "causer-pays" principle, if appropriate).

Feasibility/acceptance

13. Burden measurements and observations are always recommendable for assessment of the extraneous water/drainage-system water situation. Where these indicate that specified concentration data requirements have been achieved contrary to the state-of-the-art practice as a result of dilution, there is, even for this reason alone, a need for action. The investigation results will then provide a firm basis for argumentation to the relevant political personages that the municipality needs to take action.

14. The handling of drainage systems is a controversial subject in the intensely disputed zone of building protection/assuredness of supply and disposal/protection of environmental water and the soil, and one in which the financial and actual commensurateness of various alternative solutions must be verified.

- Law

15. Where there is a need for action (in case, for example, of non-adherence to official requirements, hydraulic problems, damp problems), the subject of drainage systems must be tackled, even irrespective of tightness testing of private sewage systems.

- Strategic decision/higher-level target for solution options

16. A strategic decision which includes a holistic concept for the rehabilitation of smaller sub-areas should be preferred over a solution concept which is aimed at a large area but does not permanently and sustainably solve the problems.

The series of discussions and interchanges of experience which took place with the participating municipalities, the experts and the representatives of the regional governments in NRW in the context of this project demonstrated that there is, in principle, a requirement for a standard implementation procedure, without intervening in the individual decisions that form part of the mandatory discretion of the supervisory authority. In addition, freedom of decision, taking due account of local conditions, continues to reside with the municipality in question.

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Connecting North America and Europe

Leveraging our mutual strength

By William Busch, SR/WA

The thought of exporting and integrating our Association's resources globally has economic and functional potential that is phenomenally exciting. As IRWA continues to expand its reach around the globe, the Association recently formalized a relationship with the Institute for Underground Infrastructure (IKT) in Germany, with the signing of a Memorandum of Understanding between our two organizations. We have already found our relationship to be very useful, learning much from our exchange of best practices and webinar sessions, as well as from both in-person and virtual meetings.

Reaching out

It all started four years ago when I was working for the San Diego County Water Authority and found myself in need of some technical data regarding potential tree root damage to underground pipelines. While conducting some research for her master's degree, my wife Marjorie Busch came across IKT and identified it as a potential information resource for me as well. We reached out to Christoph Bennerscheidt, PE, the Lead Research Engineer at IKT. I quickly realized that not only did IKT's engineering and research staff have specific tree root invasion information pertinent to my right of way management issues, but we also had many professional interests in common. The IKT is a neutral, independent, nonprofit research, testing and consulting institute. It focuses on the construction of underground pipes and networks for gas, water and waste-water. It is a frequent research and testing partner for utilities, sewer system operators, water associations and other industries. A few months after first contacting them, Majorie and I met with IKT staff in person at their facility in Gelsenkirchen, Germany.

Since that simple beginning, representatives from IKT have been featured seminar speakers at IRWA Annual Conferences, covering topics such as how the growth potential of roots can affect utilities, Germany's conversion from nuclear to green energy, and managing utilities in the crowded urban underground environment. They have become a welcome addition to the Association's international outreach efforts, and in early 2013, Christoph became IRWA's first member in Germany. We have also cooperated on articles for Right of Way Magazine.

A meeting of minds

At IRWA's 2013 Annual International Education Conference in Charleston, West Virginia, IKT and IRWA had high-level discussions regarding future cooperation that included outlining our compatible strengths. Both organizations have broad international ties and are internationally recognized as experts in our respective fields of influence - IKT for technical research and IRWA for management practices, education and certification programs. Additionally, each organization is looking to expand its international influence. We also both deal with underground utilities and have similar educational training interests. The foundation laid at IRWA's 2013 Conference has resulted in rapid developments. On September 14, 2013, IRWA and IKT executed the Memorandum of Understanding, establishing a six person working group to promote cooperation. The IRWA portion of the group is comprised of myself, Glenn Winfree, SR/WA from Duke Energy and Bill Rose, PE from the San Diego County Water Authority. The German group members are Christoph, Bert Bosseler, Ph.D., the Head Scientist at IKT, and Peter Lampret, Ph.D., a Director at the German utility ELE. The first meeting was held at IKT headquarters in Germany in October and was attended in person by the three German members and myself, and via telecom by Glenn and Bill. During this meeting, IKT proposed a webinar series that IRWA and IKT would co-sponsor at no cost to IRWA. The webinar we developed is an eight-part series dealing with management of crowded underground utilities in the urban environment. Nineteen infrastructure specialists from the United States, Germany, France, Belgium, The Netherlands, Luxemburg and Algeria took part in the first installment of the webinar, which was held in October and promoted cooperation and an international information exchange between our countries.

From left to right: Bill and Marjorie Busch traveled to Germany to meet with Christoph Bennerscheidt and Bert Bosseler for the inaugural working group meeting at IKT headquarters.

Cooperation

Growing through collaboration

To leverage our compatible strengths and common goals, the working group is also currently evaluating the demand and feasibility of an international certification that would require participants to take a combination of IRWA and IKT courses, participate in webinars, and view certain on-site locations. There will likely be more information to share on this following some market research and curriculum development.

IKT's Bert Bosseler presented at IRWA's 2013 Conference on the challenges Germany is experiencing in switching from nuclear power to renewable.

This collaborative effort with our new affiliate in Germany is a perfect example of how our members are already beginning to benefit from IRWA's international expansion. These partnerships will continue to fuel our growth as we are joined by transportation experts from Australia, oil and gas specialists from the Middle East, and appraisers, surveyors and electric utility land agents from various areas of Africa and Central America as well.

It is possible that this webinar, in conjunction with courses developed by IRWA and IKT, could form the basis for an international certification. Imagine individuals from around the world logging on to IRWA online courses to achieve a certification that is internationally recognized! In a few short months, we have developed significant strategies and resources for sharing information internationally, and we are just getting started. We live in exciting times and are taking advantage of the highly technological world to take IRWA and IKT to the next level.

Bill Busch, SR/WA is the retired Director of Right of Way for the San Diego County Water Authority. He is an independent Right of Way Specialist in Kentucky, and serves on the Executive Board of IRWA's Chapter 25.

For more information about IRWA, the International Right of Way Association, visit www.irwaonline.org

New contact in the Netherlands

The IKT has now founded a branch at Arnhem, in the Netherlands: IKT director Roland W. Waniek and branch manager Peter Brink recently celebrated the opening of „IKT Nederland". Dutch and Flemish drain/sewer system operators thus now have a new contact for all matters concerning drain and sewer operation. This new IKT centre provides technical engineering advice, organises relevant events, and is the first accredited test centre for tube liners in the Netherlands.

Following its opening at the start of the year, the still young branch was able to achieve a major success the following summer: after intensive preparatory work, the IKT Nederland test facility was officially accredited with „DAkkS", Germany's national accreditation body. „It is thus the first independent, impartial and accredited test facility for tube liners on the Dutch market", enthuses Peter Brink, head of IKT Nederland.

Peter Brink, head of IKT Nederland

Interesting training opportunities

The branch team has already succeeded in making numerous contacts with the representatives of municipalities, drain and sewer system operators, engineering consultancies and companies working in this industry. In addition to the well attended inaugural event, the attractive range of opportunities offered by IKT Nederland also without doubt facilitated these successes. The range includes seminars held at the new centre on the subject of tube-liner repairs, and an event on the topic of manhole refurbishing, which was organised jointly with a number of Dutch refurbishing contractors and held at IKT headquarters in Gelsenkirchen. The first in-house training provisions have also already been completed on-the-spot at system operators' premises. The spectrum of interesting events is also to be further expanded.

Materials testing and structural-analysis calculations

During the opening ceremony, Stefan Kötters, deputy head of IKT Nederland and deputy test-facility manager at the IKT in Gelsenkirchen, focused in detail on the range of services available at the new location. These include both testing of tube liners for their important short-term properties (short-term modulus of elasticity and short-term bending strength) and water tightness, plus structural-analysis calculation of tube liners - and all impartially and independently, exactly as you would expect from the IKT! Stefan Kötters also focused on the direct link between materials testing and structural-analysis calculation in his address.

Making new contacts: Peter Brink (2nd from left), head of IKT Nederland, talking to guests at the opening ceremony.

Cross-border co-operation

IKT Nederland's aim is to assist in cross-border co-operation between Europe's drain and sewer system operators. The problems are in many cases similar, emphasises PD Dr.-Ing. Bert Bosseler, scientific head of the IKT. Operators in northern and western Germany, for example, also struggle with high groundwater tables, like their counterparts in the Netherlands and Belgium. With its new branch in Arnhem, the IKT has demonstrated its commitment to furthering constructive interchange of knowledge and experience across national boundaries. This, too, can also only provide benefits for system operators.

IKT Nederland

Prof. Dr.-Ing. Bert Bosseler, scientific head of the IKT, advocates cross-border exchange of knowledge and experience.

New measuring technology under development: Erik Laurentzen, of the City of Arnhem, reports on the practical use of the MAC system under his city.

View into the laboratory: Materials tester Sebastiaan Luimes demonstrates the liner tests performed at the new IKT location.

Stability of large-calibre conduits

The first co-operative projects involving Dutch drain/sewer system operators have already been successfully initiated, as Erik Laurentzen, Senior „Rioolbeheerder" for the City of Arnhem, reported at the opening event concerning the practical use of the MAC method, currently undergoing further development, in a historic sewer under the city. This system makes it possible to assess the stability of large-calibre conduits on the basis of minimal deformations in the sewer. The resultant measured data can be used to evolve ecologically and economically rational drain/sewer refurbishing strategies. The IKT is currently working on the further technological development of the MAC method, with the aim of achieving more efficient, semi-automated measurement. Further deployments in Europe before the end of this year are also planned.

Test laboratory for tube liners

Between the individual groups of addresses, visitors to the IKT Nederland laboratory were able to gain an impression of the various tests performed on samples of tube liners. Materials tester Sebastiaan Luimes explained the test apparatus to the visitors, and demonstrated the main tests performed using specimens taken on site.

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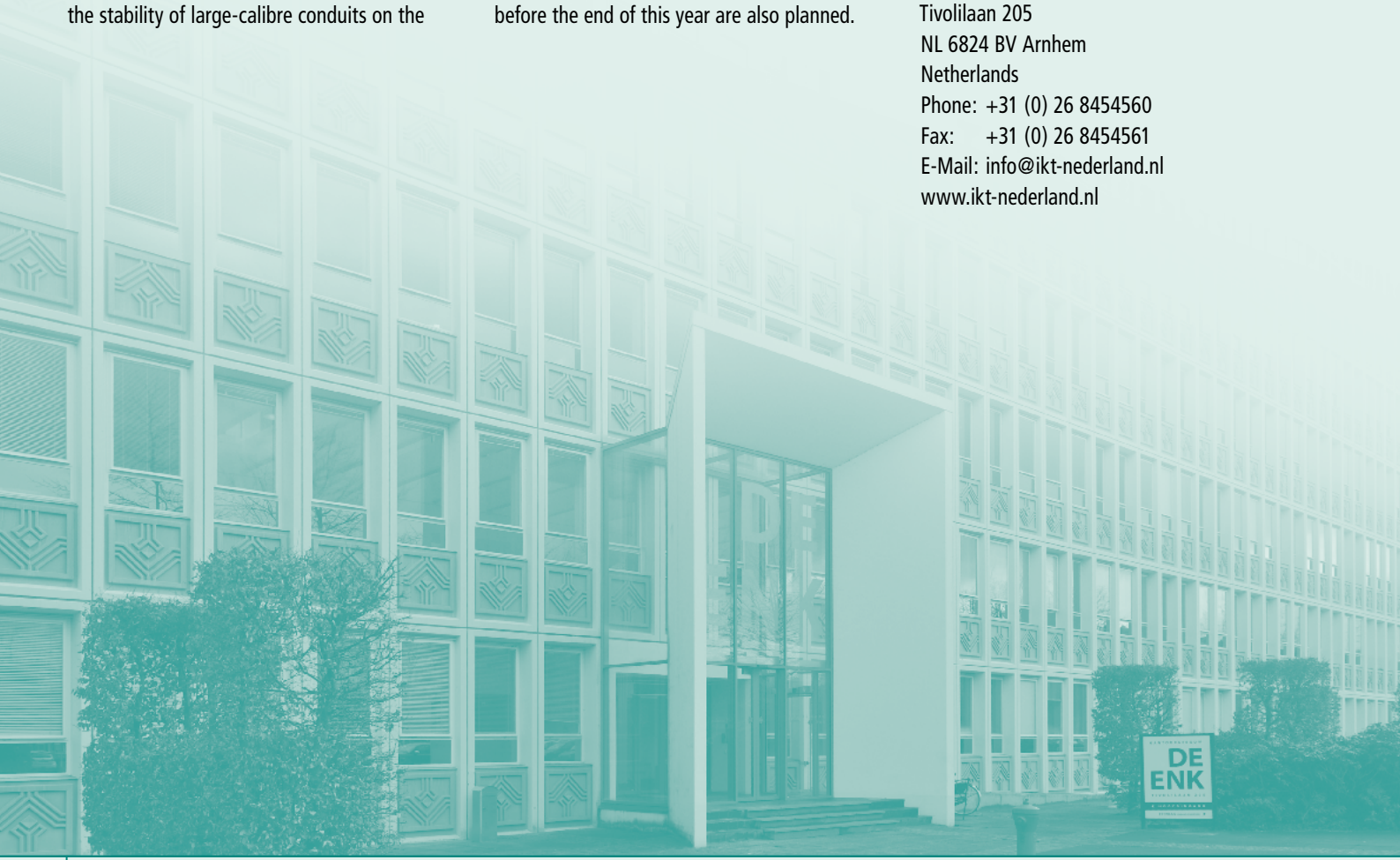

IKT test centres reaccredited

The IKT's test centre for building products in Gelsenkirchen has been reaccredited.

Following the new provisions concerning accreditation in Germany, the IKT has now had its building-product test centre in Gelsenkirchen reaccredited, and that in Arnhem (Netherlands) accredited for the first time. The IKT test centres have thus given unequivocal proof of their competence, as is documented under DAkkS (German National Accreditation Body) accreditation number D-PL-18196-01-00.

Tube-liner testing - and more!

The IKT provides quality-assuring, practically orientated product and system tests, plus on-site supervision services, for system operators. Testing of samples of tube liners accounts for a large proportion of the institute's work. The accredited building-product testing, auditing and certification centres operated by the IKT and IKT Nederland in this field perform, inter alia, the following tests:

- Water-tightness testing (APS test procedure)
- Three-point bending test (DIN EN ISO 11296, Part 4 and ISO 178), also covering modulus of elasticity, flexural tensile strength and wall thickness
- 24 h creep tendency (EN ISO 899, Part 2)

Further analyses, including quantification of residual styrene content, resin type and glass/filler content, for example, can also be commissioned, in addition to the standard tests listed above.

In addition, the IKT test centres can also determine resistance to high-pressure flushing as a materials test (Method 1) on pipes and test samples of, for example, tube liners in accordance with DIN 19523:2008, Part 08. The IKT also conducts practical flushing tests (Method 2) using the test parameters specified in this standard.

Manhole-shaft coatings: IKT on-site testing

The IKT building-product test centres perform for system operators tests that permit on-site determination of the quality of manhole-shaft coatings. These on-site tests include, for example:

- Assessment of substrate preparation, including measurement of pull-off strength, plus assessment of roughness and pre-sealing;
- The tensile adhesion of the coating for assessment of the effectiveness of refurbishing and
- Visual inspection of the completed coating.

Individual test programme

The IKT test centres, in close consultation with the customer, are always pleased to compile a programme of testing individually tailored to the specific product. The test centre staff are pleased to provide assistance to clients.

DAkkS supersedes DAR

The „Deutsche Akkreditierungsstelle" (DAkkS) accreditation body is the national accreditation organisation for the Federal Republic of Germany. It recently took over these functions from the „Deutscher Akkreditierungsrat" (DAR), or „German Accreditation Council". Accreditation by DAkkS provides official confirmation that inspection and certification bodies, and the relevant laboratories, perform their tasks with the necessary expertise and in accordance with the applicable requirements.

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Liner samples are cut to the size and shape needed for testing.

The IKT test laboratory in the Netherlands has also undergone accreditation.

What does IKT do?

The IKT is a neutral, independent non-profit institution, and works on a practically and application-oriented basis on questions concerning underground sewer, pipe and other conduit engineering, its primary focus being on sewer systems. The institute conducts research projects, inspections, product tests, consultations and seminars on the construction, operation and renovation of underground infrastructures.

The IKT's main target group consists of the operators of both public and private conduit systems; its fields of activity are primarily oriented around questions and problems encountered by system operators, activities which derive from the institute's founding charter, signed in 1994, and stating its aims as the acquisition of scientifically founded expertise for the achievement of the cost-effective, technically innovative, and both environmentally and citizen-friendly installation, renovation and maintenance of conduit systems.

The IKT also performs other supporting activities in the field of testing and trial of new products and methods for industrial companies.

The fields of activity of the IKT are in details:

- Practice-oriented research
- Construction supervision, materials testing, flow measurement
- Comparative product tests
- Organisation of networks
- Further training
- Consultation and expert appraisals

Practice-oriented research

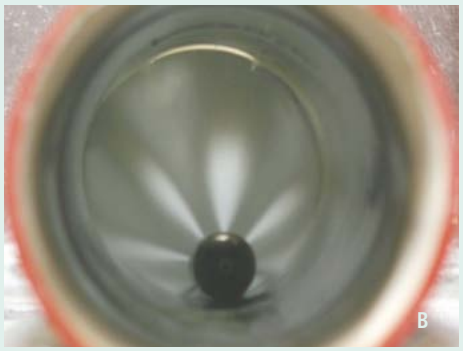
The IKT's application-related research focuses predominantly on the solution of system operators' problems and questions. The institute maintains continuous close contacts with the operators, in order to detect topics needing attention. The system operators' steering committees support and monitor all IKT research projects; members of these steering groups select the products to be tested and evaluated, determine boundary conditions for such tests, and are directly informed concerning the latest findings and developments at regular intervals.

The first step in any IKT research project is a thorough analysis and definition of the problem.

Hydraulic cylinder in the IKT large scale test facility

IKT jacking simulator, DN 1600

IKT-Services



A View into a sewer manhole
B HP nozzle in sewer
C Root ingrowth into a sewer

Practical solutions are then drafted, and subsequently implemented at pilot sites or incorporated into instructions for action and recommendations for the system operators.

Research topics:

- Sewer operation
- Sewer cleaning
- Urban drainage
- Sewer renovation
- Sewer manholes
- Sewer construction
- Pipe-jacking
- Root ingrowth

Construction supervision, material testing, and flow measurement

The results of the IKT's research activities are incorporated via short routes into the institute's subsequent activities.

- Vertical compression test
- Flow measurement
- Adhesive pull test on a coated manhole

The IKT provides system operators with practical product and system tests for Quality Assurance purposes, construction supervision, comparative flow measurements at sewage treatment plants, storm-water tanks and reservoir channels, calibration of flow and control equipment, and also tests in accordance with the self-diagnosis ordinances of the federal German states.

Initial and suitability tests, standard materials tests, DIBt certification procedures, special individually co-ordinated tests, and also supporting tests for method development, can be performed for manufacturers.

These tests are performed by the IKT's three test centres:

The three IKT test centres

Test centre for construction products	Test centre for flow measurements	Test centre for water-permeable surface coatings
Accredited in accordance with D-PL-18196-01-00 DIBt-accredited • Test, supervision and certification unit	**Nationally accredited** • in accordance with EKVO Hessen • in accordance with SüwV Kom NRW	**DIBt-designated**
Main focus • Materials tests (plastics, concrete, vitrified clay, tube liners) • Construction supervision • Quality Assurance (e.g. of sewer and manhole renovation projects) • Test institute for DIBt construction-supervision certification	**Main focus** • Comparative measurements at sewage treatment plants, storm-water tanks, reservoir channels • Calibration of flow-measurement and control instruments • Tests in accordance with SüwV-Kan and SüwV-Kom • Detection/quantification of extraneous water • Expert appraisals	**Main focus** • Suitability tests for surface coatings • Verification of water permeability • Pollutant-retention studies • DIBt certification test

Crown pressure test

Adhesive pull test on a coated manhole

Examination of stability

In addition, first and suitability tests, standard material tests, technical approval by the Deutsches Institut für Bautechnik (German Institute for Construction Technology, a government body, German abbreviation: DIBt), individually coordinated special tests, as well as supporting tests in procedure development can be carried out for product manufacturers.

Comparative product tests

Comparative product tests, in which products and methods are intensively tested under both laboratory and practical conditions, are a particular IKT speciality. All product tests are conducted by a group of system operators. Decisions concerning test contents, procedures and criteria, and also the concluding assessment, are taken jointly by a group control committee, thus ensuring that these tests are performed on a practical basis, impartially, and without influence by commercial interests.

The test results supply sound and reliable information on the strengths and weaknesses of the products available on the market to system operators, enabling them to make purchasing decisions on the basis of facts, rather than manufacturers' advertising. The IKT's product tests also provide suppliers with criteria for the improvement of the products and procedures tested, and thus for enhancing their market position.

Organisation of networks

The IKT increasingly sees its role as that of providing a platform for networks. The "Municipal Network for Site Drainage" (KomNetGEW) has existed since as long ago as the summer of 2008. The principal concern of the around sixty-five member municipalities is "citizen-friendly" implementation of tightness testing in accordance with Article 61a LWG NRW. Materials for PR activities and advisory services for citizens are centrally drafted under the overall leadership of the IKT and provided for use by all participants. The KomNetGEW has, in addition, now also certified several hundred site drainage consultants and expert tightness inspectors.

System operators assess dismantled test objects

Construction of a pipeline system at the IKT large-scale test facility

Network members adopt common paths

IKT-Services

Training and further-training at the IKT

The "Sewer Operators Forum" within the IKT was founded in 2011 and provides all waste-water organisations with the opportunity for intensive interchange of experience. The results obtained in workshops, workgroups and research activities are structured and summarised by the IKT.

Further training

Over the years, the IKT has acquired a pleasing reputation as a training and further-training institution. Consultants certified in Gelsenkirchen are trained in site drainage at regular intervals. Expert tightness inspectors also obtain the necessary know-how here. The "Site Drainage Day", held by the IKT for the fifth time in 2014, has also become a permanent feature in the industry's events calendar. The "Conduit Cleaning Day" is also worth to note. The institute's further-training programme is rounded off by training events and courses on various topics of waste-water management, including manhole renovation, occupational health and safety, and photo reference catalogue.

Consultation and expert assessments

The IKT provides, on the basis of findings from research, inspection and testing activities, support services orientated around specific questions encountered by system operators (e.g. on-site analyses, feasibility studies, presentation and mediation, technical and economic assessments, economic and social cost analyses, etc.). The IKT's services also include thoroughly scientifically founded expert assessments for courts, municipal and private system operators, building contractors, product manufacturers and engineering consultancies (e.g. expert damage assessments, expert opinions as evidence in court and in out-of-court settlements). An overview of the IKT's specific consulting services in its various fields of activity is shown below:

IKT consulting services

Sewer cleaning/operation

Day of practical sewer operation, checking of tendering, assessment of damage caused by sewer cleaning (e.g. flow back-ups, cellar flooding, etc.), cause analysis of cleaning damage to sewage conduits, malfunction analysis (drain blockages, clogging, etc.), assessment of cleaning strategies, recommendations for non-destructive sewer cleaning, drafting of market surveys, recommendations concerning the high-pressure flushing resistance of pipe products, organisation and presentation of system operators' regional interest groups, optimisation of reporting.

New sewer construction

Trenchless ("no-dig") installation (pipe-jacking), open-trench installation (timbering supported, pipe-trenches), statics calculations (stability), core drilling and testing (materials testing), damage documentation and assessment, registration and evaluation of current construction methods.

Manhole renovation

Selection of renovation procedures, Quality Assurance for renovation projects, registration and assessment of renovation quality, analysis and evaluation of renovation damage, practical suitability testing of renovation systems.

Sewer renovation
Quality Assurance for renovation projects, recommendations concerning use of modern materials in sewer renovation (and plastics, in particular), tube liners, part-liners and coating methods; analysis and inspection of renovation damage.

Urban drainage
Trenchless installation methods (renovation of connection points and pipes), open-trench installation (pipe installation, connection to main sewer systems), malfunctions (drain blockages, clogging, etc.), damage documentation and evaluation, registration and evaluation of actual condition.

Water-permeable surface coating
Seepage capacity, pollutant retention, drain performance, DIBt certification.

Root ingrowth into sewer systems
Tree identification using samples of ingrown roots, documentation and evaluation of cases of damage, recommendations for the removal of ingrown roots and for repair of damage.

Reporting and self-diagnosis ordinance
Consulting services on implementation of legal requirements (EKVO, SüwVKan), documentation and optimisation of structure and flow organisation, updating of servicing and operating instructions orientated around the relevant requirements, finalisation and systematisation of reporting, co-ordination with responsible supervisory authorities.

Flow analysis and comparative measurement
Review of measuring instruments for use at storm-water tanks and sewage treatment plants, on-site comparative measurements using ultra-modern measuring instruments calibrated at regular intervals, measurement of extraneous water flows, determination of extraneous water sources and causes.

Economic analyses
Cost:benefit analyses comparing trenchless and open-trench installation methods, evaluation of investment and rehabilitation strategies, economic evaluation of sewer systems and structure, cost-cutting and economic optimisation provisions, macro- and microeconomic analyses.

More information?
We are always pleased to answer your questions about our services - just contact us!

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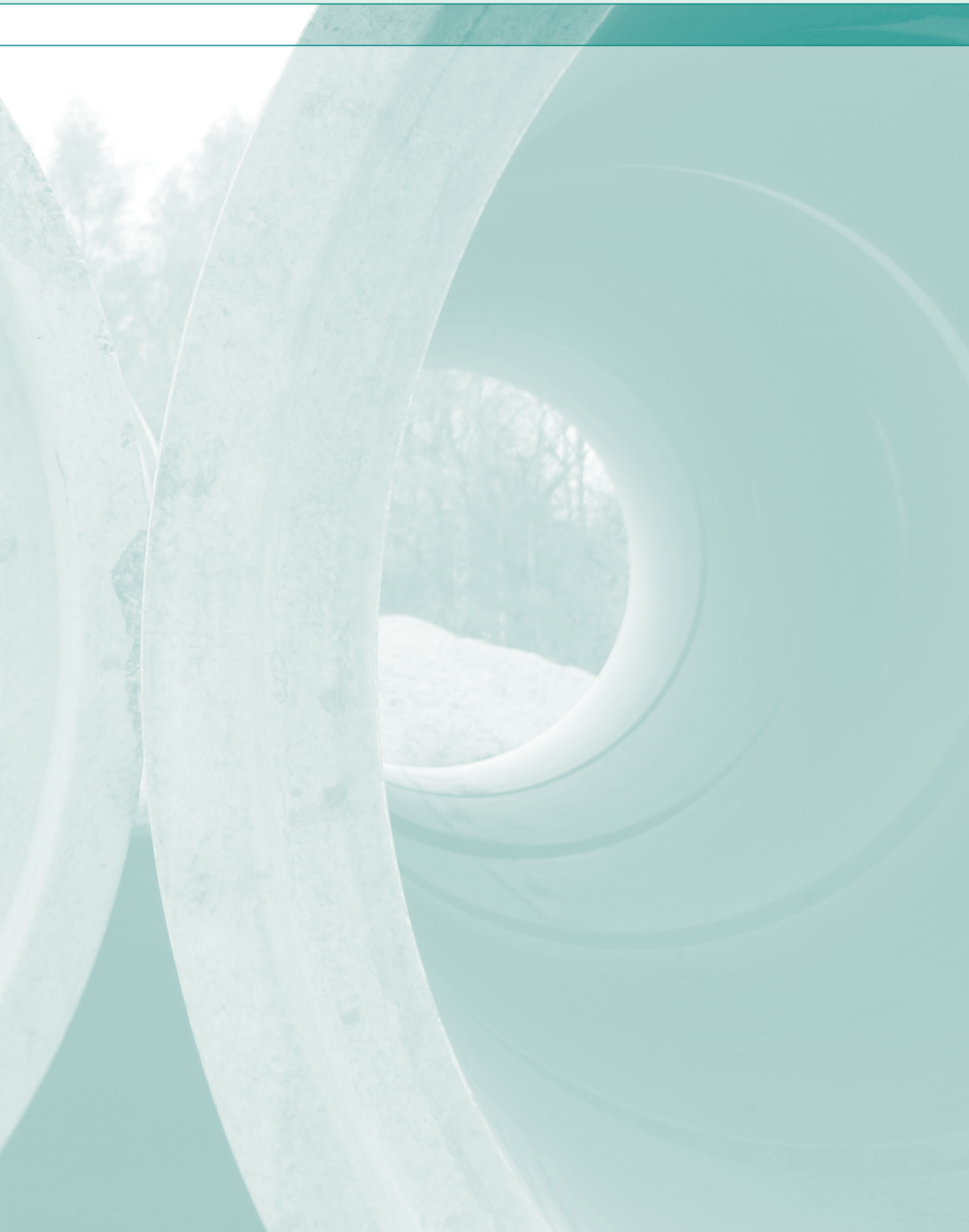

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neutral
independent
non-profit institute

IKT - Institute for Underground Infrastructure

ABOUT IKT

IKT - Institute for Underground Infrastructure is a research, consultancy and testing institute specialized in the field of sewers. It is neutral and independent and operates on a non-profit basis. It is oriented towards practical applications and works on issues surrounding underground pipe construction. Its key focus is centred on sewage systems. IKT provides scientifically backed analysis and advice.

IKT has been established in 1994 as a spin-off from Bochum University, Germany.

The initial funding for setting up the institute has been provided by the Ministry for the Environment of the State of North-Rhine Westphalia, Germany's largest federal state.

However, IKT is not owned by the Government. Its owners are two associations which are again non-profit organizations of their own:

a) IKT-Association of Network Operators:
Members are more than 120 cities, among them Berlin, Hamburg, Cologne and London (Thames Water). They hold together 66.6% of IKT.

b) IKT-Association of Industry and Service:
Members are more than 60 companies. They hold together 33.3% of IKT.

You can find information on projects and services at:
www.ikt.de

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